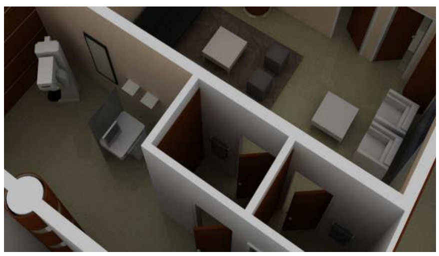
PLANNING AND DESIGN

DIAGNOSTIC IMAGING AND RADIOTHERAPY DEPARTMENTS



J.A. GARCIA

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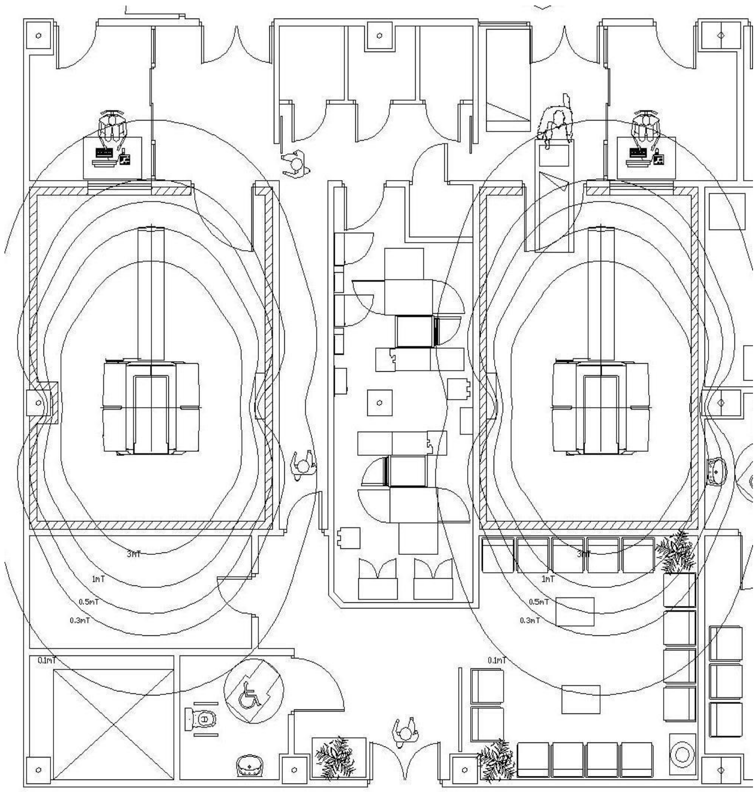
DEPARTMENTS



J.A. GARCIA

.I.S.B.N. in English language:

Note about this edition

The economic results of the author of this edition in Spanish are intended to support research in the field of Multiple Sclerosis. The author yields profits to research laboratories of Multiple Sclerosis of the Hospital Puerta de Hierro in Madrid through the Foundation of biomedical research of the Hospital.

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INTRODUCTION

The Director of a Diagnostic Imaging Department

Professor Avedis Donabedian, regarding international issues of healthcare quality, said insistently, that if we have a good structure (understood as the physical plant and material, human and organizational resources), and a suitable Process (referring to the set of actions and performances that take place around the care activity), a result of excellent quality is almost guaranteed. And this is especially applicable to radiology services that we can say without fear of being wrong, that the quality of the final product begins to take shape with the architectural design.

And it is happening that our services, unlike what occurs with other areas of the hospital, have a very pointed personality and linked to the technology changes and specific functional aspects. Not only their location, dimensions, circuits, relationship with the rest of the hospital, but also aspects more related with the strict civil work itself, as forged, general facilities, shields etc. are characteristics that confer to a service of radiology, own personality.

Our country, birthplace of eminent and prestigious architects have not been characterized, except numbered examples and even despite the fact that the trend is changing in recent years, by having a recognized hospital architectural trajectory and more specifically in radiology.

But this little tradition has not been a problem reduced exclusively to architects. Spanish radiologists have also contributed to this situation in contrast with references throughout the developed world where eminent colleagues have devoted much of his professional life to study and improve the physical structure of the services of radiology (among them, and not to mention everyone, especially remember Fischer in USA, Ture Holm in Sweden and Lamarque in France).

And not only lack of habits in terms of design, but that we have not taken care of habitability. Our services have been unfriendly, inaccessible and cold spaces, in short, little humanized. Also in this aspect things are changing and start to become more comfortable places, happily for all.

By fortune, the panorama and the interest in these issues is improving in our country and is increasing with more frequency the multidisciplinary participation (architects, radiologists, physical, health planners, interior designers etc.) in the design and planning of radiology services.

José Angel Garcia Ruiz is a professional well known and, above all, respected, in the field of Spanish Radiology and has toured all over the ladder in the world of our specialty (research, manufacture, marketing etc.), performing his duties , over the past 38 years in of the sector in the most important multinationals in the world. His vision and, above all, willingness and attitude, always friendly and generous, led him to collaborate with a multitude of radiologists in tasks of planning, design and equipment not only of radiology services but, also, of nuclear medicine and radiotherapy.

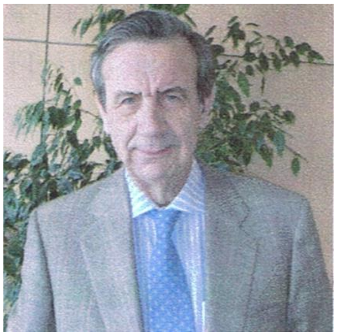
The book presented by the author, "Planning and Design of Departments of Diagnostic Imaging an Radiotherapy", collects his extensive and rich professional experience and covers a space of a huge utility, and essential not only for architects and health planners but, above all, for radiologists, responding to the classic issues of what to do, how to do and for what purpose.

Both the SERAM, with the promotion, publication and diffusion of the decisive Guide for Management for Radiology Services, as its subsidiary, the SEGECA (Section of Management and Quality), with his proverbial devotion to radiological management issues, have driven the knowledge and interest in all the aspects related to planning of radiology services, which Garcia Ruiz's work now comes complete with opportunity and magisterium.

Ginés Madrid García
Radiologist
Academic Numerary of the Medicine and Surgery Academy in the Region of Murcia

INTRODUCTION

The Director of a Public Hospital Organization



Introduce the book of *José Angel Garcia*, is a great personal satisfaction for the dual reason of being a friend and a magnificent professional.

I know Jose Angel from the times that came to advise to one executive of the hospital management, and he was a technician, of the different companies that have worked, all first-line of the radiological equipment. He was and remains a good investment strategy advisor. He did not sell you one equipment, he advised you to make a perfectly balanced total investment. And when finally the service was in operation, the demand was satisfied with good performance of the equipment and a perfect use of the staff.

The book that the reader has today in their hands, needs no introduction. Who is lucky enough to meet it in the library, will notice its quality and the great need we had the professionals of the hospitals, in its edition. We didn't have until their arrival, of an updated book, with drawings and so current graphic in the publishing world. A resemblance has with other already edited long ago that outpaces certainly in modern information and architectural solutions.

It is a book, made for professionals of Radiology, Nuclear Medicine, and Radiation Therapy. It is essential for anyone who is engaged in the design of hospitals and those who perform management tasks and those who obviously have the responsibilities to invest in these services.

It has a comprehensive presentation of each unit, from its technical conception exposed with great simplicity, capable to be understood by the student for these materials, from the teaching of medicine, to the postgraduates entering in the specialty.

Everything related to the evolution of the demand is treated in a very careful way, as well as the evolution of the costs.

An important part of the book describes with precision of drawings and data, a solution made in the Hospital de La Ribera in Alzira (Valencia, Spain), on the other hand a benchmark experience of a management model that is spreading in Valencia and currently in Madrid. This total service design and the detailed units will allow any manager responsible for commissioning underway of a regional hospital to replicate the design placing the new technology of the different modalities. The balance in the design requires today exclusively devote some time and money to upgrade in the Radiotherapy Simulator. The radiology emergency, allowed the hospital the optimal performance for external and internal hospital emergencies demand.

The professionalism of the author, at the time responsible for a new company, not recognized in Spain at the forefront, made me to bet on its comprehensive solution, knowing that the risk taking was very low due to its large capacity. The design, delivery and implementation underway was carried out with mathematical precision in a hospital since its inception until its total operation had eighteen months, and being the first diagnostic unit that integrates the Electronic Clinical Records with PCAS and RIS. Additional integration was made among all supplier of equipment and electronic processing information. This Project Management like was performed by Jose Angel Garcia deserved being considered like one innovator inside his specialty.

A book to have on the bench from professionals in the field. It is welcome.

Antonio Burgueño Carbonell.
General Director
Community of Madrid. Hospitals

ABOUT THE AUTHOR

Jose Angel Garcia Ruiz finished his studies of industrial engineering at the High School of Industrial Engineers of Madrid in 1970 and begins his professional activity designing x-ray generators in the laboratories of the General Electric Medical Division Spain, in Madrid, developing the first three phase Spanish x ray generator, Genetron 725.

Subsequently graduated in business management and marketing at the School of Commercial Research (ESIC) and held senior positions in the direction of the radiology business of Siemens Spain, Toshiba Medical Systems Spain , the general management at Picker Spain and manager of East/South Area of Philips Medical Systems.

From the perspective of its business occupations, for over thirty-eight years, has designed and/or collaborated in the designs of many new departments of hospitals, health centers and private imaging facilities, as well as the update and upgrade of many old departments.

Permanent observer of the evolution of new technologies, has worked in depth in the introduction of computers in imaging departments starring in several projects of RIS and PACS that have today become hospitals with exclusive digital image.

The work done in this book is an overview of his interest in the area of planning and design and reflects the intense activity in projects of the last twenty years.

At the time of the publication of this book continues his career in the field of planning and design of departments of diagnostic imaging and radiation therapy as a consultant and company director of Alrad Consulting, in the fields of planning, design, general consulting and teaching with conferences and seminars in the area of diagnostic imaging and radiotherapy.

To my son José Angel, who began his work as engineer projecting PACS systems for diagnostic imaging departments, in the hope that with God's help, can someday update this book.

CONTENT

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BOOK OBJECTIVES

The Milky Way, a simple galaxy of the universe, is full of "Super Earths", millions of planets similar to ours. Prestigious astronomers argue that many of them could host life, and confirm an acceptable probability of almost all stars similar to the Sun have orbiting around a planet that hostel life as Earth.

In the same way that the planets of our solar system revolve with precise orbits around its star reference, descending into our health systems, we can also assimilate their orbit around its center of reference in its final sense, it is always the patient.

The patient is the rotation center of any medical act and for which are stablished objectives of the existing health systems and health organizations that apply extraordinary economical and personnel resources. The patient is the center of most of the analysis, details and conclusions of the next chapters. The design of a room of diagnostic imaging, either of radiology, ultrasound, multislice tomography, MRI, nuclear medicine, etc., must have a prime objective in the care of the patient, his comfort, his good care during the citation, wait, scanning, delivery of the reports process and consultations with physicians when required.

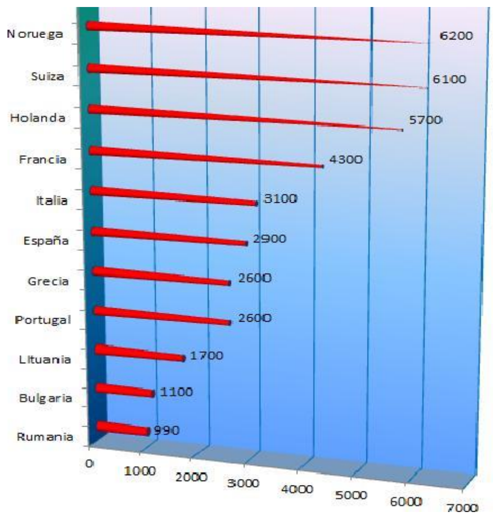
The health personnel, starting with the technicians who performed the imaging exams or radio therapeutic treatments, medical specialists who diagnosed on their workstations, appointments organized by staff, provision of sanitary material, drugs, and clinical needs for processing other diagnostic or therapeutic procedures, administrators who plan, control and adjust the economy of the single imaging room or the entire department of diagnostic imaging, need designs that facilitate their daily activity, which allow the development of all their day-to-day functions in a simple, comfortable and productive way, and thereby meet their two most important purposes: the social and the economic.

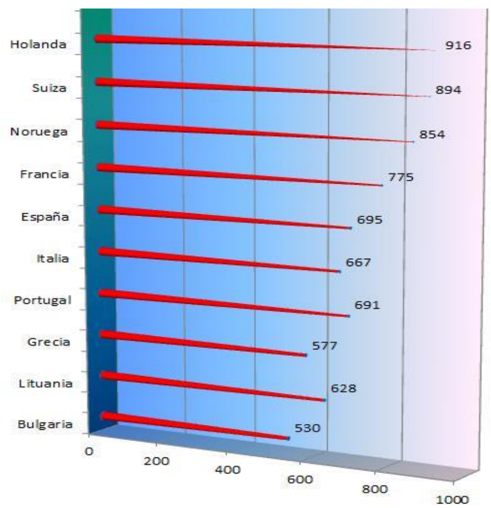
The architecture of the image room or the image department resulting from the technical design, must respond to the needs of the patient and the professional, and should support the future development of the department. Diagnostic imaging has been one of the clinical areas of growth over the past years and is expected to remain so for the next coming years, and is already in sight to be seen more developments of innovative imaging systems that will carry to increase the number of exams and therapeutic procedures that will be performed in the near future.

The leaders of public and private administrations with responsibilities in the health management should take into account the importance of good design and construction of diagnostic imaging services in the health care of the patients and therefore in the economy of their respective health systems.

Imaging services respond today of the direct and indirect costs of the various clinical procedures and therefore the general health economy whose costs continue to grow in all countries, looking for an improvement of the quality of health care, and requires research, analysis, organization, and effort for the best profitability of this expenditure for the benefit of patients.

In the table below we see the observation of the EHCI (Euro Health Consumer Index) 2015 on spending in European Health Systems. Only a few countries of the 31 published by EHCI are included.





(Total health expenditure per capita (US$; WHO 2013) and points related 1000 of the quality perception by users)

There are published data, which extend this graph, by other international bodies with researchers in the area of health, which can be found at the WEB pages of organizations such as OECD, UNSCEAR, WHO, etc., and can contribute to a better understanding by part of those interested in health investment in each country. As can be seen there is not an exact correspondence between perception of consumers (EHCI) on quality of service and investment. Clearly the management of the resources plays an important role, while increased investment remains the highest score range in perception.

Health expenditure per capita has its correspondence in the investment in high-technology diagnostic and therapeutic equipment that are one of the purposes of this book in all related to the planning and design of facilities.

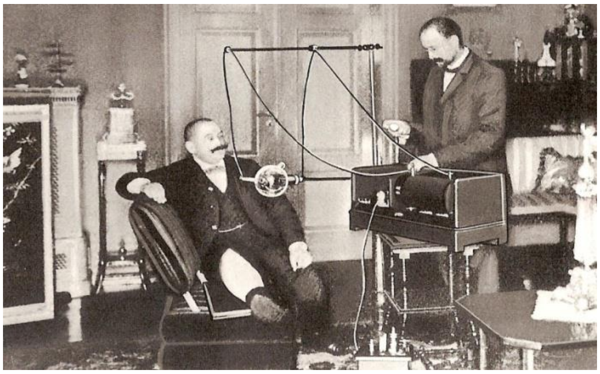
Since more than ten years ago health care researchers have emphasized that investment in high-tech medical equipment is one percent of the total health spending, some claim that today can have uploaded this ratio. It is easy to infer from this data, traditionally accepted and even an approximate, the investment in this equipment in every country of the outstanding data provided by EHCI. It is confirmed that within this high investment in medical technology occupies a high quantity, probably the largest investment, the area of imaging diagnostic and radiotherapy.

The book is organized into four parts. The first two analyze issues related to planning and design, and the last develops general aspects surrounding the first two, such as a summary of the techniques of management and project management and standardization to watch by the professionals. It begins with the evolution of the planning until the end of the last century. It is on the border between the two centuries when technology allows the complete digitization and informatics have reached their effective introduction in the departments. An analysis of the exams demand and the surrounding department environment serve as basis to define the surfaces of the examination rooms of the present modalities. This calculation of the surfaces is addressed in Chapter V. Once calculated this and located the department design starts; first the individual rooms and after the entire department. Four additional chapters are devoted to this task. At the end one addendum covered by the last three Chapters make a profitable guide to follow as a process all the tasks related with the planning and design of the departments. Chapter XV, the last one, is devoted in a very simple way, to point out the financial aspects of the total process.

We strive our best wishes that this publication will contribute to facilitate practical information, in a special way to all those involved in the planning and design of facilities for diagnostic imaging and radiotherapy, since administrators of health organizations, to architects, engineers, consultants, suppliers of equipment, builders and installers. And in a very special way for radiologists, nuclear medicine specialists and radiation therapists, technicians and nurses who live daily in the departments, those who have to model in the process of planning and support in its phase of design with the utmost care; there will stay many years enjoying his previous good work.

The investment that takes place in one image room will be widely rewarded if the patient is treated in a fully satisfactory way. Also will be rewarded the professional team that carried out the exploration and diagnosis, and the time will indicate to the investment managers the high profitability that provides a design and construction well done.

I.- HISTORICAL EVOLUTION



I. RADIOLOGY

II. RADIOTHERAPY

III. NUCLEAR MEDICINE

IV. ULTRASOUND

V. COMPUTED TOMOGRAPHY

VI. MAGNETIC RESONANCE

VII. OTHER IMAGING TECHNIQUES

VIII. INFORMATION SYSEMS. PACS

Historically, the expansion on the properties of radiation was a fulminating effect. On few occasions, not to say almost none, a strictly scientific finding has caused so much commotion.

Felip Cid

I.- HISTORICAL EVOLUTION

The evolution in the different diagnostic imaging systems offers a captivating and amazing impression about the ability of the human ingenuity in his attempt, evrytime harder, to increase the need of diagnosing diseases with the best possible detail, greater reliability and minimal time, and with minimal aggression to the patient, staff and the environment. This development has been quantitative and qualitative and has allowed the improvement of the comfort of the patient in diagnostic studies and the elimination or attenuation of the therapeutic risks, many of them, through procedures that facilitate and allow the today existing equipment. These require in some cases high economic investment, while providing very high productivity. Its installation in the imaging departments is planned and designed in highly technified rooms.

In the development of different technologies over time we can appreciate how evolved the needs of space, energy, physical structure, human resources, etc., for correct use of the different modalities in its clinic applications. A basic concept in the planning of services for diagnostic imaging, which we can see in the following pages, is the growth of the architectural resources in the future, after construct and inaugurate the department. It continuously grows with time, and is convenient plan the dimensions with more space and with the necessary financial resources, in the range of vision of the technology we know and we can foresee. A perspective of the time horizon of several five years periods would enable its functions without continuous architectural modifications to which everybody is accustomed, many of them the result of improvisation.

The purpose of this book is not the exhaustive analysis of the evolution of the technologies and diagnostic imaging techniques, but only the conclusions which provide its evolution, from its invention to the current date, in the planning, design, construction and maintenance of the facilities and its future in such a way that the financial management of health resources lead to the basic objective of this analysis: the patient.

Will be starting with the technique of conventional radiology, genesis of diagnostic imaging, to continue with the nuclear medicine, ultrasound, multislice tomography, magnetic resonance imaging, and technologies of information and communication with its several radiologic computing systems, like RIS and communication and archiving of images or PACS systems, as well as the intersection of these systems with the clinical and administrative computer management. Emerging techniques such as molecular imaging, whose history has been growing over the last two decades of the 20th century, and that tends to become one of the most important disciplines of modern technologies is also commented. And with a predictable future development of very high expectations.

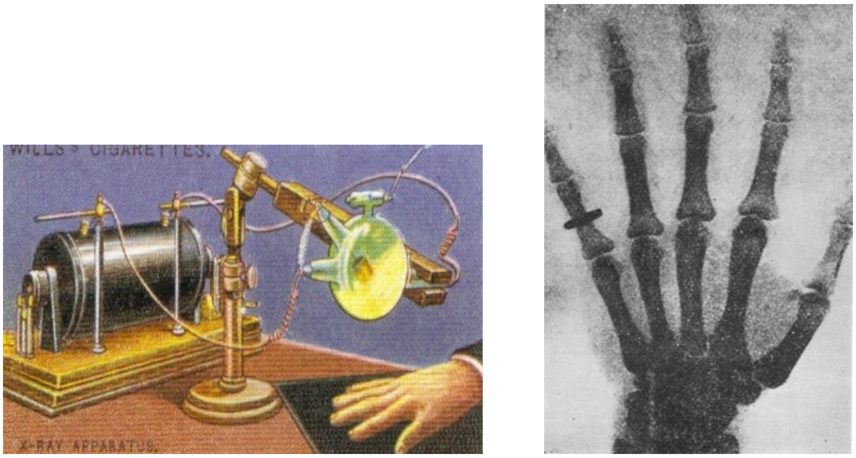
I.I.- RADIOLOGY

In the German city of Würzburg, on the afternoon of December 28, 1895, the physics professor Wilhem Conrad Roentgen presented at a scientific meeting of the German Society of Medical Physics, the experiences that he had carried out in the laboratories of the Department of Physics at the University of that city, and whose final results had been obtained a few days earlier, on November 8th.

(1.1.W.C. Roentgen, first Nobel Prize for Medicine in 1901)

Roentgen had researched for quite some time on the type Hittorf-Crookess tubes discharges with rarefied gas and had found that applying an induced electric current produced by a spool of H.D. Ruhmkorff through a Crookess tube type, produces a peculiar light on the cathode side, which had the property of leave a shadow on a paper with platinum barium cyanide, and that if stood an object between the tube and the paper produced a shadow of the object in the cited paper.

There are numerous publications chronicling, several with many details, the prolegomena of the discovery and the details over the rapid diffusion trough the scientific circuits and the communications media of the time.



(1.2.- First image of a hand with x-rays)

At a next meeting, on January 23, 1896, on the aforementioned Society of Medical Physics, in Würzburg, presented Roentgen his experiences with the title "**on a new form of radiation**", which was called by the ignorance of its nature **X- Rays**.

Between the date of communication of the discovery and the official presentation in the medical society of the cited January 23, the diffusion was huge and conducted to similar experiences in many cities in the Western World, despite the limitations of communication of the moment. Also in the successive months began to publish applications that in principle found in traumatology, gynecology, determination of foreign bodies, etc.

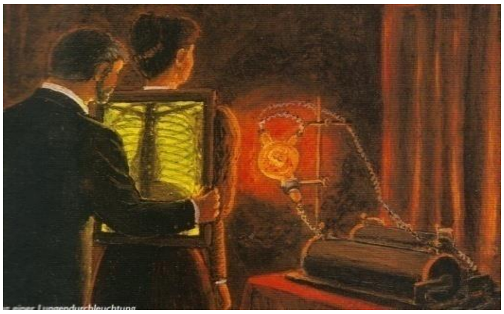
It is the birth of Radiology as a medical discipline, which can be said without equivocation, began in the first months of the 1896 (12-41-64).

The first images taken by Roentgen, with similar equipment to (1.2) had between five and fifteen-minute exposure times, and as we can see with serious problems of radiation protection.

The harmful effects of exposure to x rays were soon noted by researchers and began the task of radiological protection, which was soon set as scientific discipline of inestimable value for the development of medical diagnostics with ionizing radiation.

Already in 1927, when the concept of electron appears, it was determined that x-rays are produced by accelerated electrons which emanate from a cathode and impact against the vacuum tube anode material; these rays wavelength varies between 0.02 and 0.07 A, they are propagated in a straight line in a vacuum to the speed of light and having no electric charge are not deflected by magnetic fields, and that they had the possibility of altering the silver salts, which prompted rapid development of radiographic films.

Therefore, early x-ray room design was confined to a room with a table that supported the spool-generator, one high-voltage vacuum tube emitting X rays and one receptor composed by radiographic film as support of the radiological image. These components with some batteries for the electric power supply was all the necessary infrastructure. Radiological exposure times ranged between five and fifteen minutes.



(1.3-X-Ray fluorescent screen)

Already at this time begin to indicate clearly the four subsystems that make up an imaging system for diagnostic radiology:

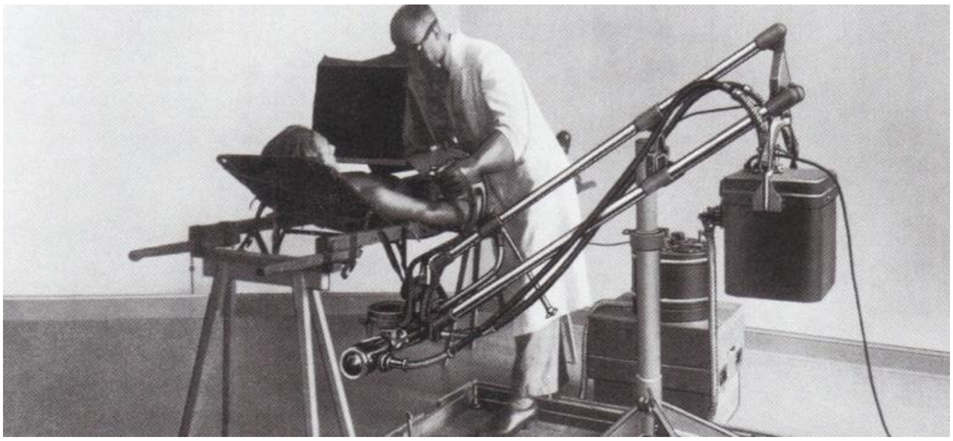
- **The high voltage generator and tube starter.**
- **The x-ray tube as radiation emitter, with the elements of collimation.**
- **The radiographic image collector** (that has changed from the x-ray film to the sensor plate or flat panel, passing through computed radiography reusable plates).
- **The mechanical system** that supports the patient and emitting and receiving elements.

With this technological base, in 1912 Coolidge discovered a new system to increase the thermal capacity of the anode and reduce exposure times, which were a clear limitation to many radiological procedures.

He designed a tube where could be possible to perform a high vacuum, that have a cathode with a tungsten filament that is fed with a high electric current intensity and low voltage and an anode tilted about 45 degrees with respect to the impact of electrons accelerated from the cathode and formed by a tungsten layer of very high melting point, coupled on a layer of molybdenum with a great capacity of thermal heat evacuation. Exposure times, with this tubes, dropped under the second in only seventeen years.

Over the 40ths years began to manufacture radiation emitting assemblies within shields, insulated with oil and the glass recipients where surrounded with a few windings, stators, to turn the anodes, rotors, with which further increase the anode disc thermal capacity, which had rhenium added to prevent cracking by strong thermal contractions. With all of this new inventions exposure times of the order of tenths of seconds were reached, starting the run-up of modern x-ray tubes of rotating anode.

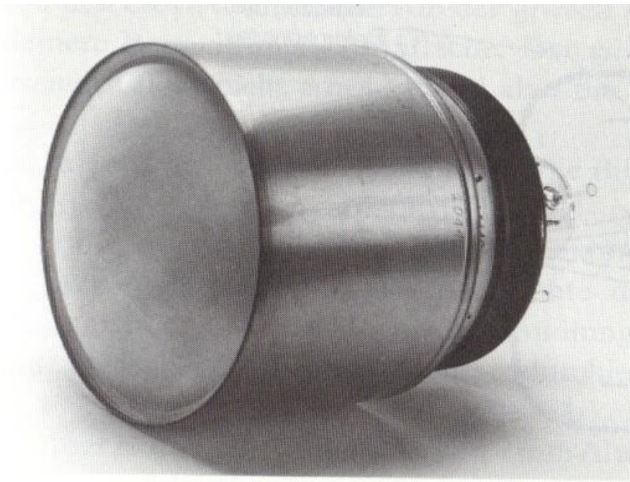
The high-voltage generators to provide elevated voltages between anode and cathode that are necessary for the acceleration of the electrons underwent a great evolution in the years of the Coolidge tube, formed by a transformer which provided AC voltage to the tube that was in turn the rectifier, using only the half wave of positive potential for generating radiation. Into the 1930s, with urban distribution of AC high voltage, transformers with oil insulated were definitely stablished. It was around the 1950s when vacuum valves were introduced to rectify the current in high-voltage and increase yields of the x-ray tube, reaching times of the order of the hundredth of a second, which allows to do practically all of the dynamic x-ray examinations.



(1.4.- Radiological Installation)

In installation of figure 1.4, of the Year 1935, we can see a tube with its protective cover, a tank with the high voltage transformer, insulated cables, table to support the patient, x-ray tube support, and fluorescent radiation screen. Basic installation where the present components of an x-ray facility are patents. Even decades would be needed to improve yields, and above all the radiological protection for the patient and the physician radiologist (65).

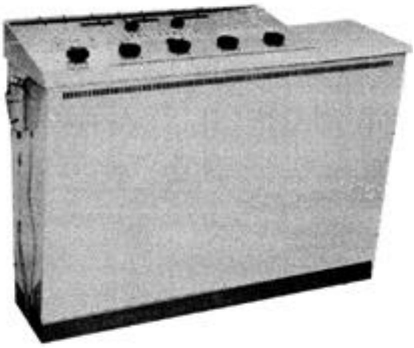
In the 1950s, the discovery of the image intensifier (1.5) completed the panorama of the radiological equipment, in the way that increased the mechanical, electrical and radiation protection securities allowing almost reaching the levels existing today and expanding the range of clinical applications.



(1.5.- Image Intensifier)

The image intensifier has a fluorescent screen attached to a photocathode. The incident x-ray input screen produce light that the photocathode transforms in electrons. These are driven and accelerated by several electronic lenses placed inside a glass tube on a secondary screen that again transforms these electrons on light. The process provides a high increase of the level of brightness of the image in this small secondary output screen, so can be seen at a glance, without darkness, as it was necessary with fluoroscopic screens. Originally an optical lens allowed to enlarge the small images of the secondary screen. Later a chain of closed-circuit television process the image of the secondary display and transmitted it to a TV monitor, displaying images at the level of ambient room lighting. The image intensifier expanded the ranges of dynamic procedures: digestive, surgical, angiographic, hemodynamic, etc., and until the beginning of the 21st century, it has been a basic peace in any radiological system where images are produced in movement (08).

Analog electronics and electrical engineering was the technological basis for the equipment of the 1970s (1.6), where the digital memories were designed with small core ferrite toroids, being in many cases the selection of the exposure parameters made by manual settings; with the keyboards of the time with contacts with lower reliability than the modern keyboards of today; with analogue indicators for exposure parameters and with hard rotary switches.



(1.6. -First Spanish three-phase generator. The author's design)

(1.7. - 100kW-150 kV generator. Planning of the author)

And later, at the beginning of the 1980s, with selections of the above parameters servo controlled (1.7). In the decade of the 1980s were introduced x-ray generators and remote controlled tables as is shown in the pictures (1.8) and (1.9). Analog components begins to combine with the digital technology producing more simple equipment and with highest performance.

(1.8.-Two pulses single phase generator. Author marketing planning)

In the last years of the past century, were configured multiple advances of the radiological equipment, allowing to significantly increase both the comfort of the patient and in the examinations by the technical radiographers, as well as the systems to make the diagnosis by radiologists. It was the aftermath of the analog radiology and the link with the modern digital equipment with witch are projected and designed the current radiological diagnostic rooms of the imaging departments.

(1.9-Remote control table with twelve pulses three-phase generator)

(1.10-Room for general radiography)

Thus, at the beginning of the Year 2000, had the following final status for radiological rooms design: radiographic and fluoroscopic.

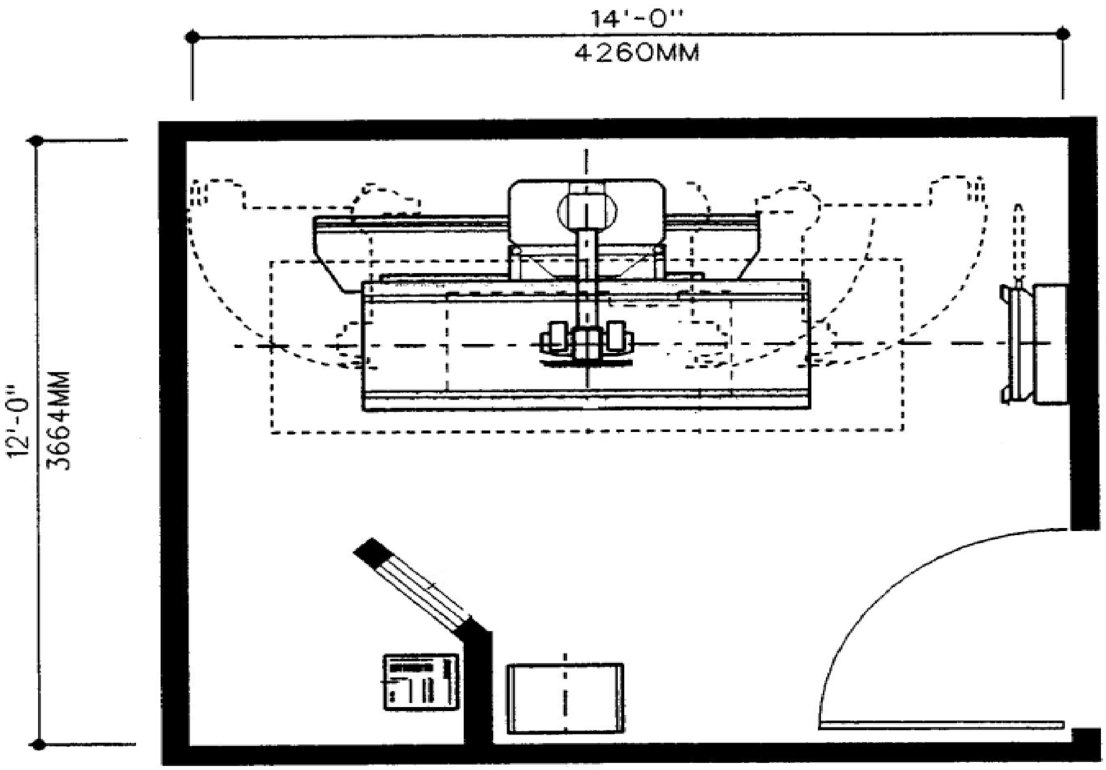
The radiographic rooms with high-frequency generators (high reduction in the size of high voltage transformers), power from 30 to 80 kW and exposure times of up to 1 millisecond. High voltage cables with high flexibility and high insulation, reducing its sections. Patient support tables with floating tabletop of low attenuation and high mechanical strength to withstand important patient weights, up to 300 kg. Stands of x-ray tube suspended from ceilings or columns tube support of high mobility in the radiographic examination room. Systems control consoles designed with microprocessors.

The average radiographic examination room dimensions reach 20-25 m2 (215-269 ft2), whereas in addition a control room and two to three cabins for changing clothes of the patients.

All dynamic procedures, examinations of digestive, vascular, etc. require 50-100 kW generators with radioscopy and radiography systems and image intensifiers with input fields from 17 to 40 cm (6,7-15,7 in) and TV networks of up to 1.249 lines; in the last years of this time all systems have digital converters for the digitization of images and file them in digital disks.

Average radioscopic-radiographic room surfaces, taking into account the needs of the procedures with patients who arrive on stretchers and the mobility of these within the room, are reaching the 25-30 m2 (269–323 ft2). Considering in addition two cabins, a toilet, a control room for operator and a technique room for the generator and imaging electronic systems. It is needed to calculate the heat dissipation of the technical room with its corresponding air conditioning for at least 2 kW, and

the mechanical loads on floor and ceiling. Space and cooling requirements are even higher in the vascular and cardiac catheterization rooms.



(1.11- Lay out of a general radiography room)

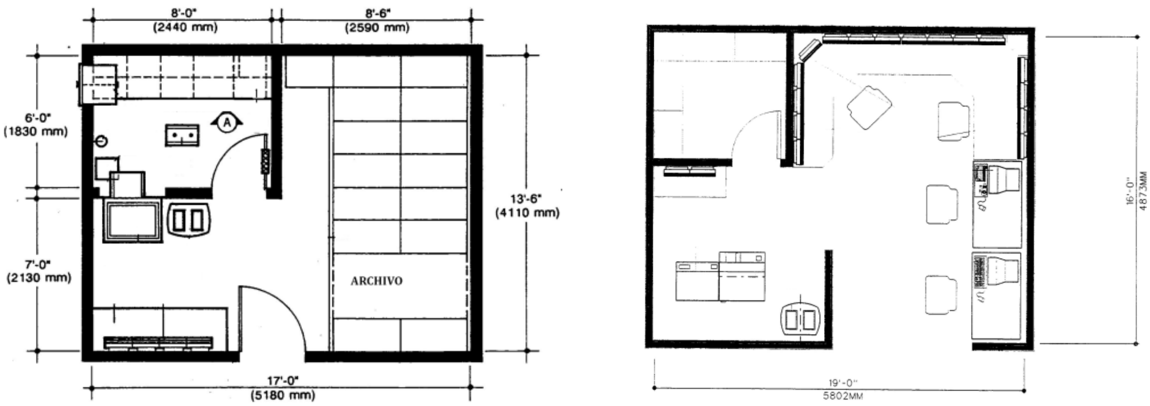
The manual operation of radiographic cassettes and development machines were replaced by day light automated systems in all high performance image departments, increasing the production and productivity and allowing to cancel the dark rooms with their loading and developing systems existing until the last years of the last century.

Day light system included different dispensing drawer where films of different formats were staying; from these they glided toward the chassis in the automatic feeding process. After radiation exposure, the chassis was introduced in the intake system, there the film is released with its radiological image and passed to the developer at processing speed. With this feature were reached high process cycles and high performance for the department.

(1.12.- Developing system "daylight" and reader of CR reusable plates with cassettes)

Since the 1990s CR (Computed Radiography) systems perform the digitization of x-ray images, eliminating the conventional image film replaced by reusable plates. The process is similar to that described in the previous paragraph, as well instead of developer, the reading of the radiological image recorded on reusable plates is carried out with very high definition lasers readers.

Reading rooms, with different x-ray film viewers, where radiologists perform diagnostics, which are stored at voice recorders, or written to computers directly, or lately, in systems of voice recognition to send to its archive and later edition through the first appearing digital systems.



(1.13.- Darkroom with film developer and file. Also with daylight and workstations for diagnosis)

An example of an emergency image department on late 90s (1.14) with modalities of radiology and ultrasound, and where can be appreciated a conventional radiology room and a remote control table.

The system works with a CR for the digitization of the images that are sent to a central PACS archive. Initially started with a report room which had monitors and x-ray film viewers.

(1.14-Emergency imaging department)

I.II. RADIOTHERAPY

After the discovery of the x rays by Roentgen began the perception of the harmful effects caused in the tissues of the human body and also the possible curative effects which could be in certain pathologies. The first treatments of radiotherapy occur shortly after the discovery of Roentgen and clinical reports on radio therapeutic applications occur immediately

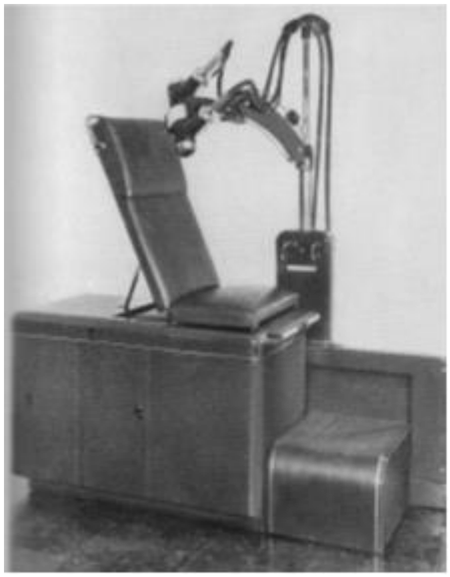
In April 1896 Daniels, of Vanderbilt University, reports on the fall of the hair of the head of a colleague whose skull has been "photographed with X Ray". Leopold Freund, a physicist from Vienna, who had read these reports, argues that x rays could be used for hair removal in therapeutic indications. In 1897 Freund informed to his local medical society have treated a patient with hairy naevus. Freund was probably the first to apply the x rays based on their known biological actions, whose previous use was purely empirical (52).

From this moment the publications increase its intensity and Gosht used e.g. in the treatment of the breast cancer in 1902, Morton in fibromyomas in 1903, etc.

The development of applications of x rays in radiotherapy followed the same course of the instrumentation that has been suggested at the beginning of this chapter, and was Coolidge around 1914 who designed cascaded tubes capable to generate very high voltages, provided by the high-voltage generators that different manufacturers produced already at this time. The most important changes in the construction of high-voltage generators were designed by Lawrence and Van der Graaf. The first developed the cyclotron, and the second a very high voltage static generator; both reached several million volts.

Researchers first recognized the importance of determining the dose required to produce a certain biological effect. The initial measures corresponded to the milliammeter installed on the machine. Already in 1907 were presented reports on the possibilities to measure doses using ionizing properties of x rays, and William Duan built a camera in 1914 for measurements of doses in therapeutic radiology and the unit of measurement, roentgen, was established in the Second International Congress of Radiology, held in Stockholm in 1929.

Therapeutic radiology machines were designed in different levels of kilo voltages, depending on its application. By the 1950s were available low kvp equipment (1.15), for applications requiring low penetration as in dermatology; they have the advantage of the high intensity of the radiation in very short therapeutic time. Most of the dose is absorbed in the first millimeters of tissue.



(1.15.-Contact therapy 45 kV). (1.16.-Working unit with medium kilo voltage operating between 80 and 120 kV)

Medium kVp radiation equipment used generators with voltages between 85 and 120 kV. It was the technique with priority to select for injuries in the skin and not very deep tissue.

Radiation with high voltage equipment were the general election for all treatments that took place until the 1950s (1.17). Generators producing voltages in the range of 200 to 250 kV. The use was for all tumors situated one centimeter below the skin (38).

Equipment with x rays generated at voltages higher than 1.000 kV were called super voltage radiation. Doses produced with these machines needed proper planning of treatments to avoid greater damages in the healthy tissues. The penetration capability was very high.

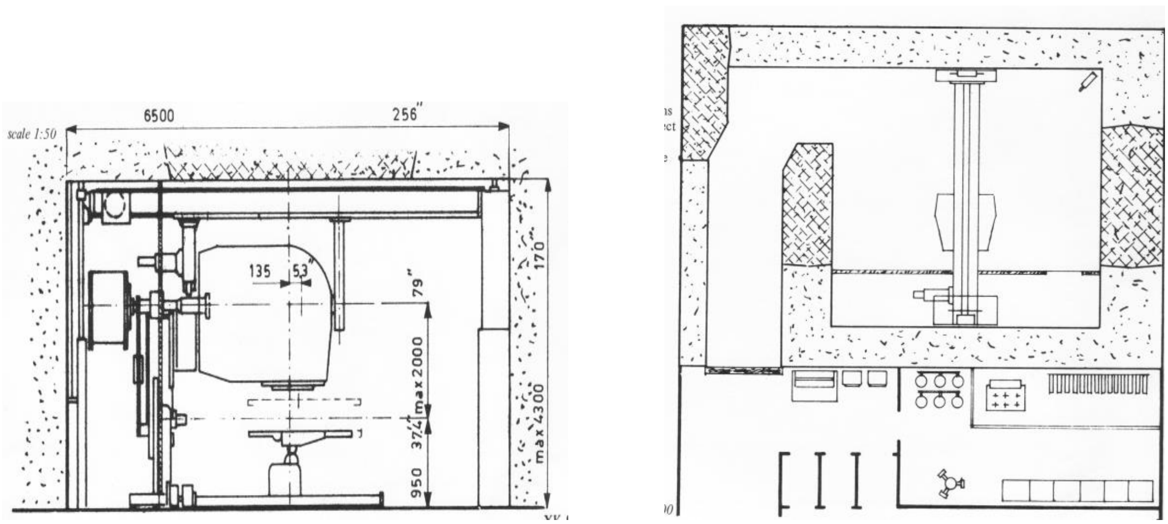
In 1948 several companies presented the betatron, equipment for treatment with mega voltage, capable of generating high doses with electrons and photons in a very short time, reaching very high energies.

The image of a betatron can be seen in (1.18) with energy in electrons between 3 and 45 MeV and from 30 to 45 MeV in photons. The dose in electron can reach up to 500 Rmin and in photons up to 80 Rmin at photon measured in a field of 20 x 20 cm (7,8 x 7,8 in) to 1.1 m (3,28 ft) FSD.

(1.18.- Betatron)

(1.17.- High Voltage equipment)

The system required concrete construction of configuration similar to that required by the current linear accelerators, while most voluminous, with sufficient structure strength to support the head of the betatron that weights of up to 12.000 kg (26.455 lb) (1.19).



(1.19.- Side cut and plant for betatron bunker)

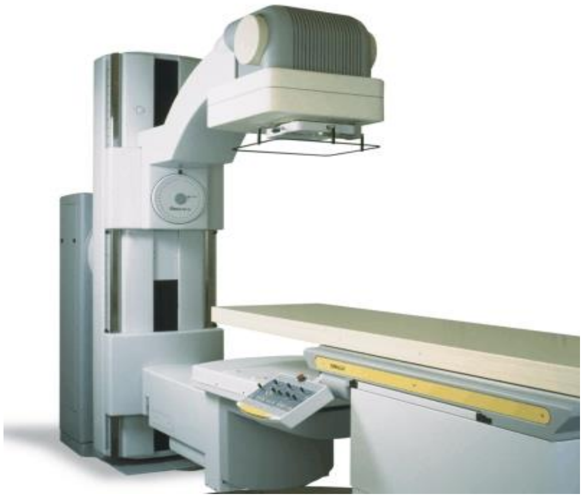
The construction of the bunker, along with control and cabins needed a surface next to the 150 m2 (179,4 yr2) with a power of 40 kW for the own betatron consumption and additionally other 16 kW of auxiliary equipment.

The betatrons were in operation until the 1980s where they were replaced by the first linear accelerators.

Cobalt units which there are still at the beginning of the 21st century some units installed, are based on the activity of the Co-60. This emits gamma rays at two wavelengths clearly defined 1.1 and 1.3 MeVs and some weak beta rays. Co 60 has an average life of 5.3 years and during this time is a source of radiation for super voltage therapy. The bunker construction for a cobalt system is similar to a betatron, but something simpler. Co 60 tablets manipulation requires careful execution protocols by their dangerousness and in the same way the operation of the Co units also requires exceptional care and special monitoring of the requirements of the National Regulation of Radiation Protection Bodies.

The first linear accelerators, successors of the betatrons, were announced in 1953, providing a refinement of these energies, dose and spaces, introducing and incorporating new technological bases appeared between the years 1960 and 1970.

(1.20.- LINAC)



(1.21.- Simulator with image intensifier)

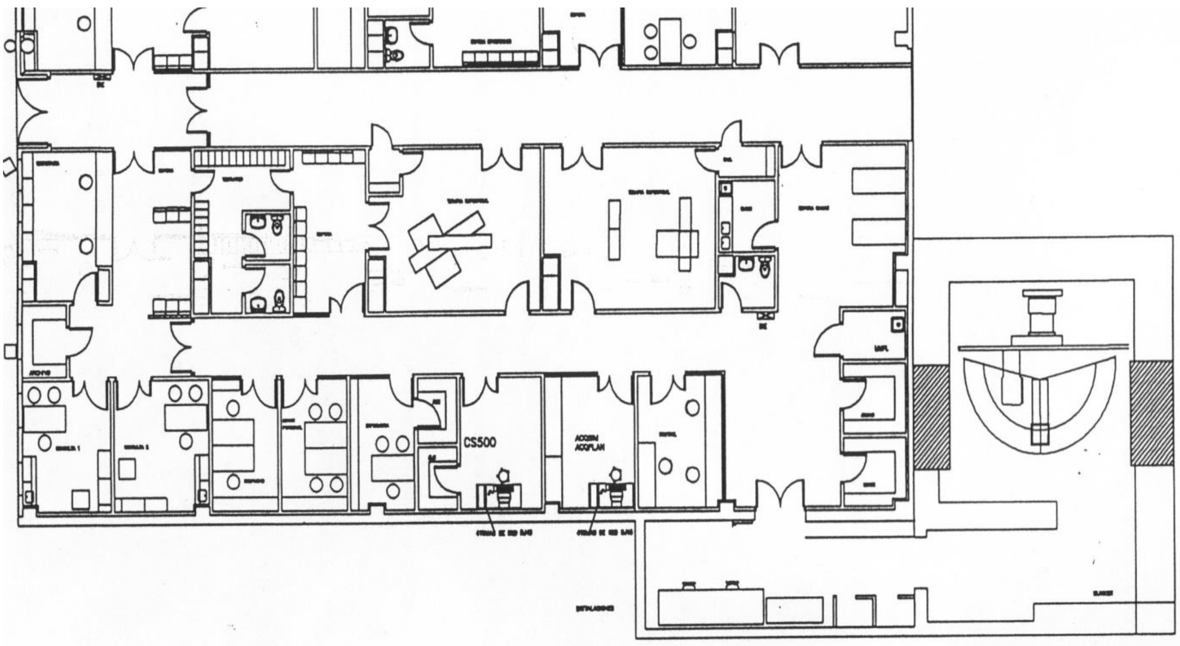
Linear accelerators (1.20) form the basis of radiotherapy treatment at the end of the 1990s. Its location, and bunkers, are smaller than the betatron, but similar in its construction. The thickness of the walls for protection is function of the energy in photons, the possible generation of very high energy neutrons and the zones to be protected (59-60).

The planning of treatments experienced an important development with software improvements and the introduction of the protocol DICOM RT, which allows to link the different components of the department to tune the tasks. Simulator, planner and LINAC are connected through a network of radiation therapy, so treatment is highly automated.

Simulators for the location and preparation of the treatment (1.21) evolved from image intensifier x-ray systems to simulators with CT and light beams with lasers for alignment, which began to enter in service at the end of the 1980s. Room design requires the same components as a CT, dimensioning the examination room for the exploration to be carried out.

Brachytherapy continues its role in the treatment of gynecological tumors and intracavitary where can be accessed with corresponding applicators. The design of the rooms required detailed examination of the flow of patients and radionuclides for the radiological protection of the service personnel.

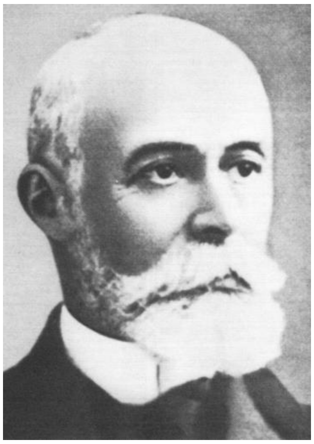
An example of radiotherapy service with a linear accelerator and brachytherapy unit, with a CT simulator, a room of protective masks and one for planning is what can be seen in (1.22). The facility ended its installation with connection in DICOM RT.



(1.22.- Radiotherapy department)

I.III. NUCLEAR MEDICINE

Between 1892 and 1895 Becquerel made experiences with uranium salts in his laboratory of the Polytechnic School of Paris, and noted that uranium phosphorescent salts exposed to light acted on a photographic plate wrapped in a black paper. Becquerel showed that the phenomenon was responding to a specific property of uranium and its components and was independent of the state in which the uranium was. However, the discovery of the medical effects of radioactivity corresponded to a casual phenomenon. In 1901, holding a test tube of 200 milligrams of uranium salt in his jacket pocket, he observed a burn on the skin next to the location of the tube. Later the skin ulcerates and it took long time to heal.



(1.23.-H.Bequerel)

Subsequent investigation showed that the resulting radiation consisted of two components: one that is propagated in straight line identical to x-rays, and another that could deflect with a powerful electromagnet.

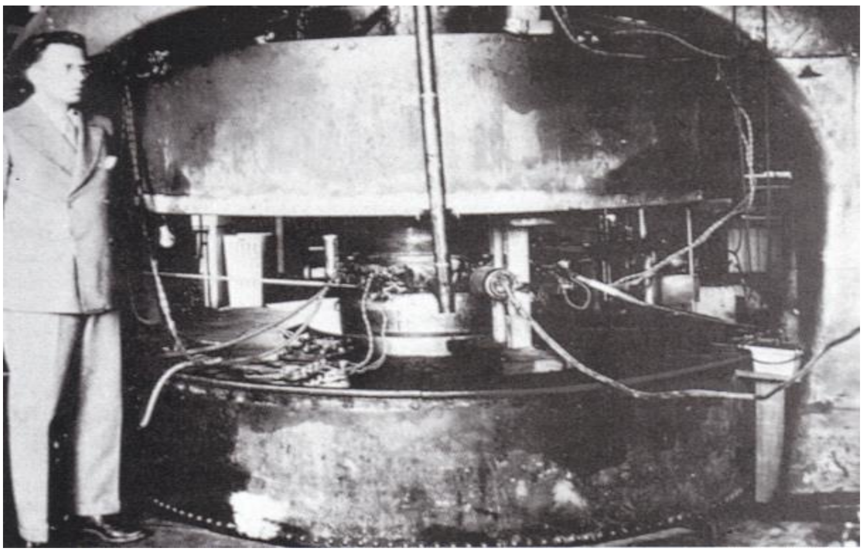
The marriage Curie focused his work on Becquerel Radiation Laboratory of the Physics School of Paris, available from the year 1892. Mme. Curie concentrated in discovering the origin of the energy producing phosphorescence. It was found that radioactivity was proportional to the amount of uranium in the sample and she discovered the existence of the natural radioactivity in thorium, uranium and polonium, coming to the discovery of radium. The discovery of natural radioactivity and the works of Becquerel led them to the award of the Nobel Prize in Physics in 1903, who shared the spouses Curie with Becquerel (41).

(1.24.- Pierre and Marie Curíe)

In 1913, F. Soddy along with Rutherford discover changes in chemical elements due to the nuclear disintegration.

Ten years later, G. von Hevesy develops techniques of tracers in biological exploration methods.

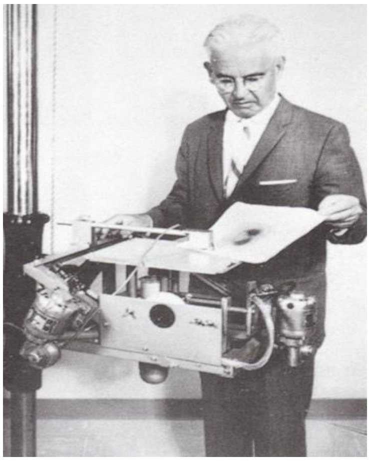
E Lawrence built in 1931 the first cyclotron, which begins production of radionuclides.

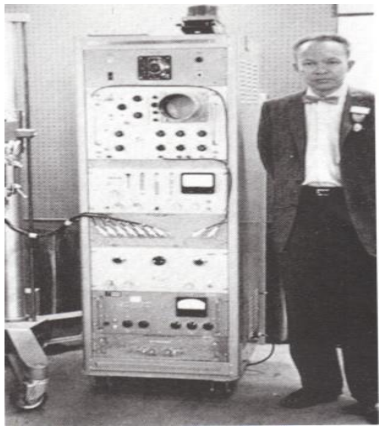


(1.25.- Lawrence)

In 1934 the spouses Joliot and Irene Curie (daughter of Mme. Curie) discovered artificial radioactivity to bombard boron, magnesium and aluminum with an alpha particle of a source of polonium. They thus produced three radioactive isotopes of nitrogen, silicon and phosphorus. This fact is considered as the beginning of Nuclear Medicine given that is the branch of medicine that uses artificial radioisotopes.

The first scintillation counter designed to locate radioactive iodine in biological systems was built in 1949 by B. Cassen at UCLA, with the support of the Atomic Energy Commission. The counter was formed by a crystal coupled with a calcium tungstate photomultiplier tube.





(1.26.-Cassen y Anger)

In 1951 L.Reed and R. Libby developed the Scanner with the introduction of a sodium iodide scintillation crystal.

In 1963 H.O. Anger builds his famous scintillation camera with 19 photomultiplier tubes.

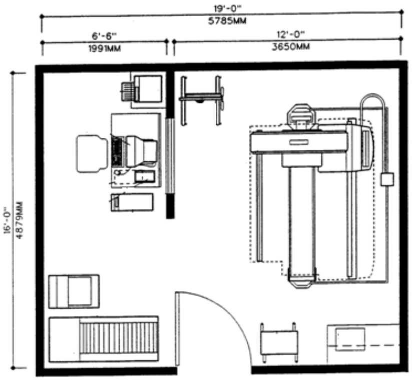
Since then, there have been developments with advances in electronics, computing and computerized axial tomography, leading to the acceptance of the SPECT and PET techniques as a very high diagnostic value, not only in oncology and cardiology but in functional explorations of diseases in all areas of the human body (25).

At the end of the 1990s, Nuclear Medicine technology was based on gammacameras composed of a scintillation crystal and a high number of photomultiplier tubes for the detection of gamma rays coming from the patient and a computer capable of processing the data coming in from the analog digital converters that are located at the exit of the photomultiplier tubes (62).

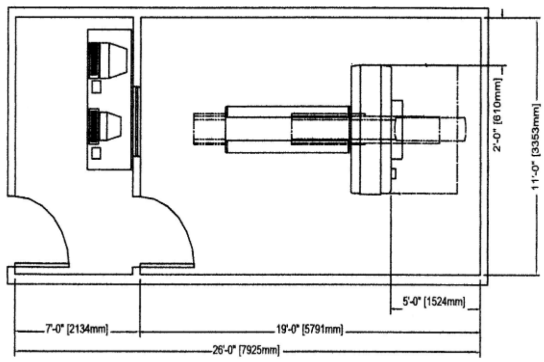
(1.27.- Gamma camera of three detectors)

A gamma camera requires an examination room with an area in the order of 22–30 m2 (236,8- 322,9 ft2) where besides the gantry with their detectors and examination table is hosted the compartment that stores various collimators that adapt the image acquisition to the energy of the isotopes. The floor must support loads above a ton of Kgs (2.204,6 pounds) and electric power demanded in the range of 20 kW. The camera control, or acquisition station, and a workstation for processing of the images configured the installation.

The Positron Emission Tomography, PET, essential in the current oncology in combination with multi-slice CT, had its full definition in the last years of the 90s, consisting of a cylindrical body with rings of crystal detectors of different luminescent materials and the photomultipliers to capture the resulting signals of annihilation events. In the same way that the gamma camera resulting signals are processed in a computer capable of multiplanar and volumetric reconstructions.



(1.28.- Single detector gammacamera with collimators cart)



(1.29.- PET layout)

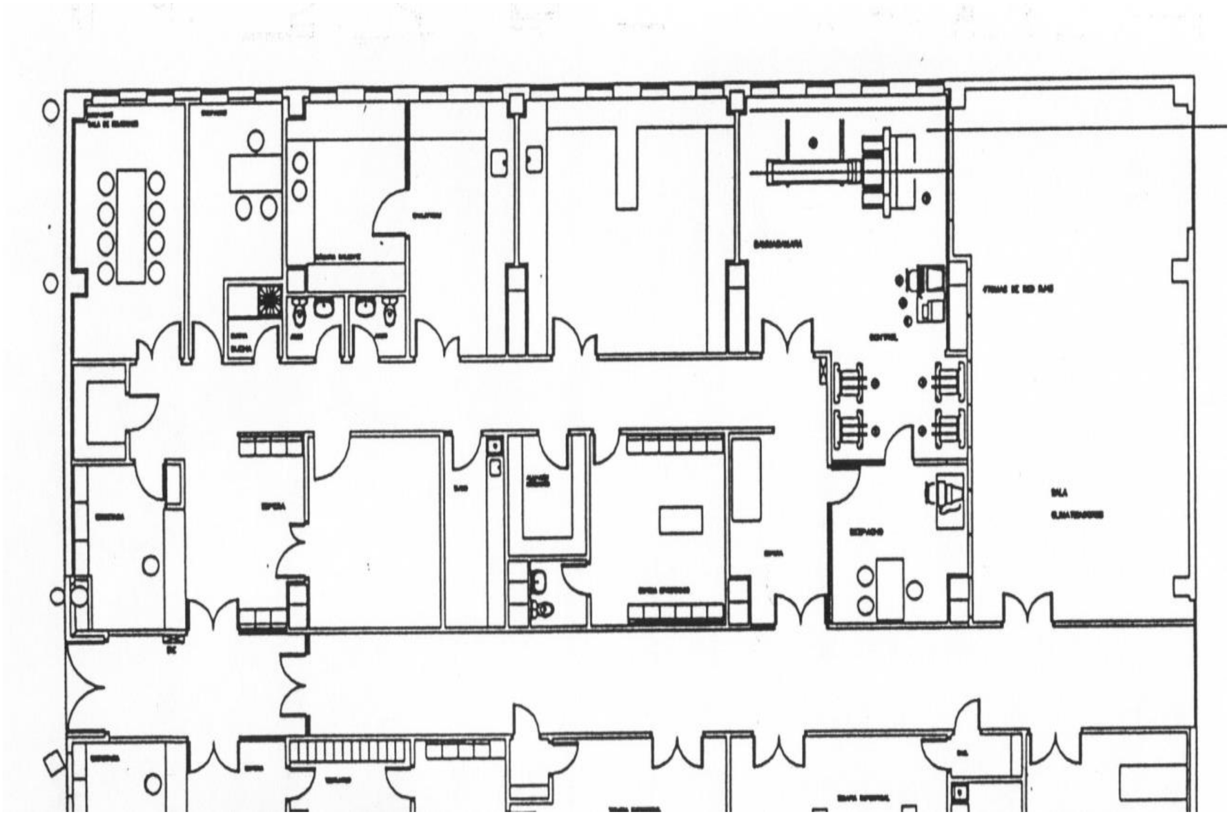
PET requires a larger dimensions than the gamma camera room, while have a more bulky gantry. An area of at least 25-35 m2 (269,1-376,7 ft2), technique room for the electronics on some systems and a control room with the acquisition computer; as well as the image processing workstation.

(1.30.- PET)

Dependencies for PET are more complex than in the case of a gamma camera because besides the areas dedicated to the nuclear laboratory for the administration of radiopharmaceuticals, preparation of doses and their waste storage, they need additional spaces for the patient injections with the F18 glucose solution and the resting areas of patients waiting the PET scan.

Nuclear Medicine facilities already reached in the 90s a high level of sophistication, requiring calculations of experts in radiation protection, as well as the observation of nuclear bodies control in safety regulations of radionuclides handling.

The nuclear medicine department in the attachment (1.31) that began operating in December of 1998 consists of a gamma camera, a room reservation for a second unit, injected patients waiting room, injection room, hot chamber and examinations reading room with a laser camera for printing images.



(1.31.- Nuclear medicine department)

I.IV.- ULTRASOUND

Medical ultrasound technology is based on the use of the ultrasonic waves reflected by the different tissues. A transducer emits a wave or train of waves that propagate through the human body. Each wall that delimits an organ or tissue generated at the same time a wave or ultrasonic reflected waves train that is captured by the same transducer and converted into a signal or electrical signals. These are converted to analog or digital values and are reconstructed in a processor that represents the images on a monitor.

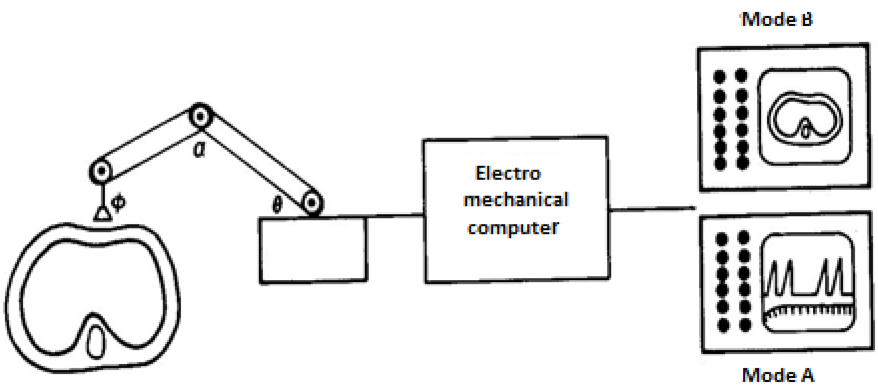
The ultrasound technique, as described above, has evolved very parallel to other imaging techniques, since their initial invention to the situation at the end of the 1990s. Thanks to the breakthrough of electronics, microcomputers and software in medical technology, has been improved the image resolution, the procedures and examination time making more simple the examinations to the physician and the patient. The ultrasound technique has become in the present the diagnostic modality with bigger growth, considering the examination numbers.

The first investigations of the reflections of waves in biological tissues were published by Ludwig and Leksell in 1955, although in materials was already reported by Solokov in 1929 and it was first used in medical technology by Dussik in their brain studies (08).

The beginning and development of sonic techniques took place during the first and second world wars with the invention of sonar for locating submarines and as military fleets navigation aid.

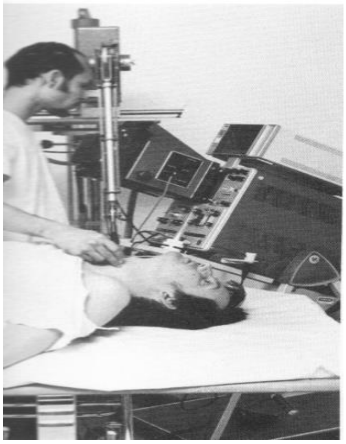
First studies by slices ultrasound imaging procedures were published by Reid and Wild as well as Howry and Bliss, in studies of tumors of the breast with 15 MHz.

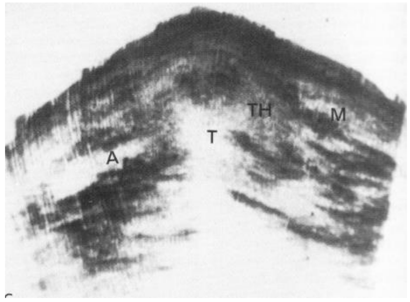
The generation of sound waves in a simple way for medical practice is facilitated with the use of the piezoelectric effect in quartz and other materials. The electrical impulses applied to the quartz of the transducer material generate waves that are introduced into the tissues, and the walls of these reflect new waves that the piezoelectric transducer converts in electric signals. These are processed to form images that are represented in a visual pattern. It is noteworthy that the piezoelectric effect in materials such as quartz, was discovered by the brothers Pierre and Jacques Curie at the end of 1880 and used in 1917 by Paul Langevine developing the sonar (41).



(1.32.- Primitive ultrasound system diagram)

In its simplest representation (1.32) this is the diagram of the first ultrasound equipment where an elemental transducer picks up echoes of an area of tissue reproducing an image in mode A, showing the lines of separation of tissues on an oscilloscope with persistence screen. Or where through an electromechanical device runs a body section overlapping paths of each received line of echoes, either on a monitor of persistence or in a photographic camera (1.33) (69)

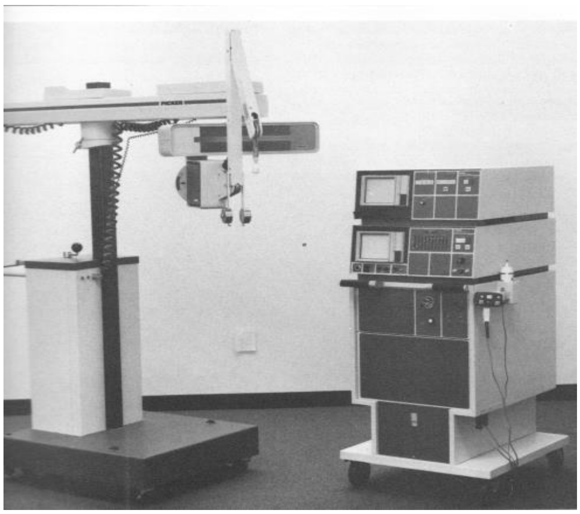




(1.33.- Thyroids exam)

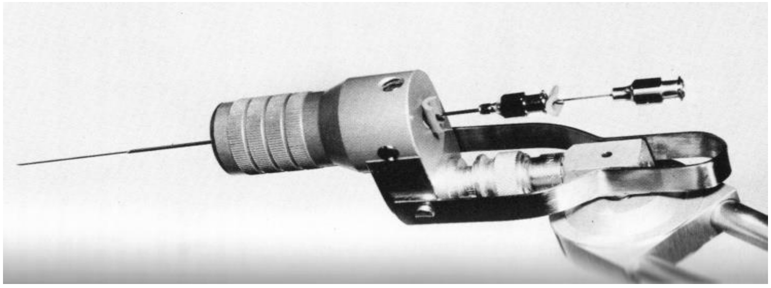
In this system of late 1960s (1.33), is shown a scan of thyroid with this type of appliance. To the right is the calculated image, where you can see the great progress made when, today, we do a retrospective comparison.

In the first time the majority were static type ultrasound scanners where the skill of the operator and the electromechanical instruments were basic for diagnostic imaging.



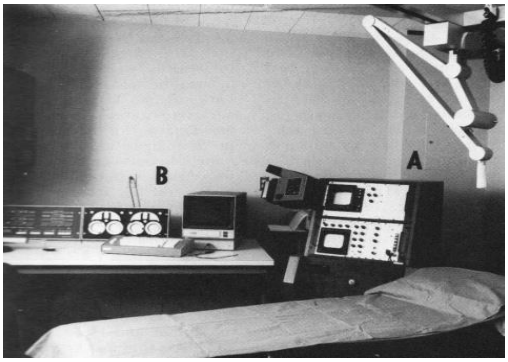
(1.34.- Static ultrasound equipment)

The development of diagnostic applications was quick thanks to new technology and broad features, as example puncture guided with ultrasound, with devices such as we see in (1.35), whose procedures were provided with devices in real time.



(1.35.- Guide for punctures)

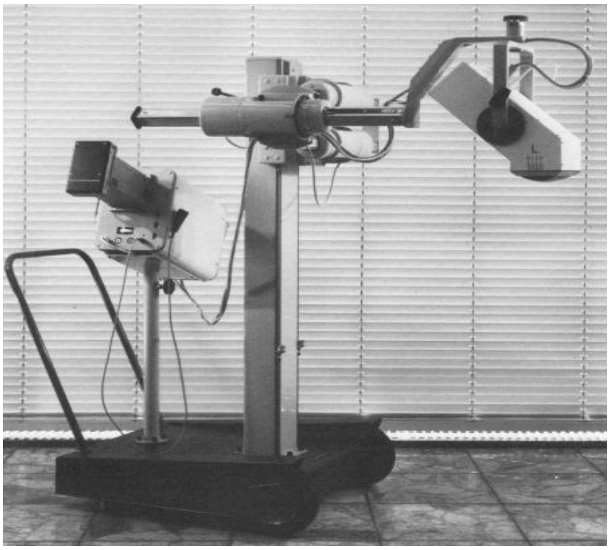
Also applications in radiotherapy planning, with systems build as we see in (1.36).



(1.36.- Radiotherapy planning)

Ultrasound images are sent to a digital computer that accepts direct input of ultrasonic information on the routine of treatment planning.

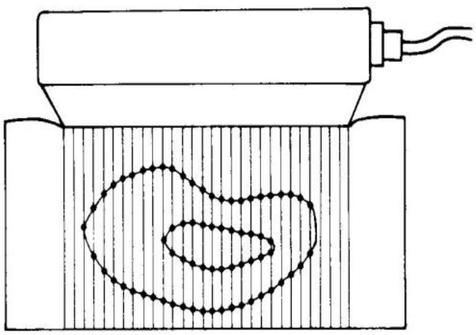
The desire to speed up the procedures led to develop equipment that could acquire and represent the images in real time, at first with artful designs as in the figure (1.37) on the following page, of the years seventy to seventy-five. Equipment features allows continuous acquisition of knowledge to medical radiologists, gynecologists and obstetricians who subsequently developed the bases of all the gynecological software existing today as part of the basic software package of a conventional ultrasound equipment. With these systems were made diagnosis at that time calculating with manual tables the parameters intraparietal and intrathoracic of the fetus to determine the probable date of birth.



(1-37-Ultrasound real time system)

From a transmitter-receiver formed by two 2.5 MHz transducers are emitted ultrasonic beams to a parabolic acoustic mirror. Reflector sends a parallel series of sound waves through a full water bag applied to the body by means of a contact gel. The field of examination is swept 15 times per second and covered with about 14 cm in length and 20 deep. The unit produced instant images that were collected in an oscilloscope and a television monitor (71).

Another solution for applying multiple beams was sequential linear transducer, formed by 64 transducers, and triggered four groups simultaneously, forming approximately 60 lines of information.



(1.38.- Lineal transducer)

Thus in the environment of the 1980s already they were available large manufacturing of equipment in real time with linear, annular and sector probes, dominating the A, B, M, and Doppler techniques for the study of the vessels of the human body. Also the echocardiography had reached a high advance with equipment working in real time and probes with an excellent intercostal entry (70).

The 1990s were a great development in the image acquisitions quality and the improvement in the patient comfort; faster and better resolution in the images with the contribution of micro-electronics, information technology and new materials for the manufacture of transducers. In the mid-1990s was introduced in the equipment the 3D technique in real time with motorized linear transducers that allows to acquire entire volumes of data to be processed and obtain multiplanar reconstructions in all three spatial axes.

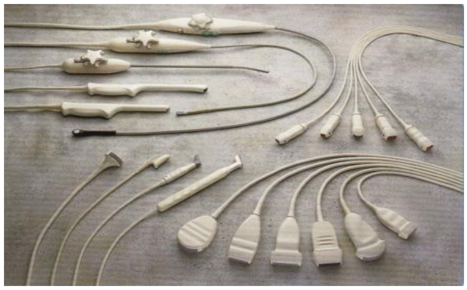
3D-4D acquisition technique, widely used in obstetrics and gynecology was applied more slowly into the area of radiology. Several workstations are designed for the extensive use of this technique that allows to export from the ultrasound system to diagnostic workstations entire volumes of data, for its subsequent image reconstruction and their medical evaluation.

(1.39.- Real time 3D ultrasound)

Already at the end of the 1990s and beginning of the new century ultrasonic equipment had acquired a considerable development, occurring as in other imaging techniques two significant facts:

- A great reduction of examination time
- A very high quality of diagnostic imaging

The equipment at that time already had more than 512 input channels of information, and digital technology were an integral part of its electronic systems. Three-dimensional images processing (1.39), and color Doppler techniques allowed to see some excellent images of the vessels, with the support of the contrast and the harmonic imaging processing techniques. There were also available a variety of probes for intracavitary and intraoperatory (1.40) procedures.



(1.40.- 3D/4D d ultrasound system and transducers used in ultrasound)

Ultrasonic diagnosis has reached such a state of sophistication and development that allows to obtain the diagnostic information without discomfort for the patient and with the complete absence of morbidity and mortality.

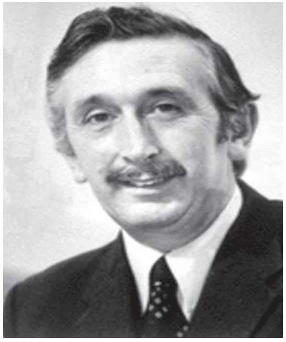
The procedure is fast, safe, noninvasive, and often can prevent or eliminate long and tedious procedures that require catheters, injections of contrast in radiographic imaging. There is not the danger of ionizing radiation, and today, in many patients is the procedure to choose to start a diagnostic. **And so much is the growth that at the beginning of the 2018 we see the next overcome, in number of examinations, to x-rays by the ultrasound technique**.

At the end of our chronological examination we have reached equipment that need very little space to make the diagnosis. An ultrasound system physically occupies less than one square meter and must add a stretcher for the patient during the exam. An area of diagnostic room to locate these components, allowing to move a patient in a bed is sufficient. An area with 12-15 m2 (129,2 – 161,5 ft2) tend to be suitable. Should be considered two cabins for changing clothes of the patient and a toilet in the room. Power on the order of 700 to 1.000 W and the ordinary environmental air conditioning. It is the simplest system for installation of all imaging systems.

I.V.- COMPUTED TOMOGRAPHY

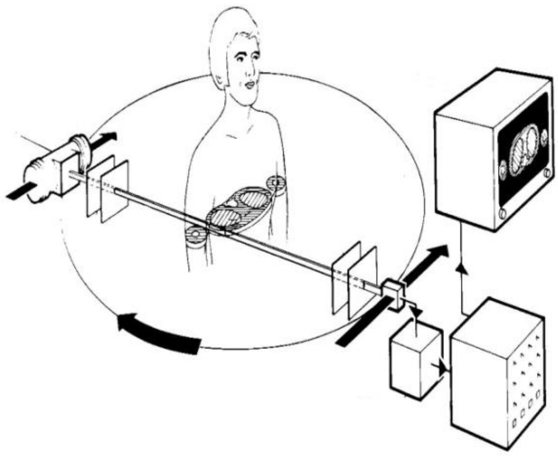
Computed Axial Tomography (CT) was introduced for the first time as a clinical diagnostic tool in 1971 when the Drs. Hounsfield and Ambrose visualized successfully a brain tumor in a 41 year old woman. The find signified for Dr. Hounsfield the award of the Nobel Prize in medicine in 1979 by the Swedish

Academy; fair compensation for an extraordinary discovery that has revolutionized the way of seeing the images of the human body and therefore how to make current Imaging.



(1.41.- G.N. Hounsfield. Medicine Nobel Prize 1979)

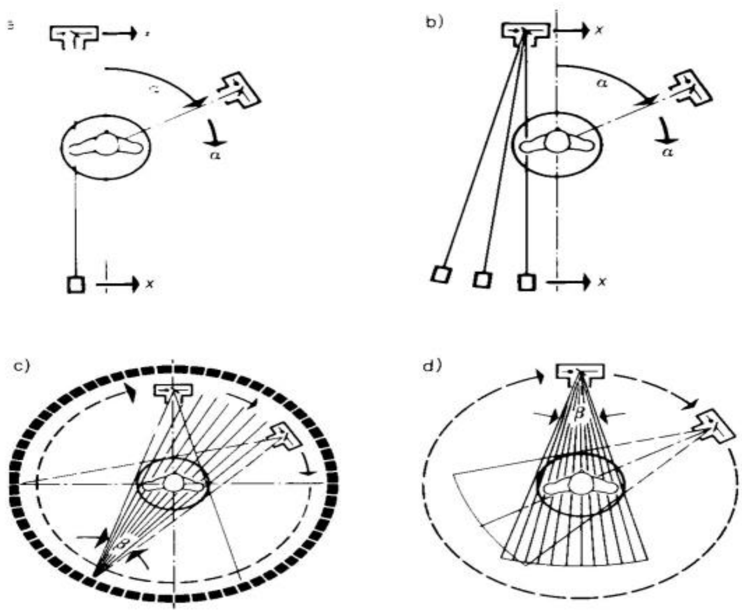
In its most elementary form, consists of a system composed of one x ray tube and one or more detectors opposite the x ray tube, and both elements turning around the patient (1.42). The tube emits radiation that a part is absorbed by the patient and the rest passes through him and falls on the detector sensor system that measures the dose that has passed through the patient on the opposite side. The assembly formed by the tube and detectors system turns around the patient taking measures, in each grade or each half degree of rotation, of the resulting radiation. Calculating these values for numerous projections, is generated a bi dimensional image with the thickness of the measured axial slice. These images have a resolution of contrast that is far superior to conventional radiography, demonstrating the ability to differentiate between tissues of very slight difference in density.



(1.42.- Scheme of a CT operation)

The first CT construction was based on the first graph (1.42), in such a way that there was only a receptor to capture the radiation transmitted through the body; they are called first generation equipment.

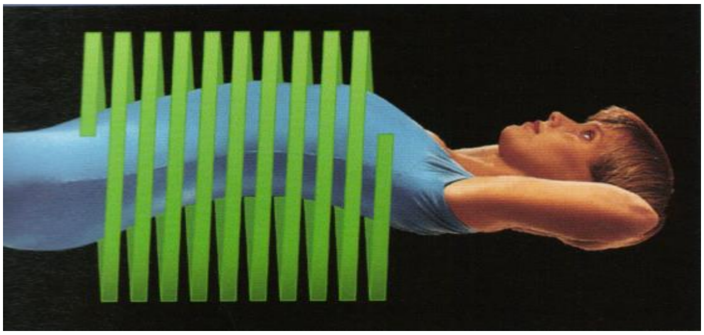
In the year 1975 there are equipment that include several detectors in the receptor system, so the acquisition times are shortened and the image quality improves substantially.



(1.43-First, second, third and fourth CT generations)

Already in 1978 was presented the first CT of the so-called 4th generation (1.43). In this the gantry contains a complete ring of stationary detectors. Only the x-ray tube rotates around the patient and provides continuous or dose pulses for the measurements to be made. Acquisition times were already close to several seconds, so the advance within a few years was impressive.

In 1988 appeared the first CT with sliding rings. These enable the transmission of power and signals during the continuous rotation of the gantry. The first through brushes, and the second mainly with optoelectronics data coupling acquisition. With this technology are avoided the problems of high voltage cables curl and it went into the modern construction of CT. Solid state detectors had already replaced the phototubes in 1980. The faster rotation was already 1 second. It was the beginning of spiral technique acquisition (1.44), so the axial techniques hitherto used, declined gradually (08-43).



(1.44.- Spiral acquisition)

The first CT multislice appeared in 1992, CT TWIN (Elscint), which got two slices for each rotation of 1 second.

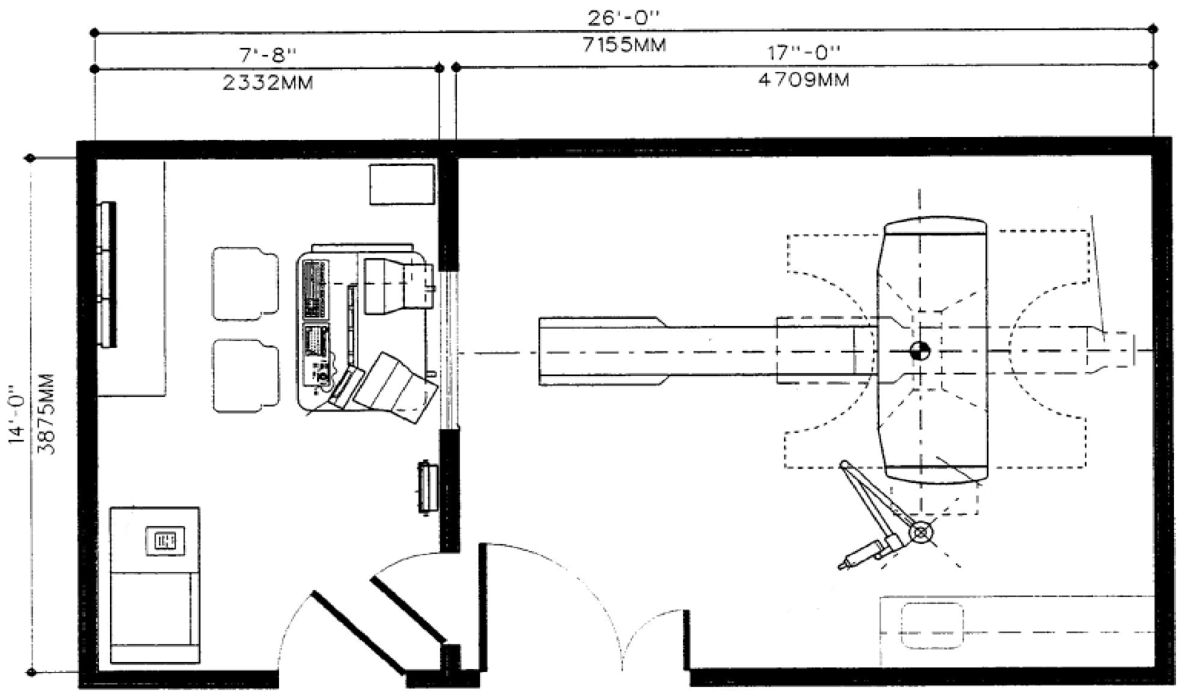
The speed of acquisition to capture more and faster events has been since then the dominant in the development of CT, still today the multislice CTs (MCT) are the basis of diagnosis with this modality.

At the end of the 90s appeared the four slices CT with rotation times reduced to a fraction of a second and could acquire up to eight slices per second.

(1.45.- MCT, multislice CT)

At the end of 20th century the CT, mostly multislice, needed one exam room space in the order of 25 m2 (269,1 ft2) , to which must be added 10 m2 (107,6 ft2) of control room, technical room (on some models) 8 m2 (86,1 ft2), and additionally the necessary spaces for preparation room, cabins and toilet.

The maximum power demand reached the 100 KVA; a weight of the exploration unit around 2.000 Kg forced to architectural calculations of soil reinforcement, and a need close to 5 kW cooling for the exam, technical and control rooms. Also the digital network for the transmission of images to the digital files already forced to place connections in control, exploration and technology rooms.



(1-46.- An example of a diagnostic imaging with CT room design, at the end of the last century)

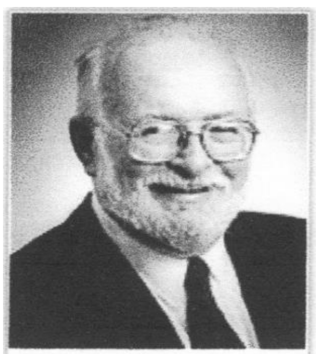
I.VI.- MAGNETIC RESONANCE

In the Year 1952 Bloch and Purcell received the Nobel Prize in Physics for his discovery of the phenomenon of magnetic resonance and by the development of the spectrometer which showed in graphics the chemical composition of different substances using such effect.

The phenomenon of nuclear resonance occurs in certain atomic elements when subjected to electromagnetic radiation that experience a precession movement around the axis of the atom of the element. The precession rotational frequency or Larmor frequency is proportional to the frequency of the absorbed energy.

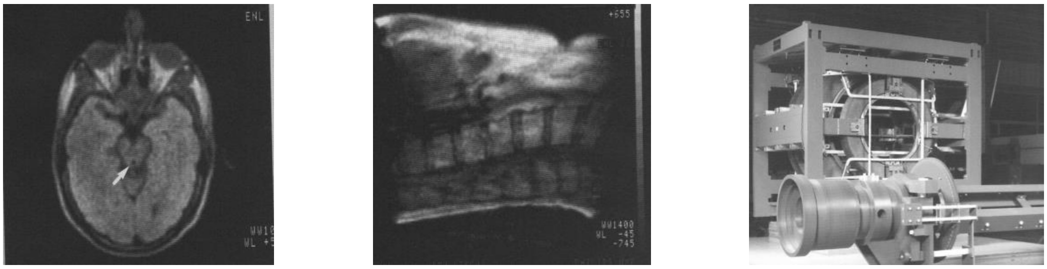
The first medical magnetic resonance images were obtained by Raimon Damadian, at beginning of the 80's. Great enthusiasm aroused by having a medical imaging technique able to obtain multiple contrasts between tissues and with the possibility of acquiring at all levels of the human body. And all without the use of ionizing radiation, that leads to a safe technique. The major constraints were the high time to acquire the images; radio frequency pulse sequences were too slow and the first images had to be reduced to anatomies with reduced mobility, head, limbs, etc. As can be seen, on a new technique, once again, the acquisition time began as the parameter to beat, like was in conventional radiology, nuclear medicine imaging, ultrasound, CT scan, etc.

In 1973 Paul Lauterbur published in the magazine Nature an article called "formation of images by induced local interactions: "Examples using magnetic resonance", where opened great expectations to the scientific, researcher and industrial world on a new way to acquire images.




(1.47.-P. Lauterbur y P. Mansfield Medicine Nobel Prize in **2003**)

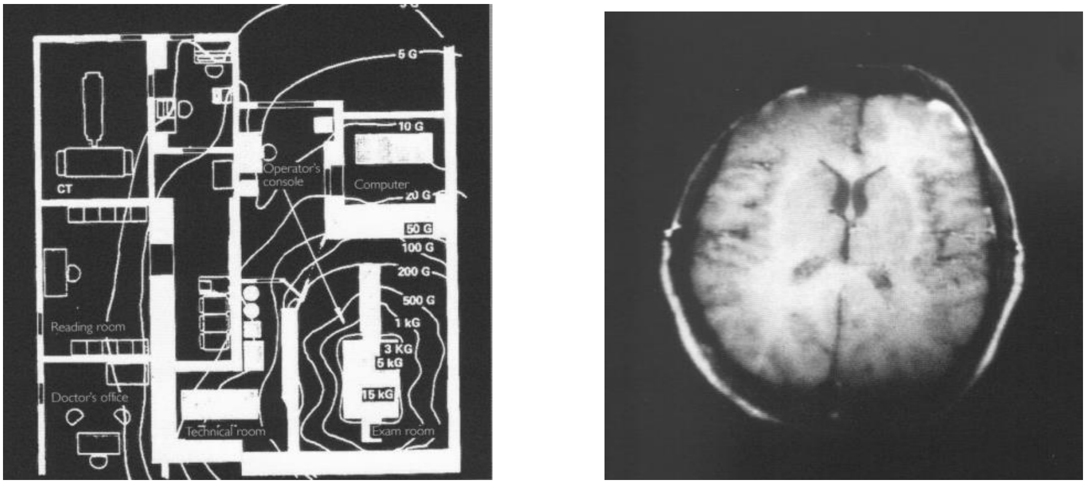
In 1981 several groups, working with resistive magnets (1.48) and magnet with superconducting showed the first clinical images acquired with this technique (04-11).



(1.48.- Resistive magnets and the images obtained)

Magnet 0,15T, resistive, with gradients working at 1 mT/m, and acceleration of 1.67 T/m/s, needed a cooling of 60 liters (15 US gal) of water per minute and consumed 60 kW of electric power. Already at this time were the first images in 3-DFT-volume with a matrix of 128 * 128 * 16 needing more than half an hour acquisition time, and very long computer calculation times.

The first images of high field arose in November of 1982, with images of skull and body. Magnetic protections conditions forced to calculate in detail the shielding, in such a way that they avoid interfering equipment and systems in the proximity.



(1.49.- Layout of 1,5T magnet and its first images)

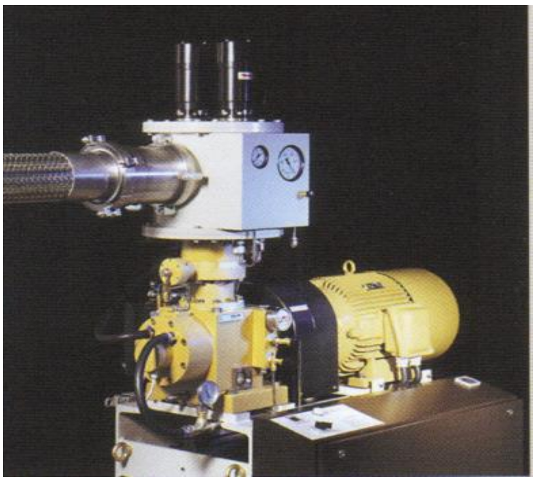
Spectroscopy begins to be an area of research where the industry began investing resources with diligence. In 1984, experiences were published in different articles, describing the first results with superconducting magnets 1.5 T and 6.3 T in animal studies and human limbs.

The search for better image quality and lower acquisition times led to the development of clinical equipment with superconducting magnets. These contributed substantial improvements with respect to the resistive magnets: higher intensity field and better uniformity, both crucial to improve image quality, but also with strong downsides:

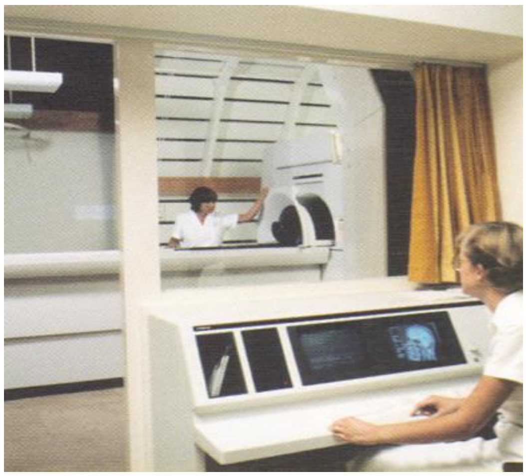
- The supply of helium, to maintain the superconductivity, with its high costs.
- The problems of magnetic shielding to locate magnets.

Helium problem was solved with the development of the so-called criogenerators (1.50). These systems, based on the Sterling principle, can cool or liquefy gases, depending on the number of stages applied. With its introduction and subsequent development, they could reduce the consumption of helium by a factor of three or more and they eliminated the consumption of liquid nitrogen that accompanied the helium in the first machines.

To alleviate the conditions of installation, both magnetic and electrostatic protection systems were designed. One of the most interesting was the famous dome, a construction of soft iron that limited the external magnetic field, thereby it could reduce the surface of the rooms a factor two or three.



(1.50.- Criogenerator)



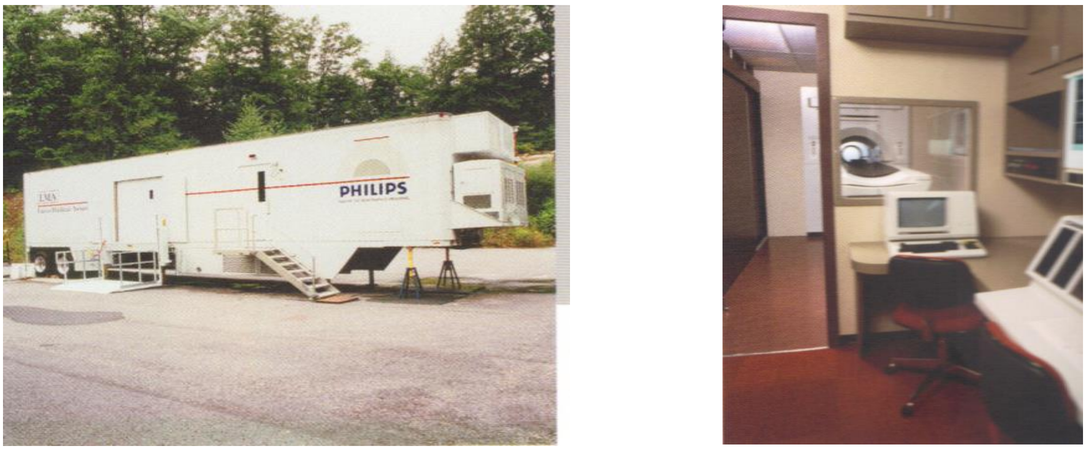
(1.51.- Shielding dome)

(1.52.- Computer system)

(1.53.- Electrostatic protection)

Computer system (1.52), between 1983 and 1985, occupied a good part of the technical room. It required a length of nearly three meters (9,1 ft). The calculation of an image of 256 x 256 with parallel processor, special for these machines, needed seven seconds per image. An example of internal electrostatic shielding in the tunnel of the magnet which got an 85 dB attenuation is shown in (1.53).

In 1986 began the installation of the first equipment in cabins moved by heads tractors, for the accomplishment of examinations in areas outside the hospital building. Annex example needed 8 tons (17.636 lb) of iron for shielding the magnet holding 5 gaus line on the walls of the cabin.

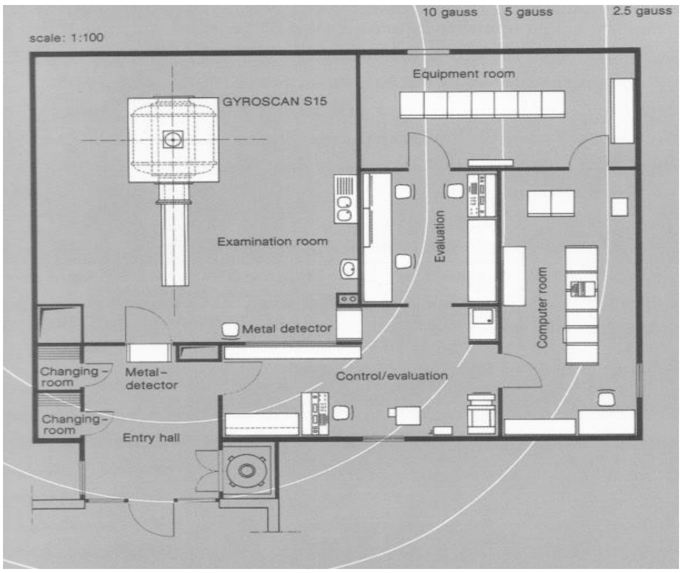


(1.54.-MR mobile systems)

Gradients of 10 mT/m brought improvements in diagnostic techniques. The slice thickness was reduced to 2 mm (1 mm in 3DFT) and acquisition of 512 * 512 matrix began to be available. It began to make increasingly more cardiac studies, and possible to calculate ejection fraction, cardiac output, and the wall thickness of the heart.

(1.55.- Archive disks)

1.5 T magnets began to be widely distributed from 1985. The field was three times higher, but the initial homogeneity was bad. Magnets manufacturers worked hard to improve the situation.



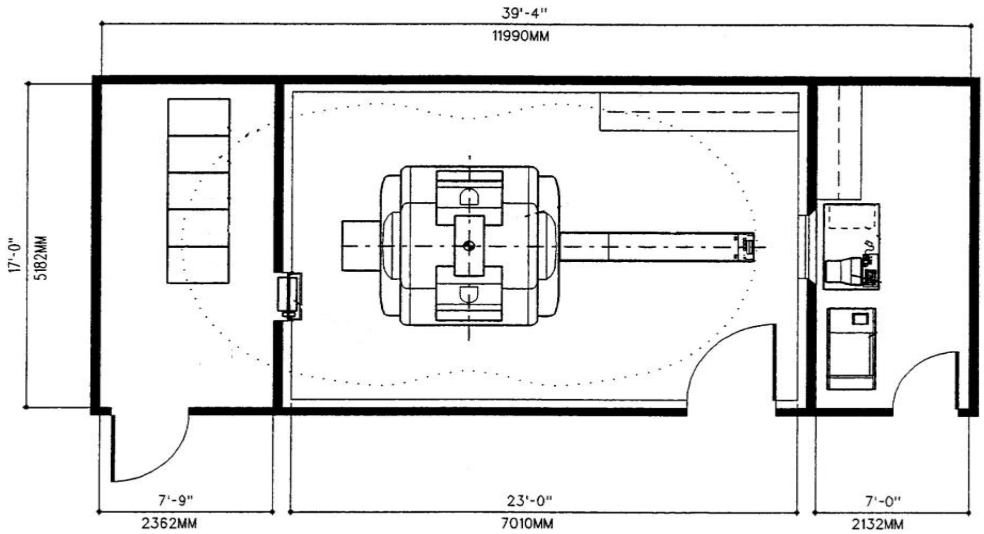
(1.56.- 1,5T system)

In 1988 with 1.5 T systems already were presented the techniques of saturation with inversion-recovery, regional saturation and halbscan, reducing acquisition times a forty percent. They also started programs with multi-stack sequences for multislice of spine discs not parallel or joint studies. Surface coils improved substantially with the "phased array" technology and multi-element coils for spine, skull, head-neck, and other anatomical areas.

Hydrogen and phosphorus spectroscopy began to be used with special hardware and software as important improvement device in high field machines.

During these years attempts have been made to determine the optimal magnetic field both for image as for spectroscopy, analyzing equipment of 2 T and 4 T. Homogeneity of field, field exploration and location requirements soon determined, for those years, the suitability of 0.5 T to 1.5 T systems. For example the experimental machine with 4 T had a 4.12 m (13,9 ft) long tunnel and being designed without shielding weighted 46.5 tons(102.514 lb).

Then attached (1.57) an example of a magnetic resonance room design at the end of the 20th century.



(1.57.- MR system layout)

At the beginning of the 21st century, there are two different types of MR equipment: Superconductors, cylindrical body, with fields of 0, 5 - 1,0 - 1,5 – 3,0 T and resistive open field, ranging from 0,2 to 0,7 T. The electrical power absorbed to operate the first reached the 120 kVA and the resistive up to 70 kVA. Strong cooling requirements forcing them to use 30 kW of power coolers. The weights of up to 35 tons (77.161 lb) needed solid reinforcements in the structures of the buildings. The needs of space for exam rooms varied between 25 m2 and 45 m2 (269,1-484,4 ft2) and additional for control rooms, technical, preparation, cabins, toilets, etc.

I.VII.- OTHER IMAGING TECHNIQUES

A few diagnostic imaging techniques have been used in the past years and are now in little use or disuse, even though some of them, with the today existing improvements in components and computer technologies can experience new developments and open an additional hole in the techniques for diagnostic imaging.

A special case was the thermography, wich in the 1970s served as an important field in the research of diseases of the breast. Thermography equipment used a thermal capturing camera to pick up the human body temperatures and represent a map with different levels of the acquisition.

For the designer of imaging departments do not represent any demand today, but if technique were to be used again, for example in sport medicine, the design of the rooms is of very high simplicity, much more than the ultrasound.

A technique, already today in use, and which promises high development is that of molecular imaging.

This technique was originated several decades ago in the field of nuclear medicine, as the case of scans with monoclonal antibodies and receivers, but currently covers techniques of nuclear medicine and radiology and optical image, such as SPECT, PET, SPECT-CT, CT-PET, PET-MR, functional MRI, MR spectroscopy, intravascular ultrasound, and phosphorescence Imaging.

Molecular imaging techniques allow, directly or indirectly, collect and follow the space-temporal distribution of molecular or cellular processes with applications not only clinical, but also basic (biochemical and physiological).

Indications of molecular imaging, although many of them are at an experimental stage, are being developed at a very rapid pace. Currently seem to be consolidated in oncological applications, in the field of angiology, central nervous system and heart, with multiple advances in other areas of research.

The current equipment is based on the techniques currently in use and the equipment already analyzed, while the laboratories of research related to these techniques are working at a high rhythm to present specific equipment to which the planner and designer should be aware for future departments of diagnostic imaging.

I.VIII.- INFORMACION SYSTEMS AND PACS

The imaging department, over the past few decades called radiology department, has a high complexity of management. A hospital with 250 beds, produces between 150.000 and 200.000 annual exams and their correct operation requires an enormous amount of human and material resources.

It is a functional unit in a hospital system, with the need of very substantial economic resources.

The patient is first appointed for an exam, then received in the department to be scanned, make the examination, diagnose the acquired images, deliver the results to the patient or send them to the specialist, make backups for the file, review cases clinically, program and develop clinical training, and many other activities. And to be able to do all this should be planned the activity, have the necessary supplies for the assistance to the patient and medical personnel, invoice the examinations and perform all economic management.

Until the beginning of the 1980s the hospitals performed all these tasks, basically with classical manual procedures, noting in paper the appointments, archiving images in films inside large envelopes in a central radiological file and billing with the conventional administrative procedures. At the beginning of these years 80, the development of the minicomputers, the possibility of forming networks in Imaging departments, cheap CRT terminals and personal computers, allowed to introduce the first RIS (Radiology Information System). It is clear the first stage in the computerization of the imaging departments with the aim of streamlining workflows and tasks, introducing an important element of improving individual and team productivity of the department, improving patient care and reducing the costs.

(1.58. Reception)

The first task to be performed by the RIS is citation. Citation allows you to attach patients to times and rooms. Additionally the RIS can be programmed to coordinate the staff, rooms and equipment, special materials required, as contrasts, catheters, etc.., and the transport of patients according to their needs.

Once these have been clearly identified the date and the time are set automatically in the appropriate work list.

Work lists are adapted to the needs as changes occur, allowing staff to devote himself to his clinical work. When the patient reaches the department, the patient information arrival is sent to the examination room. The operator checks the patient, check computer system display or printing for details. The display is updated as changes occur.

In general, were designed user/screen graphics adapters that allowed to operate a wide variety of users in the department; administrative, technical, radiologists and financial.

At the end of the 1990s the demographics of the patient already enter directly in the radiological imaging room operator station, ultrasound, CT, etc., facilitating even more the task of the radiographer, and the subsequent identification of images. The introduction of the HL7 and DICOM standards, were the key to such a high level of automation.

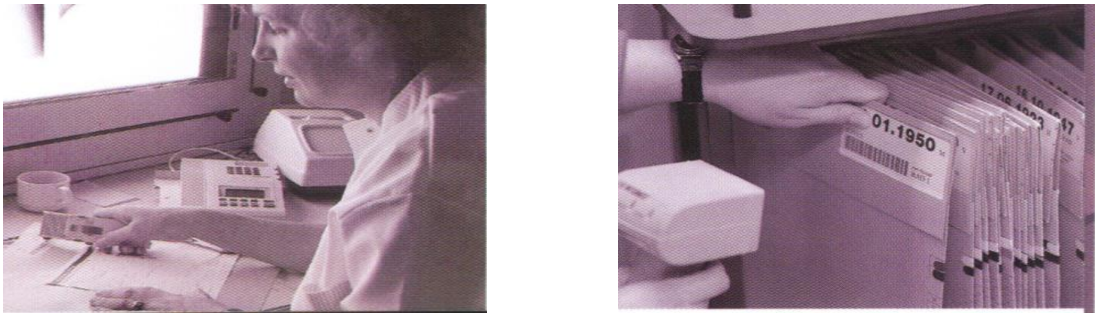
After the exam the radiologist receives information from completion of the examination from the RIS and reports with films that reads in the viewbox. Write the report on the keyboard of the computer and at the end of the 90 can dictate it and transcribe in the voice recognition systems with dictionaries specialized in diagnostic imaging.

(1.59.- RIS terminal in starter systems)

(1.60.- Reporting with voice recognition)

The reports may be linked to a number of procedures of identification in the file, e.g. barcodes that are easily searchable in envelopes along with the films. Reports are also stored as a file in the hard disk of the minicomputer server.

Reports rendered with conventional recorders could also be followed by the RIS to perform corrections and subsequent transcriptions.



(1.61 Reading of barcodes and envelopes over radiographic films in the archive)

Data stored in the RIS allows a good set of statistics that facilitate the analysis of the operation of each user and operation of the department in general, as far as yields per room, diagnoses by radiologist, and economic management.

The billing is done automatically. Each test has a code that allows to link to lists of tariffs for each medical society, company, public service, etc., the billing is made automatically and immediately.

(1.62.-Invoicing)

The development of the RIS has been one extraordinary progress in increasing productivity of imaging departments. Already a European hospital published in early 90s that only in the delivery of reports, thanks to this tool, time had been reduced from 5 to 3 days.

Systems RIS at the end of the 90 were already fully developed, and image departments planning had to have the necessary components for its correct implementation designs. The space required by the server and file, a small room 4 m2 (43,1 ft2), its air conditioning, installation of digital network of

100 Mbs to 1 Gbs (tending to rise today), the location of the PC terminals on the diagnostic rooms and radiologists reading rooms are the considerations to take into account in the design of RIS for imaging departments.

In the mid-80s already existed storage systems of digital data for massive files capable to save the images generated by the digital imaging systems: CT, digital remote control tables, ultrasound, MRI and nuclear medicine. But it was still in a very preliminary situation the digitization of 75-80 percent of the imaging exams, those of conventional radiology. A few years later the CR systems began its implementation, and at the end of the 1990s image sensors systems using flat panels of radiation image detectors.

On this basis began the development of systems of communication and image archiving, PACS, which have been the culmination of the productivity tools in the imaging departments.

The first problem to solve was, logically, the digitization of all diagnostic images that are produced in the imaging department, and the rest of the images that are generated in the hospital. Digitization that should involve maintenance, or improvement, of the resolutions of the images obtained by analog procedures.

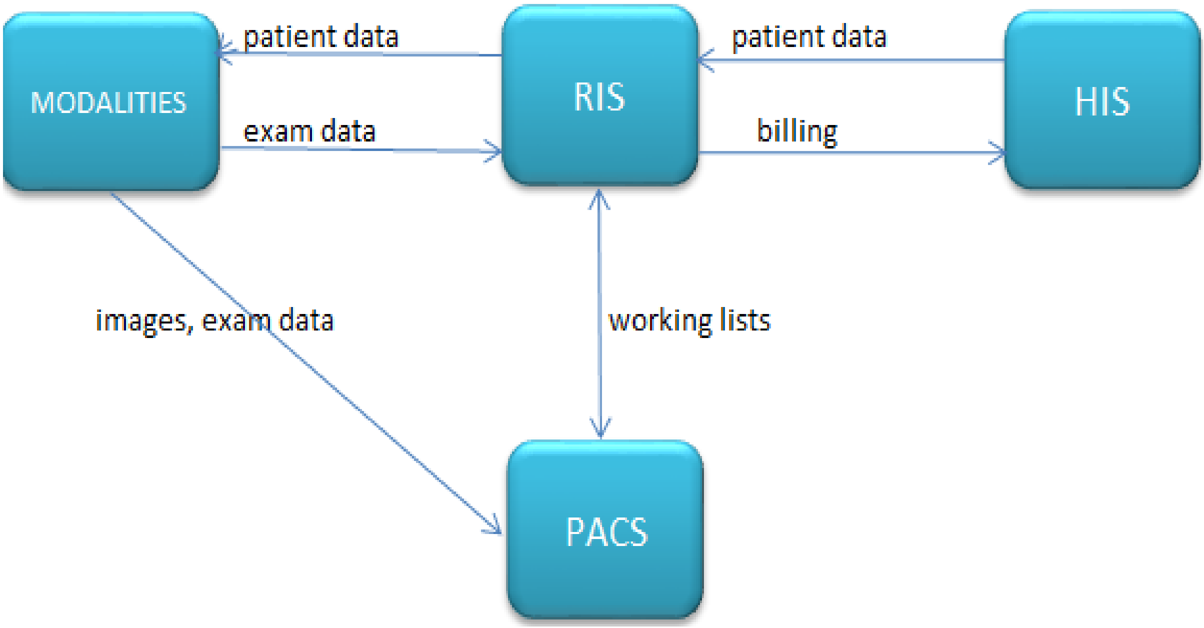
The second problem was the digital format of the images. Originally each manufacturer had their systems of digital format proprietary, not compatible with digital images produced by equipment from other producers and in many cases using other forms of the same company.

The third problem to solve was the RIS system with PACS system integration and with HIS hospital information systems, or its electronic clinical records (ECR). Were necessary tools for standardization of messages (HL7), hospital systems integration (IHE) and assurance of confidentiality of patient data (HIPAA).

A PACS System aims to improve the assistance to the patient by increasing productivity in general in all the imaging departments. This digital images produced by the diagnostic modalities are sent through the digital network of the department until the servers and hard disks of temporary storage, from where the diagnostics will be connected. For this the radiologists have workstations, with several appropriate high resolution image monitors, where display them and report the examinations.

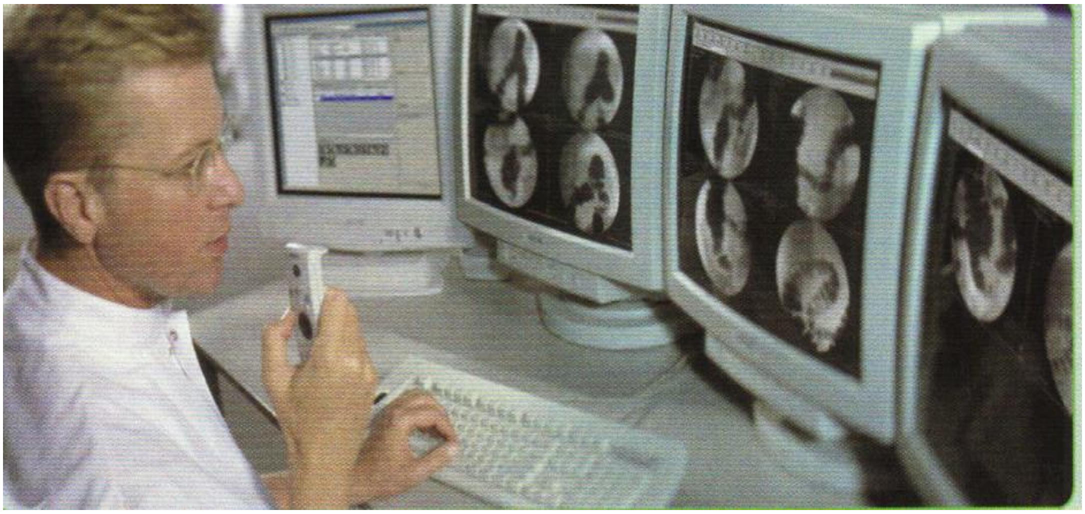
Once informed, the exams passed to final files, formed in the 1990s by high-capacity tapes, with backups in case of destruction by accident.

The union of efforts between public health departments, manufacturers of medical equipment and regulators in communication of images led, to half of the 90s, to the definition of a common format of transmission of images in medicine: the DICOM format.



(1.64.-Information flow schematic)

The standard DICOM (Digital Imaging and Communications in Medicine) has allowed sending images from modalities to digital central files independent of the manufacturer. Everyone from these years, began to design their equipment in such a way that they send and receive in DICOM. At the beginning only sent (DICOM SEND) after they sent and received (SEND and RETRIVE), then they began with formats for films laser printers (DICOM PRINT), for radiotherapy (DICOM RT), and DICOM to allow enter patient demographic data and listings of patients on equipment from the HIS and RIS (DICOM WOKR LIST) and more likely introduced after the start of the 21st century such as those that allow to manage the dose levels received by the patient (DICOM RDSR).



(1.63.- PACS system by the end of XX century)

Each equipment or imaging system, or every computer system, performs some functions that are integrated in the image department and in the hospital operation system, and its functionality is defined in DICOM by its DICOM Conformance Statement. These conformity rules allow systems integrators to operate with great freedom in the configuration of new departments.

The patient demographic data communication standard HL7 (Health Leven 7), has allowed the communication of hospital information systems (HIS) with the systems of production of images (modalities) and communication and image archive systems (PACS). Its development at the end of the 90 reported invaluable savings of integration time in later years.

(1.65.- PACS diagnostic workstation)

(1.66.- Hard disk archive)

The standards-based interoperability of equipment and systems and attending to the ultimate goal of the patient is observed from standards IHE (Integrating the Healthcare Enterprise). This interoperability is tested in each system before putting on the market. Each company defines the tested conditions. Teams of experts are working in many countries in this respect, and will contribute in the coming years to widely improve the integration of image departments in all its functions.

HIPAA (Health Insurance Portability and Accountability) requirements are not standards but a series of recommendations started to develop at the end of the 90s and followed by all manufacturers, trying the protection of information systems against unauthorized access, or modify the information in the stages of storage, processing or transit. The challenge is to enable authorized users to access the information without difficulty, produce an audit access to the information service, not compromise the ability of health workers to access information needs and allow storage of records in the long run with long periods of consultation.

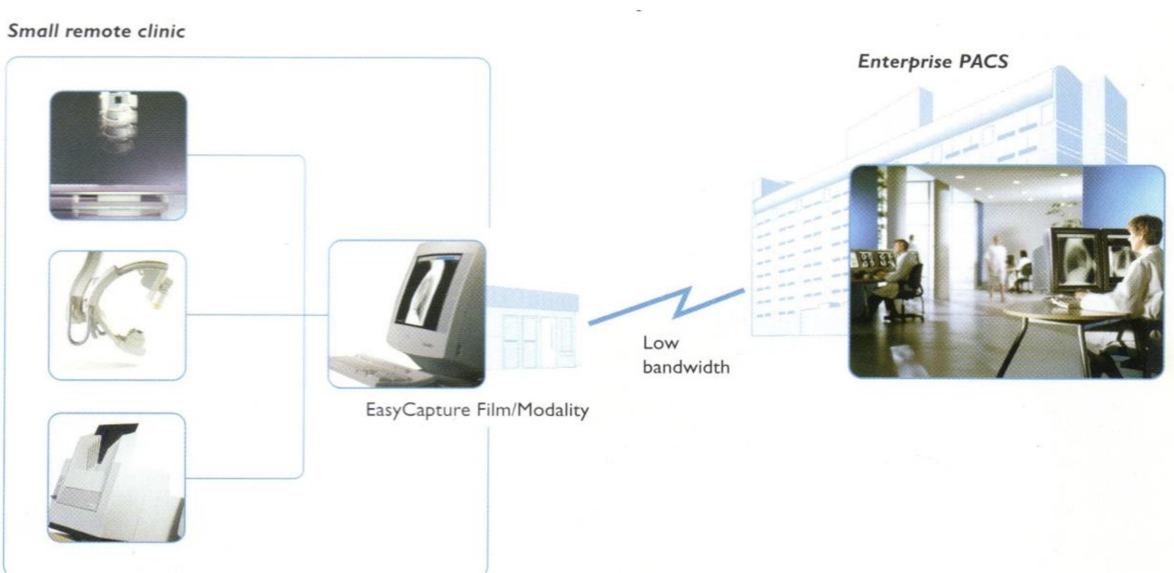
Image files, disks and tapes at the end of the 90s, could cost-effectively archive the diagnostic images generated then in the departments. The matrix range of each DICOM image varies from 250 kB of an ultrasound image up to 16 MB for a mammography image that by this time were only produced with specialized film digitizers, as the CRs for mammography and the digital mammographic images acquired with flat panels began years later.

The access time to archived images were of the order of 5 to 6 seconds, now reduced to less than 1 sec. This and the number of images circulating in the internal network of the hospital led to distribute the images in other departments of the hospital, not in DICOM format, but in JPEG, whose weight is of the order of the KB but with less chance of treatment and post-processing, but with sufficient capacity to display pathologies previously reported by radiologists in the image department (1.67).

A WEB server that is connected to the server of PACS and RIS, and these to the central archive of images, allows to distribute these images and reports to the hospital by embedding it in the hospital information system facilitating the rapid observation of images and reports throughout the hospital, as well as in the health centers in the same environment, or with hospital consultants outside to the hospital.

New possibilities of communication by means of broadband (ADSL), cable and optical fiber networks, at end of the 90s were installed in many countries with high technology, allowed the development of the teleradiology, to inform and check examinations at distance.

(1.67.- WEB distribution in surgical rooms)

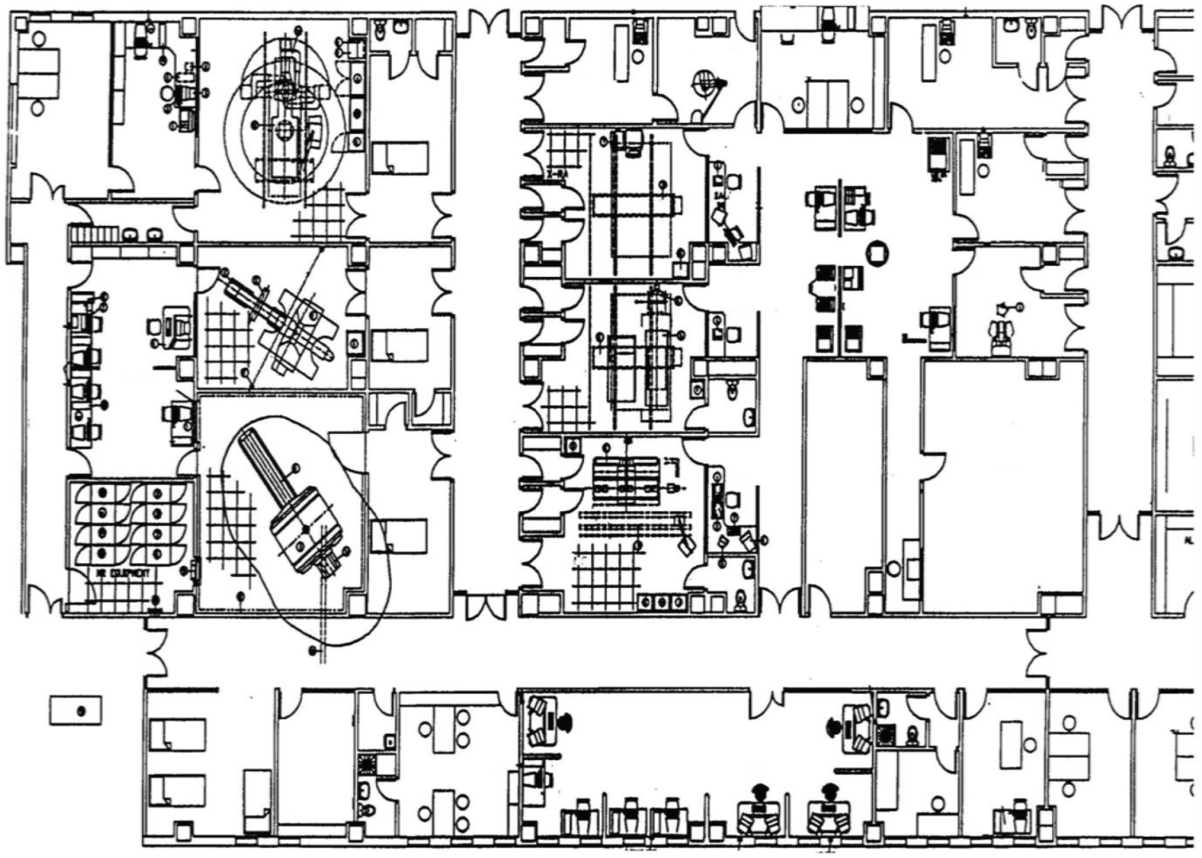


(1-68.- Teleradiology)

This technique will be a prelude to the change in the work flow in the imaging departments for years to come (starting from the reports area) and has to be considered in the design of new public and private services. In this technological environment, with RIS and PACS in the departments, but with some systems even with problems of digitalization, the designs of departments already considered these techniques in his works, mainly in the reading or diagnosis rooms, where lived in harmony workstations with x-ray film viewers, primarily to see the historical archive and mammography still with radiographic films. Historical film archives has been today mostly digitized.

An example of one image department of late of late 90's (1.69), equipped with MRI, CT, vascular, remote-control, conventional, automatic chest with CR, three ultrasound rooms, dental, mammography system with daylight, and CRs for conventional and remote control table. The reporting room is already drawn with CRT monitors and x-ray film viewers.

The waiting room is located at the top of the drawing, common for all patients who are called and directed to each room by the radiographers.



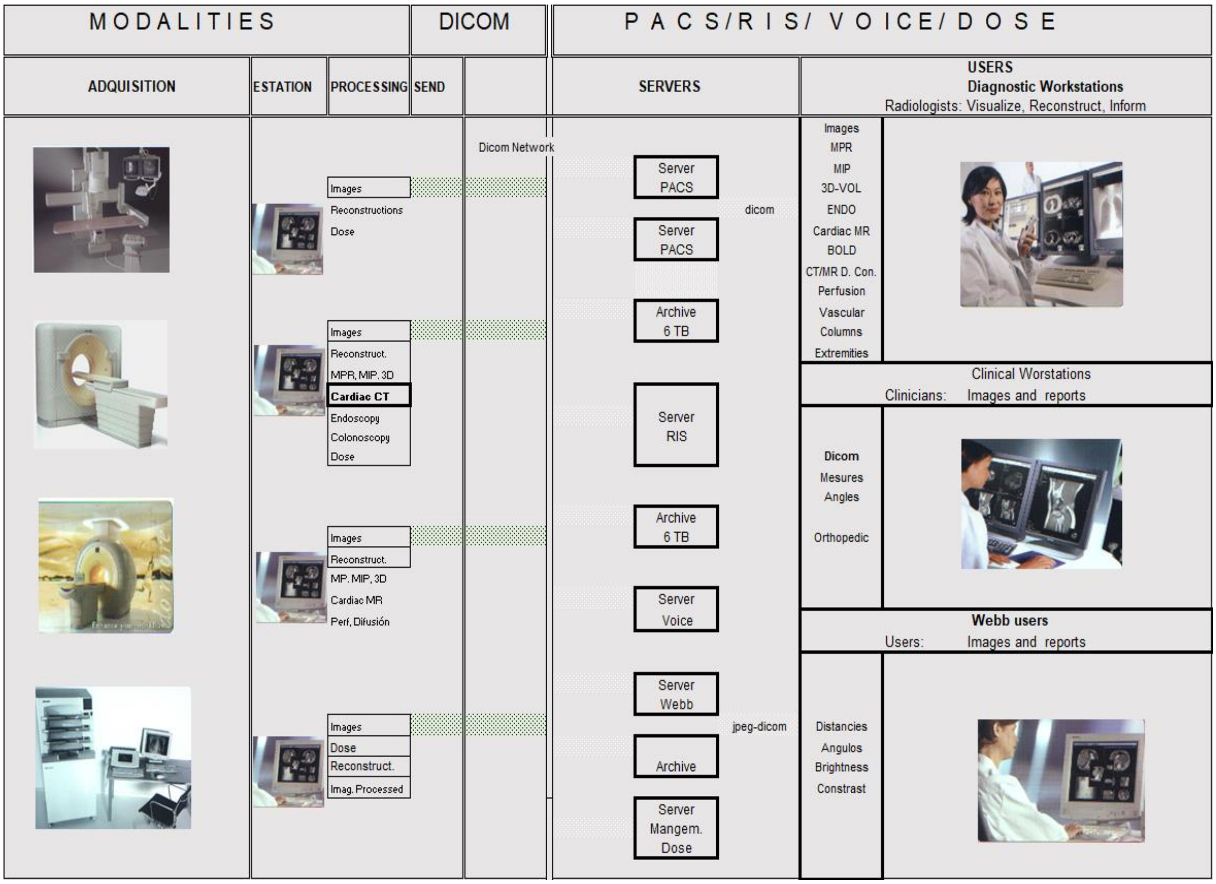
(1.69.- Image department by the end XX century)

Concerns about control of the dose absorbed by patients and health personnel has led in recent years to develop international legislation for dose control.   At the European level has led to the introduction of the policy of the European Union 2013/59 EURATOM obligatory in all State Members since February 2018.

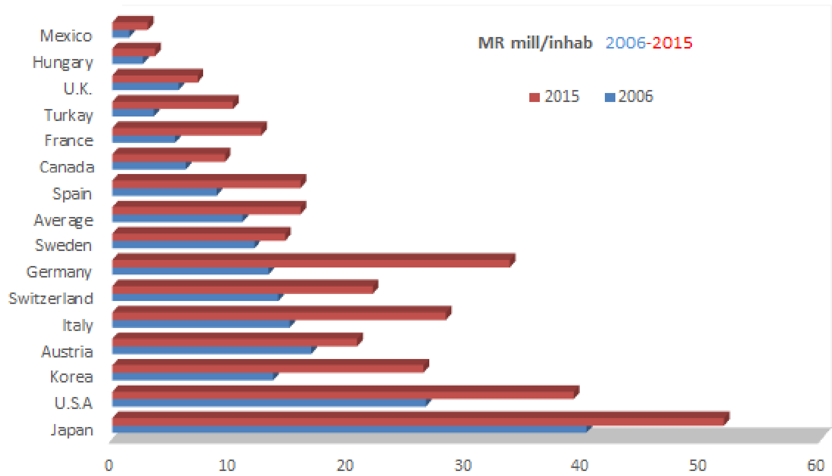
The dose management system, which is integrated as one computer system in the imaging department, allows to know the dose absorbed by the patient, establish a record of doses per patient and set alarms in case of exceeding recommended values. It allows the radiologist apply recommendations ALARA, (doses as low as possible) and it requires a periodic review of protocols from all equipment based on radiological techniques. It is a complete system of dose management that take their values from the radiologic equipment and transmits them in DICOM RDSR to the server which collects all the information generated in the rooms.

It is a new member of the computer systems integrated in the imaging department that may be o not physically within the department.

The space required by the servers and files, a small room about 8 m2 (86,1 ft2), consider their air conditioning, digital 1 Gbs network (tending to rise today). In the same room may be installed the lockers where electronic communication systems of digital network are housed, that enables telephony, images, voice and data.



II.- REFERENCES FOR PLANNING



- **I.** **HISTORIC EVOLUTION OF DIAGNOSTIC IMAGING COMSUMPTION**
- **II.** **FREQUENCY**
- **III.** **EQUIPMENTS**
- **IV.** **EXAMINATION TIME**
- **V.** **POINTS TECHNIQUES**
- **VI.** **PERSONNEL IN THE IMAGING DEPARTMENT**
- **VII.** **RADIOLOGISTS**
- **VIII.** **TECHNICIANS**
- **IX.** **NURSES**
- **X.** **OTHER PERSONNEL**
- **XI.** **PERSONNEL IN RADIOTHERAPY**
- **XII.** **EXAMS DEMAND RESEARCH**

Excavates a well before you have thirst. (Chinese proverb)

II.- REFERENCES FOR PLANNING

One image department must be planned in a long-term basis. The definition of the long term, in today's world, has its particular interpretation in every project and should respond to the objectives that planners and managers have determined. In most of the projects the basic identification of evolution of the department is related to the development and changes experienced by imaging techniques. Technological change, that has been reviewed in the previous chapter was slow in its origins at the end of the nineteenth and early twentieth Centuries, has significantly accelerated at the end of the last century and all current indicators show that this process will continue with more emphasis in the coming years.

The long term should be displayed by various factors:

- Foreseeable evolution of the population to be attend by the imaging department, in its many facets as a number of people, age, rates of birth, migration factors, education, language, etc.
- Evolution of the imaging technologies, at least in the imaginable scope at the time of planning and design.
- Evolutionary changes in conditions and evidence of new diagnostic methods.
- Economic or socio-economic factors that control or force the development of health needs or demand for imaging techniques.
- Predictable political factors which compel to change the health care objectives of the department's image.
- Organizational or social labor conditions, which alter the activity and workflow of the departments.
- Type of hospital or health center.
- Others, such as the evolution of availability and training of health care personnel: doctors, image technicians, nursing staff, etc.

These factors, as in all planning tasks of a project have clear and defined objectives components or facts, in which data are consistent and the quasi facts and so-called assumptions where the biggest risk factor concentrates. An over-sized department will cause economic problems for the largest investment in structure, equipment and personnel that can hit the soundness of the project. An Infra-sizing will cause, also important adaptation costs, at the beginning of the activity, or shortly after, that distort the workflow, not only of the image department, but all the associated referents regarding the area of influence, health center or hospital, with economic impact probably higher than in case of oversize. At least in this case the excess can be reduced to structure works, because the equipment and personnel may be delayed, or indefinitely, dedicating the physical structure to other activities.

So it is needed to have the best possible health care current data and predictable information to plan the department size as optimally as possible. This is a task that has been done traditionally too simplified, or has not been done, so the little available information by planners has led to high cost projects in its future development.

II.I.- HISTORIC EVOLUTION OF IMAGING TECHNIQUES CONSUMTION

Since the discovery of the x rays the development of the demand for diagnostic exams is a story of growth analysis. Exams have experienced continuous growth, most marked in countries with higher socio-economic level, but always growing in every country.

Until 1970 virtually the conventional radiology was majority, sharing different exams in different types of examination procedures, according to the anatomical region or body system to explore.

Between 70 and 90 were held on a regular basis specialized symposia to collate data on activity and growth of different departments, basically in the more developed countries. The ISPRAD (International Symposium on the Planning of Radiological Departments) provided a good follow-up of the planning activity of the moment in the radiological and radiotherapeutic areas (50).

Collecting data of one of the first symposium (ISPRAD) is shown in the attached table issued by Cobben (Netherlands), in the period of the 1970s.

Throughout the period rise the percentage of chest exams, while maintaining those of skull and reducing those of extremities and abdomen. At the end of the seventies, the development of endoscopy began to make a decrease in the studies of digestive system, as well as the beginning of the ultrasound and CT influenced these techniques, quantitatively reducing their exams.

Distribution of x-ray examinations in radiology departments of different sizes and characteristics

	Brogdon & Tuddenham %	Cobben A 1962–72		Cobben B 1972–75		Cobben C 1979 for 95,700 Exams	
		% of Total	% of Time	% of Total	% of Time	% of Total	% of Time
Chest	40	24.2	13.2	29	13.6	31	10.9
Skull	7.5 head, neck, etc.	10.1 skull, sinuses, dental	5.6	11.7 skull, sinuses, dental	5.6	10.7 skull sinuses, dental	4.8
Spine							
Extremities	15	46	30.7	33.7	19.4	35.6	18.6
Abdomen							
Upper GI							
Barium enema	20–25 GI track	9.9	18.4	9.9	14.4	5.6	7.7
Gallbladder							
GU-IVP		3.3	10.9	3.9	11	3	11.7
Neuro			78.8		64		53.7
Angio				2.2	16	3.2	21.3
Tomography				1.9	4.6	.8	2.5
Emergency					84.6		27.3
All others	15–20						
Ultrasound, CT						1.2	3.5

(2.1.- Cobben. Source ISPRAD)

Can be also seen in different hospitals in the United States the proportion of the tests carried out at the time of the 1970.

	Teaching Hosp. I	Naylor, 1972, 73 Teaching Hosp. II	Naylor, 1972, 73 Community Hosp. I	Community Hosp. II
Chest	39	24	25	34
Skull	12	5	10	3
Spine				
Extremities	27 Gen'l	13.6	22	30
Abbdomen				
Upper GI				
Barium enema	7.5	4.4	9.5	12
Gallbladder	1.5	.7	4	—
GU-IVP	3	4.1	3	3
Angio				
Emergency	5	41.6	23.5	15.5
All others	5[1]	6.6[1]	3[1]	2.5[1]
Ultrasound				
Total Exams	72,500	140,493	43,130	52,810

(2.2.- Naylor. Source Fisher)

The gradual introduction of the new technologies of CT, ultrasound and magnetic resonance imaging, in the years 80 and 90 modifies the percentages of exams and increases them, increasing the required surface of imaging departments.

RX Exam	U K 1983	France 1983	Italy 1983
Thorax	33.5	33.5	36.5
Abdomen	4	3.6	3.3
Digestive	5.5	5.8	7.2
Urology	2.2	4.6	2.1
Angiografy	0.6	1.9	0.4
CT	0.9	0.6	1
Mamografy	0.9	0.6	1
Others	0.6	2.6	0.9

(2.3.- Source B.J.R. 1988)

Already shown, timidly, the impact of computerized axial tomography. As well as ultrasound.

EXAM TYPE	Nº OF EXAMS	PERCENTAGE
X RAYS	34,000,000	85.25
DIG. ANGIO.	460,000	1.15
CT	900,000	2.25
GAMMACAMERA	1,000,000	2.5
SPECT	15,000	0.04
MR	10,000	0.03
ULTRASOUND	3,500,000	8.78

(2.4.- Medical imaging procedures in Italy. Source Industria. 1985)

The first MRI facilities began operating around 1984, timid way in relation to the number of total exams, but the technique would have a very high growth in a few years (42-56).

RÖNTGENCONSUMPTION NETHERLANDS		
	1985	1986
Total incl. US	7.378.752	7.294.407
US	307.382	363.331
CT	157.947	166.790
MRI	1.852	4.204
Source: RIS		

(2.5.- Radiologic exams consumption in Holand)

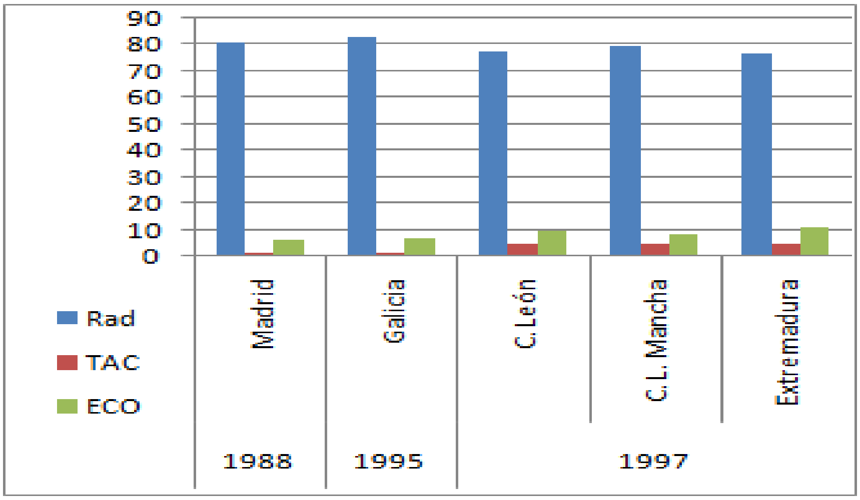
Mettler, in a work published in 1993 concerning the use of radiology in the United States in short-stay hospitals during the period from 1980 to 1990 evaluates a growth between 20 and 60% of the number of tests. He estimated a total volume varying between 260-330 million tests in 1990, highlighting a shift in a large proportion to the ambulatory activity.

In 1995, figures of 850 exams per 1.000 population with the following distribution are presented in United States.

General radiography	60 %
Fluoroscopy	3 %
Mammography	15 %
Sonography	11 %
Nuclear medicine	3 %
Angio/Interventional	1 %
CT/MT combined	7 %

(2.6 Several sources)

Between 1988 and 1997 the percentages in various Spanish regions show the reduction of the conventional radiology and the increase of the ultrasound and CT, according to studies, in the public sector, by P. Rodriguez (21-22-43-57).



(2.7.- Percentage of Rad, CT and Ultrasound in several regions)

Already in 2010, the percentages have varied widely. The following example (2.8) in a European region of income level in the average of the European Union, shows the distribution of examinations in the Years 2010 throughout 2017 that have changed due to strong investments in ultrasound and CT.

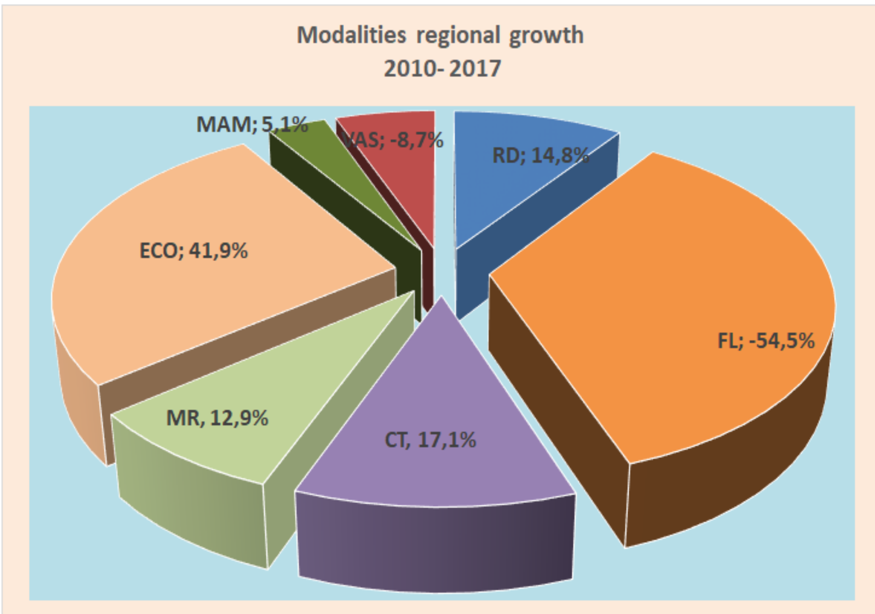
Thus is arrived the situation where the percentages vary widely among nations and regions, due to socio-economic, political impulses, etc. which already was indicated at the beginning of this section.

Exams

		RD	FL	MAM	ECO	CT	MR	VAS	
2017		971.074	5.712	36.848	259.089	125.640	108.328	3.426	**1.510.117**
		64,3%	0,4%	2,4%	17,2%	8,3%	7,2%	0,2%	
2010		845.615	12.565	35.044	182.585	107.249	95.980	3.753	**1.282.791**
		14,8%	**-54,5%**	**5,1%**	**41,9%**	**17,1%**	**12,9%**	**-8,7%**	**17,7%**

Frequency

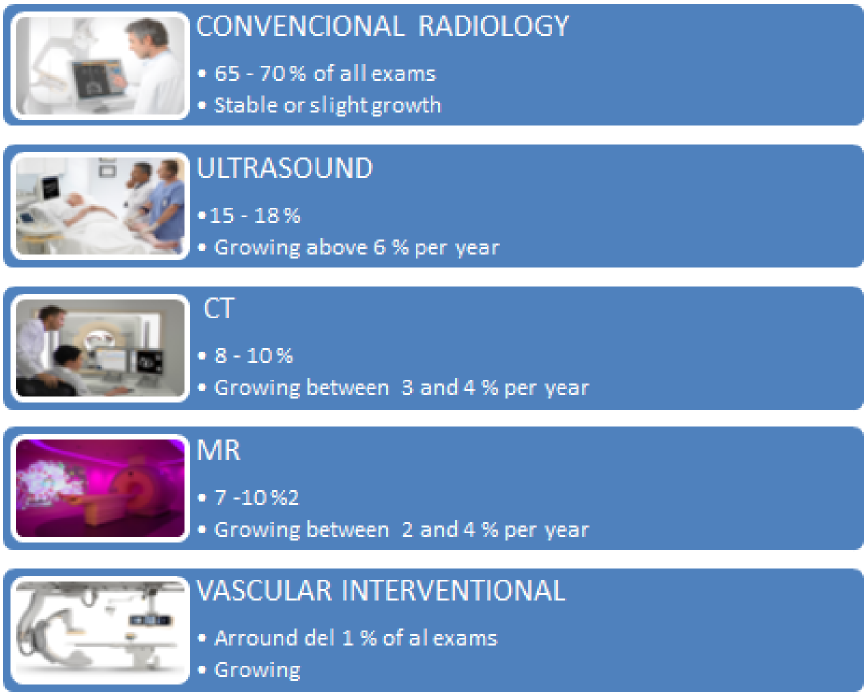
		RD	FL	MAM	ECO	CT	MR	VAS	
2017									
1.474	1.000 habit	659	4	25	176	85	73	2	**1.025**
2010									
1.462	1.000 habit	578	9	24	125	73	66	3	**877**



(2.8.- Public regional frequency. Changes between 2010 y 2017)

Significantly, can be accepted that in 2017, at the regional level in the Spanish public sector:

Conventional Radiology ranges between 65 and 70 per cent of all scans, reducing its percentage, slightly. Ultrasound, get between 15 and 18 percent. Multislice tomography reaches between 8 and 10 percent, rising slightly. Magnetic resonance imaging is between 7 and 10 percent, rise. Interventional techniques remains around 1 percent.



(2.9-Distribution of tests between modalities. Growths)

II.II.- FREQUENCY. DENSITY

After analyzing the distribution, in percentages, of the exams carried out in different institutions, regions and countries, it is needed to know the number of exams that is expected to perform the department that is the object of the analysis, in the way that will be available more precise information that allows to calculate the number of diagnostic or treatment rooms that will be needed for the fulfilment of the objectives set for the institution. Shall be defined the frequency.

The most accepted parameter is the frequency of exams or density that are defined as the number of all exams, of all modalities, which are performed per thousand people per year.

The frequency is a quantitative parameter which does not consider the difficulty or cost of each test, but it is highly valuable for the planner to make the first determination of the surface and the distribution of the spaces in the department subject to study.

The analysis of the frequency at the international level has had a detailed follow up, by some international organizations, during the last three decades, demonstrating its increase and continuous growth, having taken the new technologies with very high quantitative contributions the witness of the x rays.

A source of data is provided by UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), that although pursues the population dose health hygiene, supplies international data on frequency and its evolution throughout the 1990s. It must be emphasized that these data do not include the densities of ultrasound or magnetic resonance imaging.

The analysis of UNSCEAR for the years 1991 to 1996 shows a growth of 10% in the frequency for x-ray examinations, in relation to the previous five year period, from 1985 to 1990 , as shown in the graph (2.10), noting the significant increase in doses received by the population, mainly by the high doses delivered by CT.

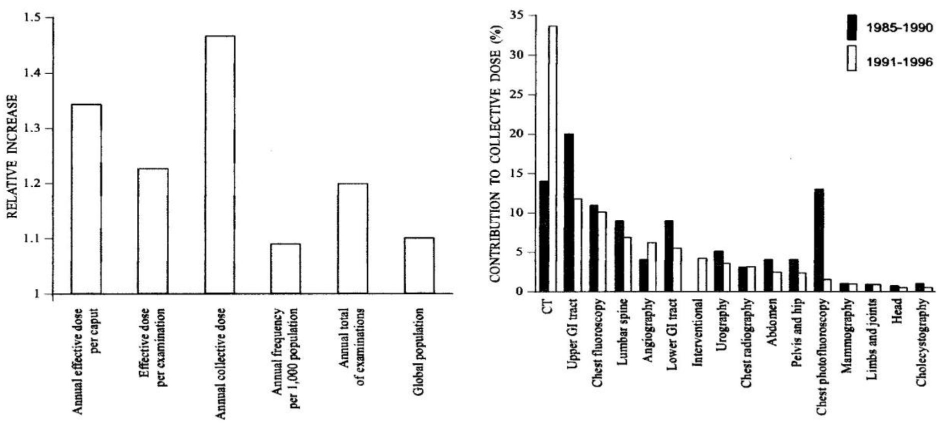


Figure IV. Temporal trends in global practice with medical x-ray examinations: average frequencies and doses for 1991-1996 relative to previous estimates for 1985-1990.

Figure V. Percentage contributions by examination type to global collective dose from medical x-ray examinations: comparison of data for 1955-1990 and 1991-1996.

(2.10.- Source UNSCEAR)

UNSCEAR classifies countries into four levels according to the number of medical physicians per thousand people, staying developed countries in level I. Globally can be seen in the chart attached one overview for different countries, while level I marked by lines that correlate the black spots which are the code of the developed countries.

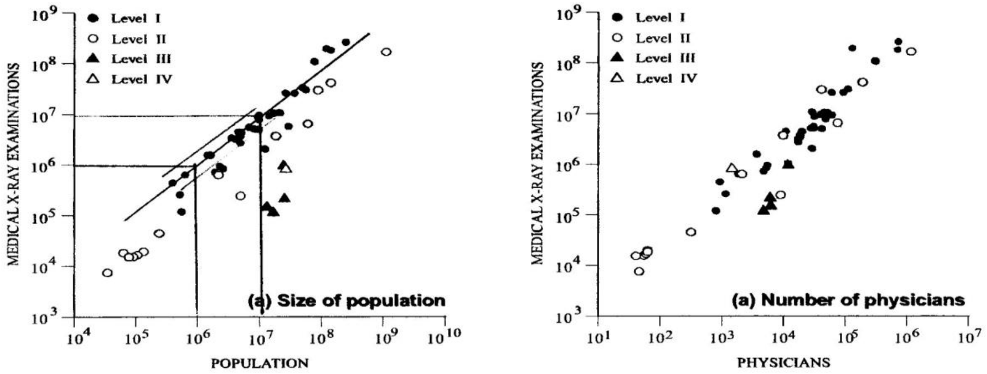
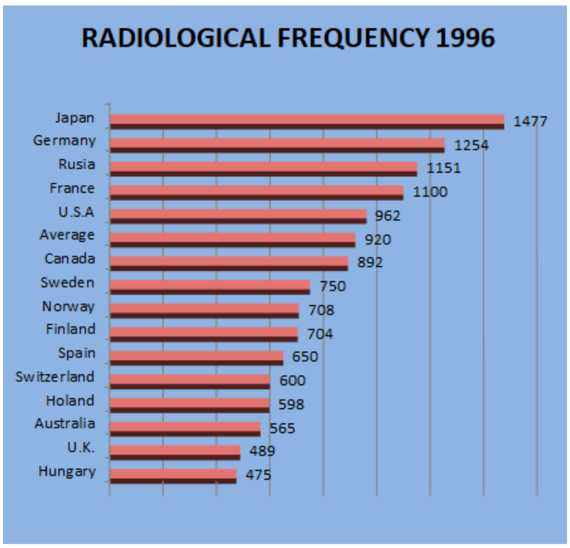


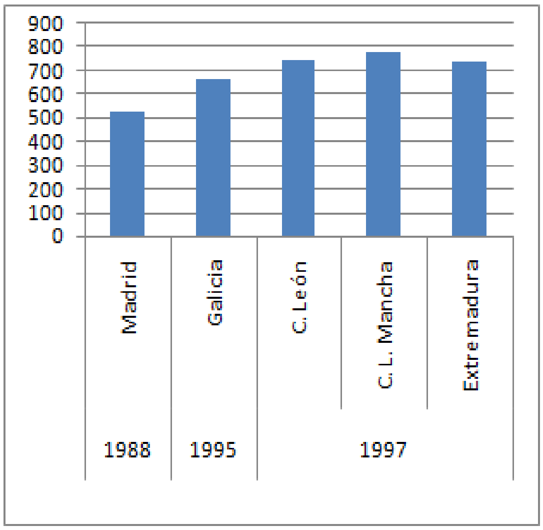
Figure I. Annual number of diagnostic medical x-ray examinations in relation to (a) size of population and (b) number of physicians.

(2.11.-Source UNSCEAR)

For the years of the study the reference of 900 to 1.000 exams per thousand inhabitants is the average of the most advanced countries, still at 150 for level II countries.

The UNSCEAR attached table shows data available in 1996 for radiological frequencies having already on this date densities for Japan of 1.477 tests per thousand people per year.





(2.11.- Frequencies in 1996. Source UNSCEAR)

(2.12.- Densities in various regions)

Data collected by UNSCEAR during the 1970s to 1996 show that the high growth of the frequency begin with 1990s when introduced more widely the CT modality. Considering, additionally, the introduction of MR and ultrasound is easy to imagine the significant increase of the frequencies of modalities from the last decade of the 20th century and the first of 21st.

Between 1988 and 1997 attendance in various Spanish regions experienced a remarkable increase, according to studies, in the public sector, by P. Rodriguez (Chart 2.12).

From the years 1995 to 2005 the increase estimated by several studies of the subject, as well as data provided in different analysis lead to regional growth, in many countries, of 10 percent for five years, such and as already happened in the years 1991-1996 with regard to the five-year period 1985-1990. It should be noted the introduction and increase in diagnostic techniques, in the years 2000, still in design at that time, although advanced, in recent studies of UNSCEAR. Techniques such as PET, PET-CT, bone densitometry exams, increase in campaigns in early detection in mammography, and the spectacular increase in ultrasound and magnetic resonance imaging, growing in recent years at the rate of 8 to 10 percent annually.

An average of 1.200 to 1.400 tests of all the diagnostic techniques for every thousand inhabitants as average of frequentation can be estimated for medical diagnostic examinations in radiology departments in developed countries in the middle of the first decade of the 21st century. Having next to the 1.600 exams in some peaking countries in diagnostic imaging techniques.

Data from different sources for the period 1997-2008 confirm this appreciation and increase the values of some countries of greater attendance providing a strong growth for radiographic values in the years 1996-2008 with respect to previous periods.

Growth in a decade in the consumption of x-ray examinations was 4.5% annual. High figure that the planner has as reference element to observe in its calculations.

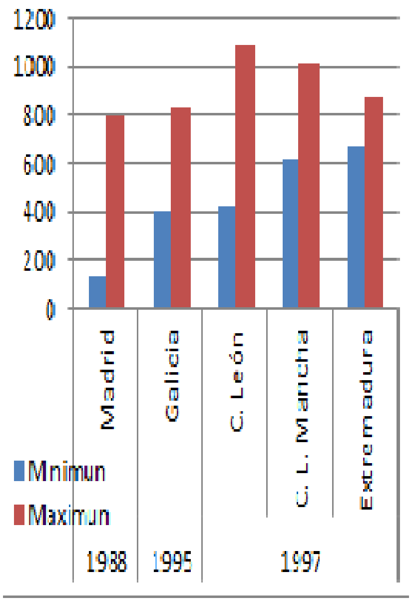
These data must be added with the frequencies of ultrasound and magnetic resonance imaging, so the average number of exams in developed countries can achieve a level of 1.550 exams per thousand inhabitants in 2008. More than 1.800 exams are easy to find in countries such as Japan and the United States.

Dental radiology tests seem to have experienced a reduction in the last ten years and do not come within the book scope those exams that are concentrated mainly in outpatient dental clinics. For reasons of planning and design of diagnostic imaging facilities, object of this work, examinations of ortopantotomography in data analysis and in the planning for departments will be included thereafter.

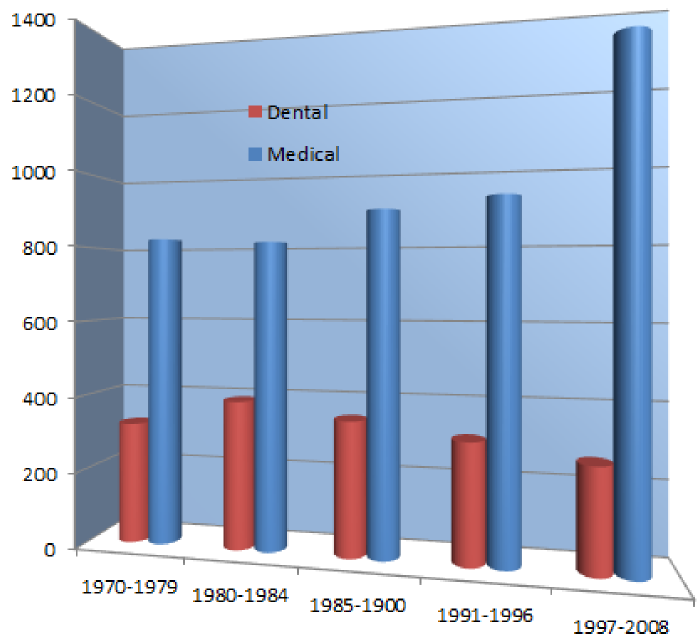
The ortopantotomography is carried out in the image departments, as well as on the cabinets devoted to examinations and dental therapeutic clinics, being a classical component, although minority, of the conventional radiology equipment that nourish image departments.

Each new planning requires a thorough study of the healthcare environment where you want to perform the installation. Frequency varies, as you can see in the attached tables, each nation and each region within the nation. Services to offer must be defined on the basis of the real needs of the population at the time of planning and its future prospects, with the objectives set out in the health center and the time perspective than the analysis of these objectives allows to determine. Can be seen in the already reviewed studio of P. Rodriguez variation of the frequency between different areas of the same region in different time periods. Looking at the data the maximum-minimum ratio is two to one.

Additionally there is to consider the trends that continue their overlap and complementation, its developments, modalities, e.g., doses in the CTs, which lead to decrease of pediatric examinations, being these replaced by ultrasound and magnetic resonance imaging.



(2.13.-Maximun and minimum frequencies in several regions)



(2.14.- Historical evolution. Source UNSCEAR and others)

A summary of the above parameters is presented in the accompanying table (2.14-2.15).

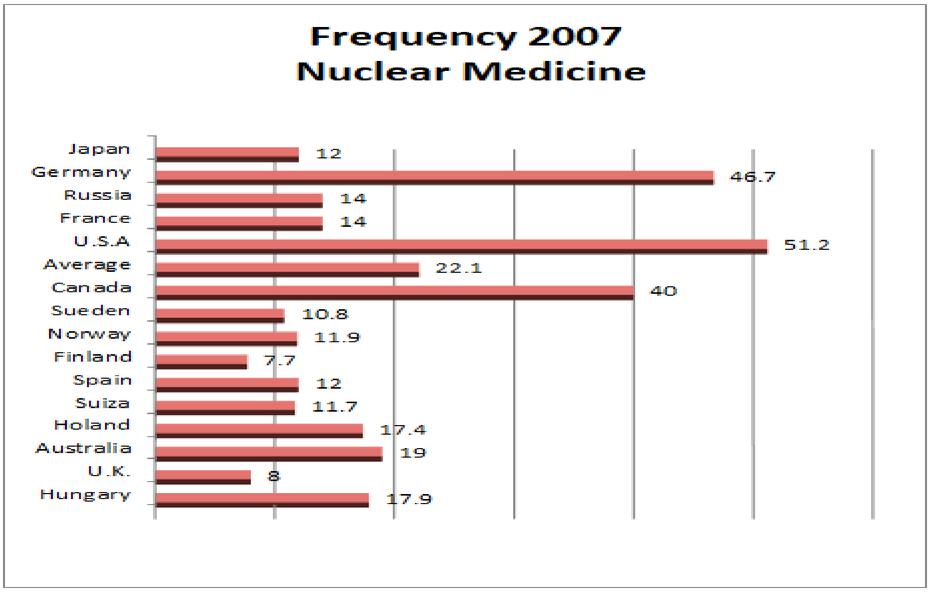
Table 9
Global use of medical radiology (1991-1996)
Estimates derived from UNSCEAR Survey of Medical Radiation Usage and Exposures [a]

PART A: NORMALIZED VALUES

Quantity		*Number per million population at health-care level*				
		I	*II*	*III*	*IV*	*Globally*
Physicians						
All physicians		2 800	700	210	45	1 100
Physicians conducting radiological procedures		110	80	5	0.1	70
X-ray imaging						
Equipment	Medical	290	60	40	4	110
	Dental	440	60	10	0.1	150
	Mammography	24	0.5	0.2	0.1	7
	CT	17	2	0.4	0.1	6
Annual number of examinations	Medical [b]	920 000	150 000	20 000		330 000
	Dental [c]	310 000	14 000	200		90 000
Radionuclide imaging						
Equipment	Gamma cameras	7.2	0.3	0.1	0.03	2.1
	Rectilinear scanners	0.9	0.3	0.1	0.01	0.4
	PET scanners	0.2	0.002	0	0	0.05
Annual number of examinations [d]		19 000	1 100	280	17	5 600
Radionuclide therapy						
Annual number of patients [e]		170	40	20	0.4	65
Teletherapy						
Equipment	X-ray	2.8	0.2	0.03	0.02	0.9
	Radionuclide	1.6	0.5	0.2	0.1	0.7
	LINAC	3.0	0.3	0.06	0	0.9
Annual number of patients [f]		1 500	690	470	50	820
Brachytherapy						
Afterloading units		1.7	0.4	0.1	0.1	0.7
Annual number of patients [g]		200	17	15	(15) [h]	70

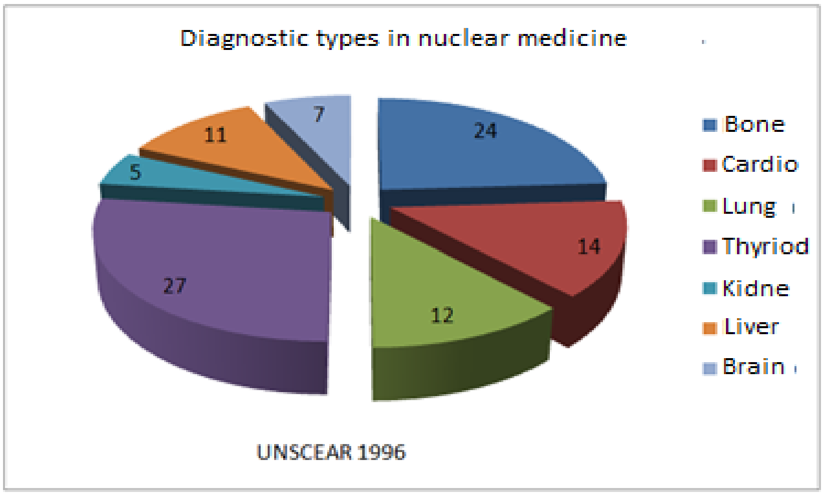
(2.15.- Equipment per million population in 1996. UNSCEAR)

In nuclear medicine figure shows (2.15) average values of several studies for the year 2007, where are shown frequency data.



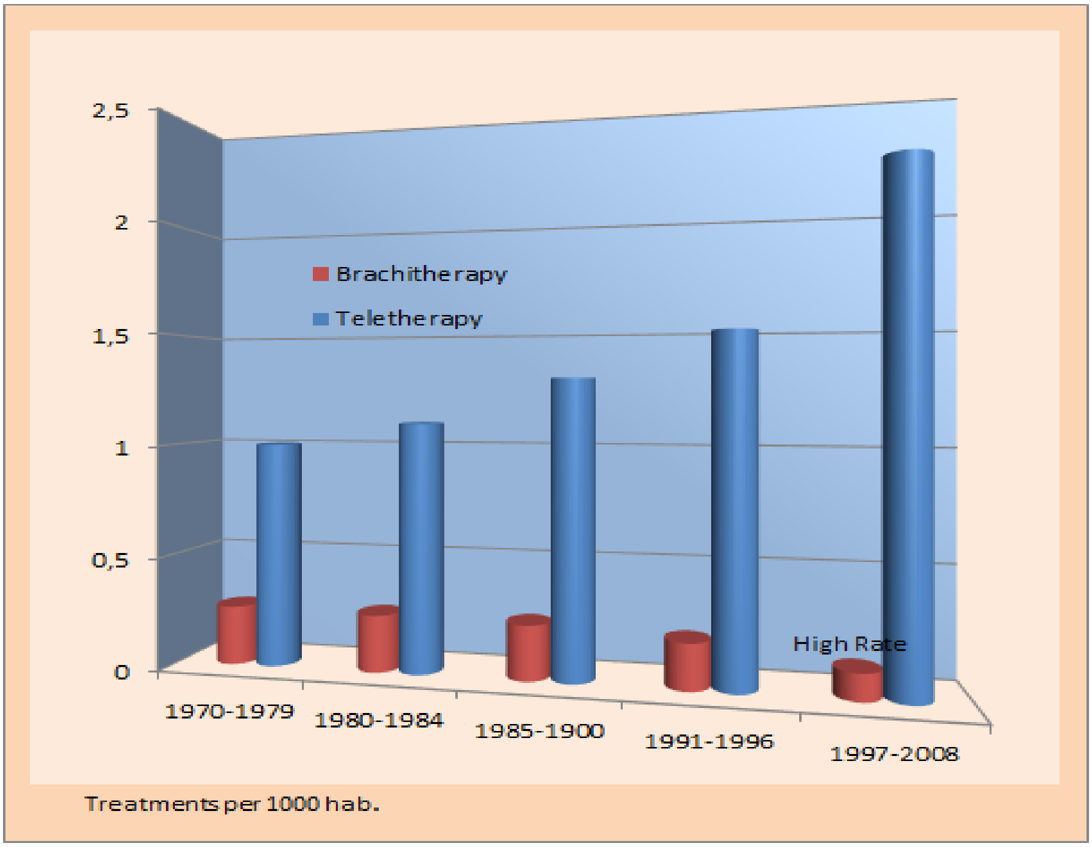
(2.16.- Frequency in nuclear medicine. Several sources)

Looking at the exams by anatomical areas, analysis of UNSCEAR in 1996, valid today, indicates the three basic areas of nuclear medicine: cardiology, bone scans and thyroid.



(2.17.- Anatomical areas in nuclear medicine. Several sources)

Radiation therapy treatments have also experienced growth during all investigated periods, although, as in diagnostic exams, the greatest growth has been in the years of the decade between the 1996 and 2008.



(2.18.- Historic evolution of the frequency in radiotherapy in developed countries. Several sources)

II.III.- EQUIPMENT

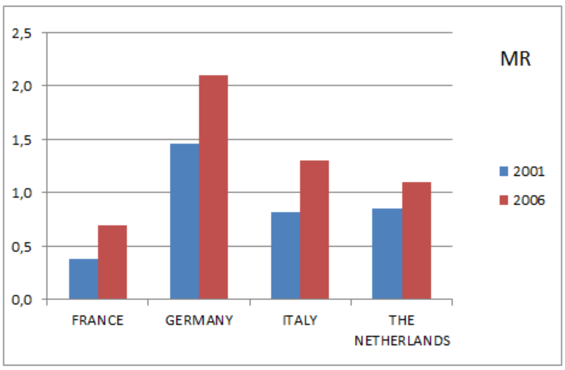
Frequency, local statistics and in summary the market research data are the basis for the calculation of the demand for tests and determining the necessary equipment to set up in the department. There is, therefore, a correlation between machines and facilities and the demand for tests and treatments, and perhaps has been the new modalities which have generated mayor increases in demands in response to rule that an improvement in the availability of health services has as response one increase in the demand, i.e. the number of scans. Economic constraints of budgets and spending, among other factors, limit the demand.

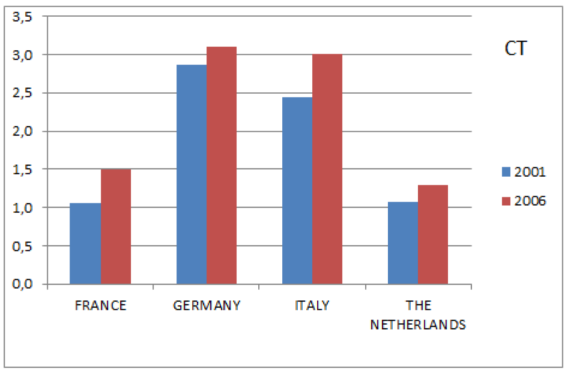
In Europe, reports of the COCIR (2.19) indicating the number of installed equipment of the more expensive technologies shows values of growth during the years 2001 and 2006. Is possible to obtain data from each country in relation to the installed volume of every modality and its relationship with the population.

INSTALLED BASE OF MEDICAL EQUIPMEN: 2001	(UNITS)	Source : COCIR

Country	CT	CT/100.000	CT/100.000	MR	MR/100.000	MR/100.000	NM	NM/100.000	Population
									.(1000)
BELGIUM	294	2,9		97	1,0		292	2,9	10.200
FINLAND	**48**	**0,9**		**37**	**0,7**		**30**	**0,6**	**5.200**
FRANCE	619	1,0	1,5	224	0,4	0,7	388	0,7	59.000
GERMANY	**2.354**	**2,9**	**3,1**	**1.198**	**1,5**	**2,1**	**1.103**	**1,3**	**82.300**
ITALY	1.407	2,4	3,0	473	0,8	1,3	574	1,0	57.800
THE NETHERLANDS	**170**	**1,1**	**1,3**	**136**	**0,9**	**1,1**	**166**	**1,0**	**15.900**
SPAIN	663	1,7		354	0,9		245	0,6	40.100
SWEDEN	**132**	**1,5**		**77**	**0,9**		**79**	**0,9**	**8.900**
UNITED KINGDOM	425	0,7		331	0,6		365	0,6	59.900
TOTAL	6.112	1,8		2.927	0,9		3.242	1,0	339.300

(2.19.-Instaled base of several high tech equipment in some European countries in 2001)

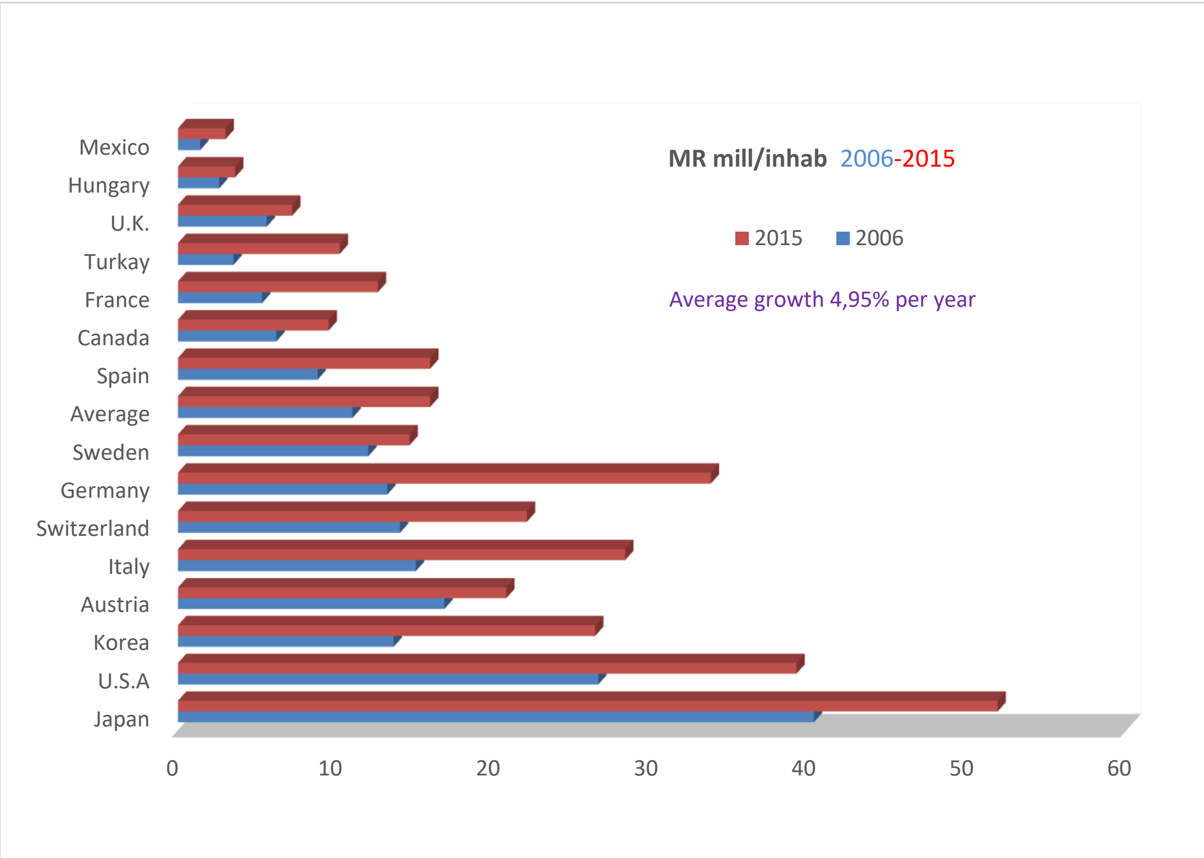




(2.20.- Growth of installed base of CT and MR per 100.000 hab. In several European countries between 2001 and 2006. COCIR)

2018 data are not available for all countries, but with the exception of France which has governmental special regulations for CT and MR equipment, the rest of the countries have experienced a modest increase (7%) in CT and huge (40%) in magnetic resonance. Value to take into account by the planner.

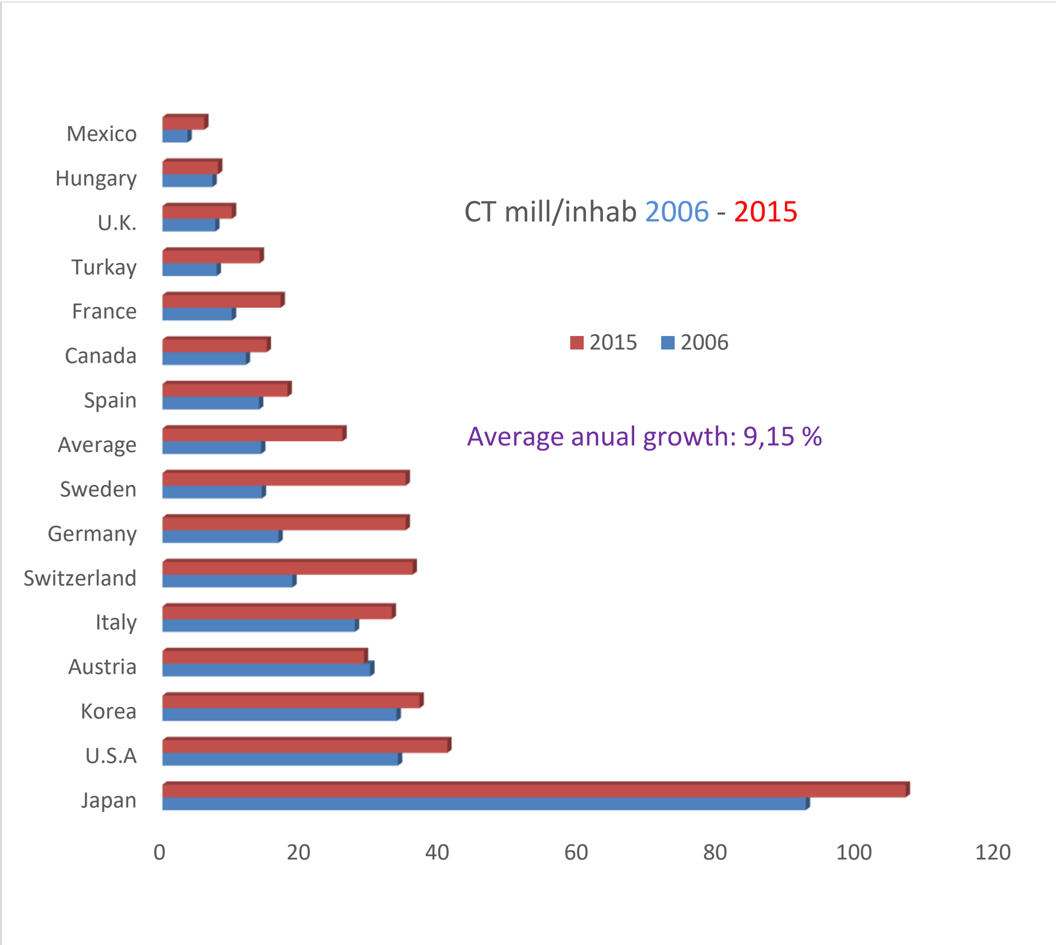
Recent publications confirm 8.800 magnetic resonance equipment installed in the United States in 2007, that means a machine installed by every 35.000 inhabitants, **or 2.87 machines per 100.000 population,** and exploration demand continues to rise, according to recent research details regarding this subject, at a rate of 3 per cent per annum in 2008. Other countries are still far from this ratio, and some, like Japan, exceed it.



(2.21.- MR installations per million inhabitants. Growth between 2006 and 2015. Source OECD)

The multislice tomography also experience, thanks to its recent advances, and despite their dose radioactive hygiene problems, growth, which is estimated in the order of 4 per cent until 2013 in

Europe, while more saturated markets are growing at slower rate like in the United States and Japan, especially in this last where is located the largest concentration of CT in the world (per capita), reaching a figure close to 107 CT per million inhabitants in 2015. In United States, Mettler studies indicate a growth in the number of examinations of 10%, maintained between 1993 and 2006.



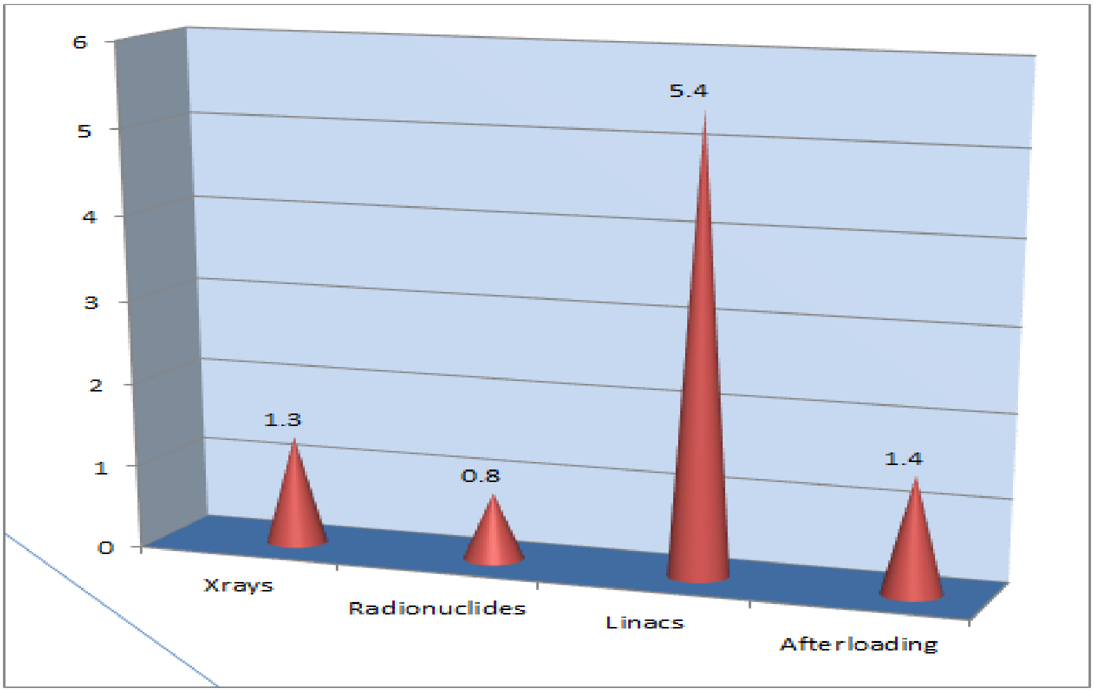
(2.22-TACs per million inhabitants. Evolution 2006-2015. Source OECD)

Global ultrasound continues increasing, estimating in 2010 a growth around 7% during the next five years in the EU market by manufacturers, and a growth worldwide of the order of 3 per cent.

The nuclear medicine examinations have experienced sustained growth in United States of 5%, and in the years 2000 were at a level of 4.5 gammacameras per 100.000 population.

Is still bigger the percentage of PET-CT growth, although in many countries the restrictions on tests, even costly, reduces the facilities development**.**

The demand for radiotherapy treatment makes also grow the number of installed linear accelerators. The United States reference for the year 2000 placed a LINAC per 93.000 inhabitants, shrinking the figure annually.



(2. 23.- Radiotherapy treatment systems installed per million inhabitants in developed countries. UNSCEAR and other sources)

The values above (2.23) are average values for developed countries with strong dispersion between them reaching a maximum in the USA with 16 systems per million population in 2008.

In conventional radiology equipment there is a vegetative growth, because tests growths according to the increase in population and its aging, but not as a percentage of the total number of tests of a department, although the turnover of manufacturers of equipment is today bigger due to the equipment prize after the introduction of computers with digital detectors, increasingly integrated in the imaging departments.

Mammography continues to grow, mainly due to the increase of programs for early detection (screening) in all developed countries of the world.

II.IV.- EXAM TIME

The determination of the number of diagnostic imaging rooms has a first parameter for its calculation that is the frequency of exams that the planning project team calculates for the health center under project. As already Indicated this depends on various factors mentioned in the previous section that need to be weighed. Once set the frequency expected and with the references of percentage distribution of exams between different diagnostic techniques also represented in the previous section will have the number of tests per diagnostic technique to carry out in the center object of the planning. The study of market research for analysis of demand of the center to project will confirm the local final data of the expected attendance. It is time to calculate the number of rooms that meet the forecasted examinations using the methodology described.

The current literature provides many details of the time that are usually used in the realization of different imaging examinations, and as following are shown two examples provided by Cobben (Netherlands) and Fisher in measurements made at the University of Chicago.

Survey of room occupancy times (in minutes) for common x-ray examinations

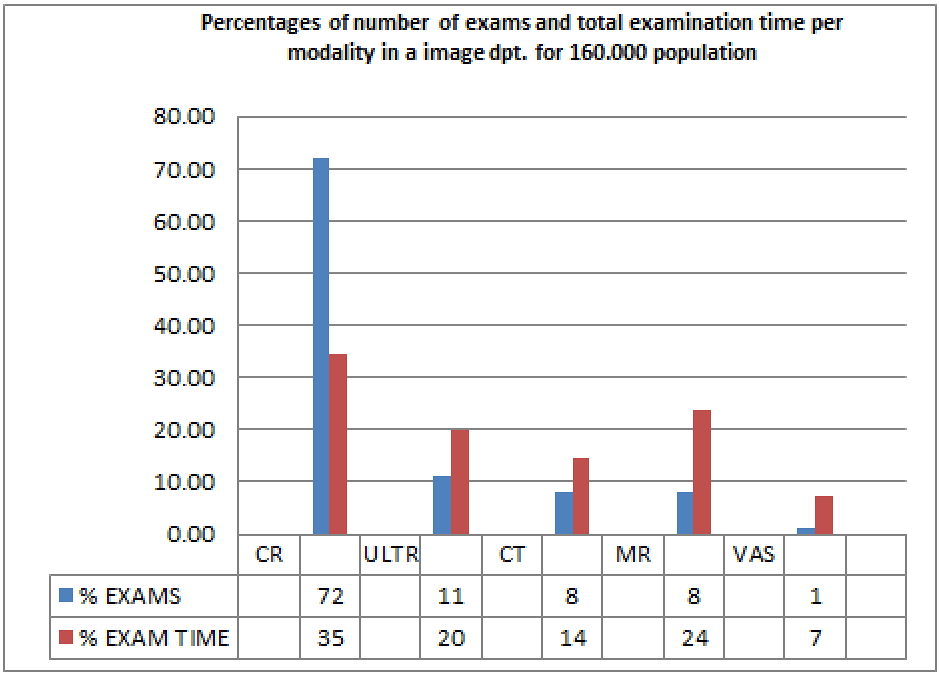
Description Examination	No. of Exams Measured	Mean	St. Dev	90% Upper Limit
Thorax	319	3.4	3.6	7.2
+ fluoroscopy	19	5.8	5.0	12.6
Extremities	120	4.3	3.8	10.8
Cerv. spine + clavicle	16	5.5	4.5	9.0
Skull	33	3.7	3.8	7.8
Sinus + adenoid	22	4.7	4.1	9.0
Petrosa mastoid	13	6.0	8.8	8.4
Tunnel view of knee	9	10.6	6.8	18.0
Mandibular joint	2	3.0	0.0	3.0
Cervical spine	31	7.6	6.2	15.0
Abdominal survey	16	3.2	4.0	6.0
Paranasal sinus	6	2.2	1.6	4.8
Lumber spine + pelvis	7	9.4	4.1	12.0
Pelvis	24	4.4	6.3	9.6
Paranasal sinus	75	3.0	7.1	4.8
Thorax + cerv. or lumb. spine	20	6.9	5.4	14.4
Lumbar spine	16	7.2	8.5	13.2
Stomach	60	12.3	7.1	20.4
IVP	92	45.1	16.7	66.0
Gallbladder	23	3.6	2.9	6.0
Colon	28	23.8	14.4	44.0
Intestine	11	9.8	7.6	18.0
IVP + thorax	8	54.0	12.0	69.0
IV cholangiogram	8	18.6	16.0	27.0
Arthrography	18	27.8	12.4	45.0
Hysterosalpingography	6	18.2	9.7	36.0
Mammography	33	16.2	6.4	25.2
Tomography	8	37.7	24.1	63.0

Information supplied by Cobben (8).

(2.24.-Room occupation times. Cobben. ISPRAD)

It is interesting to highlight that the imaging techniques with high attendance, as the chest, are both individually and globally considered of low consumption time related to the total department examination time.

The graph (2.25) represents a general hospital that provides health services to a population of 160.000 inhabitants indicates the percentage of tests that made the department of different imaging techniques and their percentages of the examinations total time of the department.



(2.25.-Ratio between exams time and number of exams)

The conventional radiology (CR) represents 72 per cent of exams and precise the 35 per cent of total department examination time, while magnetic resonance imaging (MRI) with only 8 per cent of the tests consumes 24 percent of the total department examination time.

Exam times for all coded tests are available on the websites of most of the National Societies of Radiology.

In consideration of the examination time should take into account the sum of activities comprising this concept, after calling the patient in the waiting room and accompany him to the cabin for the change of clothes:

Entrance of the patient in the exam room, positioning, exposure in radiological techniques or data acquisition on other techniques, image calculation, checking the quality of the image and leave the patient to the cabin wardrobe.

The activity of obtaining the image, or acquisition, has experienced a substantial change from the beginning of the 21st century, with the introduction of the digital techniques, eliminating the use of radiographic chassis. The use of the radiographic rooms has been simplified and its occupation has increased as well as the productivity of the technical radiographers, so the figures expressed in (2.24) are not, in general, valid for the determination of the number of radiographic rooms in the current planning of today imaging departments.

Published analyses indicate that one imaging room in a department can perform on average in between 4.000 and 12.000 tests, existing values limits lower in interventional angiography based in 1.000 interventions and upper for chest with 20.000 tests into automated systems. The attached table (2.27) provides information of American Hospitals.

Examinations per x-ray room per year and work performed in U.S. hospitals of different sizes

Hospital Bed Capacity		0–100	101–200	201–300	301–400	401–500	500 or larger
Examinations per x-ray room per year	High	11179 (2)	12069 (4)	12479 (6)	14757 (3)	10805 (6)	10217 (18)
	Low	1725 (2)	1959 (2)	3196 (5)	3133 (14)	3106 (18)	2839 (20)
	Average	5070 (3)	5851 (4)	6213 (6)	5576 (9)	6158 (10)	5165 (16)
Examinations per technologist per year	High	6495 (3)	5917 (3)	5259 (7)	4570 (12)	7148 (11)	4065 (16)
	Low	1150 (2)	1325 (3)	1622 (7)	1405 (7)	1785 (10)	1346 (9)
	Average	3042 (3)	2820 (4)	267 (6)	2819 (9)	2864 (10)	2566 (16)
Examinations per non-technologist departmental employee per year	High	18180 (2)	19014 (3)	13012 (5)	15109 (9)	7729 (7)	10147 (15)
	Low	0 (2)	1782 (4)	1743 (8)	1313 (14)	1182 (19)	920 (17)
	Average	4753 (3)	4334 (4)	3691 (6)	3301 (9)	3174 (10)	2640 (16)
Number of hospitals surveyed		78	110	92	62	52	73

(2.27.- Exams in conventional radiography rooms in1985. Fisher)

Number of minutes required for different radionuclide and ultrasound examinations in a large academic radiology department

Description	Procedure Duration Time (min)
Echography—Scan B Mode	25.0
Echography Pleural EFFU	20.0
Echography Breast Scan	55.0
Abdominal Compl. Scan B Mode	28.3
Chest Wall Thickness Scan B Mode	45.0
Hepatic Scan B Mode	29.6
Gallbladder	25.0
Renal Scan B Mode	25.0
Pancreas Scan B Mode	30.0
Spleen Scan B Mode	20.0
Abdominal Aorta Scan B Mode	30.6
Retroperitoneal Scan B Mode	35.0
Urinary Bladder Scan B Mode	25.0
Pregnancy Diagnosis Scan B Mode	17.5
Echography—Scan B Mode Fetal Growth	24.8
Echography Placental Localization	35.0
Echography Pregnancy Complete	26.6
Echography Intrauterine Contraceptive Device	30.0
Echography Scan B Mode Pelvis Mass Diagnosis	24.5
Real Time Scan Portable	24.8
Gallium Scan (5 MA)	64.9
Liver/Spleen Scan	44.4
Bone Scan	54.6
Renal Scan (Function)	42.8
Lung Scan (Ventilation)	44.4
Brain Scan	47.1
Lung Scan (Perfusion)	34.4
Thyroid Scan (Isotope)	54.1
Myocardial Imaging IC-99M Pyrophosphate	41.7
Liver (Biliary Scan)	42.5
Myocardial Function Study (Imaging) SHA	58.5
Nuclear Medicine—Other	66.0
Bone Marrow Scan	53.3
Renal Blood Flow and Clearance/Delay Comparison	13.3
Pancreas Scan	56.9
Thallium-201 Myocardial Image	72.1
1131 Total Body Scan	69.3
Calcium Tumor Staging Scan	65.6
Thyroid Scan (Fluorescent)	5.0
Nuclide Angiogram	29.6
Renal Scan (Anatomy)	34.4
Joint Scan (One Pair)	60.0
Meckelogram	65.0

Information supplied by Chi systems (29).
Measurements were made at the University of Chicago.

(2.26.- Examination times with technology of 1990)

The data of number of tests per room presented and the theorists calculated with the exam times doesn't match without the consideration of the so-called **Room Utilization Coefficient**, which is never 100 percent.

In the occupation of a room should be considered room cleaning times, setup times of a new patient, delays in the arrival of patients, technical downtime, training and teaching, failures, quality control activities, cooperation of the technical staff with the nurses, etc. All these facts lead to a percentage of occupation of 70 to 75 per cent that is considered today very good in many departments.

Actual room occupancy figures

Six Nuffield Hospitals	31.4%	Wilkinson[1]	32–47.8%
		Blanjaar[2]	53.4% am
	33.4		44.5% pm
	34.6	Cobben[4]	60% optimum
	43.4	Health & Welfare, Canada[5]	80% used in calculations
	48.2	McCreadie[3]	70%
	30.7	McEwin	45%

(2.28.- Occupation time of a radiology room with film. Fisher)

Also new digital, both in 2D, 3D and 4D ultrasound technology have significantly accelerated the ultrasound examination time reducing it respect to those shown in the previous tables by the aforementioned authors and many radiological societies.

In CT analysis with data from the 2001 in USA was detected that for more than 6.000 exams of production per year the institutions acquire a second CT, and get maximum of 8.000 CT tests production, when there are more than one scanner.

Figures for magnetic resonance of 2001 indicate that centers with more than one machine performed about 5.400 tests per unit, which cannot reach institutions with a single machine. The existence of multiple machines in one image department brings a synergy involving improved individual productivity of each machine.

In nuclear medicine, for the year 2001 they also suggest a production per machine of 1.700 tests, when they have several machines in the department.

In the same analysis indicated that with PET facilities are carried out an average of 860 tests per year.

In mammography hospitals with greater demand will reach 3.200 annual examinations per room, based on data from the year 2001.

New technologies have accelerated, in general, the exam time, being a management challenge improve exam times to enhance the occupation time of the rooms to increase exams production, the profitability of the equipment and staff productivity.

The gammacameras of two or three detectors have accelerated times of exploration in nuclear medicine, reducing appreciably the exam time with respect to the figures indicated previously.

References for analysis in imaging departments with proven experience in digital radiography rooms with two detectors show average times of exploration between 2 and 3 minutes per patient measured at times of maximum activity, which usually occurs between 9 and 12 h am in the centers where the sampling was conducted.

The exam times of mammography with flat detector digital mammography have fallen by half, being able to take the times from above reduced in the same proportion.

X ray techniques for image of extremities, of high complexity by manipulating 30 x 90 cm chassis with films has been reduced to half time, or less with experience , with flat panel detectors digital rooms or remote controlled tables, with a quick scan of several seconds and image calculation on the workstation.

Techniques of digestive also benefited from the digital techniques with the elimination of the spot film devices and chassis in the remote control table. Exam times are significantly lower, not only in digestive system, but in the few techniques that has not removed the ultrasound and endoscopy to the remote control tables, like histerosalpingography, which still is a demand.

Also the CT multislice, or CTM, reduce exam times, although the time needed for the diagnosis by radiologists increased due to the explosion of images that are produced with the modern CT, currently up to 320 slices per rotation and upper announced by the manufacturers.

In magnetic resonance the parallel techniques, new coils, multichannel acquisition and new software have reduced the time of exploration in all techniques, although new applications, like the tractography, requires more scanning time or more magnetic field intensity for each exam. Also increases the time of radiological diagnosis.

The new PET or PET-CT with improved detection systems have reduced scan times by half, while this factor could in this modality not be the determinant of production, largely depending to the logistics of radiopharmaceuticals, in many installations.

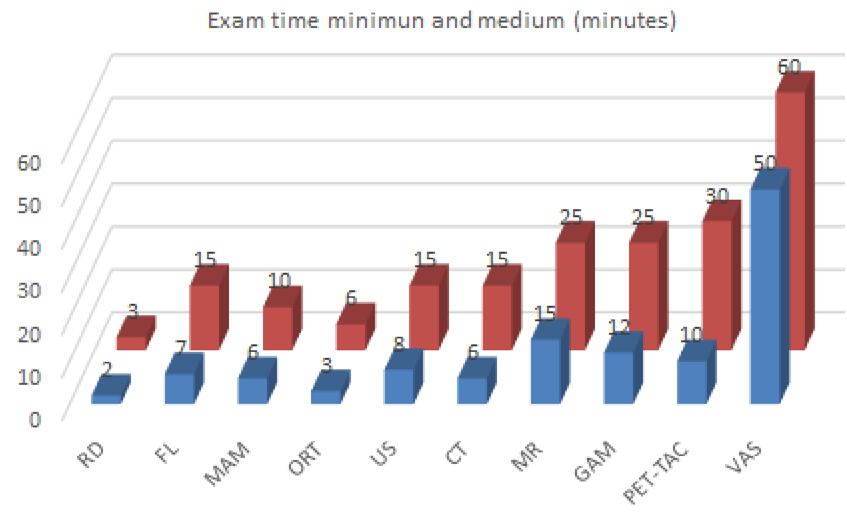
EXAM TIME		MINIMUM	AVERAGE
RADIOGRAPHY (DR)	•2 detectorS	2	3
REMOTE CONTROLLED TABLE	•1 detector	7	15
MAMMOGRAPHY	•1 detector	6	10
ORTOPANTOTOMOGRAPHY	•1 detector	3	6
ULTRASOUND	•2D-3D	8	15
CT	•16 Slices	6	15
MR	•1,5 T	15	25
GAMMACAMERA	•2 detectors	12	25
PET-CT	•	10	30
VASCULAR INTERV.	•1 detector	40	60

MINUTES

(2.29.- Exam time with digital systems)

These times referred to patients with normal mobility are increased 50 percent if the patient is coming in a wheelchair or bed. Also in pediatrics, and for some patients, the need for anesthesia or sedation forces to significantly expand widely the exam times, mostly CT, MR, MN or PET-CT. It is required that before entering to the examination room allow a previous preparation, in the proper room, for the required patient operations, and avoid to dilate exam room occupation to excessive and unproductive terms.

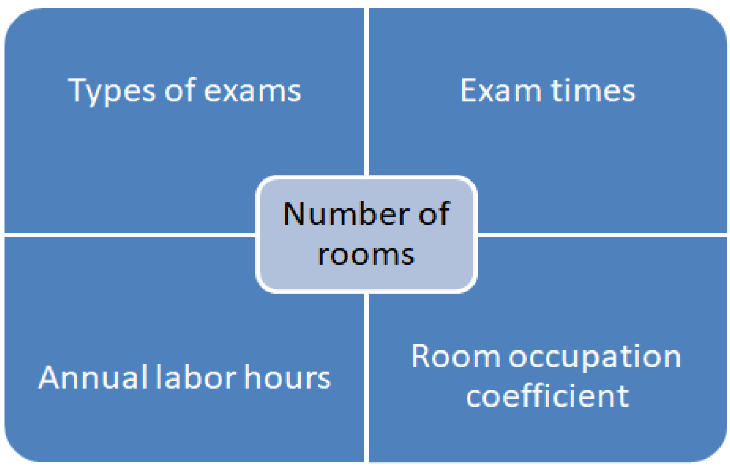
The exam times of conventional digital radiography in rooms with two detectors (2.30) are averages of the measures carried out in the radiology departments of hospitals: Torrevieja Hospital (Alicante) (4 rooms), University of Murcia General Hospital (3 rooms) and Northwest District Hospital of Murcia (1 room).



(2.30.- Exam times minimum and medium)

The calculation of the number of diagnostic rooms required for the imaging department, once determined the predictable attendance, will be carried out accurately determining:

- **Types of examinations**
- **Exam times**
- **Gross annual labor hours**
- **Room occupation coefficient**



(2.31.- Factors for the calculation of the number of rooms)

Expected frequency provides the types of tests according to market research in the area of influence of the hospital or diagnostic center. A preliminary analysis has to be performed by the consultant responsible for the project. Also depending on a university hospital, regional or county hospital will be different than in a health center or a center where only become outpatients.

The average examination times are a good starting point for the calculation. Watch recommendations done for pediatrics, and patients coming in wheelchair and beds.

Annual working hours are different for rooms of emergency (365 days) to general rooms of the central imaging department, where they work from 230 to 260 days according to employment contracts and with a continuous duty cycle (from early morning to late afternoon with a break at noon), or a half-day shift, or two shifts.

Occupations vary depending on the productivity of staff, transport of patients, faults and quality controls of the rooms, etc. Occupation factors of 70 to 75 percent represent optimal data of calculation in many centers. Very well organized centers can reach occupations of 80 percent or slightly higher.

With this can be determined the number of rooms that are expected to be used. Logically it is necessary to take recommendations to long-term, and for this the consultant and planner team have to extrapolate population data, growth and aging, increase in use of new technologies and forecast data of income and organization of competitors or collaborator imaging services that may offset the increase in demand.

II.V.- POINTS TECHNIQUES

Traditionally, and still today it continues to, the measures of the workload in one imaging department have been calculated in terms of number of tests or procedures that show a high degree of congruence. In this case the classical measure is appropriate. However with the arrival of the computed tomography, ultrasound, etc. the diversity of procedures has expanded and historical measurement techniques are less appropriate for all aspects of workload analysis. When a model is required, either for business, or to optimize the statistical analysis in the measurement of workload, requires a method that allows to correlate, in addition to the requirements of the personnel, details of the frequency at which the process takes place, difficulty of the procedure, difficulties in the management of patients and other related factors.

In each imaging procedure there is a great diversity between the resources it needs with the consumption of resources of other imaging procedures, so the measure of the workload requires complex adjustments. The method of relative values or technical points to measure the workload of imaging installations is the only statistically appropriate method of analysis in view of the diversity that exists among the variety of the today imaging procedures. **It provides an indication (measure) of the workload based on the consumption of resources.**

The first step is to determine the basic unit. A statistical value for each test is obtained relative to the base, so the total time consumed for each procedure are a series of points with respect to the base unit.

To use a relative value system, or to design one for a imaging department or a series of departments, must be a basic concert in the identification of tests, procedures and functions of support made by the staff of the department, introduce a precise method to count the number of such tasks performed, and the conversion of these data in units to obtain the average support and personnel required to perform the tests and procedures.

RADIOLOGICAL PROCEDURE (Resource consumption)	
Abdomen Series (Three views)	
User resources	minutes
Radiographer time	**13**
Support time (archive, transcription, reception),	**20**
Direction, supervision and quality control (17% of direct time)	**5,6**
Productivity adjustments (vacations, holidays, desease, etc.(13,8% of direct time)	**4,6**
Total time consumption	43,2

(2.32- Consumption time of resources. Data from 1985)

Identification of the exams is widely developed and there are national and regional codes to make it. Then there is to determine the number of technicians required to perform each test and procedure and the exact time consumed. Then must be evaluated the time of the support activities (nurses, reception, transcription, etc.), and finally to combine different types of times of resources consumed for each exam in a tabular format. Additional counting needs are in times of management compensation, management and adjustment of unproductive as holiday parties, diseases, training, etc. We have an example in the table below, where additionally have to be included the medical time.

With the current RIS, data are entered into computers at the time of the installation of RIS, although changes by new technologies or processes productivity improvements should allow carry out corrections from time to time.

The conversion to units of value, or points, should be determined by taking a reference to which is given the value of 1.0 points. The simplest method is what determines the value of 1.0 to the simplest radiographic exam: a simple view of chest imaging. Thus the relative value of each test or procedure is established by dividing the time of this by the time consumed by the base unit, in the example described below the simple examination of the chest. A partial list is attached in the following table.

CODE	PROCEDURE	Room occupation time min	Medical time	Activity Unit	Relative Value Unit
	Radiology				
	Chest				
70001	Chest, PA	6,0	5,0	0,9	0,8
70002	Chest, PA and LAT	8,0	5,0	1,0	1,0
70003	Chest in decubitus	8,0	5.0	0,9	0,9
70011	Rib cage	6,0	5,0	0,9	0,9
70012	Sternum	10,0	5,0	1,0	0,9
70013	Rib cage AP and oblique	8,0	5,0	1,0	1,0
	Special Chest examinations				
70113	Examinations with portable generator	8,0	8,0	1,4	1,4
	Chest fluoroscopy				
70123	Chest portable	20,0	5,0	1,6	1,1
70122	Other portable examinations	20,0	5,0	1,6	1,1

(2.33.- Point technique)

Each institution may adopt a different reference value, and in fact so has occurred, making little comparable values of relative units of different health systems e.g. the Canadian Government has taken as a statistical value of 1.0 an hour of productive time of one employee. The Finnish system establishes to the simplest test 10 points and the most complex in 180 points. The table indicates (2.34) points awarded to different tests according to different countries.

Comparison of four point systems

Exam	Finnish	Scandinavian	German	British Radiologist	British Technologist
Wrist	10	5	2	1	6
Chest	10	15	3	1	6
Pelvis	15	10	1	1	10
Upper GI	30	30	10	7	13
Renal angiogram	180	180	15	24	180

(2.34.- Comparison of various techniques by points systems. Fisher)

The activity of the imaging department is linked to the general activity of the institution, except on radiological consultations or health centers, in such a way that the correlation between the two is determined for in-patients relating the number of tests with days of stay and for the outpatient exams with visits to the institution. Having a relative value technique it is easy and helpful statistically to assess the annual variation of the relative values of internal radiology patients compared with the days of stay. If the relative values increase over time rather than the procedures for days indicate increased consumption of radiology resources. The same way for outpatient the relationship between value units consumed by the outpatients with respect to the number of visits and the procedures, and exams of external patients regarding the number of visits gives us a clear indication of the changes in demand for the department's image.

In the planning phase is already useful the technique by points, if the references from other centers have standardized data, because knowing the demand of exams of the imaging department may know all the points of the department and thus have determinations of the necessary staff.

II.VI.- PERSONNEL IN THE IMAGING DIAGNOSTIC DEPARTMENT

Classic imaging departments have traditionally employed several specific types of personnel: physicians, technicians, nurses, secretarial and administrative. This staff develops functions interdependent to achieve a final department product which are the reports of diagnostic and therapeutic procedures. Currently the staff is made up of a diverse series of medical radiologists, administrators, managers, supervisors, technicians, nurses, clerks, receptionists, accountants, secretaries, caretakers, etc. With the changes in many facets of the financial and computer activities of rapid development in the healthcare environment, there are certain classifications of staff previously absent in most of the departments that are now being added to this diverse group.

The development of a focus towards the health market increases the responsibilities of physicians and administrative staff, and depending on the depth of this market orientation the department may require the inclusion of a market analyst and a planner with the responsibility to assess market conditions, changes in operations, the consumption demands and technological changes, with the marketing plan of the department.

According to the department become more in a computerized entity, under the operational point of view, and is necessary to assess the staff capabilities and information systems hardware and software requirements that handle and include an expert (or experts) in information systems, in small centers can be carried out by the staff of the center with enough knowledge. Utilization, with success, the RIS and PACS installations depends on this staff and therefore the substantial improvement of the satisfaction of patients, staff, and department productivity.

The quality of the department service has to be monitored continuously, not only for reasons of logical control of their production but for government reasons and competition. The responsibility of this role includes the preparation, implementation and monitoring of a program of quality control and additionally assessing training needs, evaluation of radiologists, quality of image, repetitions, surveys with patients, and other related activities. This quality management responsible must have the help of radiologists and the supervisor and is a key piece in the optimal care of patients.

Dose controls, generally conducted by external consultants licensed by the authority on radio protection while in large departments make their own responsible for radiation protection, figure that can additionally do training not only in radiation protection but also protection of radio frequency and electrical and mechanical action of machinery in accordance with the laws of each country.

Can't forget about the instrumentation, the technology base of diagnostic activity, the equipment. While they are subject, in general, to maintenance contracts with suppliers, It is necessary to establish, in large institutions, technical maintenance of equipment on the basis of technical staff of the supplier attached to the health center. These technicians with sufficient general knowledge to handle most of the machinery existing in the department, repair frequent breakdowns, more simple but the majority, and coordinating the assistance of the supplier in the shortest possible time. Minimize the machinery down time is highly efficient not only financially but in the quality of health care.

II.VII.- RADIOLOGISTS

The final product of one imaging department is the report of the radiological act or medical imaging act. The radiologist, expert with many years of training, is responsible for the correct performance of the report.

Classically, has been established that a radiologist performs between 8.000 and 10.000 reports per year, but this figure varies within wide limits depending on the activity of the radiologist in the imaging department and the type of department. Various publications on management, referring to past situations, described as an interventional radiologist can do between 1.000 and 1.500 interventions per year, and a radiologist dedicated to the diagnosis of chest can pass 20.000. There are, in addition, to consider the production relationship with employment contracts, working hours varies widely between different countries, while the shortage of diagnostic imaging professionals is a constant in most of the developed countries with which many institutions and many professionals do day extension.

In a hospital medical environment, and also in many centers of outpatients the activities developed by the radiologist can be separated as follows:

- Reading and report with workstation and voice recognition 55
- Quality control of reports 10
- Clinical sessions and consultations with clinicians 10
- Support technical staff 8
- Training, congress, symposium 7
- Personal needs 6

- Attention to patients 4

Although this classification of tasks varies for each modality and therefore for every radiologist, there are many common focusing on these percentages. New technologies and the way of working of the imaging department also may change the percentages of activity and production in terms of reports.

The radiologist who study the ultrasound personally without the intervention of technicians at sonography examinations in some countries, carried out in the own room of ultrasound the diagnostic report, with the workstation inside the room, for what should be space available, and his efficiency in reports cannot reach the figures given at the beginning. If we consider one average time of 12 minutes per test, and the time on the image workstation for reading and to write a report, after the change of patient, etc. is very difficult to perform more than 20 patients per day in seven hours, reaching productions between 4.000 and 6.000 reports per year, according to the different working hours that today exist in different regions, far from the 8.000 to 10.000 mentioned at the beginning.

Likewise in multislice tomography, with the introduction of machines capable of generating an average of 500 slices per patient, and while the current workstations have software capable of generating volumetric images for easier reading, the radiologist requires significant time to read images and diagnose. The transcription of the report through voice recognition and further analysis of quality control, by the same radiologist or another radiologist do not allow to achieve more number of reports that the aforementioned in ultrasound.

Exactly the same situation of multislice tomography is the existing magnetic resonance, where each sequence analysis is even more complicated and it requires even more analysis time in the station, especially in the pathologies of neurology, cardiology, oncology and breast where the number of sequences to elucidate a pathology is greater. Productivity in reports can be even lower than that of multislice tomography if there is a high specialization, the case in large hospitals with large size imaging departments.

The size and dedication of the hospital is an additional factor in the determination of the production of radiologists. Large teaching hospitals reduce significantly the number of reports capable of performing for the dedication to the training of residents, during the three - four years which they require in their formation as radiologists. In these cases averages 4.000 to 5.000 reports per year, per radiologist, are frequent and even lower depending on the institution.

The table (2.35), Fisher, describes some of these data in the late eighties, in tune with the aforementioned data, and without the introduction of the new current modalities.

Nuclear medicine physicians have similar production than the obtained with the multislice tomography exams and magnetic resonance and PET- CT or PET MR further reduces yields mostly for related facts with rooms scanning capabilities and drug logistics than by medical capabilities.

	Radiologist	Technologist		Clerical		Other
Fischer						
Diag.	6,667	2,778[1]		4,313		8 TA 4.5 Ty[4]
Nuclear						1.5 TA
Ultrasound						
Gage[2]—duPont		Average	Range	Average	Range	
0–100 beds		3,042	1,150–6,495	4,753	1–18,180	
101–200		2,820	1,325–5,917	4,334	1,782–19,014	
201–300		2,867	1,622–5,259	3,691	1,743–13,012	
301–400		2,819	1,405–4,570	3,301	1,313–15,109	
401–500		2,864	1,785–7,148	3,174	1,182–7,729	
500 or larger		2,566	1,346–4,065	2,640	920–10,147	
Holm	5,000–7,5000	5,000–7,500				5,000–7,500 (darkroom [illegible]
Hospitals		2,500–4,500 B scan 1,000–1,500 Echocard.				
	5,000	1,500–3,000 general ultrasound				
Janower[3]	10,000	3,500[3]		7,500 file room		darkroom man 30–4[illegible]

(2.35.-Annual production of different personnel. 1985. ISPRAD)

Radiologists demand will continue to grow because frequency growth and for reasons of complexity of the exams with the new modalities, as well as by the introduction of new technologies in the near future with new therapeutic techniques that will be held in the image department, while technological development can bring new guidelines to help the radiologist in their efforts to report. An example of this are the new computerized aid diagnosis programs, widely developed in chest, breast, and colon and with a tendency to get into other diagnostic areas. They take a while to find adaptation mechanisms of these new AIDS diagnosis to legality and current applications, but they will undoubtedly have an important housing in imaging departments.

II.VIII.- IMAGING TECHNICIANS

The modern radiological systems with digital flat panel detectors have simplified part of the work of the traditional radiographer, with expected yields hovered in the vicinity of 2.000 to 5.000 exams

per year on average in the 1980s, according to the table already displayed by Fisher. The removal of the chassis in the darkroom and later the daylight systems, as well as the elimination of film archives allows to increase the productivity of the technicians in conventional radiology exams, reaching higher values to the ones existing with traditional old automatic chest devices, where the developer machine was attached to the chest device, while the technician still took 60 seconds to observe the film to check the quality of the image and to validate it for radiological diagnosis. Therefore with exam averages of 3 minutes in conventional radiology stays the productivity with superior returns, with less technical fatigue due to huge transport of chassis from the examination room until processing and then the film to the diagnostic area. All this technician mobility can be incorporated to examination activities, consequently increasing its performance in number of tests and improving their patient care. Today a conventional radiographic room can perform easily 24.000 examinations per year in a 7-hour day, with 250 working days per year and an occupation of 70 per cent. The two technicians that perform this operation have been carried out 12.000 tests a year.

The tasks carrying out by technician every day can be classified in the following way:

- See the citation in the RIS of the modality where works.
- Prepare image rooms to carry out the tests.
- Call patients who are waiting, according to citation of the RIS, showing them the cabins if they need changing clothes, or introduce them into the exam room. They may require help from guards if they come into beds or wheelchairs.
- Carry out the test, check images and send them to PACS for his diagnostic file. Help the patient to enter his cabin and dismiss him, to quote a new one.
- Carry out tests on hospital beds in plants with mobile equipment.
- Training to personnel and students, in its modalities or new modalities.
- Personal activity (coffee, lunch, calls, etc.).

The activity of technicians in other diagnostic imaging modalities , such as US, CT, MRI, or MN, to obtain images, where the acquisition times and the needs of preparing the patient for the test are more complicated, leads to lower exams productions and without appreciable changes with respect to those indicated by the traditional literature.

In ultrasound scan is performed, by countries, by radiologists or by sonographers (USA, England, etc.). Recent reports indicate that in the United States the majority of hospitals have graduates sonographers, leaving the images to the radiologist in the file of the PACS for its interpretation and requesting the support of the radiologist in cases where the sonographer has reasonable doubts about the validity of the acquisition of the images for the clinical diagnosis. The performance is inside the classical figures already described previously.

In tomography multi-slice and magnetic resonance, and partly in nuclear medicine, in addition to the tasks of image acquisition begins to be very valuable the work of technicians in the reconstructions of images, so teaching the technicians in these tasks can bring important benefits to the operation of the department, even more in time of shortage of medical radiologists.

In general the relationship of 2.5 technicians per radiologist has been accepted so far as valid, therefor with new digital technologies, new CT multislice, new stations for reconstruction, this figure will expand up to a factor of 3 or already has been extended in some imaging centers.

II.IX.- NURSES

Performing techniques more and more invasive in the imaging department the care of patients in most difficult conditions require nurses to support the different tests or procedures. Most of multislice tomography exams require iodinated contrast injections, in the same way that contrasts of gadolinium in MRI, and increasingly in ultrasound with contrasts for ultrasonic, not forgetting the angiography rooms and interventional medicine. The number of nurses required will depend on the activity of these rooms as well as the type of imaging center and patients who come to the department. One outpatient diagnostic center is very different from one acute hospital with several equipment in the type already mentioned. Therefore requires an analysis of the activity of the center for nursing resources, today is in general higher than that described in the technical literature of a nurse for every six rooms.

II.X.- OTHER PERSONNEL

In past years had great importance the staff dedicated to the transcription of reports. The radiologists dictated on tapes of his voice recorders and a good number of secretaries write out these on paper for his signature by the responsible radiologist. With voice recognition systems have been replaced these posts to other tasks of the imaging department, as the reception or the accompaniment of patients up to its previous examinations waits.

The citation is in general in the RIS and this comes through the hospital HIS, or directly included in the agendas of the RIS. Patients come to the reception with their citation documents, increasingly more simple, that is contrasted by the receptionist and they are sent to the waiting. This control and verification time is the one that determine the number of required receptionist staff, in accordance with the flow of patients expected in the imaging department. Large hospitals require numerous personnel in this task to receive and accommodate the patients in their waiting and avoid queues at the reception which make difficult the operation of the department and the poor reception of the patient, giving the feeling of poor service. The reception staff and the reception room are the first human and physical contacts of the patient with the department and poor training of the staff and inadequate reception position caused the bad perception of the patient about the services that will be offered in the department. Management team must care the training of these persons and the designer of the service the required space to make it nice and avoid queues of difficult acceptance for the patient.

The administrative work of the department will be in the hands of appropriate personnel to these needs vary widely depending on the organization of the center or department. A private outpatient consultation requires management to invoicing and tracking of tasks of accounting in accordance with national laws, while some hospitals have centralized the task of invoicing and do not need personnel in that area.

Human resources today occupies a significant area in the direction and organization of one imaging department. In many departments this task lies, even, at the head of the department or the administrative chief, either this delegate to the central services of the hospital, but the work of recruit the best, train personnel, cover casualties, overview managing personnel, will be increasingly important in the work of one imaging department. Well-organized departments have clear separation of tasks: medical, financial, personnel, etc., by clearly defining the responsibilities of the director of the department in clinic and scientific and the financial, personnel and logistics, for administrative director reporting to the director of the department and the chief financial officer of the center.

Logistics of the image department requires an organization to its supplies and waste disposal. Orders for accessory, pharmacological, material of radiological protection, hospitality, etc., they must be made in accordance with the hospital organization were is included and using the administrative resources required for the operation of the department. This will depend on the size, activity, organization of the healthcare environment, etc.

We must not forget the transport of patients, with guards that carry them from the rooms in beds or wheelchairs up to the image department for their exams. Wardens may depend on the department itself or the central organization of the hospital. The transport of patients in also important in outpatient imaging centers. The design of access for ambulances must take into account by the designer of centers of external patients that occasionally receiving them, and should be considered the stay of the patients that come with this means of transport, waiting until the examination and their forwarding to the ambulance after the test, not forgetting the recommendations anteriorly made in the reception.

Previously stated, depending on the complexity of the center, new occupations arise today under the protection of the diversity of the tasks that are performed in one imaging department and the heavy investment that are carried out. These tasks and occupations should be considered in the planning of the facilities and in the design of spaces needed to.

II.XI.- PERSONNEL IN RADIOTHERAPY

While in diagnostic imaging technology has had a high acceleration since the 1970s, this development is equal, or possibly higher in radiation oncology systems from the 80s with the advanced development of linear accelerators, and in the last two decades with the introduction of novel stereotaxy techniques and treatments with proton accelerators. This has forced a greater definition of the functions of the department staff and a growing specialization of tasks required for the implementation of the therapeutic techniques.

A good and very objective study with scientific rigor has been made by the Spanish Society of Radiation Oncology (SEOR) by the study issued in the White Book of the Society published in 2012. This study quantifies and characterizes the human resources assigned to the radiation oncology in Spain, analyzing their evolution and associated workloads. Six years later the results are coming.

II.XI.I.- RADIATION THERAPY ONCOLOGISTS

The definition of the workload of each therapeutic oncologist is defined by the number of radiotherapy treatments performed annually. Its estimate varies according to the different scenarios of sharing of tasks between medical practitioners. This charge is different considering the dedication to teaching, the percentage of brachytherapy which is done, cases of stereotaxy and dedication to administrative tasks.

The accompanying table relates different sources of research in this regard.

For comparative purposes there are data of three associations in medical radiation therapy area, and can be seen only a small difference. This production data can be used by the team in charge with the planning for the calculation of a new radiotherapy department.

Radiation Oncology Physicians per number of new patients/year		
SEOR	178/191	Average
ESTRO	250	Without Chemotherapy and teaching
GMENMA	200	Recommendation

SEOR	Sociedad Española de Oncologia Radioterapica	2008
ESTRO	European Society for Radiotherapy & Oncology	2008
GMENMA	The Graduate Medical Edutation National Advisory Committee Stud	1990

II.XI.II.- RADIATION ONCOLOGY TECHNICIANS

The number of technicians required for each unit of treatment depends on the number of daily hours of operation, also the productivity and labor laws. The majority of treatment planning systems work between 50 and 60 hours per week, and in this approach by treatment unit the average of technicians stands at 4.15 in cases of double work shift, being reduced by half in the case of one shift.

The recommendation of ESTRO is 2 technicians by linear accelerator and the surveys practiced in the United States in 1990 indicate an average of 2.3 technicians by machine.

The technical dosimetrist, although is not even a standard in many centers, in the White Book of the SEOR write around running 164 technicians working in 2009, with a ratio of 1.14 technical dosimetrist by treatment unit. The ESTRO has not explicit a recommendation for the dosimetrists, and American Registry indicates that the collective doubled in the period 1986-1990. The current estimate in Spain is 461 treatments by dosimetrist.

II.XI.III.- NURSES

The number of treatments per nurse is located, according to the study by the SEOR, in 335, equivalent to 1.75 nurses per unit of treatment.

There are no data in SEOR on the subject and there are not international standards, while accepted nursing care to improve tolerance to treatments and consultation of nursing are a fact in radiation oncology services.

II.XI.IV.- RADIOPHYSICS

The ESTRO recommends one radio physician per unit of treatment or 1 physical for one amount of patients between 450 and 500 per year. In the study of the SEOR data indicate the existence of 1.4 radio physician per unit of treatment, or a total of 373 treatments by physicist and year.

In general the medical doctor/radio physician relationship is 2:1.

II.XI.V.- OTHER PERSONNEL

The increasing complexities of the treatments added new types of professionals to radiotherapy services. Dieticians, psychologists, computer scientists are professionals increasingly involved in the departments. Its quantification depend on the type of centers and surely will continue to grow in the coming years as go moving custom applications of treatments.

II.XII.- EXAMS DEMAND RESEARCH

A lot of references have been included to encourage the planner to devote the time and resources needed to determine, as accurately as possible, the number of tests that should be done in the department that want to plan. Throughout the chapter there are many quotes from current information sources, although they do not provide the particular data needed for the job, they can be very useful in current and historical evolution and comparative analysis.

Demand analysis task is a work of marketing research and therefore the techniques of this discipline will be very helpful in their preparation.

The activity to develop will be different if the department will provide public or private services. In this first case will be, in principle, more simple due to the knowledge and information of local, provincial and national public institutions on the current frequency in each area, while may require actions of consulting on the development of new techniques or procedures already developed in other areas and not implanted in the one of our project that could need future resources that is needed to provide today. A good example is the development of the hybrid equipment PET-CT whose introduction in oncology continuing in frank expansion and not all public areas have required coverage of their demand.

The private departments are of much more complex research, and in many cases this is linked to negotiation with providers of patients. Therefore required a more extensive research work, paced and linked in many cases to the negotiation of the promoters of the project, to obtain more precise results. Must not be forgotten that these results will be the baseline data for the calculation of the number of rooms and surfaces, as will be displayed in chapter V.

Traditionally many departments have been created based on satisfaction of demand actions motivated by electoral promises of political candidates for public jobs or by managers in the process, but the latent demand in the majority of these cases was visually high, so research techniques have not needed to tie many links, and in many cases little to nothing has been done. Currently the economic and human resources that come into play are very high so the costs of commercial research arising from these projects are little significant beside bulging budgets that will be generated. And its results can be vital to the success of the project.

The list, reference, figure (2.36), describes the most important activities that allow completing a study of demand. There are more tasks but they vary with the type of care center and its objectives.

The population is the first key to investigate. Today there are many data provided by the municipalities in their WEB sites, and of the national and provincial administrations. However many border barriers, in Europe especially has been eliminated and the freedom in movements of population has facilitated the displacement of people between regions and nations and today is more difficult to know the exact demand only through the municipal register. Tourist, seasonal migrations, etc., should be considered and the marketing research study complicates widely.

Current frequentation studies are in many regions non-existent, or made only under the magnifying glass of hospital demand. Frequencies at the provincial level are little known and regarding this task force should be used to find for details as accurately as possible. Approximate studies exist in general but need technical and documentary rigor to plan bloated budgets.

Existing image facilities to local, provincial or national level are partially known. Although there are official registers to document all equipment, not always is accessible. Studies at the national level do not exist, precisely, in the majority of countries and studies of consultants who have published their works for references are used. There are registers, in many countries, which would identify the number of equipment with radiologic technique, or using radiation, due to mandatory legislation controlling the use of ionizing radiation, but those records are poor today, for the preparation of statistics, and the existing ones are not published. Information about the installed equipment of ultrasound, MRI and other non-radiological techniques are not available in an organized manner so the research team must perform a systematic task of tracking the units in the target area.

Public and private institutions in the vicinity of the study area are easier to identify, but it is necessary to know its regulations and habits, and of course the legislation which allows communication between them and the target center must be observed and comply with.

The socio-economic environment and its evolution must be important subject in the study. The future of the project depends on their stadium and evolution. Information is available in the responsible public agencies and also they have many economic and social entities of private sector studies that can be obtained and consulted with few difficulties. The business and social organizations can provide documentation and valid opinions for researchers.

Analysis of availability of personnel for the center is a basic step for the possible validation of the project. Certain areas have large number of radiologists and technicians but elsewhere there are strong difficulties for their displacement. Special incentive actions may be required to provide the imaging department under study of demand for the necessary staff to operate.

National regulations which the department must comply should be observed from the study of demand. These involve hiring of specialized companies and costs of experts and registers. If there are therefore a factor which affects the project must be known from the beginning. Not calculated inspection periods can lead to heavy costs, which can be ignored or calculated. Chapter XII indicates concerning international regulations, but locally legislations and regulations should be studied because they will be of immediate application. Documentation about it is easy to obtain in the national agencies.

Local regulations, such as location of the lots in the registers of the property, licensing of construction of the municipalities, licenses of opening of premises for health activities and corresponding registration they are also matter of observation in the research phase as they carry time and costs.

The commitments of sending the patients, or areas where are located the providers of patients that will come to the department are a matter of negotiation in which the marketing research team must be working together with the promoters of the projects, to ensure the basic data of demand on which is build the diagnostic imaging or radiation therapy department projects.

(2.36.- List of activities in the marketing research)

III.- TYPES OF DIAGNOSTIC IMAGING DEPARTMENTS

I. **OUTPATIENS IMAGING CENTERS**

II. **DISTRICT HOSPITALS**

III. **REGIONAL HOSPITALS**

IV. **GENERAL HOSPITALS**

V. **VERY LARGE HOSPITALS**

VI. **MONOGRAPHIC HOSPITALS**

VII. **EMERGENCIES**

VIII. **MOBILE DIAGNOSTIC IMAGING**

IX. **IMAGING IN THE HOSPITAL OUTSIDE DE IMAGING DEPARTMENT**

Planning should be based on the needs of the patients and the department members.

(H. Fisher)

III.- TYPES OF IMAGING DEPARTMENTS

It is almost impossible to imagine a garden without certain specific elements that give it a look different from each fund, we are talking about plants. These are not all equal and every garden is more inclined to one or other. There are thousands of varieties and kinds of plants.

If kinds of plants are divided according to their way of reproduction, then we would have a very technical classification, cryptogams, phanerogams, etc. But becoming a little less technicians will group the different types of plants using a more simple language; in this division we must begin by the trees, these are without doubt the largest plants that exist, there are of different shapes and sizes: from small fruit trees up to the redwoods.

Trees differs from other vegetables because they possess a single stem, which we call trunk, it is hard and woody. Among the types of plants are also shrubs, they are smaller than the trees but bigger than herbs. Herbaceous plants are small and protruding from the floor to a few centimeters, most of them does not have a long life but as maximum can reach live two years; oddly enough, most of the planet is covered with wild herbaceous plants.

Our healthcare environment, cannot be imagined without certain specific elements, which are providers of health services, and also have these classifications, ones more technical than other, but all of them try to satisfy basic and intrinsic needs of the human being, their health needs. These are the basis for the generation of demand for diagnostic imaging exams and subsequent therapeutic actions.

The offer of health services is organized in multiple ways to provide the health care in the best suited manner to the patient needs who receive them. Health care providers have deployed installations of very different levels of complexity, starting from the classic medical consultation very close to the patients until the large hospitals, where the distances to the patients is in general large, and receive patients from distant geographical areas.

Patients who come to clinical consultations, may be family medical assistance or specialists, they are referred for imaging to reference centers, as general in the geographic proximity. These imaging centers, make the first examinations and meet the patient needs. They have traditionally been radiology facilities equipped with conventional equipment and most modern with ultrasound. Here has been made all exams of thorax, skeleton, abdomen, etc., with the technology of the moment, commonly with horizontal tables and wall buckys for chest x-rays, the digestive and studies with contrasts with remote control table or tilting tables and mammograms and panoramic dental with their own dedicated equipment. Diagnostic imaging facilities with multislice tomography and magnetic resonance have appeared separately, or together with other modalities, forming **outpatient diagnostic centers** of great medical importance for the high number of tests carried out and the simplicity added to patients by the availability and rapidity with which perform services. Outpatient diagnostic centers, with PET and PET-CT are being installed in greater profusion according to the development of the imaging technic, complementing in many cases existing facilities of nuclear medicine.

Another way to provide image diagnostic facilities next to the patient are mobile diagnostic systems, as are those of tomography multislice, magnetic resonance, mammography, PET and still in some countries studies of thorax. The designs of these mobile equipment have their special characteristics in such a way that will satisfy the requirements for the correct patient care and mechanical, electrical, environmental needs and safety of machines for operators and patients.

District hospitals present a diagnostic imaging solutions more advanced than most of the diagnostic centers for outpatients, requiring the planning of diagnostic requirements, its profitability, the needs of staff, etc., as well as the location of the department in the healthcare environment in such a way that should be made one optimal design for the traffic of patients and their comfort. These centers that commonly have no more than 150 beds provide services to patients with general diseases, as well as obstetrical services, consultations and general surgery. Facilities include conventional radiology and ultrasound, CT multislice and magnetic resonance equipment.

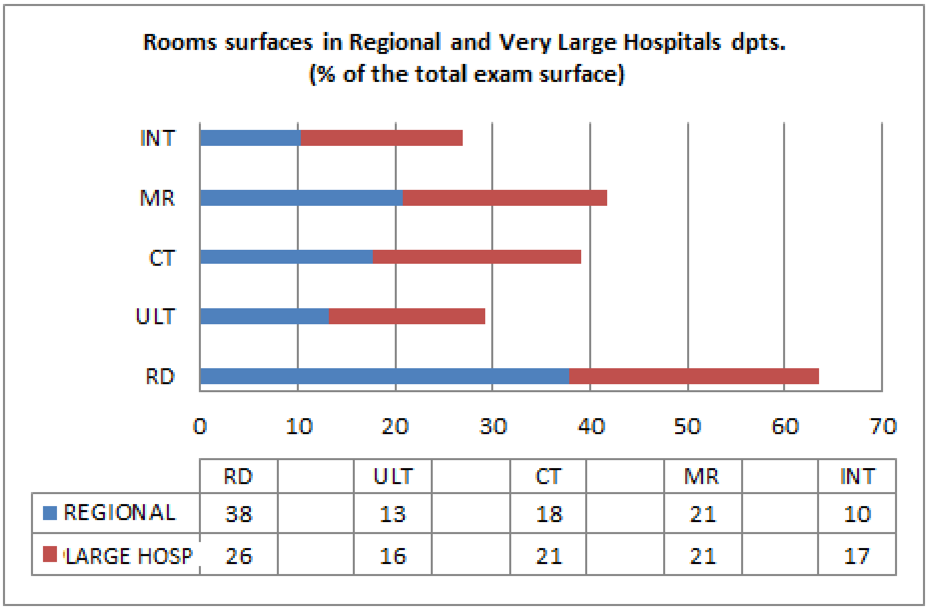
Regional hospitals from 150 beds to more than 300 beds they attend large sectors of population offering a greater range of services than the regional hospitals and in some of them a variety that adds nuclear medicine imaging and radiation oncology treatments.

General hospitals with more than 300 beds, require more complete imaging departments and many of them include all diagnostic modalities, with the realization of all the current therapeutic and interventional procedures, needing to define well the therapeutic areas and the requirements of space, media and the design that such a rooms need. Some of these hospitals, with university rank require additionally in its design consideration of the needs for teaching admitting lower production of diagnostic rooms and greater number of professionals for the education requirements.

In the present hospital organization the rising costs of many new treatments are forcing planners of smaller hospitals offering services that in the past were only offered by hospitals of higher rank. For this reason there are currently smaller hospitals offering services in similar ranges to general hospitals, so the imaging and radiotherapy services planner should consider all the services offered by the hospital rather than the considerations of the number of beds.

The very large hospitals with more than 900 beds they have even greater image services design needs. In addition to conducting all types of tests and procedures consider the tasks of research that make most of them. More extensive diagnostic and therapeutic rooms, rooms reserved for the future, more flexibility to technological changes, better adaptation to the requirements of researchers, increased interrelation of diagnostic modalities, radioactive isotopes and radio therapeutic treatments.

Important differences appear to observe the examination of diagnostic modalities space needs, between regional hospitals and large hospitals. In the latter the surface needs for CT and MR reach the one of conventional diagnostic radiology and if the hemodynamics rooms were included in the surface of total consideration of image, could be checked how in large hospitals the surface examination of areas of vascular-Interventional and cardiac catheterization is superior to the conventional radiographic diagnosis, historically the biggest.



	RD		ULT		CT		MR		INT
REGIONAL	38		13		18		21		10
LARGE HOSP	26		16		21		21		17

(3.1.- Comparison of percentage modality areas in diagnostic imaging between regional hospitals and large hospitals)

Monographic hospitals have special considerations, such as oncology, pediatric, orthopedic, etc., given the specific diagnostic and therapeutic needs of these centers of different number of beds but, in general, sizes small and medium.

Military hospitals are a very special type of hospitals. They are intended for the armed forces, and especially the campaign hospitals, where the mobile image requires specific and unique benefits.

III.I.- OUTPATIENTS IMAGING DIAGNOSTIC CENTERS

From the simple and classic radiographic room individually installed in a medical center, up to the most sophisticated diagnostic centers with all modern technologies, all have a common goal: attention to outpatient, or external patients, who come from different clinical specialist consultations. Depending on the country, they are called health centers in cases of public medicine, or diagnostic centers by private imaging to provide services exclusively to private patients or sent by the corresponding health public system under authorization or directly if it is concerted.

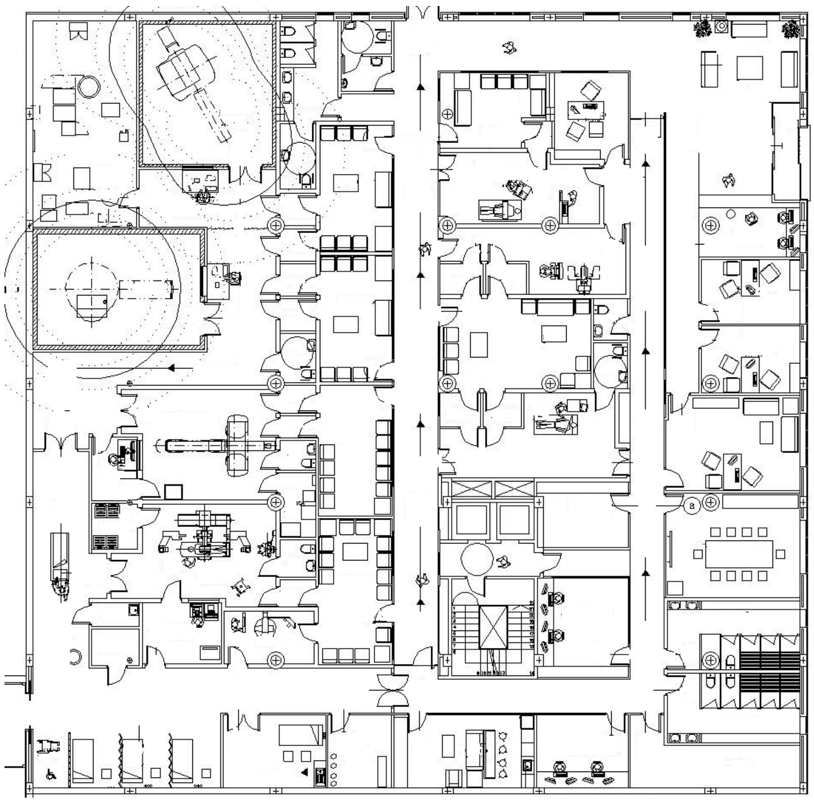
Planning requires a sensible study of the market diagnostic needs with detail to facilitate the return of the investment and the optimal care to patients. The parameter frequency in the target area is for the private projects of relative value, lists only tests that are carried out, but to reach potential patients to come to the center it is required to analyze with more detail the competition in the area and the possibilities of cooperation with public medicine to define the potential tests and the necessary equipment. Normally requires knowledge about the level of performance offered by the competitors to provide services not covered by others or actions to ensure improvement in quality or cost.

Public health centers are easier for planning since one that it is known the reference population that will attend the imaging department it is only required to determine the coordination of its services with referral hospitals. The frequency may be the parameter that guide planning.

All these sites have a common characteristic: the patient care. Typically mass in public and personalized in private. There must be space in the way that the waiting, exam and patient care are optimized. It is necessary to plan the space so that the patient is relaxed and feel treated with dignity and efficiency. This is in the hands of the planner.

The following example (3.2) is a department of diagnostic imaging for outpatients, with possibilities to attend for patients in beds or in wheelchairs arriving in ambulances from hospitals. It is a center of high performance with the 3T MR and open MR of 1T, CT 256 multislice slices for cardiologic examinations, remote controlled table with wall bucky coupled to the conventional radiology, ultrasound of high-resolution, mammography system and equipment for bone densitometry exams.

The reception, in the top right, distributes the patients to the rooms down the center aisle, where each room has its individual waiting. The personnel has its circulation, side corridor, completely separate of the ambulant patients and can mingle, exclusively, with some patient who arriving in ambulance that moves in the stretchers to the corresponding examination room. The center occupies, in the building where is housed, a plant of 1.200 m2 (12.916,7 ft2) and patients have access from the parking area outside at the street entrance. Medical personnel can be accessed from the parking car in the lower basement.



(3.2.- High-tech outpatient center)

Cooling systems for air conditioning and for MR refrigeration are located on the roof of the six-storey building and the telephone central, and HIS and PACS servers are located in the room next to the elevators. There are offices for medical consultation, management and administration.

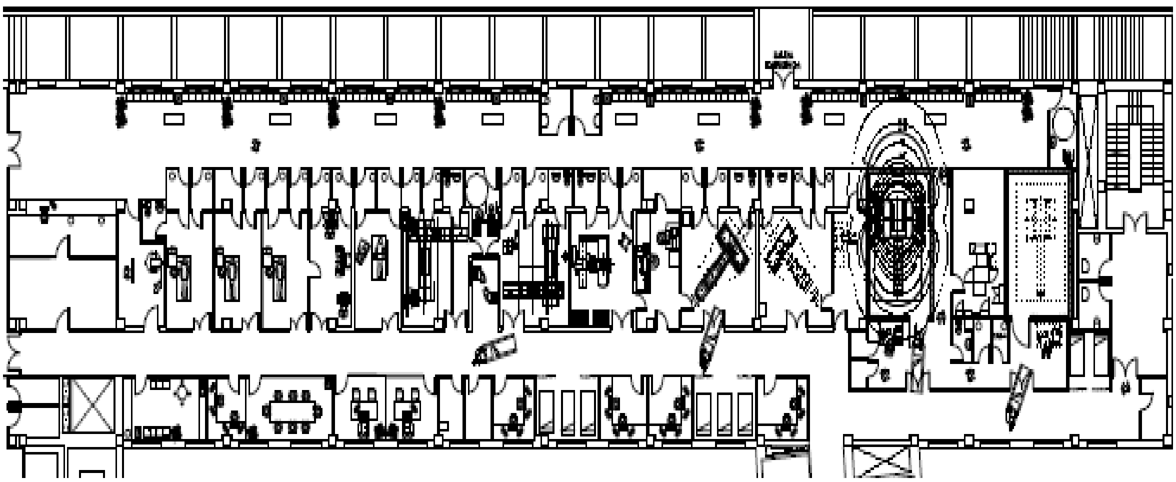
Very important is the provision of medicinal gases and the emergency room, with equipment of resuscitation and monitoring of the patient in case of unfavorable contrast reactions (rare but possible) and transitory ailments of patients. This aspect should not be forgotten in any installation with ambulant patients.

III.II.- DISTRIC HOSPITALS. SMALL HOSPITALS

These are centers that provide health services to small communities or local communities. Commonly they have organization and resources to meet all the needs of general medicine, not offering comprehensive oncology, neurosurgery and cardiac surgery services, dedicated to the rest of the common diseases in acute patients.

Those centers, with extraordinary activity, are designed with a maximum around 150 beds, providing services to a population whose maximum ranges between 100.000 and 130.000 inhabitants. In terms of number of exams and with the today average frequencies for this population, in general would be expected on the order of 100.000 to 150.000 exams per year (depending on the region).

It currently has the majority of diagnostic modalities except nuclear medicine and angiography-angiocardiography, whose patients are referred to most complete facilities



(3.3.-Diagnostic imaging department in a district hospital)

Outpatients and internal patient circulations are separate (3.3). Emergencies have one own radiographic room. Health personnel circulates through the same corridor of in-patients. The department, with CR (x-ray computed radiography), has three rooms of ultrasound, one mammography system, one room for studies of densitometry, one equipment for ortopantotomography, a multislice tomograph and a magnetic resonance imaging system, with reserves of space to provide for next growth. A total of 11 rooms of imaging for a hospital of these features was difficult to estimate 20 years ago, when were estimated between 3 and 5 rooms of x-ray for every 100 beds. However it is advisable to have an additional space for independent technical patient corridor and more space for activities of staff that in the present design is reduced.

The foreseeable demand for inpatient determines beds waiting spaces design. If 20 percent of all patients are internal will have a total between 90 and 100 patient daily that reaches the image department from plants in beds or wheelchairs. If proper citation, the surface for six bed waiting can be adjusted but this is what the space reserved for the image department allows.

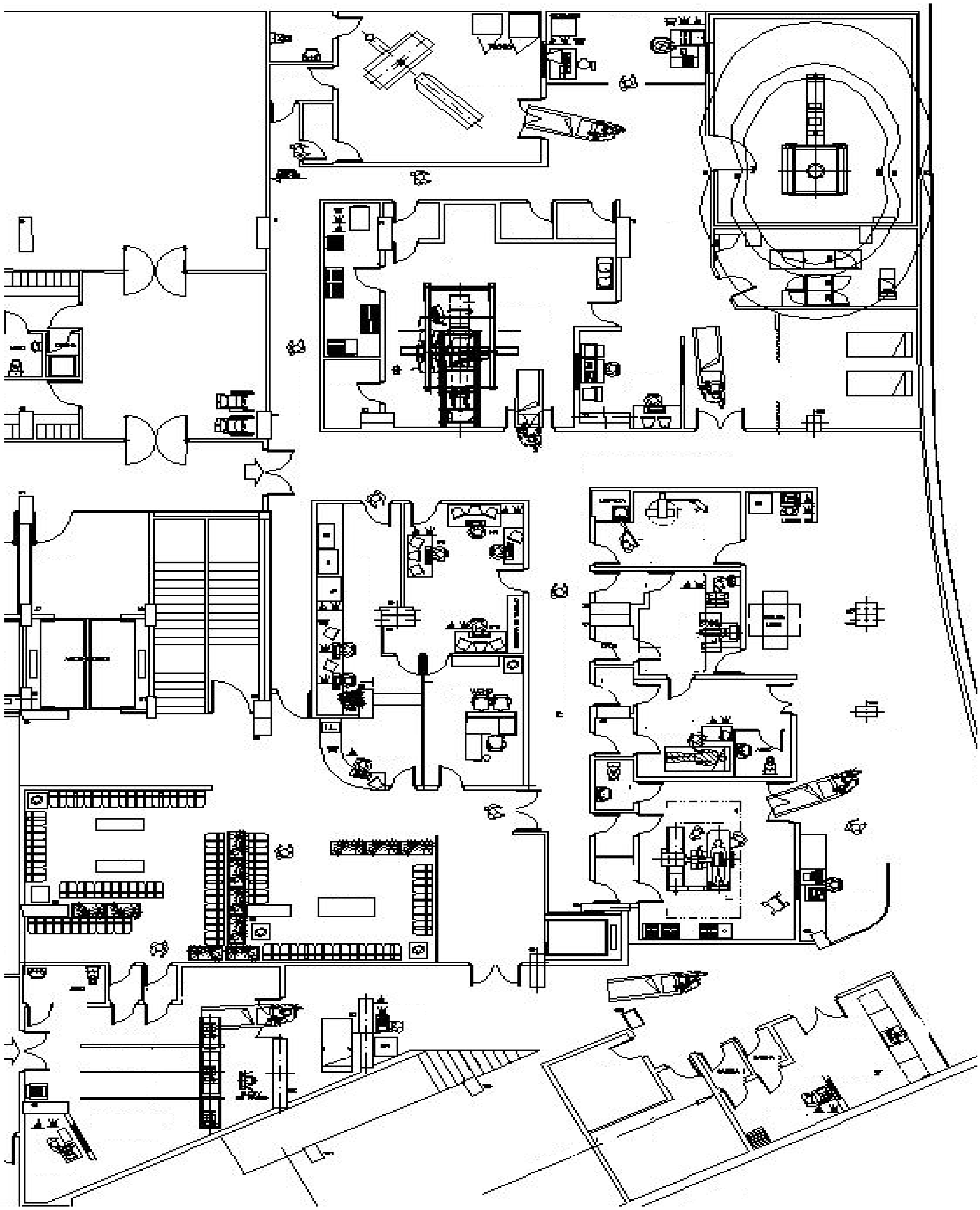
Enter too in this group many hospitals without belonging to a specific region they are part of secular or religious groups, with own sanitary organizations, or business groups, etc..; in general communities or private organizations that founded a hospital to provide services to its members. One example are the health insurance companies with their own hospitals or clinics in this order of services that provide care to subscribers who pay your regular insurance policies, although they own also large size hospitals.

The planning and design of these departments will require, as already described above, a detailed analysis of the sanitary conditions of the area to determine the potential demand of patients to the department.

High-level hospitals deserve a special section, commonly private and small, but high-performance that provide services of high quality and availability to all types of patients. They are equipped with departments of image with all modalities, offering many of the care of general hospitals with high degree of privacy for the patient.

In the attached example (3.4) we see the image department of a high-performance 110 beds hospital with the separation of the respective areas, patients, staff, diagnostic test and technology occupation, that will be detailed in Chapter 6, but that highlighting for convenience.

The varied equipment leads to the department of higher dimensions that would be for a hospital of the described number of beds. Perform around 35.000 annual exams with all diagnostic and therapeutic modalities. A service of nuclear medicine in the lower floor complete the image department of the hospital.



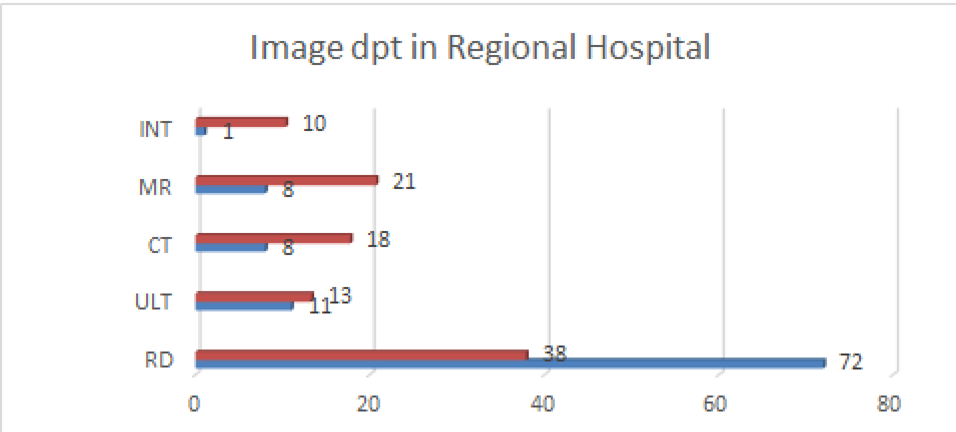
(3.4.- Imaging department in a private hospital)

III.III.- REGIONAL HOSPITALS

A breakthrough in services offered leads to more image rooms and greater production equipment capable to do more tests per time unit. This is possible to achieve with digital techniques, e.g. in conventional radiology using two detectors rooms, one on the table and another in wall Bucky, or nuclear medicine gammacameras of two or three detectors.

In the past have been proposed various formulas and methods for calculating the number of rays x rooms in relation to the number of beds. Today is not available statistical data to make this correlation. The huge increase in examinations as a result of the availability of outpatient tests attached to many hospitals, but whose patients come finally to the central imaging department and the introduction of new modalities does not allow to determine the number of imaging rooms depending on the number of beds, while the number of beds and average stay of patients in bed are very variable between hospitals and are very important parameters for the planner because they allow to calculate predictable beds waiting rooms and the width of the corridors to avoid collisions in the particular traffic circulation of the inpatients in the image department.

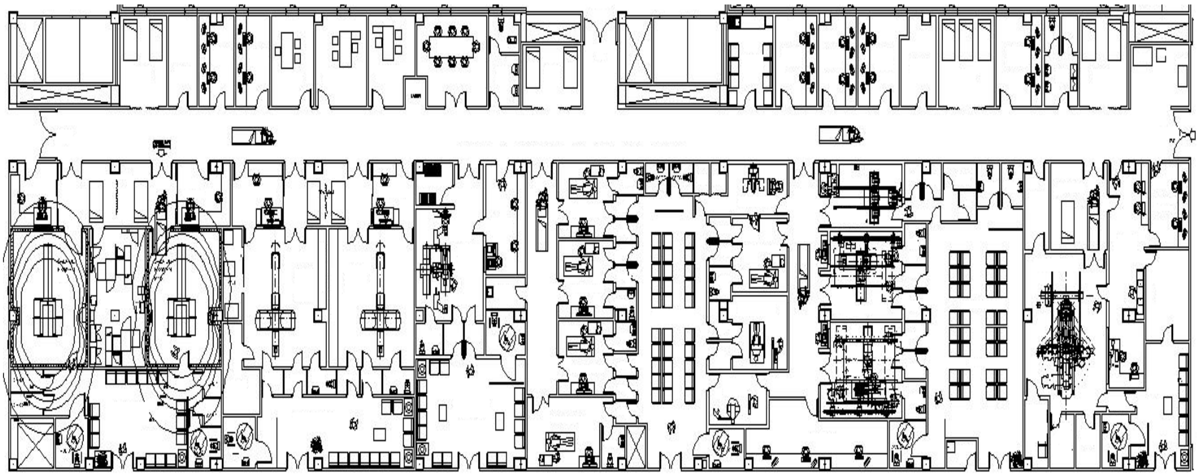
The graph (3.5) shows the relationship between the percentage of tests that performs an imaging technique and the percentage of exam surface occupied in this type of hospitals. Conventional radiology means 72 percent of tests that are done at the hospital and the occupied space is 38 per cent of the examination surface of the department.



	RD		ULT		CT		MR		INT
% SURFACE	38		13		18		21		10
% EXAMS	72		11		8		8		1

(3.5.- Relationship between examination modalities and surface occupied by modality)

A regional hospital with 270 beds like the one presented below has an imaging department and separated nuclear medicine and radiotherapy departments.



(3.6.-Regional Hospital)

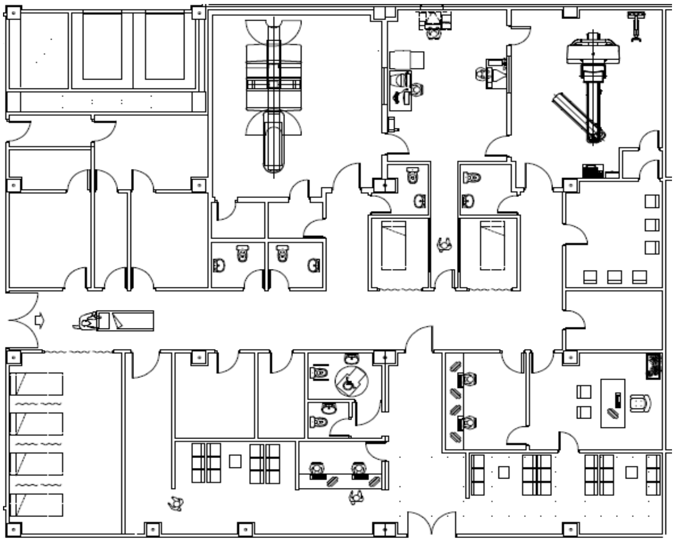
The department is calculated for a peak demand of 200.000 exams, and includes two MRIs, two CT multislice, one remote controlled table, three rooms of x-rays with two detectors, five ultrasound rooms, a mammography machine, one ortopantotomografh, bone densitometry and one integrated facility for angiography, cardiovascular and Interventional.

Waits of beds foreseen spaces for thirteen beds, fourteen between waiting rooms and preparation rooms that will be sufficient with a correct programming.

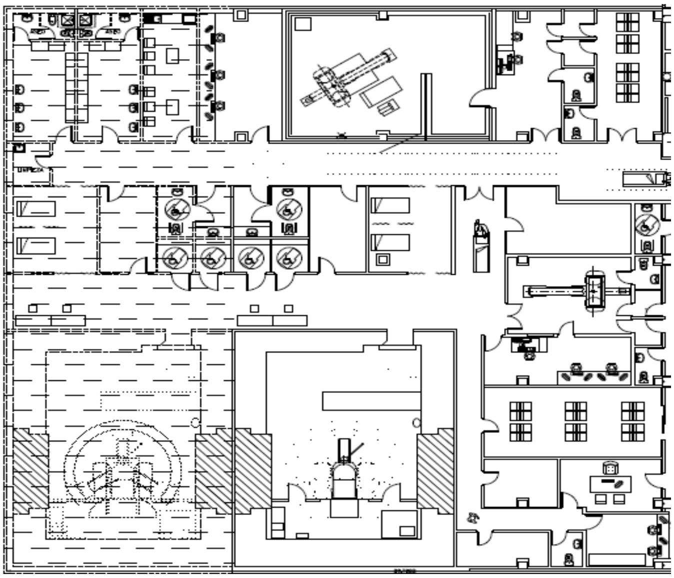
Additionally it includes a nuclear medicine department. The target population for this service reaches the estimated for the hospital population 240.000 inhabitants and in addition other 200.000 from nearby populations.

A PET-CT and a gamma camera of two detectors set up the nuclear medicine department with their ancillary services. Only one camera for this population, with the current demand, is clearly insufficient but in the environment there are already two cameras installed in facilities in operation that will share the workload. The same considerations exist for the PET-CT.

The department of radiotherapy (3.8) boasts a LINAC, expandable to two, a unit of high rate, a virtual simulator with CT for radiotherapy, brachytherapy, a room for making lead-masks molds for protection and grip, as well as a room for the LINAC and brachytherapy planning.



(3.7.- Nuclear medicine at regional hospital)



(3.8.- Radiotherapy in regional hospital)

Circuits of patients for consultation, simulation, and waiting rooms, are separated from the treatment. Waiting areas for beds are designed by each treatment system with two beds of standby capacity per unit. Again the forecasts of machinery are determined in accordance with existing services already in the area, in such a way that the ratios allow to determine a balance of services between all providers. Logically the competition will allow decant some patients depending on their quality.

III.IV.-GENERAL HOSPITALS

Planned to give health care to large population groups, in the order of 200.000 to 350.000 inhabitants in large urban areas, providing services in addition to whole regions. They have broader services than regional and district hospitals and, therefore, require much more complex image departments. Most provide teaching and university services, engaging in the training of medical residents in radiology so the surface requiring the staff area is somewhat larger than the non-university hospitals.

The imaging department has all current modalities and there is a department of nuclear medicine, integrated or separated from the image department, and also have a department of radiotherapy, with several units of treatment. The same considerations for specialist teaching than in imaging diagnostic.

An example of a design to give service to a population of 300.000 people have in figure (3.9)

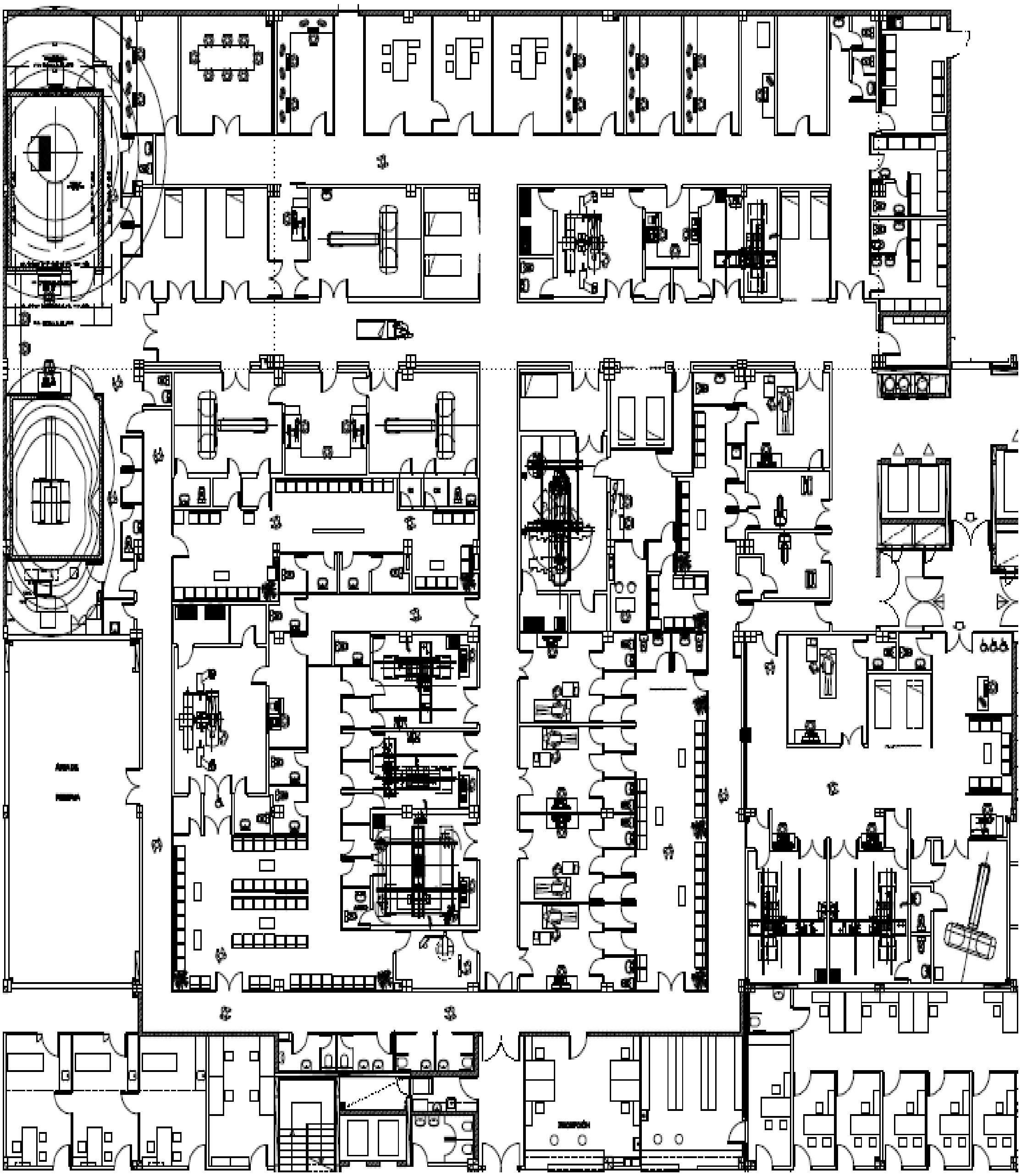
III.V.-VERY LARGE HOSPITALS

Hospitals in the order of 1.000 beds exist in all developed countries providing all health services today existing and, in general university systems for teaching of medical, nursing, physical, etc., as well as clinical or pharmacological research programs that make up the border of the current health development. They are generally associated with medical schools in the vicinity of large cities.

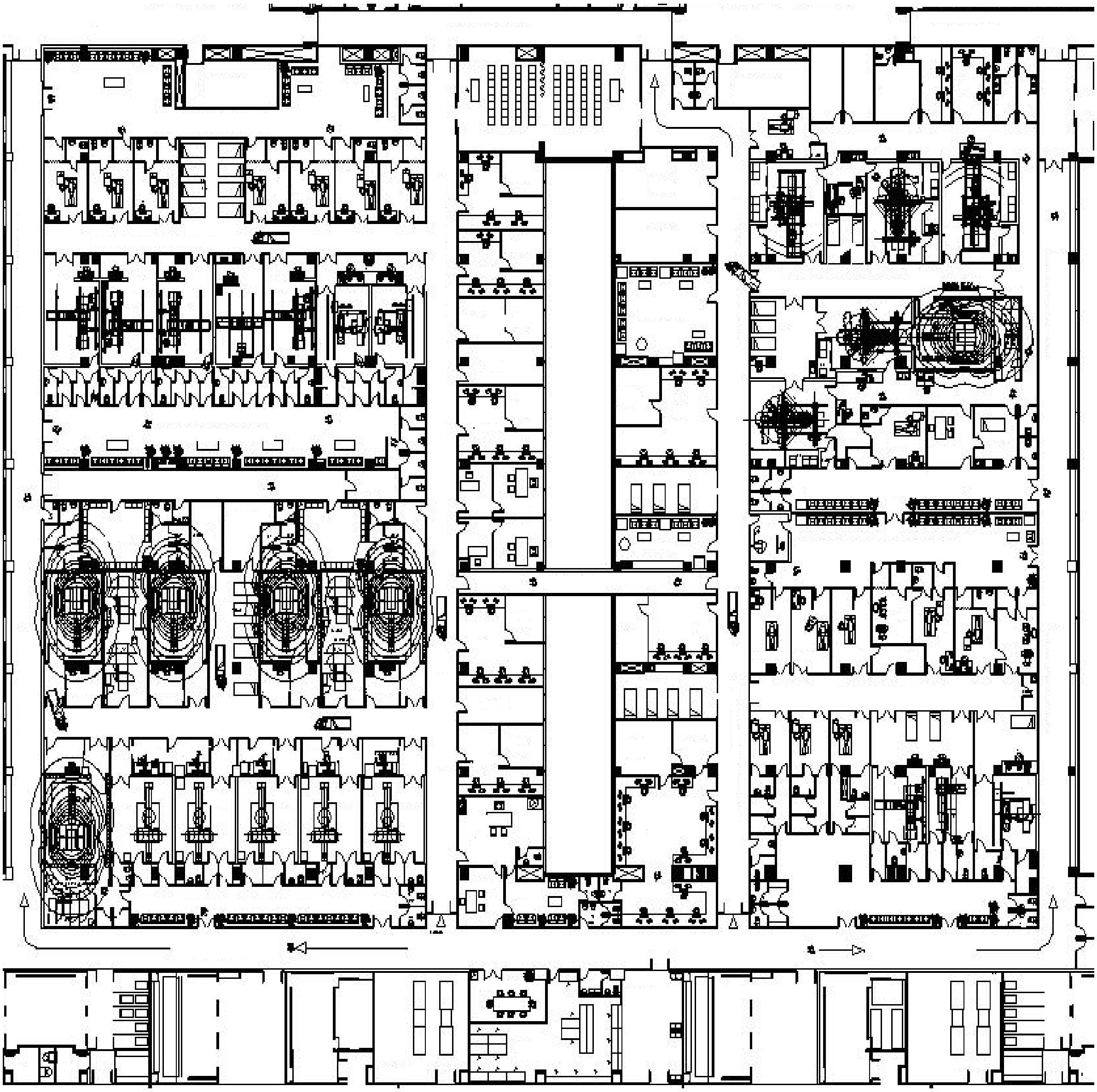
Provides services of diagnostic imaging and nuclear medicine within the department of image or as a separate department, as well as a radiotherapy department with good number of treatment units.

It can be said without error, that large hospitals offer in their departments of diagnostic imaging and radiotherapy the wider service catalogue than today exists in modern medicine. Advanced MRI facilities, multislice CT, positron detection imaging systems, cardiovascular monoplane or biplane systems and particularly for advanced radiotherapy accelerators.

The following example (3.10) is a modern university hospital with 900 beds with an expected incidence of 500.000 annual exams. Fortunately image of emergency service is separate from the department's image and integrated in the emergency department, but under the faculty of the image department.



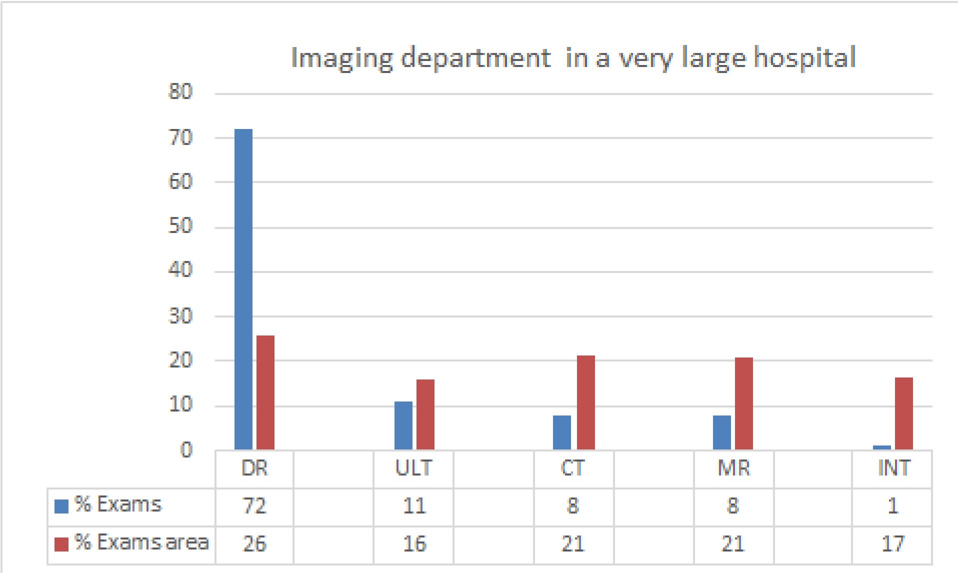
(3.9.-General hospital)



(3-10.-Imaging department of a very large university hospital)

Outpatient circuits are separate from inpatients and health personnel. Also have been set up for each group of modalities waiting areas, so patients have the maximum possible waiting comfort. Areas of MRI, multislice tomography, vascular Interventional, mammography and pediatrics have their waiting rooms individualized, and the diagnosis rooms for radiologists in the proximity of examination rooms.

Graphic (3.11) shows, in percentages, relationships between numbers of tests and examination surface occupied by the diagnostic machinery.



(3.11-Relations between exams and required surface)

The previous experience of the hospital, coming from a very large old hospital, allows to know the existence of an inpatient flow close to 25% of the total with a similar workload of image exams, 40 per cent of patients coming from external consultation and the rest are emergency patients, While in some ways is not the existing distribution, e.g. in magnetic resonance where the majority are outpatients, followed by internal patients.

For internal patients has been arranged areas of waiting for beds in all groups of modalities in such a way that with a consistent appointment the reserve of available space will be sufficient.

The gross total area slightly exceeds the 6.000 m2 (64.583,5 ft2) and the distances attached to this surfaces require spaces for medical personnel in the surroundings of the skylight central to minimize trips to diagnostic examination rooms and improve intercommunication between personal.

A separate nuclear medicine department with two PET-CT and four gammacameras, is designed annex to the imaging department.

Radiotherapy department includes four units of high energy treatment, several for high rate brachytherapy and two simulators with CT multislice.

III.VI.- MONOGRAPHIC HOSPITALS

A large group of hospitals is dedicated to special patients, patients whose health care require a specialization and different care, both in their overall treatment, and particular aspects provided by professionals dedicated to the tasks of this type of assistance centers.

In generally are small hospitals, because they serve to small sections of population, but they require special care in their planning and design, because from it depends on in good part the subsequent functionality and the fulfillment of the purpose for which they were built.

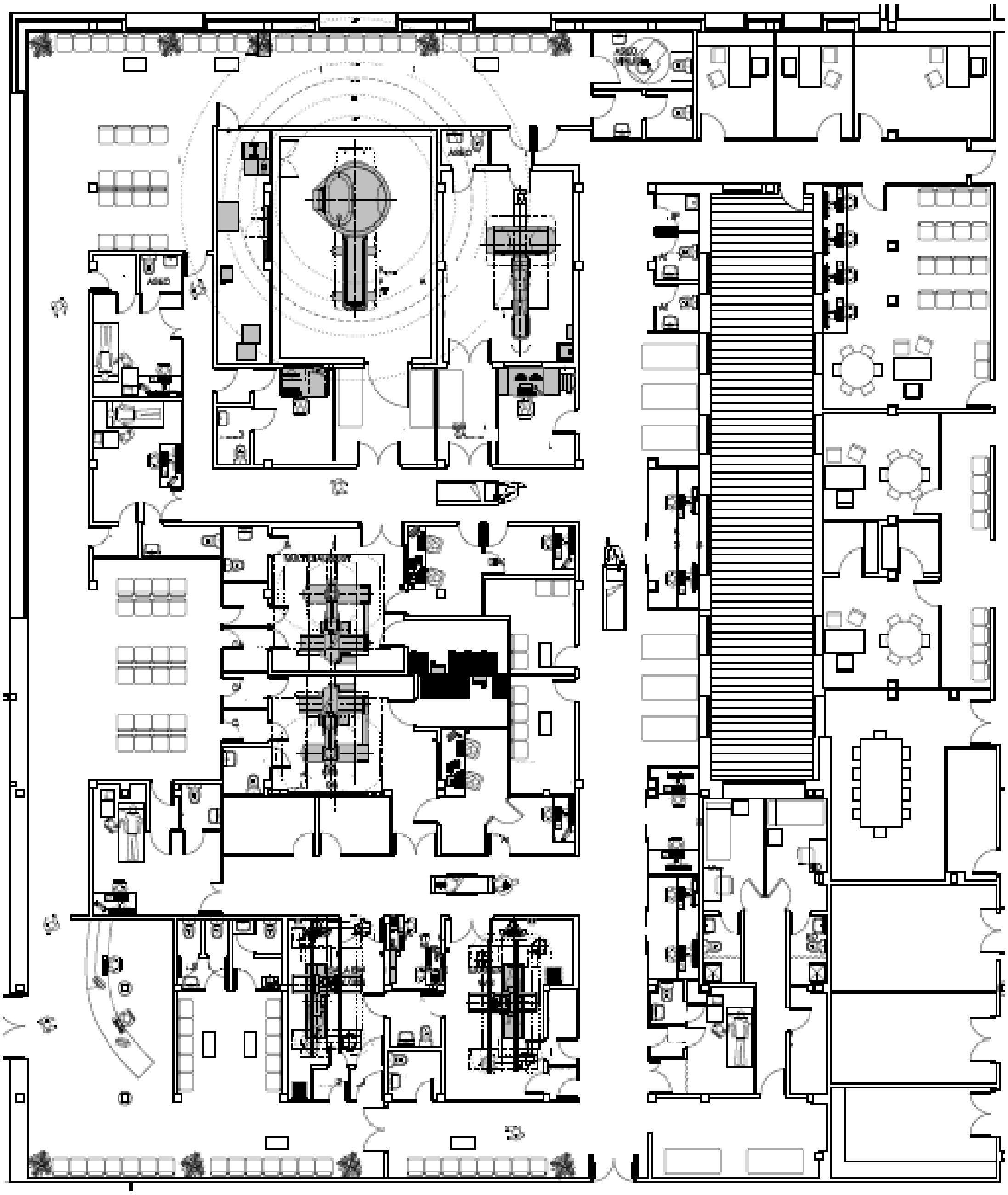
It is required an architecture much more adjusted to the needs of population groups to attend and as they improve the investment capabilities of groups that develop these centers can evolve toward more daring, more functional designs and with more attractive for patients that are intended for.

A large group are pediatric hospitals which in some countries are mixed with maternity, constituting the so-called maternal and child hospitals.

A pediatric hospital requires diagnostic imaging services adjusted to the needs of children. Many changes are required in the planning and design to suit the children's needs and build diagnostics centers where children face without fear any tests that there have to be made, from the designs of receptions, halls, waiting rooms, cabins, rooms for intermediate waits, meeting rooms, toilets, internal rooms of image, special types of lighting design and spaces for attention and explanation to the relatives of the care to be applied to children. This is the good service that is expected and provide it with quality requires space and appropriate design.

In general form the imaging departments provide almost the entire catalog of diagnostic examinations offered by large hospitals, which require the same facilities, with their particularization to the fields of diagnostic exams that requires children. Are therefore, machines in many cases dedicated to pediatrics, and in its selection process must be carefully specified to resolve the diagnostic problems of the population which have to attend.

In the attached design (3.12), from which later will be shown the planning of space and circulation diagrams, exists already very low surface provided for the planning. The reception, have to be designed wide and luminous with chairs for the children while their families makes final details of the citation at the reception. The corridors, luminous and decorated with attractive drawings, lead to waiting rooms, where there are games to entertain them during the wait, It can be long in magnetic resonance between the termination of the prior patient and the entrance of the new that has come from reception. Hour-long exams are normal in some patients, waiting for the next can be long. The toilets have to be designed with places to change babies and requires space, greater than for adults.



(3.12.-Imaging department of a pediatric hospital)

Examination rooms must be well decorated with paintings or pictures to welcome to children, luminaires with color LEDS and images that entertain the patient and do not cause him any fear for treatment or examination that will be made; the child must be entertained, relaxed and not thinking of the medical act.

Sedation or anesthesia that some procedures require, e.g. MR and CT, require spacious for prior preparation rooms, with easy capability of movement for technicians, staff nurses and doctors, with medical gases and monitoring systems and special aid for cases of adverse reactions. Resuscitation room should be provided in certain cases.

Cabins for changing clothes should also be spacious and less numerous than in adults, the child needs help to change clothes and cabins have to allow it easily.

The staff, in general, requires areas where they can work with freedom, and recover from stress, which often causes wide activity of the children. Easy-to-use diagnostic rooms and offices and meeting rooms, library and sessions room tailored to the size and characteristics of the diagnostic center.

Hospital specialization leads to the specificity of the equipment, and must concentrate resources on the needs of the center. One oncology hospital will have a greater specialization in MR, CT, PET-CT and gamma camera than in techniques such as x-rays and ultrasound. No doubt it will have these techniques but not in the same amount that a regional or district hospital, that provide services to the general population.

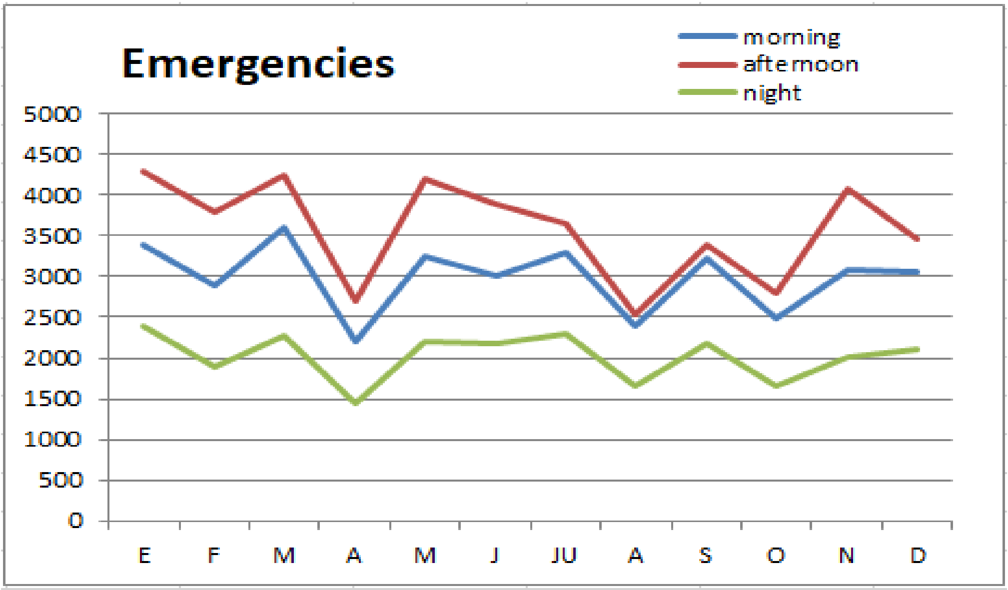
III.VII.- EMERGENCIES

Deserves a special consideration for all hospitals the design of the diagnostic imaging emergency services. The frequency of emergencies is very variable according to the type of hospital and according to the health organization in each country.

There are hospitals where tests performed in the emergency rooms exceed 30 per cent of the total hospital exams, in others where a 10 per cent is reached. The figures are so different that they cause very different needs in the design of the emergency imaging department.

The first detail to be considered by the hospital planner is the location, in its own imaging area or in the emergency department. Only a minimum analysis of the traffic of patients from the emergency department to the imaging department leads to the need to locate imaging rooms inside the imaging department or within the emergency department. The number of diagnostic rooms, modalities and additional services depends only on the number of foreseeable emergencies.

Considerations of operation of similar hospitals in the area of implementation of the project allow easy dimensioning of the number of rooms and the surface to be occupied by the imaging in the emergency department. The following graphic shows a representation of a very large hospital covering a big area of emergencies with the following graph of frequency (3.13) for 2006.



(3.13-Tests in a large hospital emergency department)

The peak demand is situated in the afternoon, between 3 p.m. and 9 p.m. shift, where the maximum demand is reached with 4.500 patients at the turn in the month of January. This is the guideline for the planning of the department's image.

The first consideration are the modalities. In general, conventional radiography resolves many of the needs of emergency, complemented with ultrasound. Large hospitals require the complement of the CT and very few locate in emergency other modalities proper of the central imaging department.

A university general hospital with more than 900 beds, It has a large emergency department, that induces to compute 140.000 annual exams. Depending on availability of space provided by the hospital planner, the designer of the image diagnostic of emergency department comes to the conclusion of the following needs, marked by a peak between 16 and 21 h of 35 tests by rush hour on weekdays.

IMAGE DIAGNOSTIC EMERGENCY DEPARTMENT IN A VERY LARGE HOSPITAL

ROOM	Modality	Exam Time min	Exams year 24*365	Occupation factor 0,6
Rad. Dig 1	RD	6	87.600	52.560
Rad. Dig 2	RD	6		52.560
Rad. Dig 3	RD	6		52.560
Rad. Dig 4	RD	6		52.560
Eco 1	Ultrasound	20	26.280	15.768
Eco 2		20		15.768
CT	CT Multislice	20	26.280	15.768

Total performance capability (exams)
241.776

(3.14.- Emergencies)

Should not be ignored that emergency patients cannot plan their citation, as in the central department of image and they tend to arrive in more severe conditions than the planned in the central department for what exam times can be extended and occupation factors will be lower, the simultaneity of patients makes necessary more rooms that the simple calculation determines. Possibly the department, at the time of its opening, can start to work with 3 rooms of digital radiography and leave spaces provided for future enlargements.

With this and the available space is reachable the following design (3.15).There is a separated circulation of patients and the movement of health workers with only one zone where can connect both, in the access to two rooms of ultrasound. There is a forecast of four general radiographic rooms with two detectors, of which three should start at the beginning of the activity in the hospital and incorporate the fourth according to the attendance increase, one CT for which the initial activity foreseen are 9.000 annual exams.

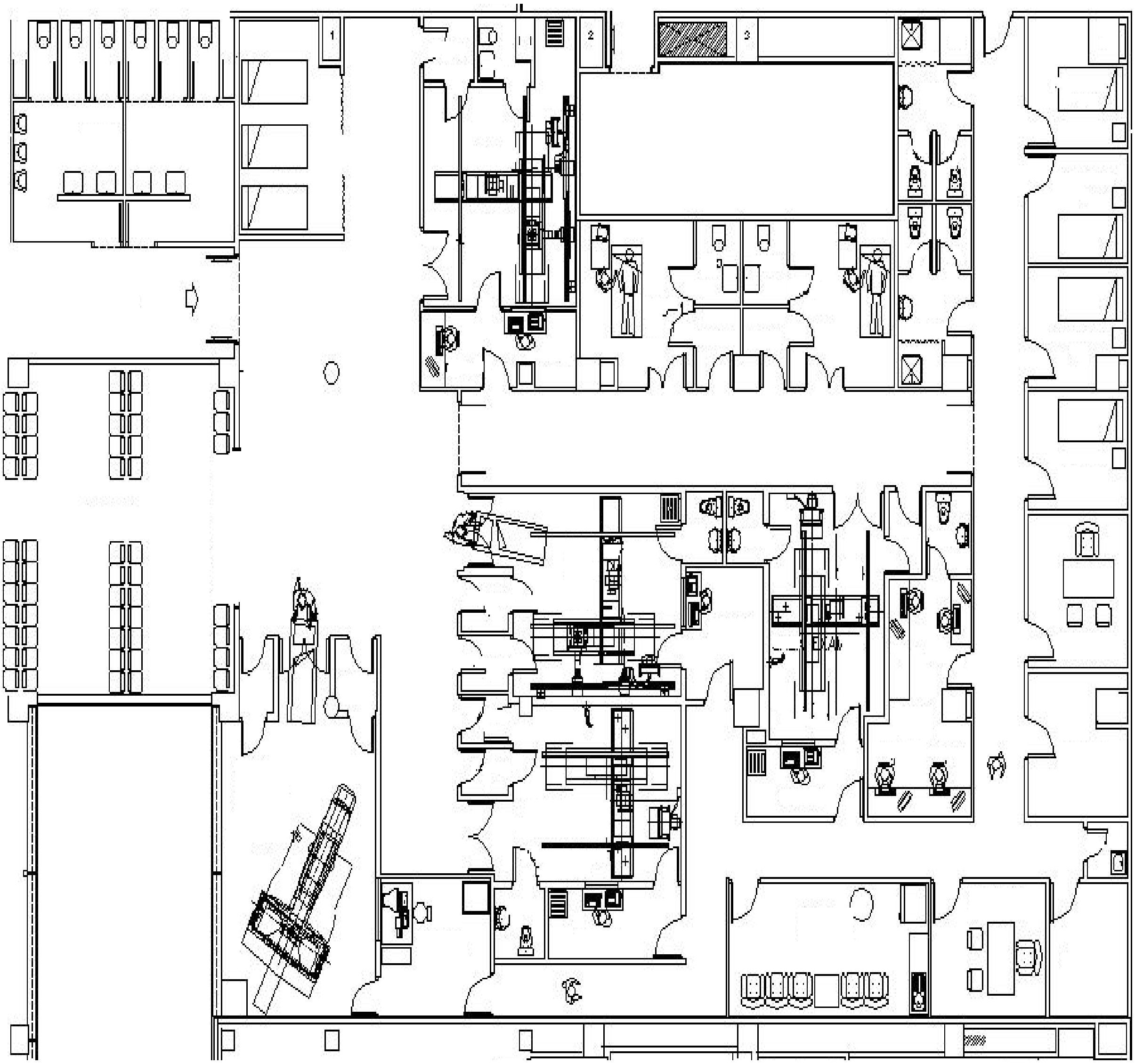
Four radiologists in several shifts made the diagnosis but always four simultaneous. A small room for rest of technicians, office of the department chief and office for technical supervisor with additional service dependencies complete the design integrated in the emergency department and next to the central diagnostic imaging department.

In a general hospital where can be expected annually visits by 250.000 patients in total, the emergency department is expected to become 140.000 imaging tests. Patients arrive at a 60 per cent walking and the rest in bed or a wheelchair.

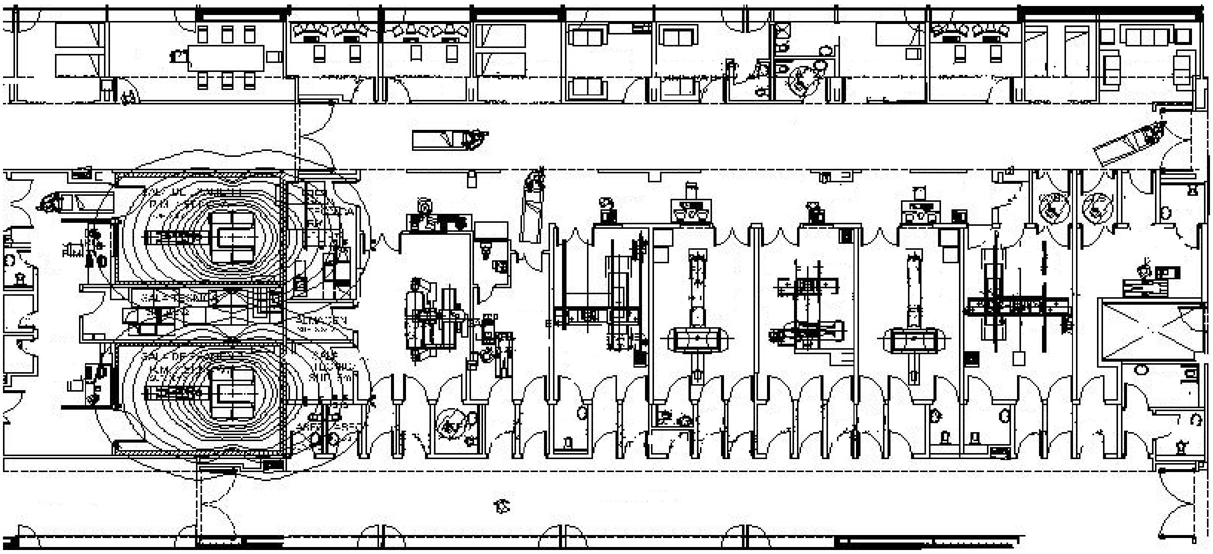
As well as in this case the hospital planners settled a small image department integrated in the emergency department does not occur in other cases where the designer has to accept alternatives which minimize traffic patients conflicts that it can cause the displacement from the area of emergency to the image area. It is necessary to estimate with the best possible data for new designs the frequency of the emergency area and the needs of diagnostic imaging that this area will require. Collisions and problems with the patient transportation which will subsequently generate are very significant impact in the operation of the emergency and diagnostic imaging departments. Also, the costs of these events are significant. Mayor costs come from lower productivity of the staff as a result of delays involving the transport of patients and subsequent reports of radiologists of the emergency patients. These are data that the planner must have in the initial phase of the project.

Design (3.16) corresponds to a hospital with 220 beds with a maximum demand foreseen in the emergency room of 200 daily tests. Patients have access to the imaging area from the emergency department, they wait in a small area of patients coming from emergency and have access to the room of ultrasound, first to the right, a conventional room with two detectors and a CT multislice. The patient access to the emergency room by the same personal circulation corridor and it could be used for internal patients in case of emergency or special needs. Also there are cabins of access from the area of ambulant patients, at the bottom of the drawing, for any care needs of these patients. Do not mix outpatient with internal or emergency, only there is a possible coincidences between urgency and internal; no doubt collide the emergencies with the staff.

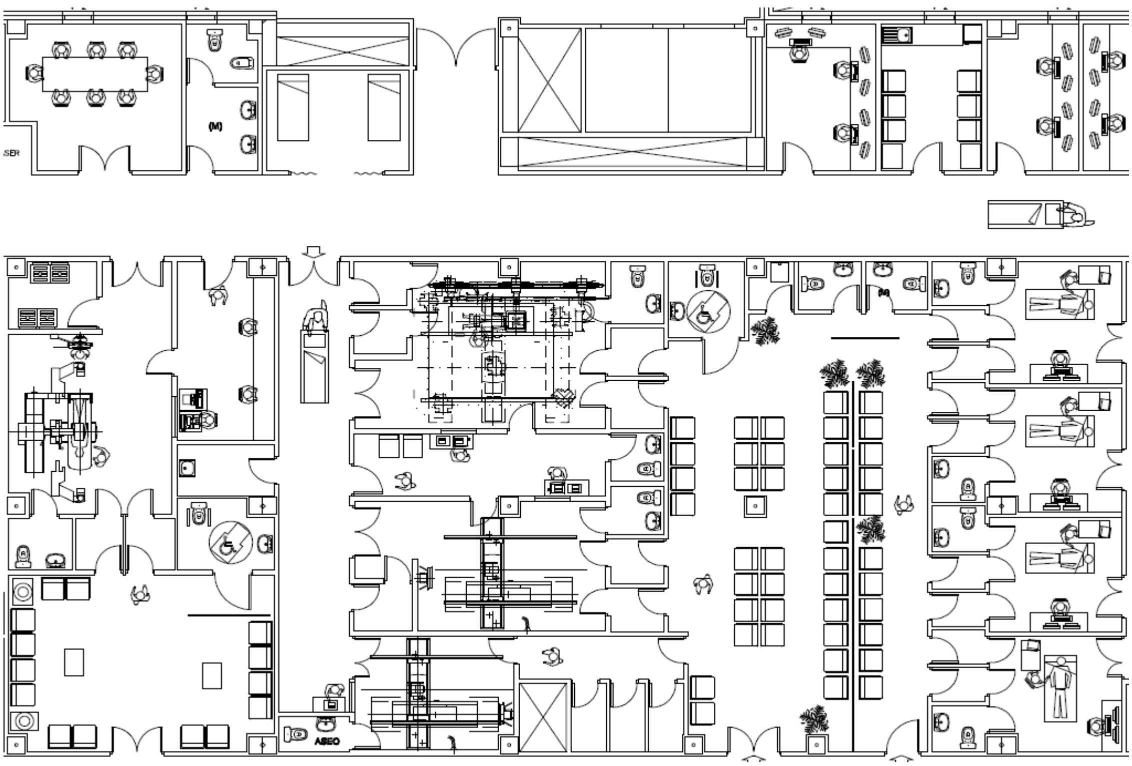
Another example of a 250 beds general hospital, with examinations in emergency provided for a maximum of 250 daily where the image of emergency is made in the central diagnostic department is shown below (3.17).



(3.15.-Emergencies in a very large hospital)



(3.16.-Regional hospital)

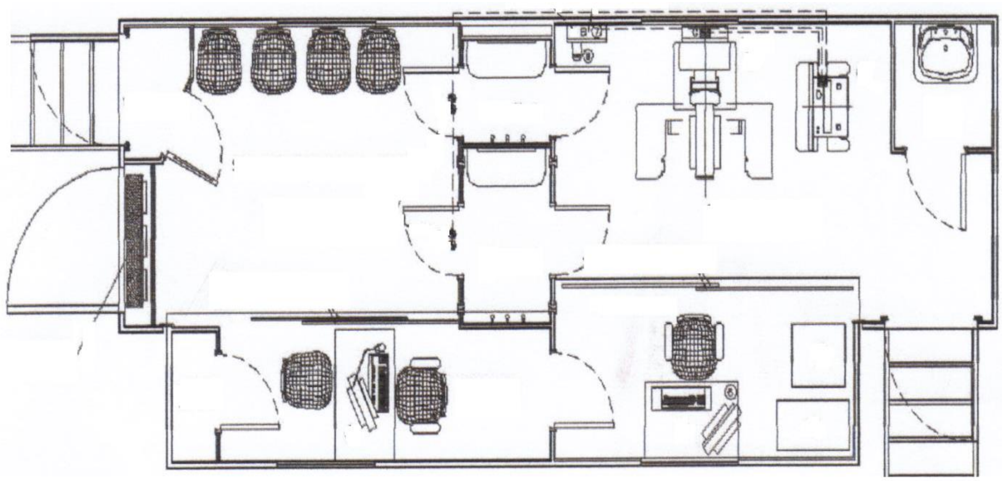


(3.17.-Emergencies in a regional hospital)

From emergency department patients enter to the conventional room having an eventual access to external patients with two cabins. In case of saturation of the first conventional emergency room patients also have access to the second or third conventional room. Outpatient circulation remains independent of medical personnel, internal and emergency, but not the case with the emergencies that interferes with the interns and medical personnel. The provisions of space in the emergency department prevented another design. The commitments to be taken in the design must lead to optimize patient care and minimize conflicts of circulations.

III.VIII.- MOBILE DIAGNOSTIC IMAGING

Radiographic Imaging tests, have been made for decades on mobile devices for applications very concrete, e.g. studies of photofluorography held for the early detection of TB, and in mining facilities for silicosis. The units had an x-ray generator and one x ray tube assembly making exposures on a chest device with which were obtained images in a photofluorography camera in format of 10 x 10 cm. that it was subsequently diagnosed by radiologists.



(3.18.- Examination cabin for breast screening)

The continuation of mobile studies was carried out with the onset of breast screening. The early discovery of breast cancer has a high value in the treatment of this pathology and two decades ago began to settle mammography in bus or specially prepared cabin for mammographic examinations transported by heads tractors from one locality to another to facilitate the attendance of the patients to the realizations of the tests. Breast screening programs are now universally accepted and have generated ingenious designs of examination (3.18) cabins.

In this design with a trailer for early diagnosis of breast exams there is a central cabin where are performed the exams and a lateral sliding cabin that opens when the trailer park, being stationary parked during the acquisition of patients exams; and when transporting the lateral cabin slips internally on the main body, so that it can fulfil national road traffic regulations in the transport position.

A staircase to the entrance of the patients leads to a reception where are read barcode data of patient citation. These pass to cabins to change of clothes to the test area. Here chassis are used with reusable screens that are read in the CR reader-digitizer. The images are archived on hard drives of high capacity for subsequent radiological reading. The patient data are constantly updated via mobile data line.

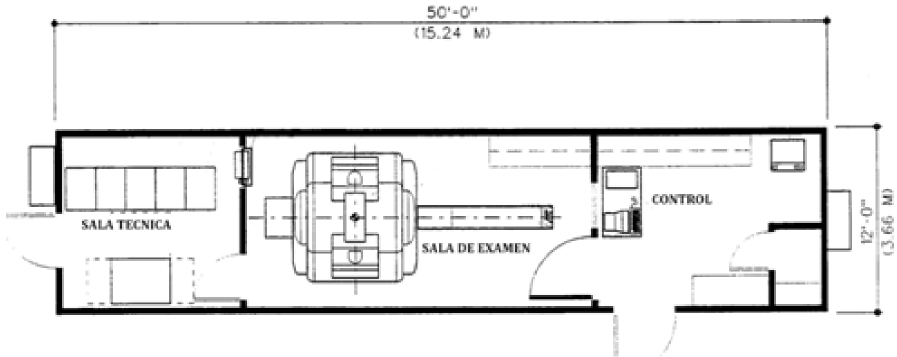
We see that the design requirements are similar to those in fixed installations with the limitations of the regulations on road traffic and power supply, which is usually obtained with local connections but can also be obtained through auto generators.

The device includes air conditioning facilities and the calculation of its radiation protection is made according to the legislation of the national authorities in this matter.

The introduction of axial CT computer throughout the seventies and the high cost of these devices encouraged many CT service providers to install them on buses or mobile booths with tractor head units.

The design is similar to that shown for mammography, except for the length specified by the CT.

Also magnetic resonance equipment have a high development in mobile installations, so in the United States reached a volume of close to 10 percent of a total volume of 8.000 installed MRIs according to the 2006 data. More than 1.400 American hospitals used 800 mobile units available at that date; also exist a growth in the number of hospitals using these services. Mainly less than 200 beds hospitals are users although large hospitals with space problems or saturation by excess demand are occasional users.

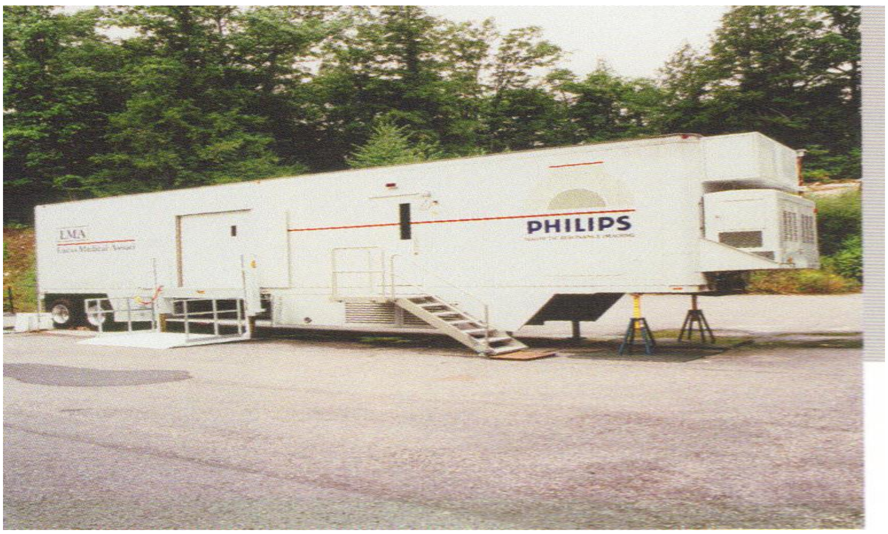


(3.19.-Mobile magnetic resonance)

In the design above a total length of 15.24 m (50.9 ft) (3.19) is reached and there is in general some add cabs on designs for the change of patients.

The study of magnetic protection determines the thickness of armor to be added to both sides of the core. With 1.5 T reaches important values which forces the calculation of stronger structures and more resistant for the trailer which needs more powerful unit tractor.

The complete design of the trailer must be completed with the air conditioning unit, the refrigerator for helium, the file for the subsequent diagnosis unit, the inclusion of some space for diagnosis in the own trailer, etc.



(3.20.- Trailer of a mobile magnetic resonance)

Other modalities and also some therapeutic systems have been installed on mobile devices in order to reach the most remote places and bring high technology into those confines. Enterprising businessmen have set up groups of units that provide these services to the health community.

Also PET and gammacameras have been installed successfully solving the problems of radiation protection according to national protection requirements.

All these units, whose application continues to grow have a number of common conditions to meet:

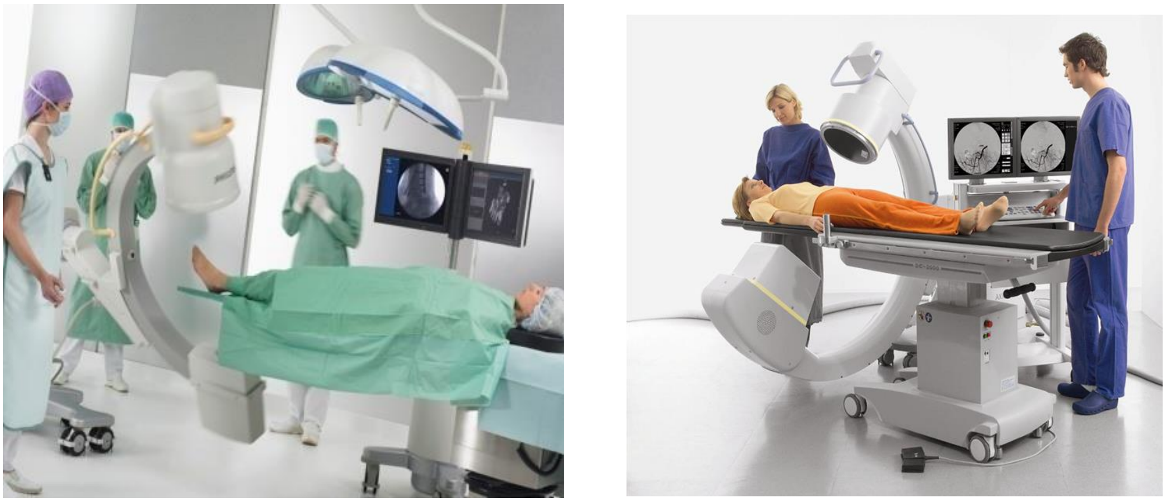
- **Mobility / Transportation.**- Observe local regulations. They change with the countries, being so varied that they impede cross-border mobility even within countries, there are details to observe with regard to road traffic, dimensions, etc.
- **Security**.- Observe local regulations and safety against the actions of the machinery, both the electromagnetic and the electromechanical.
- **Radiation protection.-** Analyze the national regulations for x-ray and handling of radioactive isotopes for medical use.
- **Magnetic resonance should be insured with the regulations on influence of magnetic fields and work environments.**

III.IX.- DIAGNOSTIC IMAGING IN THE HOSPITAL OUTSIDE DE IMAGING DEPARTMENT

Imaging techniques represent a basic support to the clinical diagnosis and its dissemination has been so great over the last three decades that are now essential for most of the medical acts and for temporary monitoring of many diseases.

The demand for imaging scans motivates not only in imaging department the exams but today are carried out practically in all hospital areas, requiring special areas for these equipment and facilities with special designs to optimize its use.

In surgery, the use of x-ray fluoroscopy and ultrasound is continuous. Different designs have facilitated the use of radioscopic-radiographic systems in the surgical block. At present the powers of the mobile C arms for surgery is, in all general applications, sufficient for the fluoroscopic monitoring of intervention, and for radiography to control at the end of operation. These equipment are small, even though the operating rooms must be designed with the provision of space for these systems, remaining in the clean area clean permanently. Years ago were designed surgical C arms suspended in the ceiling of the operating room, withstanding power x ray tubes x along with high-resolution image intensifiers. Problems of asepsis of these facilities and the improvement of the capacity of the modern mobile C arm systems for pulsed techniques with sufficient power in angiocardiography, solve the needs of imaging with good compromise.



(3.21.-C arm mobile in operating theater)

However the requirements for image-guided techniques are forcing the development of hybrid rooms, with complete angiographic systems, i.e. with the generators of the power used in angiography rooms, with 80/100 kW, flat detectors of large field and arms, or robotic systems, and surgical classic systems, but adapted to the procedures, surgical systems with special lamps for these procedures and appropriate monitoring systems.

The operating room of the figure (3.21) shows a current integration of an angiographic system arc suspended from the ceiling with flat panel detector, the table and surgical instrumentation and monitoring and clinical information systems. The assembly allows a radiological follow-up of interventions with all the data of the patient's history in real time. Cardiac surgery and interventional procedures are the greatest number of hybrid installations in the surgical area.

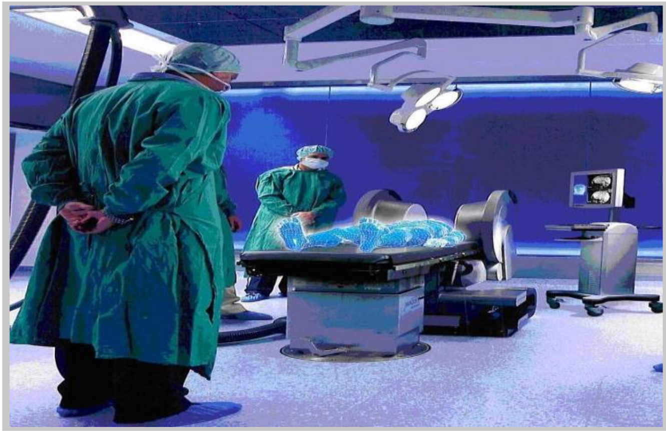
Examples of surgical facilities with MRI equipment in its immediate proximity are spread across multiple countries to take advantage of the best qualities of magnetic resonance imaging in brain and soft tissues (3.22).

(3.21.- Facilities in operating rooms and special diagnostic rooms)

(3.22-Installation of magnetic resonance in the surgical area)

We can see the transfer of the patient from the operating table to the table of magnetic resonance system in the enclosed room (3.22).

There is equipment of magnetic resonance of easy adaptation to the surgical rooms as shown in the following figure with a 0.2 T system, fully integrated into the operating room.



(3.23.- Magnetic resonance of low field in an operating room)

Also ultrasound has entered and progress continues in the surgical areas. The small space they occupy and the facilities of asepsis allows faster introduction.

The CT have occupied their space in the operating theatres. The following figure shows this equipment in an application for traumatology.

(3.24.- Installation of multislice tomography in trauma surgery)

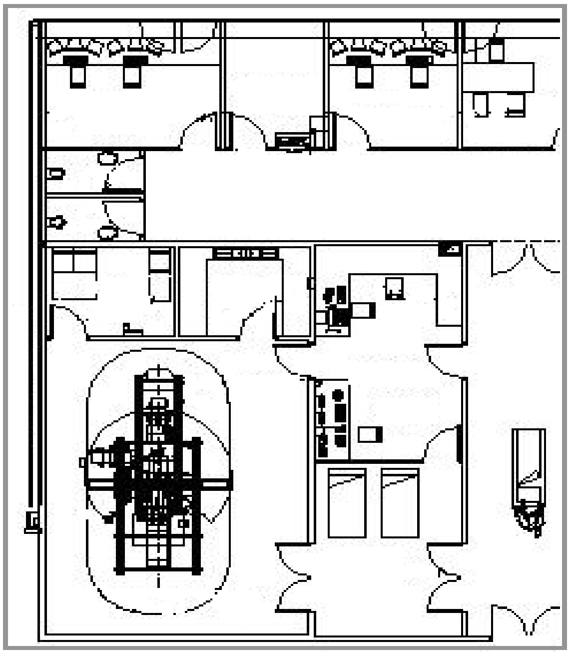
The x-ray exams to patients in beds is done today with portable generators and digital detectors. The powers from 2 to 30 kW are usually used in these mobile equipment, that instead of using radiographic chassis operate, currently, with digital image detectors. DICOM connectivity allows to keep the communication of patient data, through listings in WORK LIST. Also the images obtained in digital detectors, are sent through the WIFI system installed in the hospital to PACS server for diagnosis in the reports area of the imaging department.

(3.25.- Ultrasound and portable generator)

Ultrasound has undergone its development in every corner of the hospital and external consultations. It transpired from the scope of the department's image and is now in surgery, gastroenterology, urology, cardiology, pediatrics, ophthalmology, and others. Ease of installation and opportunities arranged by teaching centers to train the users they have led this modality to be first imaging technology in the hospital and in growth over the past twenty years, especially since the development of the compact units with real-time, and mostly since the 1990s with the development of techniques in 3D and 4D, that it currently provide more technical innovations and new applications.

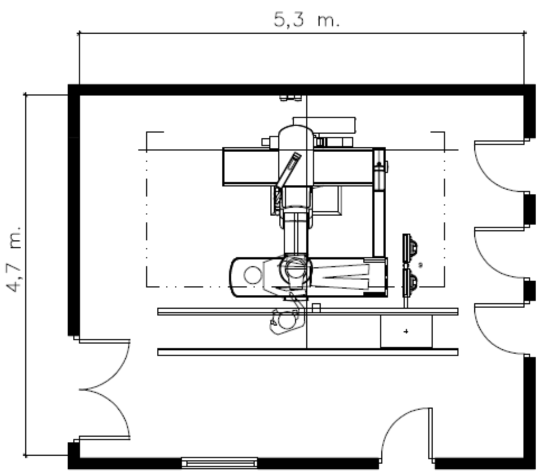
(3.26.-Ultrasound)

An important use of radiological technique, usually outside of the area of the imaging department image are the facilities of angiocardiography for interventional diagnostic imaging and therapeutic applications in the heart area, with significant progress not only in the dilatation of coronary stenosis, cardiac valves, and others, but also in the area of electrophysiology where it is expected that, over time, other imaging equipment to join these facilities outside the area of the image department, to improve the visualization of electrodes and devices used in the techniques of electrophysiology.



(3.27 Electrophisiology)

IV.- DIAGNOSTIC MODALITIES



I.- RADIOLOGICAL TECHNIQUE MODALITIES

II.- SLICE TECHNIQUE MODALITIES

III.- NUCLEAR MEDICINE MODALITIES

IV.- RADIOTHERAPY SYSTEMS

The world is changing very fast. Will no longer be the great who hit the small, will be the fast who will hit the slow.

(R. Murdoch)

IV.- DIAGNOSTIC MODALITIES

Since the invention of the integrated circuit in 1958 the number of transistors that can be placed on an integrated circuit, maintaining a cost structure, has increased exponentially, doubling approximately every two years. The trend was observed by G.E. Moore in 1965 and has continued to the present day, not expecting any change over the next decade.

Nearly all measures of the capabilities of electronic devices are linked to this Moore's law and is a guiding force for many economic sectors and also, but in more attenuated and delayed form, in diagnostic imaging technology.

This work has begun with an individual description of the evolution of the different technologies that are today used in diagnostic imaging, and now it is necessary, to plan the department with maximum correction, describe the present state of the technologies today available, provide the required surface and then make the detailed study of the spaces where will be performed the department activities; from the waiting rooms, through the examination, to the diagnosis.

Different technologies are deployed in the imaging department making functions differentiated according to clinical needs. So from the classics of conventional radiology have evolved modalities of remote control tables, mammography, general radiography and ortopantotomography. Shall not be forgotten the vascular, a modality itself, that has traditionally had various configurations. In ultrasound technique the development of the technology and the needs of the different clinical specialties have led to gynecologic ultrasonography, musculoskeletal, vascular, etc.; in nuclear medicine gammacameras and PET systems are mostly used and their modalities are available, and in the same way than in the new CT an MR techniques are specific modalities that are required in certain departments to solve their exam demand. Thus are configured in the image department the modalities, specific equipment or systems, to acquire images that after its quality control passed to the radiologic diagnosis.

The modalities comprising the department are currently linked with HIS hospital or EHR System, through internal digital data network. In the majority of cases the RIS is the intermediate element of connection. And the same way with the PACS system in the imaging department where all the images produced are archived, not only the ones coming from image department, but also the diagnostic o therapeutic images produced in other hospital departments, such as ophthalmology, dermatology, pathology, endoscopy, etc.

The different modalities require specific technical configurations in according with the particular department needs, with variations that are suited to the functionality that the department requires to carry out its tasks. There are, however, minimum characteristics that encompass under the point of view of planning, certain common details, at least in its dimensions and clearances necessary to locate the equipment within the surface that for each modality are proposed in the pages that follow below. With this will be achieved the objective of planning the total appropriate area of the department necessary to define with the greatest possible accuracy in the planning phase. In the following pages are proposed net surfaces and dimensions minimum and average, the latter base for the subsequent calculation of the total gross department area.

Later, when dealing with the final department design, the particularities of each configuration of the equipment will be introduced and the additional requirements of space that each modality and each room needs to perform the tasks assigned in the department.

Will be starting with conventional radiology, to continue with the rest of the equipment and the most significant modalities and only will be displayed the more current and presently used in the design of imaging departments that, in any way, correspond to most of the currently available.

In conventional radiology, there are different versions of rooms with columns for the tube support or tube stand; well supporting the column on a rail on the floor and on the wall or the floor and ceiling, or also with columns built into the frame of the table. These latest configurations are simpler from the constructive point of view, installation and civil works, to ceiling installations that requires to complex and expensive works and longer mounts, although it should be noted that they provide a very superior functionality. Adopts in our analysis ceiling configuration because it can adapt to net room with minimum surface and only slightly bigger than the minimum for the ones of column integrated in the frame, being valid, therefore the net spaces drawn in the next pages for the planning of systems with columns to wall, ceiling or integrated.

For remote controlled tables equipment and multifunction systems there are only slight variations, while in multifunction equipment may be differences in needs of space according to manufacturer products. In the remote controlled tables there are models with vertical displacement of the patient table top support, having most of the equipment on the market variable focal film distance that make very similar all the equipment produced by different manufacturers under the planning point of view.

CT scanners multislice (CTM) need net exam rooms with very similar surfaces, varying in some models the needs of technical room for accommodation of the cabinets with electrical and electronic elements for control and process.

Magnetic resonance imaging systems have more variation of spaces. Open systems may have needs of exam rooms more spacious, or smaller, depending on the design of the gantry; the cylindrical gantry equipment have examination surface needs very similar for the present existing magnetic fields, varying in the requirements of the technical rooms.

PET-CT and SPECT-CT presents more diversity, therefore the case of larger size is chosen, and the designer must watch the dimensions of the equipment to draw and its relationship to the proposed net surfaces.

More variation there is in radiotherapy with brachytherapy equipment and linear accelerators. Not only changes the need of treatment of different treatment rooms, but consider the therapeutic techniques to develop. This is the case where the room of brachytherapy includes a CT for simulation and imaging prior to treatment.

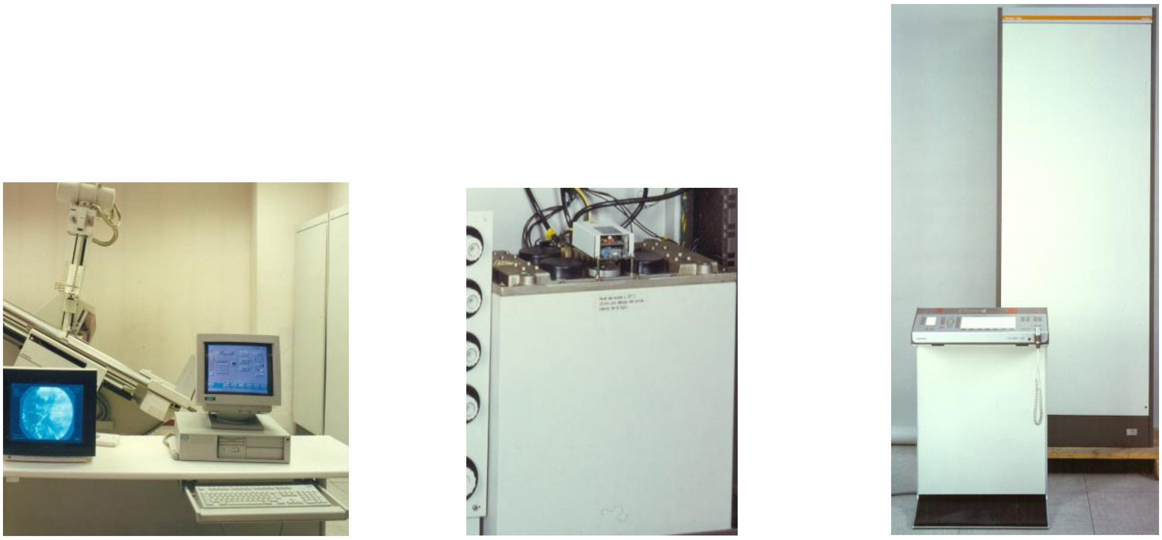
IV.I.- MODALITIES WITH RADIOLOGICAL TECHNIC

The planner is immersed inside a situation in continuous and rapid evolution in the repertoire of available equipment to meet clinical demand.

As already sown a radiological modality is subdivided into the following components**:**

- **The generator subsystem** and the high voltage controller to produce radiation**.**
- **The radiation emitter or x-ray tube,** with elements of collimation for control of the radiation beam and therefore the dose.
- **The detector subsystem or radiological image sensor** and the electronic elements to calculate the image and present it on the display screen.
- **The mechanical system that supports** the patient and the emitting and receiving elements.

High-voltage generators are no longer of twelve pulses has become multipulse. The technique of high frequency swept bulky transformers insulated in mineral oil, to reduce them to small components which occupy a fraction of the control cabinet of the generator subsystem. The section of a core of a transformer is inversely proportional to the frequency of the current flowing through the windings used in the conversion of electrical voltage, and have moved the 50 or 60 Hz network frequency to internal frequencies in the environment of the 100.000 Hz, with what volumes and weights of these components have been minimized.



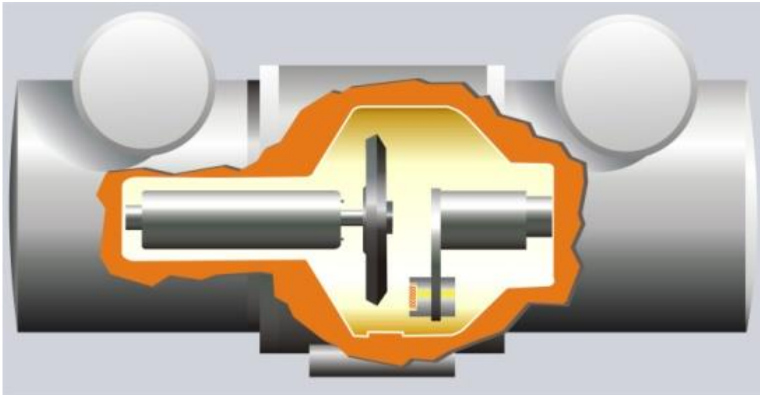
(4.1.- Operator control, two tubes transformer, full generator)

For the equipment controls has been proposed various solutions, since the use of a PC for control of the technical parameters of the generator (4.1) up to desktop controls, or with stand for mating in the control room at the height of the technical operator observation window. The generator subsystem is thus reduced to two components: the operator control console and the cabinet that houses the high voltage transformer, control of tube anode, filaments, space charge, starter, tube protections and control of low voltage power system formed by an inverter with powerful switching transistors. It is located in the high voltage generator primary and regulates the milliamps and the kV of the x-ray tube.

The dimensions have been reduced so much that some designs are hosting this technology under the table that support the patient. Radiographic powers vary from 4 kW of a generator for mammography up to 100 kW of a generator for multifunction equipment or vascular.

The radiologic assemblies or x ray emitters in conventional radiology continue having an anode comprising rhenium and molybdenum, and a cathode with two focus; a small of 0,6 mm and other gross of about 1,0 mm when the radiographic technique demands more doses. Powers of the order of 30 and 60 kW are common.

The rotating anode and the fixed cathode are housed inside a glass bulb where is made a high vacuum (4.2 and 4.3). Only one percent of the electrons which have an impact on the anode generates useful roentgen radiation for radiologic applications; the rest becomes heat which must be dissipated to prevent the merger of the anode material. This has a very high melting point (reinforced with rhenium tungsten) but in spite of this the heavy loads used need oil or heat exchangers with water cooling to dissipate the heat.



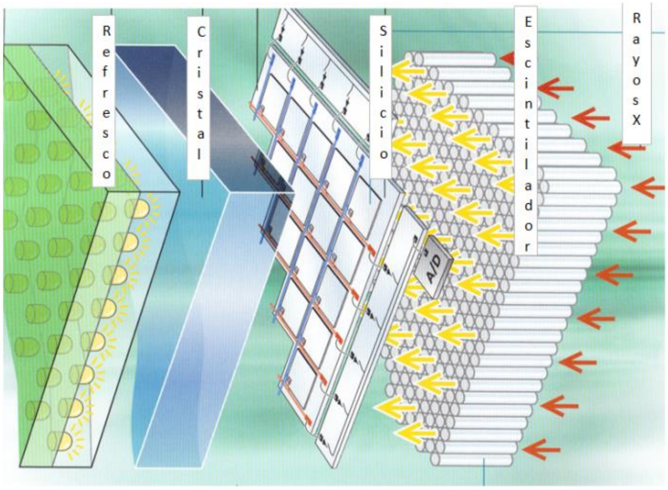
(4.2.- Section of one x ray assembly)

(4.3- X ray emitters for high load radiology and mammography)

Image capture systems are those who have had major developments in recent years and those who have contributed to consider the current stage as the complete digitalization of the imaging departments with the consequent elimination of radiographic film as a technique of radiological image capturing. Reusable plates of CR systems have been the procedure of image digitization up to the final implementation of the flat detector. The development of the current flat detectors has been slow, but efficient. It began with selenium core detectors to reach the current silicon.

(4.4.- Flat detector)

A flat detector consists of a series of components that allow conversion of rays x in electric digital signals (4.5). The heart of the flat detector is a semiconductor layer of amorphous silicon in the majority of types and some of selenium. The silicon layer is divided into an array of millions of fine sensors elements each with a switching component, with the task that their signals can be connected to a reading line in the directions of the row and the column of the matrix. In this way each silicon sensor corresponds directly to one pixel in the digital x-ray image. The electronic process can be done at the high transfer speeds of the electrical signals generated by the sensors and thus acquire moving images.



(4.5.- Composition of a flat detector)

X rays impinge on a scintillation crystal that converts roentgen radiation in light with high efficiency. A next layer of amorphous silicon elements turns light into electrons in each cell of the matrix. These are channelled towards the digital converters where the electrical signals are converted into digital signals that are processed on a computer whose software calculates digital radiological images.

An add-on to mention is a crystal which channels the refresh lighting for silicon panel after capturing each image frame.

(4.6.- Flat panel in vascular installation)

The detector efficiency is measured by the factor DQE (Detector Quantum Efficiency) measuring the conversion of x rays on radiological images in terms of dose and image quality.

The sizes of the flat panels vary depending on the application. Cardiology detectors can measure 18 x 18 cm, which replaces the old intensifier of image 9 ", However for vascular applications in pelvis are required at least 30 x 40 or 40 x 40 cm (11x15 or 15x15 in).

The number of pixels, or picture elements, has a correspondence with the image quality and the DQE. A detector for conventional radiography, that covers a classic field of exploration of 35 x 43 cm (13x16 in), have an array between 2.000 and 3.000 pixels and reaches at least 3.5 pl/mm resolution that can replace conventional radiology CR plates without loss of radiological information and with high processing capacity, not only the image to be displayed but also in various CAD programs that can help the radiologist in their daily work.

There is no doubt that the highest resolution flat detectors are in mammography: 24 x 30 cm (7x11 in) scan fields cover the diagnostic area and matrices which exceed the 4.000 x 4.000 pixels are needed to achieve a minimum resolution of 7 pl/mm.

The gantries that support the patient and the emitter and receiver systems are having very innovative designs by introducing robotics elements in medical facilities.

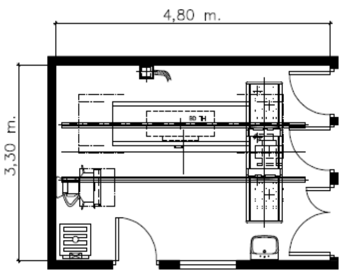
(4.7.- Vascular arch with flat panel and robotic bracket fixed to the floor)

Supports with similar designs have been developed for general diagnostic facilities and is expected to continue more in the near future to simplify the radiographic examination rooms and provide more diagnostic imaging utilities.

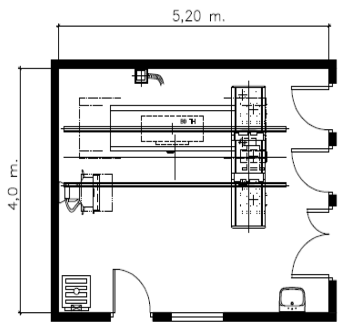
(4.8-Portable generator with flat panel included in the carrying case)

CONVENTIONAL RADIOGRAPHIC ROOMS

Application	General Radiography
Generators	30 a 65 kW, 150 kV, automatic exposure
X Ray Assembly	Dual Focus. High speed anode
Horizontal Table	Elevating tabletop. Floating
Wall Bucky	Elevating. Tilting
Tube Support	Ceiling suspension or column
Detectors	2.000 a 3.000 pixels (18 MB/image)
Operator Control	Desk with PC and monitor
Weight	Ceiling 400 Kg (881 lb), Floor 600 Kg (1322 lb)
Power	50 a 130 kVA.



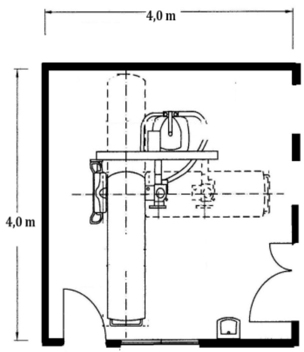
MINIMUM (16 m2)(172 ft2)



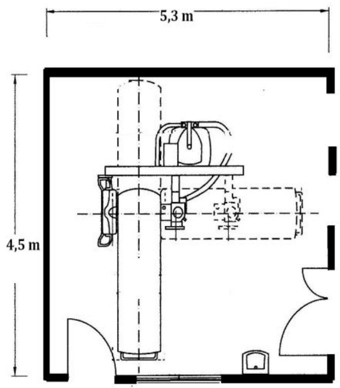
MEDIUM (20 m2)(215 ft2)

UNIVERSAL RADIOGRAPHIC ROOM

• Application	General radiography
• Generators	30 to 65 kW
• X Ray Assembly	Dual focus, high speed anode
• Universal Stand	Elevation. Arm rotation, etc.
• Table	Movable with wheels. Brakes.
• Detector	2.000 a 3.000 pixels(18 MB/image)
• Operator Control	Desk with PC and monitor
• Weight	400 Kg (881 lb)., without table
• Power	From 50 a 130 kVA



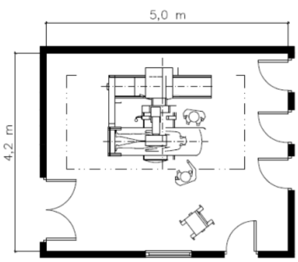
MINIMUM (16 m2)(172 ft2)



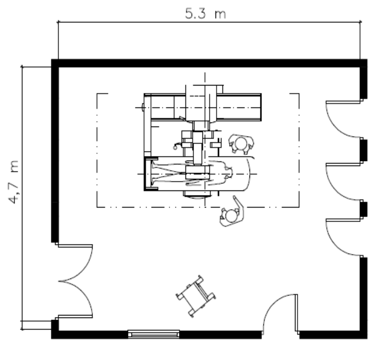
MEDIUM (24 m2)(258 ft2)

REMOTE CONTROLLED TABLES

- Application — Digestive, Gynecology, Urology, Vascular, etc.
- Generators — 60 a 80 kW, Radiography, Fluoro, Autom. Exposure
- Remote Controlled Table — Motor tilting 30/90º to 90/90º
  Tabletop elevation and floating
  Variable focal distance from 110 to 150 cm
- X Ray Assembly — Dual focus, high thermal capacity, high speed anode
- Image System — Flat panel, 40 cm (17 in)
- Room Monitor Support — Ceiling suspension or over cart
- Operator Control — Desk with monitor and keyboard
- Recon Workstation — Dedicated software (opc.)
- Weight — 900 to 1.400 Kg (1984 to 3086 lb)
- Power — From 60 to 150 kVA



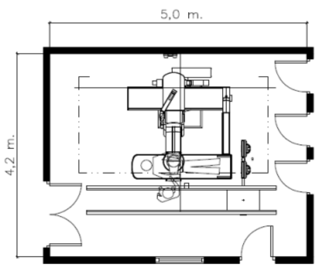
MINIMUM (21 m2)(226 ft2)



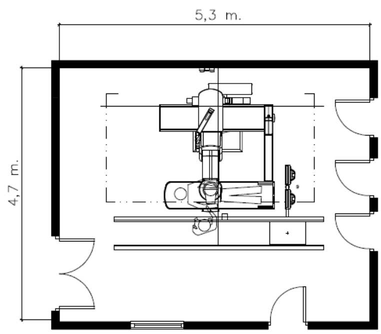
MEDIUM (25 m2)(269 ft2)

MULTIFUNCION SYSTEMS

• Application	Remote table and interventional
• Generators	60-80 kW
• X Ray Assembly	Dual focus. High speed anode
• Patient Table	Remoted Controlled. Tilting 90/90
• Tube Support	C Arm. Tube and detector
• Focus Film Distance	Variable continually
• Image System	Digital flat panel detector
• Room Monitor Support	Ceiling suspension or mobile cart
• Control	Desk with monitor
• Recon Workstation	Dedicated software (opc.)
• Weight	1.500-1.900 Kg.(3306 to 4188 lb)
• Power	130 to 160 KVA



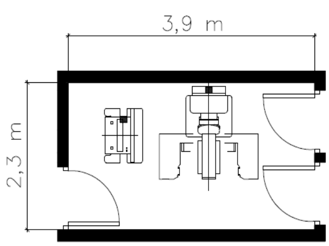
MINIMUM (21 m2)(226 ft2)



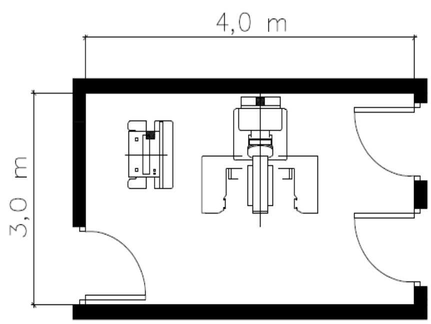
MEDIUM (25 m2)(269 ft2)

MAMMOGRAPHY

• Generator	3 to 5 kW, AEC
• X Ray Assembly	Dual focus. High speed anode
• Gantry	Arm support for tube and detector
• Detector	24x30 cm (6-8 lp/mm) (9x11 in)
• Operator Shielding	Glass leaded panel
• Control	Desk with monitor
• Weight	300 a 450 Kg.(661 to992 lb)
• Power	3 to 6 kW

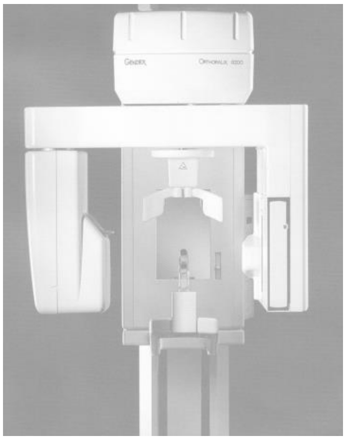


MINIMUM (9 m2)(96 ft2)

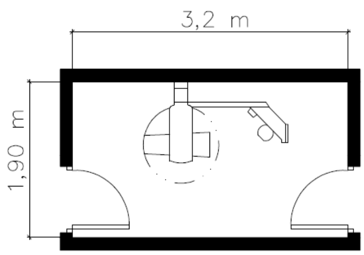


MEDIUM (12 m2)(129ft2)

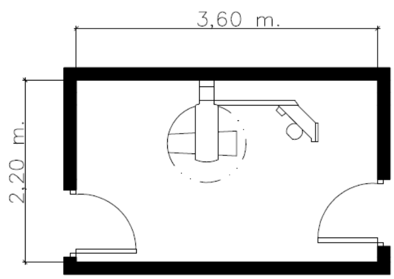
ORTOPANTOTOMOGRAPHY



• Application	Dental Panoramic, Cephalometry
• X Ray Assembly	Tank. generator 2-3 kW and tube
• X Ray Tube	One focus. Fixed anode
• Support	Motor elevation
• U Arm	Supports tank and detector
• Detector	Flat panel (>2,5 lp/mm)
• Control	Desk with monitor
• Weight	200 to 350 Kg (551 to 771 lb)
• Power	2 to 3 kW



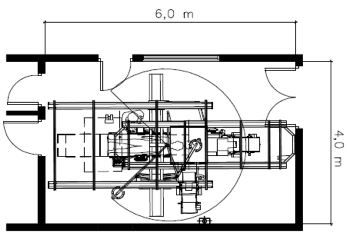
MINIMUM (6 m2)(64 ft2)



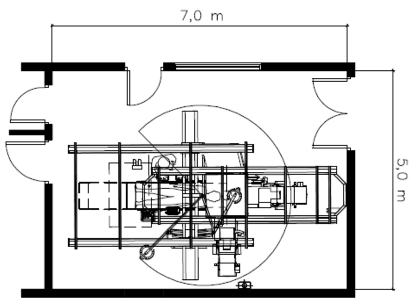
MEDIUM (8 m2)(86 ft2)

SINGLE PLANE VASCULAR AND HEMODINAMIC SYSTEMS

Application	Vascular and Interventional
Generator	80-100 kW, AEC
Arc Support	Floor and ceiling. C Arm for panel and tube.
X Ray Assembly	Dual focus. High power
Image Detector	Input fields higher 18 and 38 cm (7 and 14 in)
Patient Table	Floating. High load
Image System	Matrix of 1.024 and 2.048 píxel
Room Monitor	Ceiling support
Control	Desk with two monitors
Recon Workstation	Special software (opc.)
Weight	Ceiling1.200 Kg (2645 lb). Floor 400 Kg(881 lb)
Power	From 16 a 200 KVA



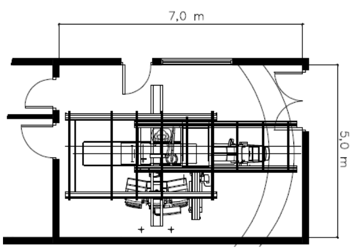
MINIMUM (24 m2)(258 ft2)



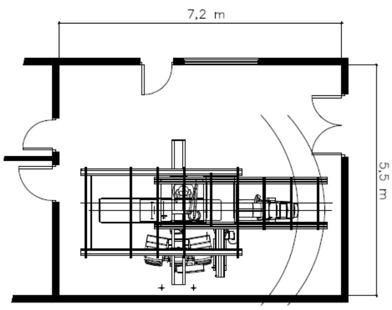
MEDIUM (35 m2)(376 ft2)

BIPLANE VASCULAR AND INTERVENTIONAL SYSTEMS

• Application	Vascular and Interventional
• Generator	80-100 kW
• Arc Support	Floor ceiling. C and U
• X Ray Assembly	Two three focus. High power
• Image Detectors	Input Fields higher than 18 and 38 cm
• Patient Table	Floating. Tilting. High load
• Image Systems	Matrix 1.024 and 2.048 pixels
• Monitors	Ceiling support in room
• Control	Desk with three monitors
• Recon Workstation	Special software (opc.)
• Weight	Ceiling 2.000 Kg (4409 lb). Floor 1.100 kg(2425 lb)
• Power	Between 180 y 200 kVA



MINIMUM (35 m2)(376 ft2)

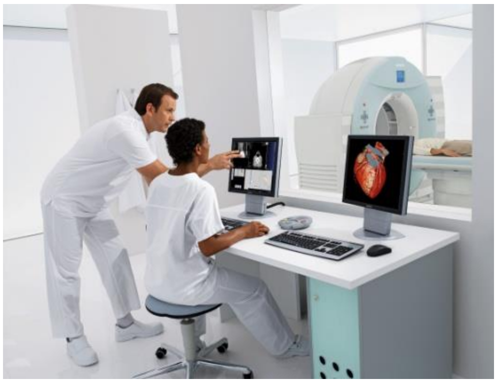


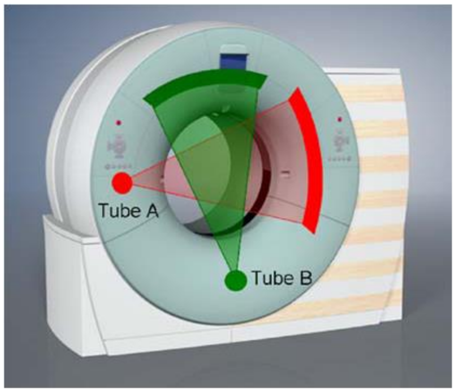
MEDIUM (40 m2)(430 ft2)

IV.II.- SLICE IMAGING MODALITIES

Slice imaging like ultrasound, CT multislice and magnetic resonance have experienced a great innovation, of undoubted scope from end of the last century. Today the heart is scanned with CT in less than one cardiac cycle, it is available the technique of tractography on 3.0 T magnetic resonance systems and there are 3D electronic transducers in real time in both cardiac and abdominal ultrasound. Examination times has been reduced and expanded the performance of the equipment increasing its production capacity.

Multislice tomography equipment have reached tube rotation time and detectors in the gantry of the equipment of the order, or slightly higher, than the 0.25 sec. This development has been accompanied with the rise of the number of detectors in the machines, reaching matrices that allow more than 320 slices per rotation in a few models and also dual systems which are available with two sets of emitters and detectors in the gantry. In these systems, with similar rotation speed to those described above, the acquisition time is reduced substantially although detectors take 2 x 128 slices per rotation which are sufficient to acquire a heart in diastole. It has come to acquire and reconstruct the image of a heart in less than one cardiac cycle, in less than 10 years since the appearance of the first CT multislice on the market.





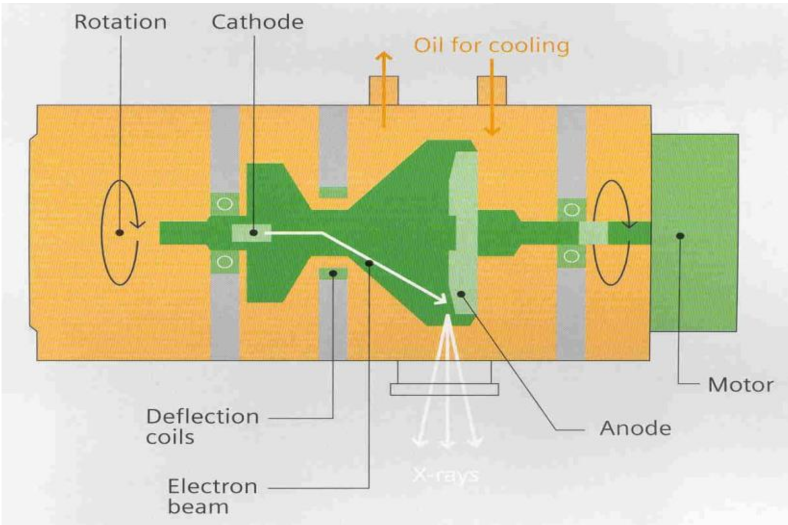
(4.9.- CT for cardiac applications. Dual system)

Get this performance and clinical level has been possible with the development of four basic components of this technology:

- Tubes of high thermal capacity.
- High density matrix detectors.
- The mechanics of rotation of tube and detectors inside the gantry.

- Computer and software processing of the massive acquired data.

Cardiac imaging requirements are very high. The generators exceeds the 100 kW, with a consequent increase in demand for line power with respect to the previous systems and the thermal storage capacity of the tubes are much higher than in the former CT with 16 slices. Storage capacity of up to 30 MHU tubes are available for cardiology, with liquid cooling and special heat exchangers, whose location must provide the designer in the technical rooms and in the exterior of buildings in some cases.



(4.10.- Very high performance CT x-ray tube)

The detectors have improved their detection capability and in many cases new designs have enabled to reduce the dose, which is the more radioactive hygiene objection of CT, although hopefully manufacturers are making quick and important corrections in their products. Flat Panels are used in detection systems for CT (FPCT) competing with the standard multi detectors (MSCT).

The rotors in the CT gantries have pneumatic systems to facilitate high speed rotation of large masses, and have to be provided space and sound insulation for corresponding compressors that are installed in the technical rooms.

Computer science has made it possible to have adequate capacity to process large number of images and it occurs in short periods of time. Images with reconstruction algorithms as the conic, switched today for the linear reconstructions to provide low dose reliable images to clinicians and the introduction of new CAD programs for the diagnosis of various diseases; one of these is for the colon polyps diagnostic.

In magnetic resonance have increased the number of models of machines that are available in a significant way.

Has been established a clear differentiation of the machines according to the intensity of the magnetic field**:**

- **High, composed by machines with magnets of 3.0 T and 7.0 T**
- **Medium, integrating open and cylindrical with magnets with fields between 1.5 T and 1.0 T**
- **Low, machines with field strengths of from 0.2 T to 0.7 T. Most open systems**

The systems with high-field magnets are penetrating in the diagnostic market image in a continuous and progressive way. They have a clear potential for improvement diagnostic with respect to the medium field and their yields are also higher. The investment is the highest, but its benefits may outweigh it depending of the clinical and production requirements.

(4.11.- Magnetic resonance imaging of 3,0T)

The new equipment are supplied with gradients in the order of 40 mili Tesla by meter and higher, and configurations of digital acquisition of up to 64 channels. There are surface coils with multiple elements and parallel acquisition capacity, with which factors of acceleration up to 16, and higher, are today possible, widely increasing examination speed and image quality. The weights are in the order of the usual machines of 1.5 T.

The medium field, with magnets between 1.0 T and 1.2 T open and cylindrical of 1.5 T comprises the largest number of operational facilities and will continue to be so for a long time. The greater provision of high field machines have their limitations in knowledge and demand for such services and their costs of acquisition, and although its incorporation is a progressive phenomenon, the use of the medium field is strongly introduced in the clinical diagnostic methods.

A salutary lesson and revulsive have been 1.0 and 1.2 T open systems. Machines of superconductors, with reduced consumption of helium which attenuate or eliminate the feeling of claustrophobia of the closed cylindrical machines and will replace many of them gradually as they improve their acquisition costs. These machines with features similar to the 1.5 T needed for it planning a space slightly higher and, for now, are somewhat more sensitive to external fields interference and must take care of its location. The details of planning and design are the same in principle as to the rest of the machines.

(4.12- MR 1.0 T open)

Low field equipment occupy a wide spectrum in the range of 0.2 to 0.7 T based on various technologies for its construction: resistive, permanent magnet and superconducting. For the planner provide interesting features for the minimal space requirements and low power consuming. It maintains the need for air conditioning and cooling system of gradients.

Special magnetic resonance machines for very specific applications were already shown in Chapter III and more are displayed in Chapter VIII and play an outstanding role in the imaging diagnostic departments because its low cost. It is expected that to the existing today for extremities and breast are added new developments for other special explorations.

(4.13.- Open MR)

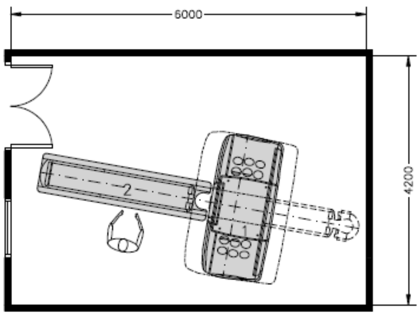
Ultrasound has expanded its spectrum of diagnostic applications and ultrasound scanners are now in all areas of the hospital, not only in the imaging department. Techniques 3D and 4D in real-time with electronic transducers are perhaps the most prominent, as well as the introduction of elastography.

(4.14.Ecocardiographs)

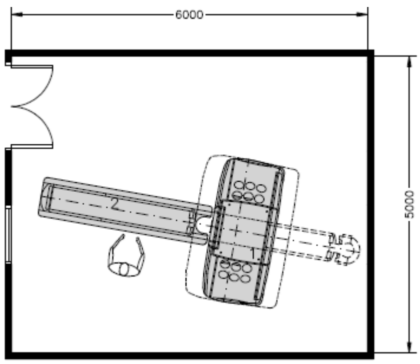
There are no new requirements for the planner, outside the already shown. Just indicate on the mixed use of techniques should provide space for an ultrasound in many vascular and interventional rooms and in the design of the ultrasound rooms have to be considered the use of additional instrumentation around the ultrasound, as well as in cardiology and interventional rooms. The new techniques of molecular imaging will point out, very likely, ultrasound rooms more spacious.

MULTISLICE CT (MSCT) AND VOLUME CT (FPCT)

Generator	30-120 kW
X Ray Tube Assembly	From 2 MHU to 30 MHU
Gantry	Aperture 70-85 cm (27 to 33 in)
Detection System	From 1 to 320 sectors
Resolution	14 lp/cm to 24 lp/cm
Patient Table	Supports 200 kg (440 lb)
Operators Console	Desk with computer and monitor
Recon Workstation	Special software (opc.)
Weight	Between 1.400 and 2.200 kg.(3.086 to 4.850 lb)
Power	From 60 to 230 KVA



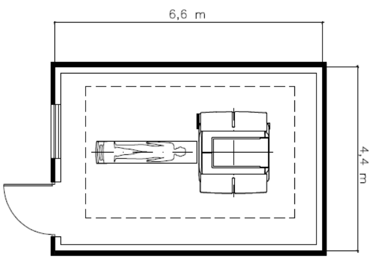
MINIMUM (25 m2) (269 ft 2)



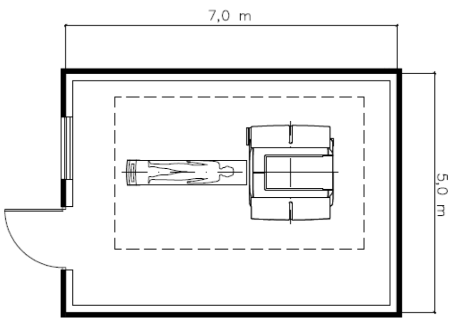
MEDIUM (30 m2) (332 ft 2)

MAGNETIC RESONANCE WITH FIELDS 1.5 AND 3.0 T

- Field Strength — 1.5 and 3.0 T. Low He consumption.
- Radiofrequency — Until 64 simultaneous channels
- Surface Coils — Lineal. Quadrature, Multi element
- Calculation Computer — Until 4.000 imag/sec.
- Operator Console — Desk. Computer. Monitor.
- Recon Workstation — Special programs (opc.)
- Weight — Between 2 to 5 Tm.
- Power — From 90 y 130 kVA.



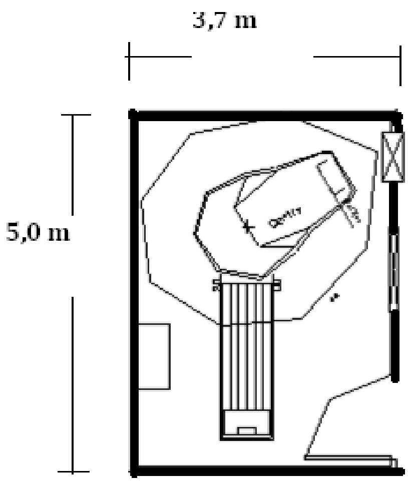
MINIMUM (29 m2)(312 ft2)



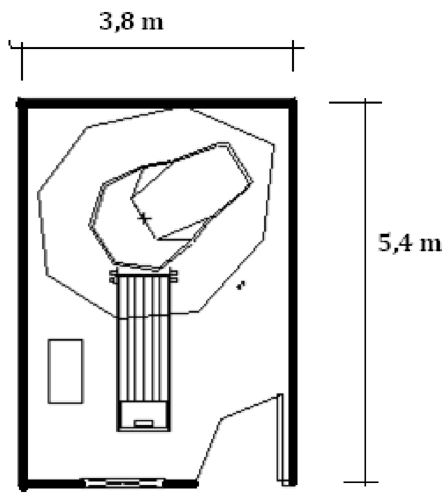
MEDIUM (35 m2)(376 ft2)

LOW FIELD OPEN MAGNETIC RESONANCE

Field Strength	0.2 to 0.7 T. Resistive, Superc. Perman.
Radiofrequency	Until 4 simultaneous channels
Coils	Linear, Quadrature, Multi element
Calculation Computer	Until 500 imag/sec
Operator Console	Desk. Computer. Monitor
Weight	Between 7 and 34 Tm
Power	From 10 to 60 kVA

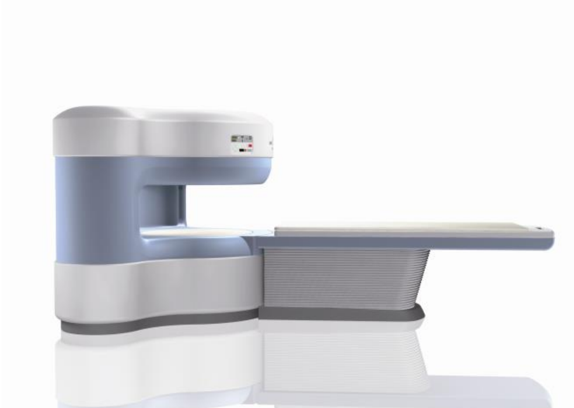


MINIMUM (18,6 m2) (200.2 ft2)

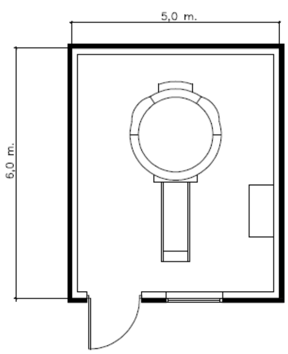


MEDIUM (20,8m2)(223 ft2)

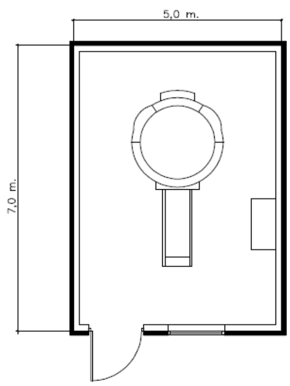
MEDIUM - HIGH FIELD OPEN MAGNETIC RESONANCE



• Field Strength	1.0 to 1.2 T. Superconductor
• Radiofrequency	Until 8 simultaneous channels
• Coils	Lineal. Quadrature. Multi element
• Calculation Computer	Until 4.000 imag./sec.
• Operator Console	Desk .Computer. Monitor
• Recon Workstation	Special software (opc.)
• Weight	Between 7 and 14 Tm
• Power	Between 40 and 90 kVA



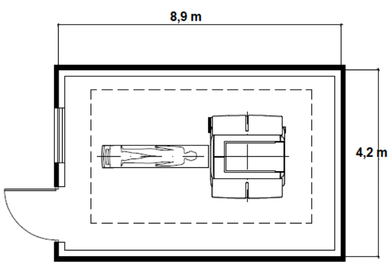
MINIMUM (30 m2)(322 ft2)



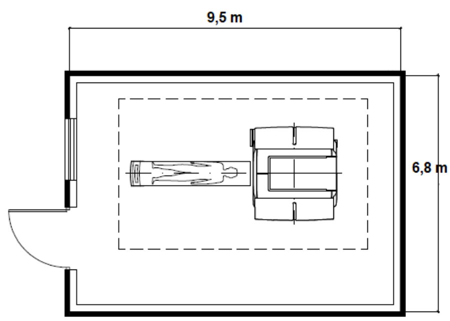
MEDIUM (35 m2)(376 ft2)

VERY HIGH FIELD MAGNETIC RESONANCE (7.0 T)

• Field Strength	7.0 T Superconductor
• Radiofrequency	From 8 to 64 simultaneous channels
• Coils	Linear, Quadrature, Multi element
• Calculation Computer	Until 4.000 imag/sec
• Operator Console	Desk. Computer. Monitors
• Recon Workstation	Special programs (opc.)
• Weight	20 Tm
• Power	180 KVA



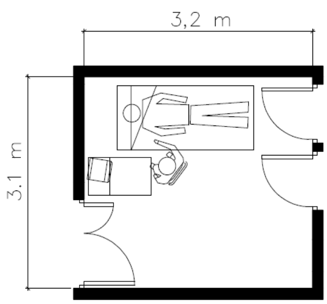
MINIMUM (37,4 m2) (402 ft2)



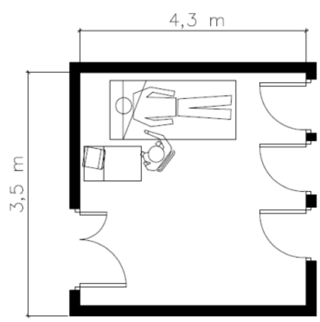
MEDIUM (64,6 m2)(695 ft2)

ULTRASOUND

- Application — General
- Channels Emission Reception — 1.000-40.000 digital
- Techniques — A-B-M-3D-4D
- Transducers — Lineal, Sector, Intracav., 3D
- Computer — PC. Windows
- Monitor — 17-19" color
- Weight — Between 200 and 600 kg(440 and 1322 lb)
- Power — Between 200 and 900 W



MINIMUN (10 m2)(107 ft2)



MEDIUM (15 m2)(161 ft2)

IV.III.- MODALITIES IN NUCLEAR MEDICINE

The first modality in clinical use is still the gamma camera performing SPECT and PLANAR features. The integration of the SPECT technique with flat panels has provided a new dimension to this technique with its radiographic images and CT reconstructions without moving the patient table between these acquisitions. Flexible protocols optimized for localization and attenuation correction with CT as well as images with high resolution and low dose levels has been designed.

(4.15.- Gamma camera with acquisition station)

(4.16.- Gamma camera of two detectors)

The gammacameras detectors have improved resolution and sensitivity, they have around 50 phototubes and its output to the processor is completely digital. They can be delivered with thin or thick crystals to choice by the user and have visual fields around 40 x 50 cm (15x19 in). Collimators range is widely distributed in low, medium and high energy with selections in the resolution and there are devices that allow an automatic or semi-automatic change of collimators.

The detector for the acquisition of radiographic imaging or CT function has an acquisition field of the order of 30 x 40 cm (11x15 in) with high resolution and element arrays in the order of 3.000 x 3.000 pixels, allows a large number of slices and the CT calculation time for the images in order of the minute.

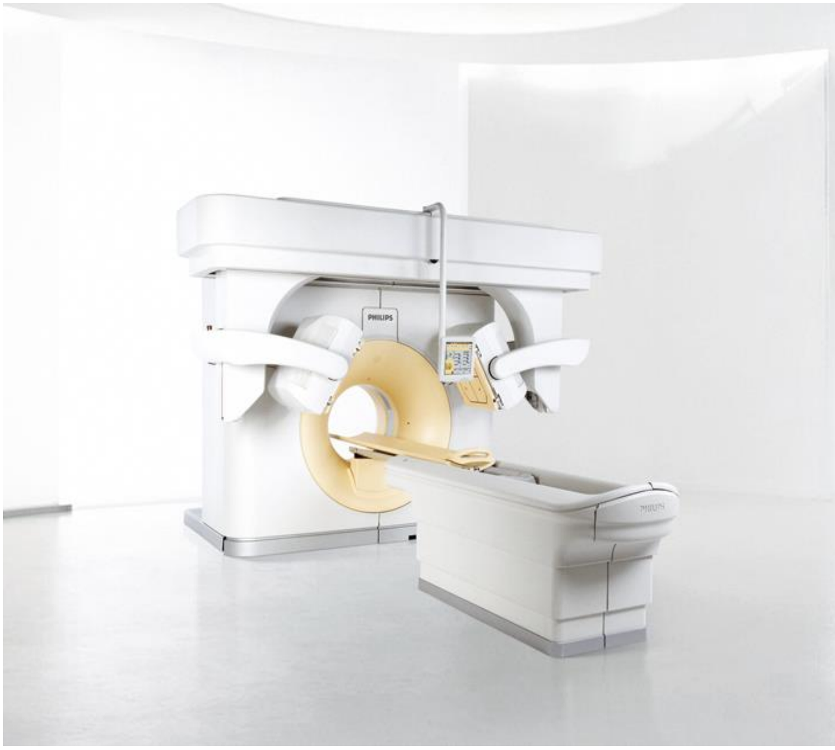
One x ray tube of medium power emits radiation over the detector to produce the required images, while the multipulse generator is located at the base of the camera.

Computers for control and processing have been simplified and for the machine control have one acquisition station and other for processing.

SPEC-CT hybrid systems are a solution that integrates the function and morphology in examinations of cardiology, radiology, nuclear medicine, oncology or neurology where hybrid techniques and the fusion of images provide a new confidence pattern in diagnostic nuclear medicine.

The CT used has been described previously, being of normal use of 6, 16 and 64 slices.

Weight of 4.500 kg (9.920 lb) for the entire system can be reached and must be calculated the load to floor with the appropriate load bearing capacity.



(4.17.- SPECT – CT system)

The room design should provide adequate space for collimators cart and additional equipment of the CT, as injector contrast, control monitor for electrocardiography signals, etc.

PET-CT systems have, in the last years, halved their examination times and increased their resolutions.

The PET that makes up the hybrid system contains about 30.000 crystals of different materials for the acquisition, depending on the manufacturer, but with very high resolution. Also the number of photomultipliers has increased proportionally to crystals. Has been developed electronics technology capable of accurate time discrimination, on the order of a nanosecond, the impact of each photon and is capable of identifying the origin of annihilation. Acquisition programs allow multiple forms both in 2D and 3D. Software processing with review images of PET and CT, as well as specific programs for different functions.

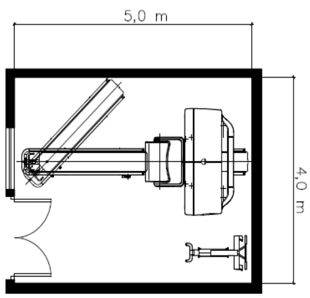
(4.18.- High performance PET-CT)

Weights in the order of 4.500 Kg (9.920 lb) are to be considered for the calculation of reinforcement structure. Energy consumption should be expected for apparent power of the order of 100 KVA.

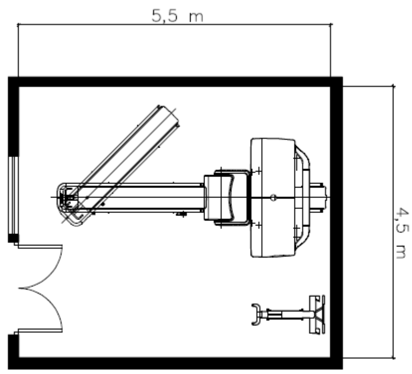
Pre-clinical tests have accelerated the introduction of equipment for the study of new molecules and small animal testing. The planner has to consider the research capacity of the imaging departments to add space for those equipment and their ancillary needs.

GAMMACAMERAS

• Detectors	1,2, 3 with multiple phototubes
• Gantry	Floor or ceiling
• Collimators	LE, ME, HE, Pinhole
• Table	Low absorption, high load
• Acquisition Console	Desk with PC and monitor
• Recon Workstation	Dedicated software
• Weight	Between 1.400 / 2.100 kg (3.086 / 4.629 lb)
• Power	Between 10 and 30 kVA



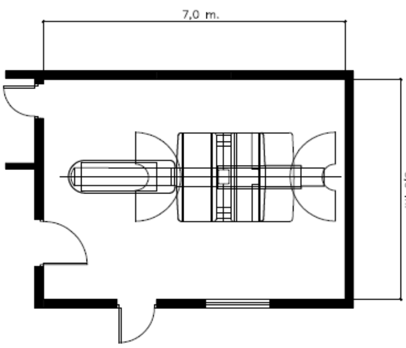
MINIMUM (20 m2) (215 ft 2)



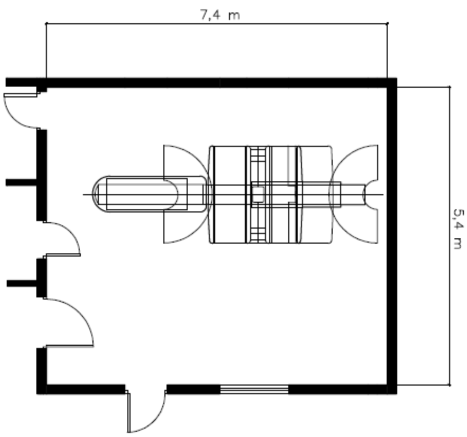
MEDIUM (25 m2) (269 ft 2)

PET - CT

- PET — Between 12.000 y 40.000 detectors
- Acquisition — 2D-3D
- CT — 4-64 slices
- Acquisition Console — Acquisition, processing.
- Recon Workstation — Special software (opc.)
- Weight — 4.000 to 6.000 kg (8.818 to 13.227 lb)
- Power — Between 130 and 230 kVA



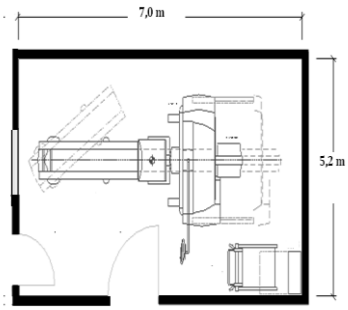
MINIMUM (35 m2) (376 ft2)



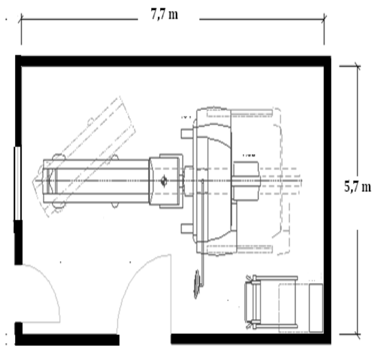
MEDIUM (40 m2) (430 ft 2)

SPECT- CT

• SPECT	Two detectors camera
• CT	6-16 Slices
• Weight	3.500-4.000 kg (7.716 to 8.818 lb)
• Acquisition Console	Acquisition. Processing.
• Recon Workstation	Dedicated programs (opc.)
• Power	Between 130 and 230 kVA



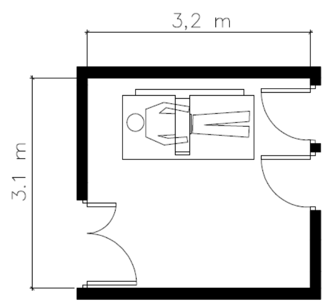
MINIMUM (38 m2) (409 ft2)



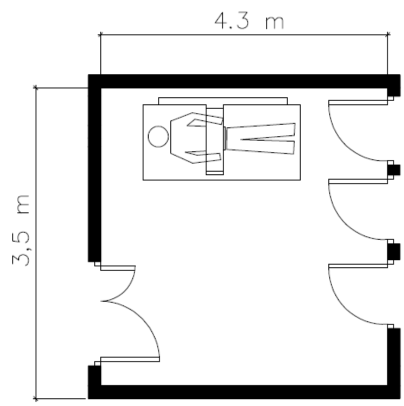
MEDIUM (44 m2) (473 ft2)

BONE DENSITOMETRY

• Generator	1,5-3 kW
• Acquisition	Single detector-fan array
• Computer	PC Windows
• Patient Table	Radiolucent. Patient until 200 Kg (440 lb)
• Operator Console	Desk. Computer and monitor
• Weight	300-500 kg (661 to 1.102 lb)
• Power	3 to 12 kW



MINIMUM (10 m2) (107 ft2)



MEDIUM (15 m2) (161 ft2)

IV.IV.- RADIOTHERAPY

Linear accelerators (LINACS) are the basis of radiotherapy treatments with external beam. Sophisticated machines and complex that continue to increase in density of installation with continuous improvements in their yields, in beam quality and ability to track the treatment in real time and therefore the quality of the treatment.

Radiation generation is still done with microwave sources composed by high power magnetrons and klystrons and acceleration systems have not changed in recent years.

The equipment provide two sources of radiation: x ray photons in the range from 4 to 25 MeV and electrons in a similar range. Multi leaf collimators (MLC) facilitate the implementation of these doses to areas of treatment, reaching until 100 or more lead leafs for this purpose.

The modern techniques of intensity modulated (IMRT) allow the ability to conform the dose while minimizing the intensity in enclosed structures, as well as in the healthy tissues. The LINACS integrated imaging techniques allow to visualize internal structures with reference to the framework of treatment and reduce geometric uncertainties with radiological volume techniques. The possibility of watching the point of treatment in the target position reduces the disadvantages of moving parts and inspires confidence to IMRT radiation. This leads to routine irradiation with 4D techniques and IGRT (Image-Guided Radiotherapy) present in the modern linear accelerators that have included an intense development in robotics.

Stereotaxy techniques have improved with the introduced novelties, described above, both in the area of the brain and out of this. Single or multiple fractions of stereotaxy radiosurgery are feasible with special attachments, such as location and immobilization systems.

Brachytherapy treatment systems have improved capabilities allowing multiple channels operating simultaneously and improving the safety of operation of the equipment, existing alternatives in the direct application of the radioactive isotopes that this technique provides.

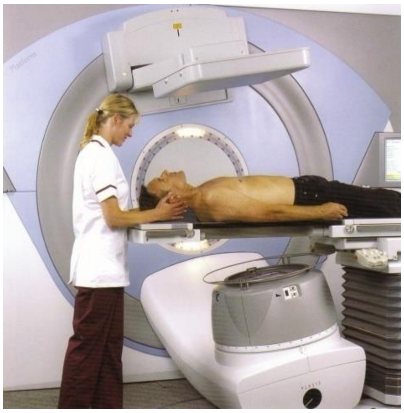
High rate techniques are the most widely spread in the departments of radiotherapy and they are widely used in cancer therapy of prostate, breast and other organs where the scope of applicators allows to reach the body safely, avoiding collateral risks. The doses applied and the isodose curves are calculated with the brachytherapy planner computer, for which should have space in the calculation of the room of the physicists responsible for this task, with its network connections for images in DICOM RT that allows import and export plans prior to irradiation.

(4.19.- LINAC with imaging system for IGRT)

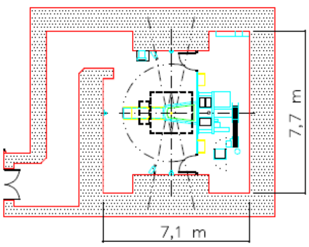
The virtual simulation continues being the basis of radiotherapeutic simulation with new CT that have more than 85 cm (33 in) patient access fields, which facilitates the examination of patients where is required to locate and simulate the treatment of breast, thick patients and cases of whole body. These CT for radiotherapy have detection systems with capacity to acquire information of the patient with 16 and 64 simultaneous slices per rotation. Not only are being used for radiotherapy with external beam, LINACS, but also for brachytherapy. These last facilities are including one CT or a magnetic resonance system in the brachytherapy bunker. In this way the location, planning and control of treatment are made with the patient in the treatment room.

The dose treatment planners for the calculation of the therapeutic doses have diversified. Today are planned treatments with linear accelerators, with brachytherapy, with stereotaxy and radiosurgery. It is required equipment capable of making accurately these operations. The planner and the designer of the department must calculate the space needed for the physicists that perform these task, that usually are not with a single planning system but there are resorting to various systems that require space to be located and temperature conditions for their operation.

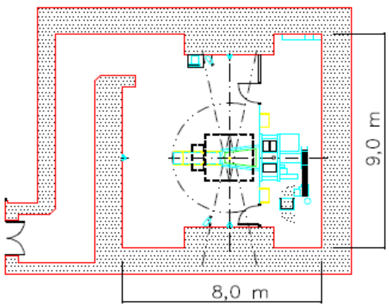
LINEAR ACCELERATORS



Application	Radiotherapy with external beam
Photons Energy	From 4 to 25 MeV (low, medium, high)
Electrons Energy	From 4 to 22 MeV
Gantry	Supports collimator and treatment unit
Multi Leaf Collimator	From 40 to 120 Leafs
Positioning Detector	Digital flat panel
Patient Table	Elevation. Floating table top
Treatment Techniques	Conventional. IMRT, Gated.
Operator Control	Desk with several monitors and TV
Weight	7.000-11.000 kg (15.432 to 24.259 lb)
Power	110 a 140 kVA



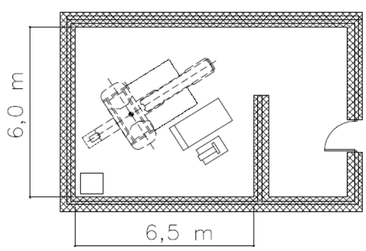
MINIMUM (55 m2) (592 ft2)



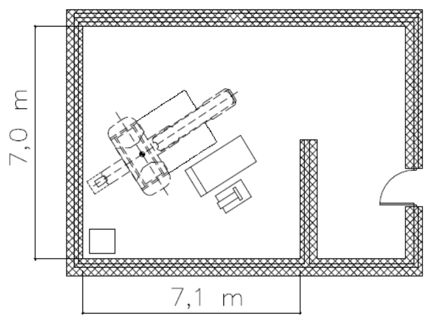
MEDIUM (72 m2) (775 ft2)

BRACHYTHERAPY

• Application	Internal radiotherapy with guided sources
• Gantry	Container with radioactive sources
• Applicator	With different channel
• Methods	Low and high rate. Pulsed
• Planning System	For dose calculations (option)
• Simulators	For localization and simulation in situ (option)
• Operator Control	Desk with PC monitor and TV monitors
• Weight	150 to 300 kg. (551 to 661)
• Power	2 – 4 kW



MINIMUM (39m2) (419 ft2)

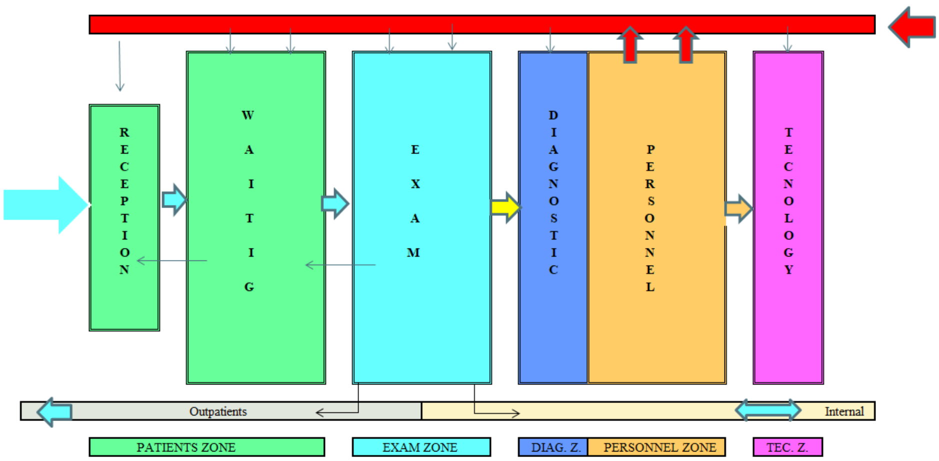


MEDIUM (50 m2) (538 ft2)

DATA SUMARY OF MODALITIES AND TREATMENT UNITS

MODALITY	EXAM ROOM minimun m2	EXAM ROOM medium m2	WEIGHT floor kg	WEIGHT ceiling kg	POWER kVA
	ft2	ft2	lb	lb	
Conventional Radiography	16	20	400	600	50-130
	172	215	881	1.322	
Universal Radiography	16	24	400		30-130
	172	258	881		
Remote Controlled Table	21	25	900-1.400		50-150
	226	269	1.980-3.086		
Multifuntion	21	25	1.500-1.600		130-160
	226	269	3.306-3.527		
Mammography	9	12	300-450		3.-5
	96	129	661-992		
Ortopantotomography	6	8	200-500		43.161
	64	86	440-1.102		
Vascular-Hemodinamics	24	35	1.200	400	160-200
			400	1.200	
	258	376	2645-881	881-2645	
Vas-Hemod. Biplan	35	40	2.000	1.100	180-200
			1.100	2.000	
	376	430	4.409-2.425	2.425-4.409	
CT	25	30	1.400-2.000		60-230
	269	332	3.086-4.409		
MR 1,5-3T	29	35	2.000-5.000		90-130
	312	376	4.409-1.1023		
MR Open Low Field	18	21	7.000-34.000		10.-60
	193	226	15.432-74.957		
MR Open High Field	35	45	7.000-15.000		60-90
	376	484	15.432-33.069		
Ultrasound	10	15	200-600		0,2-0,9
	107	161	440-1.322		
Gammacamera	20	25	1.400-2.000		10.-30
	215	269	3.086-4.409		
SPECT-CT	38	44	3.500-4.000		130-230
	409	473	7.716-.8818		
PET-CT	35	40	4.000-5.000		130-230
	376	430	8.818-11.023		
Bone Densitometry	10	15	300-500		40.150
	107	161	661-1.102		
LINAC	55	72	7.000-11.000		110-140
	592	775	15.432-24.250		
Brachitherapy	39	50	150-300		43.192
	419	538	330-661		

V.- ZONES AND SPACES



I. ZONES

II. LOCATION OF THE IMAGING DEPARTMENT

III. CALCULATION OF THE DEPARTMENT SURFACE:

III.I IMAGING

III.II NUCLEAR MEDICINE

III.III RADIOTHERAPY

IV SPACES

Chapter V

The architecture is the least corrupt witness of history (Octavio Paz)

V.- DEPARTMENT SURFACE (ZONES AND SPACES)

Decisive technological advances of the last decades has clearly increased the number of modalities, and these have diversified, increasing its diagnostic possibilities. There is a high complementarity between the diagnostic capabilities of the modalities, and despite the many techniques today existing no one is exclusive. Several of them, in many patients, are required to complete a diagnosis. Cannot be said that any new technique, or its different modalities, have replaced the existing ones in a comprehensive manner in the environment of time in which they operate. This has led to the imaging department to a continuous increase of the covered surface, either within the hospital, health center or outpatient consultation.

The introduction of the CT in the 1970s already meant an increase of space, which must be considered, not only the physical space of the examination room, but in addition there are dress cabins or cubicles, preparation rooms and toilets, technique room for the machinery that allows to operate the CT, space for workstations, where radiologists or technicians manipulate and reconstruct images, space for radiologists who diagnosed the images with the new modality CT, and also the space needed for such personnel to their own needs, such as toilets, changing rooms, rest rooms, offices and corridors through which circulate, since they reach the image service, and where moving internally within it.

Also happened with magnetic resonance imaging in 1980s, but given the high magnetic fields inherent in this technique, the needs of protection of the personal, as well as the greater needs of space with respect to the CT, further increased the area of the imaging department. The PET, brought even more need for space, and today has been increased with PET-CT because the patient setup requirements, management of the radioactive drugs and radiation protection needs.

New medical technologies have brought modalities with an extraordinary diagnostic value that need a support space which must be calculated in the planning and provided in the design of the department.

A new impact that has enabled a simplification, very important, has been the introduction of new information and communication techniques, and with them the implementation of the RIS software and new PACS systems, that have simplified the citation and editing reports, cancelling the consumption of films and eliminating bulky files, that no longer exist in the new centers and are being gradually removed in the places where they still exist.

With all this, there are several forces pushing to a continuous increase in the surface of imaging departments:

- **A greater dignity in the treatment of the patient**, trying to improve your stay at the department from the reception, more personalized, no queues, more personal and more intimate waiting rooms, best cabins for changing clothes, more extensive preparation rooms and rooms of rest with the best means to stay and entertainment.

- **Incorporating more technology** to imaging departments with more diagnostic modalities. Current technology with new developments and more new products still in research, pending exit from laboratories to hospitals.

- **Increased demand for diagnostic imaging,** consequence of the appreciation of its high diagnostic value for clinicians and patients.

- **Increase in therapeutic procedures,** where imaging techniques are basic in the development of the procedure. Cannot be performed a PTA, without the basic conditions of security, and a correct angiographic equipment.

- **Access of more people to imaging techniques.** Patients demand the techniques; they do not decide, in general, its application, but according to their higher cultural level exert greater pressure on the predictors to apply tests with diagnostic imaging techniques.

- **Priority in the governmental administrations in the sanitary services,** as a factor of well-being and thus to meet the social demands of the citizens that they represent and their knowledge of the low cost than imaging techniques mean, in relation to health savings provided by their information; and with the clear idea that high technology is around one percent of health expenditure.

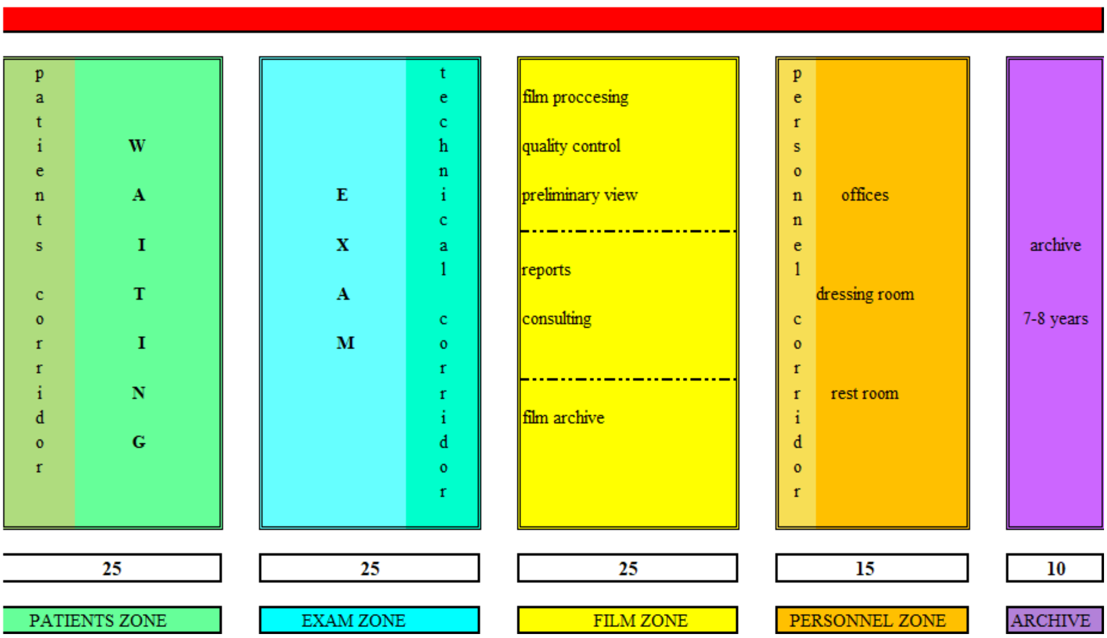
In the pages that follow, will be advanced conceptual aspects of the definition of areas in a imaging department, that although has been already widely treated by all authors of articles and documents about baking, today need a thorough review, not only because of the elimination of the film, but for new tasks in research, development and innovation than the imaging departments, as places where a large number of technologies of the highest level is concentrated have an obligation to develop a new contribution to the society they serve. After that are shown several procedures to calculate the surface to be provided in the phase of planning to the imaging and radiotherapy department, so that the design is objectively possible , and its operation meet its purposes, not only at the time of its opening, but within a reasonable period of vision.

V.I.- ZONES

In the first Radiology Departments Planning Symposium, held in Helsinki in 1972, Holms (51) introduced the concept of zones in a radiology department defining the zones as functional physical areas in the department and assigning experimental percentages of the total area of the department. The concept is very useful for the planner, as defined an area of the total space of the department in a first calculation, may be defined the inner areas with very approximate elements, that logically inside small percentages vary from a plan to another, and that can range more in certain designs of very specialized centers; but keep the concept and percentages in the generality of designs, and almost always in the separation of the functional areas.

The concept of Holms (5.1), described by Fisher (59) in detail and by other authors subsequently was the conceptual basis for the distribution of one imaging department to all planners to date, and even today with the amendments imposed by technology and the explosion of the frequentation of the past twenty years, it remains a framework of inestimable value (59). Holms defines five distinct areas that correspond to activities that are carried out in each area and the workflow developed by the department.

The patient arrives at the reception, and from there is directed, or accompanied, to the waiting room, and once called to review enters his corresponding cabin to change clothes. This is the PATIENTS ZONE.



(5.1.- Holms Zones)

Once he enters the examination room, the technician or technicians, carry out positioning, preparing the radiographic exposure, or the gamma camera, e.g. start the test, or instrumentation for the angiographic procedure, he goes back to his control room and makes radiographic exposure, or the beginning of the acquisition with the gamma camera. All of these areas of examination, control rooms and corresponding corridors are called EXAM ZONE.

Once done the radiographic exposure, until began digital technology, the technician had to develop the film making quality control and prepare the film in envelopes for its reading and radiological diagnosis. This area contained processing machines within the dark room, which later become daylight systems loading and unloading radiographic chassis. X-ray film viewers were available to make the quality control by technicians, and the films were deposit in an intermediate file until reading by the radiologists that dictates the corresponding reports, and then the next typing transcription in the corresponding area. All of these physical units were known as FILM ZONE.

The personnel of the department requires their own space, since it comes to his work, they change clothes in their wardrobes, their toilets, lounge with your coffeemaker and refrigerator to store food, offices, meeting rooms and conference room in large hospitals. These dependencies make up the PERSONNEL ZONE, which today is similar to that described by Holms.

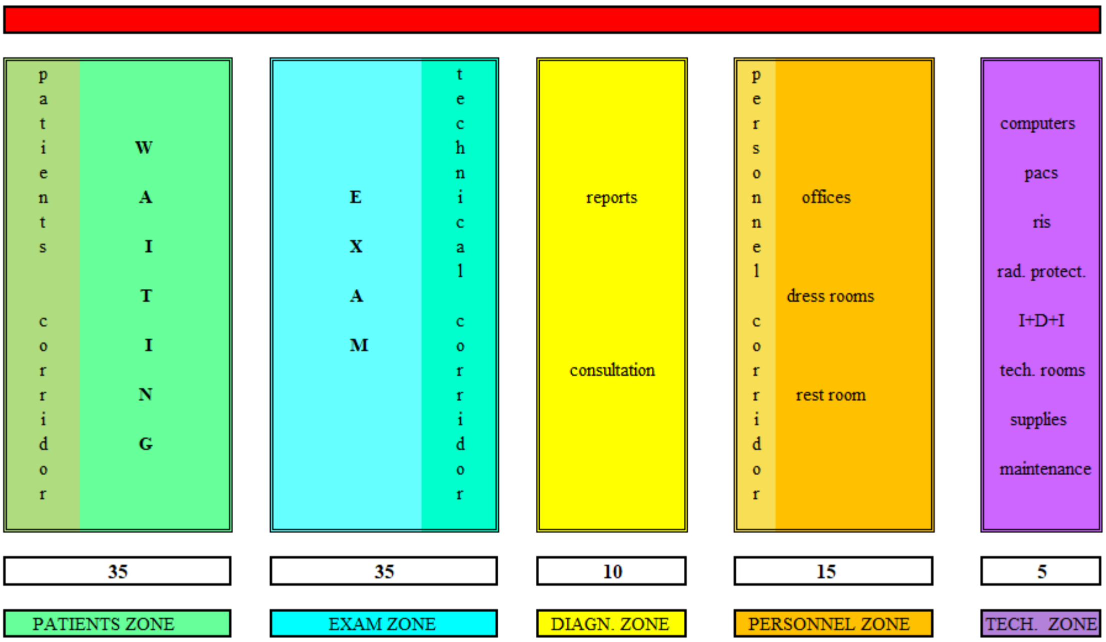
(5.2.- 3D drawing of offices in the personnel zone)

The technology has caused a major change. The fifth area of Holms, is where archived films and reports remains in the long run, that several people was needed to manage files, in many cases more than ten years, has been functionally replaced by servers and digital files with PACS and RIS. This area called FILM ZONE now takes a new dimension marked by the technology that has begun to be a basic component for the operation of the imaging department, without whose availability not only slows down the activity of the department, but it cannot be done.

Can be observed that once defined in a preliminary way a surface for a department, there is a first orientation of the distribution of activities and spaces, leaving three of these ZONES with a 25 per cent of the total area, and 15% for staff and 10 per cent for the file.

In a present department has gone the film-related activity and its associated technology. It does not exist. Therefore the technician controls the snapshot image on his workstation monitor, make the validation, and sends it to the file of the PACS for the next step in the workflow.

Therefore have disappeared many square meters for activities in the film area, becoming it in the DIAGNOSTIC ZONE. Here the radiologists from their workstations reads the images on monitors, set the diagnosis, dictates by means of voice recognition system integrated into the workstation and sings the acceptance for the file in the PACS. This distributes it via the WEB to all accepted personnel in the hospital, extra hospital or medical reference according to the distribution system set up by the organization or hospital, with adequate security and protection. This DIAGNOSTIC ZONE does not require the previous bulky multibody lightboxes for viewing, with its shelves, occupying much space, but offices with individual work stations with a substantial reduction in space.



(5.2.-Actual zones)

There is therefore a reduction in the area of archiving. There is no tangible physical material to be archived, only there are digital data, formatted images and reports that are stored on PACS and RIS servers. There are no staff that handles the file, but there are errors in the identification of patients, loss of connectivity, changes in software, hardware problems, which require attention, as well as copies and duplicates from the file of the PACS, which must be secure and in safe places against disaster. Emerges the figure of the application administrator and the responsible for data processing that in many departments small and medium can be covered by one person but in large centers will be separated in a group of persons for reasons of organization and distribution of work load.

New technologies, MRI, PET-CT, MN, etc., require technical rooms with proper conditioning, both energy (UPS, trimmers, etc.) and climate and thermal dissipation of equipment, heat exchangers air/air or air/water, with spaces that have to calculate in the department.

Increasingly important, radiological protection and dose tracking requires its own media programming, which in many departments is external. Research and development as well as innovation require spaces, mainly in hospitals with this dedication, spaces that require its calculation.

The power supply also requires space for distribution transformer, when it is necessary, energy saving systems, as well as electrical panels. Digital network and interconnect boxes are additional spaces.

We must not forget the maintenance. While contracts with providers does not usually require spaces within the department, the provision of technical maintenance of equipment inside the hospital, when the concentration of equipment allows, saves infinite problems, and singularly improves the occupation time of rooms with the consequent improvement of the productivity and profitability of the department. This technician of maintenance, or technicians, depending on the magnitude of the department, control the daily flow of information from computers and the planner have to calculate space in the department, or next to it, for its activity.

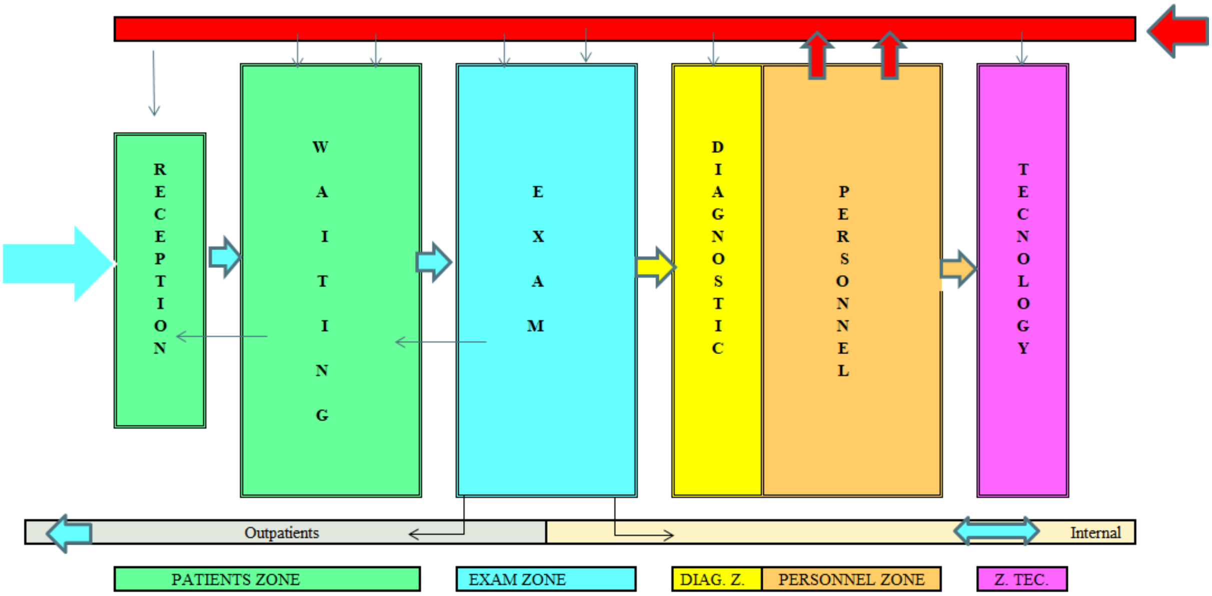
A different distribution of the percentage of spaces has emerged with the technological revolution that has entered in the imaging departments since the last decade of the last century, taking more percentage of space dedicated to patient in the waiting and exam zones, as well as the personnel zone of the department, and reducing those dedicated to archive and film, doing more technified the tasks of the diagnostic area. The technological area has contributed, of course, to the own objective and essential of a technique: to dignify the assistance to persons (patients) with less effort from the professionals. Within the same concept appears emerging variants to be discussed with practical examples.

The three models that we show with its corresponding examples, are solutions to optimize both the architectural structure and the physical space, that the real examples is mostly something less than the optimum, not only in the initial opening of the department, but at least in the following ten years of operation.

In the first (5.4 and 5.5), there is the reception attached to the patients waiting area, difference between Holms who considered it in the area of film. Now the patient, in general, do not carry with himself the envelope with the diagnostic images and reports to deliver to his specialist, because these are transmitted electronically to petitioner specialists and external reference physicians.

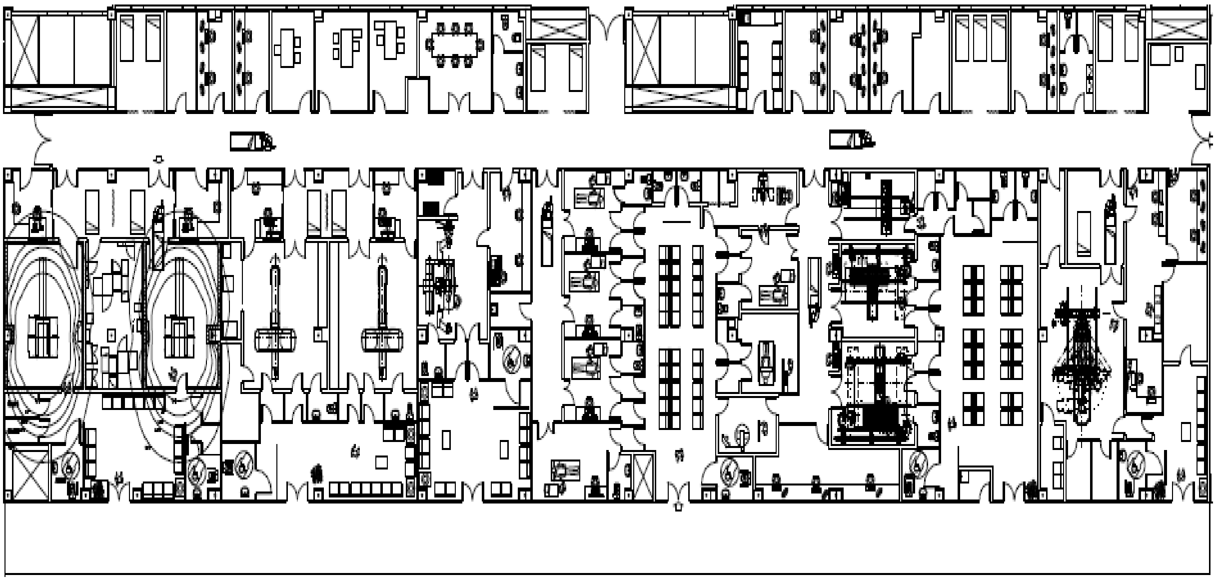
The DIAGNOSTIC ZONE and PERSONAL ZONE are integrated; in fact the location of booths or diagnostic rooms is closer to exam rooms, and the optimum use of space leads to find spaces of diagnostic radiologist rooms inside the PERSONNEL ZONE, sharing personnel corridor between both zones.

The TECHNOLOGY ZONE is a dispersed area, divided between the image department and other areas of the hospital, as the data processing center where can be located the RIS and PACs servers; the room for the technical maintenance of the equipment, which may be located in the department or in another place in the hospital; units of heat exchangers (refrigerators) for MRI located on the roof, or on the outside of the center; and other necessary technology areas of the department distributed in other possible places of the hospital.



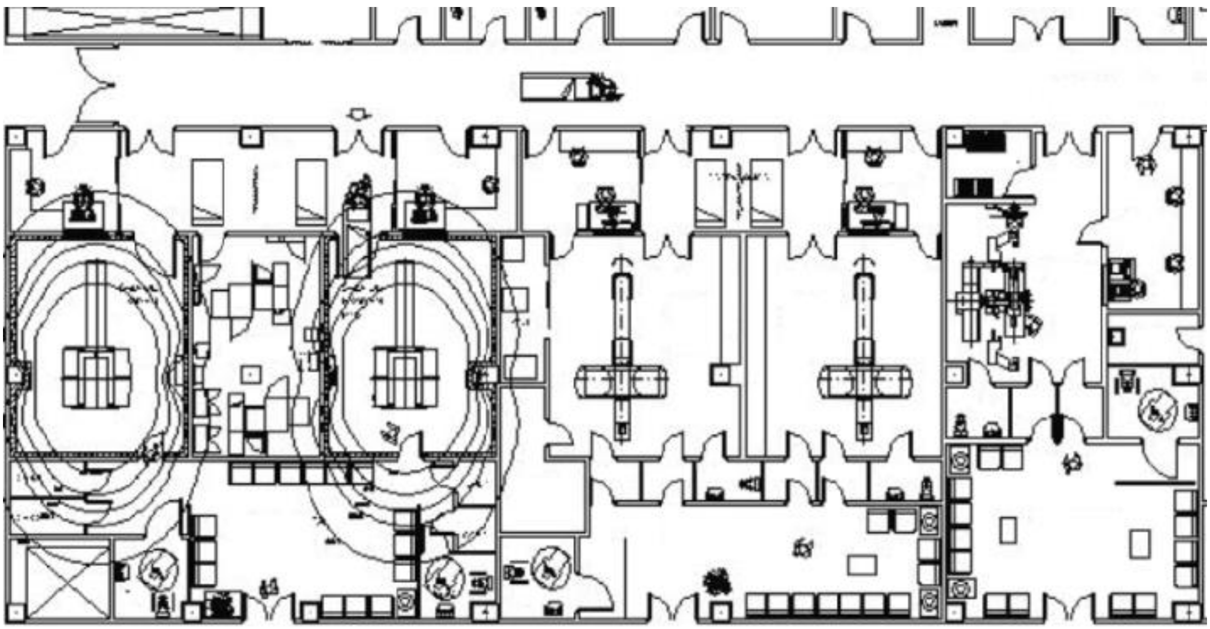
(5.4.-Reception near the waiting)

In the architectural example (5.5) the area of patients has been designed, in two different configurations, with regard to the EXAM ZONE, one horizontal for MR, CT and remote control, and vascular-cardiac catheterization to the right, and other vertical for conventional radiology, densitometry and ultrasound. The architectural distribution and sizes of rooms indicate the optimal use of space



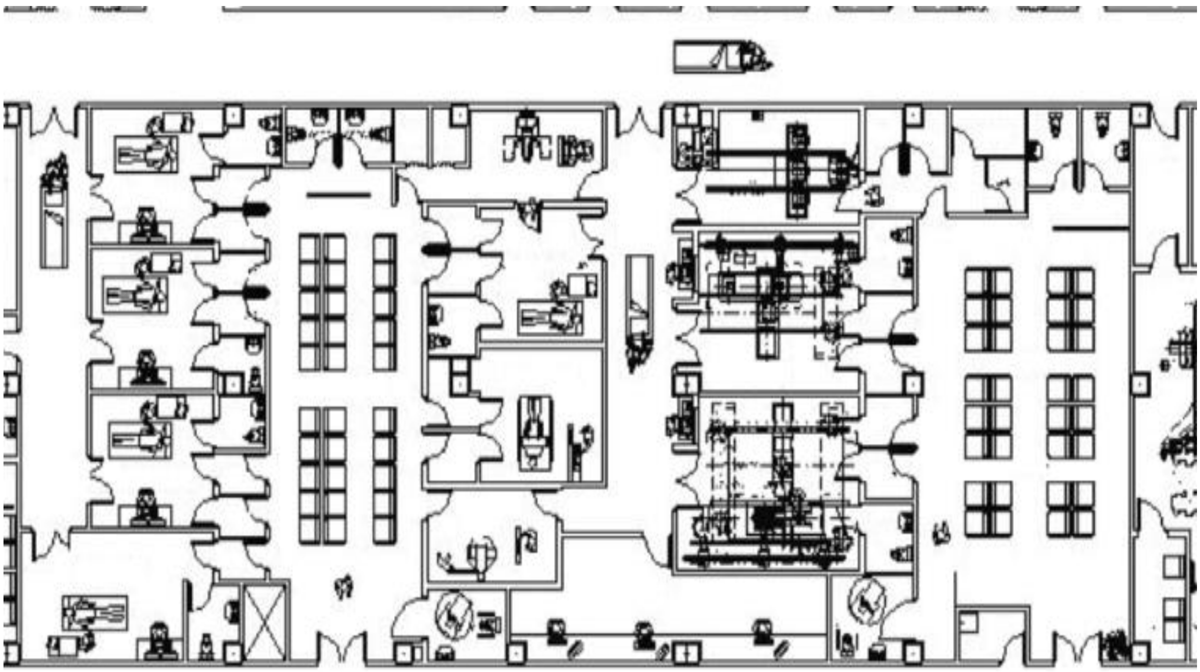
(5.5.- Patients next to test area)

Below is the separation of PATIENS ZONE and EXAM ZONE.



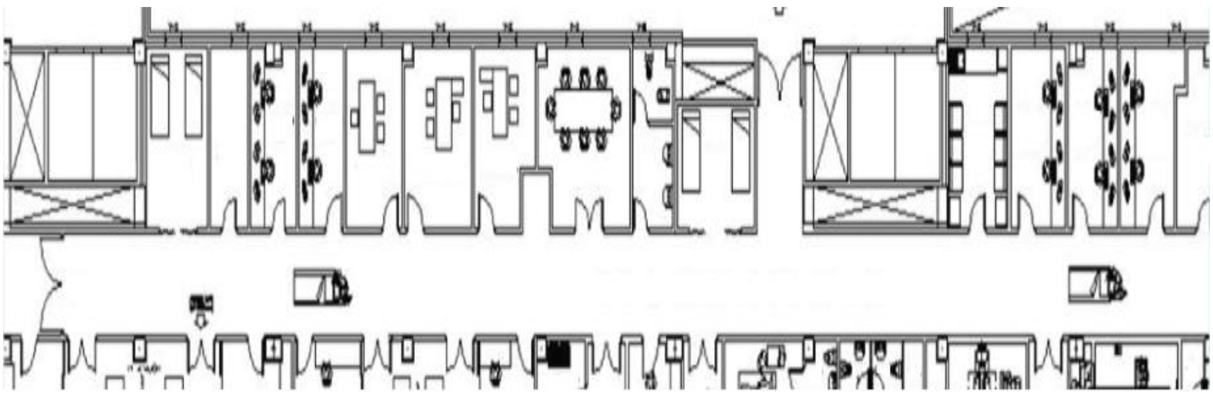
(5.6.-Patients and exam)

PATIENTS ZONE, external and internal patients at top and bottom the EXAM ZONE in the center area, and the TECHNOLOGY ZONE, for MR, CT and remote controlled table (5.6).



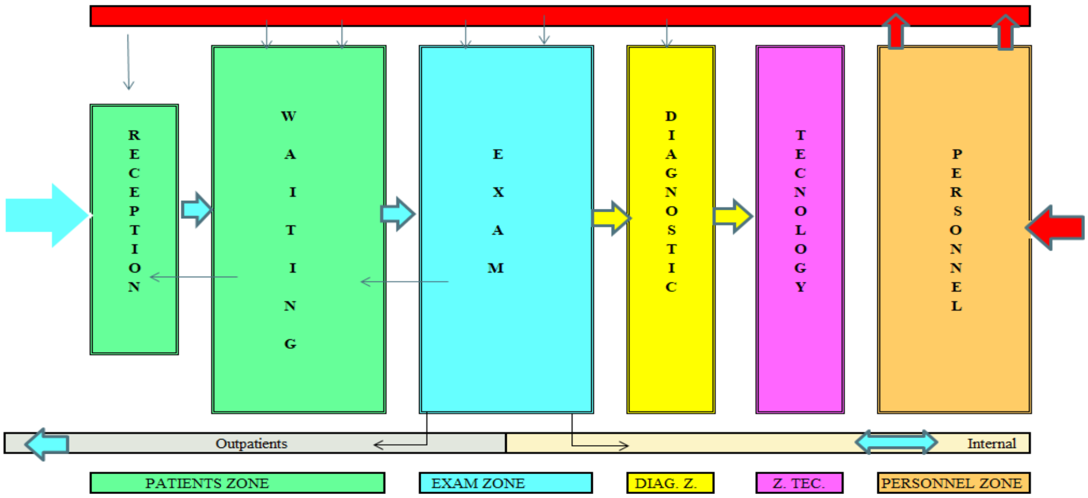
(5.7.-Conventional radiology and ultrasound)

The vertical position of those PATIENTS ZONE and EXAM applies to conventional radiology and ultrasound (5.7). Below are the DIAGNOSTIC ZONE and PERSONNEL (5.8) integrated, sharing the circulation corridor that is common for the staff and internal patients.



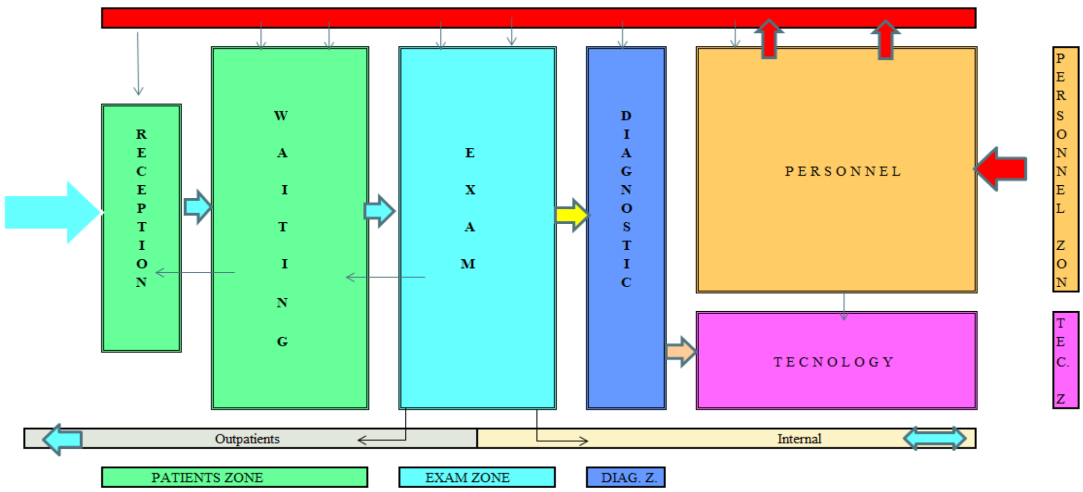
(5.8.-Diagnostic and personnel)

A second model fitted (5.9) more directly the areas of PERSONNEL and DIAGNOSTIC ZONES in a common central block with clear differentiation of corridors.



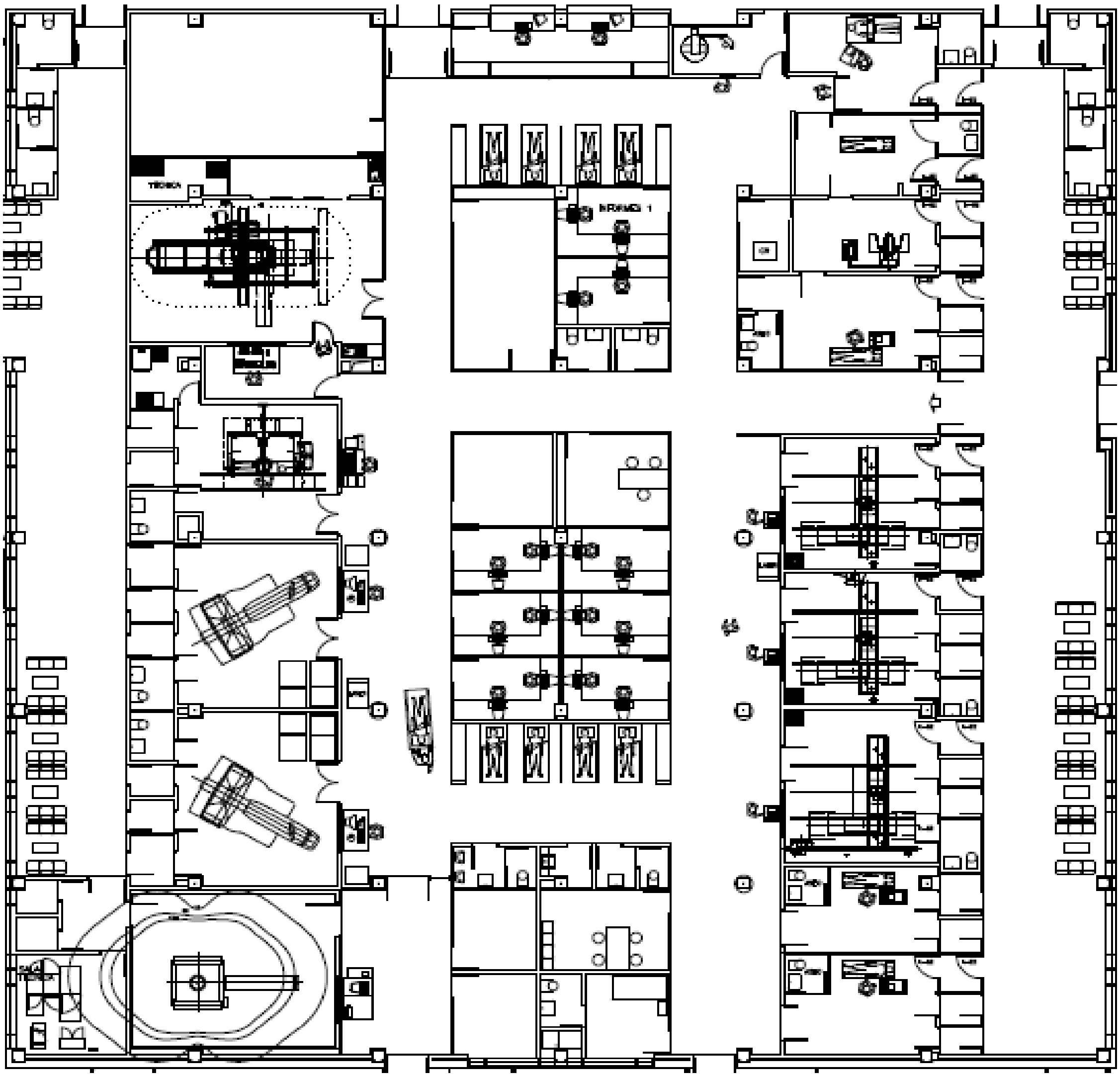
(5.9.- Diagram of movement of the personnel)

The PERSONNEL and DIAGNOSTIC ZONES share the corridor. The cabins (cubicles) in the DIAGNOSTIC ZONE are very close to the exam rooms. In-patients are mixed, in the same hall, with technicians and radiologists. The emergency use ultrasound and conventional rooms next to the emergency department. The total area of the department is 1.440 m2 (15.500 ft2)(5.11).



(5.10.- Diagnostic and personnel with separate corridors)

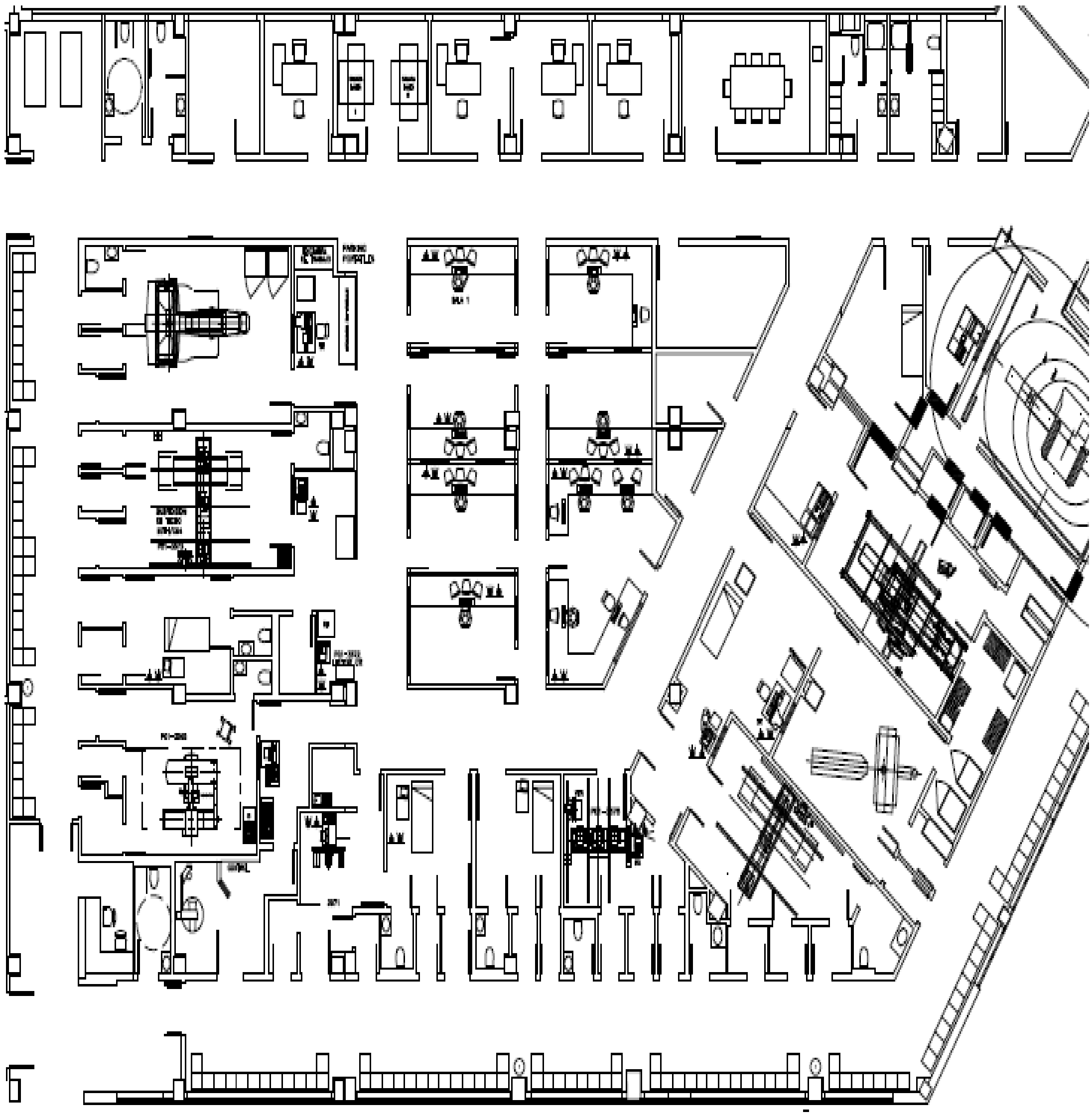
In a third model the PERSONNEL and DIAGNOSTIC ZONES (5.12) are well distinguish having a clear separation corridors allowing greater isolation and concentration to radiologists in their daily work, staying close to the modalities.



(5.11-Personnel and diagnostic share corridors)

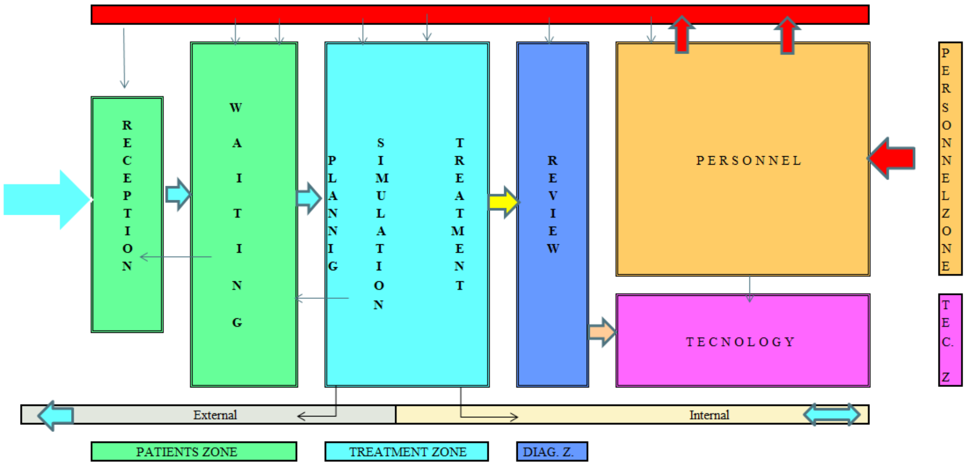
Scheme (5.12) shows the DIAGNOSTIC ZONE with rooms for diagnostic radiologists very close to the modalities, but with enough space to accommodate two reading workstations for the radiologists. The department carries out 150.000 annual exams, having reserve space for a second MRI and a second interventional vascular room. The total area is 1.613 m2 (17.362 ft2).

Conventional radiographic diagnostic rooms have two detectors except the chest, which is a single detector. Mammography make the examinations with a CR system.



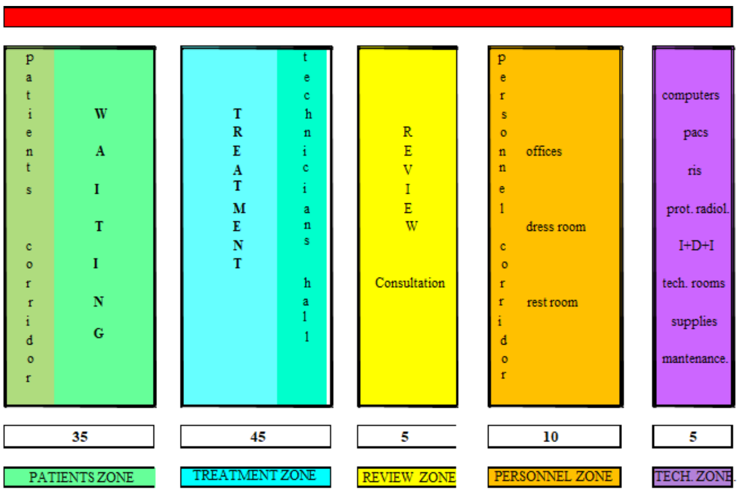
(5.12.-Diagnostic zone with independent corridors)

It is possible to extend the concept of ZONES to radiotherapy departments (5.13), and here take into account the high surface occupied by linear accelerators and brachytherapy treatment units. One analysis of various departments of this type brings us to represent areas in the following way (5.13) of the diagram.



(5.13.- Activities in a radiotherapy department)

In such a way that surfaces of the areas remain with the configuration (5.14).



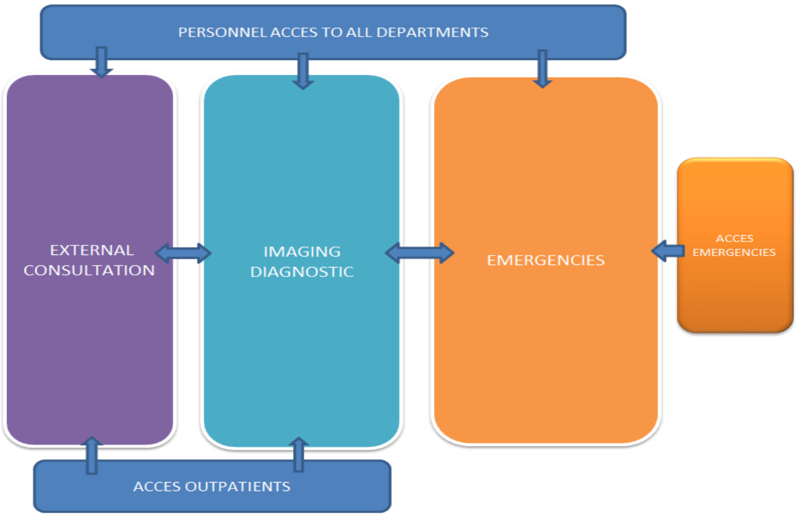
(5.14.-Zones in radiotherapy)

V.II.- LOCATION OF THE IMAGING DEPARTMENT

Within a hospital or healthcare facility that provides many medical services the location of the imaging department is a choice that needs to be done at the time of planning, leaving the proper surface, which will be determined in the next section, to subsequently make the distribution of zones and the design of the different diagnostic rooms and subordinate dependencies.

The location of the departments of nuclear imaging and radiotherapy has been for many years subjected to the influence of the basements. Aiming to prevent reinforcements in the structures of the buildings were looked for areas where not needed and the radioactive shielding costs were reduced at the same time. The counterbalance results was most difficult communication for patients and greater discomfort for the department personnel.

Today the imaging departments are mostly occupying areas on the ground floor, where the patient access is more convenient from the exterior or parking areas, and the interior area closed to the outpatient consults of the hospital. Staff access to the department must be also easy. Today, with the HIS and its integration with the RIS, citation is made from the outer query (located elsewhere in the hospital) to the room of the imaging department that has free resources. The clinician in his inquiry may have easy access at HIS citation of the RIS image department agendas. Therefore the patient on their way through the health center, and in one visit to the imaging department, can solve various required tests for the diagnosis in some cases.



(5.15.- Location of th imaging department)

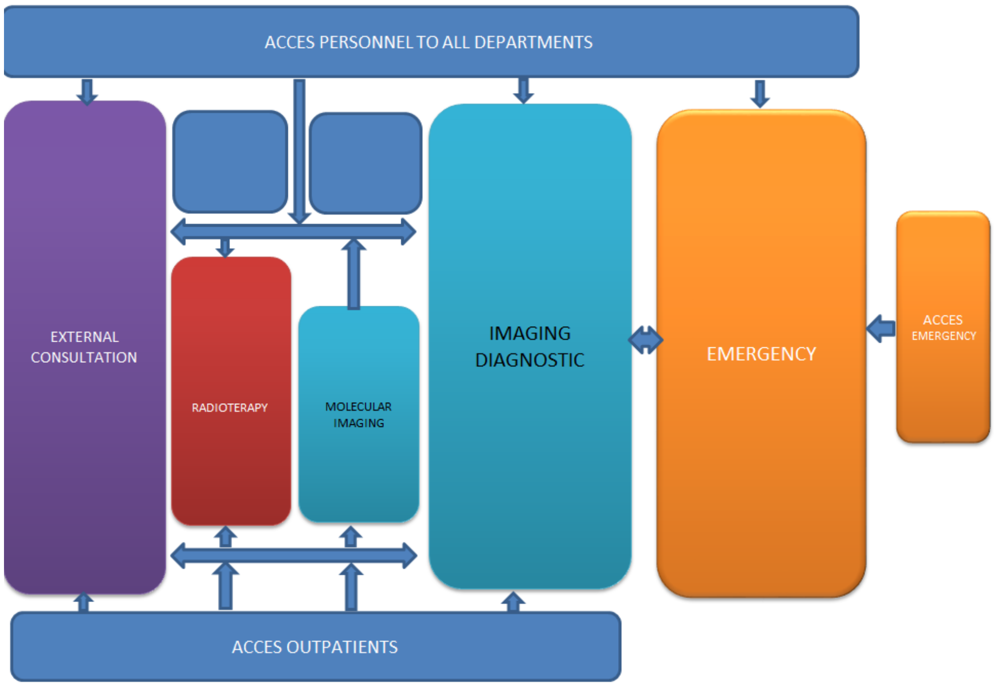
An additional factor is the access from the hospital floors to the imaging department. The architect has to find itineraries suitable, including elevator capable for stretchers, for patients in bed from their rooms until the imaging or the radiotherapy departments.

It is ideal that the emergency department has their own common diagnostic imaging within its own physical space, and otherwise, access to the imaging department must be very simple , which forces to place both departments together to connect them giving imaging services to patients in emergency, as we see in the scheme (5.15). The problem that brings is a meticulous study of the workflow in the emergency room. Some hospitals receive substantial amount of emergencies and this can block aisles, waiting and examination rooms in the imaging department if not well planned.

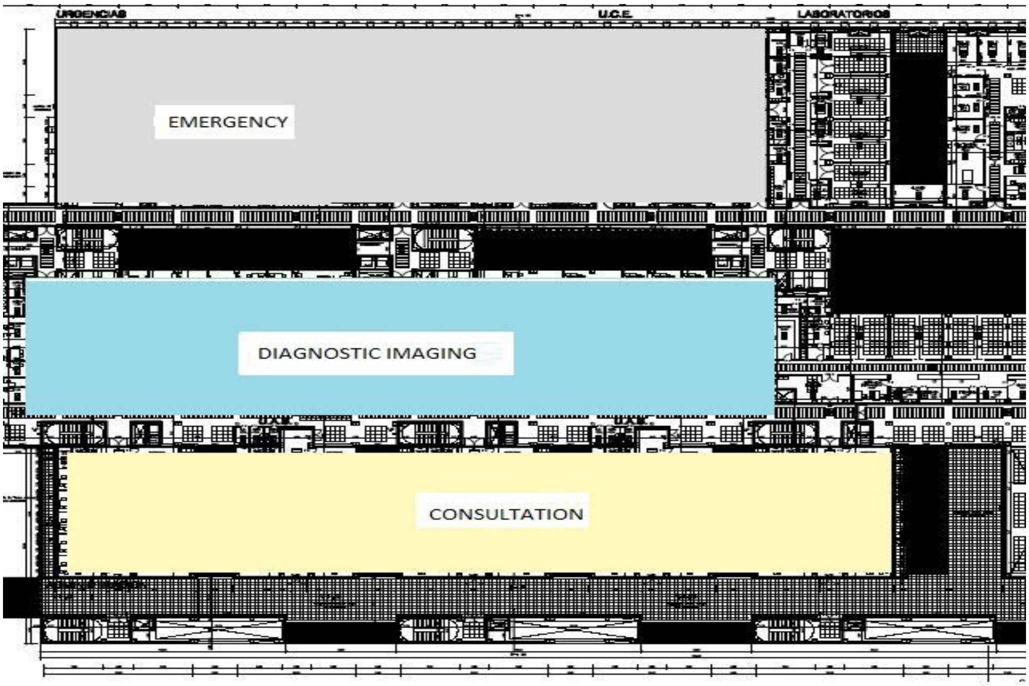
Areas of natural light are desirable for patients and staff, moreover in the department of radiotherapy that traditionally was in a basement by the construction of bunkers. A modern study of lighting with correct programming technology can alleviate the situation changing the color of white light, intensity and hue, depending on the time of day.

If nuclear medicine exams are integrated into the imaging department requires a special installation in the area of less frequentation, to meet the needs of the nuclear medicine examinations in relation to radiation protection and contamination.

An ideal location of the imaging, nuclear medicine and radiotherapy departments is represented in figure (5.16). The proximity of these three important centers of hospital activity plays an important role in cancer care and it will be more in the future, where radioactive isotopes will be more significant even with the modern molecular medicine. It should be noted that it is not always possible this provision due to architectural problems but it is desirable for the architect who design a hospital to consider this aspect in his project.



(5.16.- Location of the imaging, nuclear medicine and radiotherapy departments)



(5.17.- Location of the department between external consultations and emergencies)

Special mention are the image departments dedicated exclusively to the diagnosis for outpatients, without additional services. The study of the location depends on very different parameters that should define a proper analysis of the supply of services and the availability of these services that the health center managers may wish to provide. Market research to define the implementation of the center must be extended to the correct geographical, urban and architectural location of the center.

V.III.- DEPARTMENT SURFACE CALCULATION

The goal of the planner, since the first phase of his actuation, is to know what is the space required by the location of the imaging services that aims to provide. Space costs money, and in some projects can be a large part of the total cost of the project, probably less than the equipment, but undoubtedly very valuable. Possibly have to be considered licensing of local authorities for the installation of the department, and other efforts to weigh with architects and builders for the evaluation of the project, and therefore has to be calculated in detail the surface required for the imaging, nuclear medicine and radiotherapy department.

The knowledge of the activity planned for the department is, logically, the basis for the calculation and after this fact the determination of the production of each room and the estimated number of professional personnel that will carry out the assistance work.

Next will be discussed several procedures to calculate the gross surface area of the department, i.e. with walls, skylights, pillars, downpipes, etc.

- Calculation on the basis of the net area of examination rooms. This method primarily apply through a worksheet uses experimental factors based on current designs included in this publication, and were also described by Fisher in the early 1980s.
- Calculation based on all net surfaces required, and considers an approximate experimental factor that estimated the thickness of walls, pillars, sizes of downspouts, corridors, etc.
- Approximate calculation as a direct function of frequency.

V.III.I.- IMAGING DIAGNOSTIC DEPARTMENTS

The impressive development of imaging techniques described in Chapter 2, has led to a continuous evolution of the surface in the imaging departments, or as called for some imaging units, by the needs of the increasing population, aging and the growth of different imaging techniques which demand has increased, in almost all, inexorably throughout its history. For this reason it is essential to analyze, in the temporal field of view possible, the foreseeable future to establish the criteria of growth of the department.

Various methods have been described for the determination of the surface, some proven lack of reliability, and other dependents of temporary variables in the evolution of the expectations of some modalities. Have prevailed the ones based on a research, first on the care demand envisaged for the department, and then fixing the workload, as real as possible , that will have the department, not only at the time of the opening to the patients, but in a period of reasonable foresight, which should at least reach ten years.

An analysis of the demand seems simple in the centers of public healthcare, where the population is assigned to a health center in a territory and there is a known number of persons. Just investigate the frequency of the area and assign the part of this that will come to the center in question, discounting those that already exist, which reduce the frequentation of the area of the center. If the distribution of examinations is known by modalities, as it was explained in Chapter 2, can be reached easily the example exposed in figure (5.18) for one image department of a hospital with 240 beds, and a population of 160.000 inhabitants. The total density of the area, which is 1.200 is known and there are imaging units providing services that reduce the frequency to 1.000 to the hospital in question.

There are cases where the situation is more complicated and in-depth market research is required to provide clear information and sufficient, to allow a correct planning workload and obtaining the economic outcomes that requests the project. The research team must, not only consult local sources, but international data and to establish correlations and constraints for the determination of workload. Chapter 2 reference data can provide guidance for finding information.

In this spreadsheet (5.18) have been obtained the average of each room productions using data (5.19) of medium acquisition times described in Chapter 2 for digital equipment, that for convenience are reproduced in the table of figure (5.19). In a not very long future time, this list will increase with the incorporation of new modalities which are already announced by the manufacturers for the new techniques of molecular imaging

Population	Freq.	Exams	%	Nº Ex/room	Aver.prod.	Nº	Surface		Surf.(1)	
					*(1)	rooms	m2	ft2	m2	ft2
		RD	64	102.400	26.250	4,0	20	215	80	861
		Fluoro	3	4.800	5.250	1,0	25	269	25	269
		Ortopantot.	1	1.600	13.125	1,0	8	86	8	86
		Bone Miner.	1	1.600	7.875	1,0	15	161	15	161
160.000	1000	Mammogr.	4	6.400	7.875	1,0	12	129	12	129
			73							
		CT	8	12.800	10.500	2,0	30	322	60	645
		MR	8	12.800	6.300	2,0	35	376	70	753
		Ultrasound	10	16.000	5.250	3,0	15	161	45	484
		Vascular	1	1.600	1.575	1,0	35	376	35	376
			27							
			100	160.000		16			350	3.764
		Net examination surface							350	3.764
		Gross department surface			**Regional Hospital**				**2.100**	**26.348**

(5.18.-. Calculation of the surface)

EXAMINATION TIME		MINIMUM	MEDIUM
RADIOGRAPHY (RD)	•2 detectorS	2	3
FLUORO	•1 detector	7	15
MAMMOGRAPHY	•1 detector	6	10
ORTOPANTOTOMOGRAPHY	•1 detector	3	6
ULTRASOUND	•2D-3D	8	15
CT MULTISLICE(TMC)	•16 slices	6	15
MAGNETIC RESONANCE(MR)	•1,5 T	15	25
GAMMACAMERA	•2 detectors	12	25
PET- CT	•	10	30
INTERVENTIONAL	•1 detector	40	60

MINUTES

(5.19.-Examination times)

The journey has seven hours in the working day, 250 days per year, exception of CT and MR where are work calculated in a double journey, double shift, and the room with 75 percent occupation factor. Average surface for the examination room are those described in Chapter 4. The calculation of the total net exam area, multiplied by a factor 6 leads to practical results, with a total gross area of 2,100 m2 (12.916 ft2) for the imaging department. This factor is experimental and contrasted in various current projects of departments of diagnostic imaging, some exposed in this book. These are data from the moment of opening or beginning of the activity of the health center. Now we must include correction factors with forecasts of population growth, if there is any in the area, and so must resort to local statistics and also look for the growth of demand for each one of the modalities. The following worksheet expand (5.20) the calculations to 10 years.

The entered criteria of growth, for this case, are of a 2 percent annual population, occurring in areas of immigration, by services of residential tourism, or both, and a mixture of growths of different modalities according to recent data of the last few years.

The table would propose us to increase the area of the department by 50 percent, then to avoid it must be taken, if architecturally and financially there is no other solution, measures of double shift in the rooms where only worked on a seven hour shift , to increase the production of the rooms and increasing the surface in areas of the rooms where it had already been projected the department with two seven-hour shifts, like the magnetic resonance e.g., where with these growth parameters the increase from 2 to 4 rooms in 10 years seems inevitable unless they are measures of subcontracting with other diagnostic centers to examine the foreseeable surplus of patients, if really there is no more

IMAGING DEPARTMENT GROSS SURFACE CALCULATION

Population	Freq.	Modalities	%	Exams/ Room	Average Production	Nº	Medium Surface		Surface 1		Population Growth	Nº	Modality Growth	Nº	Surface 2	
	ex/yr				*(1)	rooms	m2	ft2	m2	ft2	*2	rooms	*(3)	rooms	m2	ft2
		RD	64	102.400	26.250	4,0	20	215	80	861		5,0	0	5,0	100	1.076
		Fluoro	3	4.800	5.250	1,0	25	269	25	269		1,0	0	1,0	25	269
		Ortopantot.	1	1.600	13.125	1,0	8	86	8	86		1,0	0	1,0	8	86
		Bone Min.	1	1.600	7.875	1,0	15	161	15	161		1,0	2	1,0	15	161
160.000	1000	Mammogr.	4	6.400	7.875	1,0	12	129	12	129	2	1,0	2	1,0	12	129
			73													
		CT	8	12.800	10.500	2,0	30	645	60	645		2,0	3	2,0	60	645
		MR	8	12.800	6.300	2,0	35	753	70	753		3,0	6	4,0	140	1.506
		Ultrasound	10	16.000	5.250	3,0	15	161	45	484		4,0	5	5,0	75	807
		Intervent.	1	1.600	1.575	1,0	35	378	35	378		1,0	7	2,0	70	753
			27													
			100	160.000		16			350	3764		19,0		22,0	505	5.432
		Net Exam Surface							350	3.764					505	5.432
		Gross Depatment Surface			Regional Hospital				**2.100**	26.348					**3.030**	32.592

*(1) Experimental data with digital equipment

Working hours	7	14	Days/Year	250

Occupation Factor	0,75

*(2) Wath Region Statistics.

Population Growth	2

Years considered	10

*(3) Wach Region and International Statistics

Modalities Growth

MR	6
CT	3
ULTRASOUND	5
VASCULAR	7
RD	0

MAMMOGRAPHY	2
BONE MINERAL DENSITY	2

(5.20.- Calculation considering increases in population and demand of modalities)

space in the health center. Additionally must be studied other management measures to improve efficiency, etc.

IMAGING DEPARTMENT GROSS SURFACE CALCULATION

Population	Frequency	Modality	%	Exams	t exa	Medium Production	R	R	Medium Surface	Net Surface	Population Growth	R	R	Modality Growth	R	R	Total Net Surface
Population	Exam/1000				min	Exams			m 2	m 2	%						m 2
160.000	1.000	DR	34	54.400	3	26.250	2,1	3	20	60		2,5	3,0	0	2,5	3	60
		FL	3	4.800	15	5.250	0,9	1	25	25		1,1	1,0	0	1,1	1	25
		ORT	1	1.600	6	13.125	0,1	1	8	8		0,1	1,0	0	0,1	1	8
		DEN	1	1.600	15	5.250	0,3	1	15	15		0,4	1,0	4	0,5	1	15
		MAM.	3	4.800	10	7.875	0,6	1	12	12		0,7	1,0	4	1,0	1	12
		CT	6	9.600	15	10.500	0,9	2	30	60		1,1	1,0	4	1,5	2	60
		MR	8	12.800	25	6.300	2,0	2	35	70		2,4	3,0	5	3,7	4	140
		US	8	12.800	15	5.250	2,4	2	15	30		2,9	3,0	5	4,4	5	75
		VAS	1	1.600	60	1.313	1,2	1	35	35	2	1,5	1,0	5	2,2	2	70
160.000	1.000	US	3	4.800	15	26.280	0,2	1	15	15		0,2	1,0	5	0,3	1	15
		DR	30	48.000	3	131.400	0,4	1	20	20		0,4	1,0	0	0,4	1	20
		CT	2	3.200	15	26.280	0,1	0	35	0		0,1	0,0	4	0,2	0	0
			100														
0	0	DR	67	0	8	19.688	0,0	0	20	0		0,0	0,0	0	0,0	0	0
		FL	7	0	30	5.833	0,0	0	25	0		0,0	0,0	0	0,0	0	0
		US	10	0	20	5.625	0,0	0	15	0		0,0	0,0	5	0,0	0	0
		CT	8	0	25	6.300	0,0	0	30	0		0,0	0,0	4	0,0	0	0
		MR	8	0	60	2.625	0,0	0	35	0		0,0	0,0	5	0,0	0	0
			100														
				160.000				16		350			17,0			22	500

NET EXAMINATION SURFACE	350	500
DEPARTMENT GROSS SURFACE	2.100 22.604 ft2	3.000 32.291 ft2

GREATER NEED OF SPACE BECAUSE:
* Population Growth
* Modality Demand Increase

CALCULATION PARAMETERS

Jornada (horas) =	7	14	24
Dias/ año =	250	250	365

*(2) Watch Statistics for every Region

Population Growth (%) 2

*(3) Watch Statistics National and International

Room Occupation Factor 0,75

Years of Growth 10

Modalities Growth

MR	5	RD	0
CT	4	Fluoro	0
Ultrasound	5	Mammogr	4
Vascular	5	Bone Min.	4

(5.21.- Calculation of the surface with emergencies)

Spreadsheet with two columns, one for the calculated room and another adjacent to the corresponding round is shown above in the page, figure (5.21).

There are countries, or regions, where emergencies are a very important component of the total workload. In some cases it exceeds 50 per cent of tests that are made in the image department. Emergency exams are distributed mainly in conventional radiology, then with one smaller percentage of ultrasound and even less in multisclice CT (only in some cases currently); then it is worth separating these emergencies in the worksheet to define in the calculation, the distribution of the workload and to reorder the surface.

IMAGING DEPARTMENT GROSS SURFACE CALCULATION

Population	Freq.	Exams	%	Nº Ex/room	Prod. Med.	Nº	Med.Surface	Surface 1	Pop. Growth	Nº	rooms	Nº	Surface 2
					*(1)	rooms	m2	m2	*(2)	rooms	*(3)	salas	m2
		RD	34	54.400	26.250	2,0	20	40		3,0	0	3,0	60
		RD emerg	30	48.000	127.440	1,0	20	20		1,0	0	1,0	20
		Fluro	3	4.800	5.250	1,0	25	25		1,0	0	1,0	25
		Ortopant.	1	1.600	13.125	1,0	8	8		1,0	0	1,0	8
		Bone Min.	1	1.600	7.875	1,0	15	15		1,0	2	1,0	15
160.000	1000	Mammogr.	4	6.400	7.875	1,0	12	12	2	1,0	2	1,0	12
			73										
		CT	8	12.800	10.500	2,0	30	60		2,0	3	2,0	60
		MR	8	12.800	6.300	2,0	35	70		3,0	6	4,0	140
		Ultras.	7	11.200	5.250	2,0	15	30		3,0	5	4,0	60
		Ultrs. Emerg	3	4.800	26.280	1,0	15	15		1,0	5	1,0	15
		VASCULAR	1	1.600	1.575	1,0	35	35		1,0	7	2,0	70
			27										
				160.000		15		330		18,0		21,0	485

Net Surface		330	485
Department Gross Surface	Regional Hospital	1.980	2.910
		21312	31.322
		ft2	ft2

*(1) Regarding experimental data for Digital Equipment

Journey(hours)	7	14	Days/year	250

Room Occupation Factor	0,75

*(2) Watch Region Statistics

Crecimiento de la Población	2

Years for Calculation	10

*(3) Watch Region Statistics, National and International.

Modalities Growth

MR	6
CT	3
Ultrasound	5
Vascular	7
RD	0

Emergency 24h-365 dias

Mammographie	2
Bone Mineral Density	2

(5.22.- Calculation of the surface with emergency data separated)

The analysis leads to a slight reduction of the space by placing a conventional radiology room and another ultrasound in the emergency department, or on the imaging department away from the central work, and close to the imaging department.

In many countries, and in some centers, the modalities of nuclear medicine like gammacameras and PET-CT are located in the image department. Special considerations, in the same way should be provided for the calculation of the number of rooms and space, understanding that the frequency of NM has special connotations different from the previously described number for diagnostic imaging.

IMAGING DEPARTMENT GROSS SURFACE CALCULATION

Population	Freq.	Exams	%	Nº Ex/Room	Med. Prod. *(1)	Nº Room	Med.Surf. m2	Surface 1 m2	Popul. Growth *(2)	Nº Rooms	Modal.Growth *(3)	Nº Room	Surface 2 m2	ft2
		RD	64	102.400	26.250	4,0	20	80		5,0	0	5,0	100	1.076
		Fluoro	3	4.800	5.250	1,0	25	25		1,0	0	1,0	25	269
		Ortopantot.	1	1.600	13.125	1,0	8	8		1,0	0	1,0	8	86
		Bone Mineral	1	1.600	7.875	1,0	15	15		1,0	2	1,0	15	161
160.000	1000	Mammogr.	4	6.400	7.875	1,0	12	12	2	1,0	2	1,0	12	129
			73											
		CT	8	12.800	10.500	2,0	30	60		2,0	3	2,0	60	645
		MR	8	12.800	6.300	2,0	35	70		3,0	6	4,0	140	1.506
		Ultrasound	10	16.000	5.250	3,0	15	45		4,0	5	6,0	75	807
		Interventiona	1	1.600	1.575	1,0	35	35		1,0	7	2,0	70	753
			27											
		Gammacam.		1.300	3.150	1,0	25	25		1,0	2	1,0	25	269
400.000		PET - CT		700	2.625	1,0	40	40		1,0	6	1,0	40	430
		Lab				1,0	30	30		1,0		1,0	30	322
				162.000		16		445		22,0		26,0	600	6.458

		m2	ft2	m2	ft2
Net Surface		445	4.789	**600**	**710**
Gross Department Surface	**District Hospital**	**2.225**	**23.949**	**3.000**	**32.291**
	Regional Hospital	**2.670**	**28.739**	**3.600**	**38.750**
	University Hospital	**3.115**	**33.529**	**4.200**	**45.208**
	Outpatient Diagnostic Center	**2.670**	**28.739**	**3.600**	**38.750**

*(1) Experimental data in Digital Equipment

Jornada(horas) =	7	14	Dias/año=	250

Room Occupation Factor	0,75

*(2) Watch Aerea Statistics

Population Growth	2

Years for calculations	10

*(3) Watch National and International Statistics

Modalities Growth

MR	6
CT	3
Ultrasound	5
Vascular	7
DR	0

Mammography	**2**
Bone Mineral Density	**2**
Gammacamera	**2**
PET-CT	**6**

(5.23--Calculation of the surface with nuclear medicine)

Comparison with imaging without MN activities shows an increase of 500 m2 (5318 ft2), which should cover the needs of more space in the areas of patient, examination, diagnosis, staff and technology. As we have seen a FACTOR 6 has been used, that multiply the net area of examination to obtain the total gross surface.

The experiences in recent designs indicate a FACTOR 5 in district hospitals, smaller hospitals, where there is no vascular and only one CT and one MR, and a FACTOR 7 for university hospitals where teaching involves more space needs.

There is a special mention for the hospitals or facilities that provide care to patients mainly private, i.e. patients who do not belong to the public sector, but either pay their hospital bills directly at the hospital or come from health insurance in contracting with the hospital or outpatient center, they pay their rates of medical acts or interventions on the hospital. The patient pays its quotes to their health insurance and this pays to the hospital.

Already was indicated in chapter II that the analysis of the demand for private hospitals involves greater difficulties than for the public. Those required for the planning of the imaging department, with or without nuclear medicine and radiotherapy, with a detailed market study to predict the type of patients that attend the center, what will be the external consultations, type of pathologies will attend and what type of services will offer the hospital to the patients. Therefore attendance is only one fact to keep in mind and consider in the calculation of the area where the center is to be implanted but have to go into more detail to define the own frequency of the center. Once defined this apply the worksheet in the determination of the surfaces since the calculation parameters for the gross surface are the same.

In countries with public and private health systems, which are the most, while the percentage between them changes significantly depending on the country, frequency data for planning the imaging departments are important for both. There are interactions between the two systems that cause changes in demand assistance from one to another system based on quality and cost criteria, in addition to the economic situation of the country and the population in general. These interactions may be planned by their managers, with which the frequency data is an important orientation for both. Or not be planned and changes of the systems by the users can cause failures in one or other of the held services.

A very specific example is that of a pediatric hospital inserted in a university hospital. The first factor to observe are the estimated average production of diagnostic rooms, much lower in general services due to the greatest times per procedure with children (72).

PEDIATRIC DIAGNOSTIC IMAGING DEPARTMENT GROSS SURFACE CALCULATION													
Population	Freq	Exams	%	Nº Ex/Room	Med. Prod.	Nº	Med. Surf.	Surface 1	P. Growth	Nº	room	Nº	Surface 2
					*(1)	room	m2	m2	*(2)	room	*(3)	salas	m2
		DR	34	19.040	19.688	1,0	20	20		1,1		1,0	20
		DR Emerg.	30	16.800	49.275	1,0	20	20		0,4		1,0	20
		Fluoro	7	3.920	5.250	1,0	25	25		0,8		1,0	25
80.000	700												
			71										
		CT	8	4.480	6.300	1,0	30	30		0,8	3	1,0	30
		MR	8	4.480	2.625	2,0	35	70		1,9	5	2,0	70
		Ultrasound	10	5.600	7.875	2,0	15	30		0,8	10	3,0	45
		Ult. Emerg.	3	1.680	19.710	1,0	15	15		0,1	10	1,0	15
			29										
				56.000		9		210		5,8		10,0	225

Net Examination Surface		210	225
		2.260	2.421
		ft2	ft2
Gross Department Surface	University Hospital	1.470	1.575
		15.822	16.953
		ft2	ft2

*(1) Regarding experimental data with Digital Systems. Journey 7 h 250 days/year. 2 Technicians/room. Occupation Factor= 0,75

Working time(hours)	7	14	Days/year	250

Room Occupation Factor	0,75

*(2) Watch Region Statistics

Population Growth	1

Years for calculation	10

*(3) Watch International Statistics

Anual Modalities Growth (%).

MR	5
CT	3
Ultrasound	10
Vascular	10

DR Constant

Emergency 24 h 365 d/y

(5.25.- Surface of a pediatric imaging department)

The department is planned to work in two seven-hour shifts, and ten-year calculation is adopted with one percent annual population growth with a maximum modalities growth described in the spreadsheet.

The estimated average examination times are as follows:

Pediatric examination time with digital systems		
Modality		Medium (minutes)
DR	2 Detectors	8
Fluoro	1 Detector	30
Ultrasound	3D-4D	20
CT	64 Slices	25
MR	2D-3D	60

(5.26-Average exam time in pediatrics)

A larger model, allows to separate pediatric patients, at a large university or a general hospital, of the patients of emergency and the central imaging department (5.27). The attached schema allows to observe data calculated with round the number of rooms, in an attached column. Calculating with variables of the increase of population and increases in consumption of modalities and also provides a column with the number of rooms and one additional row with the necessary rounds.

Further optimization possibilities offer these large hospitals, where the number of inpatients is significant enough to deal with internal diagnostic rooms. This additionally allows the clearer separation of patients internal and external with workflows and circulations clearly differentiated (5.28).

A second procedure, already previously given at the beginning of this section III is based on tabular all net surfaces of each of rooms and dependencies that comprise the department (image rooms, offices, waiting rooms, etc.) and multiply the total net surface area by a factor that will allow us to reach the total gross surface of the department. Logically the determination of the number of rooms must go through the previously described tasks of frequentation, production of each room, occupation factor, etc. The following table helps to explain the procedure

IMAGING DIAGNOSTIC DEPARTMENT GROSS SURFACE CALCULATION

Population	Frequency.	Modality	%	Exams	t exa	Product. Medium	R	R	Av.Surface	Surface1	Population Growth	R	R	mODALITY Growth	R	R	Surface2
Habitantes	Exam/1000				min	Examenes			m 2	m 2							m 2
		DR External	22	96.800	3	49.000	2,0	2	20	40		2,2	4,0	0	2,2	4	80
		DR internal	12	52.800	3	49.000	1,1	1	20	20		1,6	2,0	0	2,2	2	40
		Fluoro	3	13.200	15	9.800	1,3	2	25	50		1,5	2,0	0	1,5	2	50
		Ootopantot.	1	4.400	6	24.500	0,2	1	8	8		0,2	1,0	0	0,2	1	8
		Bone Mineral	1	4.400	15	9.800	0,4	1	15	15		0,5	1,0	4	0,7	1	15
440.000	1.000	Mammogr.	3	13.200	10	14.700	0,9	1	12	12		1,0	1,0	4	1,4	2	24
		CT	6	26.400	15	9.800	2,7	3	30	90		3,0	3,0	4	4,1	4	120
		MR	8	35.200	25	5.880	6,0	6	35	210		6,6	7,0	5	9,9	10	350
		Ultrs Internal	2	8.800	15	9.800	0,9	1	15	15		1,0	4,0	5	1,5	6	90
Internal		Ultras. Ext	6	26.400	15	9.800	2,7	3	15	45		3,0	3,0	5	4,1	4	60
External		Vascular	1	4.400	60	2.450	1,8	2	35	70	1	2,0	2,0	5	3,0	3	105
		Ultrasound	3	15.000	15	24.528	0,6	1	15	15		0,7	1,0	5	1,0	1	15
500.000	1.000	DR	30	150.000	3	122.640	1,2	2	20	40		1,3	2,0	0	1,3	2	40
Emergency		CT	2	10.000	15	24.528	0,4	1	35	35		0,4	1,0	4	0,6	1	35
			100														
		DR	67	28.140	8	18.375	1,5	2	20	40		1,5	2,0	0	1,5	2	40
		Fluoro	7	2.940	30	5.444	0,5	1	25	25		0,6	1,0	0	0,6	1	25
60.000	700	Ultrasound	10	4.200	20	5.250	0,8	1	15	15		0,9	1,0	5	1,3	2	30
		CT	8	3.360	25	5.880	0,6	1	30	30		0,6	1,0	4	0,9	1	30
Pediatric		MR	8	3.360	60	2.450	1,4	1	35	35		1,5	2,0	5	2,3	3	105
			100														
				503.000				33		810			41,0			52	1.262

NET EXAMINATION SURFACE	810	1.262

DEPARTMENT GROSS SURFACE	*UNIVERSITY*	5.670 61.031 ft2	ADDED NEED OF SPACE: * Popuation Growth * Modalities growth demand	8.834 95.088 ft2

VARIABLES DE CALCULO

*(1) Regarding experimental data with Digital Systems

Journey (hours)	7	14	24
Days/year =	250	250	365

Room Occupation Factor | 0,7

*(2) Watch Statistics

Population Growth | 1

Years for calculation | 10

*(3) Watch National and International Statictics.

Modalities Growth

MR	5	DR	0
CT	4	Fluoro	0
Ultrasound	5	Mamm.	4
Vascular	5	Bone Min.	4

(5.27 y 5.28.- Calculation of the surface with breakdown of internal, external, pediatric and emergency patients)

IMAGING DEPARTMENT SURFACE CALCULATION

Regional Hospital — 240 Beds — 160.000 Exam/year

Room	Exam	Control	Prepar.	Cabins	WC	Tech	Others	Total	Units	Total
MR	35	8	9	5	2	11		**70**	2	**140**
CT	30	8	9	5	2	10		**64**	2	**128**
FLUORO	25	8	0	5	2	8		**48**	1	**48**
ULTRASOUND	15	0	0	5	2	0		**22**	4	**88**
DR	20	6		5	2	0		**33**	3	**99**
MAMMOGRAPHY	12	0		5		0		**17**	1	**17**
BONE MINERAL DENS.	15	2		5		0		**22**	1	**20**
ORTOPANTOT.	8	0				0		**8**	1	**8**
CARDIO-VASCULAR	35	12	12	2		12	18	**91**	1	**73**
DIAGNOSTIC							12	**12**	6	**72**
OFFICES							15	**15**	3	**45**
MEETING							40	**40**	1	**40**
STORAGE							20	**20**	4	**80**
WAITING BEDS							20	**20**	4	**80**
RECEPTION							20	**20**	1	**20**
REST							25	**25**	1	**25**
VEST							0	**0**	0	**0**
ELECTRICITY							3	**3**	1	**3**
TELEPHONE							3	**3**	1	**3**
WC PATIENTS							15	**15**	2	**30**
REST RADIOLOGISTS							20	**20**	1	**20**
WC PERSONNEL							10	**10**	2	**20**
WAITING 20m2*17 Rooms							20	**20**	17	**340**
NET SURFACE										**1.399**
Walls, piping, structure, others...										1,5
GROSS SURFACE										**2.099**

(5.29.- Gross surface as a multiplying by a loss factor the net surface)

The data obtained are very similar to the previous ones, even though the worksheet from the first procedure presents additional information on the evolution of the department, and it provides a valuable strategic tool to the planning team to be able to estimate the future surface or seek management formulas that solve the needs which will result in the frequency growth, by many factors that motivate it.

A third procedure for quick calculation of the surface of one imaging department (5.30), more simple, which leads to results next to the obtained with the other methods, but with lower accuracy. It consists of a surface to be calculated for every 1.000 exams. This can be drawn up in the following way:

DISTRICT HOSPITAL (100 Beds)	10 m2/1.000 exams…(107 ft2/1000)
REGIONAL HOSPITAL (150 - 300 Beds)	12m2/1.000...(129 ft2/1000)
GENERAL HOSPITAL (300 - 500 Beds)	13 m2/1.000…(139 ft2/1000)
UNIVERSITY HOSPITAL (400 - 900 Beds)	14 m2/1.000…(150 ft2/1000)

(5.30.- Fast calculation of the surface of the department)

For example (5.18) it would mean, 160.000 exams x 12m2/1000 = 1.920 m2, a difference of 12% compared to those calculated previously, and only 6.7% of the same department when the emergency (5.22) exams are broken down.

III.II.- NUCLEAR MEDICINE

Already was indicated how to undertake the calculation of imaging department when the modalities of nuclear medicine are located within this. In many cases happens that it is in a separate place and then the department planning becomes one added task to contemplate completely independent. Frequency provides a basic value, valid for the determination of the surface in the same way as in the previous section, while changes the parameters and distributions by modalities. Perhaps the first to be done is to fix the most common exam times to set the mean production of the different rooms. Already has been shown the medium surfaces of each room in chapter IV so we have the baseline data to address the calculation of the surface.

NUCLEAR MEDICINE DEPARTMENT GROSS CALCULATION SURFACE

Population	Freq	Exams	%	Nº Ex/Room	Med. Surf.	Nº	Med. Surf.	Surface 1		P.G.	Nº	M. Growth	Nº	Surface 2	
					*(1)	Room	m2	m2	ft2	*(2)	Room	*(3)	Room	m2	ft2
	30	GAMMAC-G	65	9.750	3.150	3,0	25	75	807		3,0	4	5,0	125	1.345
	30	GAMMAC-C	15	2.250	3.150	1,0	25	25	269		1,0	4	1,0	25	269
	30	SPECT-TAC	5	750	2.625	1,0	40	40	430		1,0	7	1,0	40	430
	30	PET-TAC	15	2.250	2.625	1,0	40	40	430		1,0	10	2,0	80	861
500.000		LAB		0	11.550	1,0	25	25	269	1	1,0	4	1,0	25	269
			100												
				15.000		7		205	2205		7,0		10,0	295	3.174
		Net Examination Surface						205	2.205					295	3.174
		Gross Department Surface			Univerty Hospital			**1.435**	**15.435**					**2.065**	**22.218**

*(1) Regarding experimental Data with Digital Systems

Jouney(hours)	7	14	Days/year	**250**

Room Occupation Factor	**0,75**

*(2) Watch National Statistics

Population Growth	**1**

Years for Calculation	**10**

*(3) Watch National and International Statistics

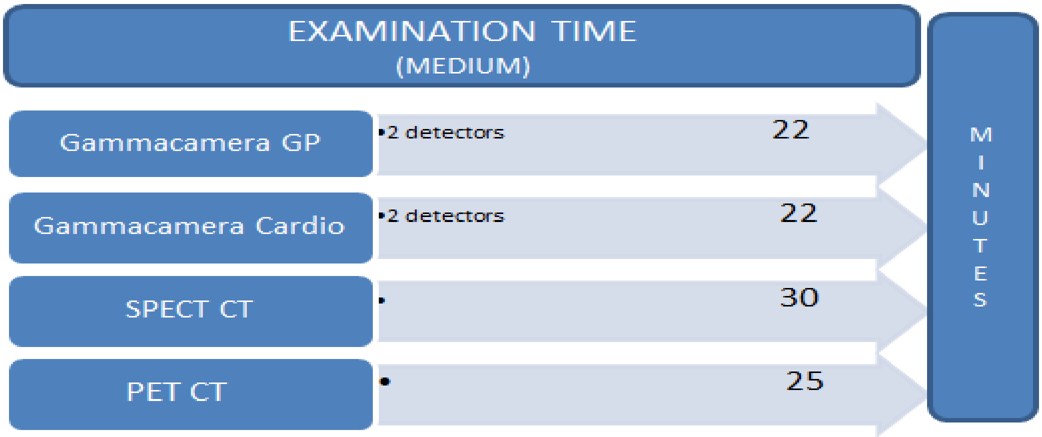
Modalities Growth

Ciclotron	**5**
Radiopharmacy	**10**
NanoPET	**5**
NanoSPECTCT	**5**
Gammacamera	**4**

SPECT CT		**7**
PET CT		**10**

(5.31.- Calculation of the surface of the nuclear medicine department)

In the spreadsheet has been considered the following examination times (5.32) and have no been rounded the calculations of the number of rooms in each category:



(5.32.- Nuclear medicine examination times)

The frequency must be carefully studied with the demand research prior to all planning activities. Examples of frequency can be seen in the UNSCEAR data for different countries. The calculations for the cyclotron and the radiopharmacy also require an analysis of demand. In general a cyclotron is able to provide isotopes and radiopharmaceuticals to various PET-CT systems and have to be calculated the demand carefully to measure the type of cyclotron and its production. In the spreadsheet has been calculated a cyclotron with radiopharmacy capable of supplying radiopharmaceuticals to ten PET- CT systems using FDG.

In the worksheet (5.33) we have the practical application of a department plan to meet the demand of a population of 500.000 inhabitants, with frequency of 30 nuclear medicine examinations per 1.000 inhabitants. An average attendance, according to the UNSCEAR data and far away from the 60 - 80 tests observed in some leading countries.

The example is of a university hospital that calculates the installation of two PETS, one initial at the beginning of the hospital and a second in a next date, with a department of research in nuclear medicine radiopharmaceuticals with preclinical testing equipment for advanced animal clinical trials. Values of exams to be carried out with these preclinical systems are light approach because it will depend on the working capacity of the research team. The cyclotron in addition to generating the necessary radiopharmaceuticals for the department will supply these for another PET equipment installed in the implementation area. It is one equipment of small production capacity which will share its operation with another local unit.

NUCLEAR MEDICINE DEPARTMENT GROSS CALCULATION SURFACE

Population	Freq	Exams	%	Nº Ex/Room	Med. Surf.	Nº	Med. Surf.	Surface 1		P.G.	Nº	M. Growth	Nº	Surface 2	
					*(1)	Room	m2	m2	ft2	*(2)	Room	*(3)	Room	m2	ft2
	30	GAMMAC-G	65	9.750	3.150	3,0	25	75	807		3,0	4	5,0	125	1.345
	30	GAMMAC-C	15	2.250	3.150	1,0	25	25	269		1,0	4	1,0	25	269
	30	SPECT-TAC	5	750	2.625	1,0	40	40	430		1,0	7	1,0	40	430
	30	PET-TAC	15	2.250	2.625	1,0	40	40	430		1,0	10	2,0	80	861
500.000		LAB		0	11.550	1,0	25	25	269	1	1,0	4	1,0	25	269
			100												
	30	CICLOTRON	15	2.250	31.500	1,0	35	35	376		1,0	10	1,0	35	376
		RADIOF.		0	31.500	1,0	40	40	430		1,0	10	1,0	40	430
	30	NANOPET	5	750	1.969	1,0	20	20	215		1,0	5	1,0	20	215
		NANSPECTC	5	750	1.969	1,0	20	20	215		1,0	5	1,0	20	215
				18.750		11		320	3441		11,0		14,0	410	4.410
		Net Examination Surface						320	3.441					410	4.410
		Gross Department Surface			Univerty Hospital			2.240	24.087					2.870	30.870

*(1) Regarding experimental Data with Digital Systems

Jouney(hours)	7	14	Days/year	250

Room Occupation Factor	0,75

*(2) Watch National Statistics

Population Growth	1

Years for Calculation	10

*(3) Watch National and International Statistics

Modalities Growth

Ciclotron	5
Radiopharmacy	10
NanoPET	5
NanoSPECTCT	5
Gammacamera	4

SPECT CT		7
PET CT		10

(5.33.- Surface in nuclear medicine)

V.III.III.- RADIOTHERAPY DEPARTMENTS

In a radiotherapy department the determination of the gross surface of the department on the basis of frequency is also possible establishing the parameters of occupation of the rooms, making the average of the number of sessions for each patient who attends treatment, either with LINAC or brachytherapy. There is an example in the following table, where part of a frequentation of 2,5 patients per thousand inhabitants. It's a moderate attendance, according to UNSCEAR, there are countries with much higher frequency values.

The number of sessions per patient has been set at 30. This data must be checked according to local habits in treatments and changes caused by technological improvements in devices that control the doses of the radiotherapy equipment.

RADIOTHERAPY DEPARTMENT GROSS SURFACE CALCULATION

Population	Incid	Treatments	%	Nº Trat./Room *Sessions	Medium Prod. *(1)	Session min	Nº Room	Medium Surface m2	Medium Surface ft2	Surface 1 m2	Surface 1 ft2	Pop.Growth *(2)	Nº Room	Mod.Growth *(3)	Nº Room	Surface 2 m2	Surface 2 ft2
		LINAC	80	33.000	13.125	12	3,0	70	753	210	1.894		3,0	6	4,0	280	3.014
		Sterotaxy	5	69	2.625	60	0,0			0			0,0	6	1,0	70	753
		Brachytherapy	15	1.031	3.938	15	1,0	50	538	50	538		1,0	4	1,0	50	538
		Planb. LINAC		1.169	1.575	50	1,0	15	161	15	161		1,0	6	1,0	15	161
550.000	2,5	Pann. Brachyth.		206	1.575	50	1,0	15	161	15	161	1	1,0	4	1,0	15	161
		Simulation		1.375	3.150	50	1,0	30	322	30	322		1,0	6	1,0	30	322
		Blocks		660	3.150	50	1,0	20	215	20	215		1,0	6	1,0	20	215
			100	37.510			8			340	3.291		8,0		10,0	480	5.164

		Surface 1 m2	Surface 1 ft2	Surface 2 m2	Surface 2 ft2
Net Treatment Surfa =		340	3291	480	5.164
Gross Department Surface					
	Regional Hospital	**1.700**	**16.455**	2.880	25.820
	University Hospital	**2.040**	**19.746**	3.360	30.984
	External Outpatient Center	**1.700**	**16.455**	2.880	25.820

*(1) Regarding experimental data with present equipment. Journey 7 h. 250 days/year. 2 Technicians/Room. Occupation Factor= 0,75

Working Hours	7	14	Days/Year	250	Occupation Factor	0,75

*(2) Wath Regional Staticstics

Population Growth	1	Years for calculation	10

*(3) Watch National and International Statictics

Treatments Growth

LINAC	6
BRACHYTHERAPY	4
PLANNING	6
SIMULATION	6

Nº Sessions/Treatment	LINAC	30
	BRAQ	5

(5.34.- Calculation of the surface of a radiation therapy department)

This worksheet (with the rounded number of rooms) is applied to a department that serves a population of 550.000 inhabitants. The same university hospital from the example of nuclear medicine, which will be equipped with three linear accelerators and the brachytherapy unit in radiotherapy which determines the worksheet. The following example shows a more simple calculation.

Population	Incidence	Modality	%	Sessions	t trat	Production Medium	Rom	Rom	Suuface Medium	Surface Total	Population Growth	R	R	Crecimiento Modalidad	R	R	Surface Total	Number of Sessions
220.000	71	LINAC	98	15.600	10	15.300	1,0	1	70	70	0,3	1,0	1	3	1,4	2	140	20.911
	0,6	STEROTAXY	1	124	80	1.913	0,1	0	70	0		0,1	0	5	0,7	1	70	1.257
	1	BRQ	1	212	50	3.060	0,1	1	50	50		0,1	1	5	0,1	1	50	339
		PLAN-LINAC		642	50	3.060	0,2	1	15	15		0,2	1	5	0,4	1	15	1.257
		PLAN-BRQ		53	50	3.060	0,0	1	15	15		0,0	1	5	0,0	1	15	85
		SIM.		538	50	3.060	0,2	1	30	30		0,2	1	5	0,7	1	30	2.114
		BLOCKS		177	25	6.120	0,0	1	20	20		0,0	1	0	0,0	1	20	182

(5.35.- Surface for the department of radiotherapy)

Extending the initial example is part of a incidence of 2,3 patients per thousand inhabitants, data that will vary for each country and that should be investigated in each partial study. Also the forecast of growth of population and increase of demand of the technique are also variables in each country. Radiotherapy schools also may vary the correlation between treatments with LINAC and with BRACHY by which additionally should be examined to improve the accuracy of the worksheet.

IV.- SPACES

Once that the needed department surface has been calculated must be addressed the design of different spaces to facilitate the development of the diagnostic or therapeutic functions to be carried out. The following chapters dealt with in a systematic manner the development of this task, from the individual rooms to complete assemblies, from the design of detailed rooms until the block diagrams for the distribution of the examination spaces and rest of dependencies.

Only will now develop a scheme of distribution of spaces which comes from the previous calculation of surface in the spreadsheets and that is based on experimental models that are particular for different types of departments described in Chapter II. A private diagnostic center has space needs different than one department located in a district hospital, and this, different from the one located in a university hospital. The development of these models exceeds the scope of this book, while as an example, is exposed the calculation of the distribution of spaces in a molecular imaging department located in a 300-bed hospital, and that it is projected to 14.000 annual exams at the time of its opening.

The calculation model begins with the separation of the outpatient and hospital internal patients to determine the surfaces intended for patients who come to the department either outpatient or internal. The latter will come mostly in beds, and some in wheelchairs, so it is also necessary to calculate the spaces for waiting for these patients. The average hospital stay, in this case 7 days, is a valuable data to calculate the internals, by varying the averages with the type of hospital and the average age of the population. In the distribution of the example of the exposed worksheet in the figure on the final page of this chapter in-patients are only 9 per cent of the total number of tests performed in the center, given the kind of department there is no emergency, and there are the modalities most usual of the molecular imaging departments, with gammacameras of general purpose and cardiology, PET CT and SPECT CT. Includes a cyclotron and radiopharmacy. Exam times are previously defined in Chapter II and remembered in spreadsheets about surface of this Chapter V. The calculated number of rooms is from 7 to the beginning of the activity of the department and the total department gross area of 1.380 m2 (14.845 ft2).

Starting from left to right is shown the modalities, exams and examination times and the calculated rooms. The spreadsheet provides a breakdown by: reception, waiting, halls, toilets, rooms of diagnosis, cabins, staff and technology, with a full overview.

DISTRIBUTION OF SPACES MOLECULAR IMAGING

EXAMINATION DATA / SURFACES IN THE DEPARTMENT

Modality	Distribution of Examinations Total	%	External	%	Internal	%	T.EX. min	Nº R	Recept	Waiting External	Waiting Beds	Hall External	Hall Internal	Hall Pers	WC	Diagnt Rooms	Cabins Preparat.		Offices Others	Tech
										m2			m2						m2	
GAM-G	4.850	35	4.365	35	485	35	15	1		22					4		4	a	24	
GAM-C	2.600	19	2.340	19	260	19	30	1		22					4		4	b	12	
SPECT-CT	2.950	21	2.655	21	295	21	20	1		39					8		15	c	23	
PET-CT	3.600	26	3.240	26	360	26	20	1		13					8		20	d	10	
LAB	10.400	74	9.360	74	1040		5	1		0					0		0			
									121		33	91	123	81	9	24				116
Ciclotron	4.100		3.740		360		dosis	1		0					7	20	0	lec	33	
Radiofarm.	4.100		3.740		360		dosis	1		0					0	23	17	ofic	12	
										41								alm	11	
										22								vest	31	
																		bibl	0	
	14.000	174	12.600	174	1.400	100		7	121	157	33	91	123	81	39	68	59		154	116

ZONES GROOS . NET

ZONAL SURFACES

	m2	%
Patients Zone	470	43
Exam Zone	193	18
Diagnostic Zone	108	10
Personal Zone	195	18
Technology Zone	116	11
Total Net Zones Surface	1.081	100
Losses	299	21,7
Total Gross Surface	1.380	1.380

FIXED AND VARIABLE PARAMETERS

HOSPITAL

Number of Beds	0
Medium Stay	0
Occup. Factor	0,85
Dept. Surface	1.380
D1 - I 51,1	27

MOLECULAR IMAGING DEP

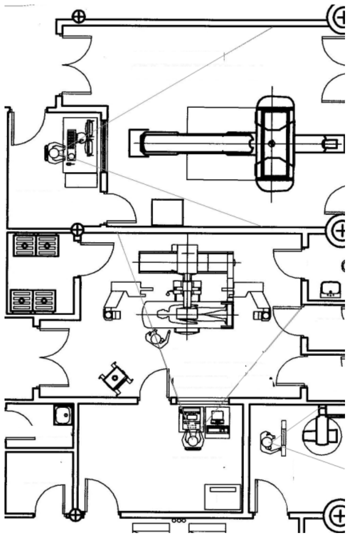
Journey (hours/d	7
Labor Journey (h)	7
Days / Year	230
Emergncy	0
	0

SUPFACES DETERMINED

Reception			Halls	
Desk	8	m2	External	
Hall	91		Internal	123
Office	23		Personnel	81
			WC	8,9
Offices			Others	
Chief	24	a	Reading	33
Superv	12	b	Office	12
Admin	23	c	Library	0
Inform	10	d	Storage	11
			Vest	31
Technology				
Servers	11		Tech Rooms	84
AC+Tel+	20		Others	

(5.36.- Distribution of the surfaces of the department)

VI.- DESIGN OF IMAGING ROOMS



I. ASPECTS RELATED WITH THE PATIENT

II. RELATED WITH THE PERSONNEL

III. RELATED WITH THE EQUIPMENT

IV. RELATED WITH THE ARCHITECTURE AND CONSTRUCTION

V. WITH THE TECHNOLGY

VI. WITH THE SECURITY

To reach the moment of realization it is necessary pass through sterile years

(R. Tagore)

VI.- DESIGN OF IMAGING ROOMS

The use of water and mud to treat various ailments is practiced since ancient times. Both Greeks, Romans and Egyptians even proved the benefits of hydrotherapy. Today the health resorts and spas has become an attractive alternative to traditional rest. In them is given all kinds of targeted treatments to restore health and well-being to those who enjoy them. These facilities have their respective designs for their correct functioning; in the same way as diagnostic imaging and radiation therapy facilities, in which the conditionings and regulations of the spas must be added others of greater technical depth due to the high-tech that they house.

The concept of area or examination surface of different modalities of diagnostic imaging has been developed in the two previous chapters, on the basis that this area is a solid concept that allows to be reference unit in the calculation of the department surface as described in chapter V. The average surface of one imaging diagnostic or therapeutic room must be adequate to perform the function of the medical objective for which the room is designed, the function performed by the imaging technicians capturing information that become diagnostic imaging for the clinical interpretation by radiologists. This physical space allows the mobility of technicians, patients, beds, accessories of patient care, transportation, and also space for maintenance and let's not forget, the modality in the moments of technical stops or periodic reviews, other words, maintenance

But this medium area, area of consideration, requires spaces and additional dependencies for the clinical practice of image acquisition, spaces that are not always the same, but vary depending on the functional objectives assigned to the room and is where the designer, or design team, have to sharpen its wits to optimize the volume allowing the patient the maximum comfort in the room. Do not forget the premises of this book in the patient as essential in the planning and design of imaging departments, but with this base, have to be optimized the profitability of the heavy investment in construction and equipment that generates an imaging department, usually the most substantial of any other department of a hospital, and let's not forget something more important than these investments: the personnel. They will serve this rooms for decades and if the design is satisfactory, will be achieved high levels of productivity and intimate satisfaction for their everyday job well done. The design should not be the cause of a painful and complicated work, but quite the opposite, and surely to equal construction costs.

Will be completed, in the following pages, the configuration or possible configurations of the rooms that can be designed for different modalities, in order to know the imaginable design alternatives and that culminate the tasks prior to the final drawing of the imaging departments. Here has to be fulfilled the exam room, the room control, or space that the technician needs to guide the image acquisition, cabins or locker rooms that require patients to change clothes, the toilets, when they are needed, and preparation rooms that widely facilitate the workflow in many modalities to improve the patient care and the performance of the room.

First, will be discussed general aspects that are wrapped around the design of the majority of the rooms, of all modalities, and then the individual design shall be undertaken, modality by modality. These general aspects can be classified, following our zones design, and adding the additional elements that physically shape the imaging department:

- **Related to the patient,**

  Such as the access to the rooms, the features of the cabins for changing clothes, dimensions of doors, the movement of the patient within the room capacity, lighting, air-conditioning, etc.

- **Related with the personnel,**

  The clothes changing rooms for staff, the rest and office rooms, rooms of image readings, the conferences, the sessions, etc**.**

- **Related with the equipment,**

  Bases of assemblies, anchoring elements, position of the components in the room, access of the equipment to the department and diagnostic rooms, air conditioning, fire detection, anti-theft, etc**.**

- **With the architectural structure and construction**

  Architectural structure, loss of spaces and their influence in the design, reinforcement of structure, gutters, finishes in vertical and horizontal walls, etc.

- **With the technology,**

  Requirements of the technical rooms, rooms of servers, uninterruptible power supply, power lines, air conditioning, etc.

- **With the security**

  Ionization radiation, mechanical, electric, acoustic, optical, fire, etc.

VI.I.- DESIGN ASPECTS RELATED WITH THE PATIENT

The workflow of the department begins with the arrival of the patient to reception and from here going toward waiting and later to the room to perform the test.

The reception should be pleasant, taking care of the details of its location in the department in dual relationship with the arrival of patients and the internal distribution of these after passing the control of reception. The decoration should be adequate to the center trying to optimize the image that the patient will form, not only of the center, but about the medical attentions to receive.

A representation in 3D of one of the designs presented in this book is shown in the figure (6.1).

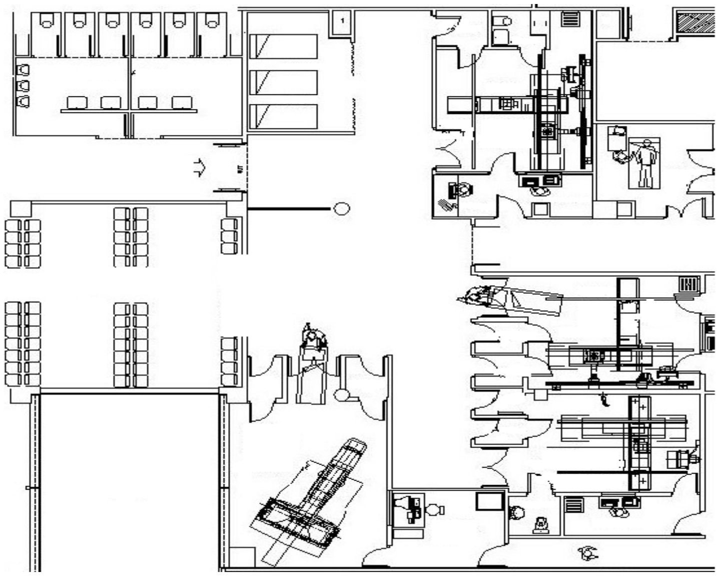
- **Waiting rooms**, are one of the areas of greatest impact for the patient. During the wait, the patient, restless, imagine the quality of care is going to be offered, therefore the imagination in the design of the waiting area in reception is valuable to appreciate the care of the patient.

(6.1.- Reception at an imaging center for outpatients)

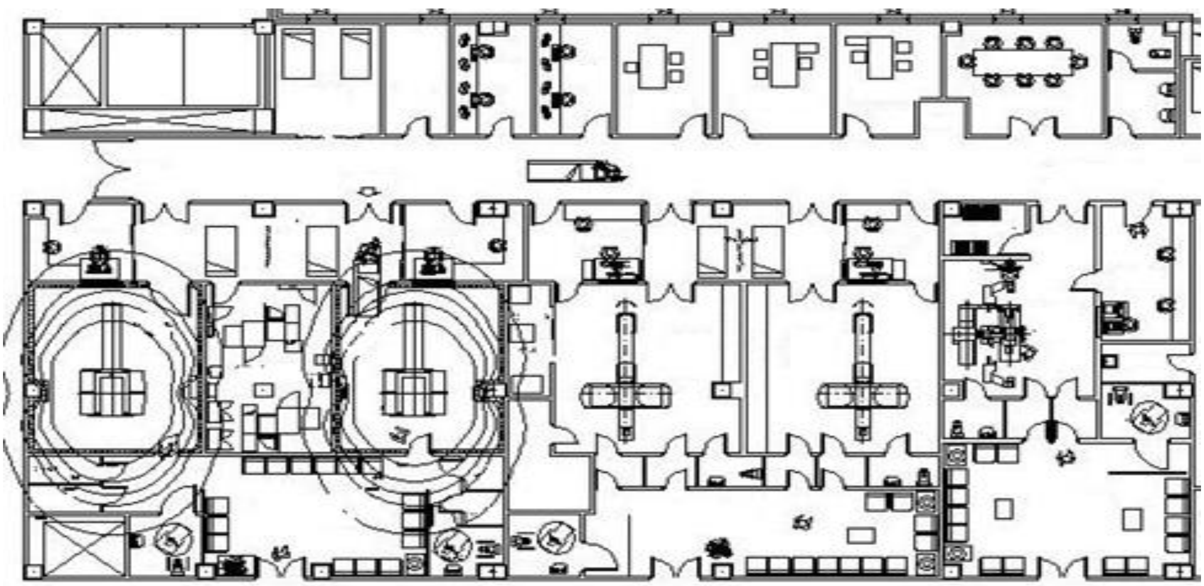
The traditional general waiting room, where all patients are waiting for all specialties have been replaced over the past twenty years by waiting rooms individualized by modalities or common waiting room for related modalities.

Waiting, in the design of the figure (6.2) is crowded and away from the reception of this emergency imaging department. Reasons for calculation of space prevent a more suitable design for the patient and companions, that have to move more distance that should be required.

A personalized care means that the patient does not have to be called by media PA, or lights panels, but that the technician leaves the examination room and called to the patient by their name, and tells where to change clothes and explains the examination details that will be submitted, as in the diagram (6.3).), where in the department section shown for resonance



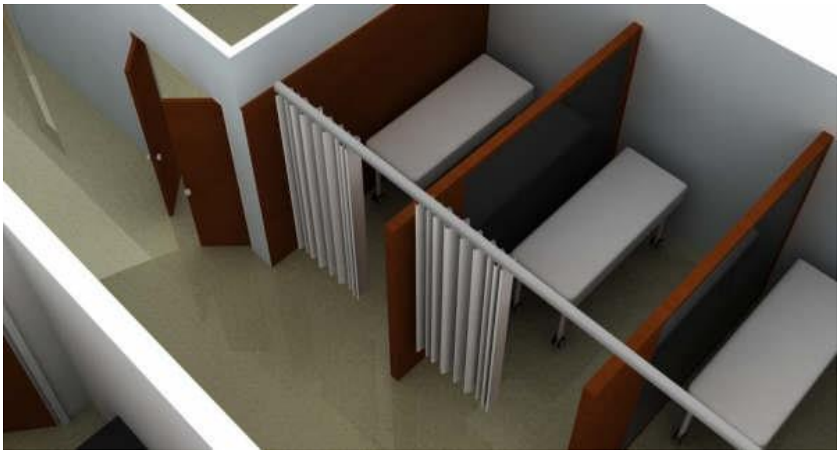
(6.2.- Traditional general wait in emergency)



(6.3.- Waiting rooms by modalities)

magnetic, tomography multi-slice and remote controlled table the patients are waiting at the entrance of the cabins of the rooms. There are no speakers, there is no public address system, there is no notices with indicator lights for the patient; is the technician, the driver of the test that calls for the patient, with his voice and with the patient's name.

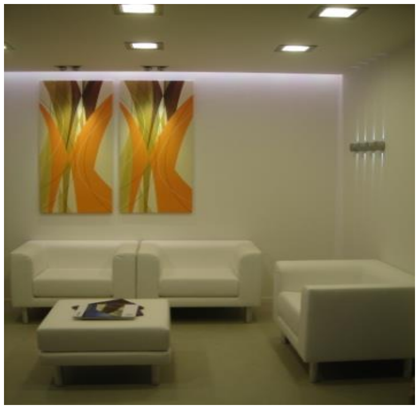
Must not be forgotten hospital inpatient waits, who are usually transferred in beds to the imaging department. Calculations are needed for the necessary spaces for these waits in the processes of planning and design, depending on the number of beds from the center, the type of hospital and the particularities of examination to be carried out.



(6.4-Individualized beds waits. Drawing in 3D)

Waiting areas must have seats comfortable, functional, with appropriate lighting and brightly decorated that relax and deter the patient of his thoughts about the exploration that will be submitted. It corresponds to the decorator, as part of the design team to undertake these tasks, that in some cases, as with the modern techniques of lighting with LEDS, or new dimmable fluorescent tubes, allow soft colors, or dynamic lighting that accommodated its intensity and color of light at the time of the day. An example of lighting with LEDS is attached (6.5). Color and illumination level can be regulated depending on the time of day, the type of patients, the decorative effect that you want to give to the room, etc.

Already existing light fixtures and commercial LED software to make the task easier, enlarge the life of the lamps and significantly reduces energy consumption. The cost benefit long term is already positive and it is expected that the increase in the consumption of these devices significantly reduce prices making the most affordable option.



(6.5.- Waiting rooms with LED lighting)

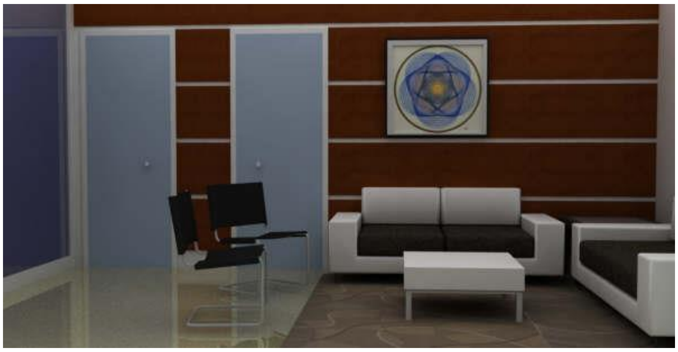
The spaces are determined by the frequency and work schedules, i.e., the work load of each room, and therefore the number of people who come to the waiting rooms per hour in the knowledge that for each patient (to a patient can be made in a room more than one exam), in general there are a companion, and two that have to assume in pediatrics. This same data is useful for the engineering design of air conditioning of the department, where the number of people and the volume to be conditioned determine the needs of each local air conditioning.

The ceiling heights must be lower than the one of the examination rooms, typically between 2.8 and 3.1 m (9 to10 ft) height. A height of 2.6 m (8.5 ft) is suitable to most of the waiting rooms even though it is a function of the total volume of the room.

A drawing in 3D of a waiting room from an example presented in chapter III 3D is shown below, (6.6).

- **Cabins or cubicles** for change of clothing must have adequate space so the patient move with ease. In general have to be designed two cabins by examination room, three in the case of specialized in chest x-ray examination rooms. Four are not necessary, except in very special cases.

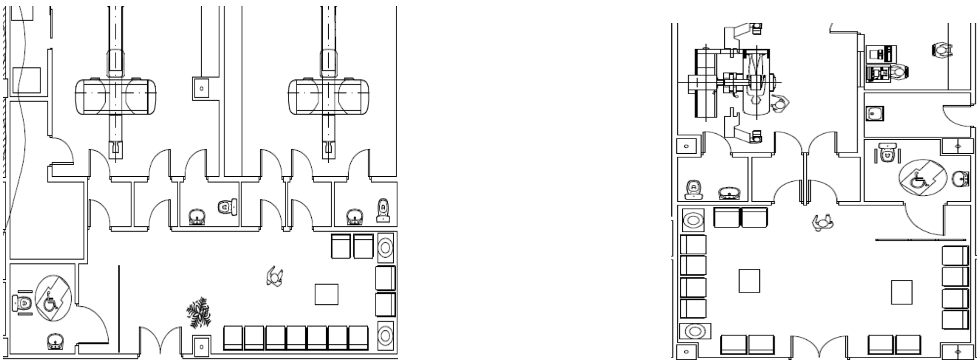
  One cabin, of the above two, should allow wheelchair access, with what doors have to be appropriate to this case. Each country has local rules with measures for designs in wheelchair spaces, so you have to read and apply local codes regarding it, but 82 cm (32 in) doors are sufficient for a correct handling. The doors to the remaining patients are usually 72 cm (28 in) wide.



(6.6.- Waiting room of a magnetic resonance facility)

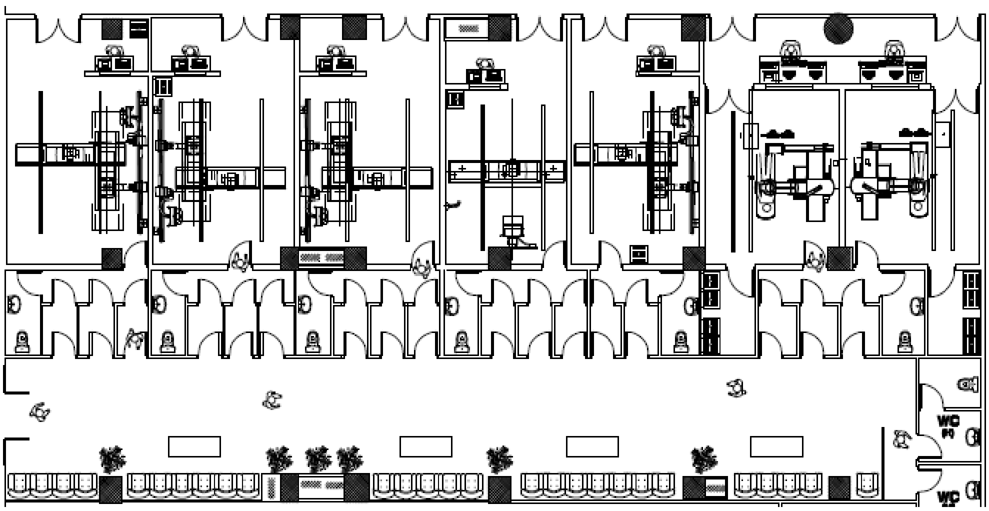
The surface should not lower the 2 square meters (22 ft2), although there are many smaller cabins, and again it is advisable to resort to concerning architectural codes. A step stool to change clothes, hangers and spot light standard with presence sensor for lighting, make up the rest.

Safety regulations require to put a red light on the top of the outer door of the cabin, should be wearing when the room is occupied and emitting radiation, with the corresponding written signs of danger of radiation at the door.



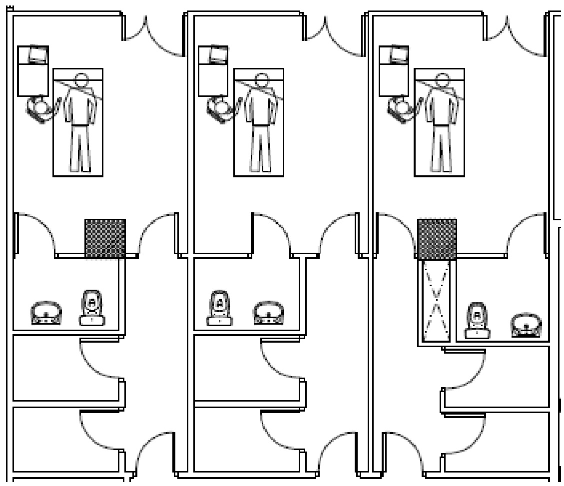
(6.7.-Cabins)

Different solutions for each case can be found in the design of cabins, placing upcoming entrance doors either by separating them, either looking for ways to reduce the cost and weight of the inner door, it must be protected by lead in all rooms with radiation, with designs like is shown below (6.8), and where the doors of the cabins should not collide in its rotation to not block the patient in the event of clinical necessity by fainting, or other cause.



(6.8-Solution where only a door must be leaded)

From each cabin comes out onto a corridor which leads to the door of the examination room, and there is a toilet for each group of cabins. The technician requires more control to preserve the privacy of the patients, but it allows more rooms available, thus e.g. in the event that the toilet is inside the room, as it is common, the room cannot be used with another patient until the first patient not let the toilet.



(6.9.- Cabins for ultrasound online solution)

The same is represented in these rooms of ultrasound with two cabins and a toilet in line with entry to the door of the examination room.

In the representation in three dimensions of the figure (6.10) can see the linkage between hall's patients, waits individualized for each modality and the access to exam rooms cabins.

(6.10.- Patient corridors, individualized waiting and examination rooms access cabins)

- **The preparation rooms**, highly useful in procedures where it is necessary to inject contrasts to the patient, either sedate previously to the examination, require in this respect adequate space. Such is the case of magnetic resonance, multislice tomography and angiography - cadioangiografy and PET- CT although in this case should always be expected injections rooms in all departments where there are nuclear medicine. Calculate a minimum of 9 m2 (97 ft2) by preparation room, depending on the application and the room. Equipment of anesthesia, monitoring and auxiliary tables need space and in general required more than the minimum indicated above. These rooms have access to stretchers and the doors should be wider than common. Doors with 1.3 m (51 in) are normal and often two-door 72 cm (28 in), are placed with what access conditions are correct. Medical gases are necessary in the preparation room as well as electricity standard connectors suitable for auxiliary equipment.

- **In exam rooms** the requirements of the patient focus on correct mobility and general ambience of the room, should be cheerful for the patient and this should feel comfortable, minimizing its concern. New systems of lighting with LED and projections on walls and ceilings achieve this purpose (6.11).

  The new LED technology allows many different types of lighting projects in which the whole planning team should be involved from the beginning of the design phase to get three objectives:

make attractive the stay of the patient in the department, reduce the high electricity costs and work for a healthy environment.

(6.11.- Dynamic lighting with LED and projections on the wall)

LED lighting systems allows to program colors and combine a program of projections of images on the walls and ceiling, with colors in the room, as in the example of magnetic resonance (6.11). The patient is in a new world that envelops them during the time prior the exam to reduce their anxiety and facilitating their collaboration.

(6.12.-Ultrasound room)

In the figure (6.12) there is one ultrasound room where the lighting combination generates effects of high entertainment and pleasant atmosphere for the patient. Medical gases, to place at the head of the patient are recommended in all rooms, at least in which is going to carry out tests with contrasts and where will be sedation or anesthesia. Oxygen, nitrous oxide, vacuum and compressed air.

Lighting; In addition to the already described led, dimmable incandescent and fluorescent luminaires (today also LED) are required to mitigate intensity during the exam time, e.g. ultrasound, where the brightness of the screen requires less light. Detectors of occupancy in cabins for energy saving.

The levels of lighting in examination rooms are 500 lux, adjustable, depending on the facilities, where once the examination begin can be reduced to 200 lux. In examinations rooms with visual inspection and treatment rooms may require 1.000 lux, with the possibility of regulation.

The air conditioning has to be calculated considering in addition to the technician and patient inside the room the machinery installed and will see more in more detail in the individual design of each room.

Furniture and sinks according to design and local standards (6.13).

(6.13.- Integration of furniture and sinks)

VI.II.- ASPECTS RELATED WITH THE PERSONNEL

The diagnostic imaging department may be, as we saw in Chapter 3, of very different sizes, and for different applications and according to this the staff will be more or less numerous and specialized and will necessitate dependencies for greater or lesser number of persons, but with similar basic fundamentals in all departments

According to the workflow of personnel, the first action when entering into the department is change clothes to accommodate the general prescriptions of the health centers, very homogenous throughout the different countries. The locker room is the first place where the staff puts foot in the department**.**

- **Changing rooms** must be equipped with lockers to store clothing and personal objects of the staff, banks to support, toilets and showers. Let's not forget that there are patients in a very delicate state and staff may need to take a shower and change clothes of work during their working day. Special requirements there may be in MN in cases of radioactive contamination. The size of changing rooms is a function of the department's human resources and the two changing rooms should be located in the personnel zone.

- One **rest room,** where coffee is available, refrigerator to store food and microwave to warm them, is required. If the department is large and depending on working hours, may be needed separation of these rooms, also depending on the type of department and its location in a health center or at an outpatient center. In places with certain ranking may need two rooms, one for technicians and one for medical staff.

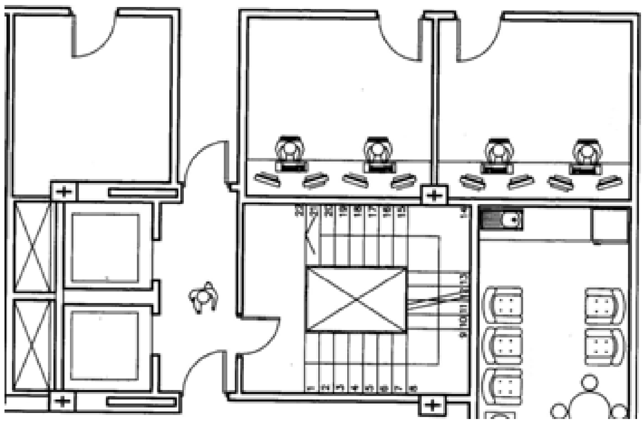
- **The activity of emergency** in certain countries requires physician journeys in the hospital more than 24 h. Some bedroom are needed for guard radiologists in these cases, bedrooms with toilets and showers located in the emergency area and next to the reports area in the emergency zone.

- **The introduction of computer systems** in the departments involved work stations for radiologists. PACS systems allow setting the report and its images instantly in any part of the health center or out of it through public or private communication networks. The design of the diagnostic rooms is a new task in order to facilitate the work of the radiologist and prevent vision fatigue with monitors and provide ergonomics at workplaces (69).

  Also have to be considered that for reasons of productivity reports are dictated by the radiologist to the voice recognition systems, which transcribe the voice to text report, show it on a screen to correct if it is so required, and are archived in the RIS system of the department. RIS-PACS integration and WEB distribution allows the instant sending of images and reports to the specialists that requested the exams.

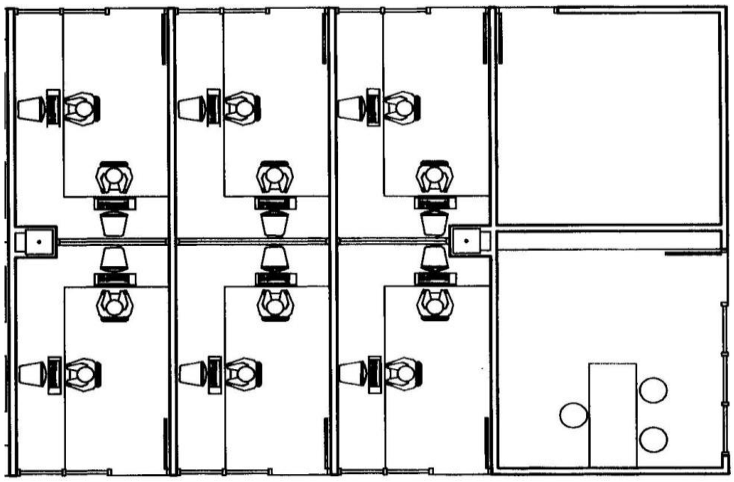
Workstation is therefore composed of monitors of image and one text monitor. In general there are two for image, but they can be up to four flat displays, or big monitors multi image at some stations. Special designs of biplane cardiovascular facilities are particular cases, and cases where besides these monitors of the diagnostic station, there are one or more for image reconstruction, are frequent, e.g. in multislice tomography, MRI, PET-CT and vascular. Therefore not all workstations are the same and to make a design consistent with the functions and costs must be well designed the workflow of the department. There are departments where radiologists reconstructed images with details of the modalities, other cases where there are technicians to these tasks, and provide already reconstructed images to the radiologist in the PACS. The spaces are not the same nor are the designs the same.

The most common design is to have a room with capacity for two radiologists and in this space are located two workstations with three monitors each (two image and one text and image) figure (6.14). This space will be called diagnostic room or reports cabin and here is where the radiologist will have most of his time. Therefore it is necessary to think about the design in ergonomic, light and environmental aspects, and space so that the radiologist has, in addition, their personal belongings: books, articles of last use, scientific journal in use, etc.



(6.14.- Rooms for diagnostic radiologists)

In the center of outpatient above two rooms encompass the activity of four diagnostic radiologists. The area of each room is 16 m2 (172 ft2) and they can include the monitors indicated above. A bench with side drawers for personal objects supports workstations. The lighting is two-fold: fluorescence for operations without diagnostic monitors, such as repairs, cleaning, etc. and dimmable incandescent for reading of images on monitors. Today became more economical installing both with LEDS. A fine spot focus on each side light documents that radiologists have laterally. Today most advisable is dimmable fluorescent lighting and the elimination of the incandescent lamps, and certainly with LED lighting. Chairs adjustable in height and with wheel.

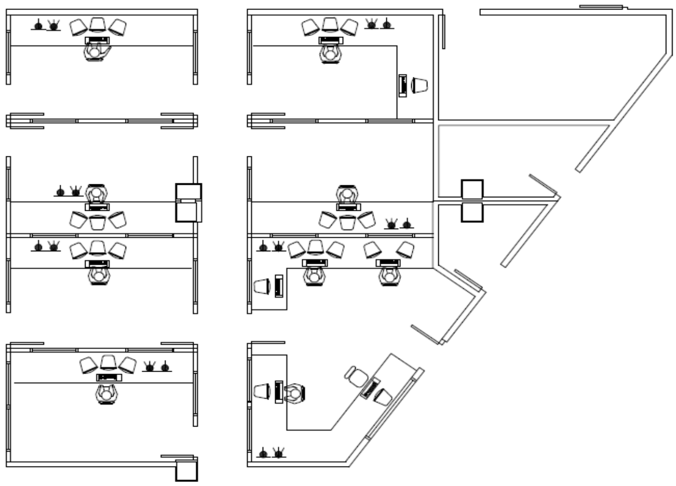


(6.15.-Reports Rooms)

In the example (6.15), which corresponds to a medium-sized general hospital, the space is smaller. The rooms are of 12 m2 (129 ft2) and can accommodate two radiologists with its workstations. While there are cases with these limitations is recommended more space, should not be forgotten that they are also consulting rooms and specialists come from the health center for discussion of special clinical cases.

In the block below, a university hospital, return to module 16 m2 (172 ft2) for two radiologists with its stations (6.16). In this university hospital activity is distributed by organs and systems and in each room you can have two workstations. Multislice tomography and magnetic resonance rooms contain an additional workstation with an LCD monitor for reconstructions. The diagnostic room for vascular and cardiovascular houses two additional workstations for reconstructions and additional cardiac visualization

Consider that the introduction of the AI (Artificial Intelligence) new software may change the present concept of reading rooms. This spaces may become in consulting hubs where patient cases may be discusses among several specialists. Will be bigger monitors and more space will be needed.



(6.16-Diagnosis rooms of a university general hospital)

Telephone system and Internet access must be available. Walls with acoustic insulation is recommended and it is desirable practicable floors for computer equipment.

Preferences for location of diagnostic rooms for two radiologists are not an exclusive. Some prefer individual diagnostic rooms. Privacy reasons leads them to advise this fact (20).

(6.17.- Diagnostic rooms 3D design with two radiologists by room)

- **The conference rooms** are spaces to design in the personnel zone. The capacity it determines the size of the department and its scientific activity. Very active university departments, use it often. Considerations of dimmable lighting, proper air conditioning and workstation with screen for projection are indispensable.

(6.18.-Conference room in an external diagnostic center)

- **The sessions room** is essential in the training and clinical operation of the department. It is part of the daily activity. Adequate to the number of radiologists, with additional capacity for some additional clinical specialist, accurate workstation with four monitors and projection of good resolution, with the same considerations of air conditioning and lighting of the conference room.

VI.III.- RELATED WITH THE EQUIPMENT

The particularized description of the rooms design in each modality is made later, but there are general aspects common to all of them that can be now detailed and as in the previous descriptions following the workflow.

- The equipment must be positioned physically within the room in a position that facilitates the work flow in the department. The ideal location is, in general, recommended by the manufacturer and described it in their pre installation documents, for the preparation of the civil work prior to the installation of equipment. This position in which are placed the equipment should allow easy access to the patient from the cabins, or from their stretchers, and easy access to health personnel for care to be applied to the patient. In a radiographic room the technician should be able to position optimally the patient, the detector and x ray tube emitter and in a room of medical interventionism technicians and nurses must be able to work freely in the environment of the patient to perform the procedure in the proper way. Visibility to the patient from control rooms must allow the observation of them at all the time.

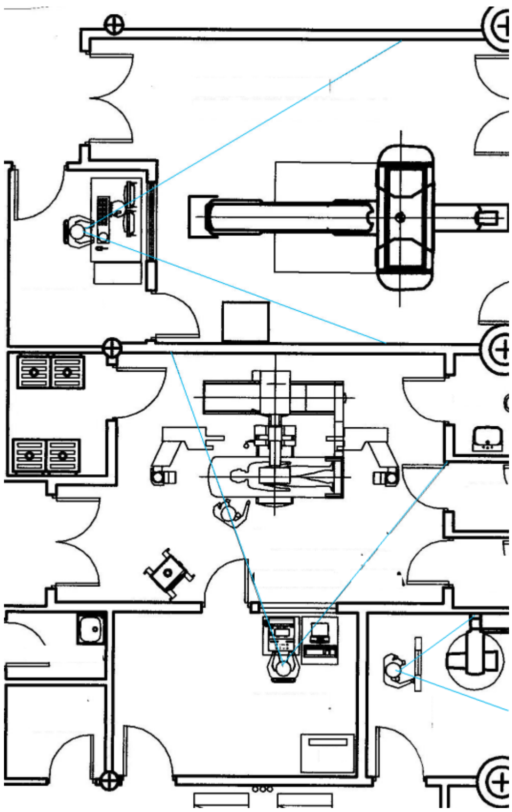
(6.19.- Amplitude in angiography room)

- **The control rooms** with its elements to govern the equipment must have a surface that enables the mobility of the technicians and the patient observation. Have to be provided space for two people, the technical operator of the room and the radiologist who can accompany the technician on certain tests.

(6.20.- Angiography room control)

The leaded glass windows, must be calculated to protect the operator in its observation to the patient and are subject to calculation of their protection capability by the authorized bodies of radiological protection. The dimensions of the window depend on the dimensions of the room, the positioning of the equipment inside the room and the position of the control cabin. Windows of 1 m long and 0,8 m in height (39x31 in) are normal in remote controlled systems equipment, lower in rooms of conventional radiology and bigger in rooms of vascular and cardiac catheterization. The height of the window over the floor depends on if the technician works sitting or standing.

(6.22--View from the control in an installation of RM. Drawing in 3D)



(6.21.- Windows wide with leaded glass protection)

In a remote controlled table, in a CT, a gamma camera the working position is sitting, and a height of the bottom frame of the window over the floor of 1 m (39 in) is suitable. In a room of chest work is standing up or in a high chair 1,10 to 1,15 m (43 to 45 in) height is normal.

Inside the control room other equipment, e.g. laser cameras, have been accommodated digitizers CR, etc., which today, with very small utilities, they tend to disappear from the control room environment and placed in a central point of the department.

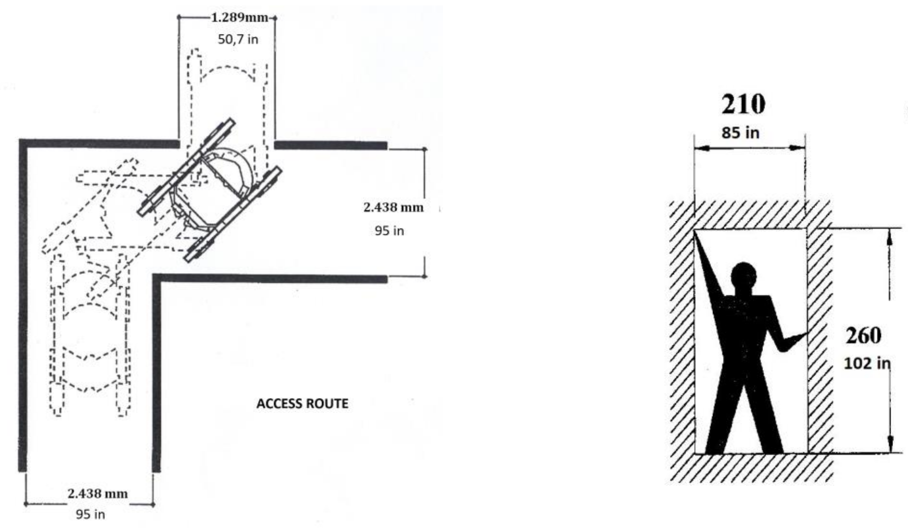
The surfaces of control rooms also vary depending on the control elements that have to accommodate. A conventional radiology room may have enough for 3-4 m2, however a vascular room requires at least 8 m2 (86 ft2).

(6.23.- Control of a CT Scanner, multi-slice for cardiac applications)

- Once the civil works ends, well cleaned the rooms, the equipment have to **access the rooms** for installation. Access roads have to be anticipated in the design of the department. Solutions of tearing down several walls to introduce the equipment in the rooms have been seen, and will be seen, ones as logic results for the antiquity of the departments, and other consequences of failings and improper designs.

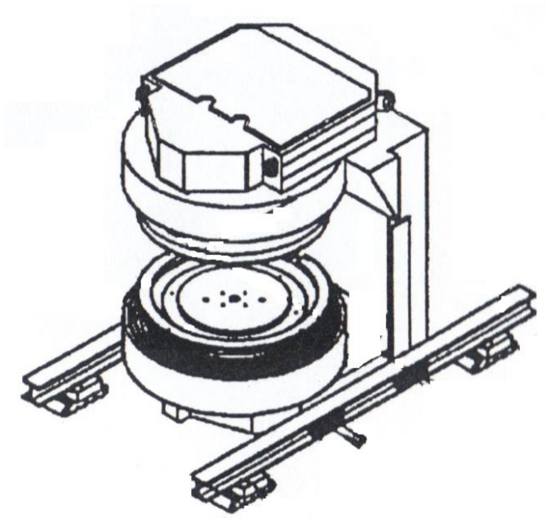
  There are very complex equipment, with its dimensions and weights, such as magnetic resonance imaging, linear accelerators, etc., which require simple paths from the outside, soil resistant to the passage and wide aisle widths. Provisions to be adopted in the planning and design.

  Access routes must first allow download of heavy trucks and unloading cranes, in some cases very large and up to 140 Tm. Let's not forget that some open MRI magnets can weigh more than 30 Tm. Aisles must be suitable for the machinery to pass, following the requirements of the suppliers drawings e information; widths of 2,30-2,50 m (90 to 98 in) are normal (6.24).



(6.24.- Access routes)

Changes and corners of the corridors must have in a way that can make the rotation, with ease of movement.



6.25.- Magnet 0.23 Ton rollers for the internal transfer)

The heights of the doors must have according to the equipment manufacturer's instructions. Many CT require heights exceeding 2.10 m (82 in), not common in many constructions. Walls and frames must be broken to pass equipment, something that can be avoided in the design.

It is required to dissipate the heat generated by the equipment to keep them within their operating temperature specifications. It is mandatory to calculate the heat to dissipate in the equipment and in the control instruments of the image acquisition in the control rooms. In the same way on other additional devices like lightings, monitors, etc. indications of operating temperatures and heat dissipation are enclosed in special drawings provided by the equipment suppliers of each room.

Smoke detectors should be placed in each room. Fire prevention is a rule of all the technical codes for construction and its regulation is inside these architectural codes.

The security against theft is difficult to predict in the design but is a component to study by the design team, if it has been stablish with the center property to make a plan in this regard.

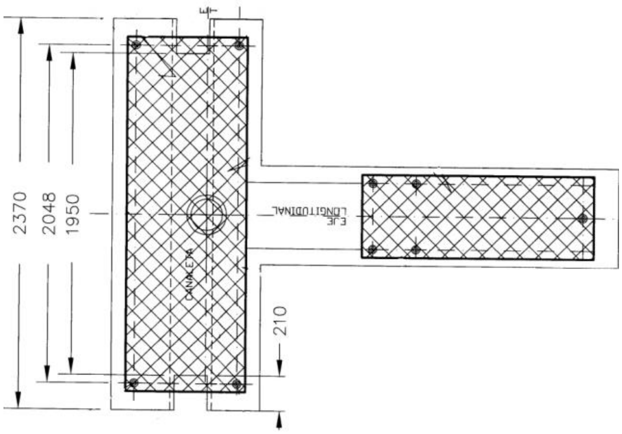
VI.IV.- ARCHITECTURAL STRUCTURE AND CONSTRUCTION

The architectural structure conditions significantly image rooms design. The designer has to fit the rooms, controls, etc., between the load-bearing walls and the concrete pillars or metal, that defines the structure of the building. A design cannot nor should have a pillar inside a imaging room. With all security staff and the patient's movements will be restricted and in stress situations the patient's care may be conditioned.

In large hospitals, the thickness of the concrete pillars are a factor to be considered in the loss of space, as pillars, with a section of 40 x 40 cm (15x15 in) or greater, and downspouts that pass through the area of the department, reduce the gross surface area to the net significantly.

In certain equipment such as magnetic resonance imaging have to be considered the iron density and metal structures that contribute to the overall magnetic system to avoid field constraints in the installation and operation of the magnet. The supplier should study with the architect or building engineer the constraints, if they exist.

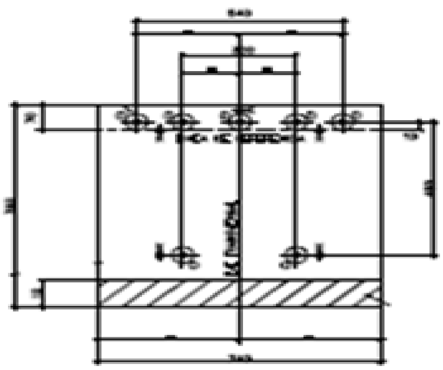
- The weight of the machines may require **reinforcements** in the structure, in some cases of very high cost. The supplier provides drawings and instructions for pre installation detailing areas of maximum load, with the point load, and the architect must calculate the reinforcement to apply.



(6.26.- Reinforcements on the ground to install a multislice CT)

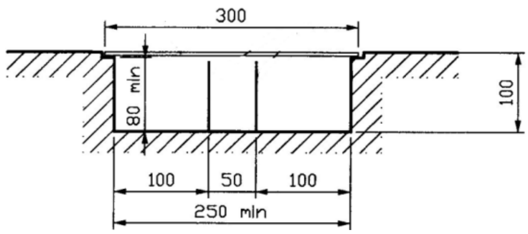
This scheme (6.26) points of fixation of a CT multislice indicates the area of implementation of the stative or gantry. The soil should be prepared, either with an iron plate or with a screed concrete depending on the thickness of the soil and the study of the load distribution on the ground that the architect makes. The more than 2.000 Kg (4.409 lb) weight of the gantry are distributed on the four points of the corners where anchor to the floor with screws. The same happens with the table of the patient with six points of anchorage to the floor.

Fixation plates or anchor systems, can be locally built following the plans of the supplier as we see below (6.27), or be an integral part of the equipment and therefore one supply more of the manufacturer.



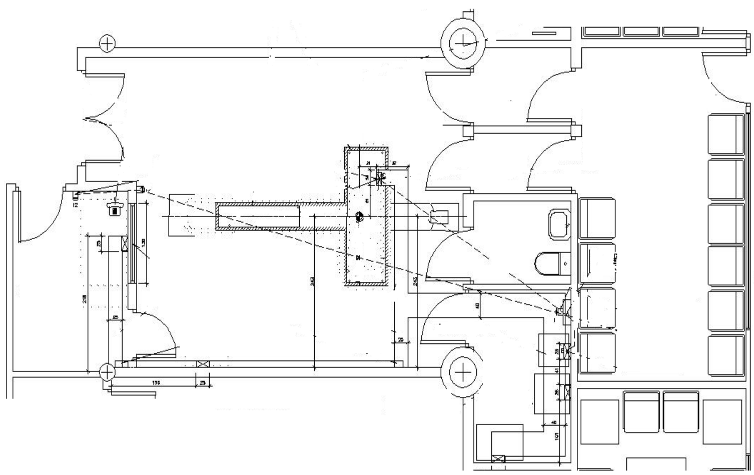
(6.27.- Iron plate fixing to the floor for a remote table)

- **The equipment wiring** are distributed, usually, by gutters that can be of very different materials, sizes and configurations. A section of a duct for one CT is represented below (6.28). Materials that make up the configuration of the gutter can be very different. Aluminum, stainless steel, sheet steel or plastic are the most common and it is needed the constructor to perform a proper supply of these components with the proper timing to dispose the specified by the draughtsman in the project drawings. Necessary electromagnetic isolation between the various cables, so the strong currents that circulate by power cables do not produce interference in the weak signal of the control cables; this is the reason for the internal metal separators (6.28).



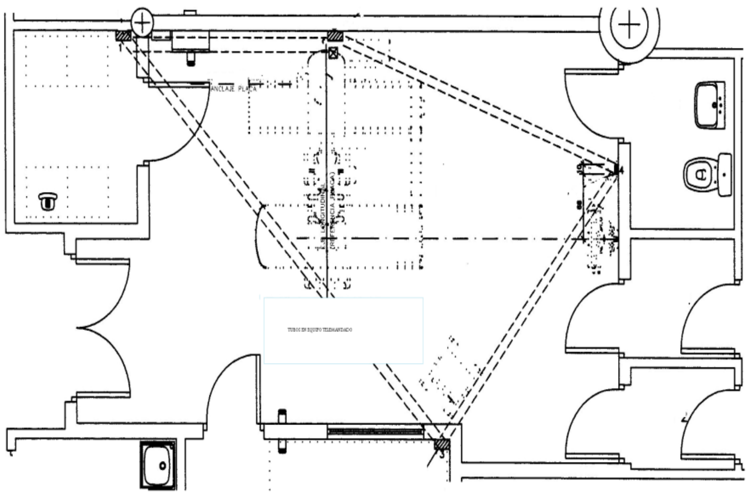
(6.28.- Duct with internal dividers)

The gutter section displays the three volumes which will extend the different wiring. Some channels must have its metal walls to the ground potential with which the construction is complicated and the contractor should take care of these details to avoid future malfunctions of equipment.



(6.29-Gutters and pipes for installation of a CT multislice)

Nowadays health centers are built with dimensions between the forged that provide a volume above the ceiling of the imaging room and another volume below the floor of this, of the down story of the department. This allows to have a space with height between 1.0 m (3 ft) and 1.4 m (3 ft) above and below the image room. These spaces will hose the ducts of air conditioning, water pipes, toilets downspouts, pipes for gases, trays with conductors of electricity supply and also will be able, in many cases, bear adequate section tubes for the necessary wires to interconnect the different components of the imaging equipment. With these tubes, will be almost completely eliminate the gutters of the imaging rooms, allowing soils without cuts or broken off, better built, better aesthetic and easy to clean. Must not be forgotten that gutters need more care, or highest tightness, so that no water enters in the daily cleaning operations. In the case of installations of vascular or hemodynamic the efficiency of the pipes in the selection of materials for the soil is very large, because conductive properties will be required, and it is very important to avoid interruption with gutters.



(6.30.- Pipes for the conveyance of interconnect cables)

The finishes of the walls and ceilings are only partially conditioned by the machines but do not condition the design of the image rooms.

- **Soils**, with the caveats that we have indicated for gutters, they can be of material that the user wishes to, either ceramic or plastic. The determining factors are easy to clean and resistant to the passage of many people moving inside the image room. There are only special requirements of conductivity and cleanliness in the angiography rooms and cardioangiography that will be detailed.

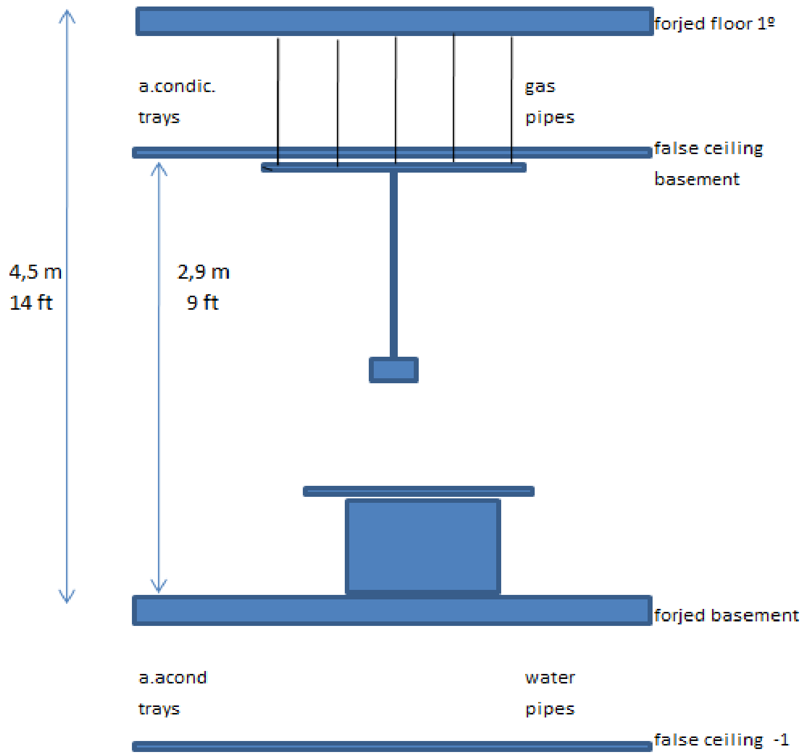
Leveling is very important to observe in detail. Are fundamental requirement in relation with the manufacturer**.** This factor influences not only the proper functioning of the equipment, e.g. CT, but also the guarantee of maintenance of its clinical indications.

- **The walls** can also be of different materials, brick or prefabricated and must take into account the radiological protection, i.e. the thickness of lead or equivalent protective barrier that should have to protect the patient and medical personnel. The protection must also extend to floors, doors and ceilings, i.e. to the entire environment of the room of radiologic imaging. The walls need some mechanical resistance, otherwise must be reinforced with additional mechanical structures the load to bear. It is the case of the wall buckys for radiography. Walls of prefabricated materials do not bear the burden. Should put a floor to ceiling beam or lay on the ground for their support. The manufacturer provides burdens to bear and usually indicates some simple alternative supports, compatible with the equipment.

- An important detail is the one concerning radiation protection on all equipment with ionizing radiation. The calculation of the overall protection, in walls, floors and ceilings is a function of the load of emitted radiation and the level of personnel protection in the areas close to the installation. The authorized head of radiological protection must calculate the level of protection barriers and the architect and constructor must choose materials that provide this level of protection. There are several common procedures in imaging departments construction:

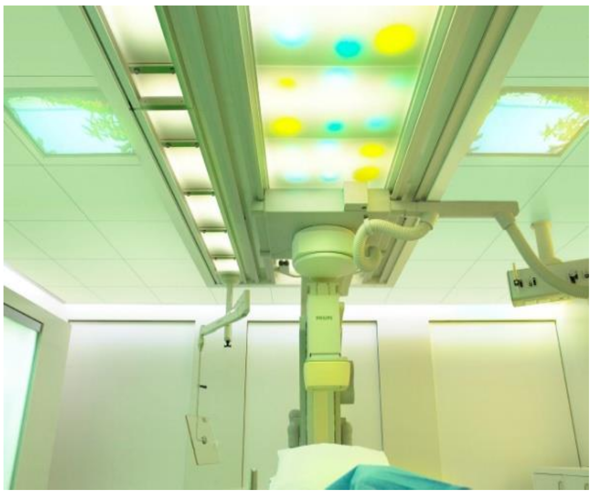
    - Lead of the calculated thickness sheets nailed over wood supports on the walls, overlapping the joints.
    - Prefabricated with high density and high attenuation coefficient
    - Brick of high density and high attenuation coefficient.

  The most common choice is the second, because simplifies construction, although it has less mechanical resistance which obliges to install components that strengthen it to accommodate equipment on vertical walls, like wall buckys. The ceilings, the false ceiling of the room is make at the same level with the suspension brackets of the x-ray tubes, or supports for the heavy arches in C for angiography machines. There are various solutions to support the suspensions, either riding a reticular structure to the ceiling that supports the suspension rails, or a mechanical structure which attaches to the upper forged of the room, and to this structure ceiling rails are screwed. The false ceiling of the room will make up the structure support leaving freedom of movement to the suspension on its rails.



(6.31- Ceiling Supports. Space under the floor and above the ceiling of the room)

The false ceiling must be practicable for easy installation of the equipment and subsequent repairs. Over this ceiling is placed lighting, outlets, etc.

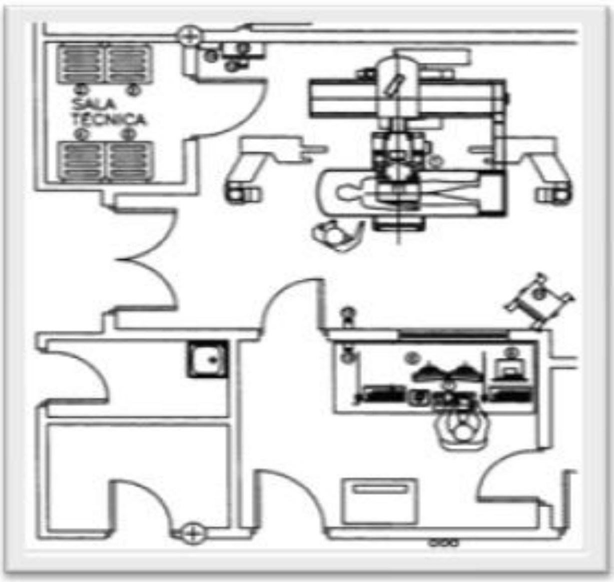


(6.32, Rails in a room with tube bracket to the ceiling)

VI.V.- RELATED WITH THE TECHNOLOGY

Technology, as already mentioned, occupies one scattered area in the imaging department and outside the department, depending on the configuration and type of health center and it is an area that presumably will continue to grow in the coming years.

- **The equipment technical room** acquire today more complexity than before, while electronics has miniaturized, so that the volume that today occupy the cabinets that encompass electronic components is less than two decades ago. We must consider that climatic conditions are more demanding in the big equipment like CT and MR.
  A technical room must take into account minimum clearances that need electronic cabinets, and mobility that require maintenance revisions and repair engineers. There is a trend to leave the technical room small of size and this leads to more time in the repair and therefore a reduction in the productivity of the room.



(6.33.- Detail of a remote control table technical room)

There are cases where the cabinets can be placed next to the wall, but it is advisable, in most cases, leave a distance of 70 cm (27 in) to gain access from the back, especially in the PACS servers. The technical room must be properly conditioned, e.g. if there are 3.000 w dissipation must calculate the required cooling and space for the cooling equipment on the ground or ceiling. Also must be provided a connection to the digital network for the equipment checkup at distance.

The floor should preferably be registrable technical floor, if possible computer type. False ceiling should be provided.

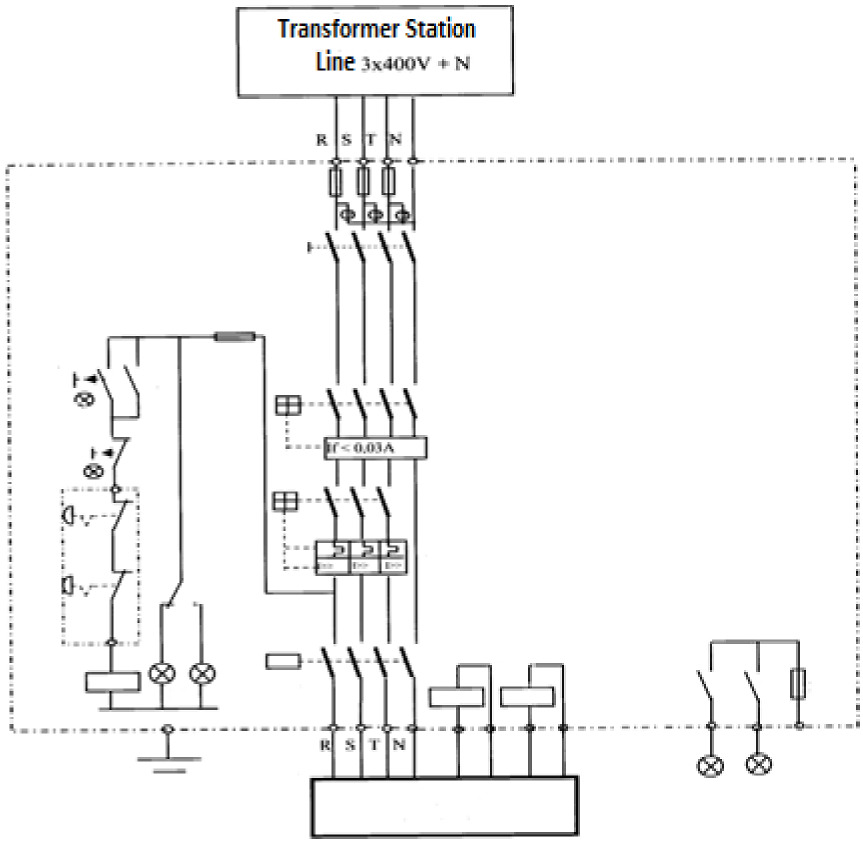
- **Server rooms** for PACS and RIS are very similar to the technical rooms, if there are additional considerations in relation to operating temperature limits, which in this case is usually smaller than in technical equipment rooms; so the air conditioning has to be more critical, not only the temperature, but in humidity and air control particles. Additionally in the case of PACS and RIS must consider the uninterruptible power supply unit, preferably in one closed room, either in the room itself, and must also take into account the copy of the file unit in different place than the PACS and RIS server room. Then there is a server room and a second, smaller, to make copies of the file and save them. The size of the server room depends on the size of the health center. If it is within the imaging department image, is of a small surface, which can range between 8 and 12 m2 (86 to 129 ft2), If the servers are installed in the hospital general data processing room they occupy a small space of the total area.

  The floor has to be computer type, registrable, where run all wires.

  The digital network wraps the image department completely. Its installation should be designed so that are well marked on a drawing the places where the network connectors will be needed for the connection of equipment and workstations. Redundant connections for future expansions or faults should be considered. This network distributes data, telephony and voice for public address. Future provisions are needed in the design and construction of the network to prevent its obsolescence. New diagnostic imaging needs carry equipment designers to build these each time with greater volume of information and it had to be transported by the network that today is designed. Certainly, change an obsolete network is not the more important cost that will face an image department but this fact can widely be dilated.

- In all rooms there must be one **electrical switchboard** which connects power to the equipment and the rest of energy supplies of the room. The one for lighting is located in the general electrical cabinet of the department. These switchboards contain protections that in accordance with the national electrical codes should apply electrical project engineers for the operation of the room and responds to the requirements of the suppliers of the equipment.
  The power that comes from the main transformation of the hospital center, passes through the fuse network, and is protected against defects to ground by a differential of high sensitivity and to overload by a circuit breaker. The bright light signs over the doors of the room are connected to the x-ray generator. And also, the security switches, inside the room and in the

control room, are interconnected in such a way that when tightening them disconnects the power.



(6.34.- Wiring diagram of the utility of the electric room box)

The power supply is usually three-phase, except on equipment with small consumption such as mammography and dental, where it is single phase. Special mention is the accurate connection quality for imaging equipment. The x-ray generators and magnetic resonance equipment need high quality lines specified by the manufacturers. Measures of line resistance is done by the installer to begin the installation, and is a key factor in the setting of the generator. Line above the specified resistance may limit or prevent the operation of the equipment. The stability of the electric power supply and its fluctuations are also specified by manufacturers. Breach can cost a lot of money on repairs and requires uninterrupted power supply units.

In cost-saving measures in power consider the presence detectors in cabins and rooms with sporadic use, programmers of stay, gear units of luminous intensity when the calculated maximum intensity is not required and new devices that the industry provides for savings in energy consumption.

Uninterruptible power supply units may be needed, depending on the quality of the power supply to the health center. These units are generally connected with the operation of each modality and they adapt the power that each machine needs. It is needed to calculate additional space in the technical rooms. For the PACS and RIS servers will be mandatory.

Examination rooms must have low power plug bases in all walls, for connection of auxiliary elements, repairs and cleaning. Also the technical rooms and control rooms must have at least one socket base available for repair and cleaning tasks.

- **Air conditioning installations** can be broken down into four types:

    - Room air conditioning
    - Cooling of the technical rooms
    - Cooling of examination rooms
    - Cooling of components of modalities such as tubes, detectors and magnets.

Ambient air is distributed from a central conditioner to the rooms with inlet air and return pipes. It can be a simple heat pump or a great machine in this regard. The technical rooms may need additional cooling, i.e. in the modern CT where it is necessary to reinforce the cooling of the room by the dissipation of at least 3.5 kW additional by the gantry. They must have additional equipment in the room, either on the ground or ceiling.

Special cooling that require a heat exchanger are given in cases of some general rooms or mammography image detectors or in the case of some x ray tubes with very high power, in the generators cooling of particle's linear accelerators and the cooling of helium that keeps the superconductivity in magnetic resonance equipment. Special facilities are required, in the imaging or therapy department or outside to provide for these equipment that are part of the technological zone, emit a high level of noise and consume significant amount of electrical energy. A summary of data from a small department of diagnostic imaging is shown in (6.35), available for the architect with the preliminary project information.

VI.VI.-SECURITY

Protection of the patient and the staff has occupied the attention of researchers since the beginning of the discovery of the x rays, after observing their harmful effects.

Radiation protection is not unique to consider in one imaging department, where there is a set of disciplines to observe regarding the protection:

Radiological, electrical, mechanical, magnetic, electromagnetic, acoustic, optical, fire, water.

- **Radiological protection** bodies in each country have already arranged binding legislation to plan and operate a radiological installation. The legislation cover actions in the installation, the operators and supervisors setting responsibilities in every part and determining the necessary controls. And very special section in the handling of radioactive isotopes and in units of radiotherapy (17-19).

- **The mechanical safety** is implicit in the calculation of machinery projects and is regulated in all architectural construction codes, as indicated in the instructions for pre installation of the manufacturers of medical equipment (30).

- **Magnetic security**, basically in magnetic resonance. It has very timely tips with the indications of the American College of Radiology, which is summarized in Chapter 12. Also has to be considered the national, or local regulations in each country (32-33).

- **Electromagnetic safety**, is also controlled by national and international standards.

- **The rules of safety and hygiene at work** regulate the decibel level of noise in a workplace, and its enforcement is necessary to have additional elements in the design, especially in magnetic resonance (03-72).

- **Optical security**, is implicit in the design of equipment and manuals of radiological protection, need to use protective goggles. There are also regulations of lighting sources potentially dangerous as the used in the centering lasers whose level is also regulated.

- **Fire and water** problems are also collected in the respective local and national and local codes.

Chapter XII contains international codes and standards in which are based the development of the national standards.

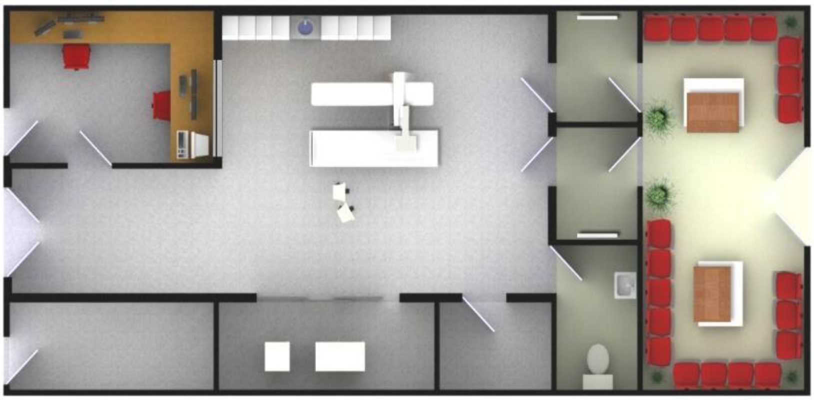
DIAGNOSTIC IMAGING DEPARTMENT

Requirements: electrical, environment, mechanical loads, access and digital network

Room	Funtion	Power(0,1s)		Cooling (wats)			Equipmen access		Radiolog	Weigth	Notes	Network Conections		
		kW	kVA	Control	Exam	Technic	Wide(cm	Heith(c	Protec.	Kg		Control	Exam	Technic
1	MR 1,5 T	60	115	500	2.000	11.000	200	250		4.600	4 support points 1150 kg/support	2		1
		Cool water in Technical Room-External Cooler Quench Pipe Faraday Cage Magnetic Shielding												
2	CT	60	100	2.300	5.800		110	210	TURP	1.800	2 support points 950 kg/support	2	1	
3	Ortopantot.	2	3		600		100	230	TURP	180		1	1	
4	Mammog.	4	7		600		100	220	TURP	200		1	1	
5	Ultrasound 1	1	1		500		80						4	
6	Ultrasound 2	1	1		500		80						4	
7	Ultrasound 3	1	1		500		80						4	
8	Remote Table	65	130	500	1.700	2.200	90	200	TURP	1.400		2		1
9	Laser	1	1		500							2		
10	RD (2)	100	200		1.500		100	145	TURP	400 floor	350kg ceiling	2		
									Tech Unit Rad Prot					
TOTAL	11 Rooms	345	659	3.300	14.200	13.200								

(6.35.- Overview of technical data of a small imaging department)

VII.- RADIOLOGY ROOMS DESIGN



I. RADIOGRAPHIC ROOMS

II. FLUOROGRAPHY RADIOGRAPHIC ROOMS

III. MAMMOGRAPHY, ORTOPANTOTOMOGRAPHY AND DENSITOMETRY

IV. ANGIOGRAPHY AND ANGIOCARDIOGRAPHY

X-ACTLY SO!

The Roentgen Rays, the Roentgen Rays,

What is this craze?

The town´s ablaze

With the new phase

Of X-ray´s ways

Wilhelma, Electrical Review
April 17 of 1896

VII.- RADIOLOGY ROOMS DESING

Alexi Assmus in his magnificent description of the early years of radiology, published in 1995 and that the reader can read on the internet, defines the discovery of X-rays in 1985 *as the beginning of a revolutionary change in our understanding of the physical world.* The change that occurred, with the speed of the moment, was unimaginable to the contemporaries of that time.

It should be remembered that most of the scientific discoveries based its success in previous works, many of these with accumulated efforts of many researchers. At the end of the XIX Century, the English physicist Sir William Crookes created a vacuum tube for his own studies of gas. The tube contained positive and negative electrodes, and an induction coil, through which could circulate electric currents with high voltage. This development was very important for the x ray investigation of the Rector of the University of Würzburg, W.C. Roentgen, that after the publication in the German newspaper Die Presse his formidable discovery was sent by telegraph to all the world.

The modality of diagnostic imaging with roentgen radiation, or X rays, is as already said, the oldest of all modalities now existing, and which has led to a new way of doing the clinical diagnosis. Just remember the process of diagnose a bone broken only with palpation of the doctor. In the same way it is the technique that continues to be massively used currently for the clinical diagnosis.

Conventional radiology, according to data from the reports of UNSCEAR, is the first choice in diagnostic imaging, and it will remain so for many years. Ultrasound is today very close in developed countries, and may surpass radiology as first selection in diagnostic imaging.

Chapter I analyzed their development and the evolution of the planning and design since its inception, more than a hundred years ago, until the beginning of the era of suppression of the film as image support. This fundamental fact in the history of radiological diagnosis occurred with the end of the last century, and as well the technological change in the departments of image is not immediate, It is occurring without pause, depending on the investment capacity of medical organizations and according to the capacity of the responsible managers of the imaging departments.

The equipment that before used chassis with radiographic films, and reusable plates after, now have sensors of the radiological images, have solid state digital detectors that have replaced not only the chassis, but also the modern image intensifiers that for fifty years have solved the radiation signal conversion in radiographic or fluoroscopic image presented on a TV screen, and from there to the multi-format cameras, files to optical discs, etc. Now static processes that capture the conventional radiographs and the dynamic processes, captured in angiographic or digestive systems have a virtually Instant playback, with file distribution instantaneous, or at the time of the order of the sub second.

Will be reviewed the designs of the rooms that host systems using roentgen radiation as energy source for image generation in their different equipment, for the multiple applications where they are used today.

For its application reasons and order it he design lead to divide rooms into the following sections:

- Radiography
- Fluorography Radiography Systems
- Mammography
- Ortopantotomography
- Bone Densitometry
- Vascular
- Hemodynamics

Will be advanced the different alternatives in the design of each room, in its different configurations and applications and will be detailed the requirements to the design that the patient, personnel, architecture, technology and safety forced it to move in one or another way. They are the same aspects that were previously analyzed in a general way but which, now, are particularized to some specific modalities.

VII.I.- RADIOGRAPHIC ROOMS

They constitute the basis of the majority of the imaging departments and may present very different configurations, depending on the application to which the rooms are intended for.

The first room to describe is the **general conventional radiographic** room. In this are carried out all the tests required for the confirmation of a general clinical diagnosis; an x-ray as a document for the physician's reference along with other diagnostic tests establishes the corresponding therapy.

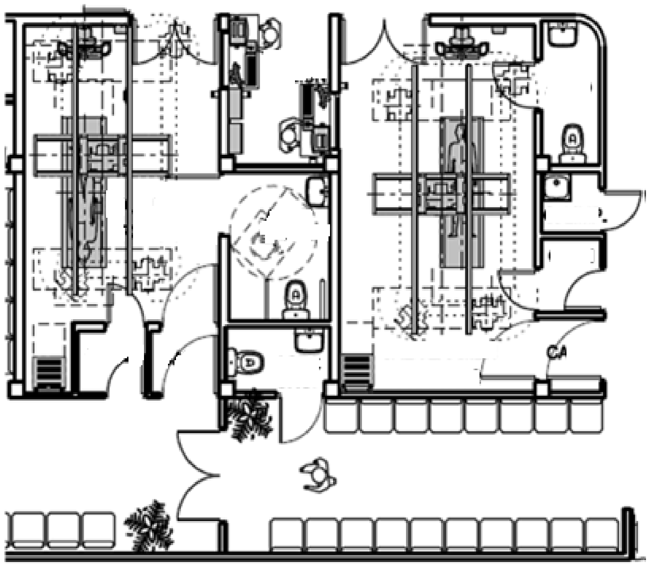
Presented with a detector or two detectors configurations. Those of higher productivity are committed to a detector under the horizontal table and other detector in the wall bucky. Detectors with large field, replace without difficulty to 35 x 43 cm (13x16 in) cassette formats, accepting image capture in smaller formats if the radiographic acquisition area so requires.

Detectors has today a very wide production and many manufacturers are offering its designs to the equipment manufactures. Resolution is improving with the time and also the pixel formats, that tend to increase the weight in Megabits of the images generated. That means more transport capability inthe networks and more necessity of archive.

(7.1.- Conventional radiography room with two detectors)

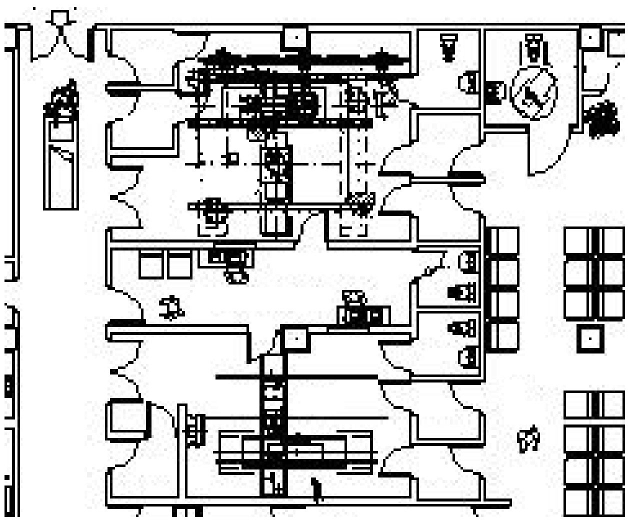
There are also two possibilities to support the radiologic tube; one in a column stand that moves on rails on the floor parallel to the horizontal table and that is fastened with other rails on the wall or on the ceiling. Another configuration, with ceiling support, it is more versatile, but it has the disadvantage of the necessary work on the ceiling to hold the rails where the tube support carriage moves. This provision has the x ray tube suspended to the ceiling. The set of rails and the cart tube support form ceiling suspension, and it is the best solution from a standpoint of ability to perform projections on the table and the wall bucky. It is also of greater mobility for the technician who easily can position the tube and the patient for the x-ray acquisition.

Figure (7.2) solution includes two rooms of conventional radiography with two detectors, one is for outpatients, left, attached to the emergency room (on the right), that in the case of saturation of one of them can be supported by the other. Can be seen the great mobility of tubes on the rooms, and although the wall buckys are aligned on the longitudinal line of the horizontal table they would be located in the front wall or anywhere else in the room. This flexibility is not available in configurations with column. On the wall bucky can be performed complete columns ans extremities with the simple vertical displacement of the tube and the detector, synchronized automatically. The patient is supported on a stand with scales to the effect. Two rooms share a common space for control and being so small space, technicians have access to examination rooms by the gateway of stretcher patients. There are two sheets of 72 cm (28 in), leaded doors.



(7.2.- Layout of conventional x-ray rooms)

Other settings, where the room should have the possibility of multiple use, both inpatient and external is displayed in (7.3).

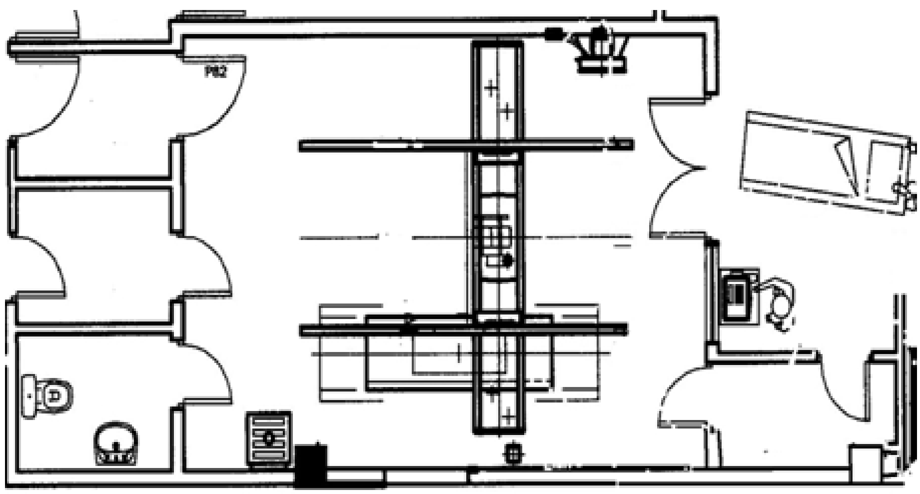


(7.3.- Conventional radiography rooms with common control)

Two rooms with the configuration of horizontal table with ceiling support and two detectors share control room with access doors, leaded, from this control to the exam rooms.

In the top is shown a configuration with two cabins for possible patients arriving in the emergency department and an entry of beds, formed by two doors of 72 cm (28 in), other two cabins for possible external patients and one internal toilet for patients.

The solution (7.4) also combines the activity of emergency with the possibility of exams to outpatients. The beds come down the emergency aisle, and there is a cabin for possible patients in emergency room who come on foot. Dimension them from the examination room is 4,5 x 6,5 m (14x21 ft) and a total area of 29,25 m2 (314 ft2) quite superior to the 21 media m2 (226 ft2) described in Chapter 4. Emergency rooms must, if possible, be designed with more space. Patient mobility is reduced and the assistance of several technicians or nurses are widely provided.

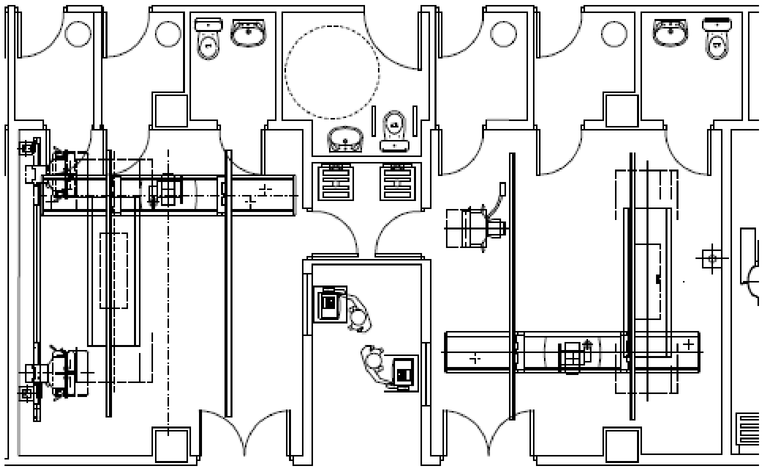


(7.4-Conventional radiology with ceiling suspension room)

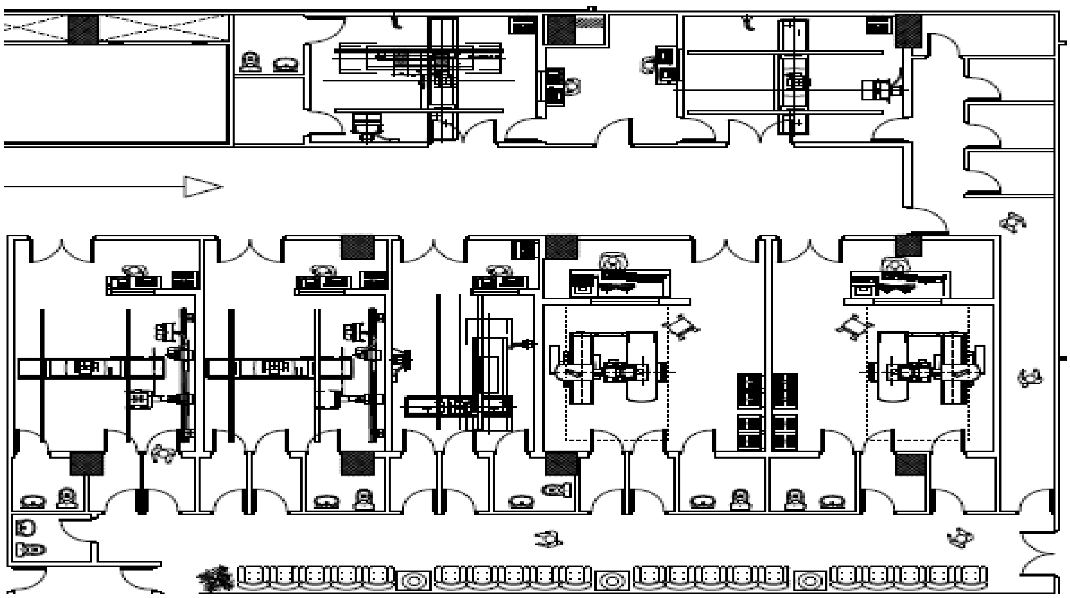
However the room could have been reduced, although the architectural situation allowed this larger space. It is noted that the total area with cabins, control and access of beds is 48 m2 (516 ft2).

An example that adapts to medium surfaces previously calculated is the figure (7.5), where there are two aligned conventional rooms. Each room with dimensions of 4,5x5,0 m (14x16 ft), are in the order of magnitude of the described medium size room. As can be seen are shared for two rooms the technical room which houses the cabinet with the generator and control electronics as well as the control room. Two cabins surface is the minimal advisable for rooms with two detectors. The workflow is very fast and exams, with the adequate staffing can be done at an average of 3 minutes, so the performance is very high. This requires cabins enough for a change of clothes, that in some patients it may take time.

A step further, in hospitals with high attendance, is shown in example (7.6) with four rooms with two detectors and one for chest with a single detector, also with ceiling support. The dimensions of each exam room of 4, 5 x 5, 5 m (14,7x18,1 ft) are in average values.

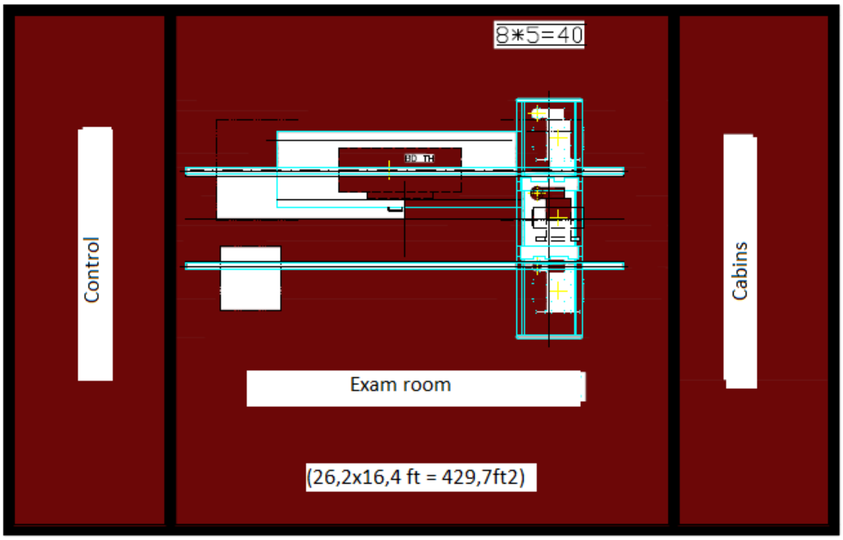


(7.5.- Radiographic rooms sharing control and technical room)



(7.6.- X-ray rooms in a large hospital)

A conventional radiographic room is only enabled for in-patients, with direct access from the beds from the corridor coming from the lifts. All rooms have two cabins, except the chest that has four, and its total area considering cabins and controls is 442 m2 (4.757 ft2). Consider the surface loss in the designated space for the existing stairs space. Fact that have to be considered in the calculation of the blocks to take in the pre-design of the department.



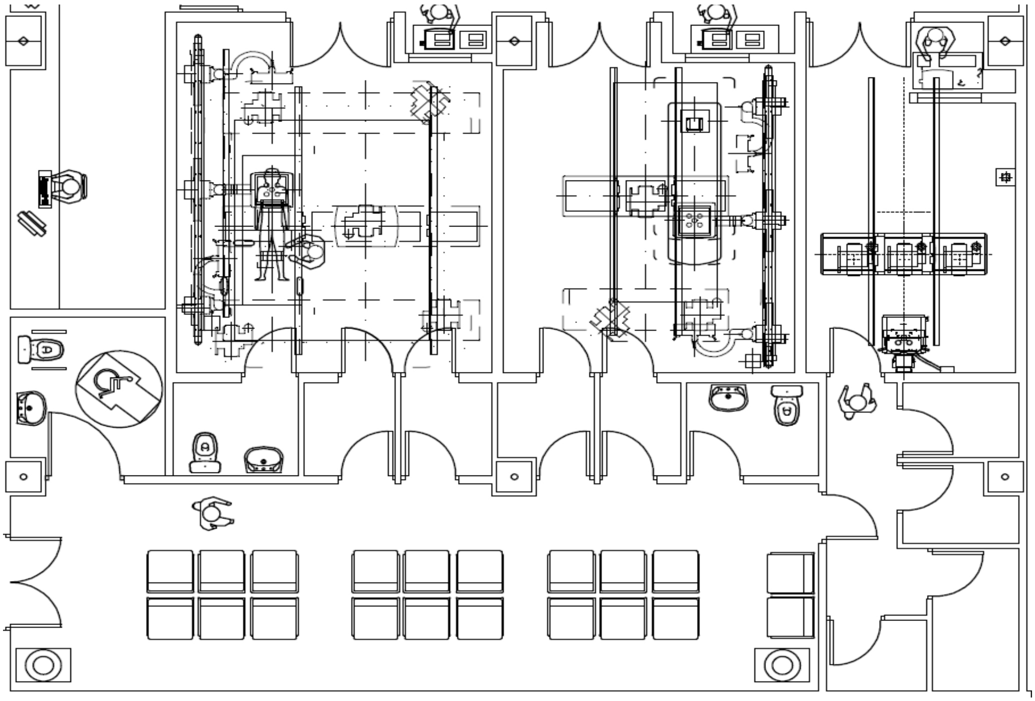
Surface of the block: 40 m2 (430 ft2)

(7.7.-Block for design)

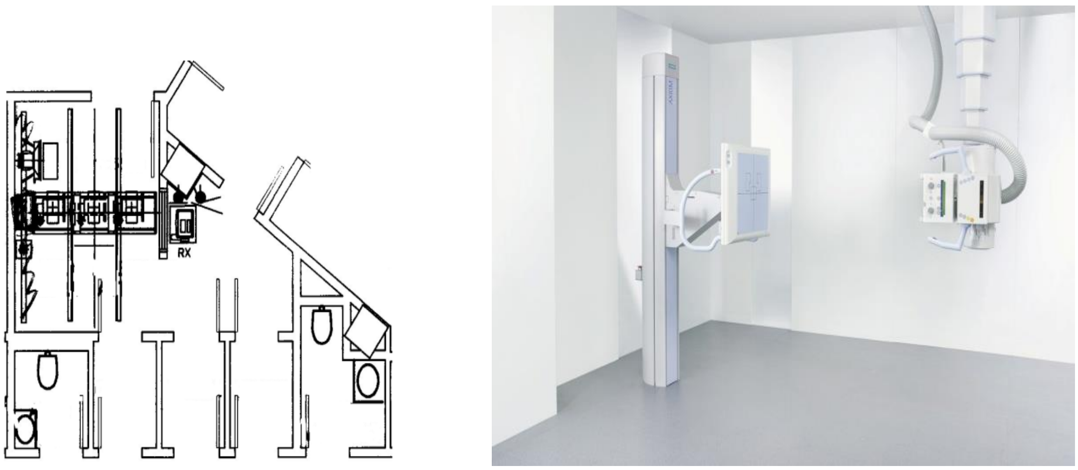
Digital chest room, successor of the automatic chest room that had a film cartridge to store the films and a developer machine integrated with the basis of the chest unit, are now of greater functionality and are able to do with the same detector thorax, skull, limbs and abdomen i.e. practically most of the procedures that make standing. With three cabins and a correct citation in the RIS the performance can be higher than the previously mentioned for general rooms with two detectors.

The chest (7.8) room below, with four cabins, has a size of 5,5 x 3,0 m (18,0x9,8 ft) with a total area with cabins and control of 33 m2 (355 ft2), enables a high production.

A chest room, taking advantage of one architectural corner, with 24 m2 (258 ft2), with three cabins (7.9) can see it in the example. The reduced dimensions of the control are sufficient for the location of the processor and image electronics, the monitor and keyboard control for the technician, with a room exam surface enough for the tests to be carried out.

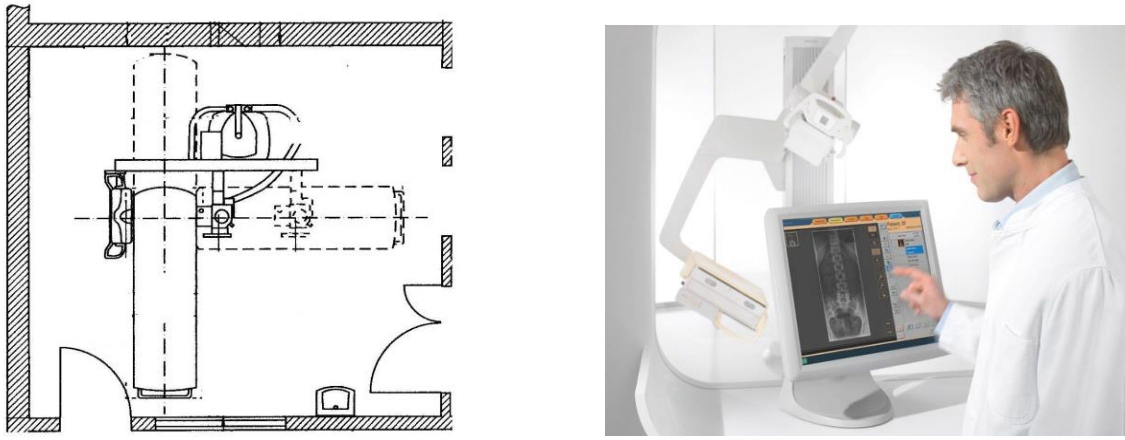


(7.8.- Set of general x-ray and chest rooms)



(7.9.- Chest radiographic room)

Important in conventional radiology is the universal stative, successor of the systems proposed by the World Health Organization in the early 1980s for basic radiology.



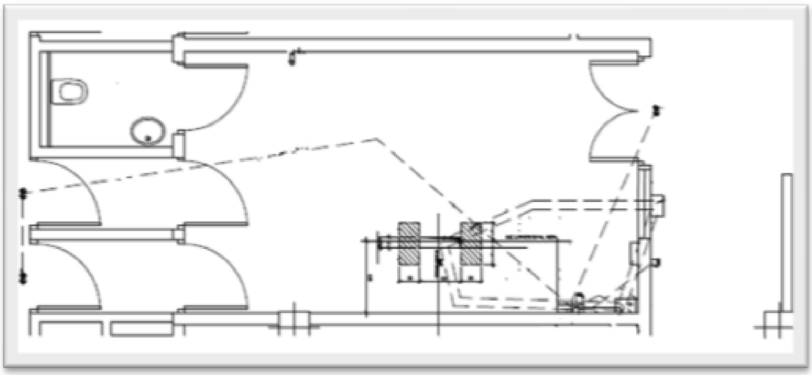
(7.10.-Universal stand. Basic radiographic unit)

The examination surface already occupies an area equal to a room with two detectors, although the cost of this universal system is significantly more reduced and its installation does not require the cost of the work on the ceiling which require rooms with tube support to the ceiling and two detectors described. If it is used without the stretcher, which occurs in outpatients, the dimensions of the examination room can be reduced widely.

Conventional diagnostic rooms have certain specific requirements, but with less demands as those that will see in the next chapters of magnetic resonance and PET-CT, as significant examples.

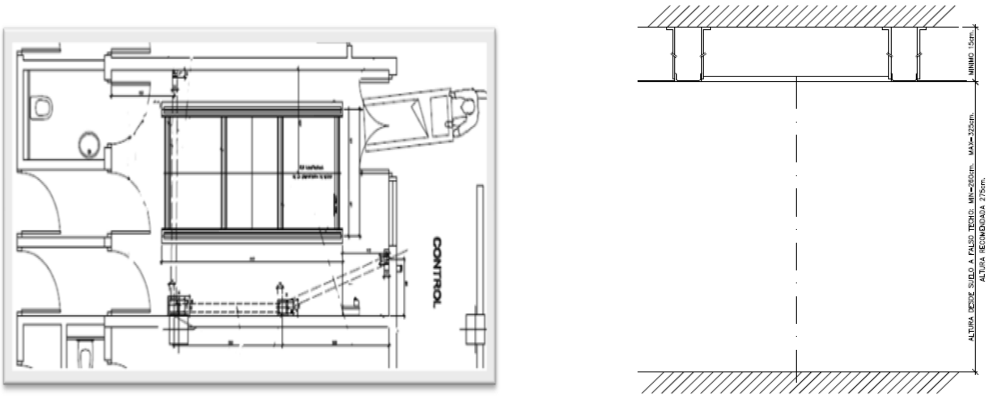
- **The patient**, which with the average dimensions for these rooms does not have special requirements. Cases of pediatrics where for the fixation of the patient required troughs or special fasteners do not condition the room design. The toilets could be eliminated in many conventional radiographic rooms, however, enemas continue, and the population increasingly older, may require these.
- **Control rooms** should have the window in such a way that the visibility allows to work standing or sitting on a high stool. 1.10 to 1.15 m (3,6 to 3,8 ft) heights are recommended. Leaded glass dimensions depend on the design, but they must allow good vision with the operator sat on a high chair and standing. Do not forget hangers for aprons.

- **In exam rooms** the ceilings must be flush with metal structures that support suspensions, and have to be designed furniture and sinks, required by building codes in various countries. Ceiling heights range between 2.7 and 3.2 m (8,9 to 10,0 ft).



(7.11.- Pipes for wiring under the soil)

- **The equipment** have manageable weights and dimensions. Corridors, with widths of 1.50 m (4,9 ft) allow for entrance the exam equipment to installation rooms, and weights below 450 Kg. (992 lb) don't present problems of loads to the ground. Only the ceilings should be prepared for the suspensions assembies.



(7.12-Tubes for wiring up the ceiling and support structure)

- **Do not usually have technical rooms.** There is only one component, an electronic cabinet, which is placed in the space of the room where less hindered mobility.

- **The heat dissipation** does not usually exceed the 2 kW, and is convenient, especially in warm climates, calculate the corresponding dissipation in exam rooms.

- **The electric connections** require mostly three-phase current and ensure total line resistance below that specified by the manufacturer. Line resistance in the range of 0.2 to 0.3 ohms are normally accepted.

VII.II.- RADIOGRAPHIC FLUOROSCOPIC SYSTEMS

The diagnosis of pathologies in the blood vessels, organs and cavities of the human body led to introduce opaque contrasts to radiation to be able to define them. Fluoroscopic and radiographic equipment (FR systems) enables to observe profiles of organs, e.g. the stomach can be viewed with high image contrast and thus diagnose their diseases. Also large number of procedures require monitoring in real time its processes, e.g. biopsies, drainages, etc. that add a full catalog of medical acts which justify the historical necessity of these machines in the imaging departments.

The most popular equipment in Europe, remote controlled tables, being tilting tables with digital imaging systems most popular in America, have been for many decades the most outstanding equipment of all the departments of diagnostic imaging. A radiology department had several of these systems that were used in many cases for all radiographic and fluoroscopic exams needed in the department. Intense marketing led in the 1980s to design variants with high dedication equipment to the digestive or pediatric fields exclusively, today already discontinued by their minor clinical need because are replaced by other modalities. They are one live examples of the changes in the procedures caused by the introduction of new forms of diagnostic causing significant substitutions. There are remote units and tilting tables with image intensifiers or flat detectors, the fluoroscopic and radiographic systems, currently used in decreasing application process.

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(7.13.- Digital remote controlled table)

Their applications are being replaced with other techniques such as endoscopy and ultrasound image, although there is still a future for these devices.

(7.14.-Tilting table FR)

Different types of designs can be overhead or featured with tilting tables o remote controlled tables, variable with the application.

The design that is shown in (7.15), a remotely table, has an examination room of 4, 5 x 6, 5 m (15x21 ft), with a surface of 29,2 m2 (314 ft2), i.e. very close to the average value of these rooms. Control room with 15 m2 (161 ft2) allows the work of the technician, radiologist and the person who is reconstructing on the workstation that often accompanies these equipment, like exams of complete column, extremities, colon, etc.. Technique room, 5 m2 (53 ft2) houses form-fitting necessary electronic cabinets. The full block, without considering the surface of patients wait, occupies a space of 67.5 m2 (726 ft2).

Waiting room, individualized to others waiting areas in the department, allows more personalized care to patients, with own toilet separated by a partition. Two cabins and an inner toilet complete the configuration of that design.

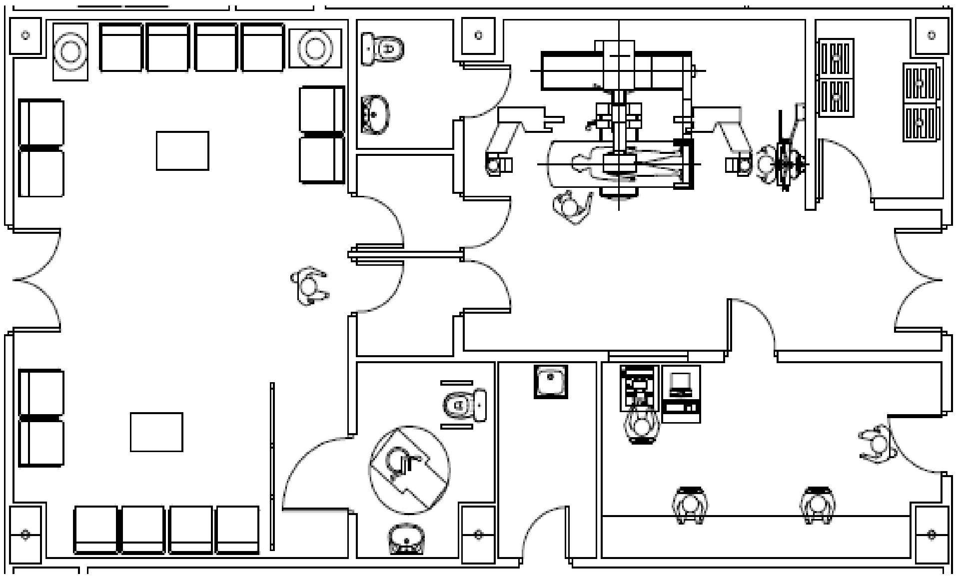
A design of more spaciousness, where the remote control in the upright tube position could shoot on a wall bucky to make chest at a distance of 2 m, is shown in the example (7.16), where the medium surfaces are already achieved.

The lateral position of the control room ensures an optimum operator view.

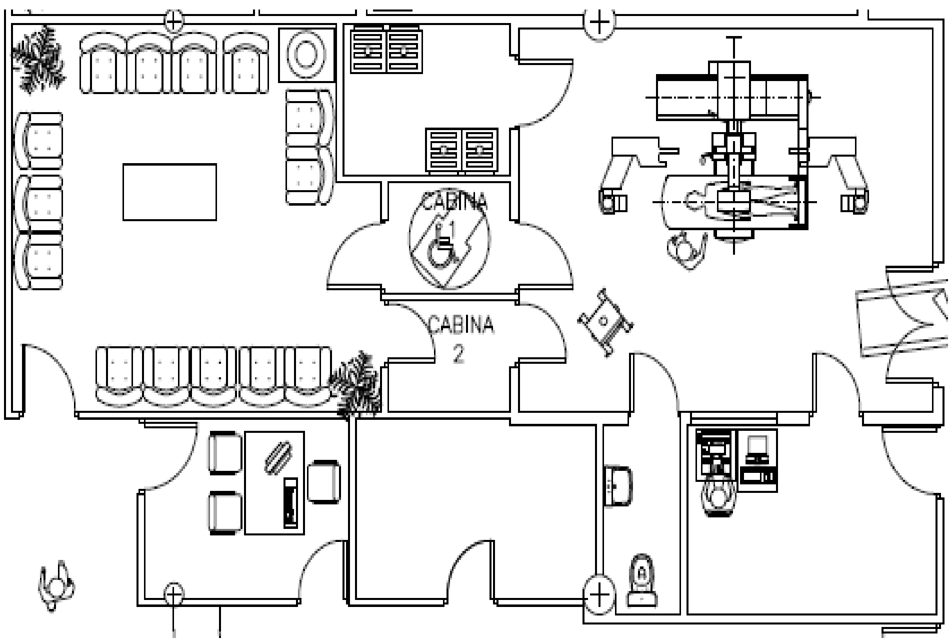
An example with two remote controlled tables is shown below (7.17).

Each remote control table has its technical room and both have common space for the controls. The diagnostic room for two radiologist is behind the controls of the technicians.

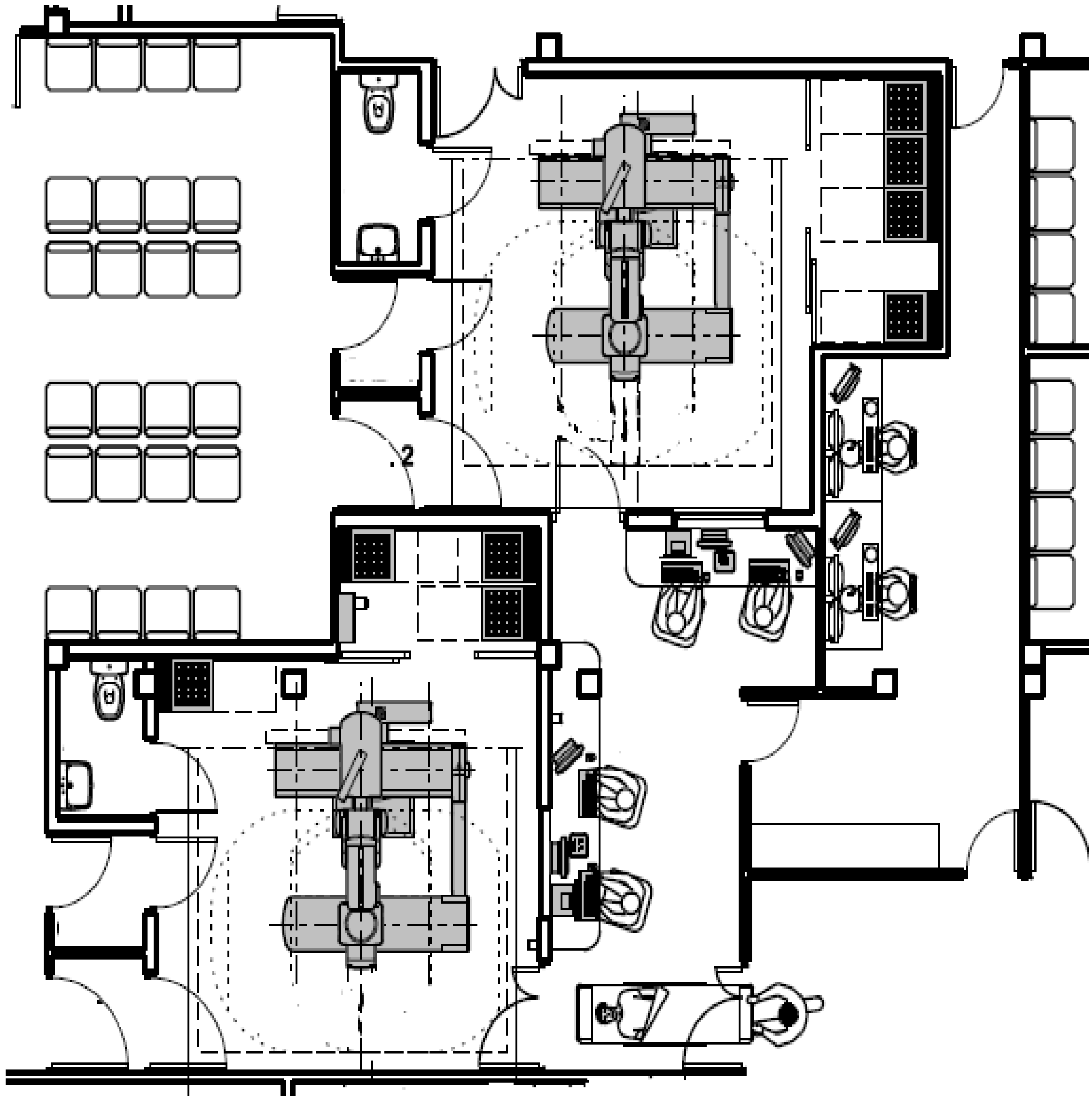
Examples of design of gutters and pipes for the conveyance of interconnect cables are shown in the figure (7.18).



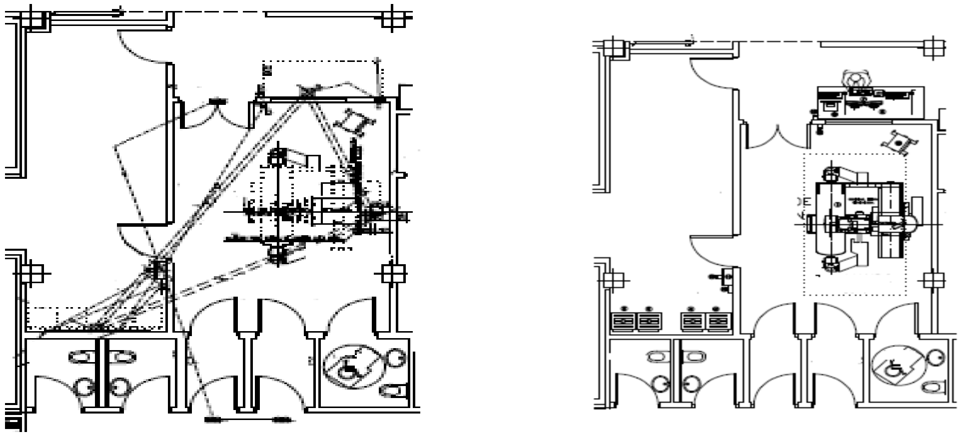
(7.15.-Remote controlled table room)



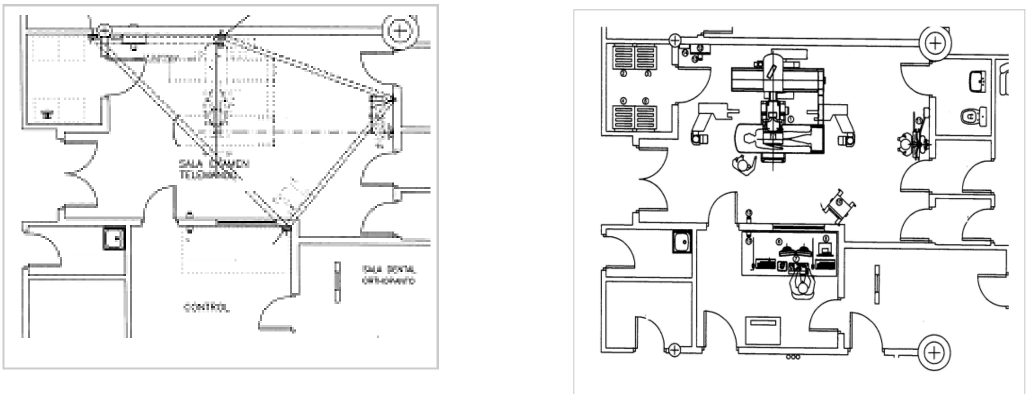
(7.16.- Room with digital remote controlled table)



(7.17.- Remote controlled tables)



(7.18.- Tubes for cables under the floor and above the suspended ceiling support)



(7.19.- Gutters and pipes for wiring)

There are details of the gutters of the technical room and tubes for the wiring connecting the different components of the equipment (7.19).

A similar situation presents the design of multifunction equipment rooms (7.20). Exam room surfaces are larger than in a conventional remote control, in general, for the dedication of the room to vascular and interventional techniques that require the work of several people in the room, as well as additional equipment that need more space, as in the case of video endoscopy, which in some cases require anesthesia. Spaces for endoscopy and anesthesia equipment as well as the operators are significant and they must be planned to perform the technique with proper care to the patient and operator. It must also include in this section the remote controls for special applications, such as radiographic urological and interventionism in urology.

(7.20.- Multifunction system and remote-control for urology)

In these rooms with electrodes or catheters, for its design, it must be considered electrical insulation systems for the installations, as safety regulations require for electrical defects at low voltage. Likewise soils must have suitable conductivity suitable for ground connectivity of the room in such a way that it is complying with the regulations in this regard.

- **The patient requirements** focus on access to the table. Most have adjustable height tabletop and do not need sidewalks to upload the patient and the dimensions of rooms for access to beds should be higher than the 4.5 m (15 ft) wide to accommodate the patient bed parallel to the table and make the transfer. Fasteners of the patient are supplied by the manufacturers of such equipment**.**

- **The dimensions of the roads or paths to access the room** in the process of installation are in the range of 1.0 x 2.5 m (3,3x8,2 ft) by going through the doors to the rooms, for beds they already have, or should have, in the order of 1.3 m (4,3 ft) wide.

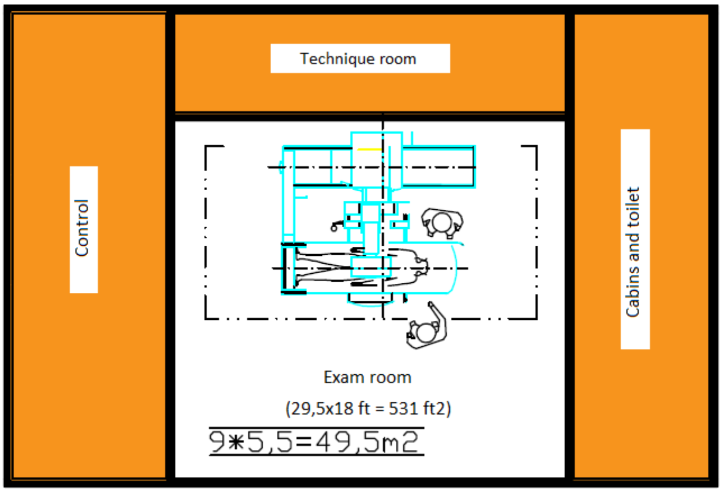
- **The weights** are a factor to be considered in many installations, and it is a limiting factor in some. 1.400 Kg (3.086 lb) of weights may require reinforcement of soil and in general non in the architectural structure.

- **Locking plates** are supplied by the manufacturers at the time prior to installation, or locally built of iron, with measures and thickness adequate to distribute the load of the table on the floor.

- **The climatic conditions** are important in the technical room. It requires temperature control, working in the range of 15 to 30 ° C. Heat dissipation is appreciable. Between 2 and 3 kW are normal dissipation in the technical room to be considered by the engineering in the calculation of the cooling equipment as well as between 1 and 2 kW in the examination room, In addition to the normal calculations of air conditioning, to provide a comfortable temperature.

- The ceiling heights already described in Chapter VI are suitable to these rooms. Below 2.8 m there are often limitations on movements in the arm and in the tilting movement of the remote-control table, so this data requires observation.

- **The blocks for a remote controlled table or a tilting table** set an area of 50 m2, addition of exam rooms, technical, control and cabins and toilet.



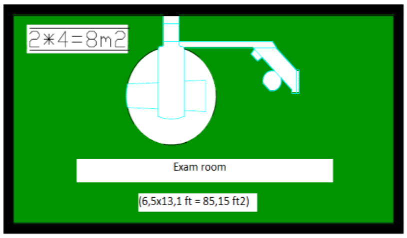
Block surface: 50 m2 (538ft2)

(7.21.-Desing block for remote controlled table and tilting table)

VII.III.- EQUIPMENT FOR MAMMOGRAPHY, ORTOPANTOTOMOGRAPHY AN BONE DENSITY

Mammography equipment and the rest of the here mentioned are the simplest, of all radiological equipment, for the design of its rooms. Also radiation protection, having very low doses in relation with other equipment, requires smaller thickness of protection barriers.

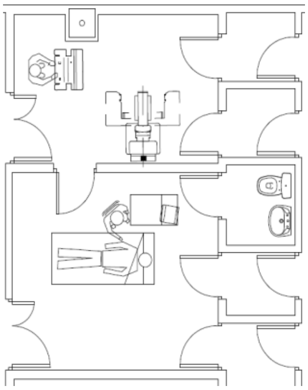
These equipment are installed in almost all of the hospital departments, although in many the productivity is medium as most of the equipment of these modalities are installed in ambulant patients centers and preventive exams facilities, case of mammography, with comprehensive campaigns of early detection of breast cancer. Many of the facilities of ortopantotomography (7.22) are also located in consultations of dentistry, outside the conventional diagnostic imaging area.



Block Surface: 8 m2 (86 ft2)

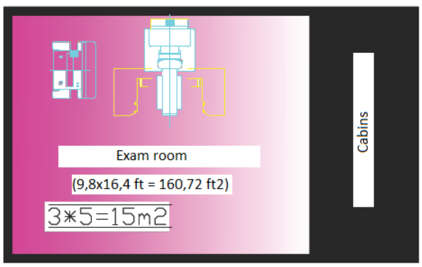
(7.22.- Block for ortopantotomograph)

Different designs can be offered to the location of mammography, in most annexed to one ultrasound room, in such a way that the patient may go trouth mommography and after to ultrasound room to a complementary scan(7.23).



(7.23.- Mamografo with ultrasound room add-on)

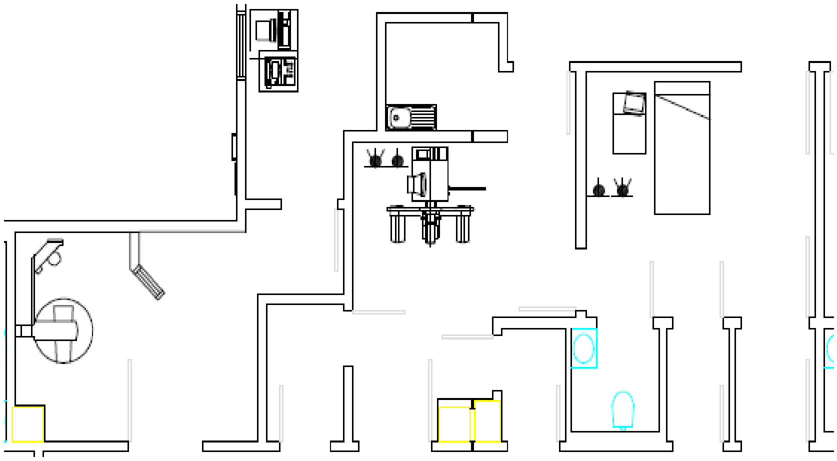
Two cabins are suitable and the dimensions of 2,5 x 4,0 m (8,2x13,0 ft), are sufficient. With cabins the design requires a total of 15 m2 (161 ft2).



Block surface: 15 m2 (161 ft2)

(7.24.- Block for mammography)

Broader designs can be specified when performing many biopsies and even more in cases where the stereotaxy is a further technique to perform. See drawing (7.25).

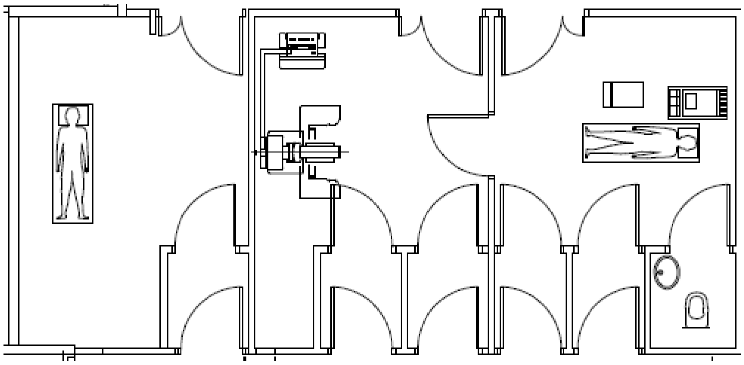


(7.25.-Mammography with stereotaxy)

Stereotaxy instrumentation is cleaned and stored in the attached space to the mammography room. Communication with the ultrasound room is also a solution, and can be seen the side room of ortopantotomography (7.25).

(7.26.- Mammography room with dynamic LEDs lighting)

The total area, with cabins and enclosed room for instrumentation reaches 19 m2 (204 ft2). The ortopantotomograph has a total area of 12 m2 (129 ft2). Areas of 8 to 10 m2 (86 to 107 ft2) are sufficient for dental panoramic installations.



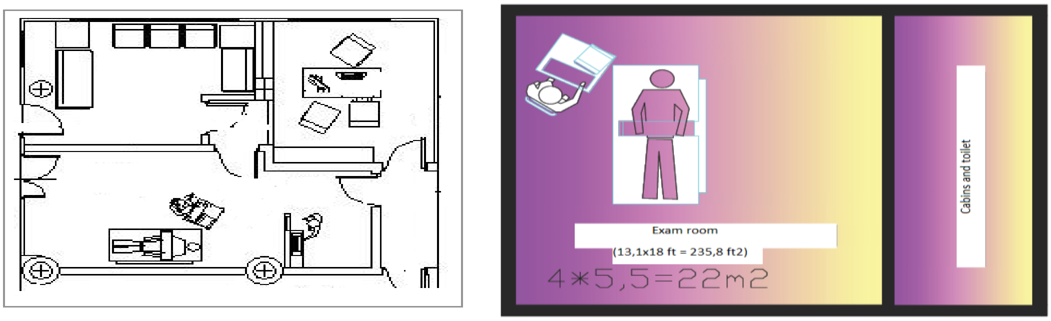
(7.27.- Block of mammography with ultrasound and room for punctures in prone position)

In this example (7.27) stereotaxy and biopsies are performed in an enclosed room on a table in prone position designed for these techniques. The three basic rooms for the diagnosis of the breast come together in a compact block for both patients and staff, occupying the three a total of 57 m2(613 ft2), including cabins and toilets. Additional design is required for furniture and room punctures in prone position.

The current 3D design allows to present with good detail and scale all the objects that are included in a room of mammographic imaging. The following figure (7.28) shows a room of mammography with details of equipment and its control with the window-barrier of leaded glass

(7.28.- Drawing 3D of a mammography equipment)

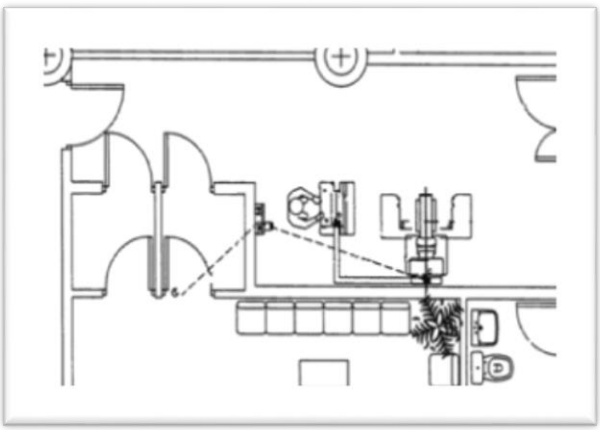
An example of design of a bone densitometry equipment shown below (7.29).



(7.29-Implementation and design of a bone densitometer block with 22 m2 (236 ft2)

- **Installation requirements** are reduced. The weight of a mammography machine is less than the 600 Kg.(1.322 lb), and is installed by fixing it to the floor with screws. The ortopantotomographs, with inferior weight tend to attach to the floor and wall, by the walls of insufficient mechanical support materials must place a slight reinforcement structure fixed to the floor or wall, or ceiling, where is screwed the equipment.

  Gutters are very simple (7.30), only there are control cables to the stative and can hide, if there is space under the floor, with tubes below this.



(7.30.- Gutter and doors of a mammography system)

- **Electric power is single-phase**, below the 5 kW, and are protected against defects, with a differential and a circuit breaker. The air conditioning has to be calculated for less than 500 W. Some equipment may need special cooling for the mammography detector.

- Block to define, considering cabins and toilets, for these equipment of 15 m2 (161 ft2), reduced to the ortopantotomograph to 8 m2 (86 ft2) (7.22) and 22 m2 (236 ft2) for the block of bone densitometry.

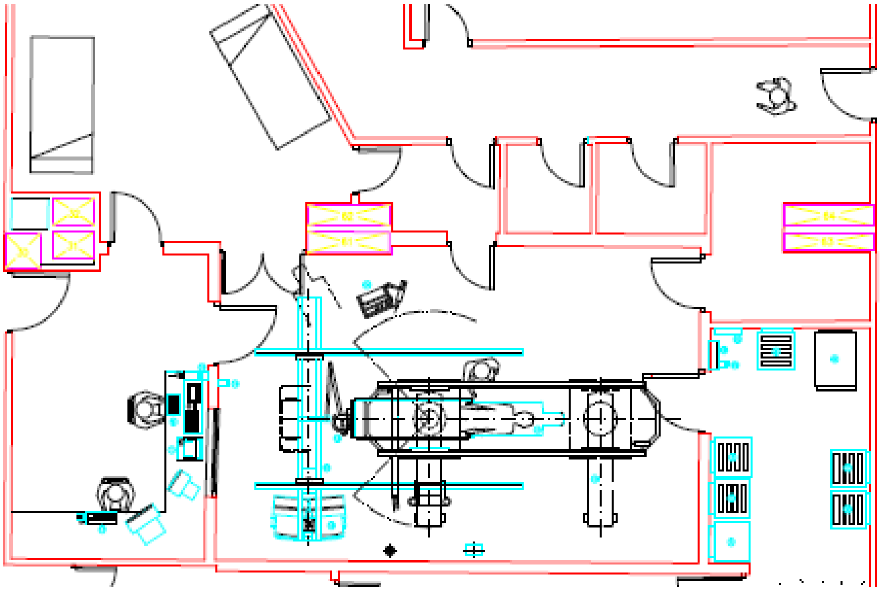
VII.IV.- ANGIOGRAPHY AND ANGIOCARDIOGRAPHY ROOMS

The design of this rooms requires dedication and experience, rooms that perform few patients daily but with exams and treatments of high specialization.

(7.31.-Vascular room)

Vascular diagnosis is being made, more and more with non-invasive techniques or minimally invasive, such as CT, magnetic resonance and ultrasound, so these highly specialized installations are having a use, more and more, essentially therapeutic and growing in use at a single rate limited by the capability of investment of health institutions and by the availability of faculty staff with experience.

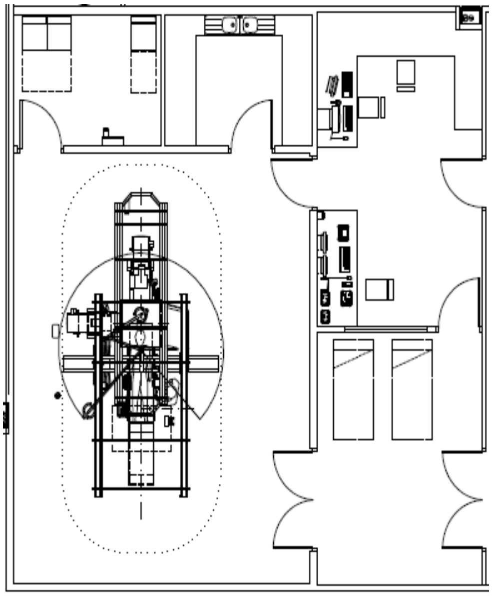
The room of interventionism (7.32) has a preparation area of 9 m2 (96 ft2), a control with front and side countertops for the controls and a technical room, which is shared with a next CT multislice. A cabin for ambulant patients, which uses the same corridor than the outpatients of the external installation of MRI of the attached room. The surface of the examination room is 31.5 m2 (339 ft2), next to the medium. It is equipped with an arch suspended in the ceiling. The figure shows the structures that support the ceiling arch and monitors, and with all the outbuildings total area is 70 m2 (753 ft2). Inside the room of catheters is doctors sink. The room of diagnostic radiologists is outside this area, but a few meters from the examination-therapeutic room.



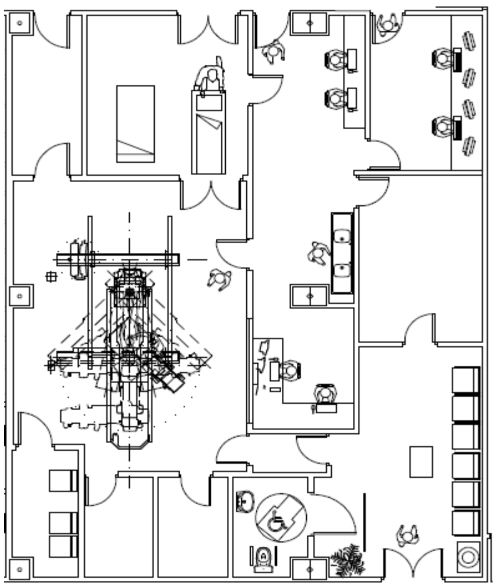
(7.32.- Vascular room drawing)

Design (7.33) is a facility dedicated to interventional vascular and cardiac catheterization, dimensions for examination of 6, 5 x 8, 5 m (21x28 ft) and an area of 55,25 m2 (594 ft2), generous in size but consider that general hemodynamics rooms, where in addition to adults, pediatrics is made they require monitoring, anesthesia, infusion pumps, truck for cardiac arrest in the room and another additional instrumentation who together with the staff who carried out the treatment need additional space not specified in other circumstances.

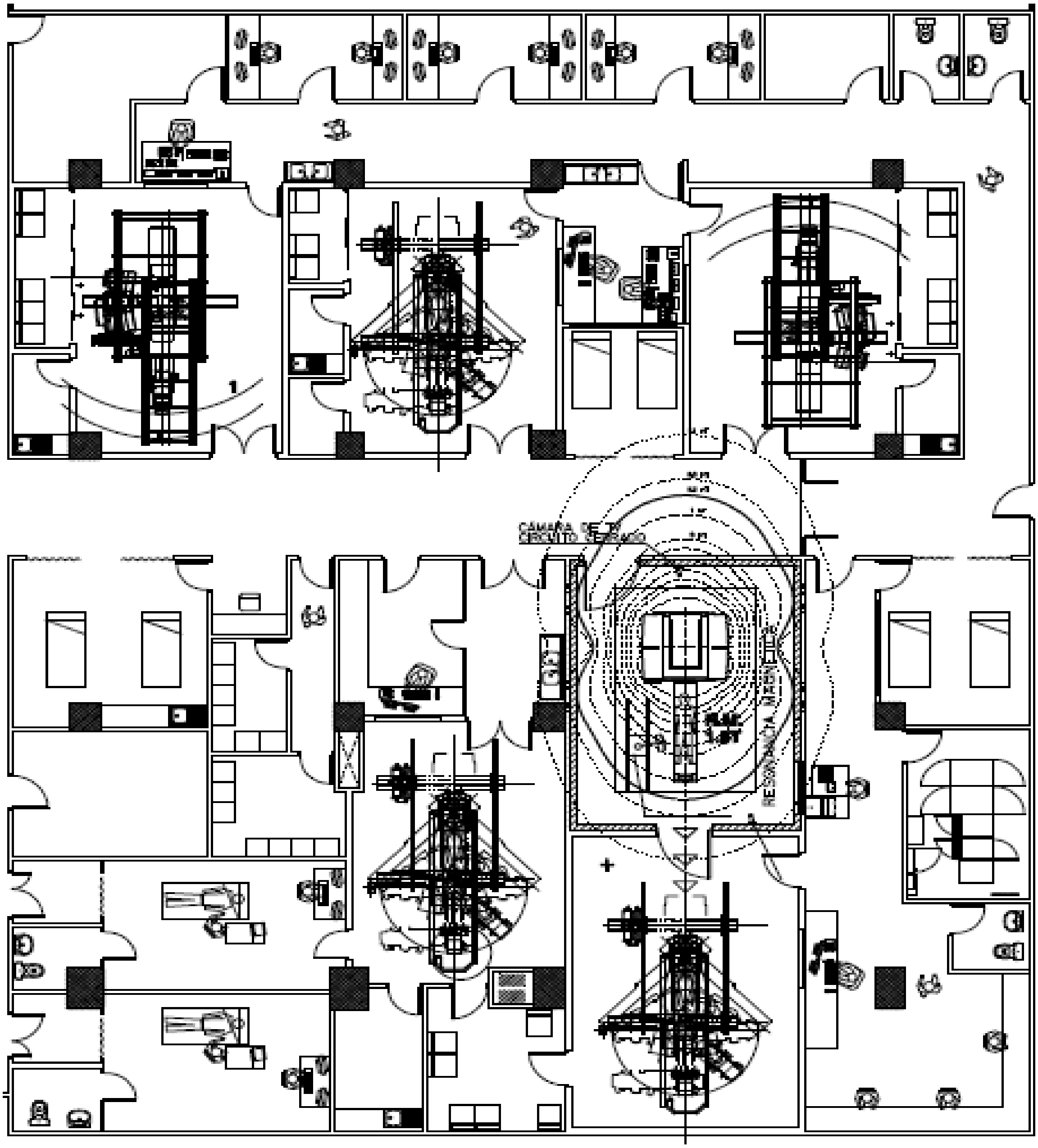
The warehouse of catheters is as in the previous case, the sink and the control room includes in addition to the radiological and hemodynamic controls the workstations of PACS and 3D calculations for diagnostic and cardiology review. Total used area is 110 m2 (1.184 ft2), whereas all necessary dependencies included in the drawing.



(7.33.- Angio – hemodynamic room)



(7.34.- Hemodynamic room. Arm supported to floor)



(7.35.-Vascular interventional block)

New design of a dual use installation (7.34), single plane arch to the ceiling, for vascular intervention and general hemodynamics. Preparation, smaller than in the previous design, clean and dirty rooms, sink in the control room, before entering the exam room, with countertops for controls angiographic and hemodynamic, and a room of consultation prior to the waiting room of patients where the interventional radiologist and cardiologist angiographer can explain to patients and family treatments to make, sign informed consents, etc. The surface of the examination room is 38 m2 (344 ft2) and the total, considering also the waiting room and the room of diagnosis for cardiologists is 166,7 m2(1.794 ft2).

An example with several vascular room, two single plane and two biplane shown above (7.35). Vascular unit, integrated in a large imaging department, also includes mixed vascular-magnetic resonance room for special applications and research. Exam rooms have an area between 30 and 35 m2 (322 to 376 ft2) having the biplanes largest surface of total occupation considering space for controls and technical room. The examination room hybrid vascular-resonance has a surface of 80 m2 (861 ft2) to which must be added controls and corridors. The total space occupied by this unit of vascular, with two ultrasound systems, diagnostic rooms, room control patients, beds waiting, and waiting for patients is of 679 m2 (7.308 ft2).

- **The requirements of patients** for these rooms are exigent. Preparation rooms must have surface suitable for care to the patient before and after the intervention, as well as accommodate the necessary instrumentation. In cases with high workload they should have two rooms, one for preparation and a second for recovery. A consultation next to the waiting room of patients, or attendant, is required to work in explanation and consent requiring intervention. It is a small office, but useful and necessary.

(7.36.- Vascular interventional room)

- **The personnel** need space in the control. They are usually several people, and more in the hemodynamic and electrophysiology, it accumulates much instrumentation to operate by different operators. Sometimes there are other doctors following intervention. It is also a necessary space for analysis of data from the procedure, basically the pre-intervention diagnostic and data post-intervention, in the various workstations existing for this regard.

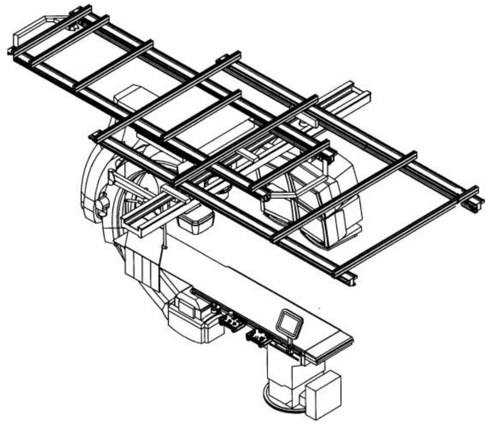
- **The sink** (7.37) must be in the path of entry to rooms, or at the entrance next to the door of the room. The catheters room should be on the inside of the room, closed, and the clean and dirty rooms connected with supply and evacuation circuits.

(7.37.- Sink at the entrance or before the interventional room)

- **Constructive needs**, consequence of the procedure and technology, are no less important.

  The access to the equipment, that exploded may have components with 1,200 Kg (2.645 lb) must have minimum spaces of 1.3 m wide by 2 to 2.1 m high (4,3 x 6,6 ft), what sets the doorway to the room and the doors of the circuit access for the equipment and its installation.

- **The examination room** must be reinforced in the ceiling to withstand the structure that supports the arch and monitors, except in the case of arches supported on floor. Schemes of structures are provided by the suppliers of these equipment, and the constructor should order to manufacture, collect and install in the civil works.



(7.38.-Ceiling support structure)

- **The technical room** can stand significant loads and as function of the requirements of the supplier, should be considered the load to soil, technical floor and false ceiling.

- **Leaded window** is larger. Two people, at least, observe the procedure.

(7.39.- Electronic cabinets)

- **The electrical installation** must have direct connection with the hospital mail transformer or the one specific for the department in the cases of large centers with own department transformers; low line resistance and protection box with high sensitivity and magneto thermal and differential to protect the different components of the system. Like one interventionism room international standards, and many of the national regulations, require a galvanic separation in the examination room through isolation transformer and insulation defects indicator. Floors should be conductive and be grounded. The switchboard will have electric busbars for equipotential connection in all metal parts. Soils of the technical rooms should be registrable, computer type, and all rooms should have false ceiling.

- **The ceiling heights** are in line with the recommendations of Chapter 4 and, in the exam room, heights between 2.9 to 3.0 m are normal heights, which must have its false ceiling.

(7.40.-Lighting in a vascular room)

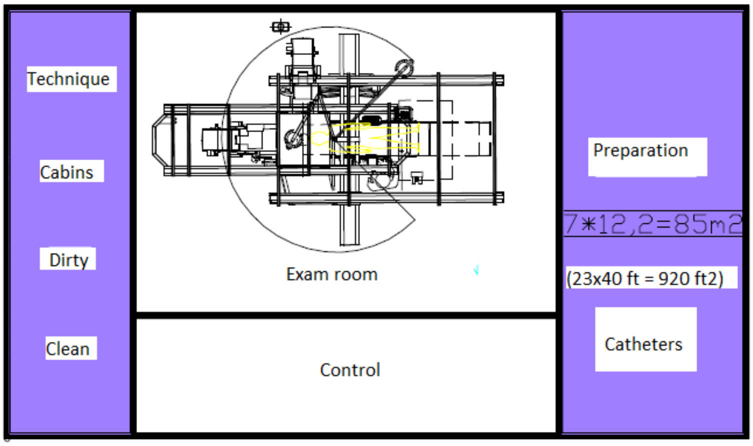
- **Lighting** plays an important factor. Although there is a cold light for the intervention room lamp, fixed and adjustable lighting in the area of examination are required for observation of the exams and monitors. Lighting to make pleasant the intervention by the patient with LEDS are increasingly used.

(7.41.- Electrophysiology installation)

An example is the picture of this installation of electrophysiology, where can be appreciated the use of ceiling suspensions that simplify the functionality of a room with much instrumentation.

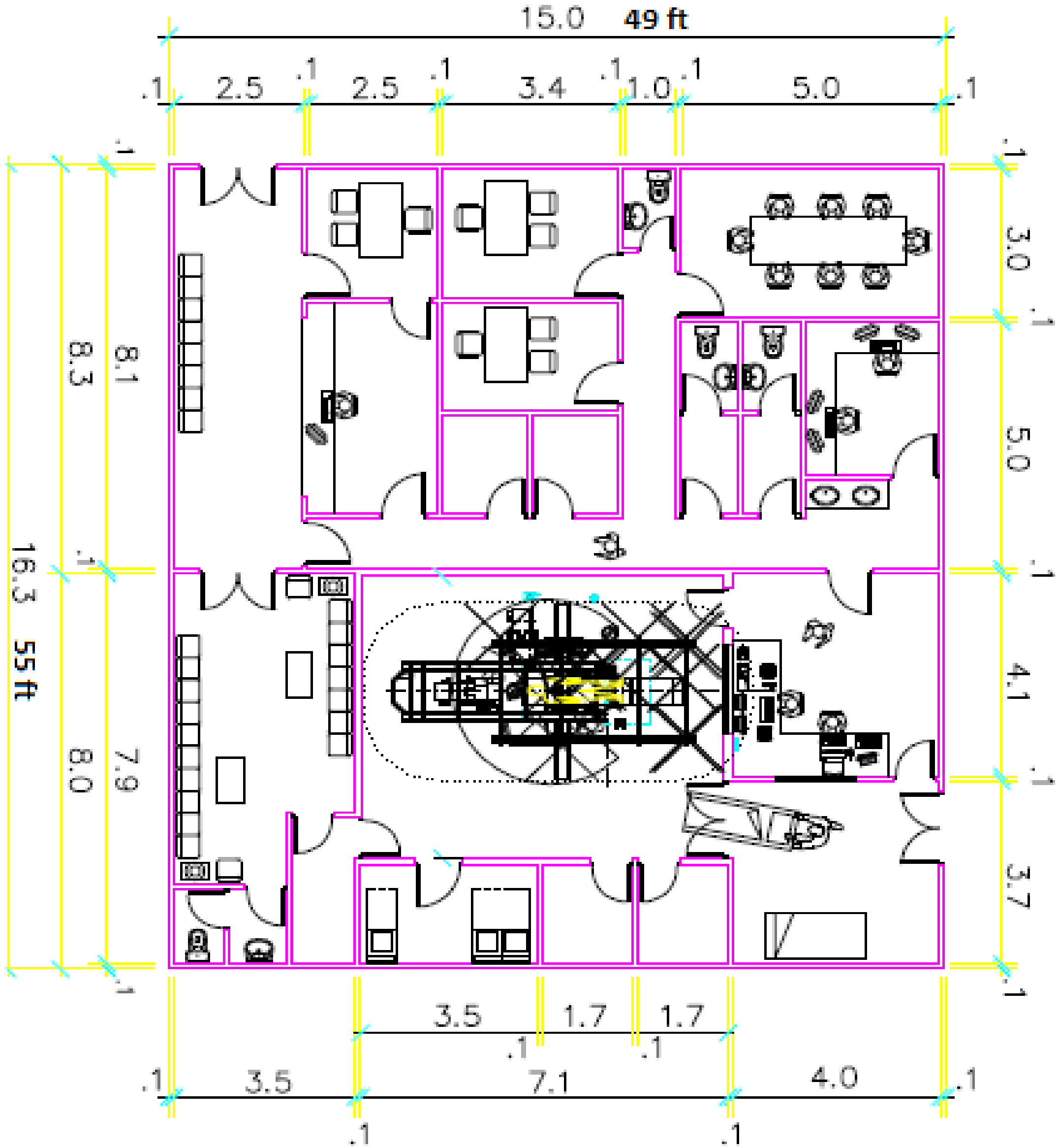
- An important section is the **air conditioning**. In the technical room may have at least 6.000 w dissipation and in the exam room the consideration is between 1.500 and 2.000 W dissipation for the technology located in its interior.

- **The block of the module** for this room (7.42), on average, must have an area of 91 m2 (979 ft2). This includes the examination room, the technique, control, the catheters, dirty and clean rooms a cabin and room preparation.



Block Surface: 91 m2 (979 ft2)

(7.42.- Blok for vascular hemodynamic)


15.0
49 ft
.1
2.5
.1
2.5
.1
3.4
.1
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5.0
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55 ft
8.3
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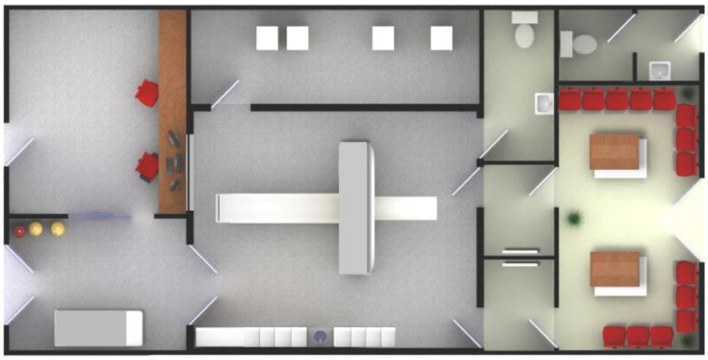
VIII.- DESIGN OF ULTRASOUND, CT AND MR ROOMS



- I. ULTRASOUND
- II. COMPUTED TOMOGRAPHY
- III. MAGNETIC RESONANCE

Today I earn my living using imaging modalities that had not been invented when I completed my board examination.

(D. Johnson. N. Orleans radiologist on the centenary of the discovery of x-rays, at the Congress of the United States)

VIII.-DESIGN OF ULTRASOUND, CT AND MR ROOMS

It seems easy to imagine the interest of a pregnant woman by details of the living being that grows during the period of gestation in the inside of her body. It is the miracle of life. The public and private media and greater Citizens awareness about health technologies, have increased the knowledge of the society in general about the possibilities to visualize the growth of the fetus and its development through the ultrasound technic. 3D-4D ultrasound has had such an impact on the population that has possibly been the most demanded technique at the level of the patient, during the last ten years.

Diagnostic imaging by slice techniques began with the development of ultrasound where static systems obtained slice images from the human body as we have seen previously. However the development of these techniques continued with the invention of the computerized axial tomography. Today more commonly known as CT, and continued with the development of magnetic resonance imaging technique. Both modes offer to the radiologist images that, even today, are axial slices, and already has arrived the time in which all of these techniques provide three-dimensional images to the radiologist for slicing depending on his clinical search.

Under the strict point of view of the planning and design of diagnostic imaging rooms have to be recognized, that the multislice CT resemble radiology facilities that have been already described in the previous chapter, having the same conditions of radiation protection for patients and staff, the same requirements of electric power to the diagnostic rooms of greater demand, as the angiography, and constructive requirements very similar to these rooms.

Magnetic resonance imaging systems have completely different security requirements for the patient, for the staff and for the external environment to the own imaging room, as well as installation conditions, demand for energy and construction requirements.

There is only one reason to join these three systems in the same chapter, its techniques of slice imaging and its historical evolution, their development as imaging techniques that has influenced their clinical use in such a way that are complemented today in its application, they go together as examination techniques and in departments organized by organs and systems play a complementary and solidary role in the diagnostic of diseases.

The growth of these technologies has been spectacular in the last 30 years and it seems that it will remain so, if we take into account its diagnostic value and its impact in the reduction of the patient stay costs at hospital, and therefore of healthcare costs.

The combination of these two latest modalities with others, such as SPECT and PET is revolutionizing the world of diagnosis and subsequent therapies, by combining excellent morphology that provide these two techniques with the functional contribution of radionuclide techniques; and the new developments, which will soon arrive in hospitals, they will allow one evolution of diagnostics and treatments with imaging techniques. This is a new challenge to the diagnostic imaging departments planning.

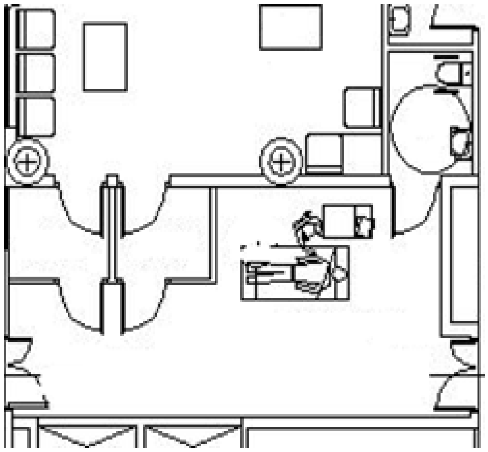
VIII.I.- DESIGN OF ULTRASOUND ROOMS

Ultrasound systems are so introduced in the field of diagnosis that virtually all medical specialties use this imaging technique. It is economic, in relation to other forms of image capturing, very simple to install and provides a high clinical value.

(8.1.-Ultrasound system)

These equipment can be found in all areas of a hospital, and in the most diverse corners, with light intensity conditioning in rooms that have previously been used for other activities. This already indicates its simplicity of design and its easy adaptability.

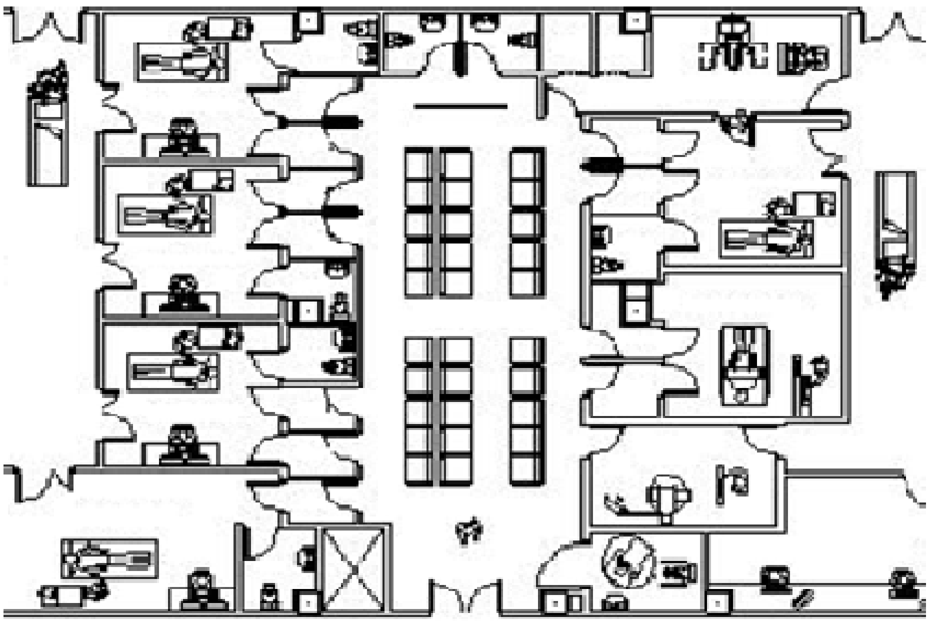
This general purpose ultrasound room has two spacious cabins and a toilet (8.2). The examination room dimensions are 5,0 x 3, 5 m (16x11 ft) to which must be added cabins, toilet and some surface for the patient access.



(8.2.-Ultrasound room)

The total area with waiting is 42 m2 (452 ft2), more generous than usual in these facilities, while there are cases in which the room surface can be even greater if there is accumulation of equipment and people to special procedures, but it is usually smaller in space.

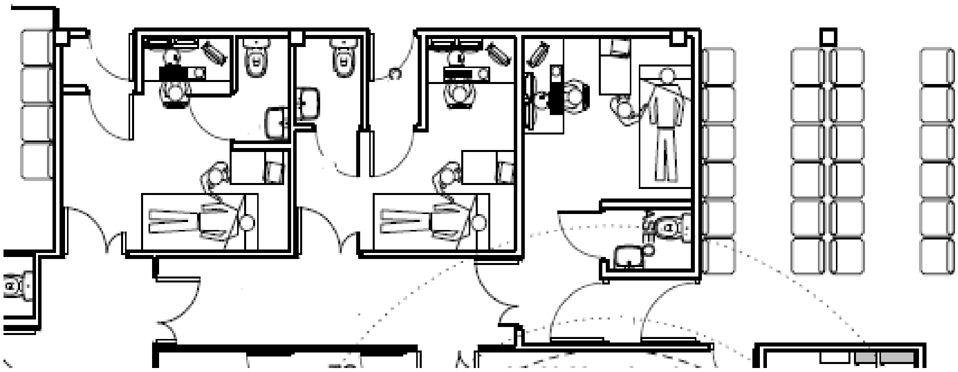
The placement of several rooms forming an ultrasound unit is shown in the design (8.3), where four ultrasound systems meet common synergies.



(8.3.- Ultrasound rooms assembly)

Space was included in each ultrasound room to accommodate a workstation with three monitors, two for image and a third for dialog and image, as well as a speech recognition system. This allows the radiologist to report after his exploration without resorting to the diagnostic room. Obviously if the exploration is made by a technical sonographer this space is not necessary, as images that captures passed from the ultrasound system to PACS server, and from here the radiologist recover them in his workstation to dictate the report.

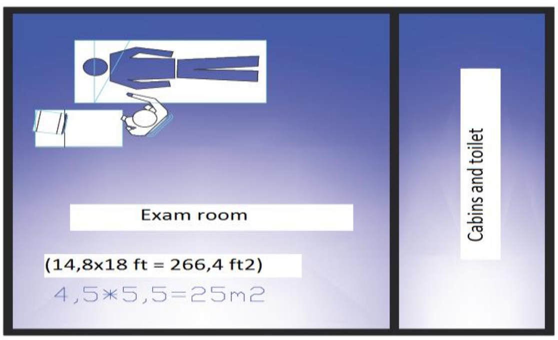
A third example, much like is these designs with integrated station is displayed it in the following (8.4).



(8.4.- Sonography rooms with reporting worstation)

The requirements of these rooms are bound to those described in Chapter VI and few peculiarities should be added in this respect. A note only recalling needs for adequate furniture and sink inside the room.

In the system of blocks that will be needed later (8.5) the total surface for sonography with workstation rooms is 25 m2, which includes cabins and the toilet.



(8.5.- Sonography bock)

Block surface: 25 m2 (269 ft2)

VIII.II.- DESIGN OF CT ROOMS

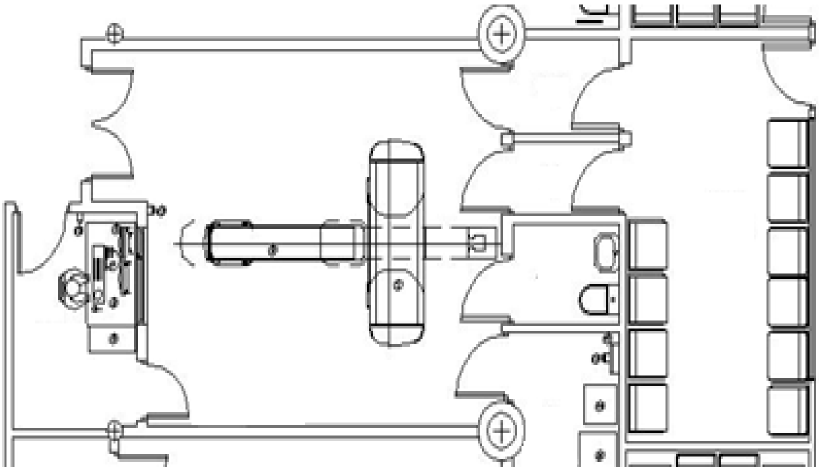
Design of rooms for computed tomography have evolved according to a simplification of the space required for the technology, that has reduced its size, so that in many systems don't need technical room, because the image processor and the power supply adapter transformer can be positioned in a corner of the room where less space is needed. Development engineers have included more technology in the stative or gantry, increasing its weight significantly and requiring greater reinforcement on the floor or in the structure of the building.

(8.6.Multislice CT)

The more simple rooms, as shown in the example (8.7), have if possible, two cabins for changing clothes and an inner toilet.

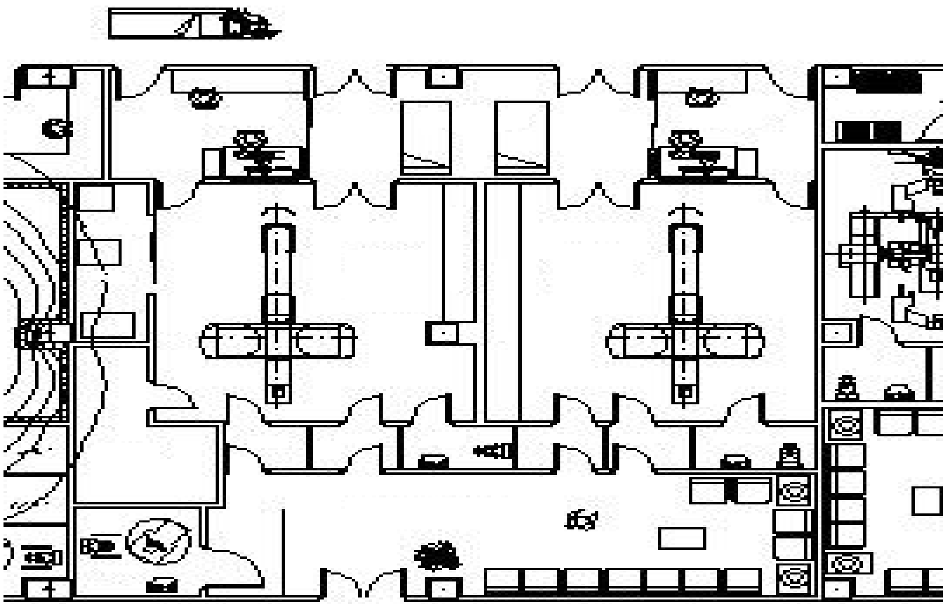
With an area of 29 m2 (312 ft2) in the examination room a patient's bedside can be managed well, so that the staff can move conveniently in their environment. Larger cabin for patients with wheelchairs, and a waiting for beds back control, set the room. The space occupied by the technology in this case of high performance CT is 8 m2 (86 ft2). The total area occupied with all dependencies is 60 m2 (645 ft2), with dimensions of 12.5 m by 4.8 m (41x16 ft).

In the example (8.8) have two CT multislice positioned in a parallel assembly into a regional hospital. Waiting is particularized to these two CT and both consist of two cabins, one bigger than another, and each exam room has an indoor toilet.



(8.7.-Layout of a multislice CT))

Very important in the design of these rooms is the provision of a preparation room for the patient, prior to the examination room, primarily for patients who require sedation or previous injection of contrast. This provision fit two beds separated by a curtain. Control is provided whit a countertop to place a workstation in each CT where a technician, or a radiologist, can reconstruct the images acquired and calculated by the scanner.

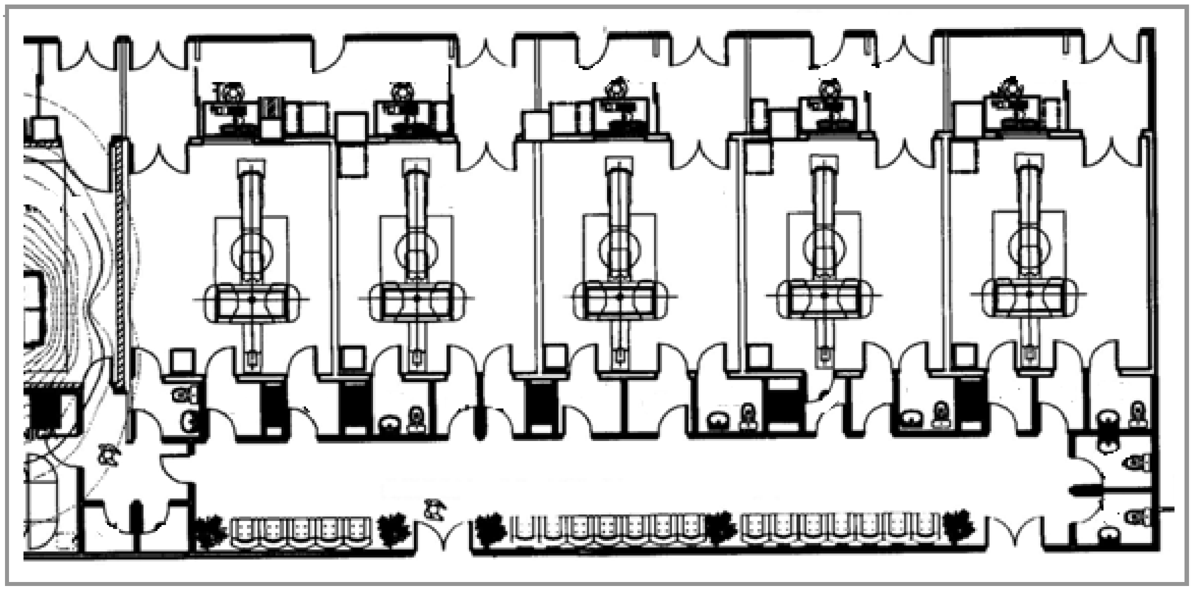


(8.8.-Examination rooms with multislice CT)

The surface of each examination room is 35,7 m2 (403 ft2), with dimensions of 5, 5 x 6, 5 m (18x21 ft). The smaller control room is 3,5 x 3,0 m i.e.(11,0x9,8 ft) 10.5 m2 (113 ft2) and only the CT on the left has a technical room to house the machinery that require the very high performance gantries. The two CT occupy a surface of 188,5 m2 (2.029 ft2) including the common waiting area. Diagnosis, outside this area surface are other 12 m2 (129 ft2) for two radiologists.

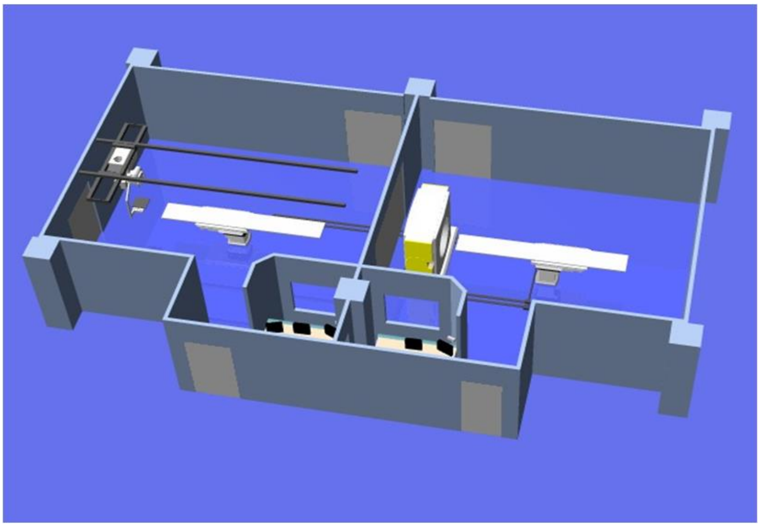
A large university hospital with five systems in line, and some more additional equipment elsewhere in the department (emergency, pediatrics, oncology), is shown below (8.9). The design philosophy is very similar to the previously described before. All examination rooms are similar with an area of 30 m2 (322 ft2), a control for the operator, the consoles of reconstruction are in a common room , near, but separate from the individual controls and a small space of preparation in each room. Common wait for outpatients is at the bottom of the drawing. The total area with outpatient waiting is 370,7 m2 (3.990 ft2).

The preparation areas have 10,5 m2 (113 ft2) for each scanner and they must allow the work of the staff, without serious drawbacks. The pillars, marked black, are hidden in the hollows between the cabins so that they do not alter the functionality of the room or its internal design. The decor and the lighting can contribute to a substantial aesthetic improvement for the favorable reception of the patient.



(8.9.- CT assembly in a large hospital)

Has been done advanced designs, performed usually by special orders, in some institutions which contribute to the research of new technical solutions to specific clinical problems. An example is the (8.10) where a gantry of a CT is shared with two tables in two adjoining examination rooms bound for traumatology. A mobile shielded door allows the gantry move about using rails and placed on the examination of one or another room area,

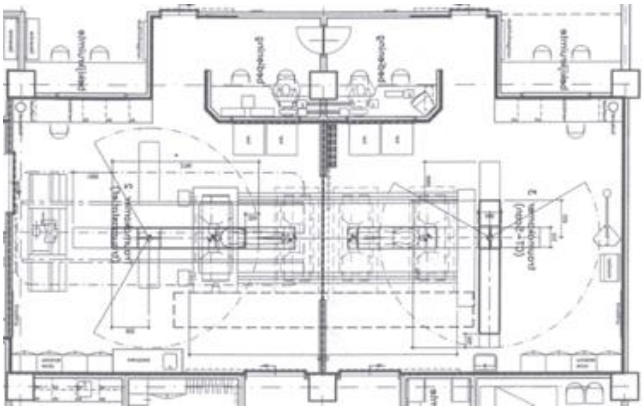


(8.10.- 3D view of the traumatology Installation with two adjacent rooms)

In one room a system of conventional radiology for traumatology, with flat detector, suspended from the ceiling, allows additionally perform single radiographs.

(8.11-Solution of CT and digital radiography for traumatology)

The scheme of the provision of equipment and controls see this in figure (8.12)



(8.12.- Implementation of the system of mobile gantry CT)

- **The requirements of the patient** for these facilities are not superior to the angiography. If the waiting room has a comfortable design, accessible to technicians to call the patient for the test with a cabin door width and capacity for patients in wheelchairs, should have everything needed for external patients. The preparation room will contribute to increasing the productivity of the room.
- **The operator** works sitting, then the window must begin at a height of 0,95 to 1,0 m (3,1 to 3,3 ft) above the floor and the breadth of the room will determine the total width of the window. Two people work frequently and the window should provide visibility to both.
- **The examination room** needs doors around 2,15 m height, superior to the standards. The gantries are height and come with small casters from the corridors. Ceiling monitors and injectors can be hung. Fixing plates subject to the forging of adequate mechanical resistance should be positioned.

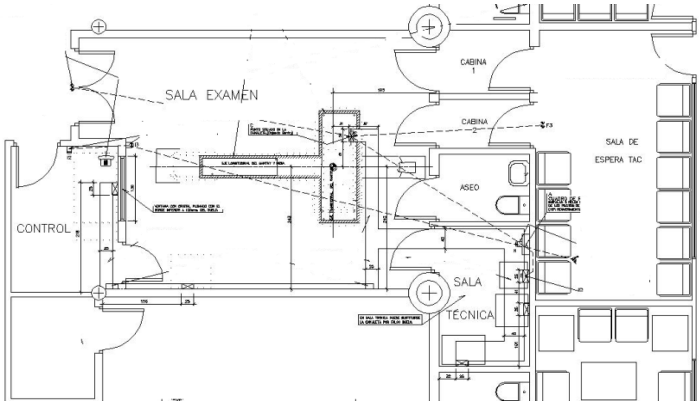
(8.13.-Control room)

- **Modern control room designs** (8.13) allow to add functionality to the technicians work, also need additional space. Lighting, fixed for the room cleaning and adjustable for the observation of the monitors, today with LEDS brings special attraction and additionally decorate the room (8.14).

(8.14.-Control room)

- **Constructive needs** may be significant. Radiological protection requires the same procedures and calculations that any radiology room. Doses are high and have to calculate with high thicknesses of lead protection barriers, mainly in the volume that surrounds the area of the gantry. The responsible authorized by local regulators in radiological protection must ensure the calculation and then submit the certificate with actual measurements to corresponding governmental records. The weight of the gantry is high, in the vicinity of the 2.000 Kg.(4.409 lb), and required reinforcements in soils. Usually the gantry and the patient table are screwed to the floor with thick screws.

- **Wiring** requires gutters or pipes to interconnect equipment. Depending on the height between floors can be tubes, through which must pass the cables with connectors, therefore have thick diameter (some 20 cm). The position of gutters, tubes, boxes, etc., is defined and delimited in the manufacturer installation drawings. Required fidelity in the execution of the construction, as well as the position of the fixing plates, or concrete structure to fix the screws. Dimensions defined in the documents are key to the functioning of the machine. Metal gutters that carry weak signal cables must be connected to ground, and if they also carry power cables must have a separation wall.



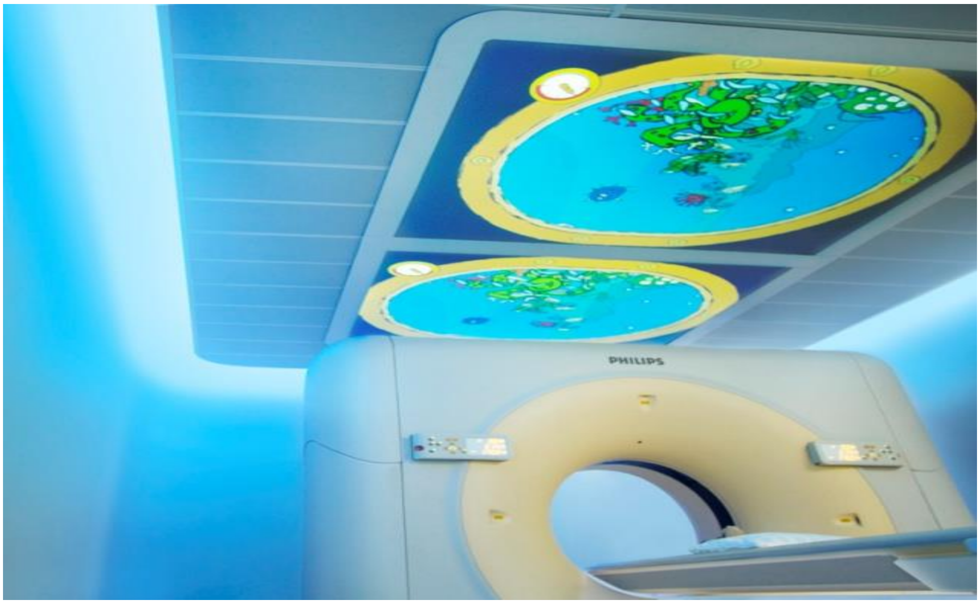
(8.15.- Gutters and wiring in a CT)

Soils require leveling, it is in general well defined by the manufacturer, who ensures the operation of the system and the precision of the images.

- **The electrical supply** is similar to high power radiology rooms, e.g. angiography , but is not required to have electrical isolation transformer or detector defects to ground; will also be rush of low-resistance line, connected to the main transformer with direct line. The electrical cabinet should include the high sensitivity differential and the breakers which requires by the manufacturer of the system and in some cases requires a phase detector.

(8.16.- LED lighting)

- **Lighting** plays a major factor. Two circuits in the examination room. One for cleaning and special operations, e.g. contrast injection and other with dimmer for exploration. LED lighting systems improve the appearance and comfort of the patient. In addition systems projection of images with programmers of sequences and motifs can facilitate the entry of the patient and entertain him during the scan (8.17).

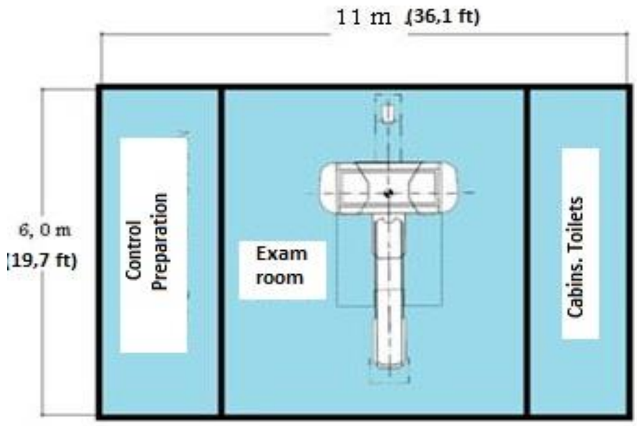


(8.17.-Ceiling proyections)

- **The air conditioning** which should be considered in the control is approximately 1 kW, in the technical room between 2 and 3 kW and in the examination room and between 2 and 5 kW depending on the type of equipment. There are equipment that need heat exchanger, so you have to have in the construction the necessary conditions for the installation of the refrigerator in the department or outside it, and the space necessary to locate it. It is one of these listed already, in Chapter V that define the technological zone. Heat exchanger may need to exchange a power of 10 kW and have to have circulation of alternative cold water for possible failures of this changer. Therefore a cold water circuit must reach the technical room in these systems, with their corresponding control keys.

- **The safety system** for disconnection in an emergency situation are defined by the planes of the suppliers of the equipment and fire safety should follow local regulations.

Whereas examination, control room, preparation and cabin surfaces, the total area of the block for pre-design reaches 64 m2 (688 ft2) (8.18).



(8.18.- CT Block)

Block Surface: 64 m2 (688 ft2)

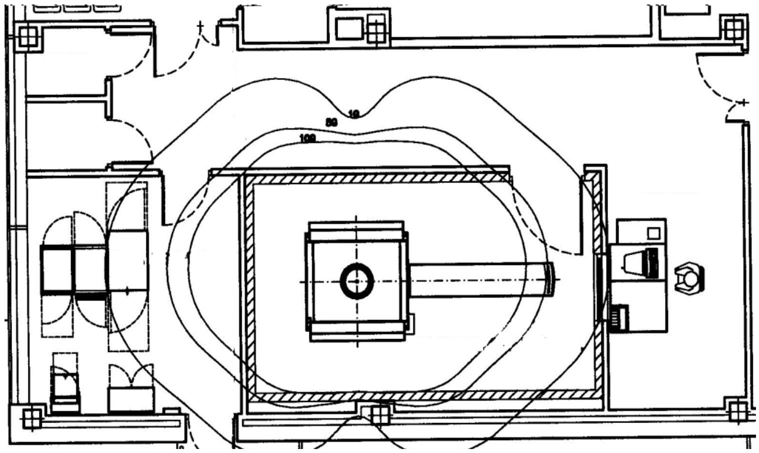
VIII.III.- MR ROOM DESIGN

This is the more modern technique of the three that is analyzed in this chapter with the clear target of showing the types of room designs. The presence of a magnetic field of high intensity and high sensitivity to external RF of the signals obtained from the human body condition the use of this technique of diagnostic imaging.

(8.19.- Magnetic resonance s ystem)

Since its inception in the clinical diagnosis it has pointed out a continuous development in the search for materials and installation methods to facilitate the location of this important imaging technique.

A first example of design for a machine of high field (1.5 T) is shown in the drawing (8.20). Patients come from the waiting area until two booths and from these to the inside of the machine, exam area.



(8.20.-RM de 1,5 T)

The technical room attached to the examination room allows easy interconnection of electronic machinery and cooling with the magnet inside a Faraday cage, marked with strokes, which limits the enclosure of the examination room.

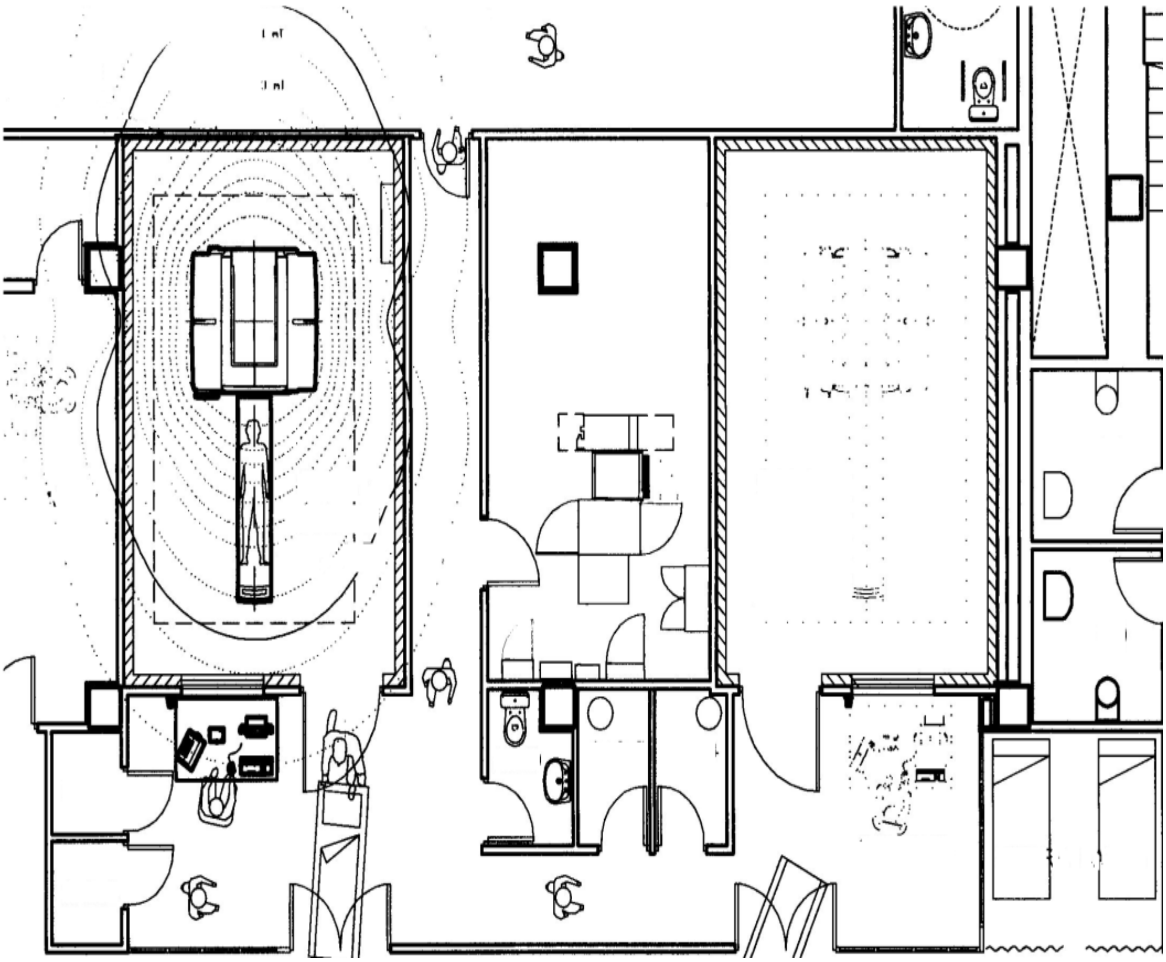
The interior of the examination room is very small, 6,0 x 3,5 m (19 x 11 ft), in this drawing with a total area of 21 m2 (226 ft2), but in its final construction increased 0.5 m more in with surface coming from patients hall, where was space enough. Control room with 6,0 x 2, 5 m (19 x 8 ft) has adequate surface and the technical room with 3,5 x 4,0 m, (14 m 2) (11 x 13 ft, 143 ft2) is also suitable. The total space occupied, important for initial drawing with blocks, is 78 m2 (839 ft2). The waiting area is not included.

A design with exam room also reduced, shown in (8.21), where the department began the operation with a single MR room but are provisions for a second, to install in a next future, when demand so justifies.

Two cabins for each machine, a common toilet and an entrance hall of patients from the waiting room common for the two machines.

The surface of each room is 27,3 m2 (293 ft2), corresponding to some internal measures of cage 6,5 x 4,2 m (21 x 13 ft). The common room for the two resonances has a surface of 22,7 m2 (298 ft2) and as in the former case there is no space for the preparation of the patient. This can cause slow down the flow of patients in each machine.

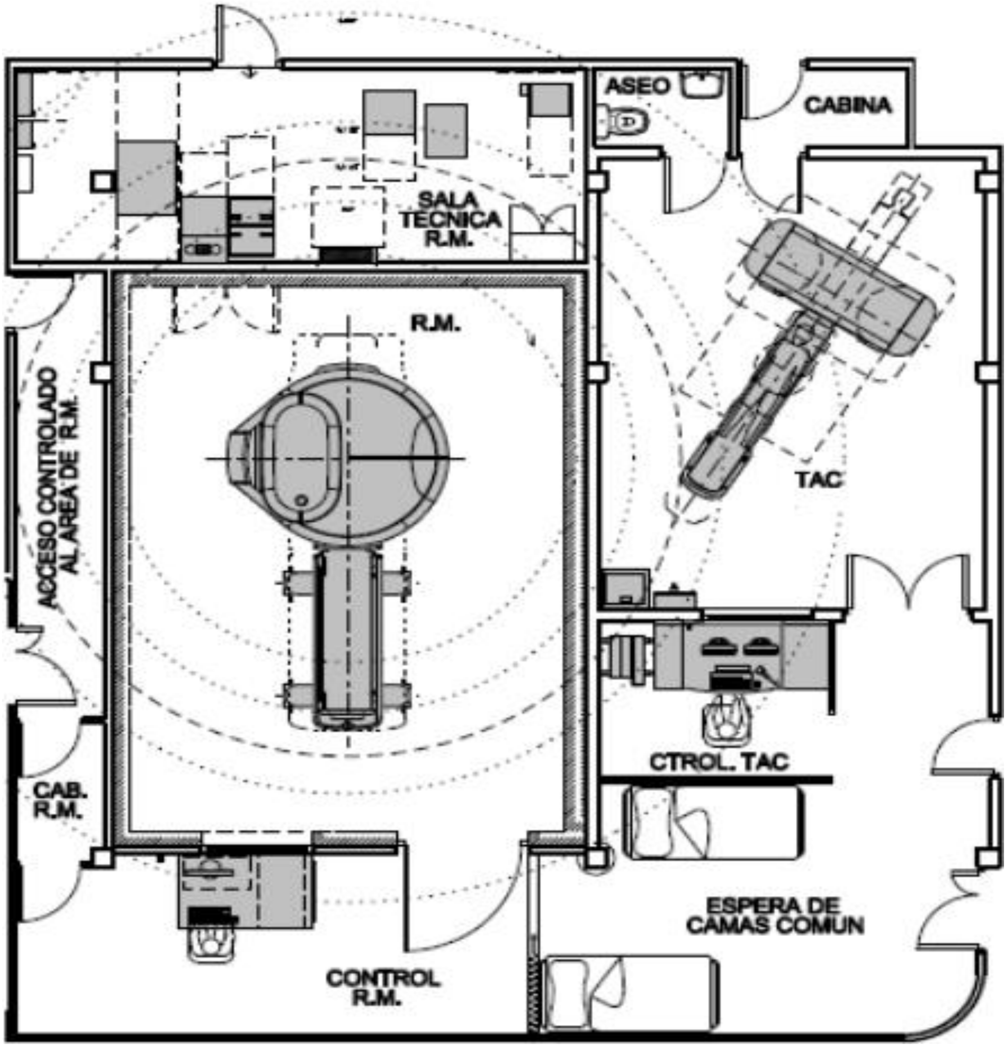
The protection of external patients may need magnetic shielding in the upper part of the machines, on the side where the patients wait. This forces the calculation of material to add, usually iron, on the walls to limit the line of force inside the examination room, where is the magnet. It is not always possible.



(8.21.- MRI of 1.5 T with large space)

The total space of the block is 140 m2, with all units of the drawing, no waiting rooms or corridors of circulation.

A design of one open core MR system of high field (1.0 T) and high field machine design, placed next to a CT is shown in the next drawing (8.22).



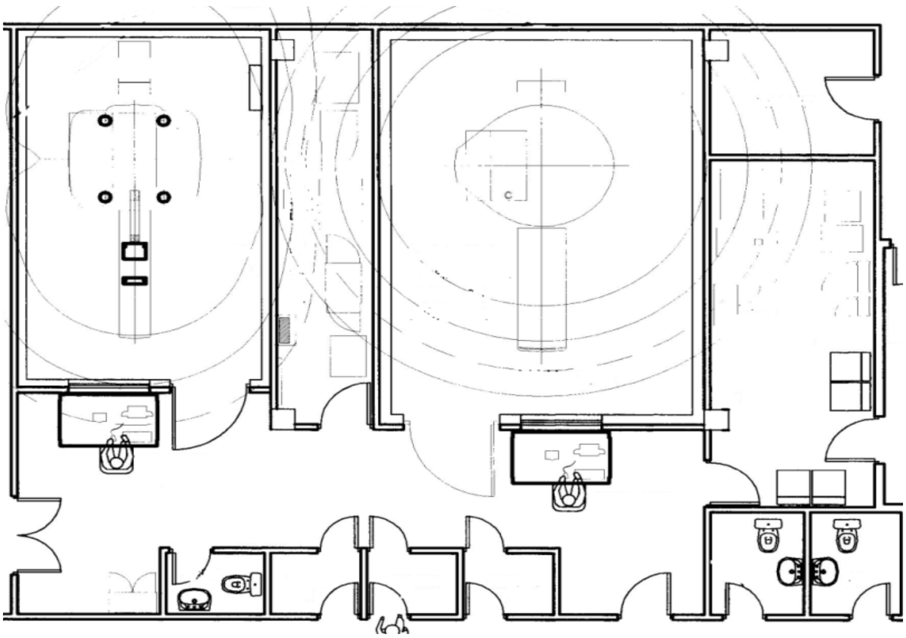
(8.22.y 8.23- Open MRI next to one CT)

And sharing a common preparation room. External patients have access to magnetic resonance imaging (8.23) from the left, and from this corridor to cabin. The block formed by magnetic resonance of 1.0 T, control room, booth, hall and waiting for beds occupied an area of 90 m2 (968 ft2). The exploration room, with dimensions of 5,5 x 7,5 m (40 m2) (18 x 24 ft; 430 ft2) is suitable for pediatric examinations where the majority of the patients have sedation or anesthesia.

The ensembles formed by 3.0T-1.0T machines have a complementation of their unique clinical features, and there are several drawings that show the way to bring synergy to the design.

(8.23 and 8.24.- Open MR and 3.0 T MRI)

In the following figure (8.25) is shown a combined design of machines 1.0 T and 3.0 T.

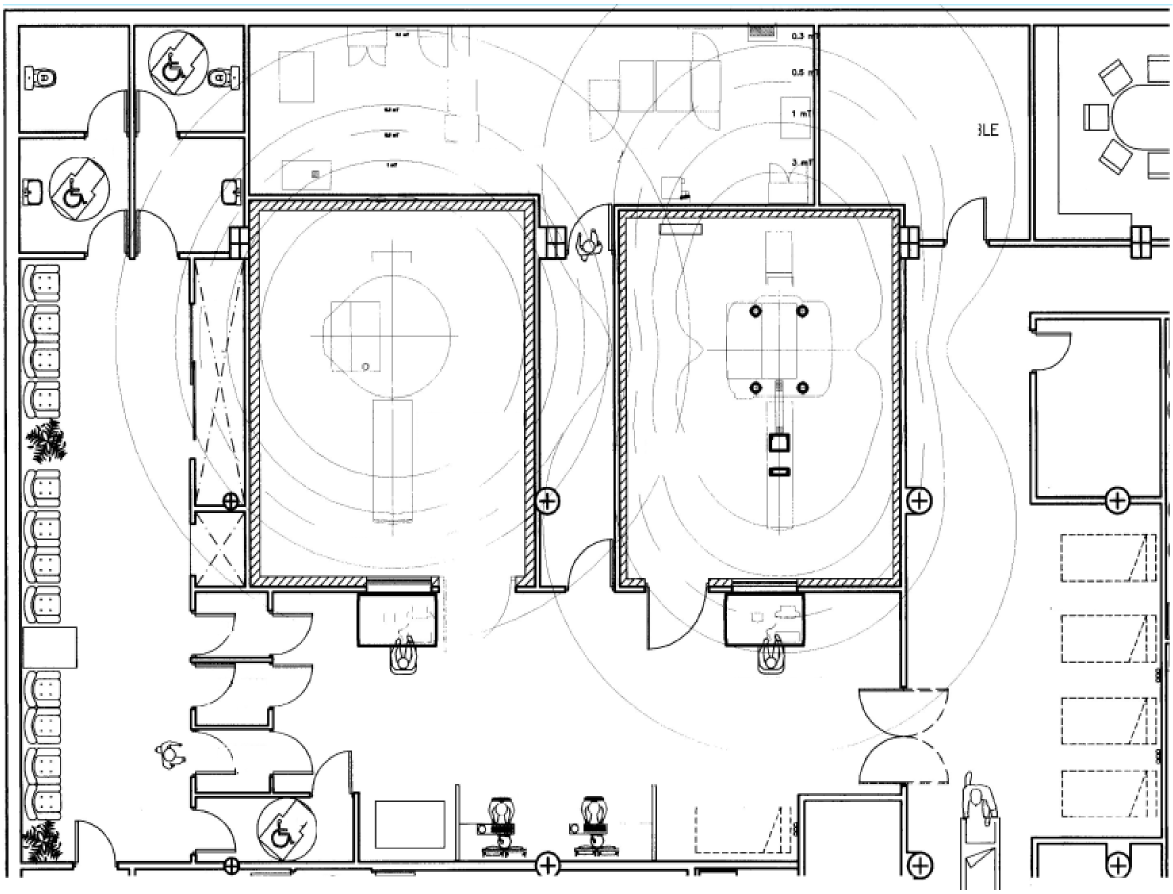


(8.25.- MRIs cylindrical and open)

The technical rooms are separated and the room of the one for 3.0 T system meets the important mission of housing all the electronics and machinery and the no less important function to separate enough the magnets to avoid the interaction of magnetic fields, so when making the homogenization of a machine will not change the homogeneity of the other. The minimum distance between centers of magnets depends on the magnitude of their intensities of field and shielding methods, and can exceed 7 meters (22 ft).

Full block, as we see without waiting or preparation has an area of 166,7 m2 (1.794 ft2) with three cabins and a toilet to share both machines.

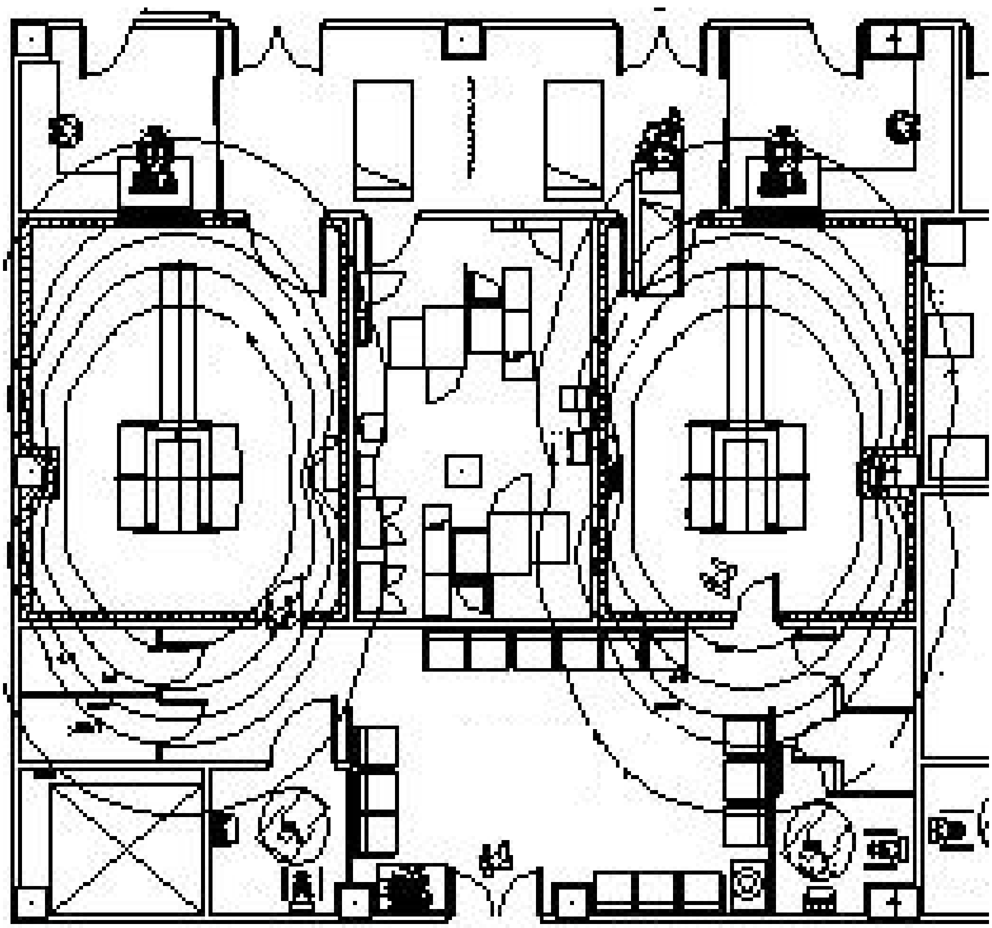
A very similar design of 3.0 T machine next to another of 1.0 T in an outpatient center is shown in the figure below.



(8.26.- Magentic resonances of 3.0 T and 1.0 T)

The space occupied by the two resonances, technical room and the control room is 13 x 16 m (42x52 ft), a total of 208 m2 (2.238 ft2).

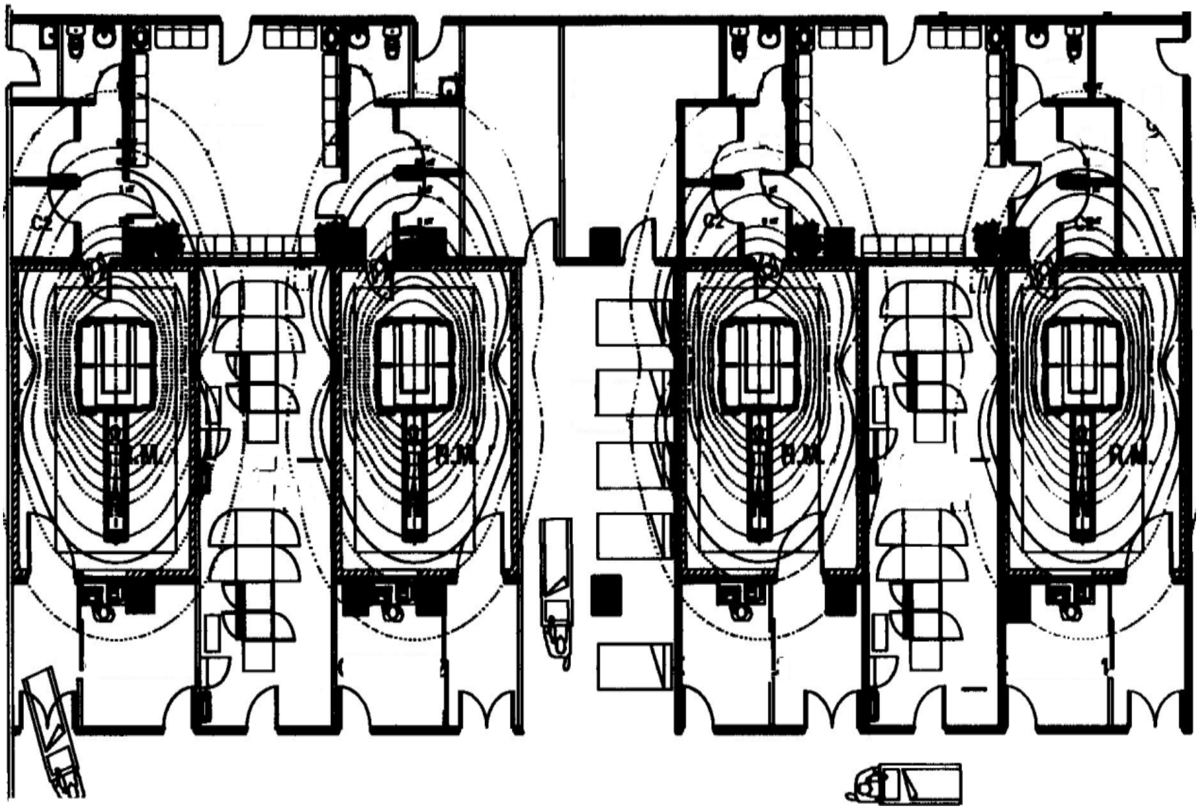
Until now all designs shown had a single door of entry to the room. This is the ideal situation, the door requires an adjustment to prevent RF from entering from the outside, and each additional door further complicates the situation. But there are cases where reasons of the workflow, the user's desire or reasons of architecture should include two doors in the design, as in the case (8.27).



(8.27.- RM cabins of two doors RF)

1.5 T and 3.0 T machines have a common technical room 26 m2 (279 ft2) which allows to include all electronic cabinets and both resonances refrigeration systems, a common room for preparation, 24 m2 (258 ft2) which can be divided in two with a folding wall, 10 m2 (107 ft2) controls that allow the stay of the operator and a technologist or radiologist carrying out reconstruction and have a waiting room common and specific to this modality. Each room has an internal surface of the RF cage with 30 m2 (322 ft2) with enough space for the management of internal equipment. The full block has dimensions of 14, 5 x 14,5 m (47x47 ft) with a surface of 210,2 m2 (2.262 ft2) with 8 m2 (86 ft2) reduced by the existing downspout to the left. The rooms are equipped with two doors, one for entrance of beds of 1.2 m (3,2 ft) wide and one for external staff of 80 cm (2,7 ft) wide.

A unit of several magnetic resonance in a large department of image is shown in the following figure. Two 3.0 T units and two units of 1.5 T with technical rooms between magnets and two rooms which share every two machines



(8.28.- Several systems of RM 1.5 T and 3.0 T)

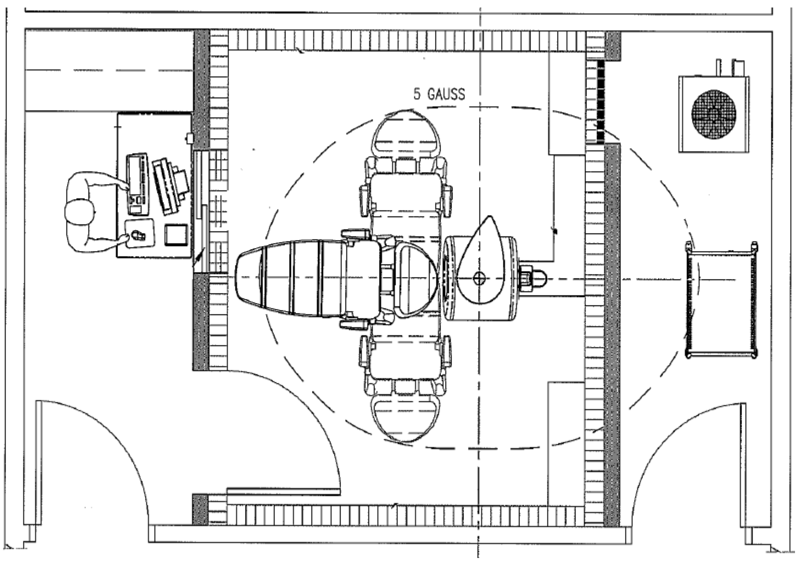
Exam rooms have a surface of 27 m2 (290 ft2), the techniques of 26 m2 (279 ft2) and control rooms with 9 m2 (96 ft2), so several people can attend the examination. A university hospital has training tasks and more space is required. Preparation rooms have an area of 8 m2 (86 ft2). Common waiting areas have space of 20 m2 (215 ft2) that with a proper citation is enough. The total area of this MRI unit is 434 m2 (4.671 ft2) without considering the access corridors both outpatient, as internal in beds.

It must detail the strong influence that has on the design the building structure, limiting the different areas.

Featuring a special appearance in magnetic resonance equipment designed for special studies of a particular part of the human body. An experienced example offer it the dedicated to extremities, today with ranges from 0.2 T resistive up to 1.5 T with superconductors

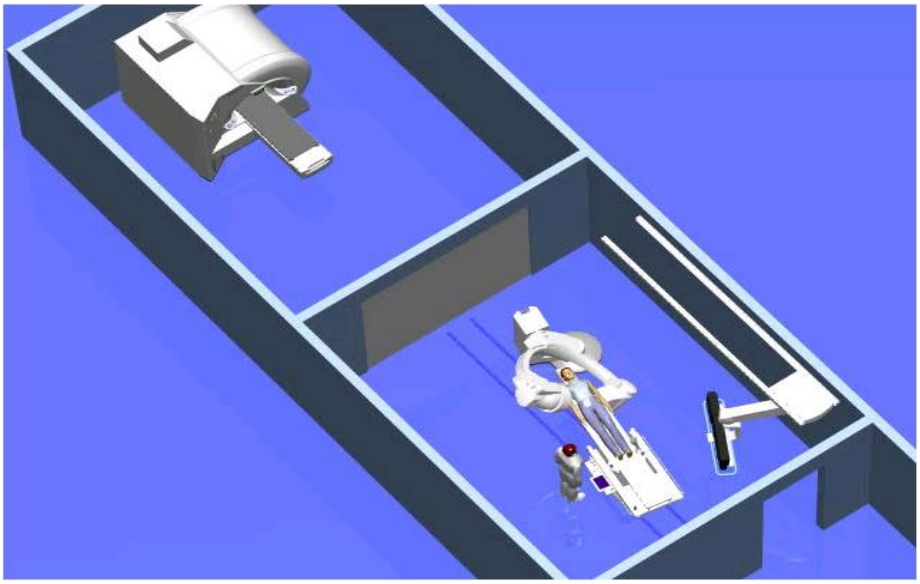
(8.29-MRI of 1.5 T for extremities)

The space is very small, compared to the full-body machines, offering excellent image quality for studies that are designed. Also the space does not exceed the 15 m2 (161 ft2) of scan room and 8 m2 (86 ft2) technique room, almost half of space than whole body equipment.



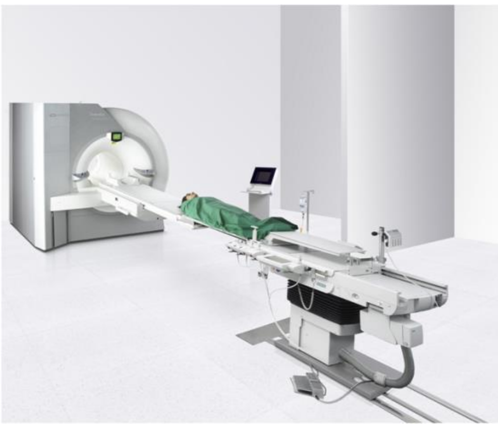
(8.30.- Layout)

Multimodality for very specific applications solutions are designed and installed for departments with high level of research on angiographic and interventionist technics. The example (8.31) is a combination of MRI and angiography room.



(8.31.- Dual room MR - angiography)

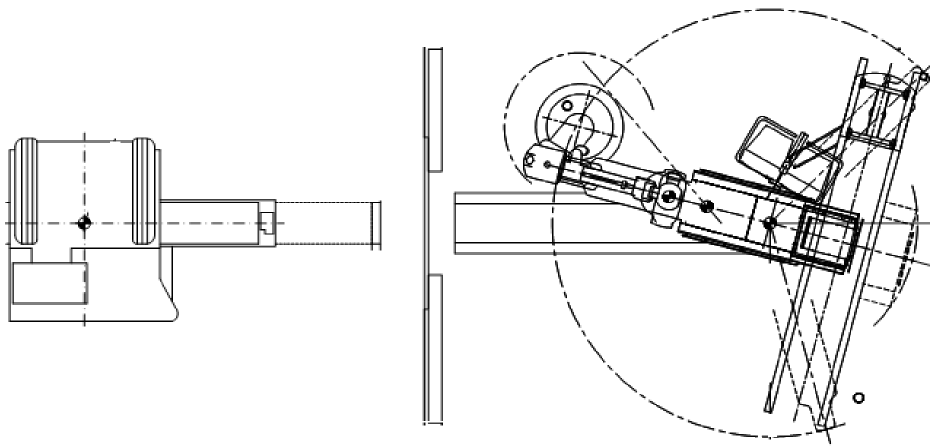
Again a security door, electrostatically and radiologically shielded, separates the two rooms, which can work either separated or jointed.



(8.32.- MR-Angio room)

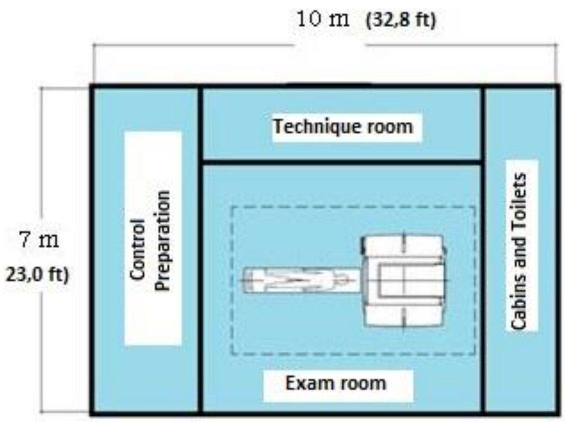
(8.33.- CT-Angio room)

As the scheme's implementation can be represented wih the shape drawn in figure (8.34).



(8.34.- Layout of the MR-Angio room)

Returning to the cylindrical machines or open high-field and full body, can conclude that the block for the initial design (8.35) can be considered in a surface around 70 m2 (753 ft2), sum of the spaces in the exam room, technical, preparation, cabins and operator control.

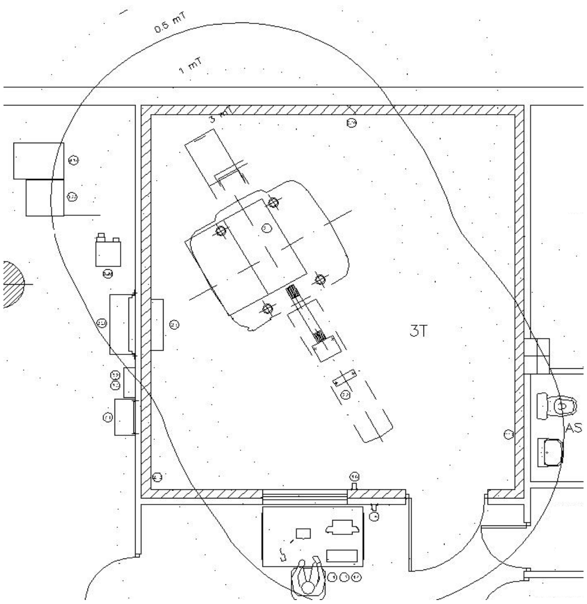


(8.35) Block Surface: 70 m2 (753 ft2)

- **The requirements of the patient** affecting the design are not only related to the patient's own but with the technique of image acquisition. The patient cannot enter in the examination room ferromagnetic objects, therefore have to change clothes and leave all values in a locker, where in general needs to be key, and move to the area of examination with the examination gown. The cylindrical core, opening between 60 and 70 cm (23 and 27 in) is long (1,6 to 1,9 m) (5 to 6 ft) and a small percentage of patients refuse under the consideration of claustrophobia. Open designs eliminate this feeling (8.36).

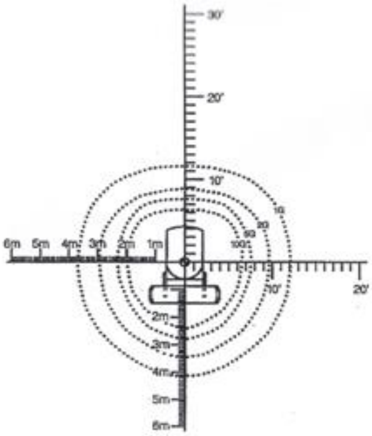
(8.36.- Open field MR)

The patient must be warned that certain examinations may not be realized, such is the case of patients with pacemakers or other components with magnetic susceptibilities introduced in the body temporarily or permanently, therefore is needed a test prior to the exam, and of course signed consent from the patient to the exam.
In waiting, or corridors, patients should be in a safe environment to the influence of the magnetic field. This has a volumetric intensity distribution and the values of the intensity of the magnetic field are provided in the three space coordinates.

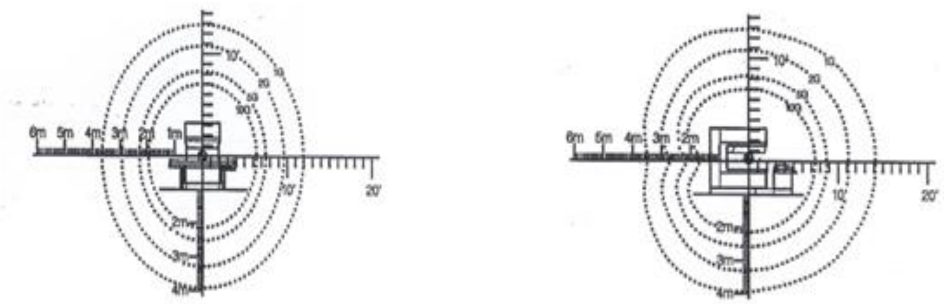


(8.37.- Line of 0.5 mT in a 3.0 T MRI)

- **In the cylindrical magnets**, shafts Y and and Z are at the plane of the magnet plant, at the height of the center of the magnet, and the axis X indicates the vertical field in the examination room. Departs from the center of the magnet and spreads to the floor of the upper story and the ceiling of the lower floor of the building. Limit values are expressed in mT (militeslas) or gauss (1 T = 10.000 G).Observe the supplier instructions to know well where are the lines in X, Y, and Z that delimit the 0.1 mT, 0.5 mT and 1 mT, because we have to avoid the influence on people, e.g. a pacemaker must be outside the line of 0.5 mT.



(8.38-Field Lines for a magnet of 0.23 T, in the X-Y plane)



(8.39.- Field lines to the same previous magnet in the Y-Z and X-Z planes)

- **The operator** works sitting, then are applicable the same information already written in CT multislice, with a height of the base of the window to the ground from 95 cm to 1,0 m (37 to 39 in). To be moving around the magnet, the same principle of what is recommended for patient safety. The technician must see the facial features of the patient. If the design does not allow it must be a closed circuit TV camera.

Due to the noise, from the compressors and gradients coils, the wall of the examination room, mostly on the side of the operator must contain absorbent elements of noise. The same for operator ceiling and the walls and ceiling of the technical room.
Control rooms can have different designs and decorations. Below is a representation in 3D of a room with two magnetic resonance controls.

(8.40.- Magnetic resonance imaging controls)

- **The technique of imaging acquisition by magnets** is the main factor to take into account. The lines of 0.1; 0.5 and 1.0 mT should have special consideration in the design, and above all to choose the site, or sites, where to locate the machine in the imaging department. The video monitors, image amplifiers, detectors of CT, ultrasound, storage devices such as diskettes, tapes, etc., must be outside the line of 0.1 mT. Gamma cameras and linear accelerators offline 0.05 mT. Cardiac pacemaker, out of the line of 0.5 mT. Black and white video monitors out of the line of 1 mT.

  In general, the media of manufacturer data leave the line of 0.5 mT within the dimensions of a room of 30 m2 (322 ft2). On the X axis, that leads, for machines of high field, at the height of ceiling, have to think in the environment of 3 m (9 ft) above the axis of the magnet. Must therefore be observed these mesurements up and down the center, and check the activity of persons and machines in these places to start to locate the magnetic resonance system. Cardiac pacemaker, out of the line of 0.5 mT

  In case of difficulties the location beeing the force lines affecting people or instruments, and is required to place the magnet in the selected area, must proceed to a study of magnetic shielding, that may result in increase in weight in the structure that in some cases may not be acceptable and we will have to reconsider the location of the system looking for the most suitable place.

- **Constructive needs** are influenced by the existence of own magnet and the implementation of a radio frequency for the images acquisition signal. The interactions of the environment and the magnet RF signals have different causes and effects which will be analyzed below:

A.- Interactions of the magnet and its surroundings.

The objects with magnetic susceptibility placed within the area of influence of the magnet are subjected to magnetic forces, this causes a distortion in the field lines that can affect the homogeneity in the center of the magnet. The iron content in the soil should follow the prescriptions of the magnet manufacturer, not having to place this next to the metal beams of the structure and separate it more than 2 - 2, 5 m (78 - 98 in).

Automobiles, elevators, subway, etc., that move next to the magnet causes a transient variation of the main field and as consequences artifacts in the image. The safety distance depends on the mass of the moving object. The table below indicates reference distances (8.41) and for each product the manufacturer must indicate these distances.

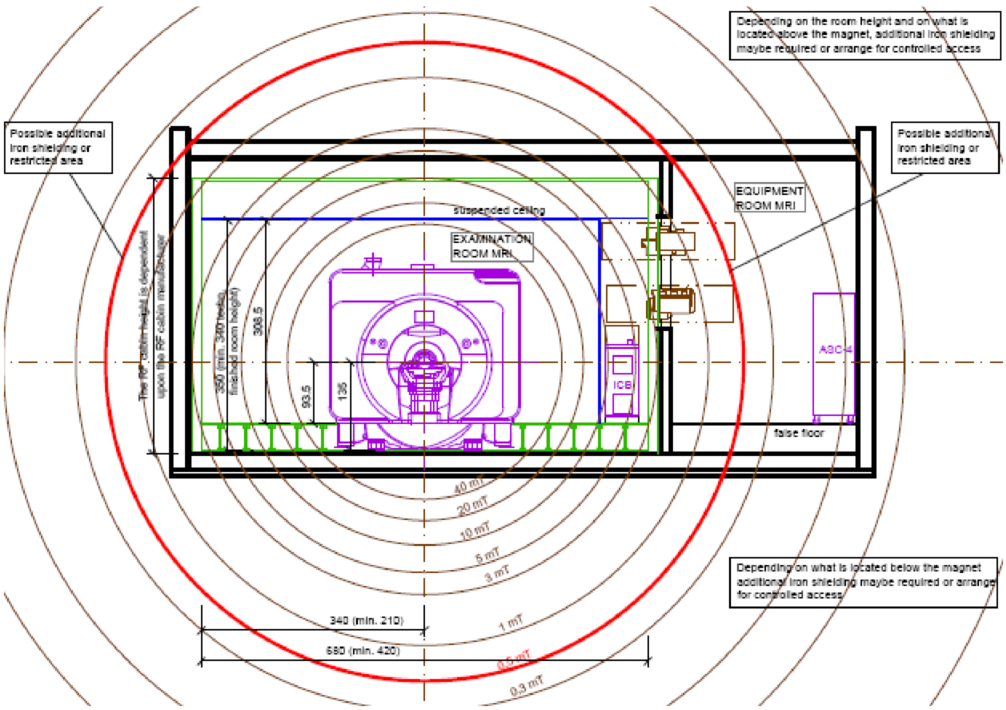
MOBILE OBJECTS		DISTANCES FOR A 3.0 T MAGNET			
Mass		Minimun distance to X o Y		Movement parallel to axis Z Minimun ditance to axis Z	
kg	lb	m	ft	m	ft
100	220	4,2	13	3	9
500	1.102	5,3	17	3,5	11
1.000	2.204	5,8	19	3,8	11
5.000	11.023	7,3	23	5,3	17
10.000	22.046	8,2	26	6,2	20
50.000	110.023	10,8	35	8,5	27

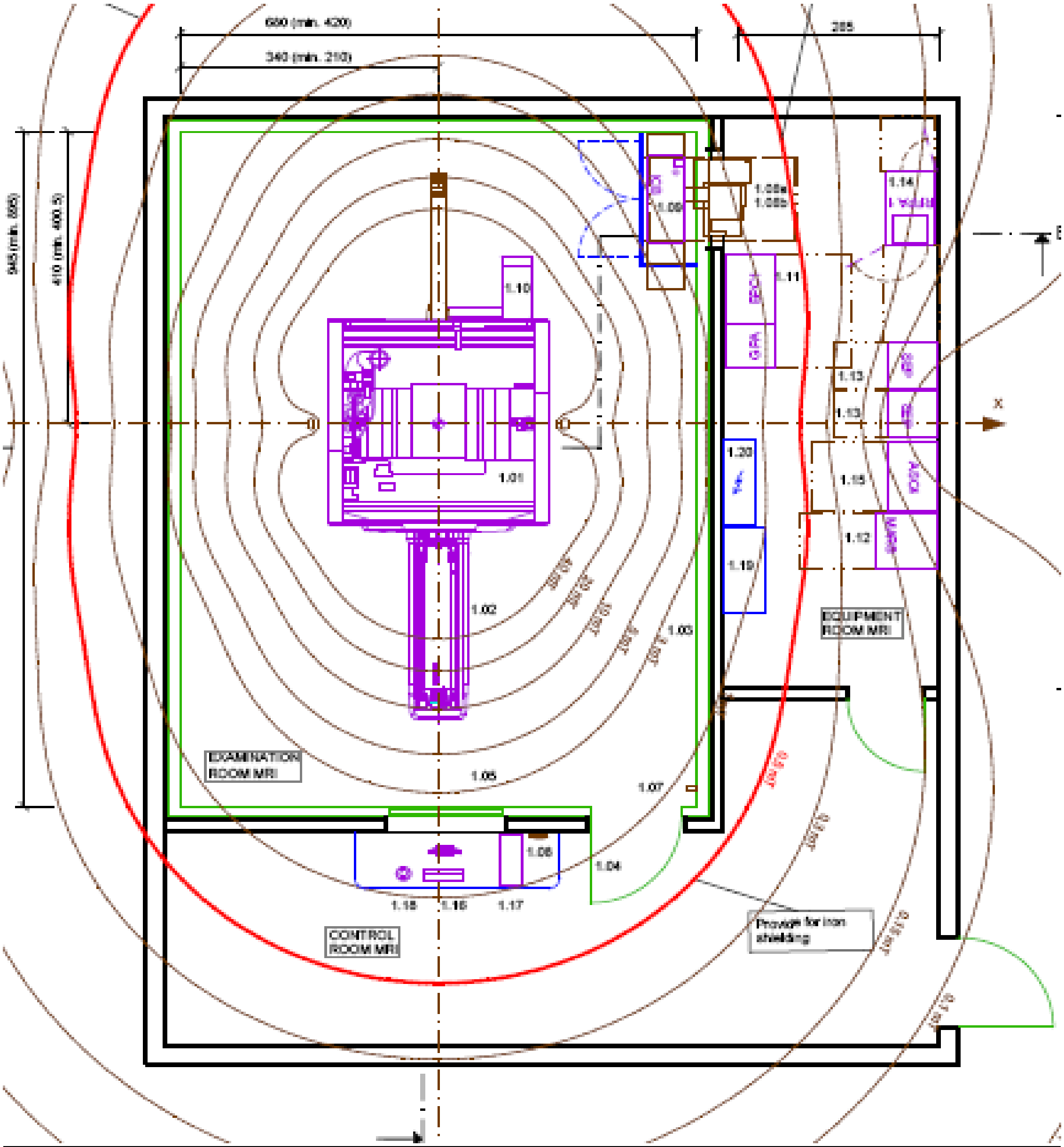
(8.41.- Approximate distances from mobile objects to a 3.0 T magnet)

If these items are electrified, as trains and trams, there is an additional interaction by the field that create these. The distances are much higher and reach between 25 and 30 meters Depending on the current of the power line and the position of this with respect to the Z axis. It is necessary to carry out measures prior to the installation of the magnet to ensure the optimum position, also to know if there are items with permanent ferromagnetic magnetizations, case which occurs frequently in installations where there has already been a magnetic resonance equipment and there is a replacement in the same location. The problem can be very serious because the distances to the elements magnetized permanently expands by a factor which in some cases is 10 times the distances mentioned above.

Internal power lines in the health center, transformers and motors have associated electromagnetic fields that alter the functioning of the machines, so should calculate distances of separation, which specified by the manufacturer, and that for a power transformer of a medium image department can reach the 10 meters of distance from the magnet.

Distances to observe are even greater in systems of 7.0 T, where the force lines of the magnet reach greater distances in the security zones.





B.- Radiofrequency Interactions.

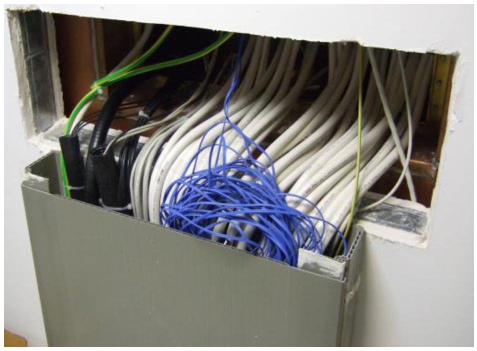
Radio frequency pulses applied to the patient drives the protons of the human body to produce the effect of magnetic resonance, therefore the machine emits powerful RF, which could interfere with the outside environment.

The radio stations and other RF sources produce waves in the spectrum close to the equipment of magnetic resonance and can interfere with the operation of these including artifacts in images that can confuse the diagnostic radiologist. Therefore it is necessary to eliminate this cause of distortion.

Faraday cages were used to isolate the magnet from the outside world. These limit the examination rooms and are connected to the electrical ground carrying there any uptake of RF which can occur inside the cage or coming from outside.

Faraday cages are dependent on the dimensions of the rooms and the type of magnet, and they are critical elements in the construction of the rooms. Cage supply is currently included in the system to deliver by the seller of the MRI equipment so this coordinates the necessary tasks with the cage manufacturer to ensure the quality of cage and its perfect compatibility with magnetic resonance equipment to be installed.

The cage should have a high attenuation to the RF signals. Over 100 dB for the frequency range of work, that for a machine 3,0T is 127.7 MHz, this means an attenuation of the RF of 100.000 times.

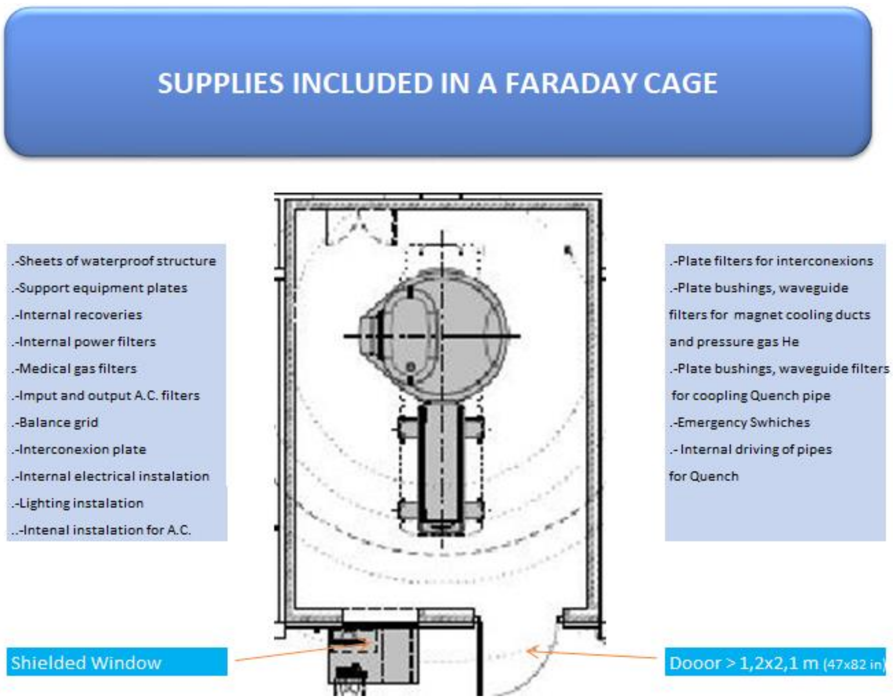


(8.42.- Panels of penetration in a RF cage)

An additional disturbing element is the vibration of the floor of the MRI room. It can alter the stability of the field and disrupt the functioning of the machine. Next compressors, engines, etc., must be studied before the location planning, and prevent its installation when the magnet is already running. The vibration can be continuous or sporadic, being this second much more damaging than the continuous and in both cases, measures are required to establish the viability of the installation. Data on vibration limits depend on each magnet and therefore, every manufacturer.

Designer should avoid carrying pipes, gutters, pipes above the Faraday cage. We must prevent any future failure could damage the cage. The floor leveling, before placing the cage, is an important element to be observed by the constructor, According to instructions of the supplier.

Magnets used in magnetic resonance have high weight, from 3.000 kg (6.613 lb) of some machines 1.5 T up to 20.000 Kg (44.092lb) for some machines of low field, therefore it is necessary to reinforce soils to support the mechanical load, and at times, the structure of the building. Weights and his supporters on the ground are dependent on the machine, should therefore be involved the manufacturer to design the place of props and make the architectural studio. It should be noted here that the internal path of the hospital or imaging department to carry the magnet from the truck at the entrance of the center and up to the examination room, must have a minimum width of 2.30 m and height of 2.60 m (90 – 102 in) in some cases. The door heights must be studied to make the planning of the department. Given their weight for discharge may require bulky cranes of up to 100 tones of Kg, whose possible presence in the environment of the hospital or department must be considered.



(8.43.- Cage of RF requirements)

No question that these components vary with each manufacturer and each machine model, therefore should consider it as a reference that indicates the level of complexity and coordination required between equipment suppliers and manufacturers of RF cage.

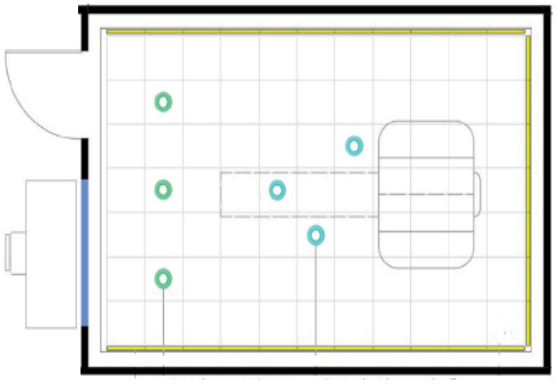
- **The technical room** also requires care in the design. It must have the space allowing to easily opening the cabinets, floor with sufficient mechanical load, some machines have a next to 2.000 kg (4.409 lb) load, in the technical room the floor should be registrable, for easy installation and later wiring inspections, and false ceiling.

- **Electrical installation** requires power appropriate to the magnet and gradient systems. Powers from 40 KVA to 120 KVA and must be a direct line, low-resistance line, from the central transformer. The switchboard must include differential, separate thermal protection and magnetic thermal and separated lines for:
    - Power of the Faraday cage
    - Air conditioning
    - Water chillers
    - Lighting
    - Others

- **The internal lighting** of the cage cannot contain ballasts, therefore LED or incandescent must cover the desired level. The two levels should be equal to those already recommended for examination rooms, 500 lux for service and 200 lux adjustable. Designs with LED give a great attraction to the room.

(8.44.- LED Lighting in one MR room)

The same directions of lighting for the control room, without objections from the ballasts. The technique room only requires a level of 500 lux.



(8.45.- Lighting design)

- Air conditioning is required in the three rooms, trying to have a temperature of 20°C. Dissipation in the control room is small, approx. 500 W, more in the exam high room, 2.000 W, and very high dissipation in the technical room, between 8.000 and 1.,000 W. Data observed by the engineering team to provide the necessary space in this technological zone.

  Cooling of compressor coolants in superconducting equipment; coils of gradients and gradient amplifiers require cold water, under conditions defined by the manufacturer, with the need to transfer between 5 and 50 kW. A closed circuit eliminates the expense of water, but there must be as a driving emergency direct cold water from the hospital for emergencies, with its corresponding key system.

(8.46-Key for refrigeration system)

- **In superconducting machines helium** requires a special treatment. Low temperature (- 260 ° C) guarantees the superconductivity of the magnet. Periodically, currently little helium every six months and in some cases longer, requires a small helium replenishment given its evaporation, that is done with containers from the technical room, so the door must allow the passage of containers. The examination room must have one oxygen level indicator. In the event of a leak of helium will impoverish the level of oxygen in the room and while helium is not toxic oxygen can disrespect the patient.

  A pipe that comes out from the top of the magnet to the outside street of the imaging department, or hospital, has to be calculated, in the case of a quick gasification of liquid helium; is the so-called Quench. The pipeline is the only one that might be on the top of the cage, occupying minimum cage roof surface and going abroad in such a way that there are no risks to the surrounding personnel. Quench tube installation is another determinant of the location of a magnetic resonance imaging system in a department. It is a metal tube between 200 and 300 mm (7 to 11 in) in diameter covered by insulating materials and their length must be the minimum possible. Details of tubes and the exits from them to the exterior are specified on the technical descriptions of the equipment suppliers.

(8.47.- The exit of the pipe for Quench and external output connections)

Previous description is a help for the planning and design of magnetic resonance imaging facilities, although it is not enough to do a full installation project. The determinations of the manufacturer, in each case, are required to make a proper work project, since each machine has its own specifications that determine its installation.

A summary picture of the design of a diagnostic outpatient center with representation in 3D drawing of the waiting rooms, the patients cabins for access to exam rooms, technical controls and the examination of two rooms of magnetic resonance, one CT and one remote controlled diagnostic table.

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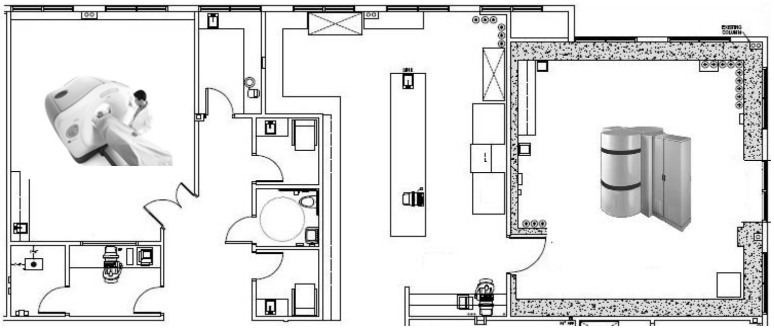
(8.48.-3D drawing for wait, cabs, control and exam rooms)

IX.- NUCLEAR MEDICINE AND RADIOTHERAPY ROOMS DESIGN



I. **GAMMACAMERAS**

II. **SPECT- COMPUTED TOMOGRAPHY**

III. **PET AND PET- CT**

IV. **CYCLOTRONS**

V. **EQUIPMENT FOR PRECLINICAL EXAMINATIONS**

VI. **RADIOTHERAPY SIMULATORS**

VII. **TREATMENT PLANNING SYSTEMS**

VIII. **BRACHYTHERAPY ROOMS**

IX. **LINEAR ACCELERATORS**

I have designated under the name of radioactive all elements emitting this radiation, and the new property of the matter discovered in this emission has received, therefore the name of radioactivity. (M.Curie. Conference to receive the Nobel Prize on 11-Dec-1911)

IX.- NUCLEAR MEDICINE AND RADIOTHERAPY ROOMS DESIGN

Since the discovery of radioactivity by Becquerel in 1896, the medical society has not leave of dreaming on the possibility of knowing with the maximum possible detail the physiological phenomena in the human body. The idea to follow step by step a molecule of carbon or nitrogen is present in the history of the clinical physiologists, and nuclear medicine specialists have collaborated during the last century, and follow even more actives in the current one, in the search for biological tracers, radiotracers, to achieve this goal. Perhaps today we are further, trying not only to visualize the itinerary inside the body of the molecules of carbon and nitrogen but send radiotracers with drugs capable to do selective therapy with this technology.

Functional studies play a pivotal role in the discovery of certain pathologies in the human body, and as was shown they began to have its maximum expression with the use the Technetium and Thallium with the gamma cameras in planar and SPECT examinations.

In the design of the rooms for this imaging technique, must not be forgotten the preparation rooms, as well as the ones for the radiopharmaceuticals to inject the patient to carry out the exploration, or the injection rooms and waiting for injected patients to enter to the imaging room and perform the scan.

The PET is being the modality that revolutionizes the medical discipline and with the hybrid machines PET-CT the coupling, or fusion, of functional and morphologic image is changing the way to address the cancer treatments. The availability of the F18 was widely improved with the introduction of new cyclotrons which with the installation of attached radio pharmacy give doses in short distance to be able the operation of the scanning equipment.

A new medical discipline, molecular Imaging has emerged to continue the primitive dream of physiologists and there is no doubt it is going to revolutionize the world of diagnosis and personalized therapy.

The research is providing a new battery of equipment that are emerging to form this new discipline and added to the hybrids PET- CT, the SPECT- CT and the latest SPECT- MRI and PET- MRI that will contribute more to this form of functional monitoring and molecular treatments.

The design of imaging rooms for this machinery has its special characteristics, but still follows the same parameters already defined in the previous chapters. Here will be analyzed its particular details.

With regard to its subsequent maintenance, it should be noted that most of these equipment uses radioactive sources for adjustments and calibrations that need special licenses from the authorities in radiation protection for their transfer, and must be provided the fulfillments of the corresponding laws for their storage, transport and returns.

The departments of radiotherapy have unique design features. Linear accelerators have radiation protection requirements that force to plan the implementation of these departments with care inside the hospital and find the right place if it will be in an outpatient center.

Is also necessary to plan the schedule of the whole project, as shall be later shown, from the concept up to the execution of civil works. In radiotherapy, also is the case in nuclear medicine, the controls of the regulators of these activities are deep and intense. This takes time and the projects should be planned with more time than a department by conventional diagnostic imaging.

Linear accelerators are the therapeutic basis for the radiotherapy department, followed in special applications for brachytherapy and both carry a simulation and planning work to ensure the success of the treatments to be applied.

Therefore the radiotherapy rooms design involves attention at every peculiarity of these equipment for synchronized operation of all facilities. The radiotherapy data network, connected with the HIS and RIS of the hospital operates as autonomous body of information in the department of radiotherapy, taking images from the diagnostic imaging department from the PACS system to learn about previous diagnoses, with their reports, to the arrival of the patient to the radiation therapy department.

Therefore will be detailed the design of the rooms:

- **GAMMACAMERAS**
- **SPECT- CT**
- **PET**
- **PET- CT**
- **CYCLOTRONS**
- **EQUIPMENT FOR PRECLINICAL EXAMINATIONS**

In the department of nuclear medicine.

And then the rooms of radiotherapy departments concentrating attention on**:**

- **SIMULATION**

- **PLANNING**
- **BRACHYTHERAPY**
- **LINEAR ACCELERATORS**

In the same way as in previous chapters, will be reviewed the requirements of the patient, staff, architecture, and technology that force to look for alternatives to each design.

IX.I.- GAMMACAMERAS

These equipment constitute the basis of nuclear medicine examinations, concentrating most on cardiology and bone studies. Additionally exams of thyroid, lung, kidney, gastric casts, etc., are less in amount, but very common in nuclear medicine.

There are models with one, two or three detectors. The basic design is the same even though the surface of the room in case of three detectors is slightly larger.

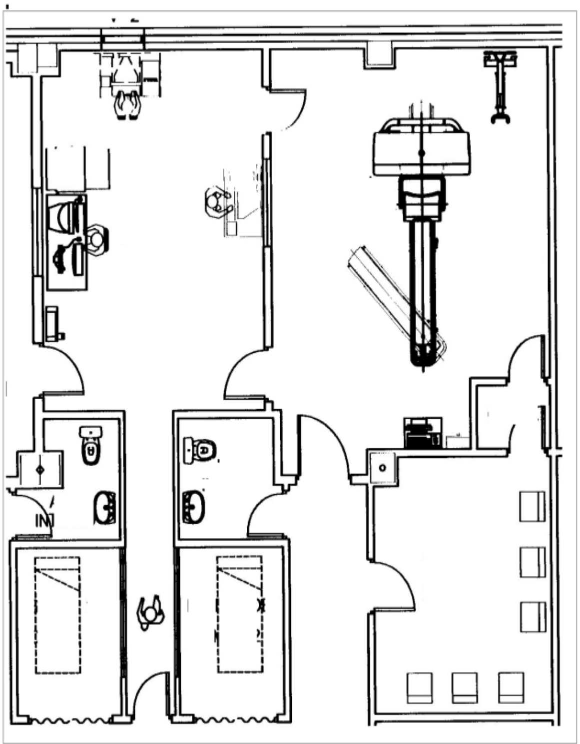
(9.1-Gamma camera of two detectors)

(9.2.- Gammacámaras with detectors in telescopic suspension)

There are also different ways of supporting the detectors, either with a cylindrical gantry, as in figure (9.1), or through one suspension that supports two detectors (9.2), today less usual. Suspension consisting of support on the ground, which constitute a pseudo structure internal in the room that allows to hang the detectors, and move it in robotic form depending on the clinical application. Collimators are in the end wall of the room, and the change is automatic.

They are two different room designs, and surfaces which are also different.

In the following example there is a room with cylindrical gantry design, where the table can perform different kind of movements, and in some models move to stay away from the test area and position the patient with an auxiliary stretcher.

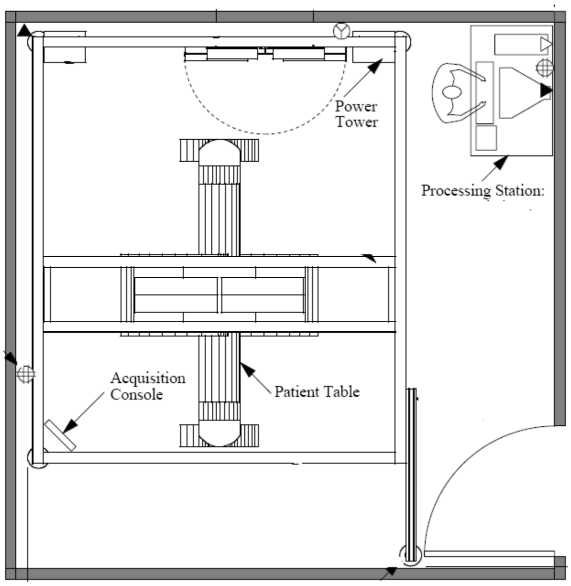


(9.3.- Implementation of a gamma camera of two detectors)

(9.4.- Exploration in bed with gamma camera of two detectors)

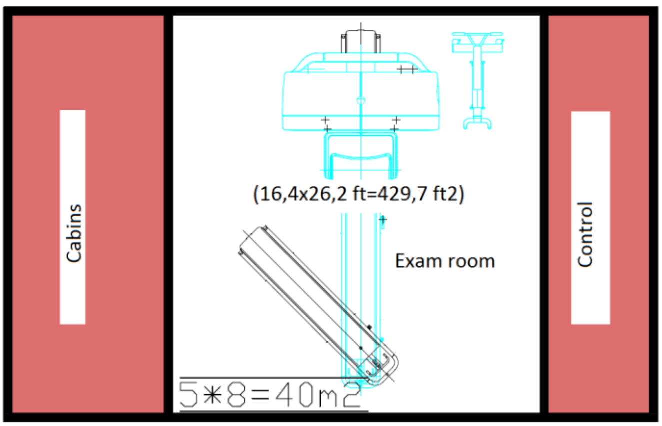
The space occupied by the examination room is 6,5 x 5,5 m (21,3x18,0 ft), with a total of 35,7 m2 (384 ft2), wide open space which includes cart for collimators exchange. The gamma camera control is in one room and shared common space with the control of a PET - CT equipment. The room at the bottom of the gamma camera is the waiting room of injected patients. Those can be passed to the examination room, across the gateway shared with the beds, or through the cabin if they have to change clothes.

The total area occupied by the gamma camera, control and the cabin reaches a total of 49 m2 (527 ft2). Space that will be taken to build the block corresponding to the preliminary design. As can be seen there is no technical room. In gammacameras all the technology is located in the gantry, so it is not needed more space. The dimensions of the room (9.5) are 3, 7 x 5, 2 m (12,1x17,1 ft) (19,24 m2) (207 ft2) and it includes everything needed to acquire the exams and for the work station for processing.



(9.5.- Layout of gamma camera with telescopic suspension)

A block of pre-design for a gamma camera will be in the following way:



Bock surface: 40 m2 (430 ft2)

(9.6.- Block for gammacamera)

In the same way as in magnetic resonance the use of high field strength magnets imposed special conditions to the design and use of the rooms, in nuclear medicine are handled radioactive isotopes from low-intensity that are injected into the human body. In this aspect the activity of radiological protection plays a special controlling role**:**

- **The storage of radionuclides that produce consistently noticeable levels of radiation.**
- **The dose of radiation received by the patients. Its exact calculation is very difficult and can vary with the metabolism of the radionuclide.**
- **The risk of external and internal radioactive contamination of staff.**

In planar and SPECT the isotopes commonly used are: Tc - 99m; TL - 201; GA-67; In - 111; I-131; XE - 133. The energy range from 70 to 370 keV. Its half-life ranges from 6 hours to 8 days.

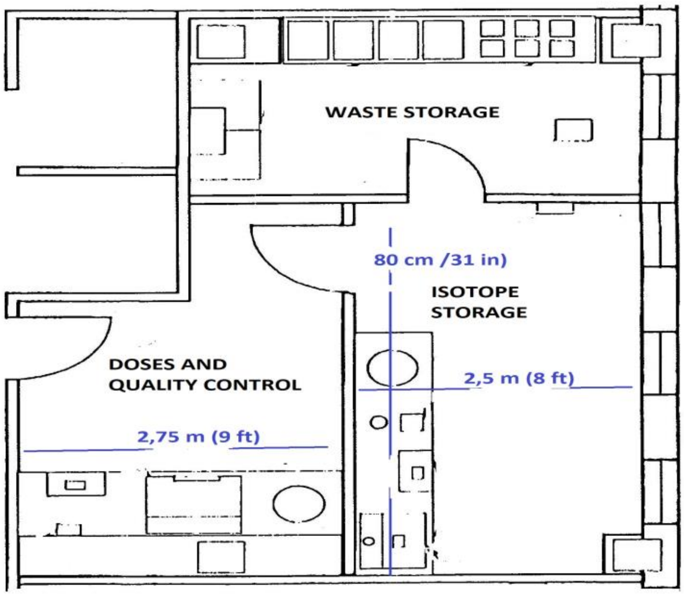
PET isotopes commonly used are F-18; C-11; N-13; RB - 82; 0-15 is the energy of 511 keV. Its half-life ranges from a few seconds to 2 hours for the F-18**.**

The space allocated to the storage, handling and conservation of radioisotopes is the nuclear lab, which for the purposes of their tasks is divided into three parts:

- **Warehouse of radioisotopes or Gammateca**
- **Preparation of doses and quality control**
- **Waste storage**

Will be reviewed the necessary conditions for the installation of the nuclear laboratory for a imaging department with two gammacameras and one PET- CT.

(9.7.- Preparation of doses in the lab)



(9.8-Dimensions of a hot chamber)

Warehouse of radioisotopes, with several enclosures for the storage and classification of these.

- Low-temperature storage enclosure. Built according to the local standards of radiation protection, with materials that allow easy decontamination.
- Low-temperature storage enclosure. Placed under the previous.
- Open enclosure handling at room temperature.

The three with small dimensions, so they have a volume of approximately 0,25 m3 (66 gal). Materials and leaded glass to visualization according to local standards of protection. A bench for manipulation completes the enclosure that in total covers a room of approximately 8 m2 (86 ft2).

Preparation of doses and quality control room includes:

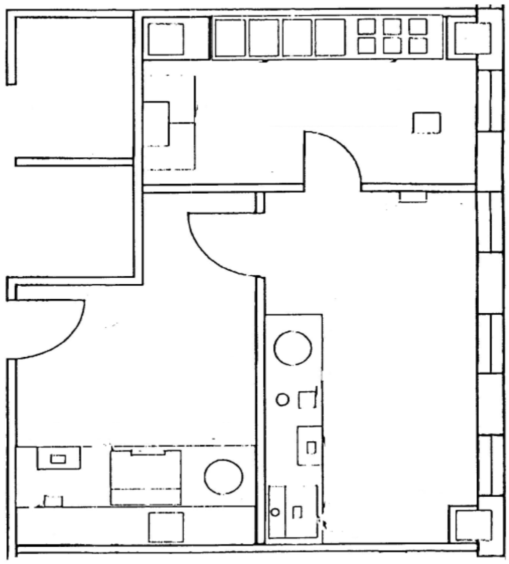
- Laminar flow hood, with leaded glass partition.
- Enclosure for preparation of doses in the environment.
- Workbench.

Waste store contains several leaded enclosures to:

- Store solid low energy radioactive waste.
- Store solid waste from other radioisotopes.

- Equipment for storage, treatment and controlled disposal of liquid radioactive waste generated in explorations "in vivo".
  The approximate surface is 6 m2 (64 ft2).

(9.9.- Waste storage)



(9.10.- Implementation of a hot chamber)

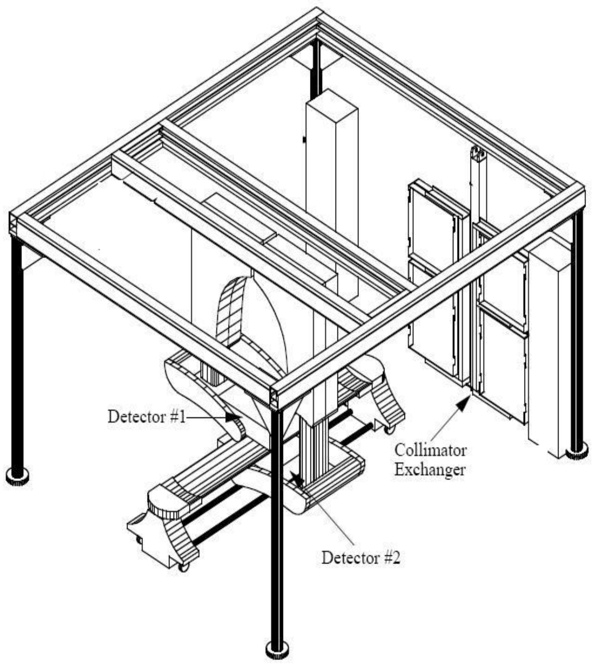
The implementation of all these cabinets, screens and storage plant according to the following figure (9.10).

The designer of the department should considered an area of 25 m2 (269 ft2) for the nuclear lab. It is subsequently, task of a supplier authorized by the bodies of local radiation protection the interior design, which has been very partially cleared, their construction and performance tests.

Additional important equipment of radiation protection are a pollution detector and environmental radiation detectors**.**

- **The special patient requirements** are also determined by the use of radioisotopes. The patient, once called by the technician for examining must go first to the injection room, small, 8 to 10 m2 (86 to 107 ft2), and from this to the waiting room of already injected patients, where patients wait until entering the room where the exploration is carried out. The toilets of patients should have a dedicated circuit for the treatment of wastewater. A deposit, placed in any part of the department or the health center, along with a purification station removes radioactive waste so that these do not reach the general sewerage. Should be considered its periodic maintenance.

- **The needs of equipment access** to the rooms are similar to the CT, access doors do not require more than 2.1 meters (6 ft) in height, because the gammacameras are smaller, and come with the detectors separated.
- **Weights are big**, of the order of 2.000 Kg (4.409 lb), so it required reinforcement on the floor that requires leveling detailed by the manufacturer.



(9.11.- Supporting structure of gamma camera for telescopic fixing)

- **The floors and walls** must be of easy decontamination materials, corners must avoided, so the finishes on floors and walls are rounded.
- **The calculation of radiation protection** should be made by a unit of protection authorized by local regulators.
- **The air conditioning** is special, have to be calculated the dissipation in the examination room between 2.5 and 3.5 kW. According to the machine model. Required stability of temperature in the room, between 16 and 25 ° C. Crystals of the detectors of the cameras do not support sudden temperature changes and variation cannot exceed 5 ° C per hour.

- **Electric energy consumption** does not usually exceed 20 kW, so the line conditions are not as strict as in other equipment, if well high sensitive differential and magneto-thermal protections must be installed in the electrical room cabinet.

IX.II.- HYBRID EQUIPMENT SPECT- CT

The hybrid imaging configures a new series of imaging diagnostic modalities, and in the future will be more and more therapeutic, which acquire anatomic and functional information of the patient in a single test creating merged images that facilitate the optimization of diagnosis and provide advantages in diagnosis that are superior to the sum of its individual parts. In addition to presenting more accurately the presence and extent of disease, the hybrid imaging equipment have the potential to accelerate the development of molecular imaging agents.

Will begin this section by SPECT- CT equipment and then will see the PET- CT.

The first users of this promising modality had proven its advantage with respect to the exclusive technique of SPECT. Pathology indicated by SPECT is perfectly defined anatomically with CT and in addition to CT provides correction for attenuation for all radioisotopes, increasing the diagnostic precision for the size and location of lesions detected.

The most interesting current application is in cardiology by the possibility of combining the information of the myocardial perfusion imaging with the tests for the determination of calcium in coronary arteries.

Another important application is in bone studies. The modality can clearly differentiate bone metastases of fractures, also with the CT can be distinguished if there is infection in one organ or its surroundings.

Several molecular imaging agents are on the near horizon for new applications of SPEC- CT, including ECDG, single photon emitter agent capable of replacing the FDG, technetium-labeled e indicated to mark areas of metabolic hyperactivity found in many types of cancer.

Altoplane is another agent promising assessment to indicate the presence of neurological diseases, including Parkinson's.

ProstaScint developed agent to diagnose primary prostate cancer and with whose images can be planned and defined the field for IMRT for treatment with radiotherapy and avoid prostatectomy procedures.

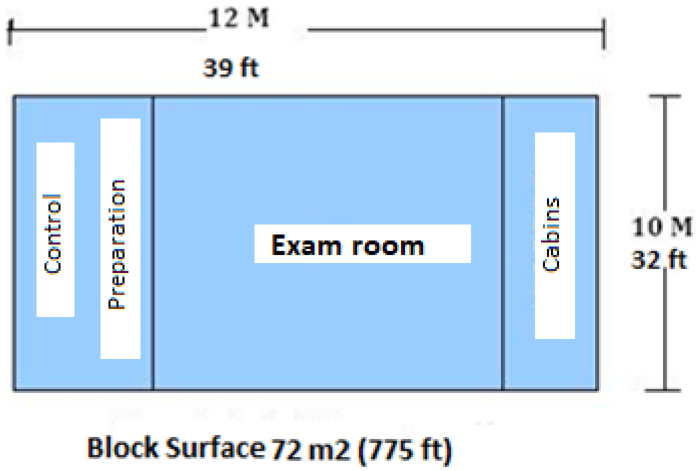
Design of the SPECT-CT rooms does not present additional difficulties to the SPECT or the CT. As already seen for these systems can be extrapolated to this modality.

(9.12.-SPECT- CT)

The room dimensions are longer that the rooms of CT and in many cases there is no technical room and therefore the designer is only committed to deal with the extra weight of the system, and then will be needed to reinforce the floor.

The requirements of patients are already indicated previously in the gamma cameras and in the description of the CT multislice.

Design block of this system is similar to a CT with a control room where there will be more control elements and an exam room where you have to add the extra space that require the detectors and truck porta collimators.



(9.13.- SPECT-CT block)

IX.III.- PET AND PET- CT

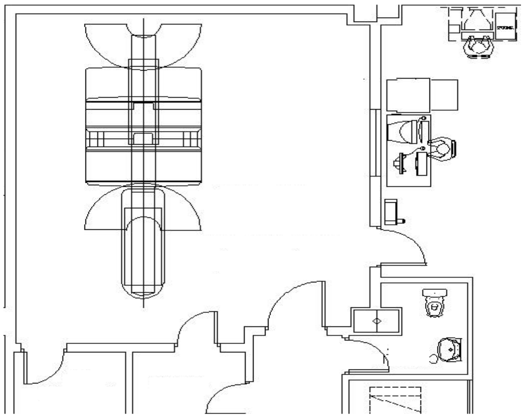
The development of a PET with a CT as a hybrid system has evolved, in such a way today, that the great clinical value of the information provided by the new modality has caused that practically, instead of using PET systems as happens before, only is supplied a PET with a CT equipment (PET-CT), with a few exceptions in specific applications were only a PET is demanded.

In the same way as at the previous modality the PET provides a functional image using radioisotopes which are injected intravenously. Also in the same way the images are acquired at a predefined time after injection. Also the PET detect gamma radiation, however the PET detects two simultaneous gamma ray in electronic detectors located at 180°, i.e. one opposite another in the ring of the detection system. Additionally, the energy of the gamma rays from the PET is 511 Kev, superior to the used in gammacameras, detail that motivates greater conditions of radiation protection.

The isotopes used in the PET, now, are F-18; C-11; N-13; RB - 82; O-15. The half-life ranges from a few seconds to two hours.

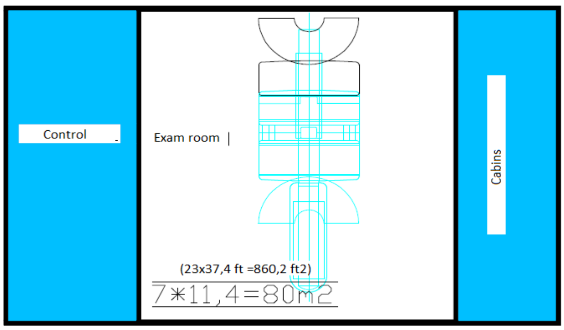
PET- CT applications are continuously expanded, in such a way that not only in oncology for diagnosis, follow-up and monitoring of therapy, also in cardiology in perfusion, function with pharmacological stress and with the CT angiography to determine the cause of ischemia indicated in the PET. In neurology in the diagnosis of epilepsy, Alzheimer's, Parkinson's and some dementias. Studies of infections, thyroid, renal studies, lung studies, etc.

The room design of PET-CT that is shown below can be an example of the space needed by this hybrid modality.



(9.14.-Layout PET- CT)

The examination room dimensions are 7,2 x 6,5 m (23,6x21,3 ft), total of 46,8 m2 (505 ft2), allow optimal mobility of staff and patients in the equipment room. Most systems do not require technical room, electronics is housed in the gantries of the equipment. The total area with control, toilet and cabin is 80 m2. The design block would be the following (9.15).



Block surface: 80 m2 (861 ft2)

(9.15.- Block for PET-CT)

- **The requirements of the patient**, in the same way that are determined by the technique of examination in gamma cameras. A series of individual rooms permit the injection and the wait to be able to carry out examination; more than 45 minutes of waiting, carried out in the same room where the injection has been made. Three cabins of waiting are generally sufficient for good equipment and room occupancy.

- **The needs for equipment access** to the rooms are similar to the CT, doors should have a minimum height of 2,1 m (6,9 ft). The corridors for access of the machines up to the room should be careful in its design. Minimum dimensions are a width of two meters and a height of 2.1 m (6,9 ft).

- **Weights are high and the floor must be reinforced** to support the load. A total of 3.500 to 4.000 Kg (7.716 to 8.818 lb) of total weight, to be distributed according to the manufacturer's instructions and should be calculated by the architect for structure reinforcement.

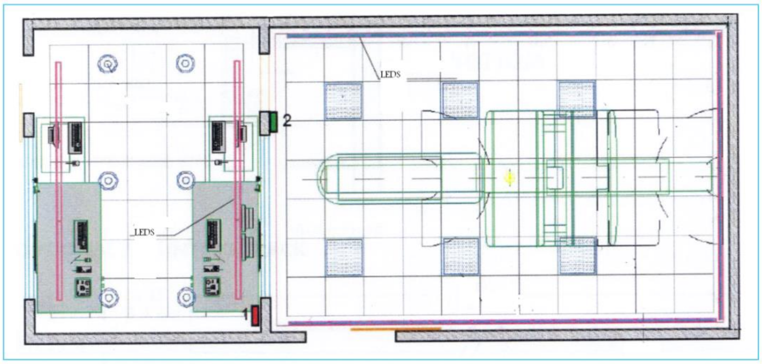
- **Floors, walls and ceilings** have the same requirements as a gamma camera (don't forget the leveling) but with greater protections to the radiation that must calculate the unit authorized and competent.

- **The air conditioning o**f the room is superior to the CT. Must be added the heat emitted by the PET. Is required to dissipate between 4 and 6 kW. In cases where there is technical room have to be calculated the cooling. Some equipment require water and external cooler and space needs must be provided by the design in the project.

- **The electrical energy** that is required varies in the range of 90 to 130 KVA., depending on the model, and the electrical control panel should collect local installation requirements.

- **The lighting** has same prescriptions that for a CT therefore must refer to Chapter VIII in the CT section in this respect.

Can be added new LED lighting designs to provide excellent opportunities to reduce the tension of the patient as well as providing communication tools with the patient through the programming of the colors of light. In the design below are colored the walls by means of LED lighting, which the technician selects with the electronic programmer located on the control.



(9.16.- Level of lighting in a room PET-CT project)

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IX.IV.- CIYCLOTRONS

It is not the purpose of this publication to enter in fields outside of the area of diagnostic imaging and radiation therapy, but the cyclotron is an element without a PET can work, therefore will be made slight reference to indicate their function, and details of its requirements, so the planner have a minimum information over the space and resources and all details needed at the time of planning the imaging department.

The production of the isotopes used in a PET requires a cyclotron that generate them. The cyclotron is a circular particle accelerator. These are accelerated by an oscillating magnetic field until they reach a suitable kinetic energy to produce nuclear reactions when colliding with a material called target or focus, obtaining the formation of radioactive isotopes, like the F-18 used in the PET.

(9.17.-Cyclotron with shielding)

In the figure (9.17) is shown the closets of power and control, with the two side semi cylinders which are radioactive protections which housed inside the particle accelerator.

There are different models of cyclotrons, according to their ability to generate different types and amounts of isotopes (curios produced). Most compact equipment produces lower number of isotopes. The most popular is the F-18; they work with energies of the order of 8-10 MeV, and can produce 2-3 CI in a bombardment of 2 to 3 hours depending on the models.

The most powerful can reach 18 MeV and can produce a very wide range of isotopes as well as more quantity in each bombardment.

- **The dimensions of a room** for a cyclotron can be of the order of 7 x 8 m (22x26 ft), i.e. 56 m2 (602,8 ft2) for stay free of problems a system. Height from floor to floor of 3.5 m (11 ft) is required in different systems.

- Important details of the cyclotron are its **radioactive shielding** needs. Again entities authorized by the competent local bodies should calculate the bunker of concrete to install the cyclotron. Since they are, in general, auto shielded, they are not in the size of radiation therapy linear accelerators, but represent a mechanical load to the soil and a respectable cost of installation. This is a limitation in the location, which has to be chosen at the time of the planning of the center.

- **The weights** are important; between 30 and 40 Tons of weight they are normal values to be considered in the design.

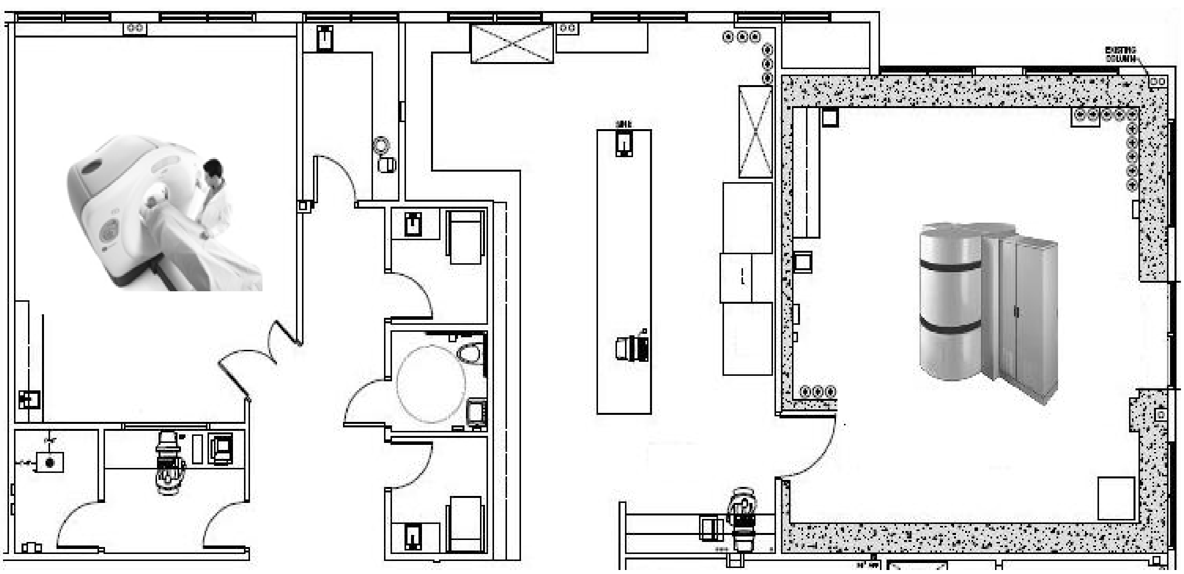
- **The dimensions of the access routes** must allow widths of 2,5 x 2,0 m (8,2x6,6 ft) for its access to the room.

- **The consumption of electrical energy** between 30 and 70 KVA, and their performance specifications require a certain quality in the supply.

- **Water,** in respectable quantities, is required for cooling.

  To take advantage of the produced isotopes, some of very short life, **radio pharmacy laboratory** should be attached, as shown in the attached drawing (9.19). This contains elements similar to the hot chamber (nuclear lab) already described but intended for higher energies, therefore with greater shielding and higher level of automation, so many preparations are scheduled without great manipulation.

(9.18.-Cyclotron)



(9.19.-Cyclotrón with radio pharmacy and PET- CT)

- **Radiopharmacy room** can take between 100 and 120 m2 (1.076 to 1.291 ft2), depending on the tasks that want to do, and consists of several units of work cells, a module of synthesis, tools for quality control, a dispensing module and a monitoring system of the process.

The project of installation of a cyclotron with its precise radiopharmacy requires for its optimal installation a thorough work between supplier, medical imaging specialist, pharmacy, architect and construction engineering unit.

IX.V.- EQUIPMENT FOR PRECLINICAL EXAMNS

The development of molecular imaging and advanced pharmacology have opened a new portfolio of equipment capable to contribute to advance in the introduction phases in humans of different type tests of pharmacology and at the same time the development of new molecules capable of being able to be used following to patient needs according to the type of pathology and patient, previously doing the necessary tests in these new diagnostic modalities designed primarily for exams with small animals.

(9.20.- Preparation of preclinical analysis)

The first equipment entering in the market of these nano products was the **nanoPET.**

It's a PET with a small aperture and small field of exploration designed to carry out tests on mice that previously has been injected and induced a certain human pathology. The objective is to see the response of certain drugs injected into the mouse pathology using tracer F-18. Therefore the test follows the same guidelines that a PET in human.

(9.21.-NanoPET- CT)

Occupied space is considerably lower than for a conventional PET but in the room must have accessories for the preparation and follow-up of the exam, and dimensions of 20 m2 (215 ft2) seem appropriate for this system.

(9.22.- Test with nano Pet-CT)

Radiation protection of the room conditions follow the same criteria as in the rest of the nuclear medicine equipment.

Energy consumption are significantly lower than in a PET of humans and mounting conditions, entry to the room, air conditioning, lighting also minor.

Another equipment from the same family of key equipment in clinical research of molecular imaging is the **nano SPECT- CT**. Basic difference with the previous is working with less energy than the PET isotopes.

(9.23.- SPECT-CT system for preclinical examinations)

The philosophy of operation are the same as have been seen in the hybrid SPECT- CT and the same comments above for the nanoPET here are valid. Must not forget that it requires a nuclear lab and the authorization of the local authorities in matters of management of radionuclides.

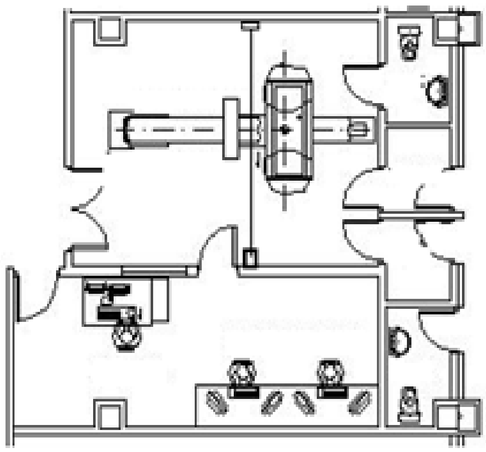
IX.VI.- RADIOTHERAPY SIMULATORS

Since the mid-80s, when began to publish radio therapeutic procedures to perform the location and simulation with axial single slice CT, has not ceased to develop these systems called Virtual Simulators, and already at the end of the 1990s there were simulators formed by a CT of one slice with big input field and large scan coverage the so called “big bores”. The images obtained with the location of the tumor and the virtual simulation, made possible to build the DRR (Digital Reconstructed Radiographs) in a simulation workstation as well as determine the coordinates of the isocenter. This information is send in DICOM RT to the radiotherapy planner to calculate the treatment plan, define the openings of collimators, and send profiles to the lead masks cutting machine to obtain the appropriate blocks and protect vital organs in the treatment with high energy particles.

The clinical need to watch the skin of the patient, also in thick patients, as well as the radiotherapeutic treatment simulation in breast, led to the design of gantries with large opening, called large bores, or big bores, exceeding 80 cm (31 in).

(9.24.- MCT virtual Simulator with big bore)

Virtual simulators with CT multislice have the same planning needs of a CT already described previously. The designer must only add the placement of lasers that define the point of start of the measures and/or the isocenter of the simulation, depending on the technique of virtual simulation. These lasers are placed on the two side walls, parallel to the gantry, and a third on the ceiling, and among the three lines define a point in its spatial junction.



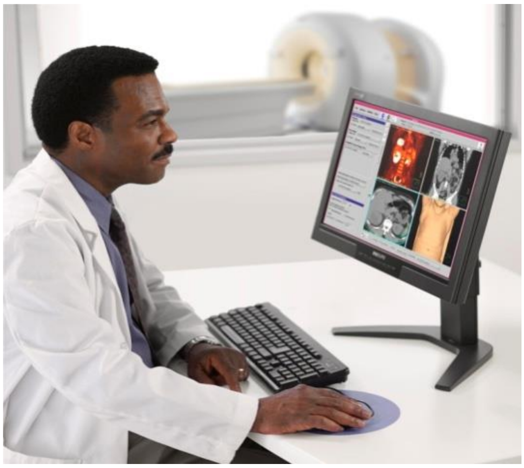
(9.25.- Virtual Simulator with lasers of location)

- Possibly the needs with respect to the number of cabins or vest rooms are less restrictive and many facilities with a cabin and one inner toilet is sufficient.
- The preparation room is desirable because many patients need contrast and in pediatrics may require sedation or anesthesia.

Refer to Chapter VIII in the description of CT requirements**.**

IX.VII.- TREATMENT PLANNING SYSTEMS

These are information systems that allow the physicists of the radiotherapy department calculate treatment conditions, and its dose, to be provided by linear accelerators with the goal to deliver the maximal dose in tumor and protect healthy tissues.



(9.26.-Radiotherapy dose planning system)

Simulation images come from virtual simulators with the CT or with magnetic resonance imaging equipment, and also makes this function a PET- CT system that can also perform in a very favorable way the task of virtual simulation.

The room required for planning, must locate servers of the planner and the space for workstations required by physical. In a radiotherapy center of medium size, with two linear accelerators, may be three physical at the same time calculating, therefore it is necessary to leave space for these tasks. May be needed more space for a brachytherapy planning and other additional for radiosurgery, space for servers and more workstations must be available. Minimum room sizes from 30 to 40 m2 (322 to 430 ft2) may be necessary, distributed according to the tasks to be carried out. Depending on the department may have two rooms of calculation, to facilitate the proximity to the treatment systems**.**

- **The conditions of these rooms** are described in Chapter 6 for equipment in general, and think in this way if encompasses different computer systems.
- Proper **air conditioning** and proper gutters for the distribution of the radiotherapy electronic network. Even better soil computer recordable in the planning room for changes required with the time in cabling when upgrading in the computer systems**.**

IX.VIII.- BRACHYTHERAPY ROOMS

This therapeutic technique is having more and more acceptance in the treatment of tumors where one applicator can take the radioactive dose to the tumor site. Several modes are available: endocavitary, intraluminal and interstitial and treatments of prostate cancer in real time.

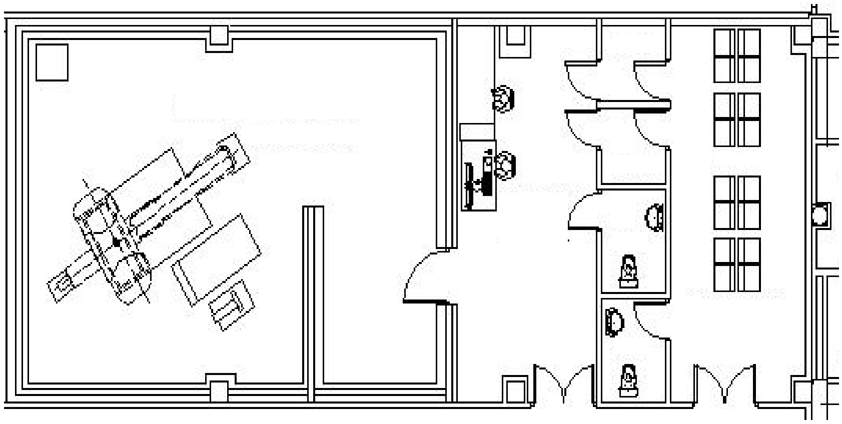
The equipment uses a radioactive source attached to a cable with high flexibility, which can easily take very small curves in the human body.

(9.27.-Brachytherapy container)

The system consists of a tripod with the container of radioactive material and a number of applicators for gynecology, skin, bronchus, esophagus, nasopharyngeal, head and neck and breast.

Also the doses are calculated in a planner, that as mentioned in the previous section will be located in the computer room of the physicists that calculate and optimize the treatments doses.

An example of a bunker to locate a brachytherapy unit shown below.



(9.28.- Layout of a system of brachytherapy)

The image shows the container device of brachytherapy in the bunker, a stretcher for the patient, and in points a CT for the location and planning in situ the treatment to be carried out. Several radiation therapists suggest one equipment of MR to make this task and on the basis of the available budget and the clinical reasons drives for one or another system.

- **Brachytherapy with control room** occupies a space of 7,5 x 14,0 m (24,6x45,9 ft), i.e. 105 m2(1.130 ft2). Rooms with more reduced space if deleted the CT or MRI. Adding the cabins can be reached 115 m2 (1.237 ft2)**.**

- **Patient requirements** depends on the type of treatment to be carried out. The cabins and toilets are standard and if space is available preparation room can be adequate to facilitate the workflow.

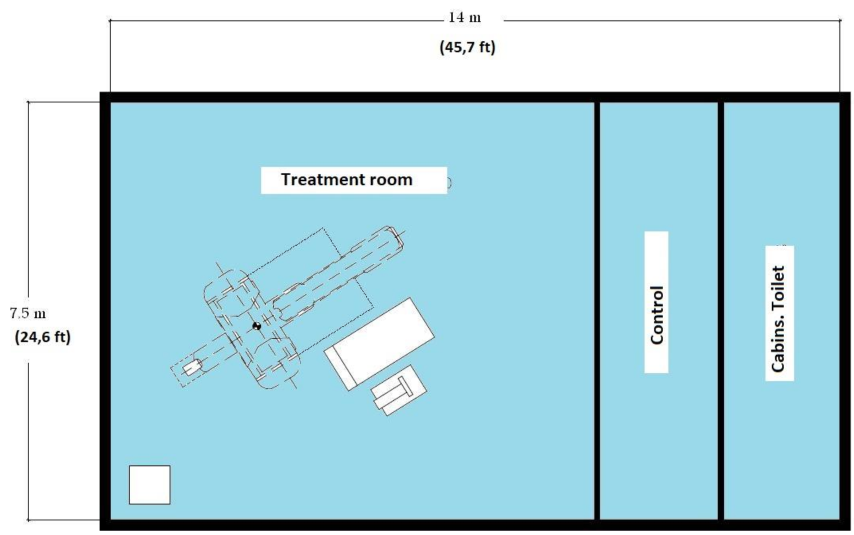
- **The room is protected by a bunker** to avoid leakage of radiation to the outside. Thickness of 50 cm for the walls of the bunker are normal. Its variation depends on the radiation protection authorized body that make the calculation.

Air conditioning, required by safety conditions in supply and ventilation of the room. The bunker is closed during treatment.

- If a CT is installed in the room must make the corresponding provisions in the design of loads to the flooring, doors, etc. In the same way that if is installed a RM will be required space for technical room, refrigerators, etc.

- **To install security mechanisms** rely on the recommendations of the supplier that should provide installation drawings to the architect for their final finishing and preparation of the construction.

The block, for purposes of reserve space in the pre-design, is as follows.



Block surface: 105 m2 (1.130 ft2)

(9.29.- Brachytherapy block)

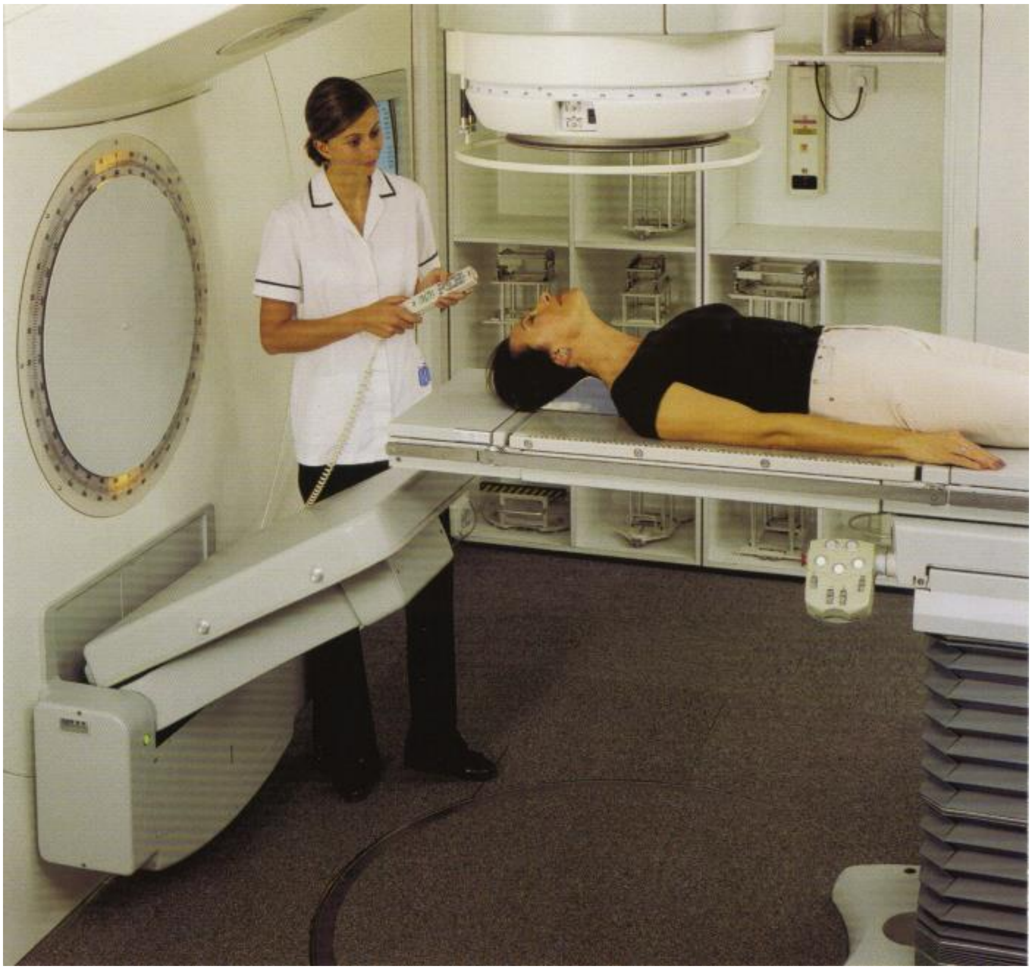
IX.IX.- LINEAR ACCELERATORS

Are the basic sources of irradiation for cancer therapeutic treatment with high energy particles. Provide photons with energies between 4 and 23 MeVs and electrons with similar ranges of energy, depending on the different models supplied.

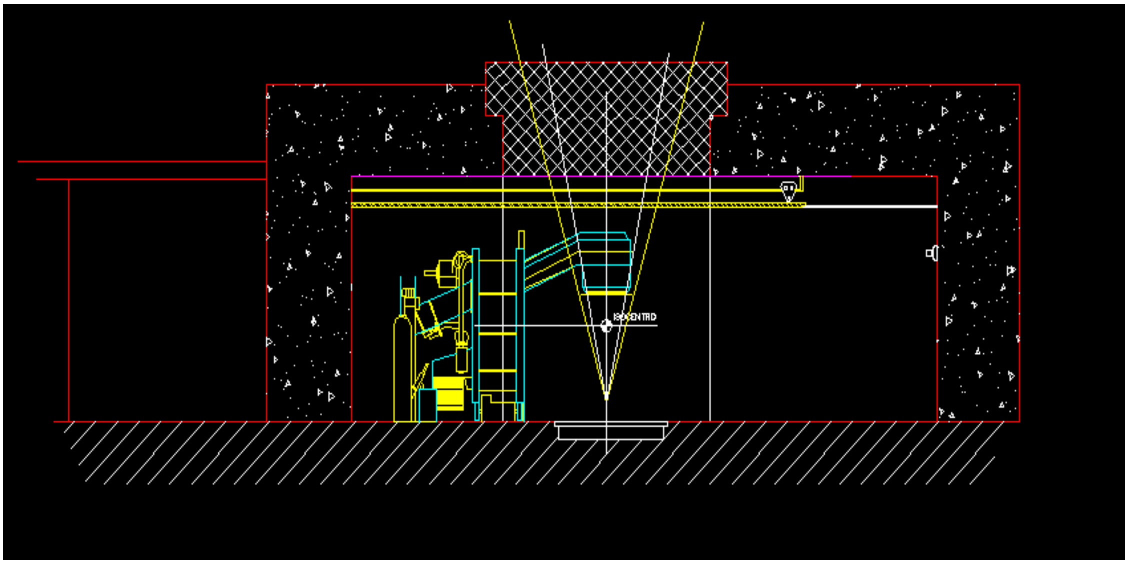
They have multi leaf collimators of thin thickness of lead sheets and with the ability to define multiple forms, according to the therapeutic planner and the treatment technique.

Digital image acquisition devices, for the control of the treatment, are included in the system first to view the field of action and then to follow up in real time the irradiation process with 2D and 3D images.

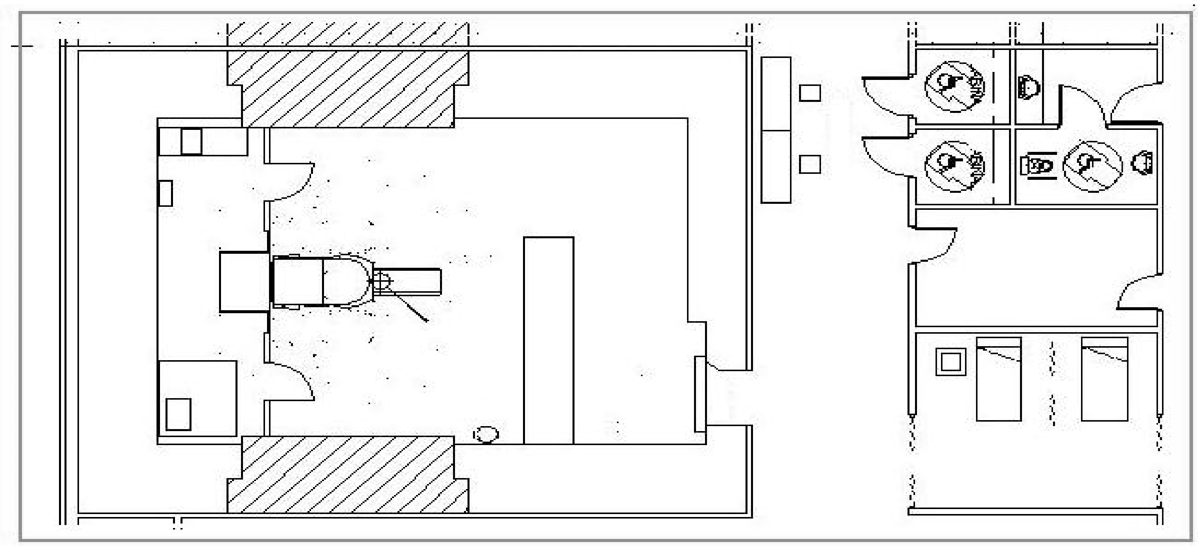
High energy particles requires extreme conditions of protection and as a result the bunkers, build with concrete, some walls with barite mixture, they have voluminous proportions and high cost of construction.



(9.30.- LINAC)



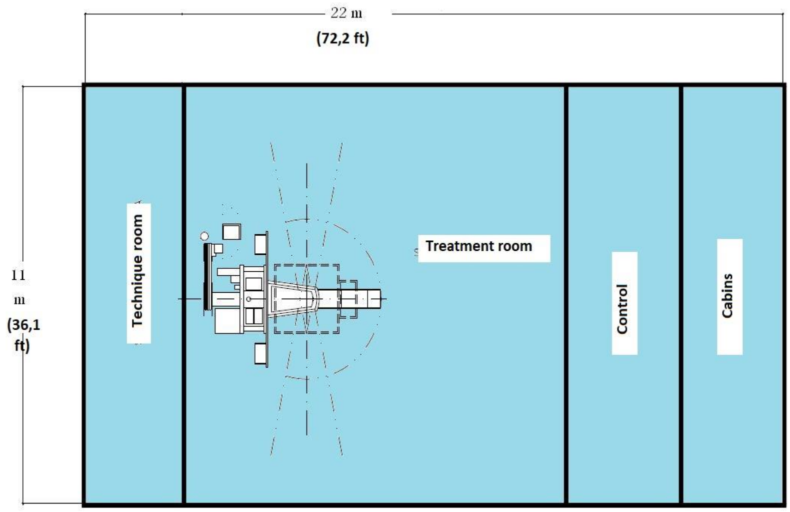
(9.31.- Section of a bunker for linear accelerator)



(9.32.- Layout of a bunker with control, cabins and waits)

Linear accelerator shown occupies a surface area of 10,5 x 7,5 m (34,4x24,6 ft), whereas the labyrinth of concrete for the entrance, in total an area of 79 m2(850 ft2). Considering the total surface of the bunker is 14 x 11 m (45,9 x 36,1 ft), with 154 m2 (1.657 ft2), and adding the control and change of clothing booths reach a total gross area of 250 m2 (2.2.690 ft2).

Therefore a block for planning could be as follows.



Block surface: 242m2 (2.604 ft2)

(9.33.- LINAC block)

The gross dimensions of the bunker depends on the type of accelerator, but the planner and designer must make provisions to future changes in the machines. Increasing the protection of a bunker for a small accelerator is no easy task, nor economic.

- **The technical room** can be included within the bunker, on the back of the gantry, and occupies a total of about 15 m2 (161 ft2).
- **The requirements of the patient** in the design of these rooms are determined by the own type of treatment. Elements of protection of organs which should not undergo irradiation are outlined not only with the multileaf collimator, but in many cases with masks of lead in this regard, therefore a room with its elements for these blocks production is required, and storage, as there is to keep them as long as last the irradiation sessions to the patient for which have been built, as well as fasteners and other accessories for treatment.
- **The machines have big weights**, between 4 and 9 Tm, and require to plan the ways of entrance to the bunkers. Corridor of between 1,5 and 2 m (4,9 and 6,6 ft) widths are needed with heights of doors of 2,1 to 2,3 m(6,9 to 7,5 ft).

(9.34.- Linear accelerator)

- **The calculation of the bunker and the study of safety and protection**, should be done by an entity authorized by the local responsible in radiation protection. Therefore the selection of the equipment to be installed is required at the same time that the planning of the department.

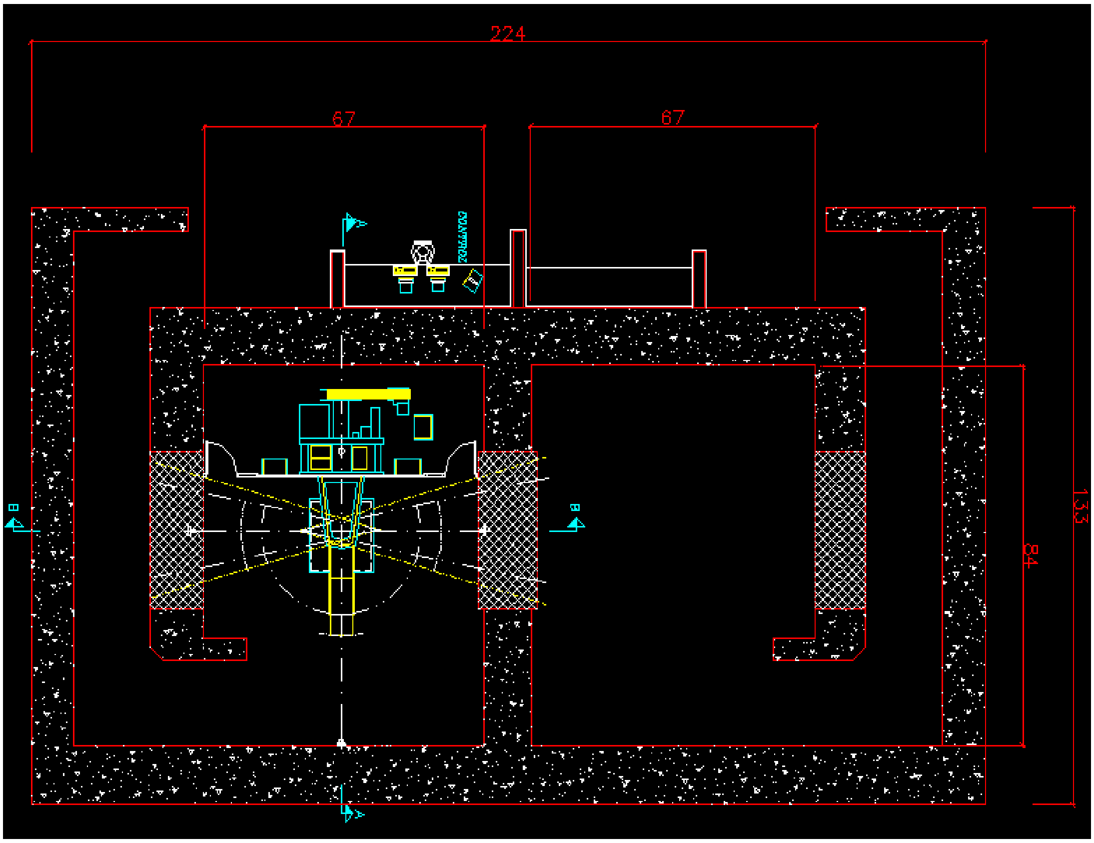
- **The total power consumption** ranges between 40 and 80 kVA, according to the model and manufacturer provides information and drawings about the electrical system requirements for the design of electrical panels.

- **The air conditioning** is important, both in the examination room, that must remain between 20 and 24 °C (68 and 75 ºF), and in the technical room. The heat emitted by the equipment in the technical room can reach 5 kW. The bunker, hermetically closed must be safe in ventilation with recommended 10 to 12 air changes per hour.

- **Cold water** is necessary to cool the particles generator system. A cooling system of 15 kW dissipation may be suitable. Independent refrigerator must be calculated and connections with the cold water piping of the hospital is recommended for cases of failure of the refrigerator.

- **The lighting** of the treatment room must be adjustable to obtain good visibility of lasers for positioning and treatment areas. Additional requirements are supplied by the manufacturers.

Other radiotherapy treatment units are located in very exclusive facilities, and currently limited to very few units devoted to special procedures (generators of positrons and stereotaxy systems with multiple radioactive sources) and they are not used as standard as the LINACS. Information will be added in the future, as soon as the economical possibilities improve de acquisition of this equipment and assume the installation costs of these new systems.



(9.35.- Plant of bunkers to host two linear accelerators)

X.- DEPARTMENTS DESIGN

I. WORK LOAD DISTRIBUTION

II. CIRCULATIONS AND BLOCK DIAGRAMS

III. SPACE WITH BLOCK DIAGRAMS

IV. ARCHITECTURAL DESIGN

V. MODULAR PROGRAMS

We can live without architecture and practicing cult without it but we cannot remember without its help. (John Ruskin)

X.- DEPARTMENTS DESIGN

The multiple communication media available today have provided in such a way the interconnection of human activities that have led to the phenomenon of globalization.

Large consumer businesses, and many professionals, have allowed transnational companies to design their stores with twin patterns, leaving very little space for individual creativity. A chain of shops, restaurants, cinemas, etc., many of them franchisees offer its franchisees the establishment model, its product offerings, their schemes of work and even their way of dress for the staff. This is not the general case of imaging diagnostic and radiotherapy departments. Each department or each renewal is a challenge of the work team to adapt at the space the technology and the function to make, always seeking to meet the main objective of the department: optimum care to the patient.

The imaging department is not only a set of exam rooms where scans are performed to diagnose diseases, It is a functional assembly that performs a basic task in a healthcare organization, both from an outpatient center and the department within a large hospital, where without the diagnostic image would not be possible to carry out the current modern medicine.

Planning space and resources is the first link in a chain where all other actions that occur over time are linked. The design of the department is one of the last steps prior to construction, the installation of equipment and commissioning of the department.

Data collected in previous chapters address the task of design. The calculated data of the surface led to a space with a sketch of the previous design, possibly be very valid, if the elapsed time from the planning to the design is not long. Then will be finished the drawings that allows the constructor to perform civil works and address this without complications for subsequent installations of imaging systems and other dependencies.

The data provided for the necessary equipment surfaces in which are included adequate space for the examination room and the required for the controls where technicians handle equipment, and the spaces of the technical corridors that may exist, are that will be used to build the circulation diagrams to which will be added each modality block; assembly drawing that allows to make an initial distribution of the available space.

The next step is to adapt the blocks and corridors of circulation to the architectural layout of the available surface. Architecture that has the pillars, either concrete or iron at certain distances, and these determine the position of the rooms and corridors. No room should have a pillar in its examination space, which is observed in some projects, as these hinder the mobility of staff, attention to the patient and the correct image acquisition act. Likewise the downspouts and water pipes, and also lifts, weirs, ladders, skylights, etc., are elements which are architecturally within the space set for the imaging department, and that the designer has to consider, obviating the drawbacks in design.

They are four steps to observe in the design of the department:

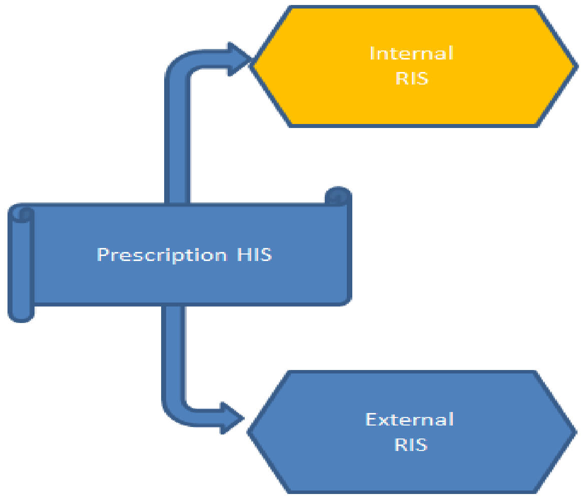
- Workflows, distribution of workloads in spaces.
- Circulations.
- Distribution of modalities in blocks.
- Design the department in the available architectonic surface.

X.I.- WORK LOAD DISTRIBUTION

The imaging and radiotherapy departments performs a function that has to have an image reflected in its design. The function consists of diverse activities that should have its representation in the drawings. Analysis of the workflow in the department, which differs from one to another, must allow to identify the areas of the department and the location of different functional elements within the zones. It should also allow the definition of spaces according to workloads. At each step, the design team must write workloads and translate them on surfaces. This is the time and this is the reason for the study of the workloads flow.

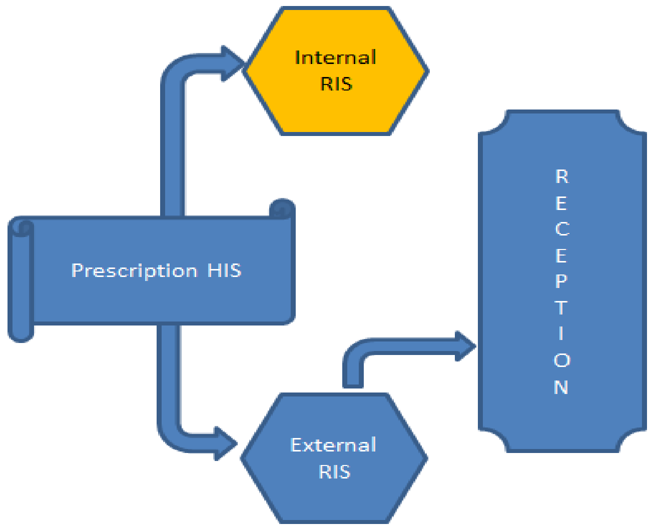
The patient assists the department resulting from the prescription of a physician, a clinical, with the need to complete a diagnostic imaging exam to facilitate a diagnosis or perform a treatment. Once this act has been done will be a therapy, and it is possible, also for therapy, the patient has to go back to the department's image. It is the case of angioplasty, it is first diagnosed the place of vessel occlusion and then interventionism in the vascular room.

Prescription (10.1) leads to a citation of the patient in the imaging department. This citation can be done by different methods. For an outpatient at the hospital, or in the case of an external imaging center, through a phone call or through the website of the hospital or external diagnostic center. Also, today, is possible directly from the office of the clinic who prescribes the test, the connection between web sites or through the direct connection between centers.



(10.1.- Prescription and appointment at RIS)

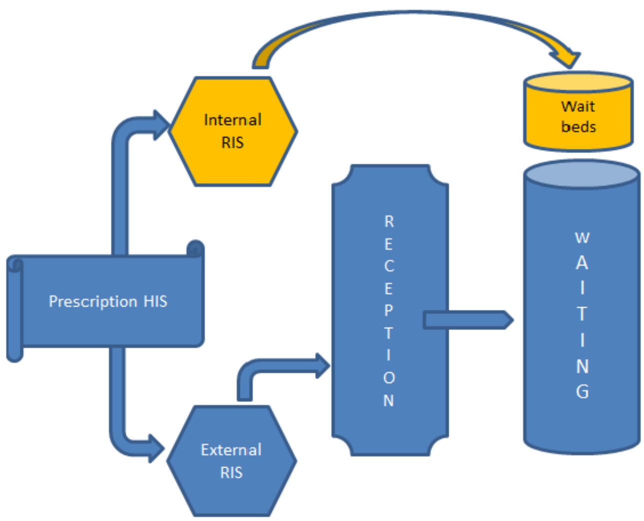
For the inpatient being in a room is an internal call, from the patient room, nursery, or medical office, to the HIS of the center, which will connect to the RIS of the department's image to show the agendas. These shows the holes available to make exams and is made the book of time and the room where the exam will be performed. From this moment the patient already has in mind the preparation of the next step: go to the imaging department above the date and time.



(10.2.- Outpatient reception)

To the arrival of the patient to the department the first place to access is the reception (10.2), and here we enter into the definition of the first element of the design of the department. It is the first contact of the patient and where to take his first impression of the place and where he is and can imagine, based on his observation of the reception, of the quality of the services that will be offering. Reception must be wide, orderly, with open spaces and lighting appropriate, attractive and well attended by the staff assigned. Nearby seats should help patients with problems to stand until items are supplied to move in the department, as chairs, etc., or to companions with difficulties.

Let us not forget that the majority of patients go to the imaging department hopeful that care which will be apply can lead to the solution of their problems, and the emotional factors at the front desk have a meaning of greater depth than we can simply estimate. Many come with a companion, and in the departments of pediatrics up to two. The reception has to be prepared for these needs. Internal patients do not go logically through reception. Are moved from their rooms, in bed or in a wheelchair, the majority, to test rooms where the exam is carried out. Their wait is generally very small in a properly organized department. After checking the citation data the patient goes, directly or helped, to the waiting rooms. Citation-checking process must be short, agile and avoiding possible queues. Calculate the number of staff on the basis of the expected demand. A receptionist may be sufficient in a small department, but in a large hospital may be needed at least four. It is a calculation of the number of potential patients per hour, during the hours of citation.



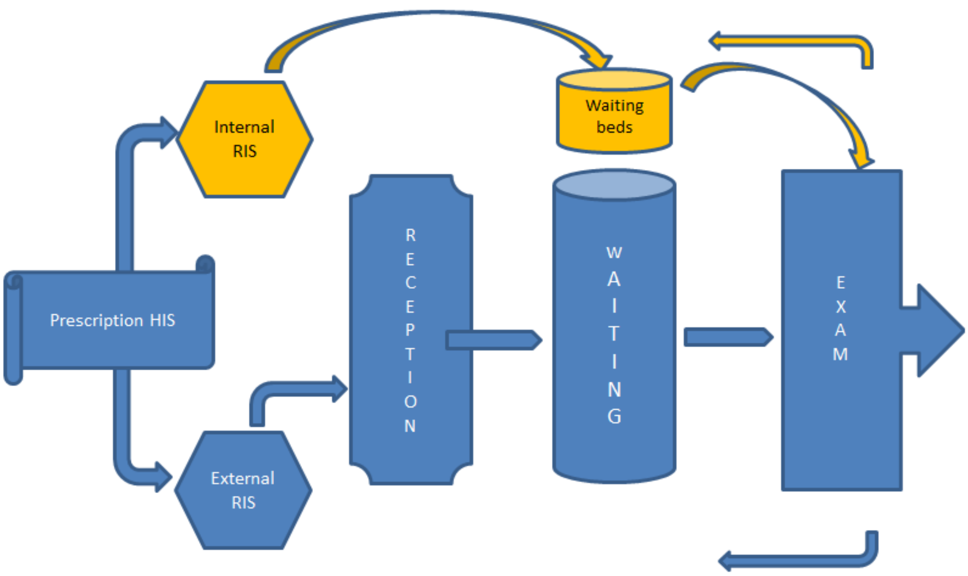
(10.3.- Waiting)

The patient arrives at the waiting room (10.3), prior to the examination room. Enters in the room, and again the urgent need for the correct design of the waiting rooms. The personalized treatment, that the patient expects, must prevail. Maximal confidentiality, convenience, entertainment if possible, amplitude, correct lighting, etc., are conditioning factors of the waiting rooms.

General waiting rooms, numerous, are works of the past, when the waiting room was a hall where patient was called, even by PA; other waits with a number on a light board, where the patient sees his call. None of these is what a patient wants to have when you expect, in many cases, with anguish the realization of a test to diagnose your ailment.

Waiting for the exam room, of few people, well appointed, with short waiting times. Expect comfortable, with simple but cheerful bouncy lighting decor and if possible with reading entertainment or media image. These are expectations that the patient is grateful and that comfort them and reaffirm their dignity as a person.

Once the technician sees in the RIS the next patient cited in the examination (10.4) room, go out into the waiting room, usually through a cabin, and calls to the patient.



(10.4.-Exam)

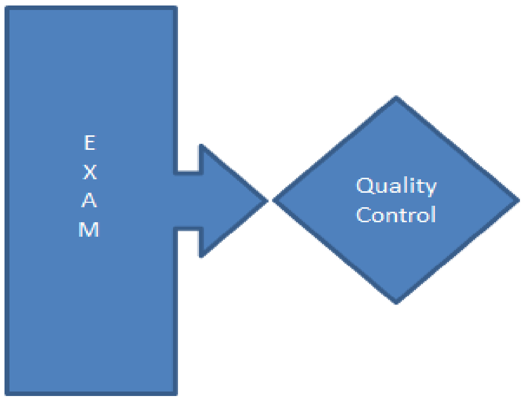
The first detail which observes the patient is the cabin. It must be adequate, with space for changing clothes and put on the exam dressing gown without movement difficulties. Cabins for the disabled must be bigger. We must observe local recommendations for these cases, where minimum dimensions to be enforced are set.

Preparation, usually for inpatient rooms, need adequate space to inject the patient, make sleepy, anesthesia is applied, or monitor it before and/or after the exam, therefore several people around the patient, the mobility should be planned and secured.

Intermediate waiting rooms, patients with long exams, may be needed to prevent low room occupation and its loss of efficiency. A room of this type for several diagnostic rooms may be sufficient.

Several chapters were developed on the design of imaging and therapy rooms, so only now indicates the need to continue with the tips of quality, comfort and ambience for the patient.

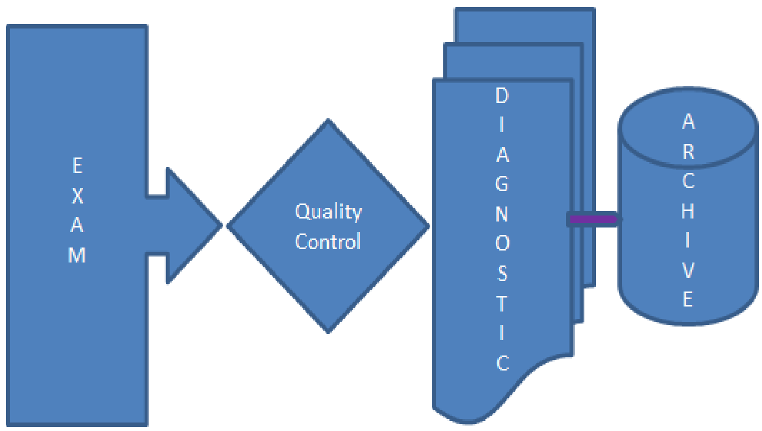
The exam leads to images that require control of quality (10.5).



(10.5.-Quality control)

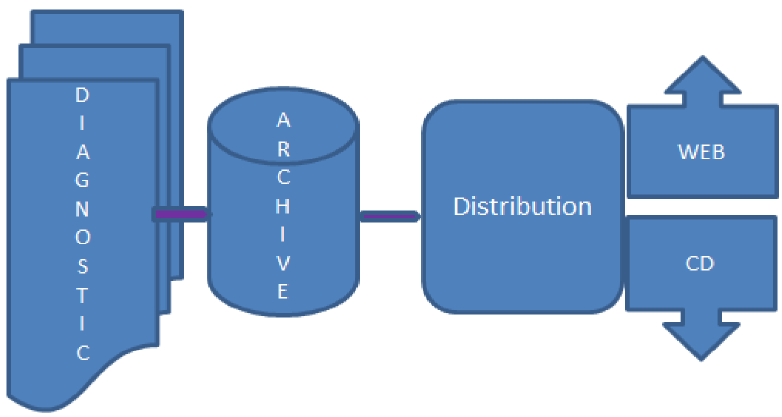
At the time of use of radiographic film this was a task that required technician time and physical space. With digital systems, the image is instantaneous and the technician, technicians, or radiologist, depends on the procedure of the department, validates the image instantly and send it to intermediate files on the PACS for his subsequent diagnosis.

Diagnosis (10.6) today, requires less space than on previous dates. We have seen that only 10 percent of the total space in the department area is for medical personnel utilization. The rooms or cabins where the workstations are hosted must be simple, comfortable, with adjustable lighting and occupancy depending of wishes, individual or to share among no more than three radiologists. Voice recognition systems, for the dictation of reports, require some privacy and is therefore an important point in the total design of the diagnostic department. They are many hours a day viewing images on monitors and it is necessary to not increase with architectural or functional design the medical personnel fatigue caused by the monitors. Rooms or diagnosis cabins as well as sessions spaces constitute a new stage in the design of imaging departments.



(10.6.- Report and archive)

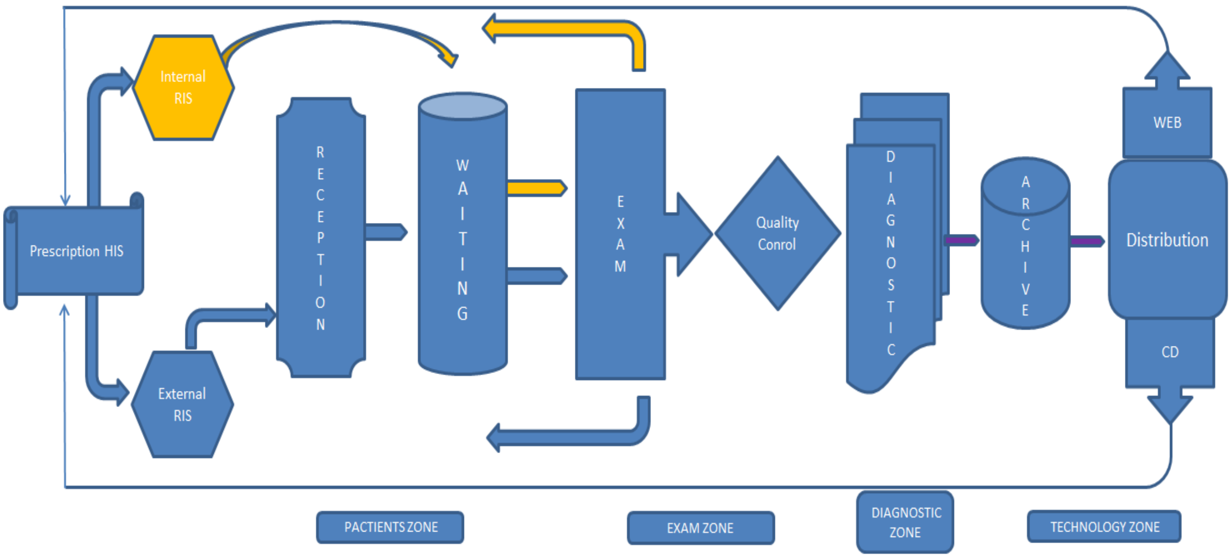
As soon as the diagnosis is completed and issued the report, image and report are archived in discs of the RIS and PACS, properly interconnected and with the associated patient number.



(10.7.-Archive and distribution)

Server of PACS and RIS (10.7) rooms, today's small space, are vital elements in the operation of the department. Air conditioning, ventilation and easy maintenance are key premises; without them it **doesn't work not only the imaging department, but the whole diagnostic in the hospital or diagnostic center**. Therefore the spaces allocated to this technological zone and the people who run it, as computer and system administrator should be designed carefully and with great detail.

Images and archived reports are distributed to referring physicians primarily through the website of the hospital or by CDs, economic in relation to ancient radiographic films, for reading in DICOM format on any available workstation that has the doctor who performed the test prescription. Thus completes the closed cycle of workflow with all the implications of design and architectural that entails.

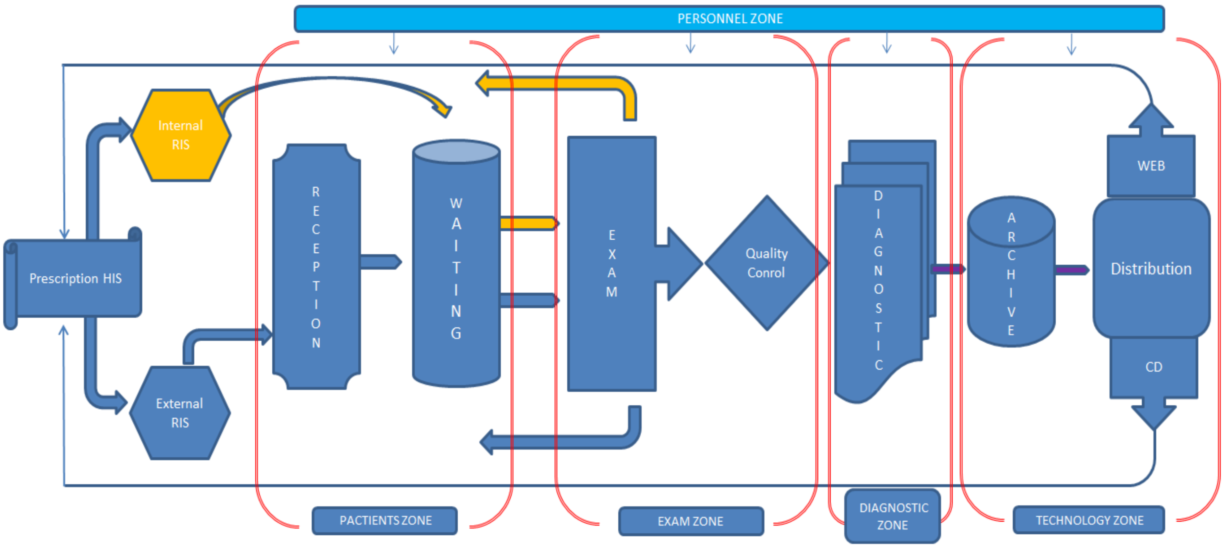


(10.8-Complete work flow diagram)

Every step that the patient has been waking, each step that the image has been climbing, has a transcription in the design of the department and in the adaptation of this design to architecture, as it will be expanded in detail in the following paragraphs of this chapter.

The workflow overlaps with the zones described in Chapter V and correlates in a complete and complex form, in further homogeneous spaces next or distributed.

Thus the **ZONES OF PATIENTS, EXAMINATION, DIAGNOSTIC AND TECHNOLOGY** follows as the activity flows in the department, always under the action of the staff who develops it, and them for its private and internal activity also has its own **ZONE.**



(10.9.- Workflow through the **ZONES** of the department)

In the **PATIENTS ZONE**, the configurations of the reception and waiting area requires details which the designer, possibly, requires the experience of to the decorator or interior architect with more intensity than in other **ZONES**, help to provide highlighting the space with positive details for best impression and comfort of patients. Waiting with comfortable seats, without excessive luxury, making ease the feelings of patients and their companions on the organization of the center and improve its expectations about the care will be given.

The **EXAMINATION ZONE**, has to be careful in their final design. Designer must take care of the cable ducts, hide in technical rooms the electronic equipment required for the operation of the systems but that do not require placed inside the rooms, care for the details of the suspensions of ceiling making them up with the false ceiling and watching with the design engineering of the center details of lighting and air conditioning, so that they can adjust according to the type of patients to treat in the room.

The **DIAGNOSTIC ZONE** requires special care in the cabins or diagnosis rooms by the already exposed details of the current workstations.

The **TECHNOLOGY ZONE** is a dispersed area in the department but key for current PACS and RIS systems, base for the functioning of the department.

X.II.- CIRCULATIONS AND BLOCK DIAGRAMS

After the definition of the total surface, with activity data provided for the department, and the flow of workloads on the surface, the task to develop is the analysis of the circulations, i.e. pathways, where are going to move the active elements of the department:

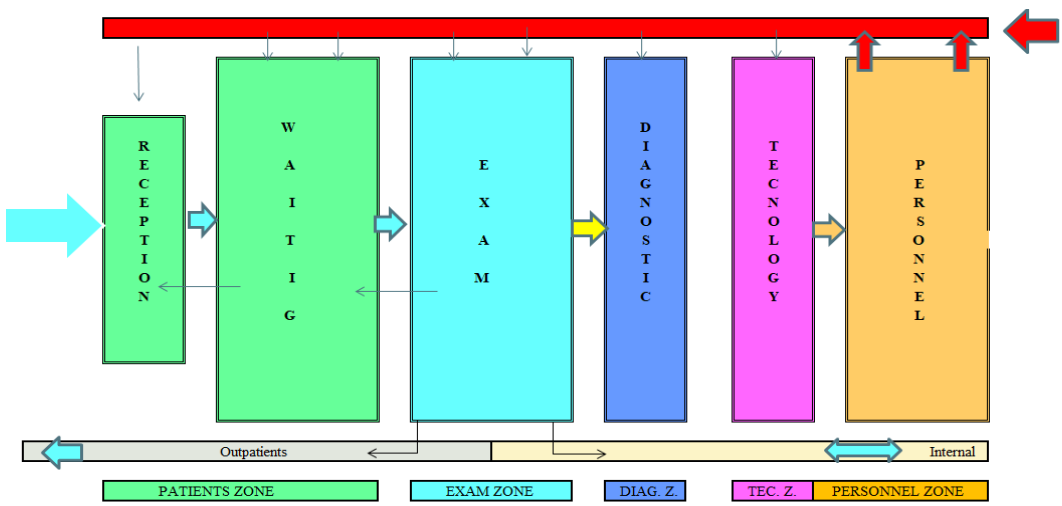
- Patients
- Technicians and nurses
- Radiologists
- Administration personnel

According to the activity level the use of the same circuits for these actors can cause serious problems not only in the quality of medical care that patients receive but also in the quality of the job of the professionals that provide care. Let's look at the details of mobility of each of these groups.

Patients can be classified in:

- Internal
- External
- Emergencies

Each of these patients have, in general, very different conditions of arrival, in personal and clinical situations without similarity and interference with each other not only is not desirable but should be avoided bay the designer.



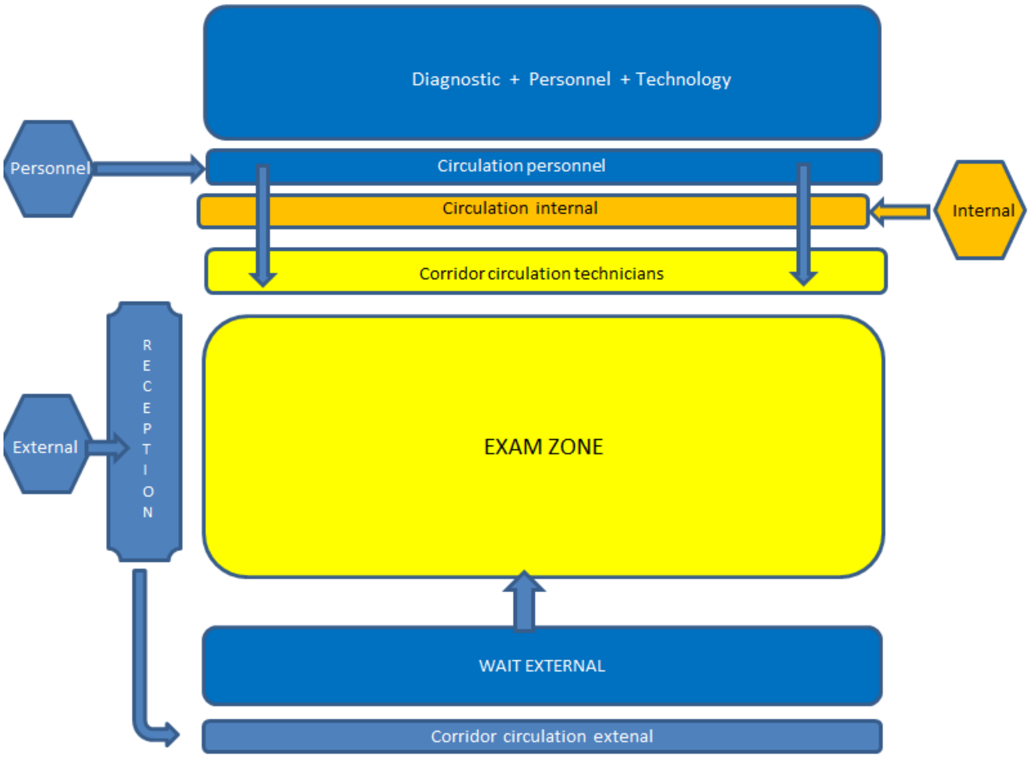
(10.10.- Separation of the circulations of patients, internal, outpatients and personnel)

External patients attend commonly walking to the reception of the department and from here go to the rooms waiting, therefore this is the circuit of these patients. Their pathologies can be severe, but can walk and do not show in general serious mobility problems, otherwise come in wheelchair.

Internal patients come to the department from their rooms at the hospital, in a wheelchair or in transport beds. Their pathologies are well marked and their state is more severe than any external patients, therefore requiring staff of transportation accompanying them; the waiting from beds in the imaging departments should have a correct citation in the RIS to minimize exam and transport times and optimize staff resources.

Emergencies can present very serious situations, in general the patient can be in very severe state and there is no possible citation.

It seems, therefore, that the simple analysis of the characteristics of the patients already indicates a need to avoid that some patients are mixed with other in the circuits conducting to the examination rooms, or to the exit of the aforementioned rooms. A separation of circulations of these three types of patients should be the first premise of the designer (10.10).



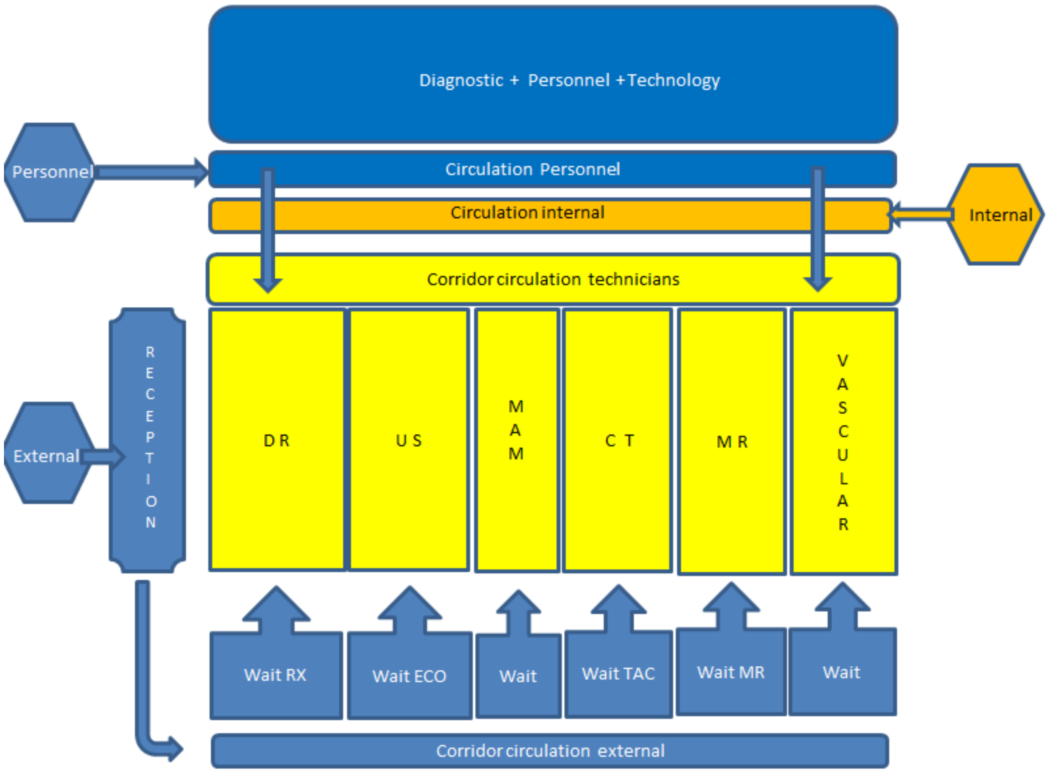
(10.11.- Separate circulations for technical and personnel)

In this scheme, where is excluded the emergency area, highlights a clear separation of internal and external patients. They have access to the rooms by two different places and exit to the same different circuits. A separate circuit for the staff also provides access to different parts of the department.

The next step is the consideration of the department workload in relation to its surface and resources. A department with 160.000 exams per year and forecast with the majority of the current modalities can be concluded in a similar circulation diagram presented above in the zonal graph (10.11).

Here are outlined the circulations of other actors operating in the department:

- Technicians and nurses
- Department personnel



(10.12-Spaces of groups of modalities)

Technicians move in the space of examination rooms and its technical corridor, and go to stores enabled the department to dispose of the drugs, material support to the patient (robes, clothing,

sheets, etc.) and utensils needed to perform examinations, as well as in the corridors of personnel to go to the office, to take their food, coffee, etc., as well as toilets, radiologists diagnostic rooms in the area of diagnostic, offices in general in the area of personnel where is realized the training and the management of the department. Therefore we must find if it is possible to have two separate circulations: one for technician circulation and other for the movement of personnel. This is a question more difficult to resolve in many designs. The question is always: if the calculation of the area of the department was made correctly to allow these spaces. Is not always the situation, for reasons of knowledge, project, or economic.
A better definition of the space to be occupied by groups of modalities in a medium-large hospital is detailed above (10.12).

The dimensions of these corridors are defined in the building codes of the different countries and the designer must agree with the project architect the widths to set up in the project. An estimate of the flow of people, according to the planned activity for the department, also allows to carry out a first assertion.

As an experimental example is proposed the table on the following page (10.14).

Corridors with 2 to 3 meters wide (6 to 9 ft) are suitable for different circuits. Have to be estimated, as it has already detailed, workloads and workflows of people who have to move, and in this function calculate the widths of corridors. A technical corridor may be reduced to 1.7 m (5 ft), but a corridor of inpatient, where two beds can cross cannot be less than two meters wide (6 ft).

(10.13-3D design of the patient corridor in a diagnostic imaging outpatient center)

ZONES	DEPARTMENT %	RELATION
Patients corridor		2,5-3,0 m (6 - 7 ft) width
PATIENTS ZONE	35	WAITING ROOMS
EXAM ZONE	35	EXAM ROOMS
Technicians corridor		2,0 m (6 ft) width
DIAGNOSTIC ZONE	10	DIAGNOSTIC ROOMS
Radiologists corridor		2,0 m (6 ft) width
Personnel corridor		2,0 m (6 ft) width
PERSONNEL ZONE	15	OFFICES - VEST
TECHNOLOGY ZONE	5	PACS-RIS-REFRIG.-MANT.

(10.14.- Corridors width)

In the following diagrams is shown how can be separated corridors in different imaging departments. Not all are equal, better saying each one is rather different.

To illustrate these aspects on circulations are described several examples that facilitate, with its single observation, the concepts here poured.

.- A big center of diagnostic imaging with 350.000 annual exams and additional 150.000 in an area of image integrated in the emergency department(10.15).

.- A outpatient center with 40.000 annual exams (10.16).

.- An image department of a pediatric hospital (10.17).

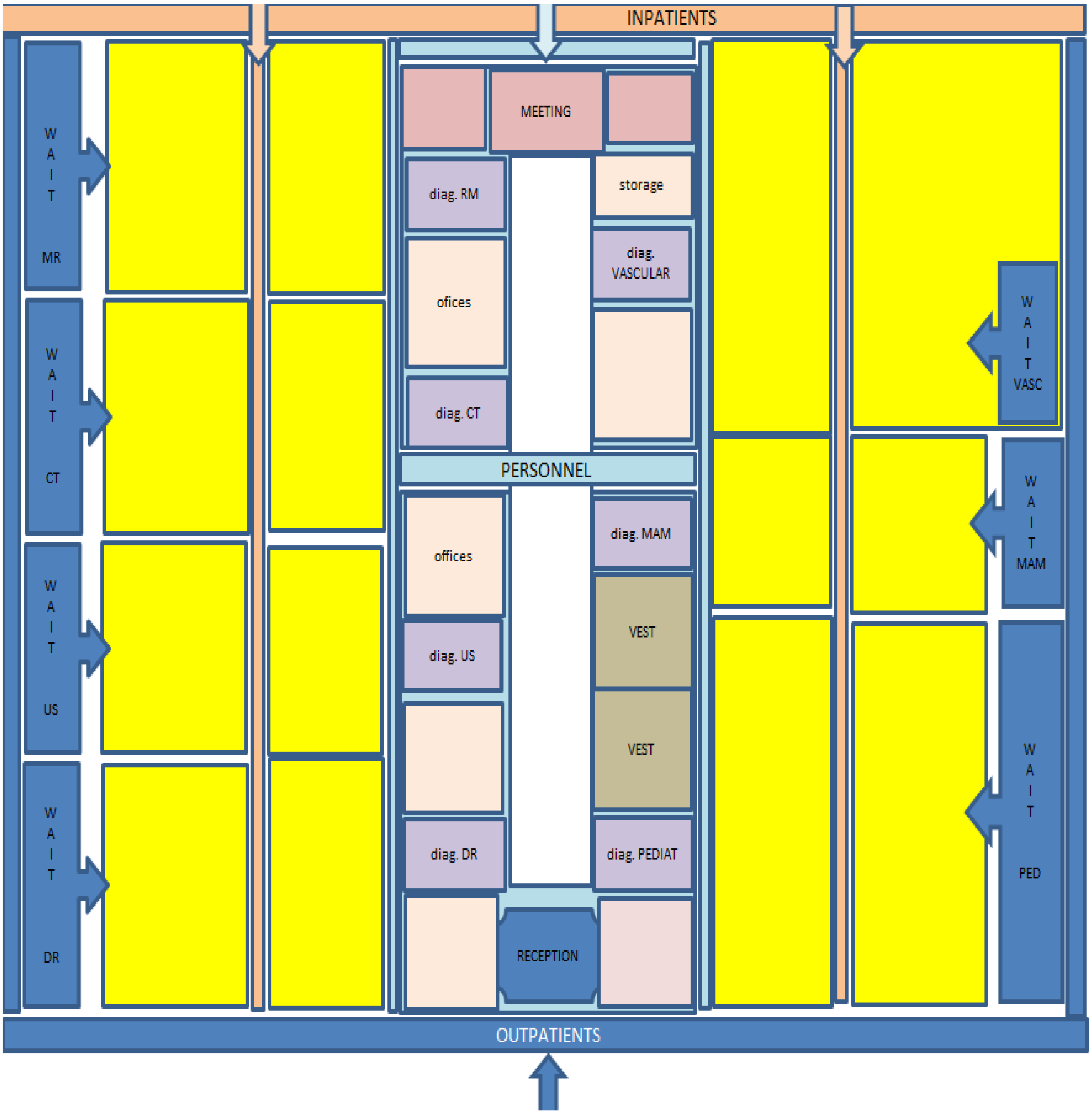
For a very large center with a workload of 350.000 annual exams is issued a proposal which can be seen below (10.15) where there is a total separation between the circulation of internal, external, personnel and technicians.

External patients access to waiting rooms from the reception halls completely independent of the inpatients who come down from the plants with the internal lifts. Entries to the department are completely separated and with their own circulation of inpatient, separated from the staff, who have access to the department by different entrance and moving in a separate patient circuit. The circulation corridors for in-patients represents together a space of more than 250 m2 (2.690 ft2), very important space in the calculation of the surface, but a department of this type is projected for many years and long-term efficiency outweighs, far, the costs of this space for in-patients corridors.

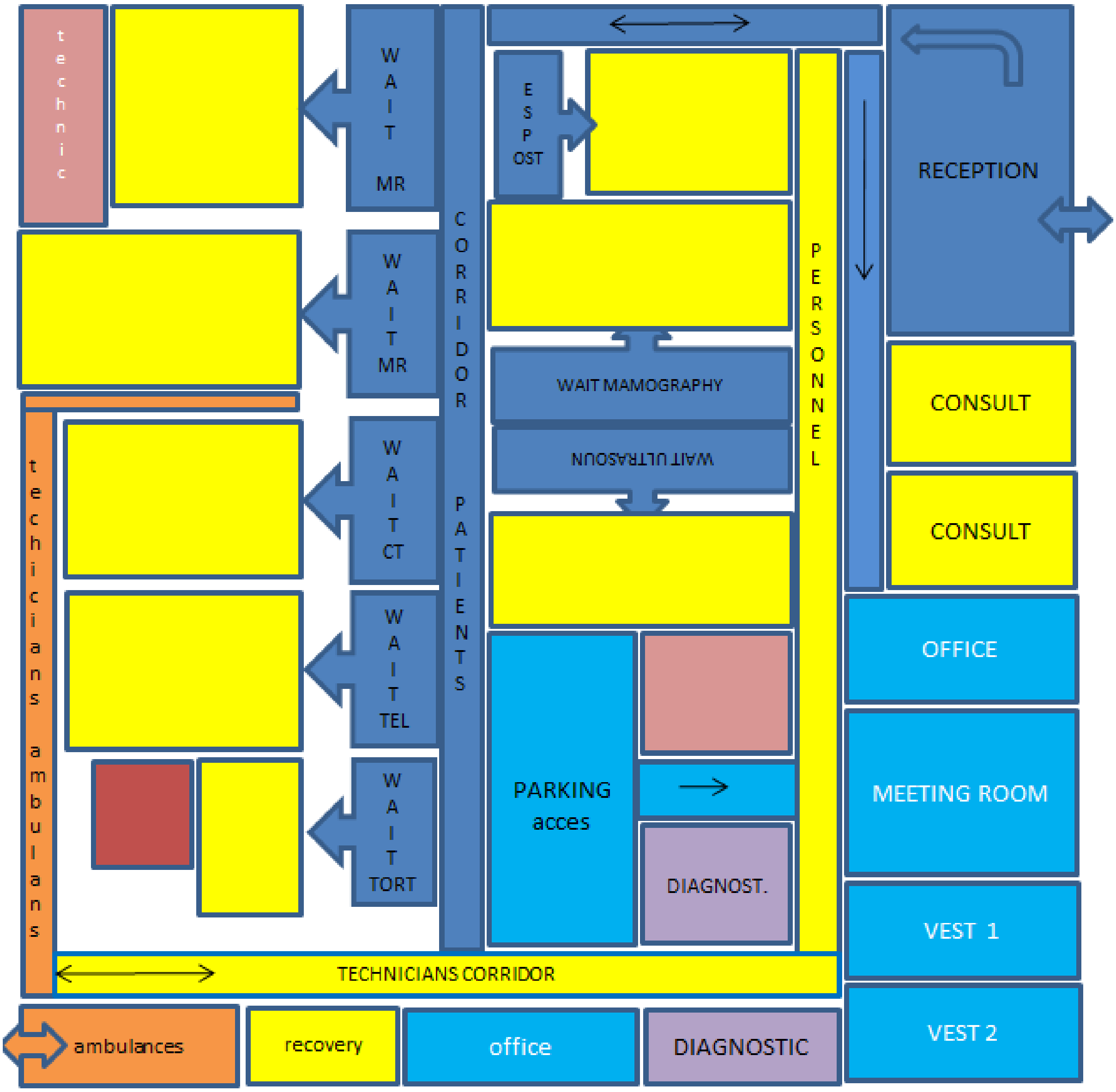
Also in outpatient imaging centers (10.16) is possible to design of circulations separated for patients and staff. In these centers, there are only circumstantially prevision of patients in beds o wheelchairs attending in ambulances. Most arrive on foot and some in a wheelchair. An example of a center with 40.000 annual exams in (10.16).

Here only produces a mixture of few outpatient, arriving in ambulances, and a small area, with technicians and nurses, but the circulations of patient to examination rooms and consultations is separated from the circulations of technicians, physicians and staff of the center.

A total separation is not always possible, and the designer has no other solution that accept compromises. The space is not always the optimal for correct design nor sufficient for the proper functioning of the assistance activity of the department and while the separation of internal and external is an indispensable premise of compliance, commitments can be taken as we see below of a pediatric hospital, where the circulations of internal patients and health workers cannot be separated for reasons of space.

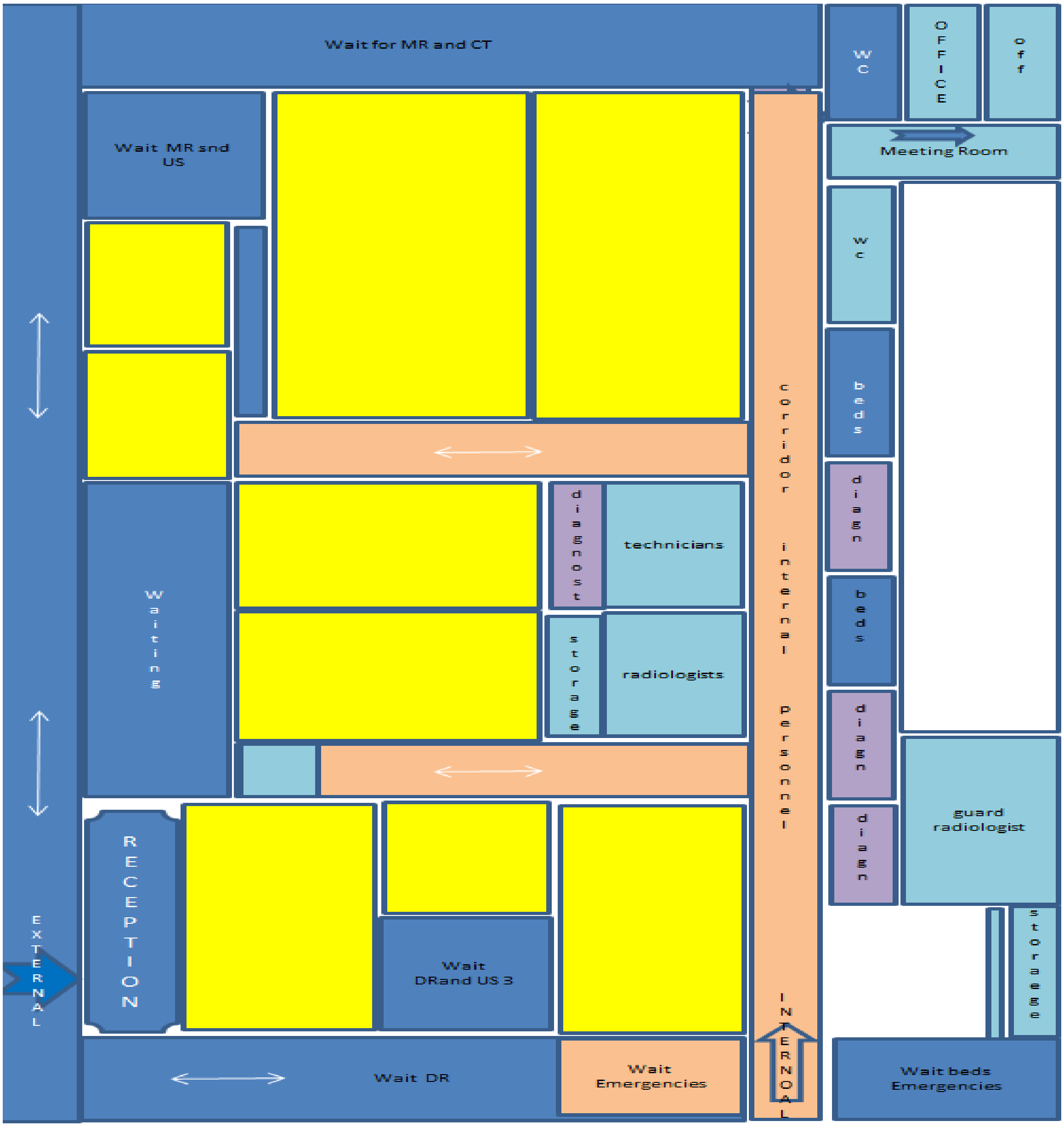


(10.15.- Circulations in a big size department)



(10.16.- Circulations in outpatient imaging center)

Even the emergencies enter the department through the same door of internal patient access, with which the designer has placed two emergency in the proximity of the door room so common travel is minimal, only in the section of access to the department (10.17).



(10.17.- Circulations in a hospital pediatric imaging department)

Exam areas are colored yellow, as in the rest of the examples presented in such a way that can be appreciated the magnitude of the different zones. The zone of external patients and waiting of beds of inpatients is colored dark blue, brown-internal circulation corridors and staff of light blue area.

X.III.- SPACE WITH BLOCK DIAGRAMS

Determination of circulations is the first task of the distribution of the surface, and facilitates a second step to find the spaces required for the location of the exam surfaces of the different modalities.

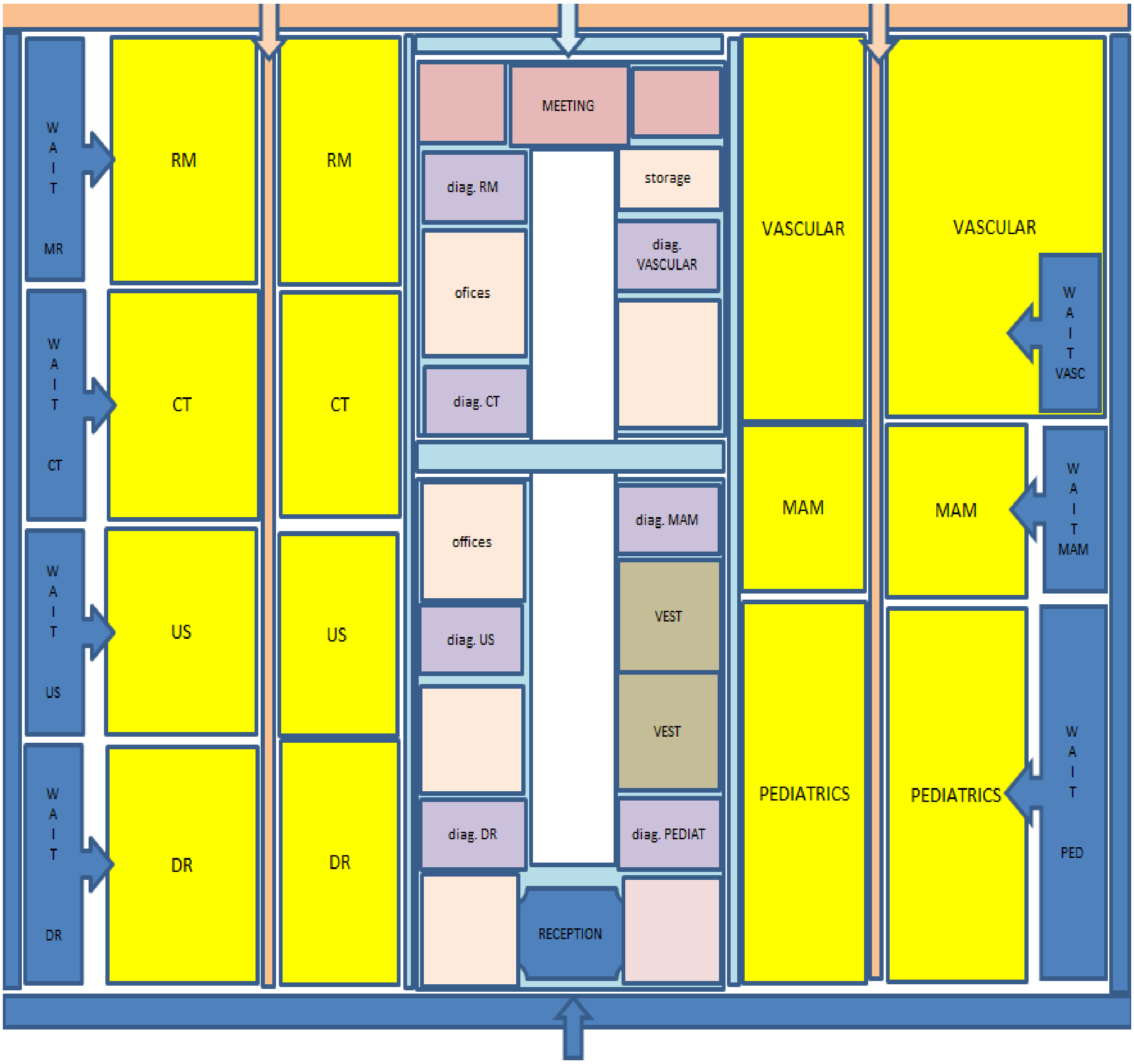
They were defined, in the calculation of the area of the department, the number of rooms needed, and subsequently the surfaces necessary for each block of modalities were determined. Included in this concept are the exam surfaces, the patient cabins, control rooms and the technical rooms that cannot be separated even though they belong to the technology zone, for technical reasons of proximity to the examination room equipment, and also were included corridors for the technicians were required. In this way can be attached blocks of modalities, to different areas of examination of the department, as well as additional blocks in the areas of diagnosis, technology and staff, preparing an initial block diagram of distribution, which can be transplanted to the subsequent architectonic drawing of the department to conclude its design.

The blocks are not difficult to calculate. Already in Chapter VI there is sufficient detail to build them and there are relatively simple the task to adapt them to the working drawing program, either AUTOCAD or any other that allow easy mobility and inclusion of these blocks. In Chapters VII, VIII and IX were defined the blocks for the most important modalities and at the end of this chapter there is a general overview.

Possible schemes of the same department with blocks are displayed with the same order as the examples of imaging departments presented in this Chapter to explain the circulations.

The first diagram (10.18) displays the exams spaces distribution as function of the demand. The greater demand, according to statistics from Chapter II, is reached by conventional radiology with 64 percent of the total patients adding internal and external. In this department the emergency are included in the emergency department and add approximately 50 percent of all conventional radiology exams. This modality must be located as near as possible in to reception, because in this form are eliminated long ways to a high number of patients and congestion in the corridors. Next highest attendance occurs in ultrasound, therefore, and following with the same criteria, the ultrasound block should be positioned below conventional radiology to minimize transportation of patients. Previous data indicated that in-patients are inferior to the external, and this leads to set the corridors in the way that the number of inpatient rooms will be less than those of external patients. The designer must know or estimate the flow of patients per hour for sizing up corridors and waits. The data of frequentation with the considerations of the worksheets in Chapter IV help in this task.

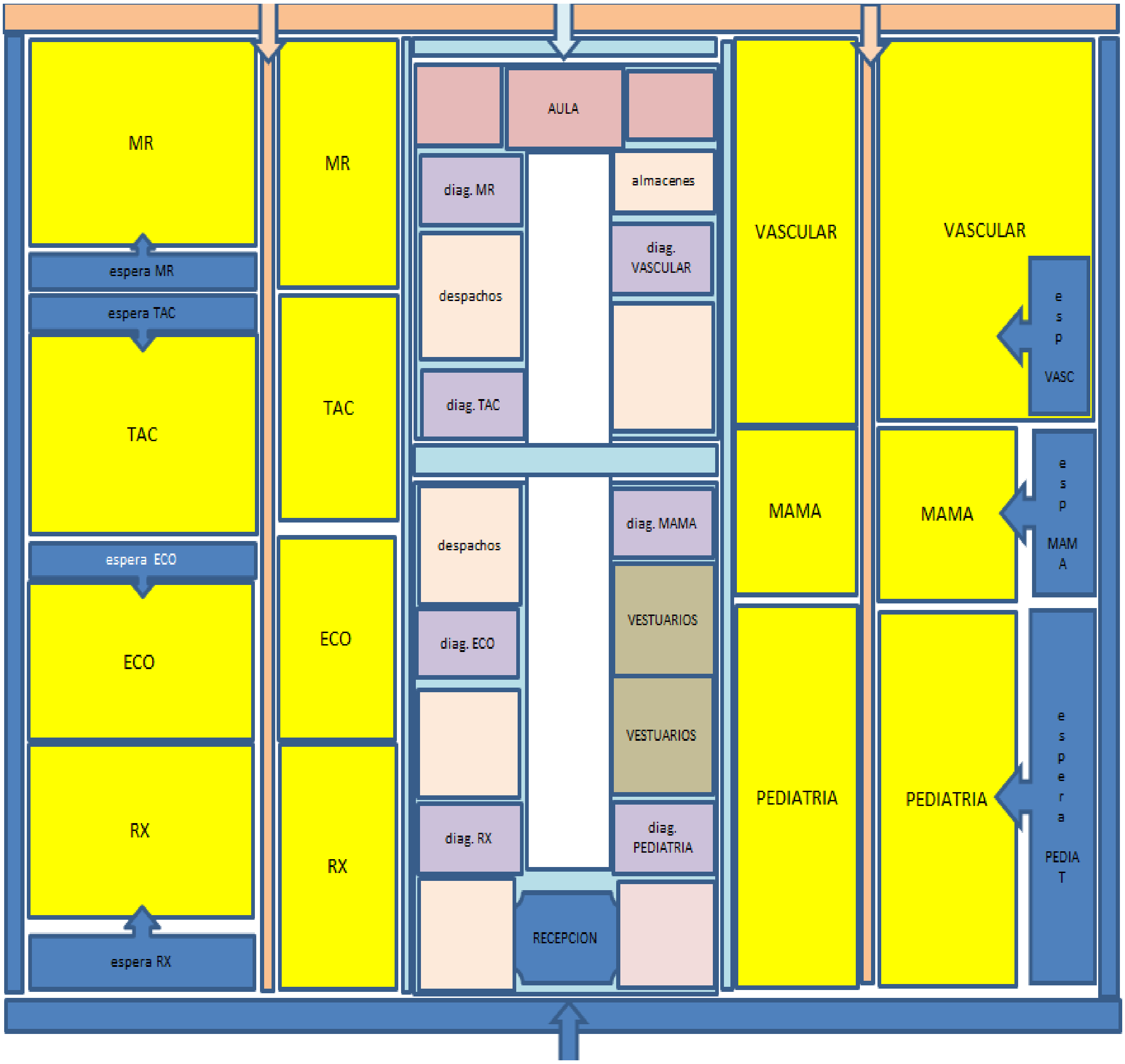
The next block of exam areas will be the area of CT multislice, with eight percent of the patients and equal the same value for magnetic resonance with another eight per cent. Logistics, architectural and security reasons can lead to settle an area before another to make the final design. Let's not forget the demands of safety of MRI systems and that their weights require access conditions more extreme than the CT equipment. This will force to select one or other area close to the entrance to ensure the equipment transport.



(10.18.- Blocks in a very large imaging department)

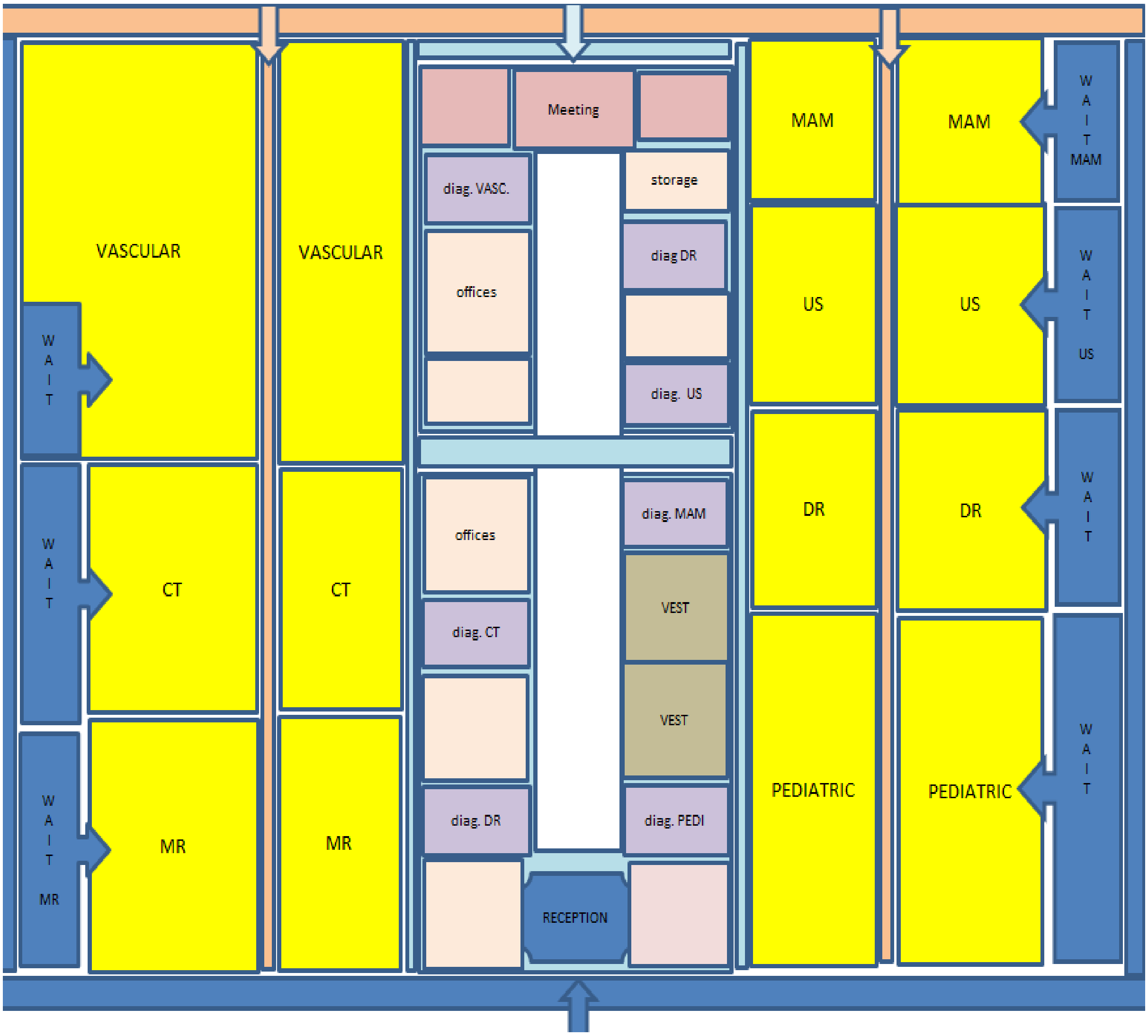
Staff enters through the center in the upper part of the drawing and has its own circulation circuit including a catwalk glazed by the middle of the skylight patio to communicate both staff working areas.

Pediatrics requires its own space. Children have an activity which often annoys adults, and possibly more to the elderly and people with severe diseases, so a separation in these cases seems more than adequate and the proximity to the reception is also important. Mammography and bone densitometry have a small percentage of exams and much less vascular, where the majority are inpatients.



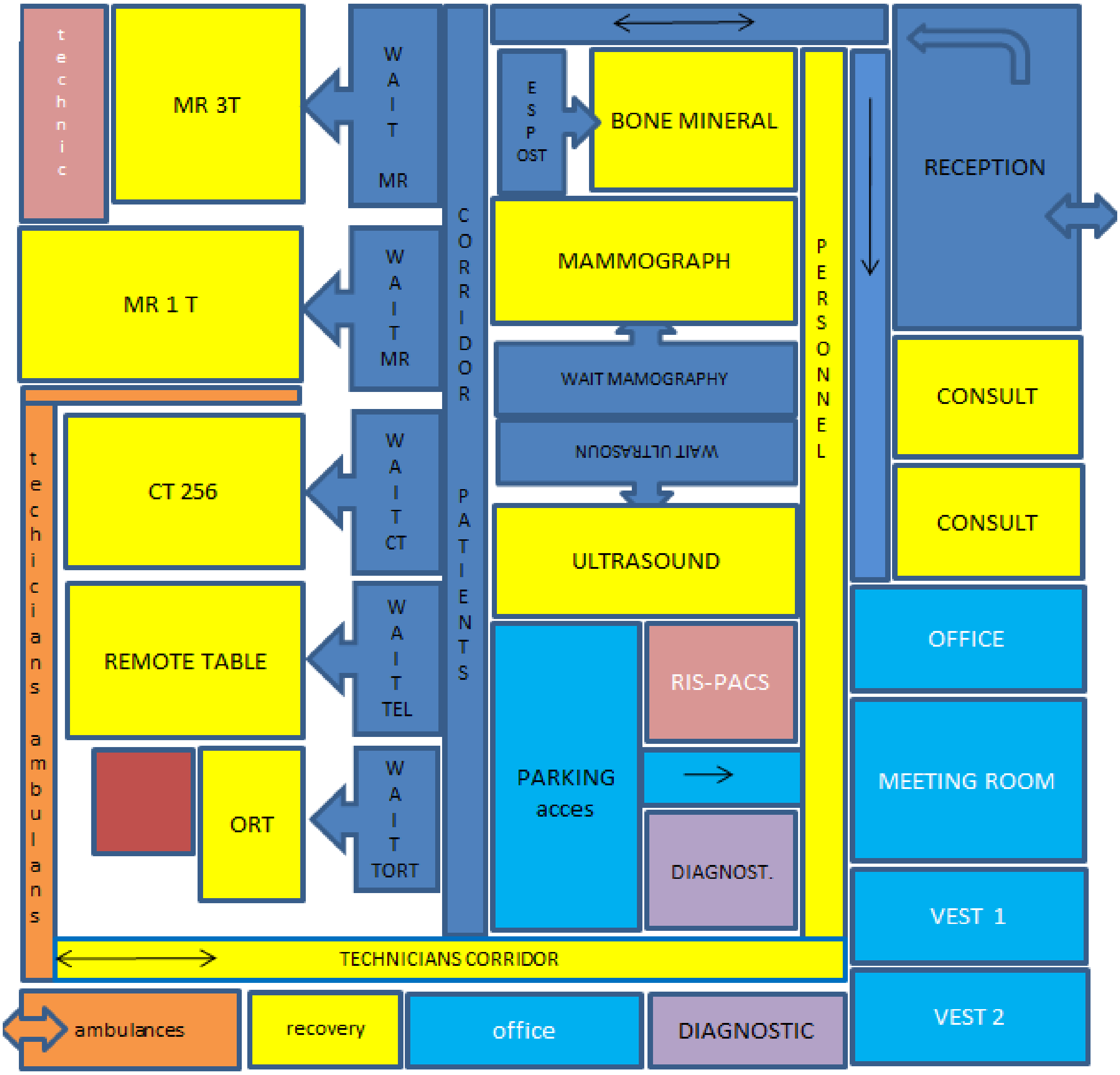
(10.19.- Provision of waiting spaces in the block diagram)

In the same schema to change the shape of waiting areas is really easy and it may be necessary in the final drawing to suit the architectural structure of the department surface. Shown in the example (10.19).



(10.20.- Alternatives allowed by block diagrams)

The areas of personnel, as modules for offices, classrooms, locker rooms and stores may be defined to set its position in relation to the workflow and the position of the exam areas. It's also really easy to change places occupying different areas of consideration in the area of the department, e.g., change the position of the vascular group to the opposite side, according to internal patient access criteria or according to the architectural structure, columns and drainpipes, that it can offer either side of the space allocated to the department. Later we will see the influence in the design of the stairs, water pipes, drains, downspouts, pipes of air, landfill, elevators, etc., that influence the final design and force changes against the block diagrams, and in many cases lost additional useful space for examination rooms and the designer has to try to attach to other needs to improve as much as possible the gross space utilization and reduce losses.



(10.21.- Blocks at an outpatient center)

An example of department for external (10.21) patients, already presented before the circulations, will be shown with the blocks schemes for the exam areas.

This case is much simpler than the former (by length) and the blocks are individualized rooms, unlike the previous where magnetic resonance imaging block includes five systems of this modality with the difficulties of installation that this requires.

The department with an area close to the 1.200 m2 (12.916 ft2) provides imaging diagnostic services to public and private patients and its activity is based on magnetic resonance imaging and CT of very high performance. The location of the different areas of examination is determined by the architecture and logistics.

The center located in a ground floor below has a basement with garage. Car movement is null in the area below the magnetic resonance, space intended for applications where are not allowed movements, no ferromagnetic nor staff movements. Also the equipment, to introduce them to their final location need reinforced roads and corridors of at least 2,4 m (7,9 ft) wide to insert the magnetic resonance nuclei within Faraday cage.

Regarding the objectives given for the center are expected that the greater movements of persons will be patients of MRI and CT. For this reason the itineraries from the reception are shortest for these patients.

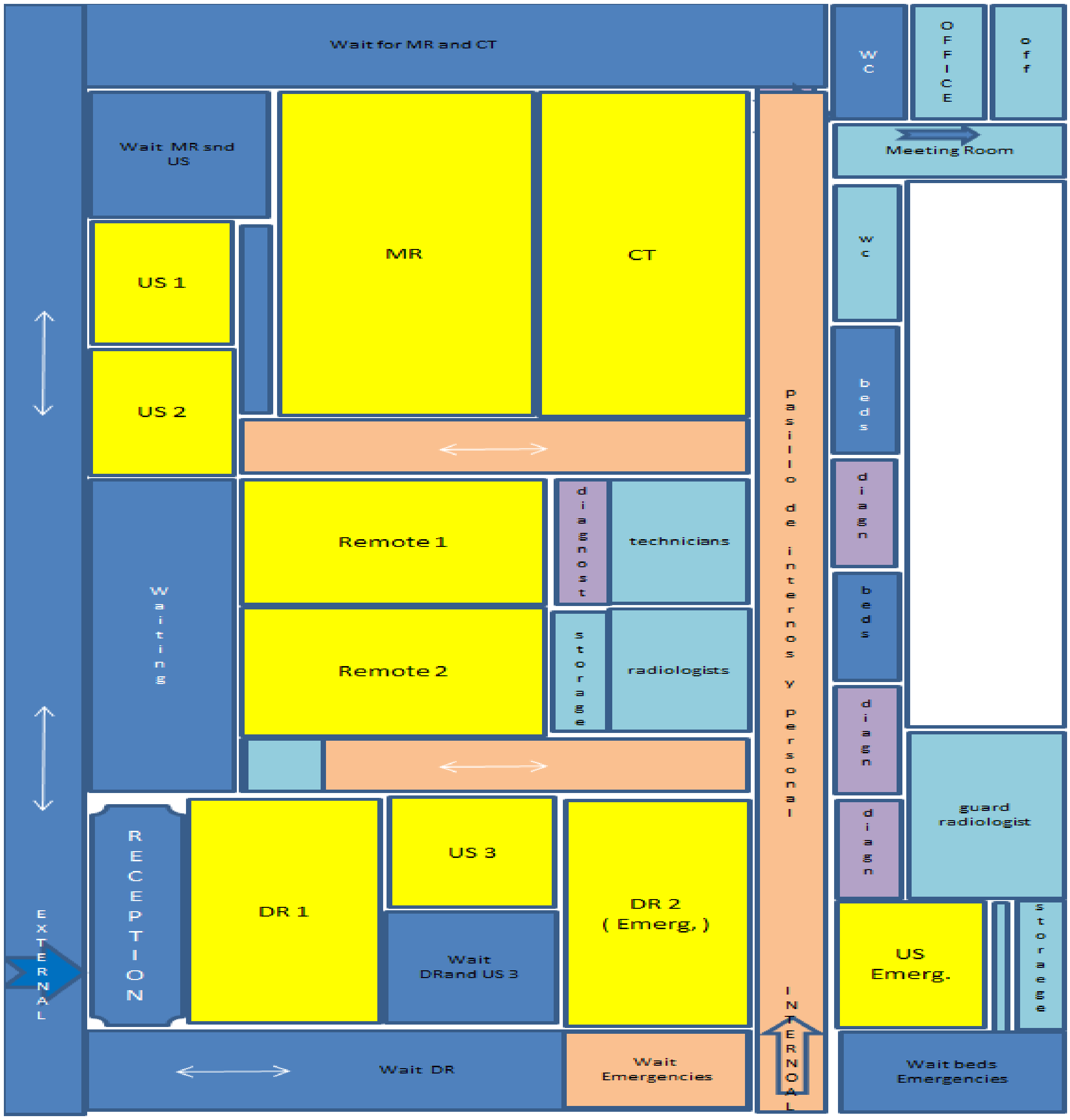
Fewer patients are waiting for ultrasound and mammography, however has been taken advantage of the quadrangular arrangement of the surface of the department to place areas of ultrasound, mammography and densitometry next to reception.

In this way, patients movements are short; the central corridor is wide (2.4 m) with what collisions or discomfort among patients should be minimal.

Next is presented one imaging pediatric department (10.22), also placing in the different areas individual equipment blocks. Its simplicity thus allows it.

The location of the x-ray room, that take the sixty five per cent of the workload are close to the reception. For reasons of lack of space the emergency room has to share conventional radiology exams for inpatient and for emergencies, which requires insulation in the final design, basically in the waiting area, and solved by positioning a sliding glass doors for separation to the outpatients waiting room of the radiography room close to the reception. Control of the doors should be performed by the technician responsible for this area. In the same way an emergency ultrasound is placed close to the entrance from emergency and internal patients, which for space problems is used for both kind of patients.

Spaces for personnel utilization, additional to emergencies, intended for guard radiologists and diagnosis of emergency imaging are integrated in this area.

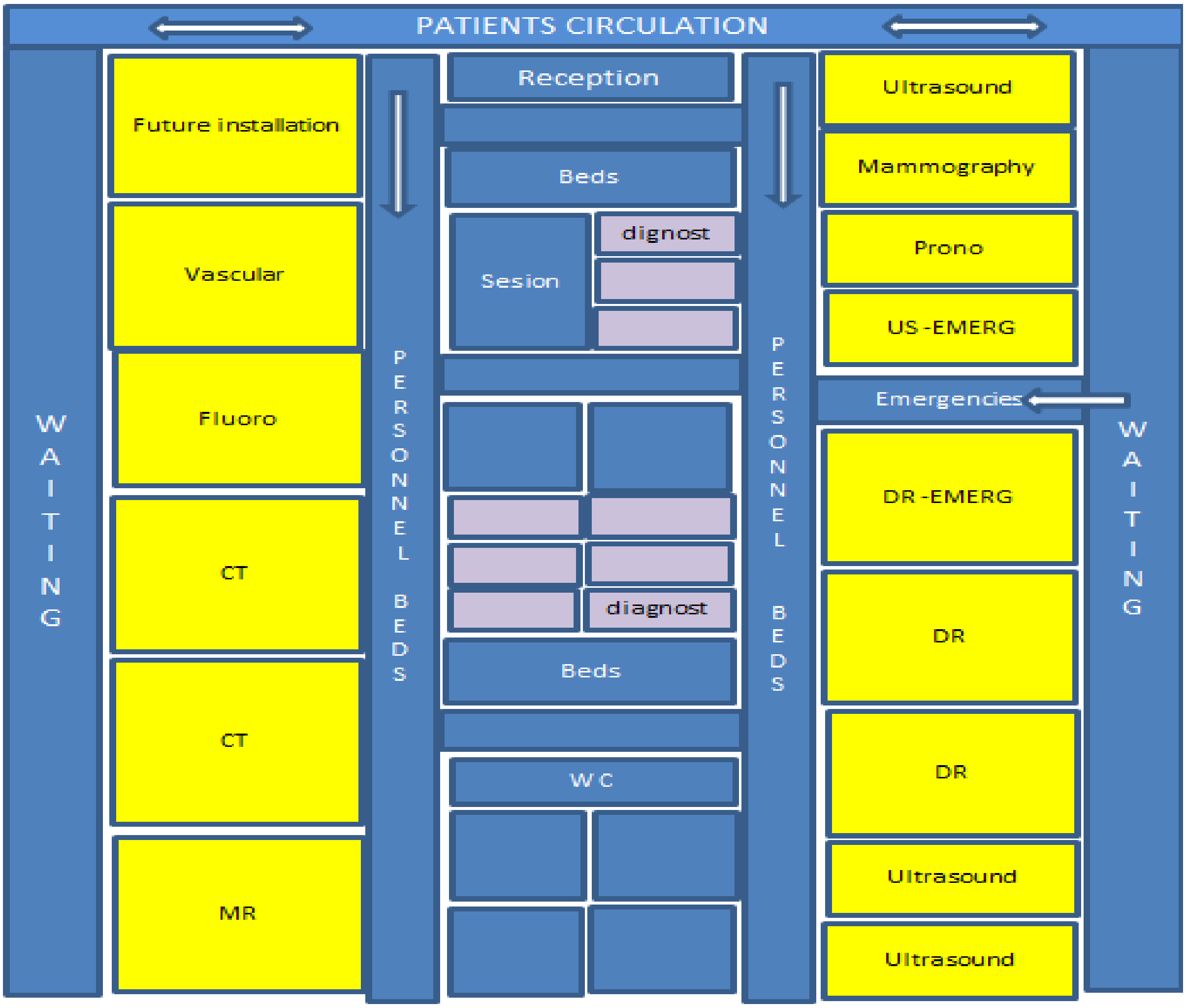


(10.22-Blocks in a department of pediatric radiology)

The sonography area is near the reception, in the same way as the area of fluoroscopy remote controlled tables. The patient wait is individualized in front of these equipment. The architectural reasons for the

MRI system access imposes the position indicated in the block, with the CT in the next room, the waiting and examination area with more distance to the reception. The inpatient corridors are shared with technicians and staff. The diagnostic rooms with workstations are located close to the areas of examination, and only the staff offices and meeting rooms and classroom are away with independent movement.

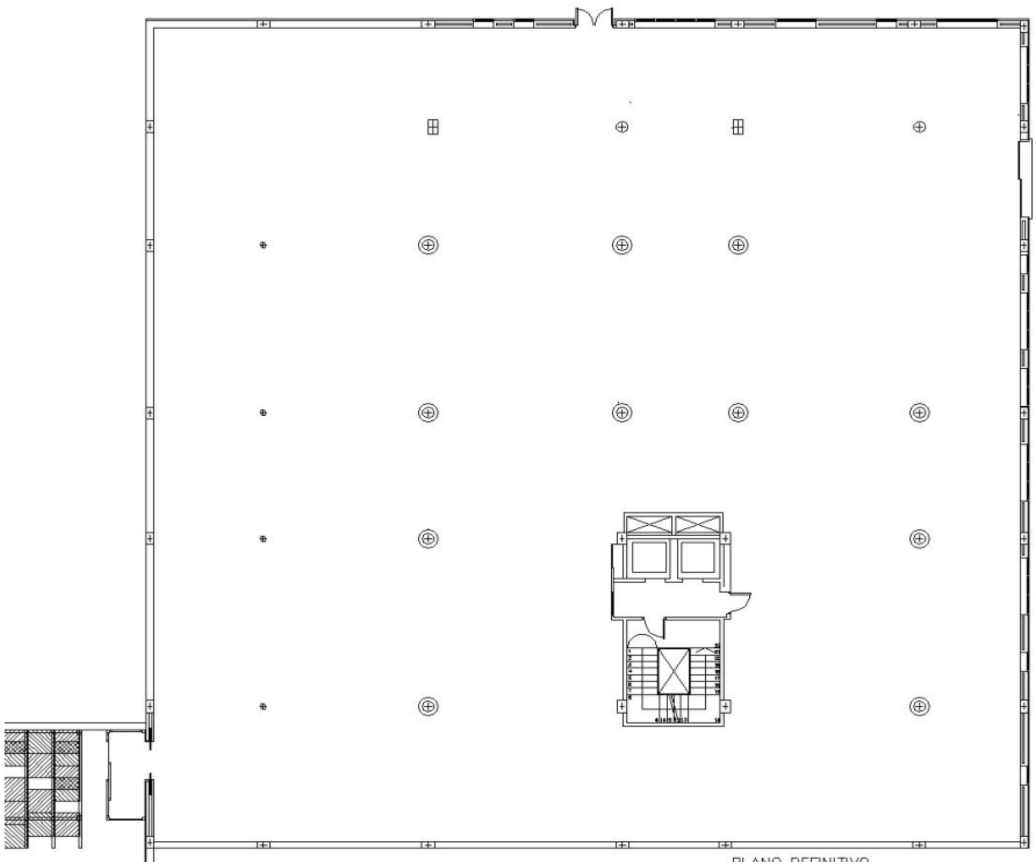
The following department (10.23), with an area of 1.440 m2(15.500 ft2) designed for 150.000 exams presents a link to emergency, in such a way that it has arranged a room of ultrasound and x-rays for this activity, which was not included in the design of the emergency department.



(10.23.- Circulations with connection to the emergency department)

X.IV.- ARCHITECTURAL DESIGN

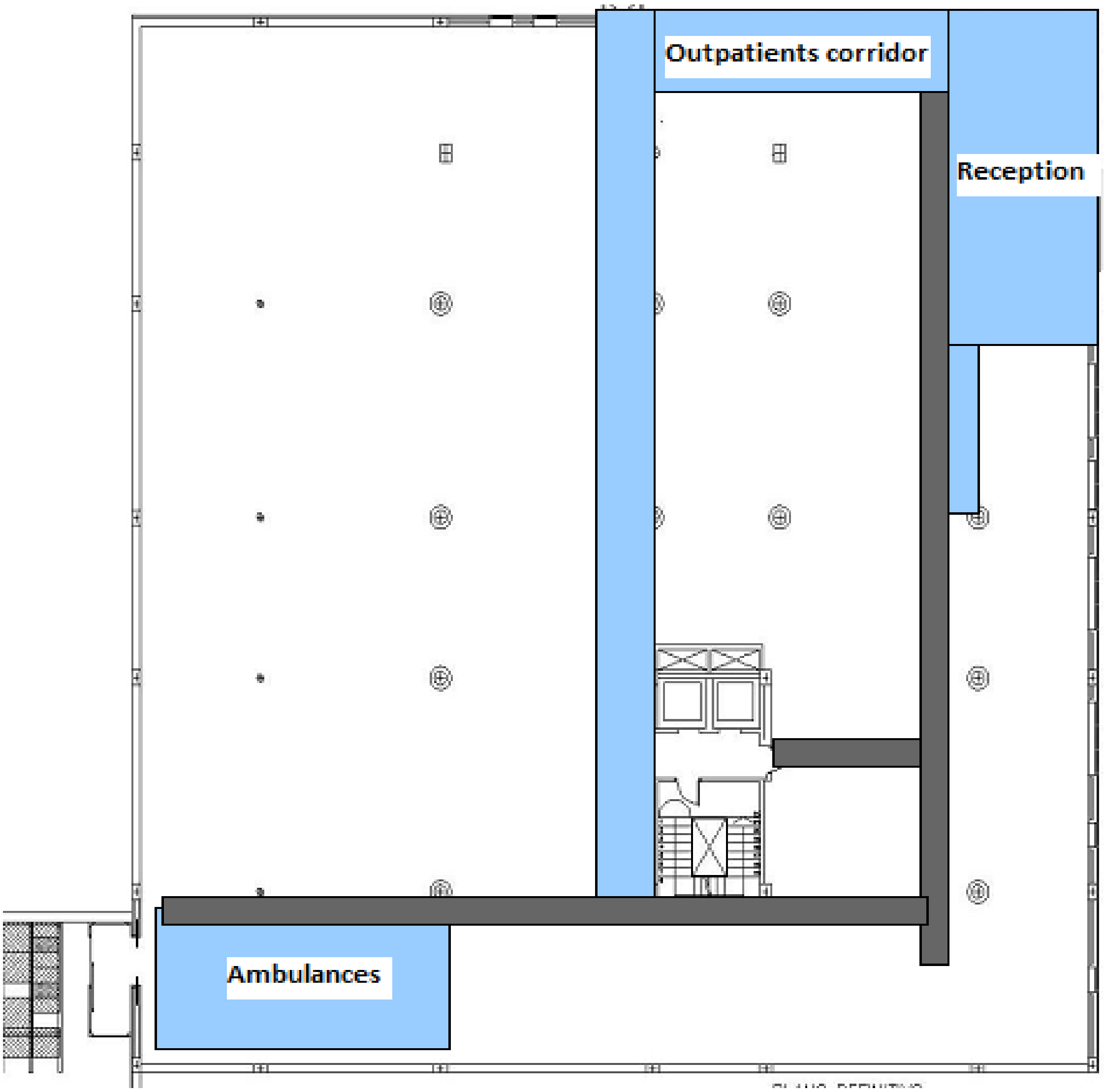
Now is the time where the designer faces the reality of an architectural drawing in any of the formats used for the building drawing; AUTOCAD, is perhaps the most popular program, and upon opening it receives the distribution of pillars of the plant and space for the imaging department. In many cases the plant already contains drawings of rooms and a distribution made in the initial design phase of the hospital project (when the imaging department is located in a hospital) that was, possibly, made by another project team , several months, or years, before begin the phase that has the present designer.



(10.24.- Basic architecture of one outpatient diagnostics center)

Above is shown the architectural layout of the plant of an outpatient center, which already reviewed in the previous section. Observing the magnitudes of the pillars, very thick in the center and thin on the left side. Also having the staircase that leads to the underground garage, the holes of the elevator, supplies and drain downspouts and entry doors, on the right, for outpatients and for a possible arrival of patients in ambulances on the dawn left.

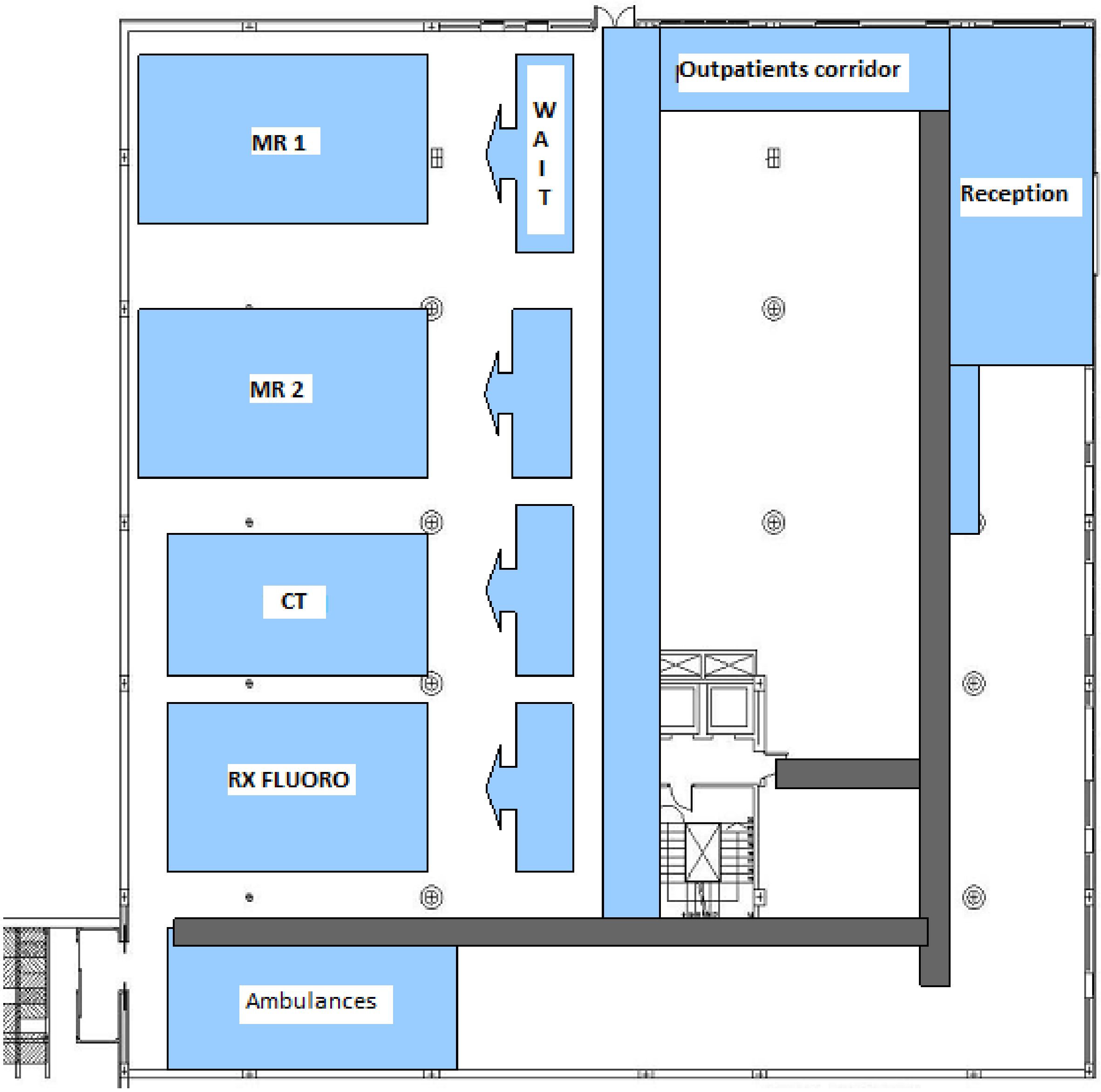
The plant is quadrangular, having it in AUTOCAD, to scale, the designer can measure and can begin to place the elements that determine the workflow on the screen. Can continue with the arrival of patients and the circulation corridors (10.25).



(10.25.-Circulations)

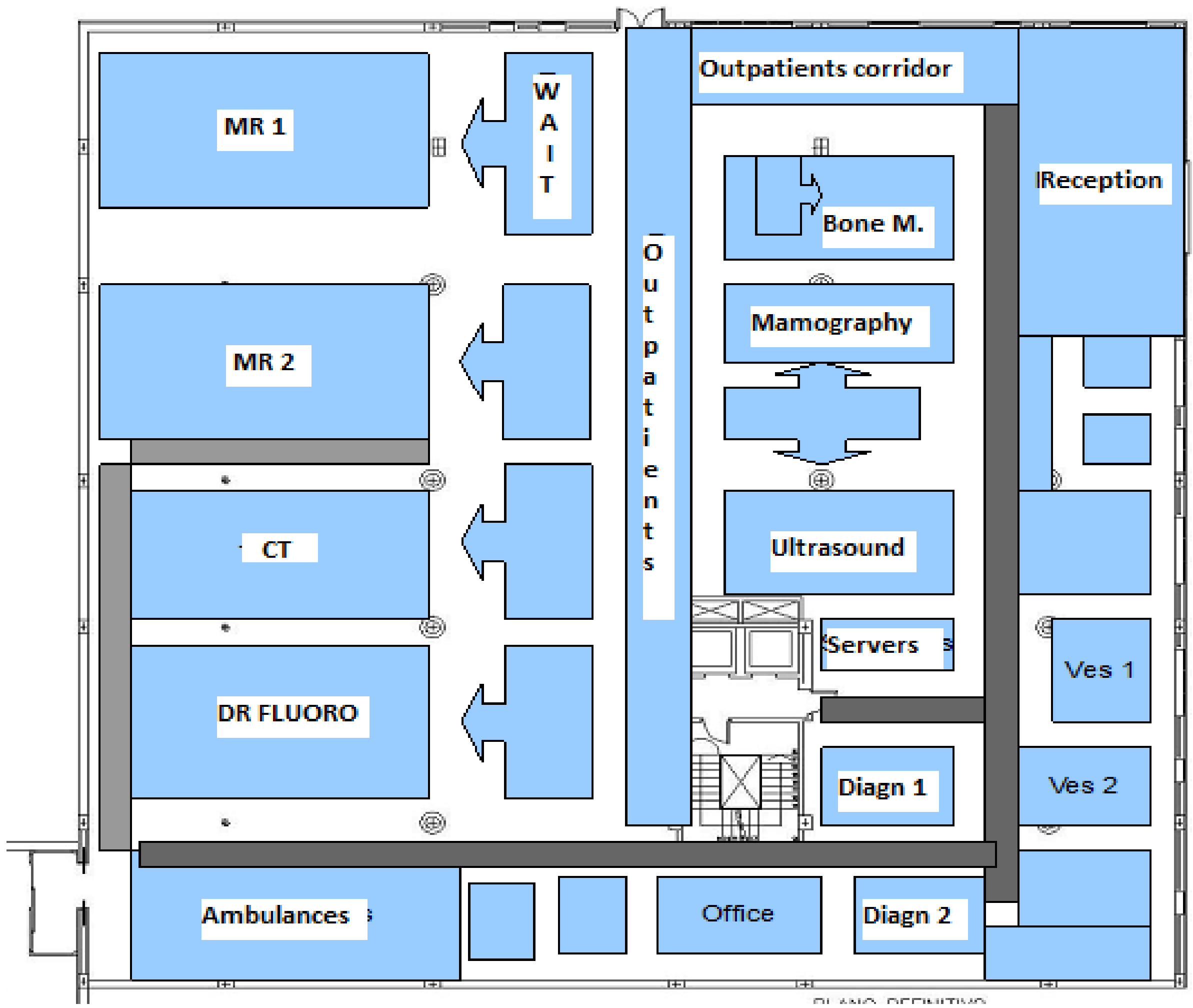
After this, continue with the placement of the blocks of the surfaces of the different equipment. Access to MRIs is the basis to start the action.

Can be shown how different equipment blocks are in the border of pillars, so that can be located equipment blocks among the building architectural structure. Personnel comes out of the garage and climbing by elevator or stairs up to the personnel corridor, in dark color. Circulation is fixed, then will begin to see if this circuit allows easy arrival to the staff dependencies, although already in AUTOCAD is shown, within a scale, dimensions from halls up to walls, so we already know that with these dimensions that it is possible to locate dressing rooms, offices and diagnosis rooms in the diagnostic zone.

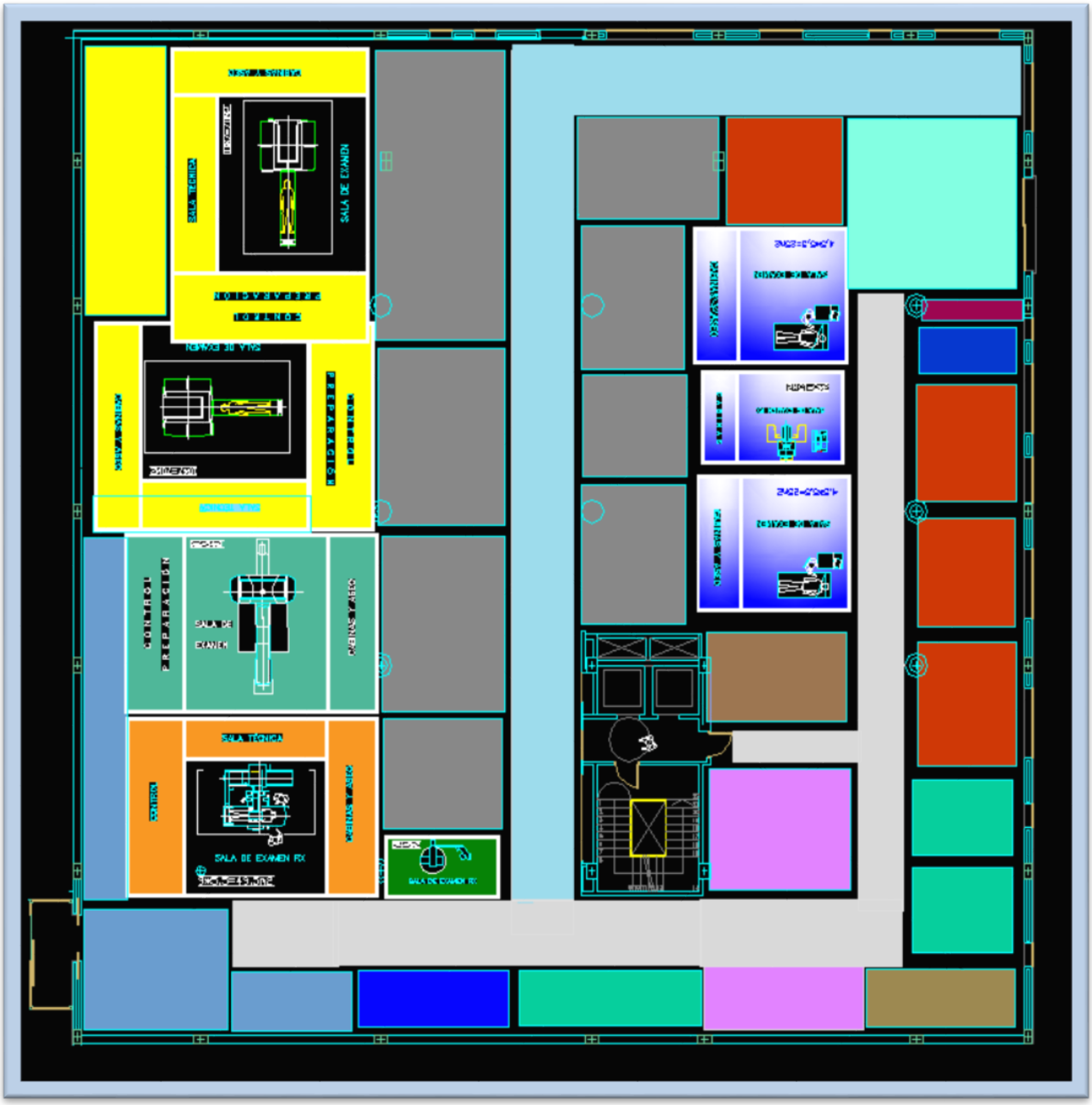


(10.26.-Blocks of modalities)

Here are the rest of the blocks and personnel, diagnostic and technological dependencies. Shall be completed the circulations of technicians and medical (10.27), from their consult offices, or from the offices of diagnosis where they have their workstations to equipment, where to go when the patient or the technician precise assistance of radiologists. This circulations are separated. A corridor for outpatients, another hall for technical and medical and there is only a small mix with the patients arriving by ambulance waiting in the arrival of ambulances area, who are on an external marquee, behind two sets of electric gates needed to prevent the weather, the noises, and allowing easy access from the outside. Also for rest room for technicians for a coffee, or have the food, the office allows a clear separation of rooms and a location of easy access. The locker rooms are next to the entrance of the garage and next to the entrance to reception with which movements of staff are really short.



(10.27.-Blocks)



(10.28.- Individual blocks described in Chapter VI and VII)

We already have a diagram, gross, with distribution of the rooms and spaces within the physical structure of the building, respecting pillars, stairs, downpipes, access and separate circulations that facilitate the mobility of patients and staff.

Now before passing to the design of interior partitions, that delimit the rooms and spaces and already allow the location of the rooms and their dependencies, should become more definition and go to the design with blocks of modalities.

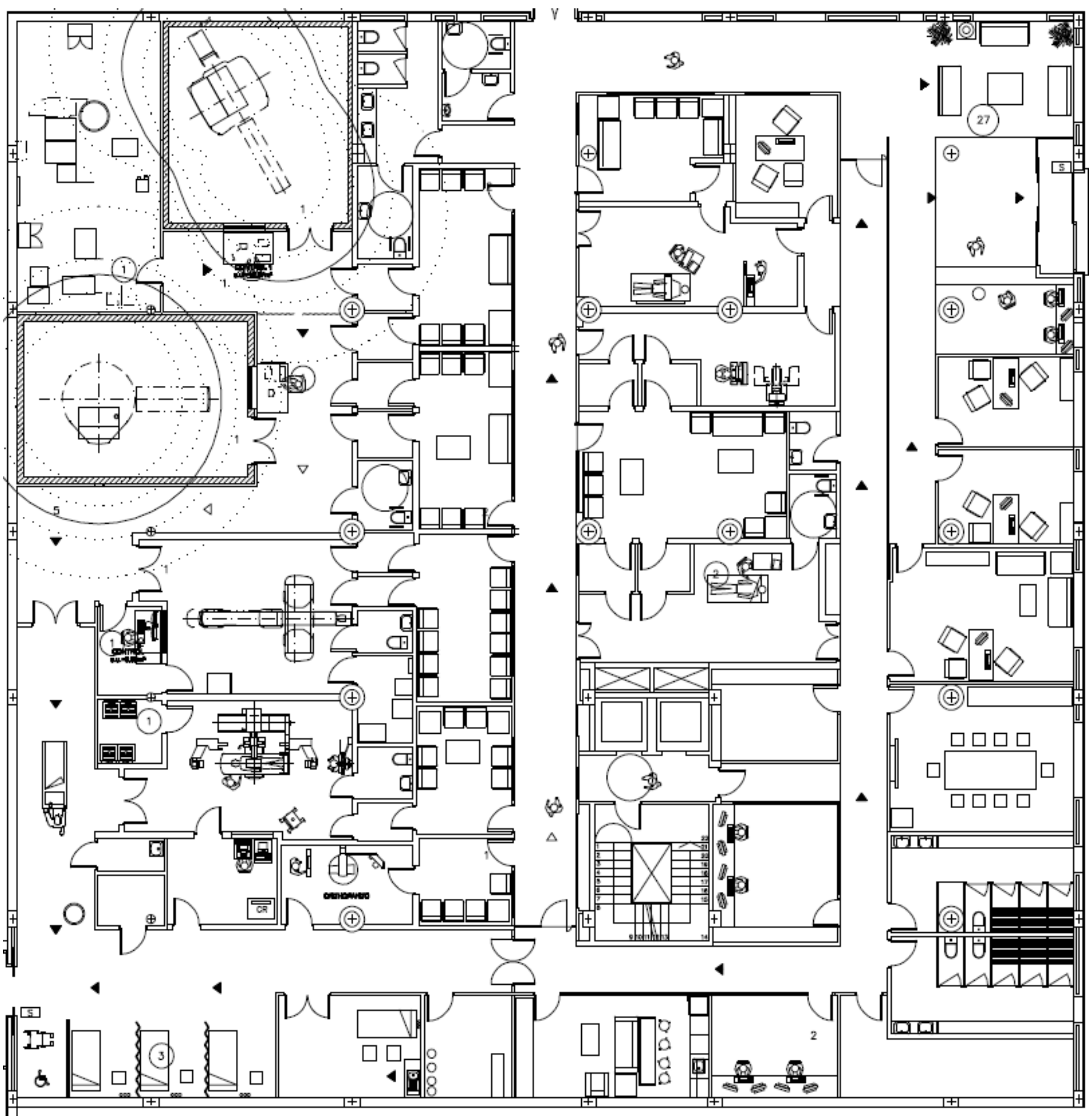
It is not an easy task, sometimes have to move the blocks on the structure several times, but several proposals can be done in a quick way performed with a scale in the drawing program, infinitely easier than thereafter to change partitions and figures on the final architectural design.

Design with AUTOCAD blocks to scale allows a more accurate location for each of these, the delimitation of the patient corridors, technicians, doctors and staff.

Blocks allow a very quick determination of the distribution of spaces in terms of pillars, so that in a short time it is possible to stablish several schemes which involve decisions easily and quickly for the project responsible and save an important gap of time to graphic designers in AUTOCAD.

The next step is the architectural design which enables in better way to delimit all the details of each space and improve the distribution looking at the next construction action.
Next is the scheme or final drawing (10.28) of the implementation of the outpatient center that has began to draw previously.

The representation in three dimensions of the drawing shpwn in figure (10.29) provides a spectacular view of the functionality of the project as well as a means of high effectivity for the project manager of the team and the civil works constructor. The details of the position of each element are reflected with great accuracy. Interior architecture can thus be combined in many ways with the equipment that will be installed and with aspects of patient and personnel that have to be taken into account in the development of the project.



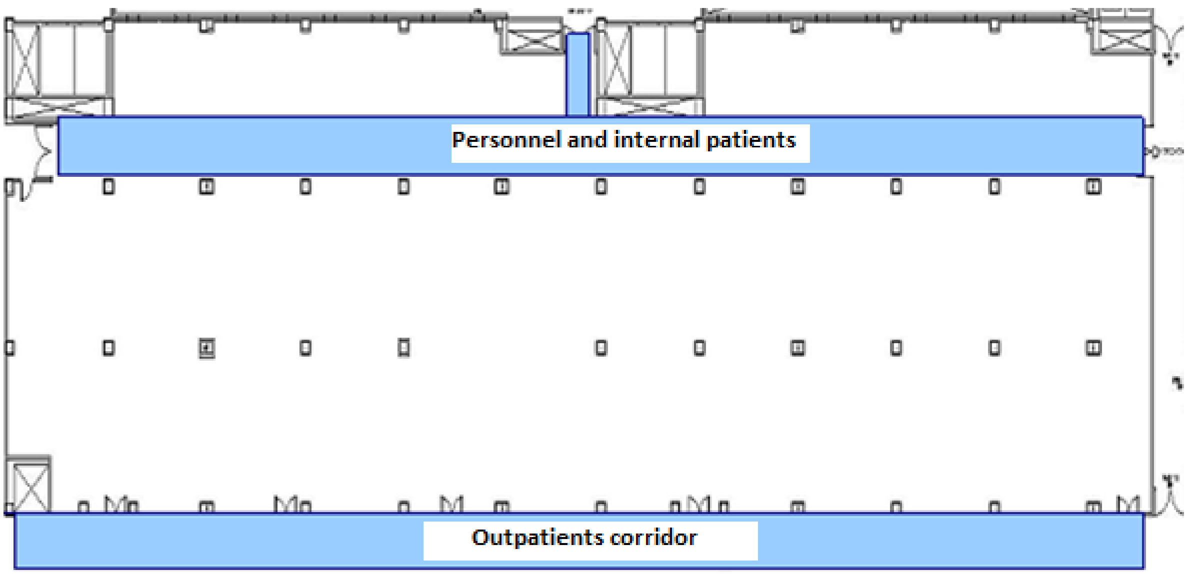
(10.29.- Final layout)

(10.30.- Three-dimensional presentation of the outpatients imaging diagnostic center)

A new design, with a rectangular configuration (10.31), where the pillars delimits the form to locate the circulations and the equipment. The department has a length of 81 m (265 ft) and a width of 21 m (68 ft), with a total area of 1.701 m2 (18.020 ft2).

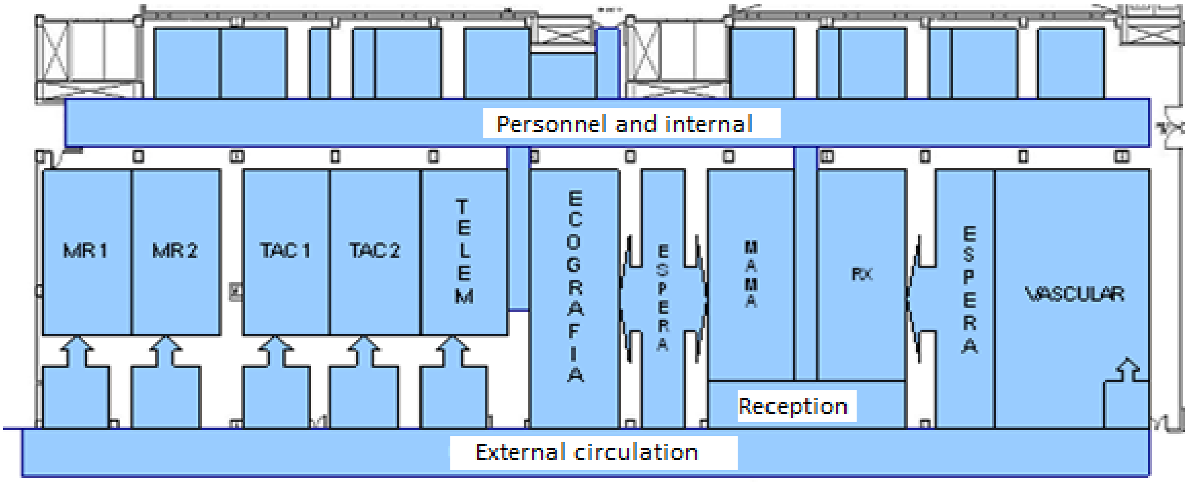
The pillars of the left hand are distributed in a box at 7 m (23 ft) distances between the axes. The right side has the same structure, while the lower part has pillars at different distances.

Access doors, already laid down by the first access designed for the department three years before the final design, here presented, already limit the configuration of the circulations, as well as movement of outpatients corridor, that it is not a unit integrated in the department, but is the circulation of the patients exiting to the imaging department from external consults. This corridor is intended for use mainly for the imaging department.



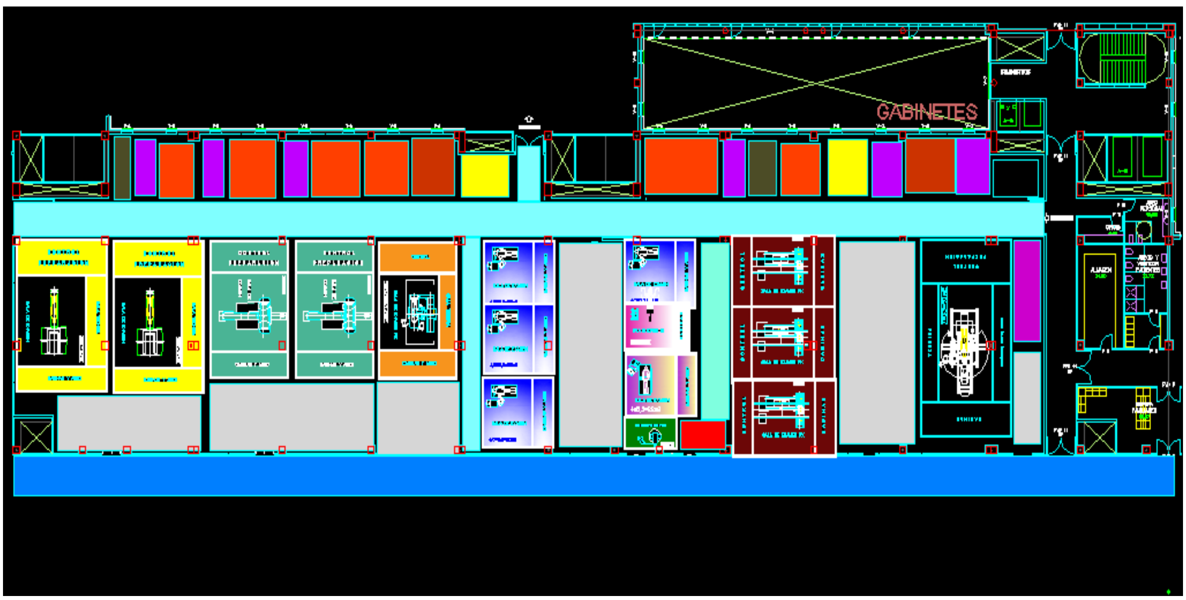
(10.31.- Rectangular department)

Will be applied the fundamentals described about workflow to define first the reception, at the point nearest the exit of outpatients from the consults, and will be placing blocks with the aim to locate closer those exam rooms who have greater workload (10.32).



(10.32.-Diagram with blocks)

Blocks, placed in AUTOCAD with its surfaces specified in the preceding chapters would be of the following form of figure (10.33).

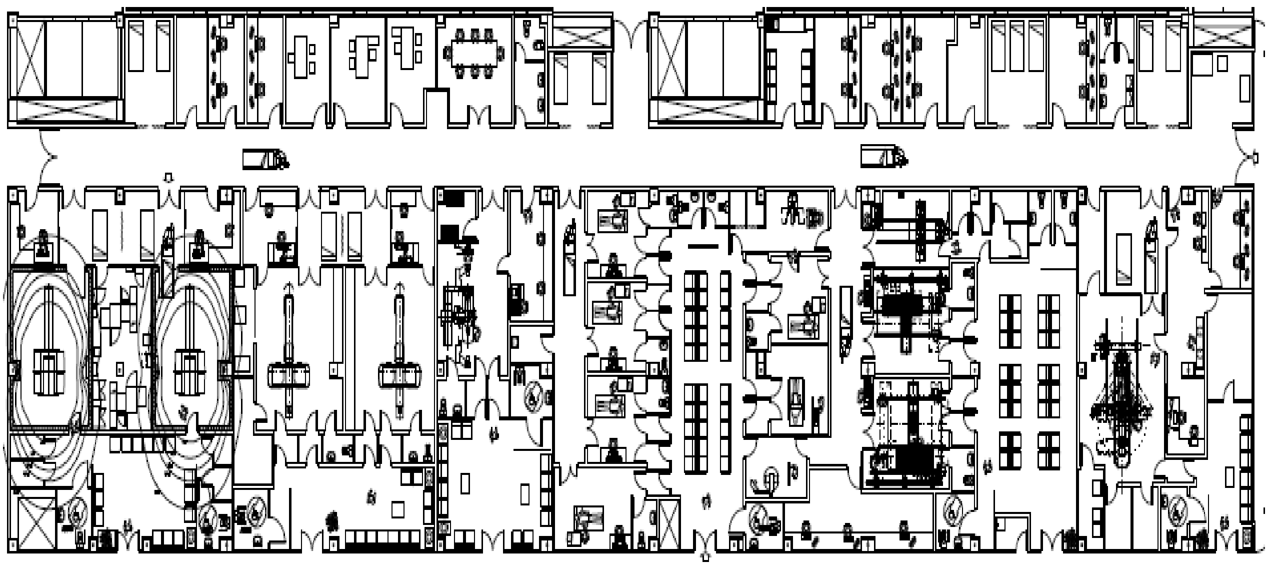


(10.33.- Blocks of modalities)

Is shown the clear delimitation of the patient corridor, waiting rooms, examinations rooms and staff offices.

The next step is the architectural design, starting with this distribution to reach the final implementation.

After placement the rooms and other dependencies in the framework of pillars is passed to the partition design locating the equipment within the exam rooms and defining dependencies with accuracy.

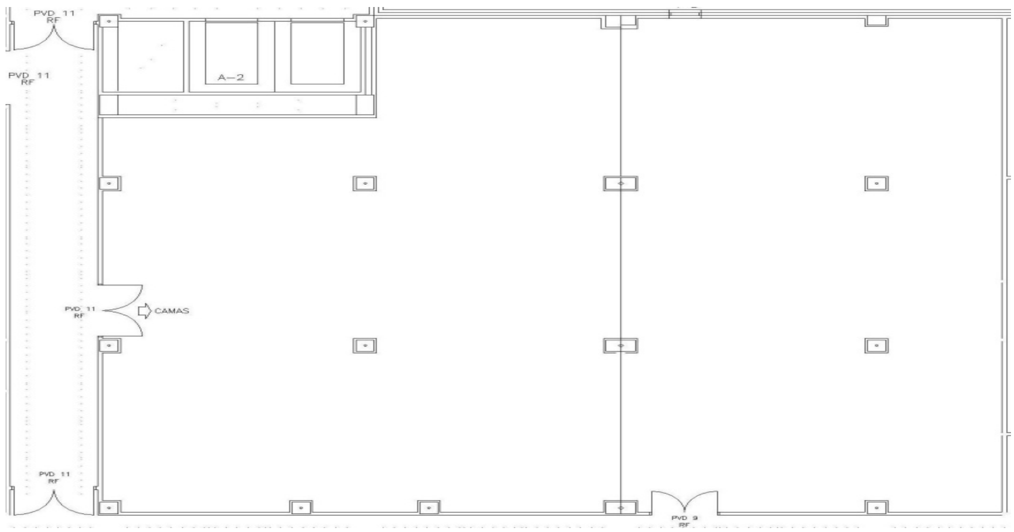


(10.34.- Final drawing of the implementation)

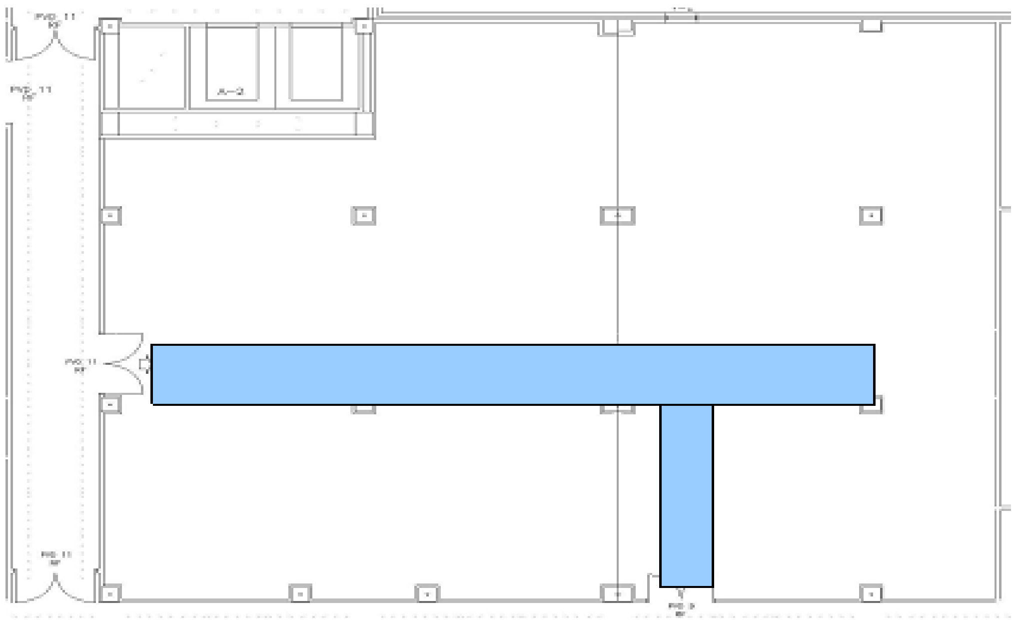
This task is not obviously simple and in spite of the initial drawing of blocks, the architectural structure and the sizing of equipment, halls, etc., can force to carry out, still, several alternatives to achieve a satisfactory design.

Now shall be undertaken a department of nuclear medicine, simple, with a single PET-CT and a gamma camera (10.35).

The department has dimensions of 25 m long by 21 m wide (82x68 ft), with an area of 504 m2 (5.425 ft2). The first layout of the circulations separates external and internal patients. Inpatients will be combined with the personal corridor.



(10.35.-Nuclear medicine)



(10.36.-Circulations)

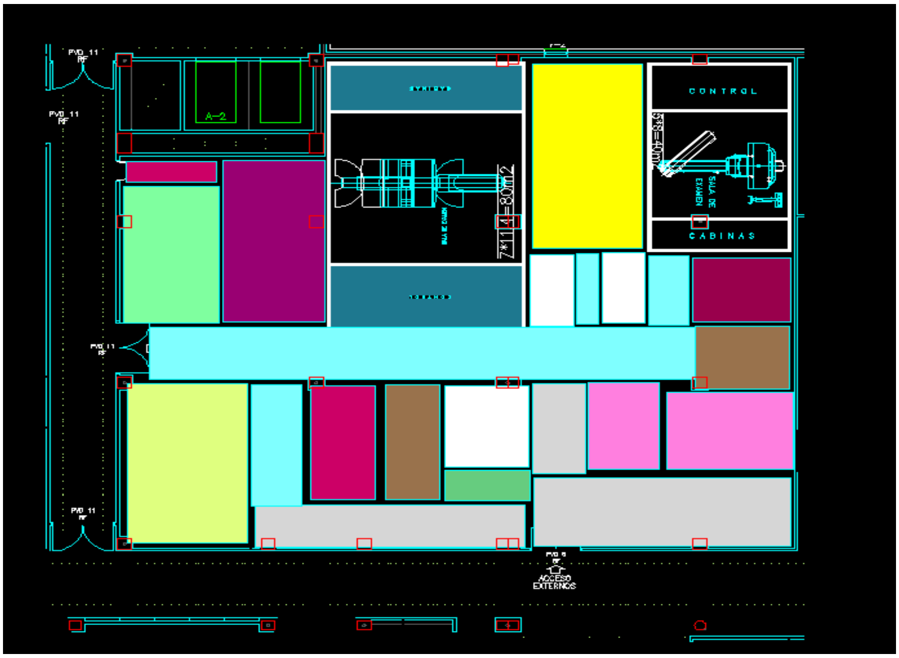
The location of the PET-CT should be next to the rest patient area after injection of the radioisotope. Similarly the gamma camera will have beside the injected patient room to scan room.

Hot chamber (nuclear lab) where prepare injections to patients, and where it is the waste store, should have a direct exit to the main corridor. The supply of radioactive material and the departure of the containers with waste are carried out in this way by one independent exit in the department (10.3)

Reception separates patients of PET-CT of the gammagraphy, and there is an office for consults of nuclear medicine physicians with patients.

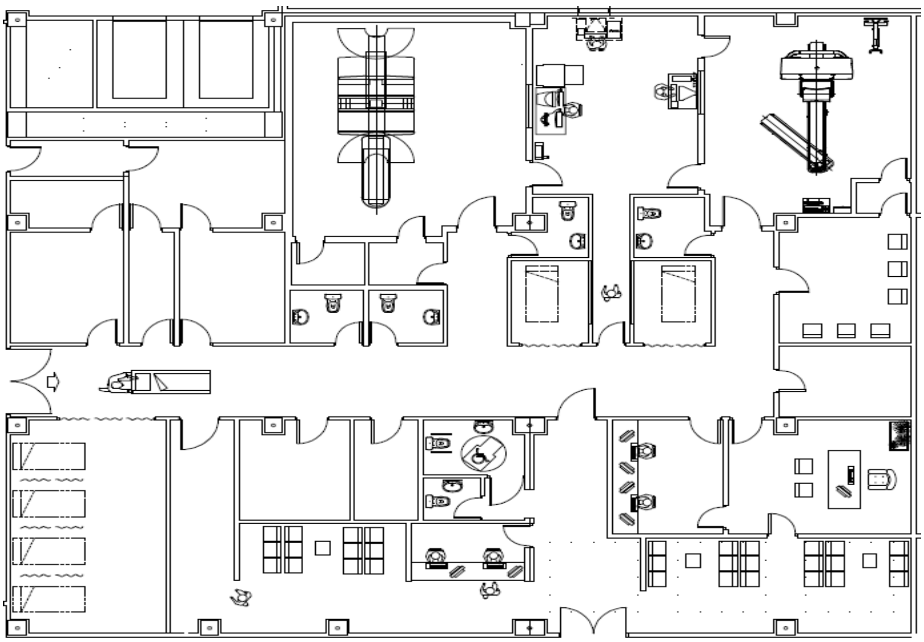
Space for toilets, etc., is not detailed but there are gaps where to attach them as shown in architectural drawing.

(10.37.- Block diagram)



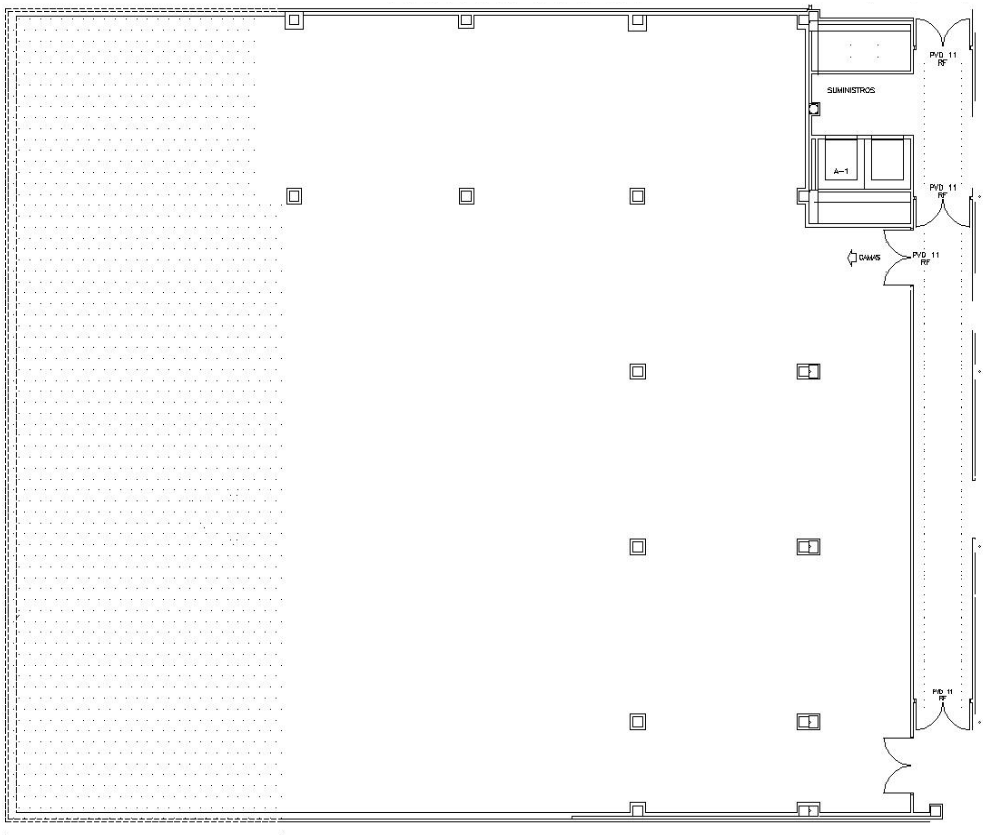
(10.38.- Blocks with modalities defined in Chap. VIII)

Below is the drawing of the final architectural implementation.



(10.39.- Architecture drawing of nuclear medicin department)

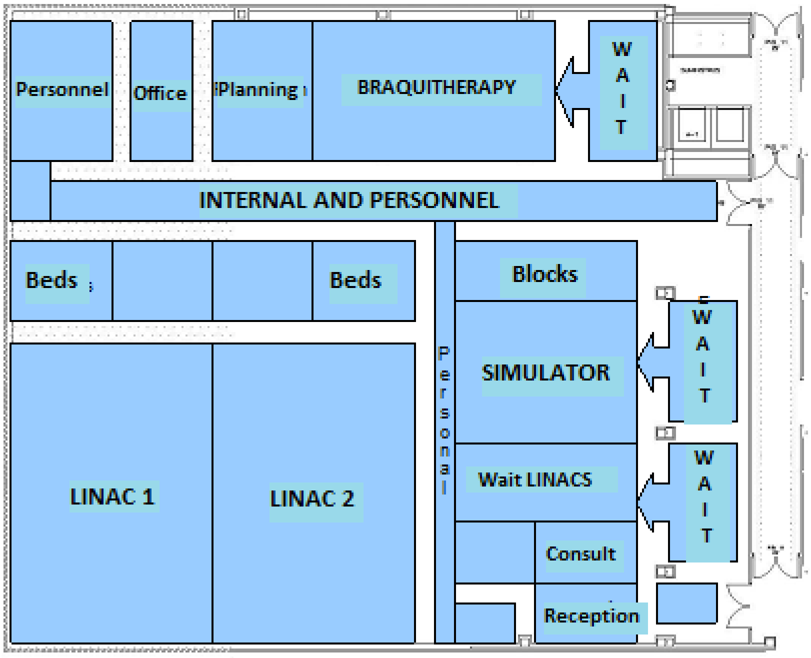
A simpler radiotherapy department, but complete in terms of the functional units containing is represented below (10.40).



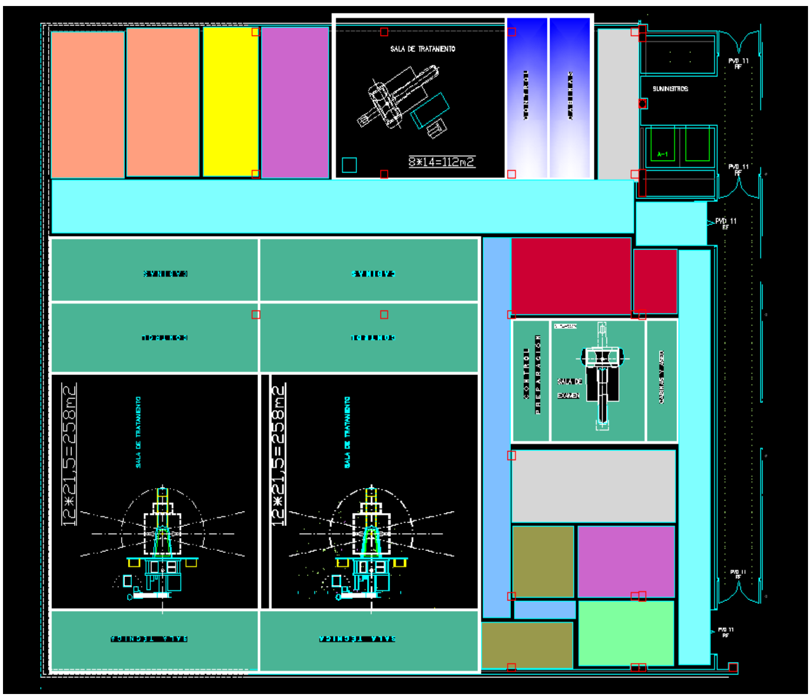
(10.40.- Pillars of the radiotherapy repartment)

In the same way as in the previous diagrams locate the circulations of staff, inpatient and outpatient. The shaded area corresponds to future expansion planned to leave the finished civil works together with the rest of the department and locate the equipment in a posterior date.

The distribution begins by placing the blocks of two linear accelerators. Its magnitude is such, in relation to the total area, which makes, adding the radiotherapy treatment zone and the examination zone, to occupy more than 40 per cent al total surface. The gross area of the department is 1.280 m2 (13.777 ft2) occupying a surface of 40 m long by 32 m wide (131x104 ft). Special mention deserve the spaces dedicated to brachytherapy and adjacent to this bunker is the area of the treatment planning, both for the LINACS and for brachytherapy. The simulator is a CT multislice large opening bore for radiotherapy.

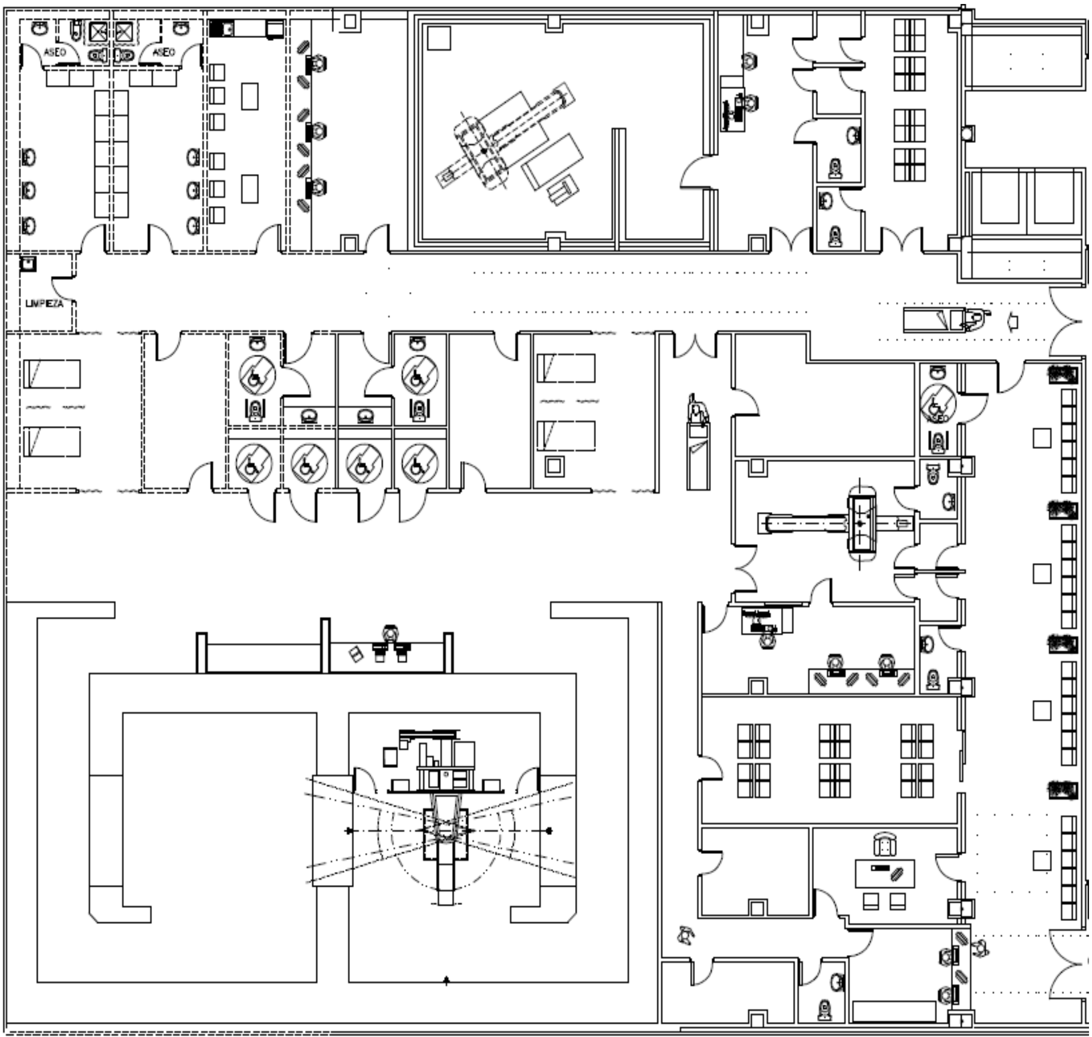


(10.41-Blocks in a radiation therapy department)



(10.42.-Blocks Chapters VII and VIII)

The final drawing of the department with equipment, the details of dependencies and circulations and waits is shown below (10.43).



(10.43.- Preliminary implementation, without calculation of bunkers, in one radiotherapy department)

One resume with the blocks to address the allocation of spaces in a scheme of pillars can be shown as a summary in figure (10.42). Although these blocks have been drawn in AUTOCAD, it can be drawn in any other drawing program that allows to keep the scale drawing. The dimensions of each block representing each modality, as described in chapters VII, VIII and IX are shown in next table. These gross dimensions are what the designer will need to remake their own blocks.

MODALITY	MEASUREMENTS BLOCK	GROSS SURF. (M2) (FT2)
DIGITAL RADIOGRAPHY	8 X 5 M	40 430
FLUORO	9 X 5,5 M	50 538
MAMMOGRAPH	3 X 5 M	15 161
BONE MINERAL	4 X 5,5 M	22 236
ORTOPANTOTOMOGRAPH	2 X 4 M	8 86
VASCULAR-HEMODINAMIC	7,5 X 12,2 M	91 979
VASCULAR BIPLAN	8 X 14 M	116 1.248
ULTRASOUND	4,5 X 5,5 M	25 269
CT MULTISLICE	6 X 10,7 M	64 688
MR 1,5/3T	7 X 10 M	70 753
MR OPEN LOW FIELD	5 X 10 M	50 538
MR OPEN HIGH FIELD	7 X 11 M	77 828
GAMMACAMERA	8 X 5 M	40 430
SPECT CT	6 X 12 M	72 775
PET CT	7 X 11,4 M	80 861
LINAC	11 X 22 M	242 2.604
BRACHITHERAPY	7,5 X 14 M	105
VIRTUAL SIMULATOR	6 X 10,7 M	64

(10.44 Blocks overview)

X.V.- MODULAR PROGRAMS

The idea of standardizing diagnostic rooms and its peripheral elements have had attention in all department planners of the last decades, where has been shown that good planning leads to better clinical results in the first decades of operation of the imaging department. A large part is due to the continuity of the action planner, in many cases a radiologist who has the opportunity to design their own future department, which in addition develops more easily the inclusion in of new diagnostic values on the team, during the configuration of the new department personnel. This team, built with method, organization and constancy in their development will have all the keys that make up its future success.

Today several authors and companies supplying equipment configure certain rooms where the concept of modularity can have a defined value, not only from the theoretical point of view, but from its practical application.

Will be presented a conceptual scheme, based on satisfactory extended experiences, that leads to a level of modularity of a department, which can facilitate their subsequent architectural development. May also be considered in reverse order, where the schemas that are defined, leading to practical architectural results after a work of adaptation by the designer and architect.

The drawings and their following schemes, are suitable for one automatic plan, programmed, resulting from the calculation of the surface area and number of rooms defined in our chapter V. A Visual Basic programming leads to a wide utility application for the planning team, in the phase of concept in the planning of the diagnostics center or department that is being studied.

The first step should allow to define individual rooms modules, as they must be printed and placed in the final scheme, positioned for better observation will be drawn in 2D and 3D.

In the same way the modules of the diagnostic rooms, offices, dressing rooms, storage, etc., they must be dimensioned depending on the type of department, i.e. if it is an external diagnostic center, or a department inside a hospital of different size, and also dimensioned in accordance with the demand of patients, i.e. the final demand for exams that must satisfy the department. Will be exhibited a practical and simple example where is proposed the design of an outpatient diagnostic center, whose drawing finally will be showed as a result of the development of a computer program that sorts the placement of each of the modules according to a certain logical order.

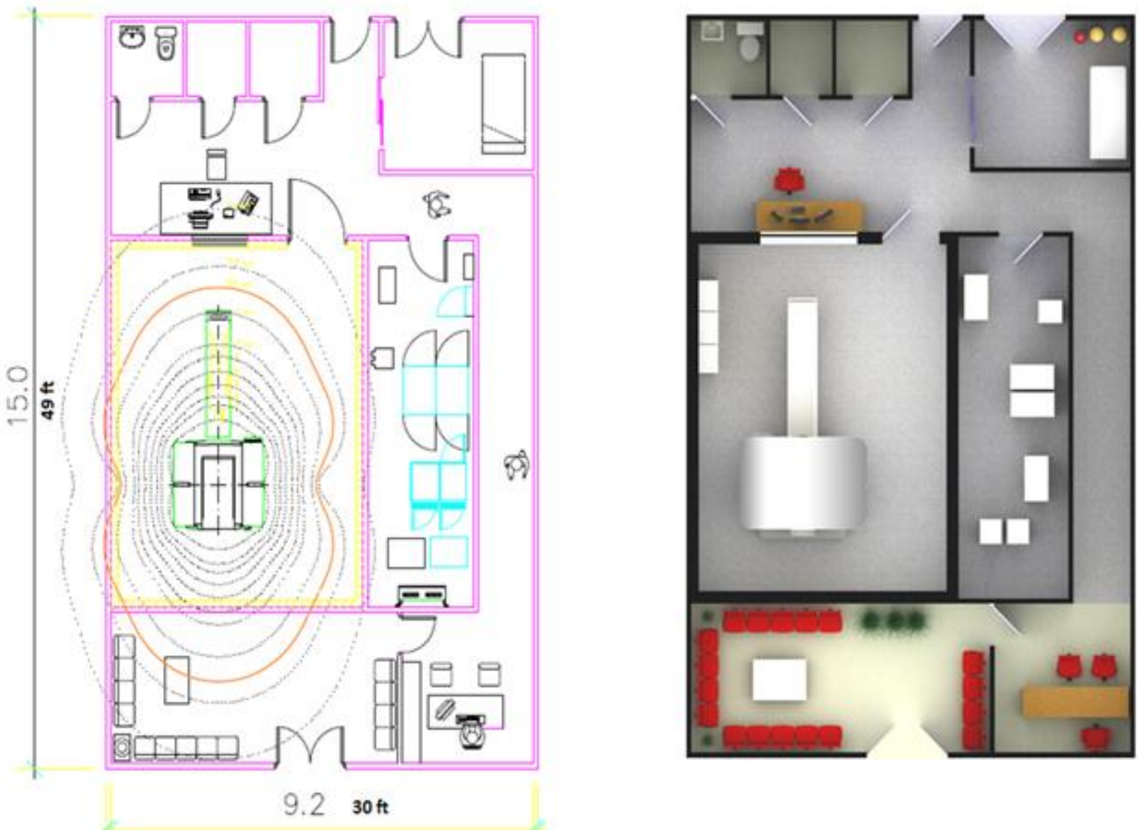
The first module designed is the installation of magnetic resonance imaging, design made following the recommendations of the American College of Radiology, whose security requirements are the admitted at this time as the most successful in the environment of the radiological community.

Multislice CT scanner module is defined in the next page. The technical room houses the necessary elements of modern systems, for its electromechanical components and the thermal dissipation.

Can be observed a length of each module in 15 m (49,2 ft) which remains the same for all modules, by varying the width of each module according to the surface modality needs.

The union of all modular rooms form a department like de one in the figure (10.51), where may be seen how are configured the circulations after adding all the modules required to compose this outpatient center, that can also assimilate to a small size center for local or regional hospital.

The module has all the features that, in general, are necessary for the operation of the modality, making modifications in some cases when working the real medical process that follows these rooms.

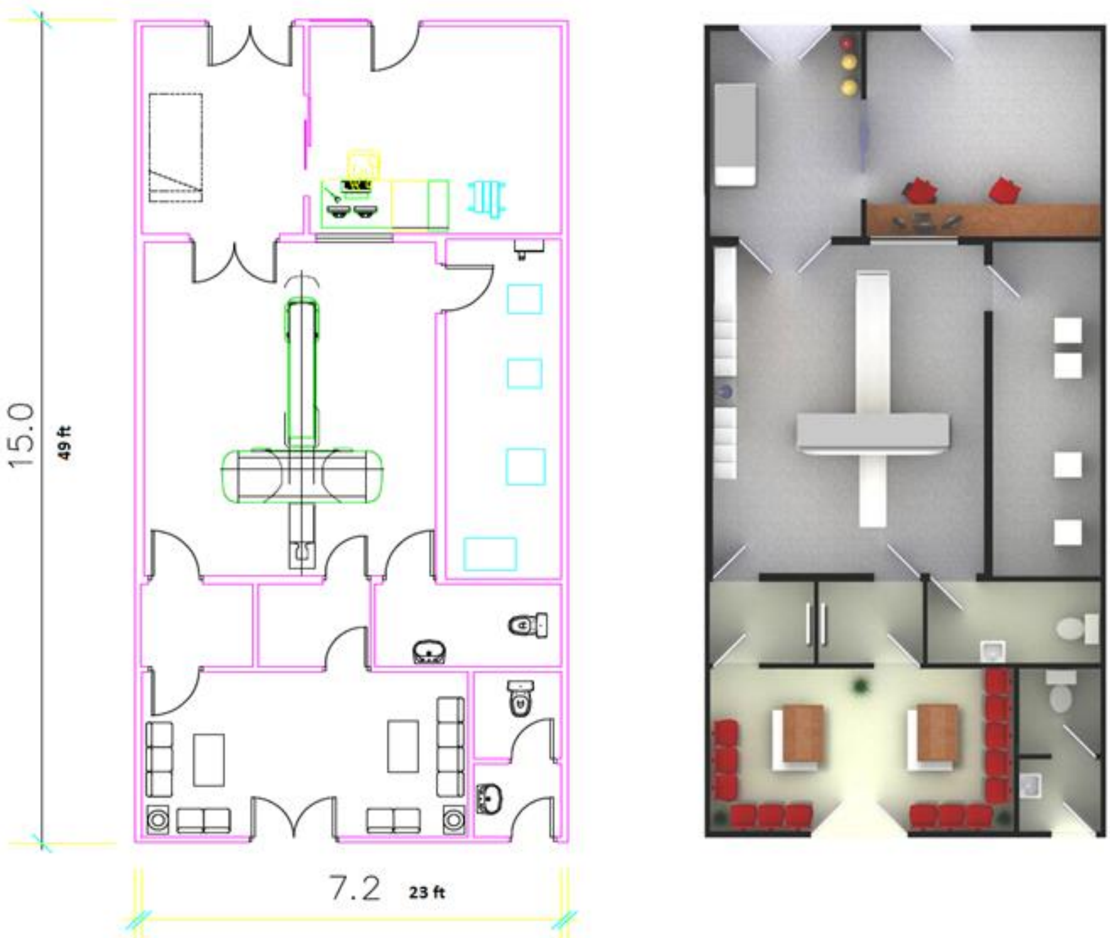


(10.45.- MR module, 2D and 3D)

Computed tomography facilities can be designed in a modular way, with the same criteria than magnetic resonance. The lengths of the modules remains at 15 m (49,2 ft) in such a way that there is one excellent fit in the final department model as will be shown at the end of this presentation, in this chapter.

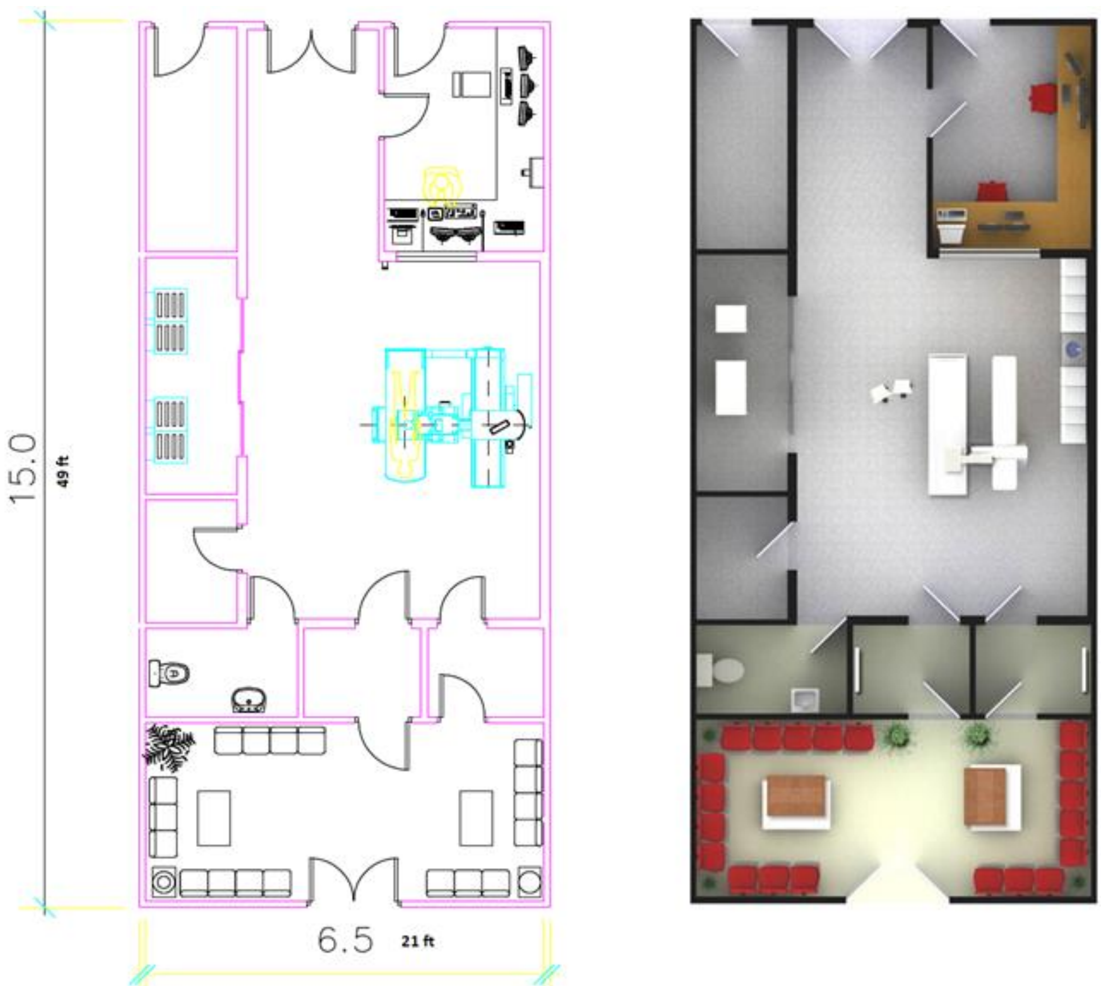
Certainly there are different models of different manufacturers of CT, but as is shown in the fourth chapter of this book can perfectly resemble, for the purposes of design, and introduced into a given surface, average for all of them. Some CT may require some small variation, primarily in the technical room for heat dissipation requirements, but all of them come in the proposed module.

Attached is the module CT, with its dimensions and 3D representation that optimizes the display and allows you to move the imagination to the proposals that could be made in relation to the decoration of the room.



(CT module. 2D and 3D)

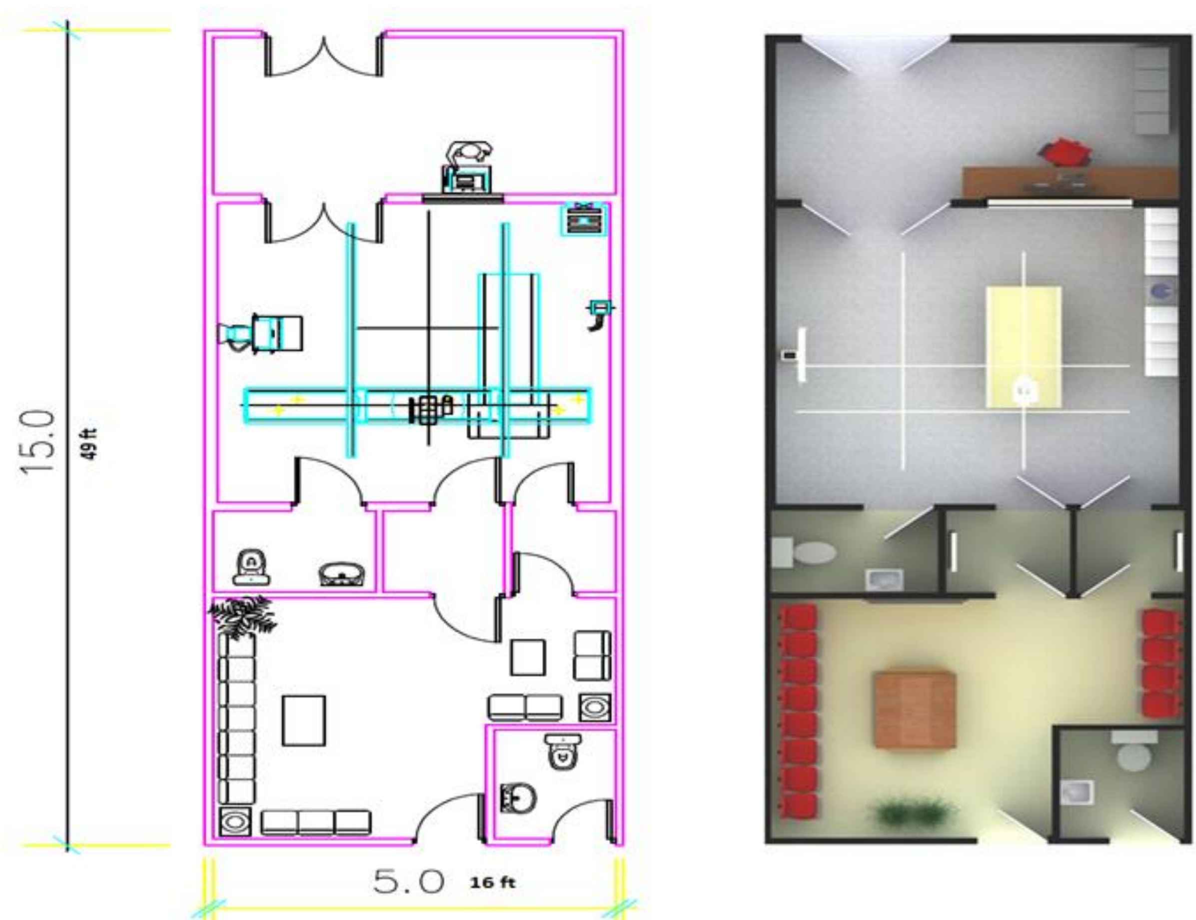
The digital remote controlled tables have a provision within the same concept, where the length of the room is 15 m constant and varying widths, depending on the specific modality and its expectations. Various commercial remote controls do not require a technical room as defined in the scheme, because their electronic cabinets can stay somewhere in little space not used of the examination room. Despite this the different needs of air conditioning of the electronics and the interior of the room indicates that a technical reserve, a technical room, simplifies the air conditioning and allow greater comfort for the patient and staff with savings on air-conditioning, especially in warmer climates.



(10.46.- 2D and 3D remote-control module)

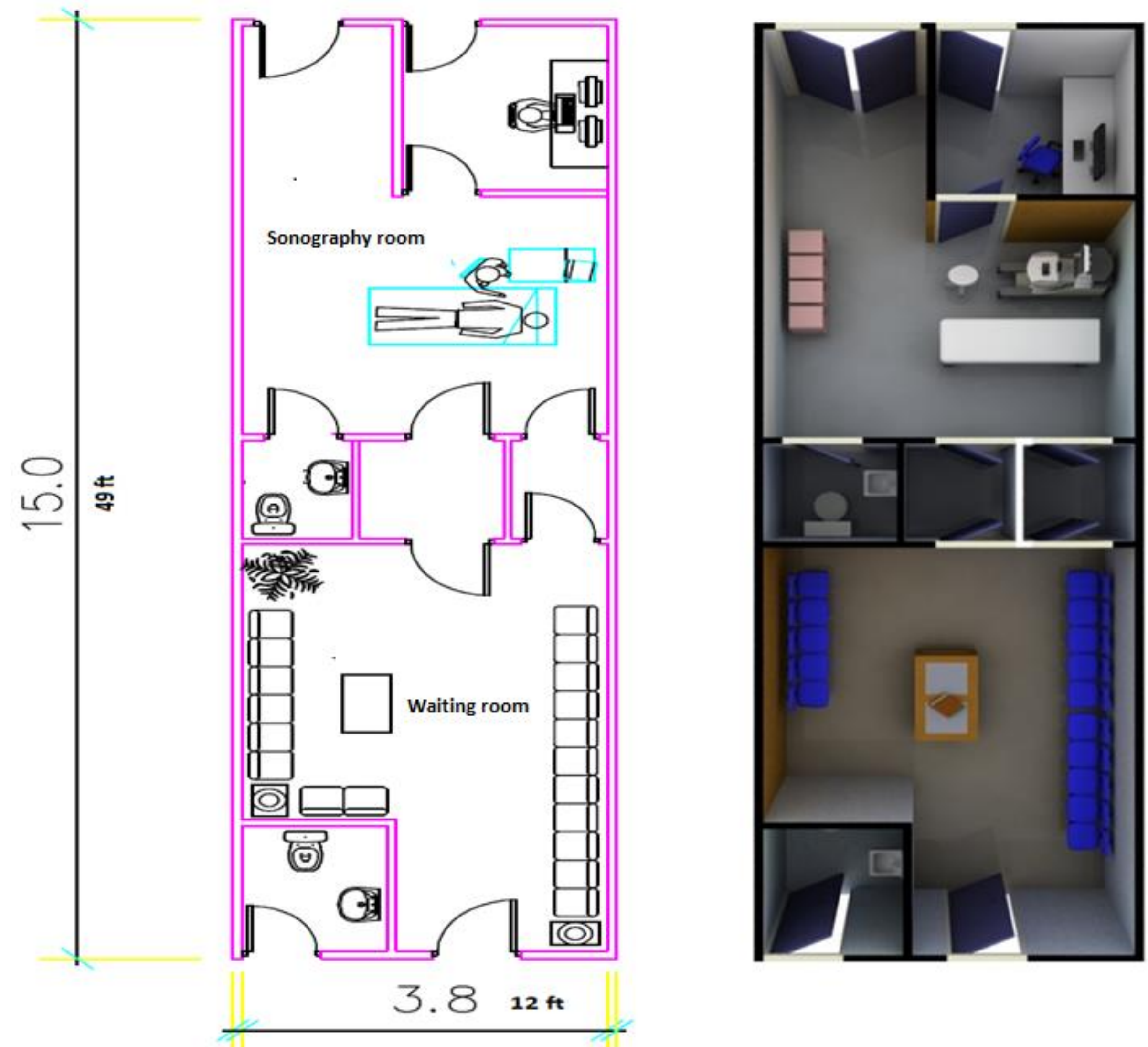
Radiography rooms, also called of conventional radiography and today more known as digital radiography rooms, engage also this modular system with 15 m in length, while its width is less than the remote control. Taking into account that there are remote controls equipment that do not require technical room, the room width could be the same.

Has been represented the room with ceiling suspension, for being the most versatile under the point of view of a hospital, and also the most widely used in the emergency departments. The high mobility of the technicians and patients in the room makes more comfortable the exams.



(DR module. 2D and 3D)

Ultrasound installation presents a similar situation, always keeping the same length of room and attaching the necessary elements for its functionality within the width of the room. The office for the radiologist who made the report after exploration may not be necessary in departments where for the exploration, routinely, the sonographer, sends images to the diagnostic room of the radiologist for his subsequent report. This would reduce the dimensions of the room.



(10.47.- 2D and 3D ultrasound room)

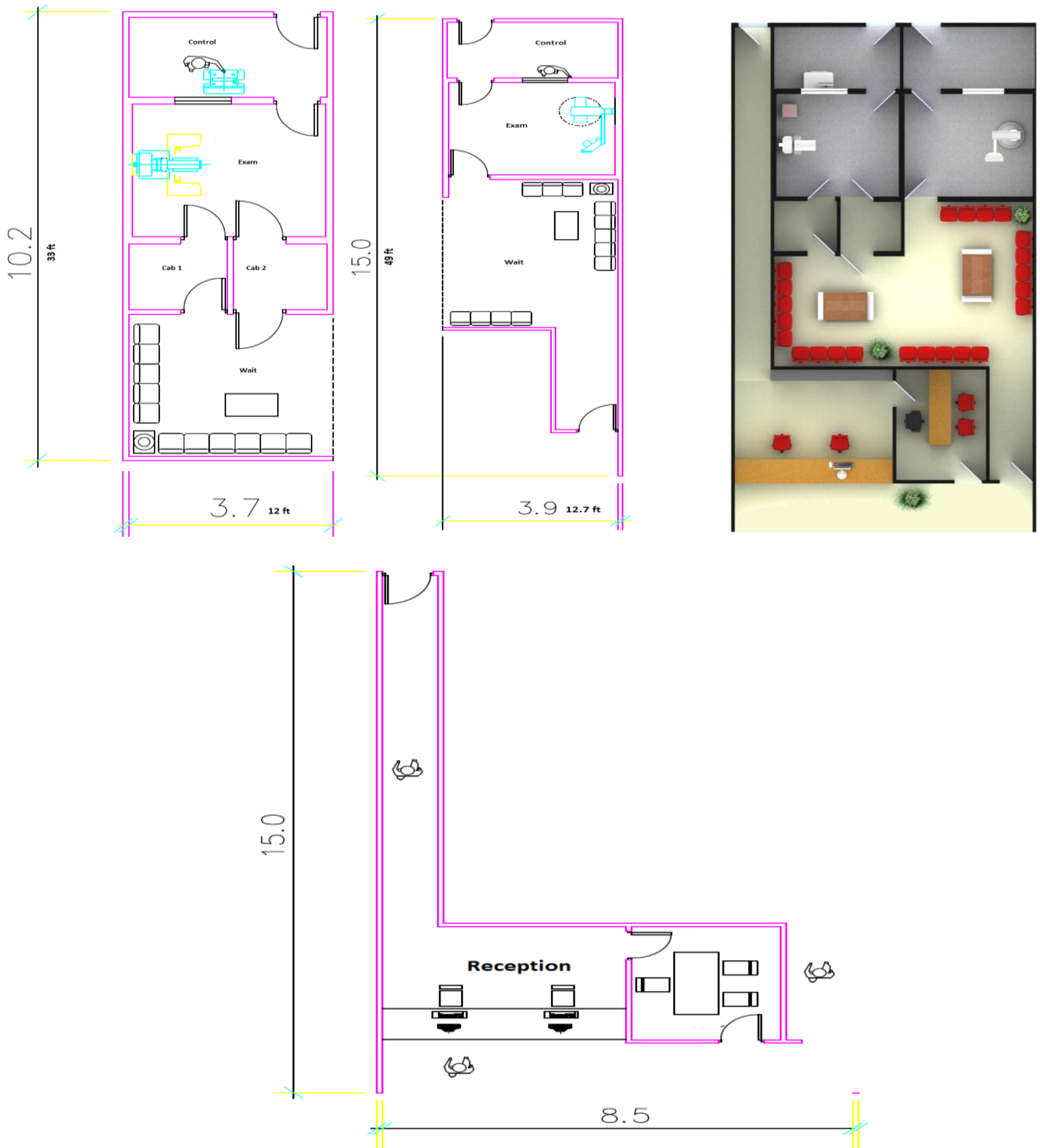
Bone densitometry has the same length as the rest of the modules with lower room width.

The enclosure of separation between the control unit and the scanning room is not always required. If that is not desired, or not required, can be removed.

This mode not always is included in the diagnostic imaging department. In different centers it can be found in departments of traumatology and others related with the diagnostic information provided by the system.

(10.48.- Bone Mineral module 2D and 3D)

Reception module has the space needed by staff, with its communication with the area of personnel and an office of special attention to patients who require privacy.



(10.49.- Mammography, ortopantotomography and reception modules)

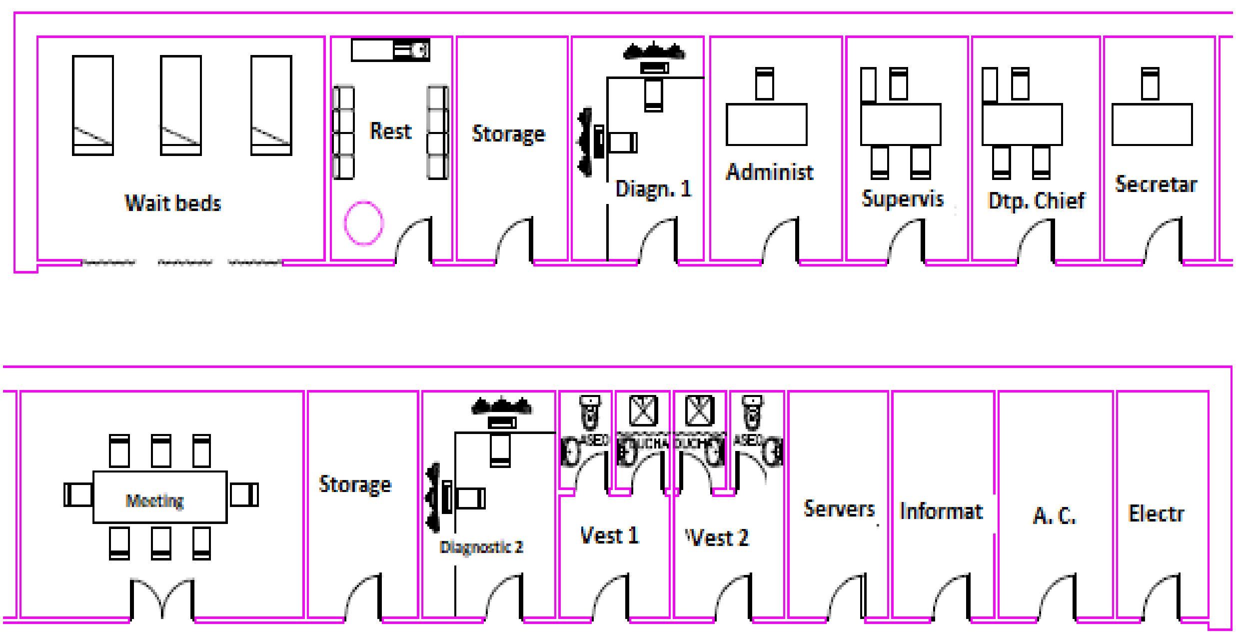
The reception is located, in the space between the entrance hall and the own space of reception for the possible rooms of mammography and ortopantotomography. In the event that modular designs do not require these rooms, for the simple fact that do not have demand for the case study, would be a space for future applications.

Mating in this reception area, taking advantage of the holes of the top are integrated the two latest mammogram and ortopantotomography modules.

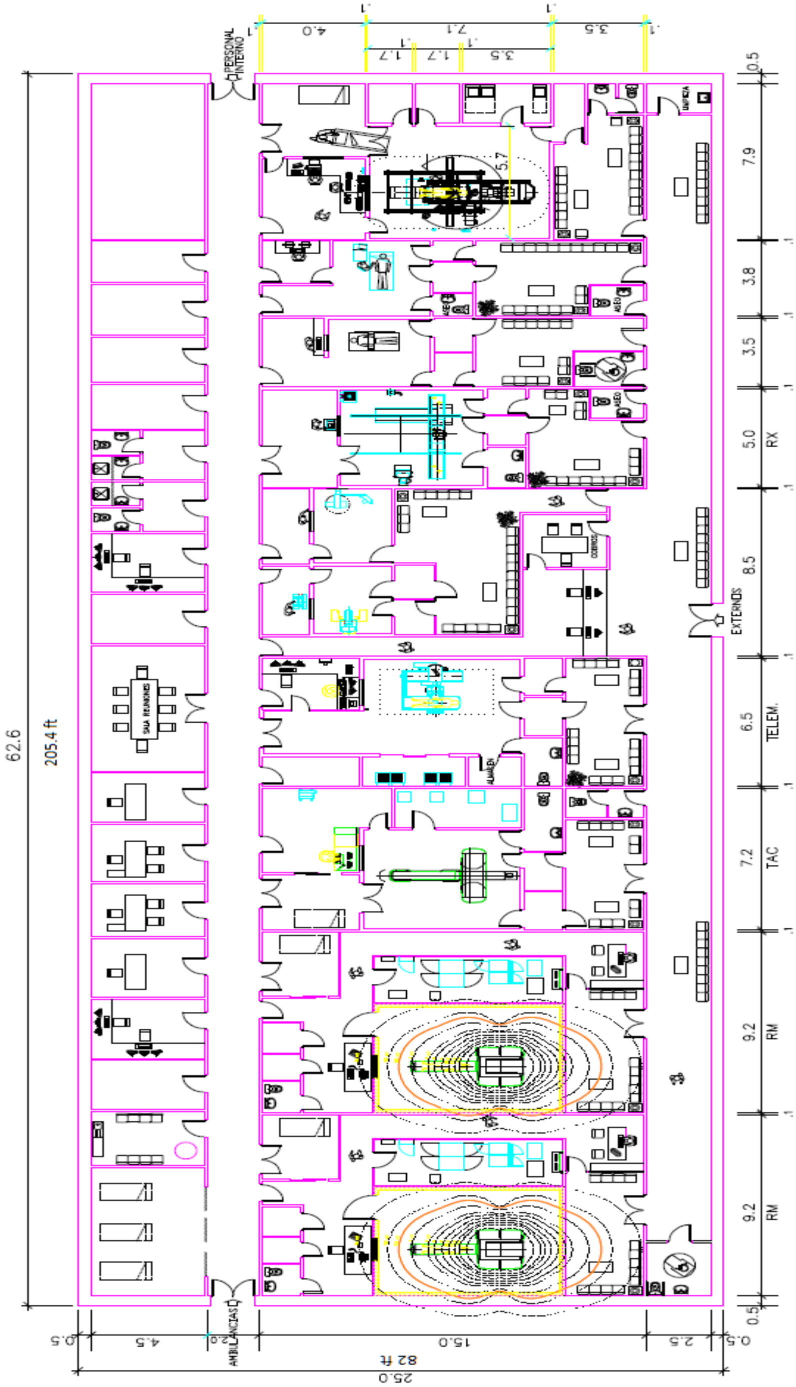
Ortopantotomography equipment fits next to the mammography machine, therefore has the same length, but narrower, in accordance with the real needs of one equipment for this function.

The personal and technological areas of the department are also configured in different modules placed by the program in the way that will be rpresented in the final figure.

These modules are reproduced in different designs in the way that is the own exams demand that determines the number of modules that draw in each drawing. It will start from left to right the waiting area of outpatients who have arrived in ambulances. Although it is, in this example of an outpatient center; in many of them are received patients in ambulances, primarily for explorations of RM and CT.



(10.50.- Personnel dependencies)

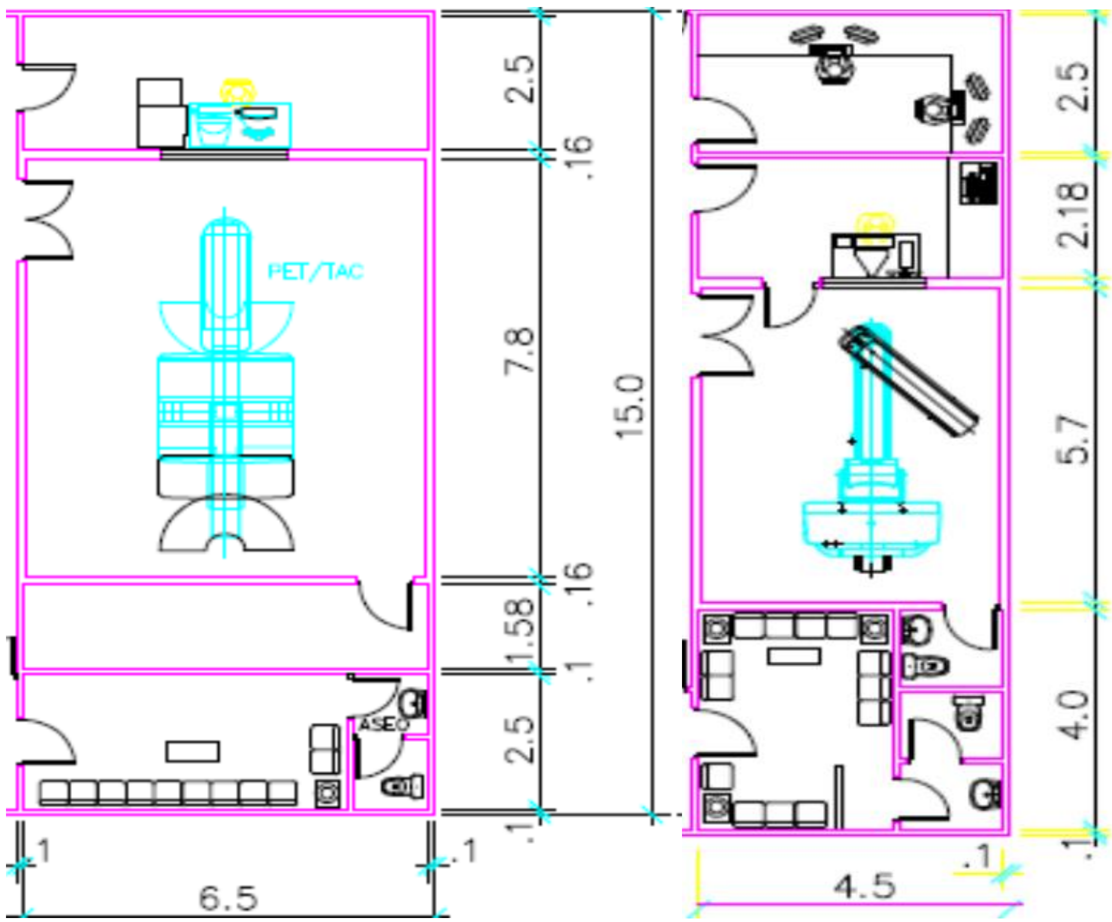


(10.51.- Final drawing)

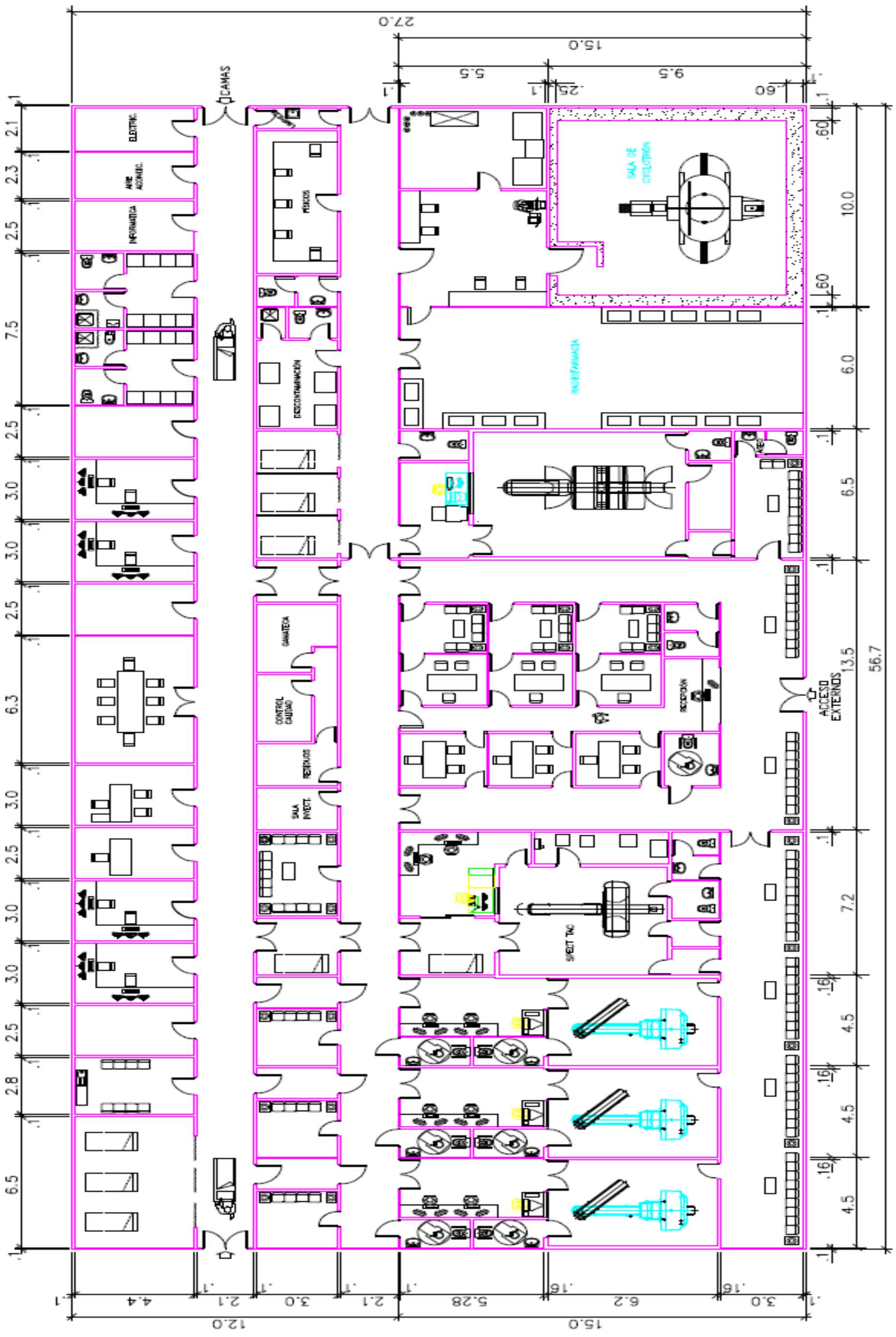
(10.57.- Final complete in 3D)

The application of the method of modules in **molecular imaging** leads to similar results as in diagnostic radiology imaging. In some centers both services are integrated in a single department.

We show, for example, two modules of molecular Imaging, gamma camera, as more representative and PET CT as a form of hybrid modality of relevant growth in departments of nuclear medicine. The rest of the modules can be seen in the full department drawing of the figure (10.54).



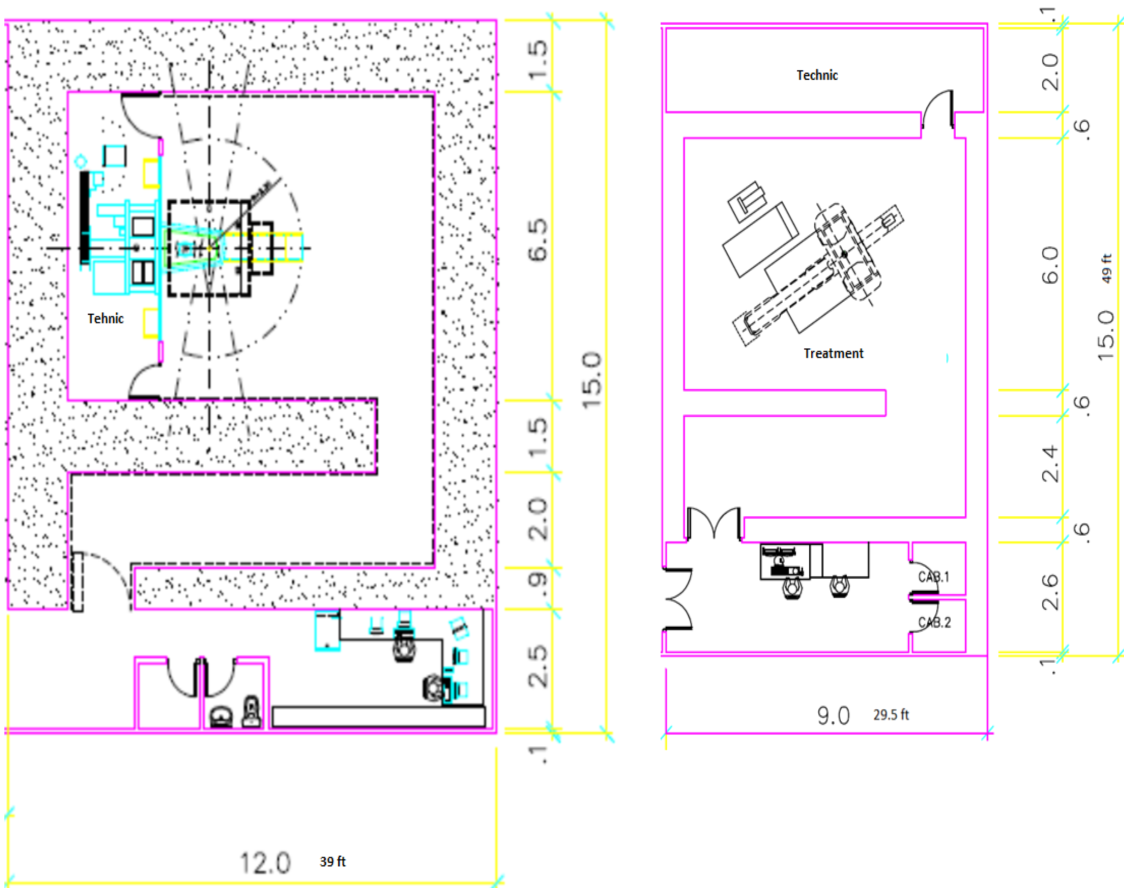
(10.53.- PET CT and Gammacamera)



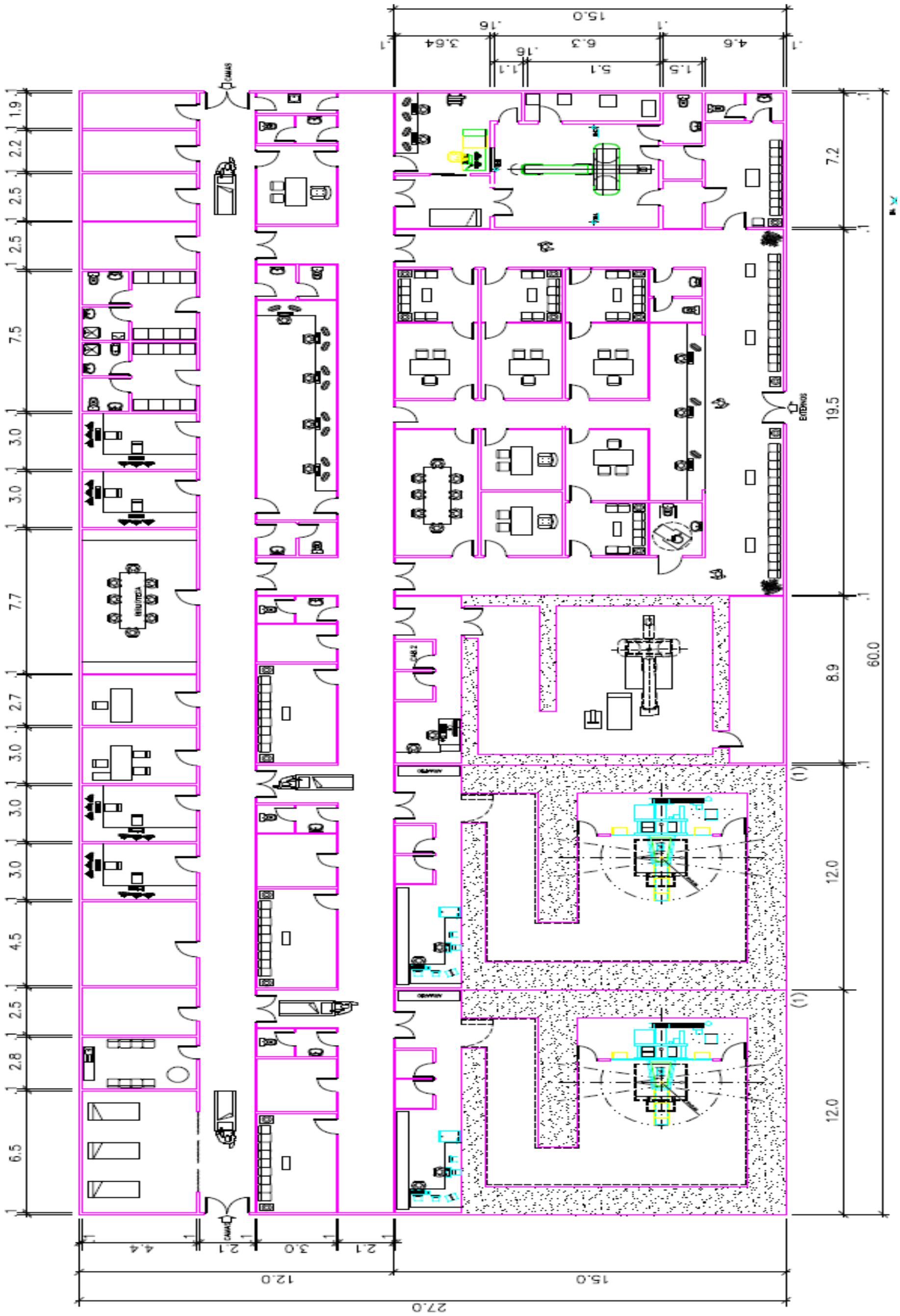
(10.54.- Molecular imaging department modular design)

The same criteria has been applied to **radiotherapy**. The modular design is valid not only for the design of the single modalities, but also for the block of offices for consults and personnel dependencies.

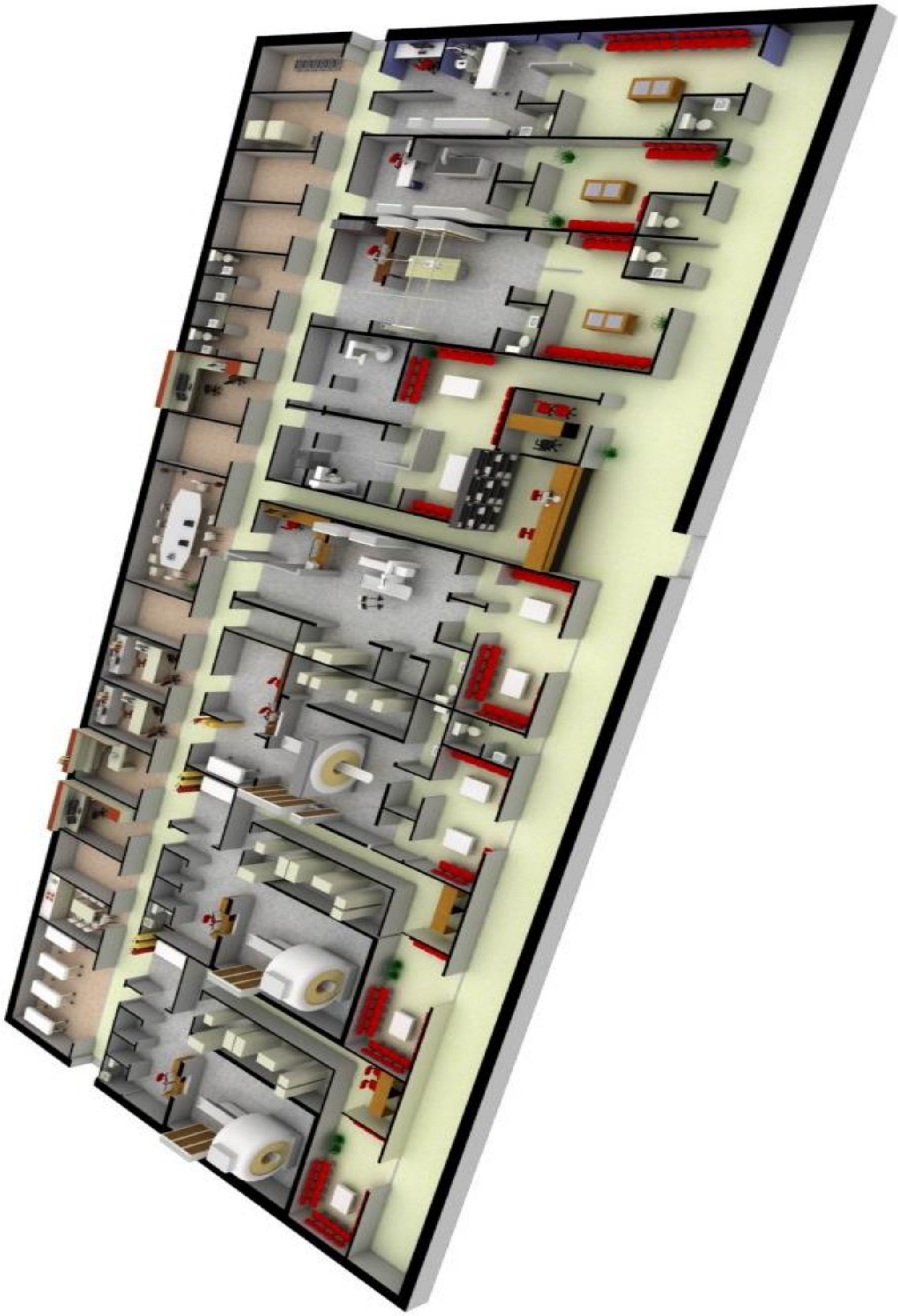
Attached are shown modules for LINAC and brachytherapy, perhaps de more representative modalities in this discipline.



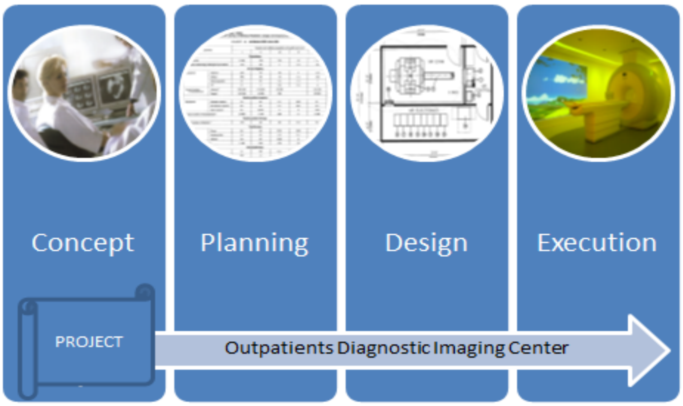
(10.55.- LINAC and brachytherapy modules)



(10.56.- Radiotherapy department. Modular design)



XI.- PROJECT DEVELOPMENT



I. CONCEPT

II. PLANNING

III. DESIGN

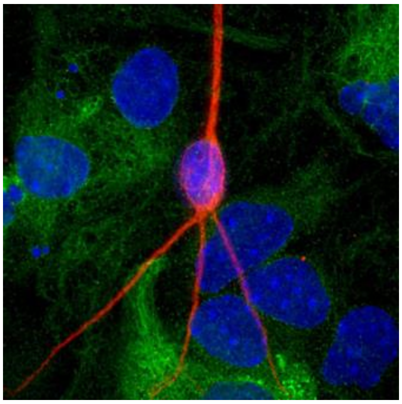
IV. EXECUTION

V. METHODOLOGY FOR FOLLOW UP AND CONTROL

Success is not achieved with special qualities. It is a work of constancy, method and organization. (J.P. Sergent)

XI.- PROJECT DEVELOPMENT

Hundreds of laboratories around the world work with stem cells in the hope of finding cure for many diseases. In this wonderful race successes and disappointments occur, but involved scientists provide daily news about his work, as presented by the California Institute of Regenerative Medicine with images, like the attached photo, that shows three neurons derived from human embryonic stem cells. This research program is much more complex than our diagnostic imaging departments, where in these we have already knowledge developed and only have to apply known techniques to facilitate the work.



So far have been travelled a long way since the beginning of this book, with the description of the discoveries of different techniques of image acquisition, and its translation into instruments capable of converting the physical principles in images, baseline for the clinical information, and design of the rooms where patients undergo the acquisition of information of the body to complete or make the diagnosis of a pathology. Statistical data guide us and help in the formation of a concept that allows to present the determination of the gross area of the department in a spreadsheet as a function of the sum of all net area employed by the examination modalities. The analysis of the workflow is the first step to begin the design of the department. The number of patients, patient itineraries, workload of each room are elements of support in the definition of the circulation corridors. Now there is enough information to begin the design of the department blocks and once approved this, finish with the ultimate goal that is the full architectural design.

Complete architectural design is the maximum task proposed here, but in reality it is not the ultimate goal, the project have to be put in construction, furnish it with the selected image systems, put them up, train staff, and then, will have been completed the project of the imaging or radiotherapy department under a purely technical point of view. Long task which requires knowledge and resources.

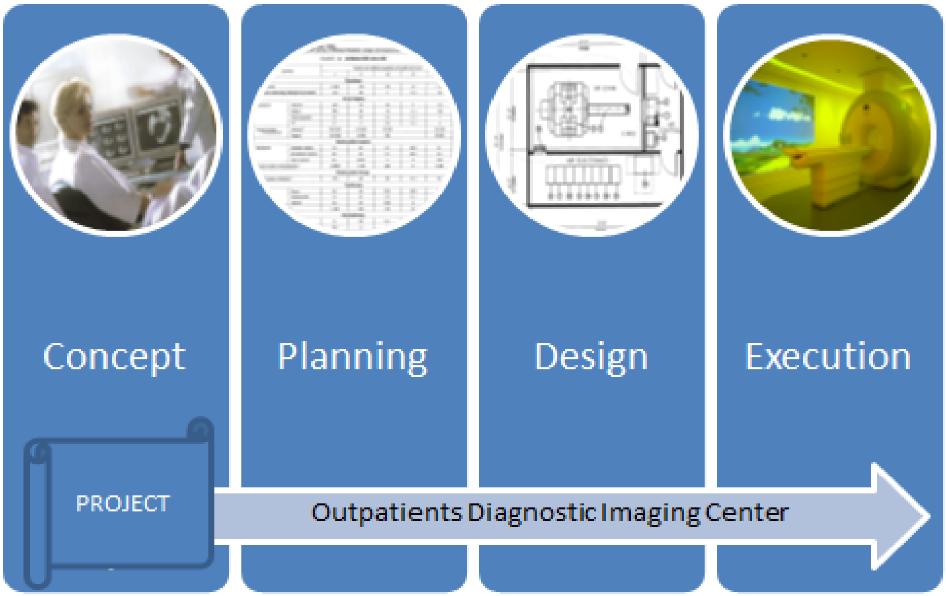
The decomposition of the total task into a series of smaller tasks and these into smaller ones leads to the need of search tools, today with computer software, that facilitate monitoring of each of the activities, performances, their times, their gaps, its renewal in a general plan that assumes the strategies and policies that the planners considered appropriate for the development of the global project of one image or radiotherapy department, which can be integrated in another major, as it is the case of a full hospital or be in itself a complete project considered in isolation. Cases of departments of external patients or cases of renovation of departments in existing health facilities are complete projects that apply all the phases that will be to described as execution of a project and all the tools that have been considered here to apply, as simple examples, without discarding many other existing and others in upcoming development today.

Independently of the legal property of the hospital and its scope, i.e. public or private, the steps are the same, but can vary the way that relate the different working groups and their codes of communication. In the case of public hospitals the laws of different countries lead to hiring different activities with public tenders, that it follow specific legislation and therefore certain steps. The hiring of private sector not always follows these steps, but here each company sets its own mechanisms to carry out engagements and for the communication between working groups, is not always the same, but usually different from one to another company.

It is time to address, in the more simple possible way, the necessary steps for the journey of a diagnostic imaging or radiotherapy project. Will be separated each set of temporary activities leading to a milestone of the project and that mark, in phases, with enough sharpness, where is required the action of the project director in the driving and key decisions making in its development.

There are four phases in which can be divided a project of one imaging or radiotherapy department, following the steps that have to be done to complete the necessary activities for the partial plans and general plan in the daily practice:

- **Concept.** Idea**.**
- **Planning.** Basic project data.
- **Design and preparation.** Architectural project, provision of resources, procurement of equipment and civil works.
- **Execution.** Licenses, permits, civil works, installations, testing, training and act of reception.



(11.1.- Phases of a project)

The time from concept to the end of it execution can range from months to several years.

Will be starting with the development of each of them and simultaneously see the tools that can be used to better control of activities and the plan.

XX.I.- CONCEPT

The initial idea may result from a variety of facts and situations that can be grouped according to the type of imaging or radiotherapy departments. The ideas have a wide range of coverage, from a single center of outpatient with a single modality, case of many MR facilities existing at that time, to a network of mobile systems moving through a country or an entire continent.

- **Individual idea** of a group of individuals that is channeled in a legal society, any type of which the law permits. The idea stems from a personal concept to make diagnostic imaging in a differential form, that can be a modality or modalities group in such a way that certain synergy can exist between them. They may be stationary external, internal or mobile units.

- **Installation plan of diagnostic outpatient centers** of public institutions or private institutions chains. It is the result of a market analysis with clear objectives of improvement of assistance and/or improvement of profitability.

- **Renovation** of one imaging or radiotherapy department whole or in part that for age reasons it has become obsolete and need a new concept.

- **New hospital** which, among its many departments, implies the imaging department. The idea of the new hospital can have a genesis similar to that expressed in the first paragraph, or be one additional unit more in the network already planned previously.

(11.2.-Concept)

In any of the situations in which are located the initial elements are very similar. Someone has the feeling and intuition that can do something useful, positive, different, economically profitable and positive for public or private health and therefore socially useful, and with these feelings becomes their ideas in analysis elements to make a sketch of his work, the genesis of his concept.

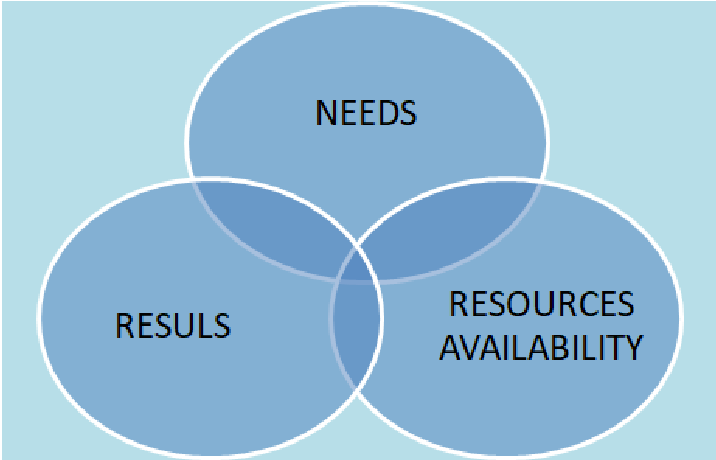
The concept, in diagnostic imaging and radiotherapy, has implied a number of premises to be realistic:

- **Need**. There must be demand of patients, already created or with the possibility of generating it in a period of time.

- **Resources availability**. There has to be human and material resources for its execution.

- **Results**. Have to generate economic or social benefits, and in general both.

And this information, with more or less detail, stead in all of those individuals that have a realistic idea of a project of diagnostic imaging o radiotherapy facilities.



(11.3.- Requirements of a concept)

The group of radiologists who come together to establish a new center of diagnostic imaging, have vague ideas of these premises (or already advanced), they have data on demand, about new technologies that may have an impact on a mass of population, or on new therapies that solve problems in certain places that are now resolved to forcing large displacements to the population with those pathologies (e.g.).

(11.4.- Promoter of a project)

They also have knowledge about human resources, physicians who dictate reports, technicians who acquire the images, the location of the department and constructive capabilities both fixed and mobile, the supply of equipment and its maintenance, and the ability to generate the necessary economic resources, usually from the payment of each patient, directly or indirectly through medical insurance. Thus they will deal with the many expenses as a result of the investments to be carried out, like required personnel, real estate, etc.

The working teams that design the health plans of large private companies or the manager of the public health systems also have these well-defined premises in their strategies when they undertake a new health center or a new imaging department for external patients. Economic resources can come from the own company financial resources, bank loans or the public budgets financed with taxes.

In this phase, where to locate the department is a question whose answer changes if it is a new hospital or an external center; but in both cases a surface is needed where to settle the building that supports the service. Therefore preliminary ideas of possible places already have at this time, or are developed in this phase, to be completed in the next, until the architecture group begins to write the department project.

The idea leads to search some formula of legal association representing the initial entrepreneurs group, and at the end of this phase should be a society with an administrator who begin to channel the activities of the next phase.

The team of this first phase is composed by the people who generated the idea and consultants specialized in image or therapy equipment, architect, and lawyer.

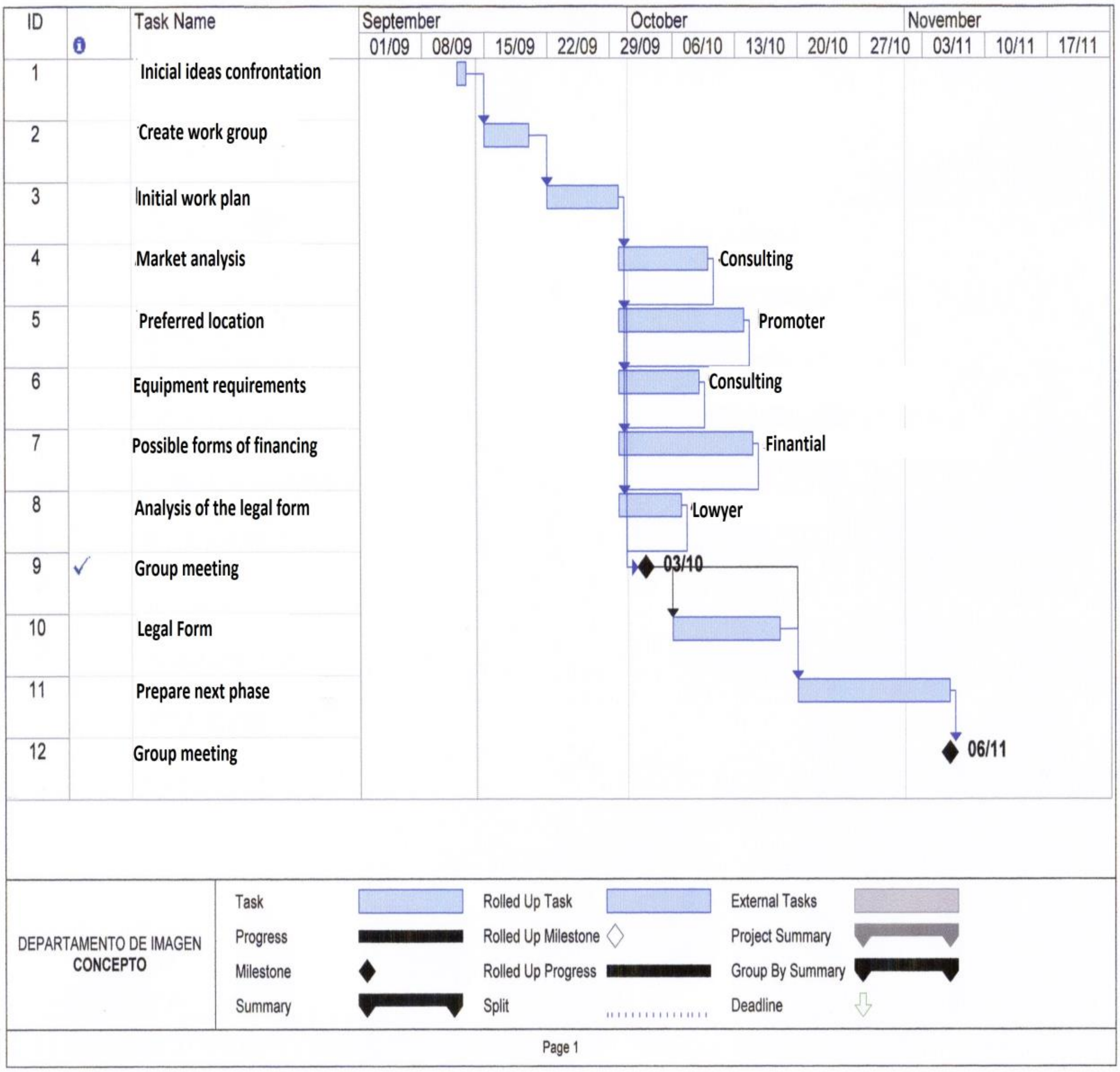
(11.5-Working group in the conceptual phase of a project)

The tasks of the group, must tend to find enough data to declare the idea viable and so go to the next stage. Otherwise the concept ends up the entire project. The following diagram shows the most common tasks to be done (11.6).

The following tasks must be finished to the completion of the conceptual phase:

- Preliminary ideas of market, showing the need for the department.
- Possible places where fitted and probable construction time.

- Costs: In one approximate form for solar, construction and equipment.
- Personnel expenses, amortizations and potential income, in realistic estimates.
- Preliminary ideas of profitability.
- Constitution of the legal form of the group, with administrator.



(11.6-GANT diagram of the first phase of a project)

XI.II.-PLANNIG

It is the most important phase of the project, because with the initial ideas of the concept have to be build a Business Plan that will lead to the success of the future department. Here is where the analysis must be rigorous and detailed and the activities planned with discipline and correction.

Constituted a legal form of organization, which can be any public, private or mixed type has been defined the Mission of the department. With it are the present and future bases of the department as well as the groups of users to which it is directed, the needs of these groups and the technologies that respond how the needs will be fulfilled.

The working group is broader, below is detailed more clearly and define itself the communication forms between the elements of the group.

(11.7-Team in the planning phase)

Will begin analyzing all aspects of the Business Plan they have to build:

- **Premise**s, with analysis of the internal and external expectations; situation of the environment in diagnostic imaging; economic sector and its evolution; potential market and competition; the number of exams per year forecast; graphics of threats, opportunities, strengths, weaknesses. At this moment consultants, or the own company (public or private) working group should do a thorough analysis of market, for maximum detail of the demand, the flows of patients and the forecast of the number of examinations that lead to the knowledge of the surface of the department and the number of rooms. It is also when designing a strategic and marketing plans, and the communication to customers and final patients.

- **Overall objectives** of the company, detailing the product portfolio, groups of target patients, medical societies, marketing objectives, price per test objectives, objectives of service, development of personnel, logistics, administration and research and development.

- **General strategies**, product portfolio, for the population to attend and/or market objective, communication to patients, clients and staff, prices for examination or treatment, logistics, commercial effort, service to patients and clients, research and development, general organization of the department. An example of communication strategy is deciding on ads in newspapers or television, or do so only through specialized magazines, or a mixture of all of them with a mailing of information to a population target.

- **The strategy on logistics**, must give way to the shape of the acquisitions of the key products of the department: the imaging or therapy equipment. The work of the consultants of equipment, or the group specialists that form the society, should lead to the drafting of specifications that allow providers to offer adequate systems and to the purchasing team compare and negotiate the best terms of delivery for the department, in quality, price, delivery times, warranties and maintenance.

- **Policies**, to apply the same items than in the strategies. Following the example of the communication policy is focusing more on one product that in another, or focusing communication in a type of tests, e.g. virtual colonoscopy, more in vascular resonance or CT multislice.

- **Programs**, detailing those beginning with the development of planning and those that will remain for the project and execution phases. Major programs are the purchase of land, estimates of construction and equipment purchase. These programs begin at this stage and should finish with it to avoid delays in the design, but programs such as the hiring of technical image acquisition systems operators can begin in this phase and continue in the phase of design and finish them at the end of the implementation phase. The staff must be hired at the beginning of the equipment operation training.

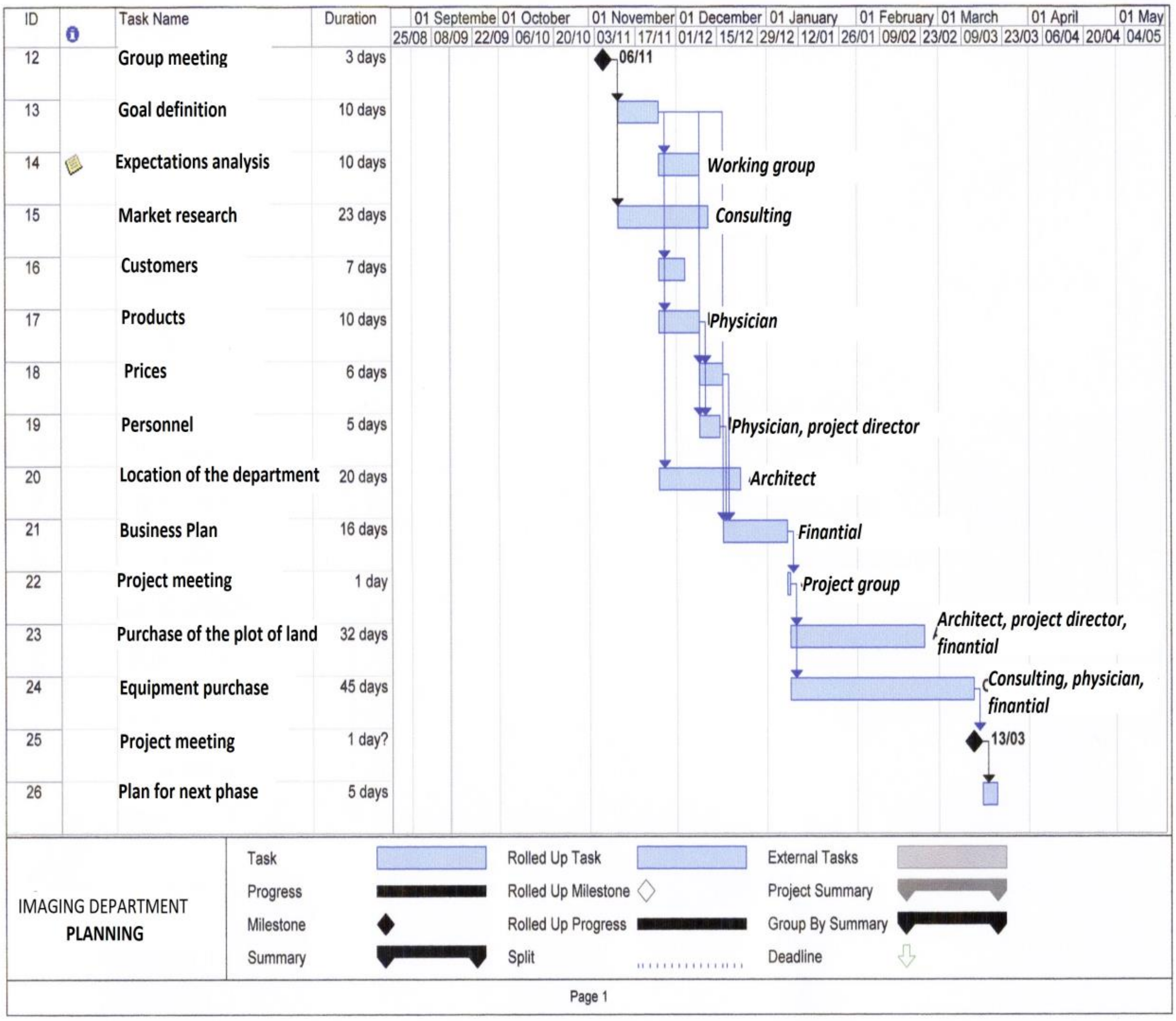
- **Procedures and rules** for development of planning and communication between the different working groups. They are necessary for the understanding of the working groups. Appointments and minutes of meetings, their writing formats and people for distribution, the procedure of sending, etc.

- **Budgets**. Full and partial project of the land parcel, equipment, construction, installations, and the annual plans of operation.

  At this stage should be clear the funding sources, may be public, with their annual budgets, or private, either bank, or contributions of shareholders in money or endorsements. The task of attracting financial resources can be widened until the end of the design stage, which may put at risk the project if there were failures in financial contributions, but it has to be completed in this phase because must have resources to pay the solar (local or building) and the equipment and have to tackle imminent costs of the construction beginning with the execution**.**

- **Rules and controls to be applied**. Fulfillment of tasks, dates and budget controls**. Measurement of deviations and delays and possible corrections. Impact on plans and budgets.**

- **The planning phase** ends with the approval by the administrator of a business plan for the operation of the department and a plan of action for the following phases of the department project and the implementation phase. The acquisition of land or buildings to locate the facilities and the purchase of equipment to be installed in the building to be built or in the buildings to be purchased, which must be conditioned, are activities that must be completed in this phase of planning .



(11.8.-GANT diagram in the planning phase)

Population	Freq.	Exams	%	Nº Ex/room	Aver.prod. *(1)	Nº rooms	Surface m2	ft2	Surf.(1) m2	ft2
		RD	64	102.400	26.250	4,0	20	215	80	861
		Fluoro	3	4.800	5.250	1,0	25	269	25	269
		Ortopantot.	1	1.600	13.125	1,0	8	86	8	86
		Bone Miner.	1	1.600	7.875	1,0	15	161	15	161
160.000	1000	Mammogr.	4	6.400	7.875	1,0	12	129	12	129
			73							
		CT	8	12.800	10.500	2,0	30	322	60	645
		MR	8	12.800	6.300	2,0	35	376	70	753
		Ultrasound	10	16.000	5.250	3,0	15	161	45	484
		Vascular	1	1.600	1.575	1,0	35	376	35	376
			27							
			100	160.000		16			350	3.764
		Net examination surface							350	3.764
		Gross department surface			**Regional Hospital**				2.100	26.348

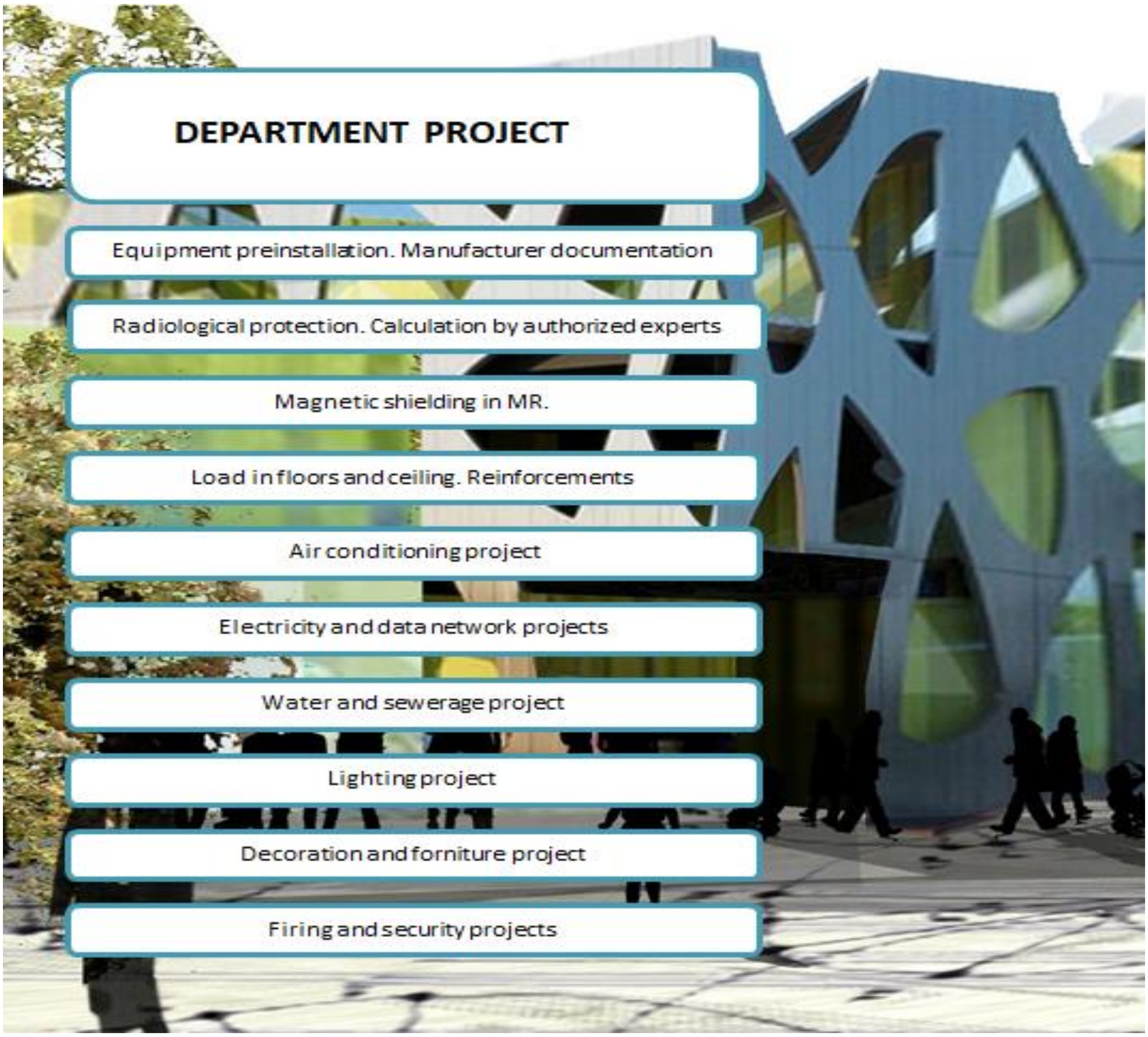
XI.III.- DESIGN

This phase is the busiest for the architecture, engineering and medical working groups. The first have to prepare the department project in order to build later, engineering has to do projects of each technical specialty in the department and the medical equipment technicians checking their clinical needs already specified in the phase of planning and develop the functional plan which will operate the department under the clinical point of view.

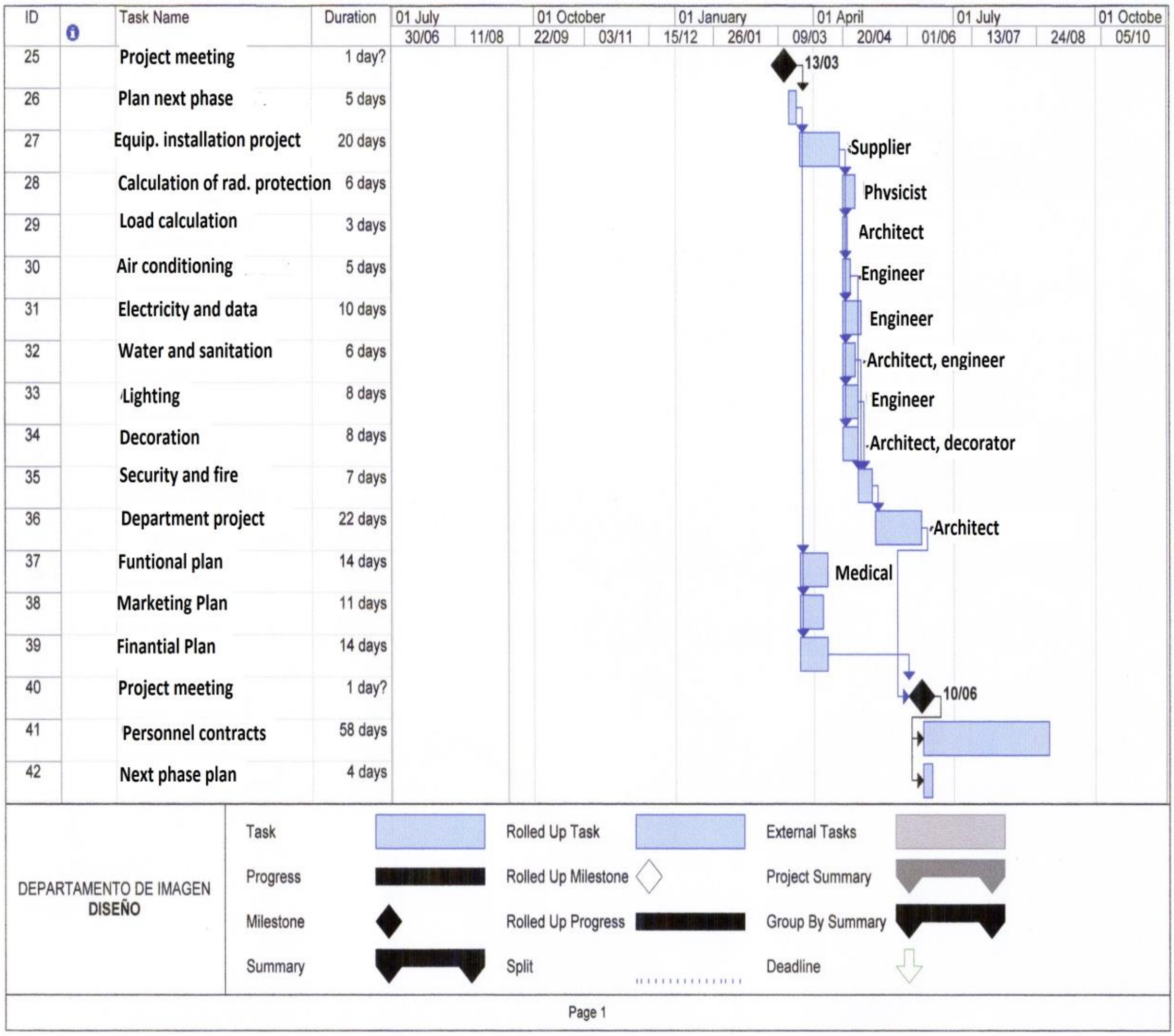
The architect or architecture studio already has the basic data to begin to prepare the project of the of imaging or radiotherapy department, as they know the site on which there is to design a building, or the building where you have to locate the department and knows which equipment have to include the design, and for its work of project preparation in particular they will need:

- Documentation of the equipment manufacturer for pre installation, basic information needed to hire subprojects of civil engineering.
- Design by the consultants of the diagram of the department in image blocks.
- Calculation of barriers of radiological protection by the authorized personnel of the rooms with ionizing radiation.
- Calculations of magnetic protections in magnetic resonance, as well as the electromagnetic and acoustic.
- Calculation of loads in floors and ceilings (and walls). Study of the necessary reinforcements in the structure. Study of the pathways to move the equipment.
- Electricity power supply project, data network and telephone, sound, etc.
- Project of water and sanitation networks.
- Lighting project.
- Furniture and decoration project.
- Security project. Against fire, theft, water, electricity, etc.

The time employed in this work varies depending on the complexity of the department and can range from a month in simple installations until several months in complicated departments. This simplified analysis can be systematized in a series of steps that would undoubtedly help the coherent development of the overall project.



(11.9.Subprojects)



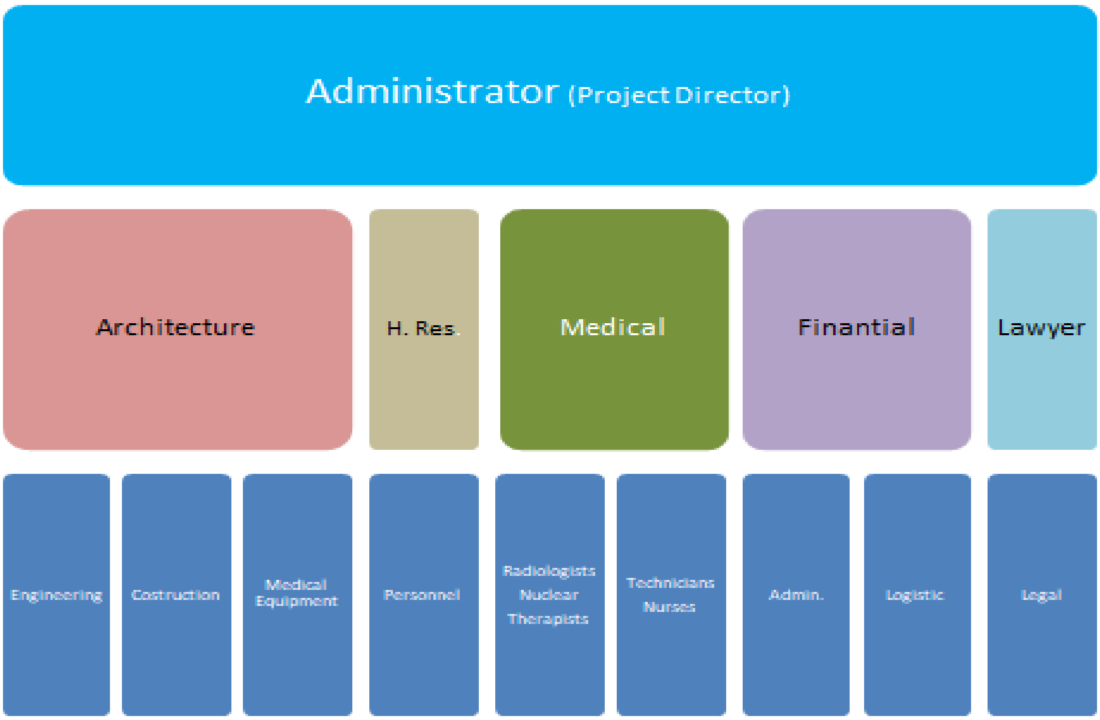
(11.10-GANT diagram of the design phase)

XI.IV.- EXECUTION

Once the project is written, and with all authorizations already cited, the first task is to hire the civil works, either in a hospital, in a building of new construction or rehabilitation. The procedure for this will depend on the institution and varies from the public tenders regulated by the laws of each country, to requests for direct offers to the builders, as happens in the private corporations.

Technical specifications for manufacturers offering the equipment are a part of the project itself and administrative specifications, such as prices, terms of delivery, warranties, etc.., they can be drafted by consultants together with the architecture team and accepted by the administrator.

The design team is broader than existing in the initial phase, and with some distinctions. Consulting tasks have been, or must have been, resolved in the planning phase, only now clarifications or minor modifications may be required, and begins the task of builders, guided by the architect, engineering companies and suppliers of equipment.



(11.11.- Team of the design phase)

With the department project completed and reviewed by the architect or architecture team, and accepted by the administrator, can start the following tasks:

- Permissions for installation of the center.
- Permissions of the civil works of the local authorities.

- Permissions of the radiation protection authorities.
- Offers of works contractors.

Local authorizations are tedious and in some municipalities complicated, the project manager must schedule these tasks with resources for the management with the local authorities, and sometimes national, to not expand excessively times of permissions for the project. Licensing costs and construction supervisions from local o regional authorities must be calculated in the budget.

(11.12.-Authorizations)

Radiation protection authorities are very careful in the implementation of departments, even more in nuclear medicine and radiotherapy, and in these two latter cases may excessively delay the phase of work. A bunker should not be started for a LINAC without the approval of the authorities in radiological control by the risk of different criteria of calculation and subsequent reinforcement of walls. There are also fees payable to regulatory agencies, which must be calculated in the budget.

(11.13.- Actions in the implementation phase)

Builders are ready to bid quickly, and the request for proposals can begin as soon as the design phase is completed, so this task can run simultaneously with the tasks of obtaining permits. Only small deviations can occur, if the planning has been correct. And after these steps the executive team headed by the administrator or project manager can:

- Hire the civil work and begin the **process of building** of the department.
- Completed civil work, made its **quality control** and accepted by the property, the equipment suppliers can begin to install the equipment.
- Finally once installed and completed acceptance tests**, training of staff** can begin to complete the global department project.

The civil work of one department's image, in the majority of cases, is not a long task, other case in radiotherapy. It is complicated and meticulous, needing the constructors continuous help from suppliers to meet the requirements for the installation of equipment; otherwise leads to delays and increases in costs in works by demolitions to impossibility of equipment installations, or inability to start up, as in the case of insufficient air-conditioning, or inadequate equipment cooling. Magnetic resonance imaging does not work, i.e. without proper cooling. If the department is in a hospital, for a size medium, a construction time between three and four months are acceptable. In a private a computed tomograph that take the average of a month, with good coordination, is reasonable.

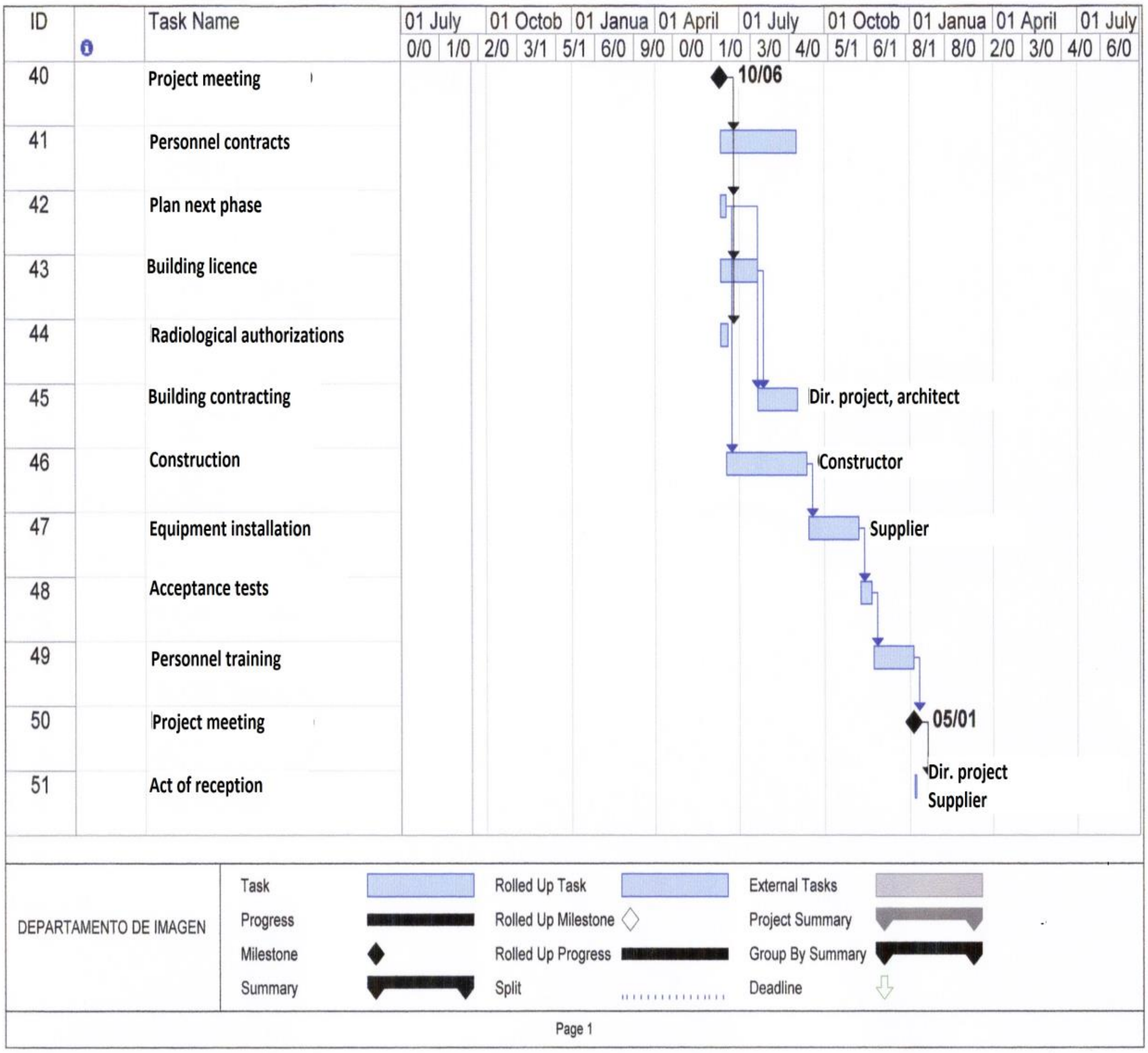
It requires a continuous monitoring of the architect and engineering teams and report weekly to the administrator or project manager for evaluation of times/costs and corrective action, if required.

Recruitment of staff tasks can encompass this activity.

Final certification of the architect occurs as soon as the equipment have been installed and running without problems relating to construction, so still will have to wait for the completion of the installation and start up to begin periods of warranty for building and installations, unless otherwise agreed between property and contractors.

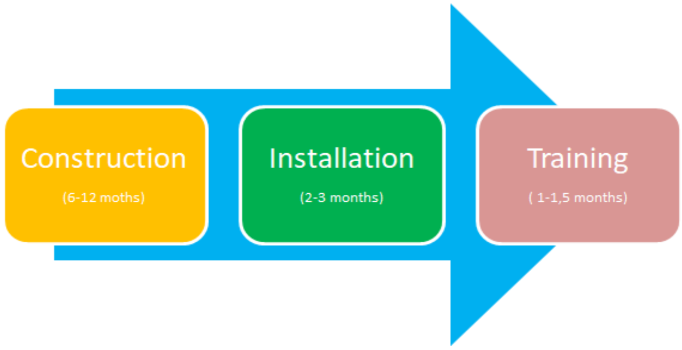
Installation of diagnostic imaging or radiotherapy equipment can begin when the work is completed and operating facilities and quality control of work and facilities are accepted by the administrator. The rooms should be clean, electricity available, electrical panels according to requirements of manufacturers and supplies of water, gas, air conditioning and refrigerators running.

An **Installation Plan** developed in the design phase, must be put in place by the equipment supplier. It includes the dates of installation, adjustments and acceptance tests of each room must be signed by the supplier and the technical manager of the administrator. Installation times of one to two weeks per room are acceptable, more for sophisticated equipment, and when it is a full department of medium size where the tasks can be synchronize, may be in the form that 14 rooms including two MRIs, two CT and a vascular Interventional can be installed in two months and finished all acceptance test in an extra month, if all the conditions of construction and facilities met with correction.



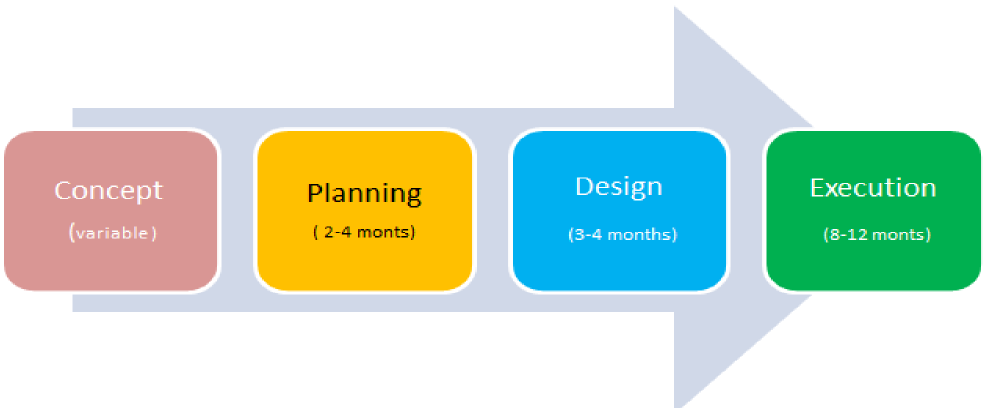
(11.14.- GANT of the execution phase)

The **Training Plan**, agreed between the administrator and the supplier or suppliers will start as soon as the equipment and personnel are available. Includes training on equipment to doctors, technicians, computer staff, maintenance personnel and administration (RIS-PACS) and can range between a month and a month and a half in total. Continuous training may be required for specific software and programmed with more time, depending on the strategies and action policies of the administrator.



(11.15.- Execution phase sequence)

Considering all time, at this stage of implementation, adding times of authorizations, with well-defined programs and activities, are needed between eight and twelve months to complete this phase of the project, so it is necessary to calculate detailed times in the planning stage and the design costs. The different phases of the project are running with a total development time that rarely can be less than year and a half.



(11.16.-Projecy development time)

In projects of nuclear medicine and radiotherapy the authorization request times may be even greater due to the actions of regulatory agencies, and these projects may need longer term planning.

The time of development of the concept is very variable. There are ideas passing to practice in a month, and others that require a year or more until the promoters find an organizational channel and a form of viable funding for partners or a technological development of their idea with better commercial or administrative possibilities.

XI.V.- METHODOLOGY FOR FOLLOW UP AND CONTROL

The duration of a diagnostic imaging or radiotherapy project is a function of its complexity, but in general is long, with many activities to develop for the total execution of the project and the achievement of the objectives. In the development of these tasks or activities can be produced many deviations in its development and expand the duration of the project in significant deadlines. The increases of time in the development of activities tend to lead to increases in costs, either for costs of the staff involved in the project or cost of material resources involved in it. The higher costs to be considered in a project of this type are the equipment and construction, in that order. A delay of two years in the development of a medium project may cause an increase of ten per cent in the costs of equipment and this can be harmful to the budget of the project, if we add the labor and construction costs. We must not forget the increases in opportunity costs. Technological changes are fast, as we have seen, and a delay of two to three years may cause to a plan with technology in their average life cycle or end, that at the completion of the project may be the technological obsolescence that will cause a greater damage to the project.

Control of the time limits for the implementation of the project is therefore, an important task for its development and requires significant attention by the director of the project to ensure the fulfilment of the objectives set out in the planning stage.

The multitude of tasks or activities, in which the overall project can be decomposed require tools for proper monitoring of compliance with deadlines and resources that surround these tasks. With all of these are controlled deadlines and resources costs, which ensures the budget and the time of completion. There are situations in which the attached contingencies to the project, are not always controllable, and do not allow the development of any activity, e.g. refusal to sell a property, is agreed prior to the installation of the equipment, in which case there is to rethink the activity and the duration of the project. Also in these cases it is favorable to the existence of follow-up and control mechanisms that allow quickly take of alternative paths, or program them previously if it is notice that they are on the critical path. How much longer is a project more need for planning, monitoring and control, because objectives may be not too well defined having difficulty in getting over a long period of time, which should be planned. The main purpose of project planning is to divide the overall objectives into manageable tasks that can be performed in relatively short periods of time.

The condition that must meet a task, or activity, to be included in planning schemes is that it contains the following elements:

- A defined working field.
- A duration defined by a start and a termination dates.
- Resources used to fulfill the task clear and defined.

Management tasks in phases and in full programming can be done with different procedures, or tools of project planning, employed by the majority of all the professionals involved in the management and execution of any type of projects.

PARTIAL OBJECTIVES FRAME

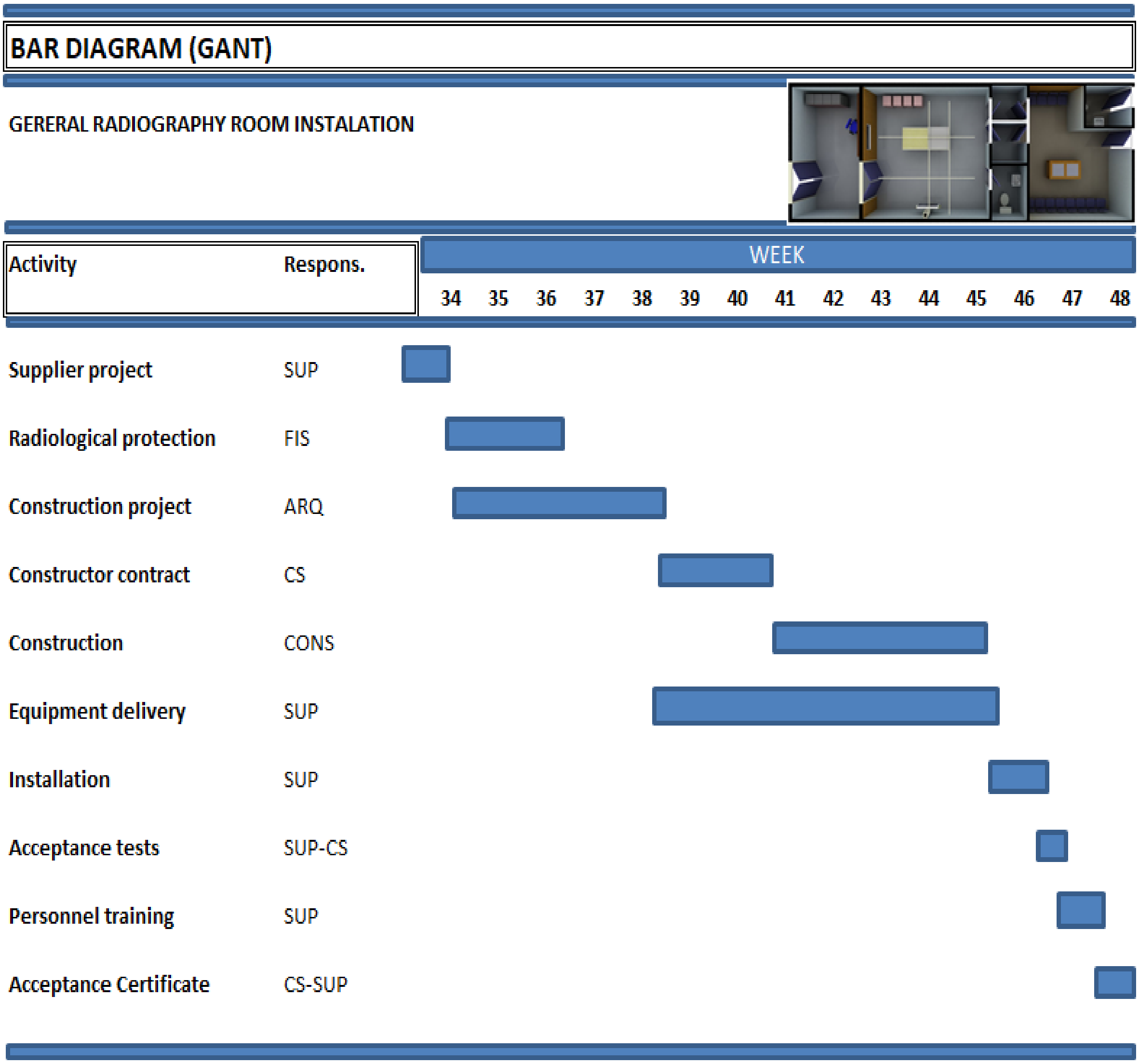
GENERAL RADIOGRAPHY ROOM INSTALLATION

Activity	Responsable	Date of termination	Real date of termination
Supplier projects	*Supplier*	**30/08/2009**	**V**
Radiological protection	*Autorized physical*	**15/09/2009**	**12/09/2009**
Construction project	*Architect*	**30/09/2009**	**V**
Construction contract	*Health Center*	**15/10/2009**	**V**
Construction	*Constructor*	**15/11/2009**	**V**
Equipment delivery	*Supplier*	**17/11/2009**	**19/11/2009**
Installation	*Supplier*	**25/11/2009**	**V**
Acceptance tests	*Supplier-Health Center*	**27/11/2009**	**V**
Personnel training	*Supplier*	**02/11/2009**	**V**
Acceptance Certificate	*Health Center-Supplier*	**04/12/2009**	**05/12/2009**

(11.17.-Partial objectives)

For very simple projects, e.g. the installation of a radiographic room, can be used the simpler procedure, which is the call of Partial Objectives. It consists in identifying the expected date of completion of each activity of the work schedule, the name of the responsible person and at the end the planned date of completion of the activity.

The method is simple and useful in projects with few activities, few interrelated people, and short development times, or, as a summary of activities in complex projects and short development times.



(11.18.-Diagram GANT)

The drawback is that it only shows the dates of completion and does not display the resources involved in each activity. These data are not always required by what may be a valid tool in such cases.

A procedure that solves some of the drawbacks of the tables of partial objectives is the bar chart, or method of GANT, which is possibly the planning tool most used by the professionals of projects. The method consists of the configuration of a list of tasks that occur in the left side of the graph followed each of a horizontal bar indicating the expected date of start and end of each task.

The main disadvantages of GANT diagram is not showing the interactions between the different tasks or do not show the critical activities for the completion of the project within schedule. Despite these drawbacks is the method most used to middle rank projects. A solution to these problems has it the PERT method and a variant of this, the CPM method, or the Critical Path Method.

The method PERT begins identifying the overall tasks to be carried out in project and then they are interrelated each other.

The graph can be built with the description of activities and their start and end dates. In this method it is possible to insert more information, not only the start and end dates but also the number of hours required per activity and the responsible for its implementation.

In addition to the control of the project several dates of meetings or reviews and the milestones of the project are introduced, so activities, time and costs can be adjusted.

The graphic representation allows to define points where delays could jeopardize the project. These milestones are more easily shown on this diagram.

Each segment has inserted the start of activity, completion dates and down the number of the activity with the hours of work required.

A variant of this is the CPM method or Method of the Critical Path that follows this path in the project once defined the interrelationships between tasks.

The programming methods are currently well implemented in computer programs that facilitate the task of their drawing. The most popular is Microsoft Project in which are already described the previous paragraphs related to the development of the phases of the project.

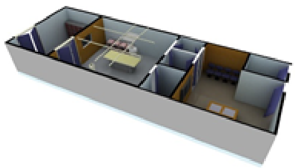
PERT CHART

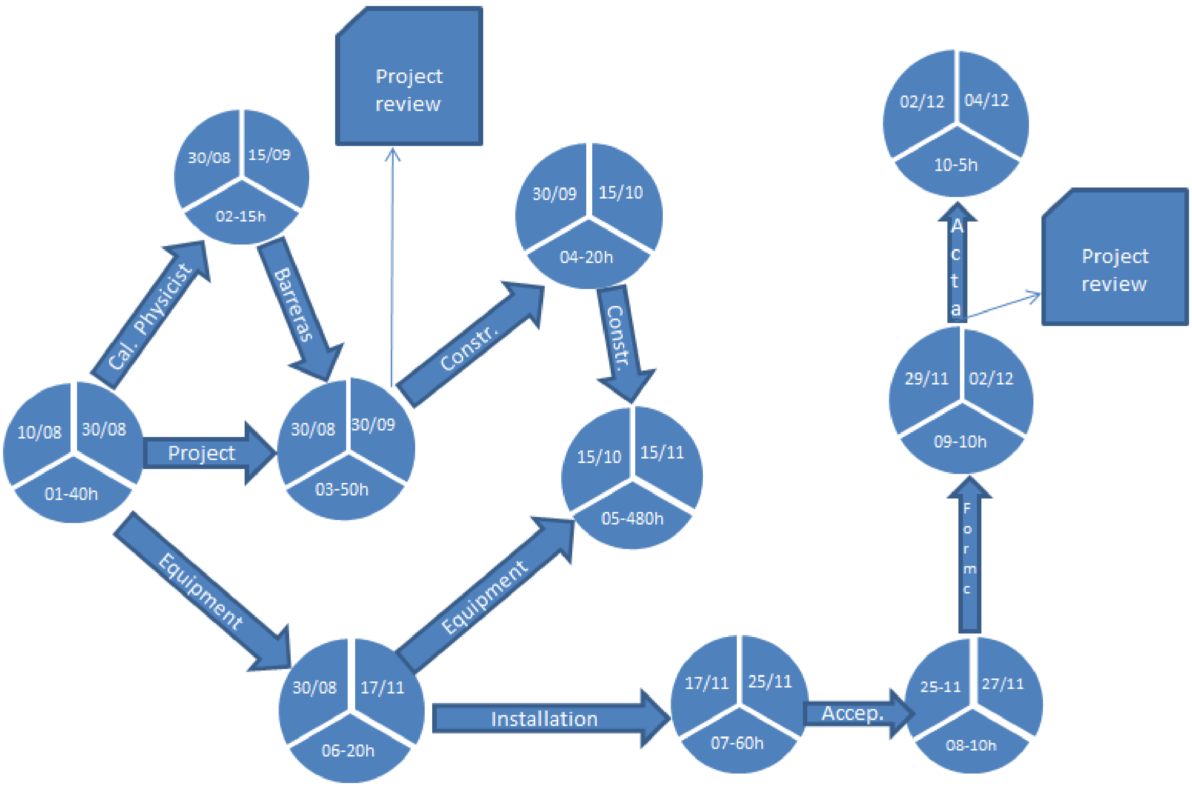
CONVENTIONAL RADIOGRAPHY ROOM INSTALATION

Activity	Activity Number	Responsable	Date Start	Date Finish
Supplier project	**1**	Supplier	**10/08/2008**	**30/08/2008**
Radiology Protection	**2**	Authorized Physical	**30/08/2008**	**15/09/2008**
Construction project	**3**	Architect	**30/08/2008**	**30/09/2008**
Constructor contract	**4**	Health Center	**30/09/2008**	**15/10/2008**
Construction	**5**	Constructor	**15/10/2008**	**15/11/2008**
Equipment delivery	**6**	Supplier	**30/08/2008**	**17/11/2008**
Installation	**7**	Supplier	**17/11/2008**	**25/11/2008**
Acceptance tests	**8**	Supplier-Health Center	**25/11/2008**	**27/11/2008**
Personnel training	**9**	Supplier	**29/11/2008**	**02/12/2008**
Acceptance Certificate	**10**	Health Center-Supplier	**02/12/2008**	**04/02/2008**

(11.19.- PERT chart)

PERT- Conventional Radiography room installation





(11.20.-Diagram PERT)

XII.- STANDARDS AND RECOMMENDATIONS

I. RECOMMENDATIONS IN RADIOLOGY

II. RECOMMENDATIONS IN NUCLEAR MEDICINE

III. RECOMMENDATIONS IN RADIOTHERAPY

IV. RECOMMENDATIONS IN MAGNETIC RESONANCE

V. ARCHITECTURAL LEGISLATION

VI. COMPUTING STANDARDS

Everything seems impossible until it is done (N. Mandela)

XII.- STANDARDS AND RECOMMENDATIONS

Medical electronic engineering has achieved the milestone of rotate the tube and detectors housed within the gantry of a CT in a quarter of a second. It represents a great impact to be able to acquire the volumetric image of the full heart of a patient in a cycle of the electrocardiogram, opening a final door to the non-invasive cardiology diagnosis.

According to publications of ICRP (International Commission on Radiological Protection - ICRP 87) the effective dose in CT's chest is in the order of 8 mSv (around 400 times more than the dose of a chest x-ray) and some CT exams as the pelvic region can be around 20 mSv. Doses absorbed by tissues with the CT can often reach or exceed the known levels that increase the likelihood of cancer as it is known by the epidemiological studies. There are today mechanisms of dose reduction in the CT to mitigate these problems, but more measures are additionally required to protect patients and staff.

After the great impact of imaging techniques with the use of ionizing radiation, its biological effects were dating, what gave rise to the regulation of the activities of installation of equipment, transport, application of the roentgen rays and handling of radionuclides, so there are safety requirements for patients, health workers and other people in the environment, which allow us to use these techniques without taking unnecessary risks. This regulatory action has led to a set of laws and regulations that must be complied, standards and recommendations in the different countries, allowing to the population enjoy the benefits of the use of ionizing radiation in diagnosis and therapy with a high degree of safety.

The introduction in diagnostic imaging the MR technique also needed recommendations so that its application is safer, avoiding the risks of intense magnetic fields that are used and high amplitudes of radiofrequency applied to the human body. Thermal deposition limits, are designed to control RF applications and avoid the burns observed at the beginning.

The ultrasound is the most harmless of all techniques although there are recommendations in the construction of equipment that defines the boundaries of power in diagnosis and therapy, which just involve minimal limitations on the use of this technique that can affect the ultrasound imaging room.

Radiology Information systems (RIS) and communication (PACS) and file systems also have their own building standards, directed rather to the specifications of the equipment than to facilities. Electrical installations are regulated in each country by the corresponding low voltage electrical codes, so the rooms are subject to regulations and national standards.

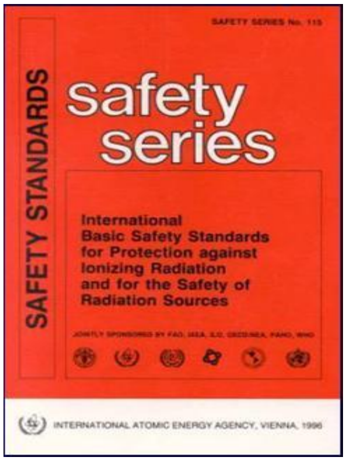
Lighting, signage of the rooms, air conditioning, also have their standards, and mandatory codes that must be observed by the designer in each project, with each national standard. All legislation, regulations and rules that must be complied within each country, had common roots in standards and recommendations of international organizations that have developed them and update regularly, collecting the technical advances and the improvement of scientific knowledge. Will be described rules and most important recommendations in each imaging technique and every technology that is involved in a imaging or therapy room in order to visualize the general framework to be applied by each designer, installer or manufacturer in its work, taking into account who must observe and comply with the laws, regulations and ordinances in the realization of their projects.

The concern about protecting workers has existed since the beginnings of the use of ionizing radiation, but what has remained without normalizing for decades has been the protection of patients. In the 80's the International Commission on Radiological Protection issued its first recommendations to protect patients in radiology, nuclear medicine and radiotherapy. The European Union established in 1984 the first directive on protection in medical exposure (exposure for diagnostic or therapeutic purposes) and later revised and expanded in 1997.

The first **international Basic Standards** of United Nations bodies, i.e. those published by the **International Atomic Energy Agency** are from 1962 and they had several revisions, all of which is envisaged in detail protection to workers but is excluded the protection in the exposure of patients. Finally, the current version, that of 1996, included detailed requirements for medical exposure. It is the **"International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources"**, published as IAEA Safety Series No. 115 (the BSS).

The BSS represent the culmination of efforts to achieve the international consensus towards the harmonization of radiation protection and safety standards and are jointly sponsored by the agencies of the United Nations, i.e. FAO (Organization of Food and Agriculture of the United Nations), IAEA (International Energy Agency atomic), ILO (International Labor Organization), PAHO (Pan-American

Health Organization) and the World Health Organization (WHO), together with the OECD Nuclear Energy Agency. The purpose of these standards is to establish basic requirements to protect people against the risks of exposures to ionizing radiation and for the safety of radiation sources that can produce these exposures.

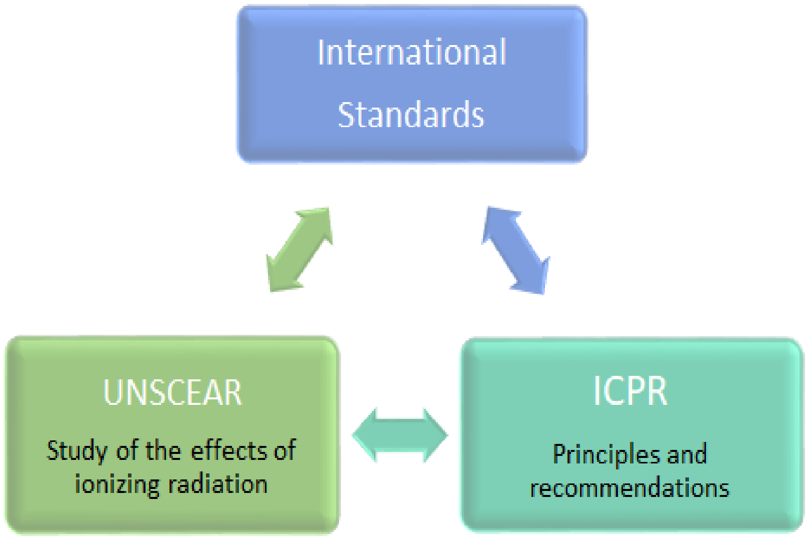


(12.1.- Security standards)

Basic international standards have a solid foundation, are based on two pillars:

- On one side, in the knowledge of the effects of the radiation that regularly collects, analyzes and disseminates the Scientific Committee of the United Nations on the Effects of Atomic Radiation, (UNSCEAR), which has a scientific and intergovernmental character.
- And other side on the basic recommendations of the ICRP (International Commission on Radiological Protection), a non-governmental scientific organization founded in 1928 by the International Society of Radiology, to establish the basic principles and the recommendations on radiation protection (26). Quantities and units used are those recommended by the International Commission of Units and Measurements of Radiation (ICRU), an organization established in 1925, at the first International Congress of Radiology.

The rules establish basic requirements for all activities related to the exposure to radiation and although they do not constitute a direct obligation of adopting them by the States Members, are written and agreed by the States in a way that serve them a basis in drafting its laws and regulations. Finally, the requirements are intended to be complied with by the departments, entrepreneurs and workers, bodies specialized in radiation protection and health and safety committees. In the preamble, international standards clarify that only can be applied effectively if there is an effective security infrastructure that includes the appropriate laws and regulations, an efficient regulatory system, experts support and services, and a security culture shared by all who have responsibilities in protection, including managers and workers. And this is what have been created by many countries, today with proper systems of safety and radiation protection.



(12.2-Design of International Standards)

- **The radiological protection expert** is the element of union between the legal owner of the installation and the public administration that legalizes the installation registering it or giving the corresponding license. This expert takes different name depending on the country but can be defined as a person who (according to the International Association of Radiological Protection IRPA):
  - Have education or experience equivalent to a graduate or master's degree from an accredited college or university in radiation protection, safety to radiation, biology, chemistry, engineering, or a science closely related to physics or biology.
  - It has acquired competence in protection to radiation, under special studies, training and practical experience. Such special studies and training must have been sufficient in the above mentioned sciences to provide skill and competence for:

1.- Anticipate and recognize interactions of radiation with matter and understand the effects of radiation on people, animals and environment.

2.- To assess, at the base of training and experience and with the help of quantitative measurement techniques, the magnitude of the radiological factors in terms of its ability to affect human health, well-being and the environment damage.

3.- Develop and implement, based on training and experience, methods to prevent, eliminate, control or reduce exposures of radiation to workers, patients, public and environment.

In most of the countries the competence of experts in radiation protection needs to be recognized by a competent authority to provide these professionals of certain responsibilities in radiological protection. Also the BSS define the responsibilities of the holders of authorizations, entrepreneurs or employers, workers, supervisors and operators, as well as the practices carried out.

- **Authorizations**

It is easier and much less expensive to incorporate security features into the design phase of the facility, that rectify deficiencies when everything is finished and working. It is needed, therefore, a system of authorization enabling the authorities to make sure *a priori* that each specific installation conditions are given to meet the regulatory requirements of security. According to their level of risk and the importance of the installation two types of authorizations, **registration and licensing** may be required.

National or local registration of radiological equipment, is a way of authorization in which is enough that the installation has been registered. This simplified system of authorization is sufficient for simple installations, whose security will be guaranteed by design and by the equipment, the use of procedures are simple and standardized, and not an extensive training is required to operate with them.

Licensing is a more detailed form of authorization, which requires an individualized analysis for more complex installations. Also if the construction of them is complex in relation to safety, usually require the authorization in two phases, prior to construction and commissioning underway, respectively. Typical example of such facilities are those of radiotherapy.

Purpose of radiological protection

The purpose of radiation protection is to allow the benefit derived from the use of radiation without undue risk to people who are exposed. The undue risk is composed of two components:

- Deterministic effects (direct radiation).
- The possible induction of cancer in the long run, of probabilistic nature.

The basic principles are aimed to prevent radiation and reduce the likelihood of cancer as much as reasonably possible. These principles are:

- Justify the practices, so the use of radiation have a benefit greater than the risk that introduce.
- Optimize the protection so that exposures as low as reasonably possible.
- Set dose limits for people who are exposed.

- **Types of exposure according to exposed persons**

From the point of view of radiation exposure, the groups of people are:

- Workers who are exposed because of their employment (occupational exposure).
- Patients, exposed by his own diagnosis or treatment (medical exposure).
- Members of the public (public exposure).

The following table presents the dose limits for occupationally exposed workers and for members of the public. Dose limits do not apply to patients exposed to his own diagnosis or treatment**.**

	Occupational exposure	Apprentices from 16 to 18 Years old, in pre-job information and students of the same age range	Exposure of the members of the public
Effective dose	*20 mSv per Year averaged over 5 consecutive Years* *50 mSv in one Year*	*6 mSv in one Year*	*1 mSv in one Year.* *In special circumstances can reach to 5 mSv in one Year as long as de average dose not exceed 1 mSv per Year*
Dose equivalent to lens of the eye	*150 mSv in one Year*	*50 mSv in one Year*	*15 mSv in one Year*
Dose equivalent to the extremities (hands, feet or skin)	*500 mSv in one Year*	*150 mSv in one Year*	*Dose equivalent to skin of 50 mSv in one Year*
Dose limits			

(12.3-Radiological dose limits)

- **Overview of the dose limits**

The requirements to protect persons against ionizing radiation are aimed to make good use of the three elements which can make to decrease the amount of radiation that is absorbed into the body:

1. Increase as much as possible the distance to the source of radiation
2. Reduce the time during which the person is exposed
3. Locate faders of the radiation (shields) between the radiation source and the people.
   This is known as the rule of the three variables, distance, time and shielding.

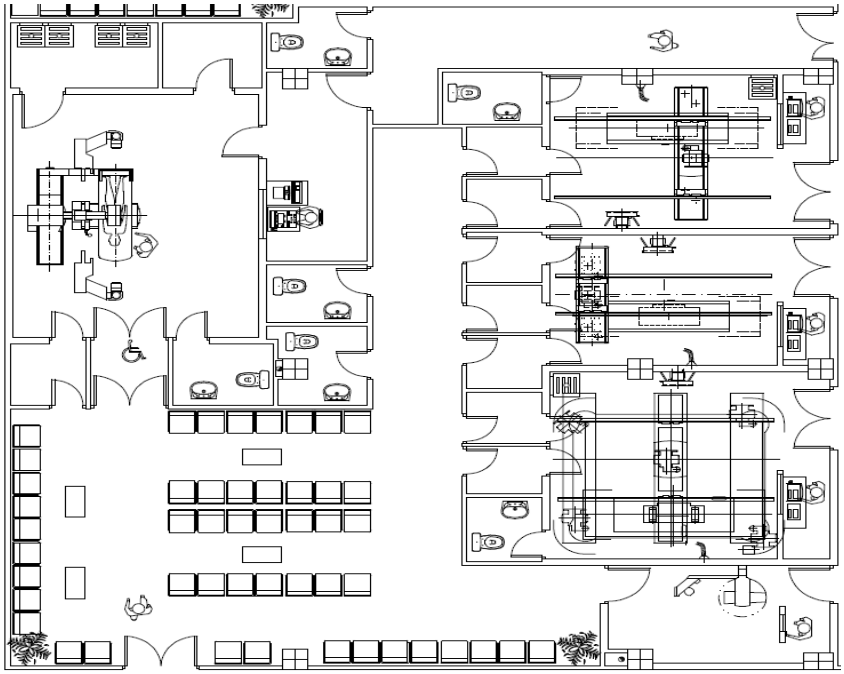
- **Requirements on occupational protection**

The dose limits ensure that will not be exceeded any threshold that can cause radiation injuries, but must also ensure that the protection is optimized, i.e. that exposure is reduced as much as it is reasonably possible, with good use of distances, time and shielding. This good use will be get fulfilling certain requirements that can be summarized in a combination of measures such as: proper assignment of duties and responsibilities, classification of work areas, rules and procedures, as well as monitoring to ensure compliance, use of dimmers of radiation, such as structural and personal shields, such as aprons in situations in which these are needed, control of individual radiation doses and environmental doses in work zones.

Zones are classified into: controlled and supervised.

- **Controlled**, are those in which may be required mediated specific security to control normal exposures, the possible contamination, and prevent or mitigate accidental exposures. The controlled areas should be, whenever possible, delimited by physical media, and marked with symbols of caution, as the symbols of the International Organization for Standardization (ISO). Also the staff must have at the entrance clothing, protective equipment and media to monitor radiation doses. As an example the x-ray rooms are controlled areas and also areas where mobile x-ray equipment used may be considered as controlled during the time that occurs in these areas radiological work.

- **Supervised**, those that without being classified as controlled requires that the occupational exposure is maintained under supervision, although specific measures of protection and security are not needed. They must be delineate and delimit with appropriate means and show signs in the appropriate points of access to the supervised areas. For example, the areas around the x-ray rooms can be supervised areas. Most of the areas for personnel fall into this category, not by the level of radiation, but because of the possibility of any person enter in an x-ray room in form inadvertently.



(12.4- Controlled and monitored areas in a block of conventional Radiology)

- **Requirements on protection in medical exposures**

Essentially, medical exposure are primarily the ones that patients receive in their own diagnosis or treatment, but also include expositions of other people, that cannot be classified as occupational or public. It is the case of the family which are exposed to help or comfort to a patient and the individuals who voluntarily expose themselves for biomedical research. The principles of justify and optimize apply also to patients but the third principle, that of the dose limits, does not apply them since his own diagnosis or treatment needs are incompatible with fixed limits.

Medical exposure has some other particular aspects so the international requirements of the BSS assigned overall responsibility for the protection of patients to physicians, they are who can decide whether they are justified, and also decide measures to enhance protection. In the task of optimization, collaborate with the physician other professionals, such as medical physicists, who have specific responsibilities in the calibration of the beams of radiation, the physical aspects of quality assurance and patients dosimetry.

The international requirements laid down that the design of equipment, both if they are manufactured in the country or as if they are imported, have to comply with industry standards such as the International Electrotechnical Commission and those of the International Organization of Standardization or other equivalent national standards.

Optimize in medical exposure is not to reduce the dose as possible but giving only the necessary to get the diagnosis or the treatment effect. In diagnosis, reduce the dose to wishful thinking may compromise the proper diagnosis and in therapy may be needed to raise the dose to the target volume to control the malignant disease. The protection in medical exposure is priority to prevent accidental exposures in radiotherapy, radiation injuries in interventional procedures, reduce unnecessary doses in diagnostic procedures and reduce the dose to the normal tissue in radiation therapy.

- **Requirements on protection of the public**.

Authorization holders and responsible for professional services should know that they are also responsible for controlling the exposure caused to the public coming by radiological practice. The three elements of protection, distance, time, and shielding are essential in the protection of the public, so main protection measures are control of access to controlled areas, the design of the shield, along with the keys to control the operation of the equipment.

In the design of medical facilities it is necessary to take into account the constant presence of members of the public in the hospitals, which affects shielding calculation and the design of the flow of traffic in the hospital.

- **Shielding calculation. Directive 2013/59/EURATOM**

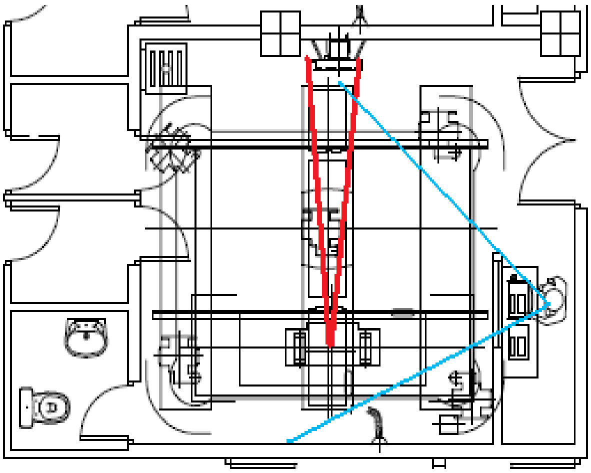
The transposition of this directive has been carried out throughout the European Union and is enforced from the beginning of 2018. Brand new standards on measures of protection to patients, staff and the public in general, and it should be noted in the design of each department by the need to integrate the data of doses received with imaging and PACS systems.

The increase in the frequency, and even more the frequency at CT has led to an increase in the radiation dose that patients receive, and therefore the probability of risk of radiation-induced cancer has also been increased, especially in children, since their life expectancy and the radiosensitivity of tissues is greater than in adults.
The directive emphasizes the need to justify the medical radiation, including exposure of asymptomatic people, and proposes stricter requirements for the information to be provided to patients, the recording and the notification of doses of medical procedures, the use of reference levels for diagnosis and the availability of indicator dose devices.

The following link provides more information to see details that influence the design and subsequent use of radiation emitting equipment.
https://www.csn.es/normativa-del-csn/normativa-ue

XII.I.- RECOMMENDATIONS IN RADIOLOGY

The International Atomic Energy Agency has published in its Safety Report Series, no.39 the implementation of safety standards in diagnostic radiology and interventional procedures using x rays, which contains recommendations on how comply the rules, and this document defines considerations to the design of x-ray rooms (29-31-19).



(12.5.- Areas of radiographic exposure in vertical wall bucky detector and vision of the operator)

The three relevant factors of reduction of dose (time, distance and shielding) must be combined in the design to enhance protection, for which wide rooms are preferred to allow easy access for patients in bed and to reduce the staff and public expositions, and at the same time allow the positioning of the patient and simplify the movements during the procedure, and in the case of fluoroscopy helps to reduce time and exposure. Examples of security measures are listed below:

- A control console barrier should be taken to protect personnel, making it unnecessary to lead aprons and other devices while the operator is working from the console.
- The design of the rooms must be such that the x-ray beam cannot be directed to any area that is not shielded. The dose received in this area would be unacceptable.
- The x-ray room is designed so that to avoid the direct incidence of x-rays beam in the access doors. The doors must be calculated to act as a protective shield for the scattered radiation and be closed when the x-rays are emitted.
- The operator needs to be able to clearly observe the patient for diagnostic x-ray procedure.
- A sign, such as recommended by ISO, indicating the presence of radiation must be attached to each entry to an x-ray room. It should also be a "controlled area" sign at the entrance of the x-ray room.
- It should be a warning light at the entrance of any room where there is one equipment using fluoroscopy or CT scan. The light should come on when x-rays are emitted.
- In all rooms with high workload in fluoroscopy, and with personnel close to the patient, such as interventional procedures rooms, is advisable to install protective leaded screens on the ceiling and on the support of the patient table.

The methodology for the calculation of the barriers of protection is described in different publications, being a very comprehensive the NCRP Report 147. The protection barriers must be calculated for the attenuation that they have to provide.

The thickness of the shielding is obtained from the attenuation factor that is required to reduce the dose that would receive the staff and the public if the shield were not installed, to values that can be considered acceptable or "optimized".

(12.6.- Protective screen with sterile cover attaches to the ceiling bracket)

Doses that could receive unshielded are calculated from values of workload, normally classified in mA min per week for the most relevant qualities of the radiation beam, taking into consideration the values of kV and filtration and occupancy factor of the area to protect.

For secondary barriers use factor is always the unit since radiation scattered and secondary spread in all directions.

Once known the dose that it would receive unshielded it is necessary to calculate the attenuation required to reduce this dose to a level deemed as 'optimized protection'.

All this shielding calculation is made with a certain number of conservative hypotheses, which are a matter of the actual dose being 1/10 to 1/30 of the calculated values of effective dose. The publication of the ICRP No. 33 clarifies that the typical conservative assumptions are:

- Not consider the attenuation of the patient and the image receptor.
- Overestimate the workload, use and occupancy factors.
- Assume that staff is always in the most exposed place in the room.

- Suppose that the distance is the minimum possible during all the time.
- Suppose that the scattered radiation is the maximum during all the time.
- Overestimate the size of the field used for the calculation of the secondary radiation.

XII.II.-RECOMMENDATIONS IN NUCLEAR MEDICINE

Following the same scheme described in the previous section, the IAEA has published the Safety Report Series No. 40, dedicated to the application of the rules of radiation safety at nuclear medicine. The paper briefly defines a typical department of nuclear medicine that requires the following areas:

- Storage and preparation of sources (radio pharmacy)
- Room of administration of radiopharmaceuticals to patients.
- Waiting areas.
- Imaging rooms.
- Measurement of samples (in vivo).
- Cabins and toilets.
- Storage of radioactive waste.
- Areas of disposable and decontamination.
- Rooms of patients with unsealed radionuclides.

In addition there are areas without radioactive materials, such as offices, rooms of reports and staff including changing rooms, showers and toilets.

The concepts to be considered in the design are: optimize exposure to external radiation and contamination, to maintain a level of background radiation low to avoid interference with the imaging equipment, meet pharmaceutical requirements and ensure security and control of radioactive sources (closure and control of the areas).

(12.7.- Gamma camera with two detectors)

The shielding should be calculated using the optimization of protection principles and taking into account the classification of areas, already described, the type of work and radionuclides to be used. It is convenient to try to shield the source, if it is possible, thereby decreasing the need for shielding of rooms and people. In general there is no need for structural shielding into the majority of areas dedicated to the diagnosis in a nuclear medicine department. However, the need for shielding the rooms at therapy non-sealed (to protect other patients and staff) and the rooms that contain sensitive tools, e.g. gammacameras and well counters (27) should be considered.

A safe and shielded storehouse for radioactive materials, should be envisaged. This can be a room or a space outside the areas of work or can be a refrigerator locked in work zones. Also separate compartments should be provided to store radiopharmaceuticals and an area to temporarily store radioactive waste. The need to avoid interference with the work in adjacent areas, such as the image counters should be considered in the design. The image rooms are normally not controlled areas.

The areas in which radioactive substances, such as the preparation of the sources, are handled must have:

- Means to prevent access by unauthorized persons.

- Adequate storage space for equipment that need to be available in the laboratory at all times, in order to control and minimize the possibility of contaminating other areas.
- A workstation for easy decontamination.
- Shielded storage for radioactive substances.
- Temporary storage for solid radioactive wastes and places designated for liquid radioactive waste, directly connected to the main service.
- Shielding to protect personnel where may be produced significant external expositions; area of washing for contaminated items, such as glasses.
- An area where can be put on protective clothing, or store and keep when not in use, and where they can wash and monitor.

The washbasin must be located in the area of low-traffic, adjacent to the work area. Faucets must operate without direct contact of the hands and disposable towels or hot-air drying. Must be installed a washing area of emergency for the eyes, next to the hands washbasin and must have access to a shower of emergency decontamination of people, inside or next to the lab.

Whenever possible, drains should go directly from the radioisotope laboratory sink into the main sewer of the building and must not be connected to other drains or sewers of the building pipes unless any of them also carry radioactive material. This is to minimize spreading contamination back to other areas not controlled. The final drawing of the sewer system, which is controlled by the maintenance personnel, must show what pipes depart from the nuclear medicine laboratory. The tubes through which flow radioactive materials must be marked to ensure that monitoring precedes to any maintenance.

Some countries require that tubes drains from the department of nuclear medicine and especially from the rooms insulated for patients undergoing radionuclide treatments up in a tank of delay. The ICRP in its publication 94, draws the following conclusions: *"the recommendations of the ICRP do not require that urine is stored. Storing urine of patients after therapy with radioactive iodine seems to have a minimum profit."*

Soils of contamination-prone areas should have finished with a waterproof material that is washable and resistant to chemical change, curved walls with all joints sealed and glued to the ground.

The walls should be finished in a surface smooth and washable, for example non-porous washable paint surface. A sign should be placed equal to the recommended by ISO on the doors, indicating the presence of radiation.

The surfaces of the room where used or stored radionuclides, such as benches, tables and seats should be smooth and non-absorbent, so that they can be cleaned and decontaminated easily. Supplies of gas, electricity and vacuum should not be mounted on top of the beds, but on walls or statives.

Soil and the benches, including work surfaces, must be sufficiently strong to withstand the weight of any necessary shielding or radionuclide generators.

Laboratories involving aerosols or gases must have a system of adequate ventilation, smoke bell, laminar flow or glove box. The ventilation system should be designed in such a way that the lab is a negative pressure compared to surrounding areas.

The surfaces of the toilets of nuclear medicine patients must be finished in easy decontamination materials. The hospital staff should not use the toilet of the patients due to contamination risks.

A gauge of activity of radionuclides and equipment must be available to monitor the workplace, including pollution monitor.

Must be available appropriate clothes of protection for staff, to be used in certain areas and that must not be carried to general areas of staff.

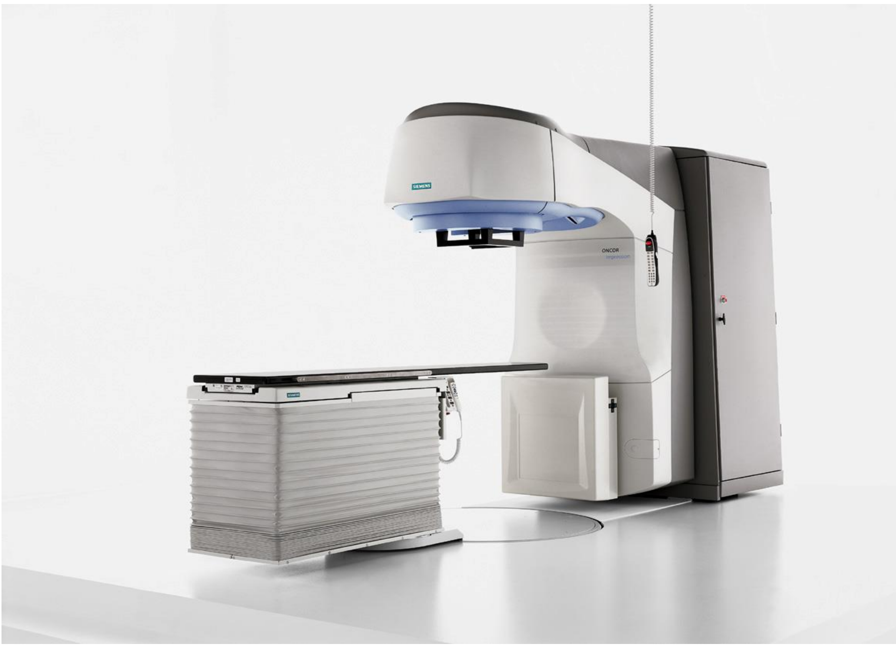
XII.III.- RECOMMENDATIOS IN RADIOTHERAPY

Following the same scheme described in the previous section, the IAEA has published Safety Report Series No. 38, dedicated to the application of the rules of radiation safety in radiotherapy, which describes, among many other aspects, those related to the radiotherapy facilities.

As a general rule, in the design of radiotherapy facilities must provide security systems or devices associated with the equipment and the rooms. This includes electrical wiring related with emergency switches, as well as safety interlocks and warning signals.

The design of the nominal dose in the occupied areas is derived from the process of optimization, in the same way already described in radiology and with the same conservative elements there cited (44).

Additional information for the design of radiotherapy facilities can be found in IAEA-TECDOC-1040 publications in the IEC Publication 61859.



(12.8.-Linear accelerator)

In the design of the rooms of manual brachytherapy, are required security arrangements for the storage and preparation of radioactive sources:

- The room should only be used to store and prepare radioactive sources, and by personnel appointed and prepared.
- It should be a sign of radiation at the door, which must have key for access control.
- Must have storage for all sources, and the outer surface of this must be made with fire-resistant materials. The system must be located next to the bank's preparation of sources to reduce the exposure of the staff during the handling and transfer of these.
- The system must have compartments for sources of different activities. Each compartment must be marked in such a way that it allows to identify quickly its contents from outside with a minimum of exposure.

- Work bench must be equipped with armor of lead blocks with a leaded glass window
- The source management area should be well lit and must have a fixed lens, to handle sources effectively and with minimum radiation exposure.
- Must have devices to handle sources, typically forceps, and a device for threading containers with supplies, with fingers protected at distance. The sources must be easily identified visually, as well as the different activities
- The surface of the bank for the preparation of sources should be smooth to prevent the loss of small sources, such as fragments of 192Ir threads.
- Must have a sink to clean sources with filters or caps to prevent its loss.
- There must be a clear indication of the level of radiation in terms of ambient dose equivalent by monitor area or meter during the handling of sources.
- Must have available containers with elements of safety and signaling.
- There must be space for container carts.

There must also be single rooms with structural shielding and phones for staff and visits.

You must have sterilization facilities for the applicators in the preparation or treatment rooms. The entrance area monitor must be there to detect if there is a source, or a patient with a source out of the room. And to ensure that does not remain any source with the patient, clothes or sheets, or in the area, after the treatment, must have a portable monitor.

In the cases of remote control high dose brachytherapy (HDR) and therapy with external beams, treatments must be done in rooms dedicated for this purpose within the department of radiotherapy, while remote low rate (LDR) brachytherapy can be made in the area of beds in which manual brachytherapy is performed.

Access to the irradiation room must have a detector with a visible sign indicating if the radiation source is connected or disconnected. In the door should be a lock or other suitable medium to prevent unauthorized access and a monitor of radiation area must be visible after the entrance to the room. The mechanism should be able to interrupt the irradiation until the door is closed and locked and verify that no person except the patient is in the room. After the interruption, if they have not changed or reselected the operating parameters, must be possible to restart the irradiation, but only from the control panel of the equipment. Should be conveniently located one or more emergency switches inside the treatment room to allow the interruption of the irradiation from the inside of the room.

The control panel must be installed in such a way that the operator has a full view of the irradiation room access at all times. You must have redundant systems so that the operator can see the patient at all times. There must be an intercom or other system of communication that will make possible the oral communication with the patient or who is in the treatment room. The presence of other personnel in the control area should be minimized to avoid distraction from the operator.

Fire-fighting systems must be available to preserve the integrity of the radioactive sources in case of fire. It must be a radiation monitor and portable detection instrument to confirm that the source is in the shielded housing.

By its very nature, the radiotherapy use very high doses of radiation that are intentionally given to human tissues. Errors and equipment failures can be fatal. Therefore, it is important to check on all radiotherapy service that the staff has in-depth knowledge of the lessons learned from the accidental exposures that have occurred around the world and how to avoid them. This information can be found in the ICRP, IAEA publications and teaching material that can be obtained free of charge in:

http://rpop.iaea.org, searching in "training" and "free material" and in http://www.icrp.org/

XIV.- RECOMMENDATIONS IN MAGNETIC RESONANCE

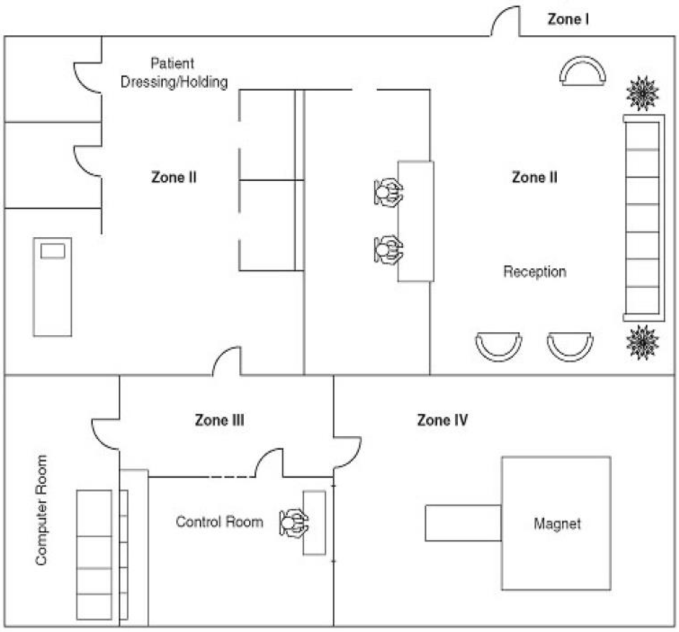
The diagnostic technique with magnetic resonance, continuous the progressive increase in its use and according to the technological development and scientific research is providing more information and gaining maturity, despite his few years in use since its discovery, It is a very important body of accumulating knowledge. These are being refined to produce an optimization in the use and safety standards can be achieved by becoming factors to observe and apply, either regulated or legislated, in the planning and design of facilities.

The American College of Radiology (ACR) in its "WHITE PAPER ON MAGNETIC RESONANCE SAFETY" has introduced safety recommendations for the practical use of magnetic resonance imaging facilities. They are probably the most commonly used currently in the preparation of guides and safety procedures for this type of facility by the responsible of this types of installations.

(12.9- 3.0 T MRI)

For the planner and designer, it is interesting to note the classification in areas that sets the document, so that allocations of spaces according to these recommendations are observed at this stage of design.

With respect to the static magnetic field set out areas where access restrictions are outlined, and conceptually divide into four zones the full installation of a magnetic resonance system.



(12.10- Zones in magnetic resonance)

Zone I, includes all the areas that have free access for the public in general. It is typically outside of the MR and is the area in which patients, staff and other employees of MR have access to the MRI surroundings**.**

Zone II is the area of adaptation between the uncontrolled zone I, accessible to the public, and strictly controlled zones III and IV. Typically patients are cared for in zone II and they cannot move freely in this, but under the supervision of the staff of RM. It is in this area where are the selective questions of MR, history of patient questions about health insurance, etc.

Zone III is the region in which free access to external to MR non selected personnel with or ferromagnetic objects or equipment may cause serious or fatal injury as a result of interactions between individuals or the equipment and the particular environment of the MR. These interactions include, but not limited to, the surrounding temporarily variable fields and the static MR field. All access to the zone III should be strictly restricted and controlled and supervised by the staff of the MR. The recommendation advises doors with keys and strict control of the personnel and the designer must place identification for entry systems: digital codes, cards, etc. The zone III, or at least the area where the force line of 5G is present should be marked as potentially dangerous.

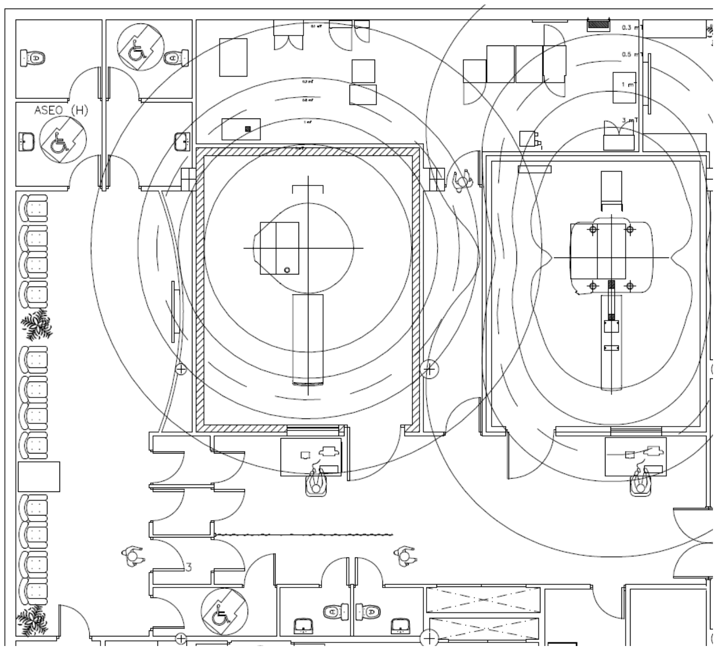
Zone IV is the own MRI magnet room area, i.e. the physical limits within which the magnet is located. Zone IV must be clearly marked to be potentially dangerous due to the presence of a very high magnetic field. Part of the zone IV restrictions require MR staff to have visual access to access paths in zone IV. Technicians can observe directly or with video monitors access from its normal position at a desk or in the control of the MR. The zone IV must be marked with a red light and a warning light indicating "magnet activated". Except for resistive systems red light and the signal must be illuminated at all times and they should have a power supply that allows operation at least 24 hours after a failure of power supply in the installation.

Magnetic resonance are the biggest emitters of acoustic noise within a department's image. The noise is annoying for the operator and also is harmful to their health, also for the patient, even though it supports only during exam time. Various international organizations have studied the permissible limits of noise in magnetic resonance and recommendations were established to measure the amount and set the allowable limits.

Most current measurement recommendations have been published by NEMA in MS 4-2006 publication.

Existing standards at the international level and the recommendations are published by the Electrical Engineering International Commission, IEC 61672-1, 2002 "On measures of levels of sound", and IEC 60601-2-33, 2002 on the particular requirements for the "Safety of Magnetic Resonance Imaging for medical diagnostics equipment".

The labor departments of the specific institutions in each country have also developed standards concerning acoustic levels in workplaces.



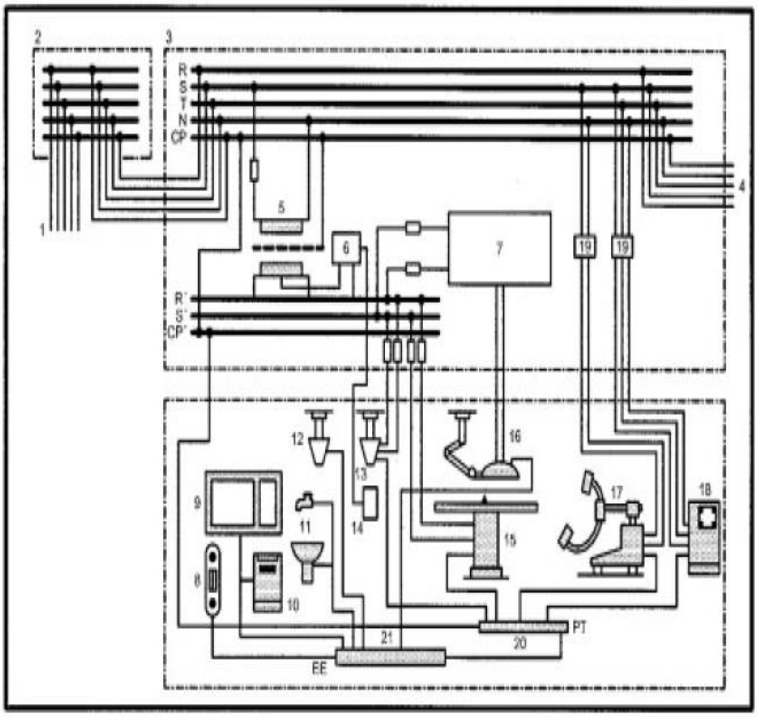
(12.11.- Zones within a block of 1.0 T and 3.0 T MRI)

XI.V.- ARCHITECTURAL LEGISLATION

Imaging or radiotherapy facilities construction and project activities are subject to the laws of all developed countries that have edited mandatory legislation for all matters related to civil construction that houses imaging or radiotherapy equipment. The Technical Building Code includes recommendations binding on the concepts of the project related to: construction, lighting levels, safety against fire, access of people, etc., and they must be observed in each country for the administrative authorization of the project and subsequent acceptance by national and local authorities of the performed work.

National codes are based on standards and national and international recommendations agreed among all States comprising the major standardization bodies, such as the "International Organization for Standardization" (ISO) and the (IEC) International Electrotechnical Commission.

Special mention deserves the regulations for electrical installations of low voltage distribution used in imaging departments. In medium-sized and above there is one or several internal distribution transformer to reduce high voltage to low voltage (380-400 VAC three-phase). The regulations for low voltage of most of the countries are based or related to IEC standards for low voltage. Perhaps a significant addendum in the power distribution of the rooms of angiography and coronary angiography was mandatory for insulation transformers and visual an acoustic signal with ground fault detector.



(12.12- Systems of insulation for vascular hemodynamics rooms and operating theatres)

The International Electrotechnical Commission is an organization for standardization comprising all national electrotechnical committees. Its objective is to promote international cooperation on all issues related to standardization in the electrical and electronic fields, collaborating with the ISO in many formal aspects.

XI.VI.- COMPUTING STANDARS

An imaging or current radiotherapy department is unable to operate without a high level of computer equipment. The RIS and PACS described in the first chapter, and introduced in the departments in the final years of the last century, are operating with a high level of compatibility between modalities, or image generators, and workstations of radiologists, who are the recipients of images to issue reports.

Following an imaging department workflow the first information that comes with the patient are their demographic data, which are in the reception of the department and come from the hospital information system (HIS). This information is now preset in HL7 format. The standard HL7 (Health Level Seven) is one of several ANSI American National Standards Institute accredited standards. HL7 provides standards for interoperability that improve the provision of health services, optimize workflow, reduce ambiguity and increase the transfer of knowledge among health services providers, state agencies, manufacturers community, physicians and patients.

The RIS receives the demographic information of the patient in HL7 of the HIS and presents it for use of the technician, physician and administrator, and also introduces to the modalities through DICOM WORK LIST.

The exchange of data (images) between modalities, servers and workstations is done in DICOM (previously NEMA PS 3.X) format which has been developed and continues its development in such a way that it behaves today many additional services to the image. The development continues and expect more services of the DICOM format in the future.

Integration of medical products in the imaging departments is included in the IHE (Integrating Healthcare Enterprise) recommendations that define the integration profiles that include integration and communication requirements of the products in the operational environment. IHE is an initiative of professionals and health industries to enhance the use of information systems in health systems. There are committees in all developed countries.

The security and privacy of the information of the patients exchanged between computer systems in the imaging departments is regulated by HIPAA (Health Insurance Portability and Accountability Act) recommendations. HIPAA is a federal law of the United States from 1996 with the primary goal of protecting the confidentiality and security of health care information, and help the health care industry to control administrative costs. In the field of the PACS defined security zones centering the first area in the image department, then the rest of the hospital and finally the internet. It defines the security in each of these areas.

(12.13.- Workstation diagnostic PACS with RIS integration and speech recognition)

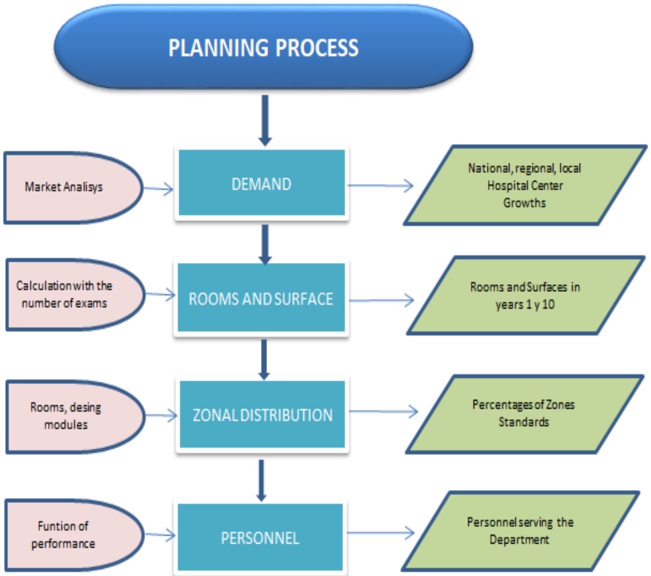
ADENDUM

XIII.- THE PLANNING PROCESS

XIV.- THE DESIGN PROCESS

XV.- BUSINESS PLAN

XIII.-THE PLANNING PROCESS



I. **DEMAND ANALYSIS**

II. **ROOMS AND SURFACE**

III. **ZONES DISTRIBUTION**

IV. **PERSONNEL**

V. **DESIGN**

“Before anything else, preparation is the key to success"

–Alexander Graham Bell

XIII.- THE PLANNING PROCESS

The previous chapters have exposed the information needed to allow planning in diagnostic imaging, radiation therapy or molecular imaging centers. They have been placing the snippets of useful detail, of each activity to develop, in the corresponding box to activate it together gradually in what is really a process, a set of interlinked actions to get a desired result.

Trying to do a comparison on the concept of planning, may be said that it is as the locomotive of a train that dragged the remaining activities and if it was not running the rest of cars would stand.

Has been obtained all the necessary information to continue the planning process, now have to be collected, prepared in the format that is more useful, and complete the task, which locates de action in halfway through the path proposed for one imaging or radiotherapy department.

Making a stop at the persecution of what to do and how to do and summarizing all the data and information, have to be completed the first part of our purpose, planning, as defined in a sentence of Terry in 1987 as:

"It is the process of selecting information and make assumptions about the future to formulate the necessary activities to achieve the organizational goals."

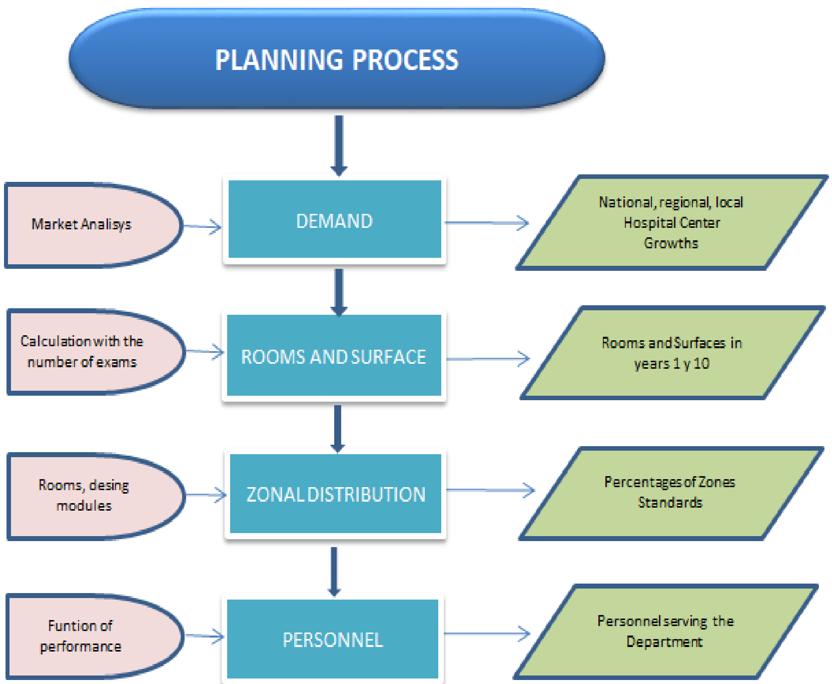
Planning on diagnostic imaging and radiation therapy involves analyzing and studying the objectives of quality, performance, and productivity, as well as the way in which the planners are going to get them. Planning is a tool of action to decide what to do and why, creating a plan. Create a plan has many benefits, but especially clarifying many doubts about the work to be carried out:

- Define the needs for human and material resources to achieve objectives.
- Clarifies the doubts regarding objectives and activities.
- Quantifies the performance levels to be successful.
- Sets priorities. Will always have a conflict between quality and performance.
- Clarifies strengths and weaknesses to achieve goals.

Planning is the process of evaluation of the department's objectives and the creation of a realistic business plan, although in our analysis and in the scope of this book is not full covered the realization of a Business Plan, which would lead to the book an extension very comprehensive to the wide of the objectives, will be exposed the general lines to make it. There are different procedures that facilitate its realization for the generation of business plan and subsequent strategic plans. There are much information regarding this in the hospital and imaging department literature which perform on a regular basis the drafting of strategic plans, and the review of them in short periods of time. Many of these are accessible free of charge by contacting directly with hospitals that already have extensive experience in this work.

Following the steps in the diagram of figure (6.1), only at a first glance come already back to the chapters that have been discussed up to this point in the book. Chapters that don't want to repeat, but enter into the detail of the analysis to show graphically the steps which will be done with the department to define as it is:

- What are the demand in tests or treatment.
- What area will occupy.
- How many rooms are needed to meet the demand and how are they organized.
- How much personnel will be required.



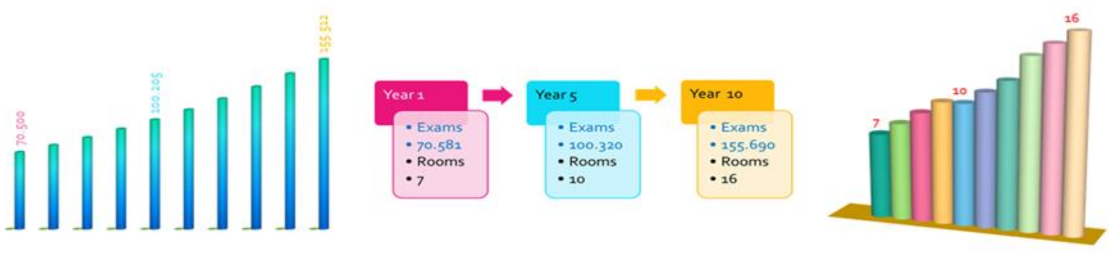
(13.I-Diagram of the process of planning in diagnostic imaging and radiotherapy)

Have to be remembered, that according to observations of many years in the design of facilities for diagnostic imaging and radiation therapy all these points have been, in one way or another in the thoughts of the planners and designers, but rarely have joined all of them in a vast majority of cases. It also occurs, mostly in public hospitals and health centers, which take place several years from the planning to the design phases and one and another study are made by different personnel (managers, radiologists, architects, engineers, etc.) and usually with different criteria, many times because of the time distance between planning and design. It is very common that from the concept or commitment to a politician or political party to install a hospital in a region until the hospital project pass several years and after the project to award the work elapses some other more, to have the suitable budget. At this time the planning tasks that were made will not have continuity, usually political or budgetary, nor technical, so it will be very difficult to keep the planning assumptions, not only because in many cases in all the time in its development the parameters have not been taken, but because years later they have changed.

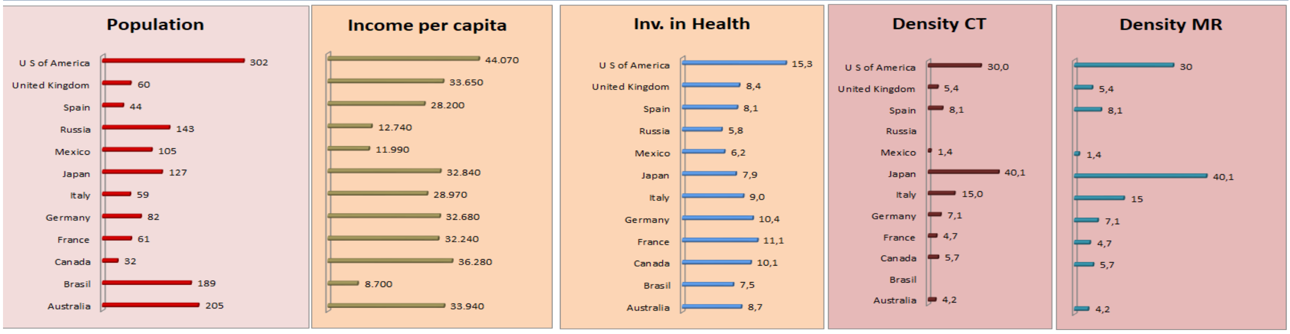
XIII.I.- DEMAND ANALYSIS

Already there is a dedicated chapter II to develop the way of ensuring the information for the planning of the department, and it is not the intention of this section to repeat concepts already exposed, just remember the steps to complete a market research that leads to obtain data with the most reliable possible demand information for exams or treatments, depending on the diagnostic, molecular imaging or radiotherapy department.

Repeating only the drawing exhibited in chapter II in this regard refer to this for the rest of necessary information, as well as the different national and international organizations to get the most up-to-date information possible. Let us remember that national bodies have information of exams from the previous one or two years (some very disordered) and the international as the WHO, UNSCEAR, EU, etc. with several years of delay.

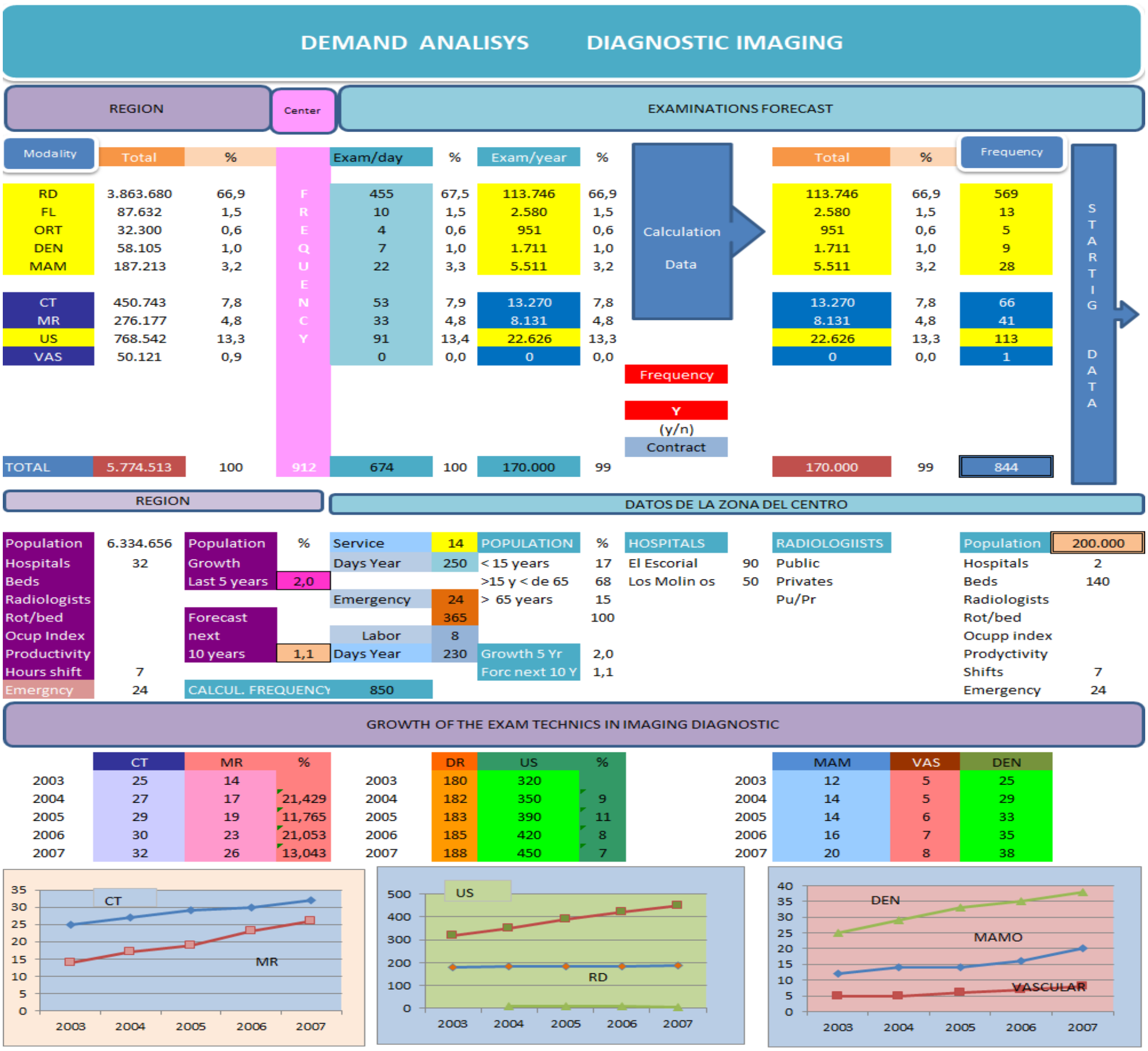


Australia	205	1,1	33.940	8,7	67,2	3.122			4,2	51,1
Brasil	189	1,3	8.700	7,5	47,9	765				
Canada	32	0,9	36.280	10,1	70,4	3.672	19,0	101,0	5,7	11,6
France	61	0,6	32.240	11,1	79,9	3.554	34,0	80,0	4,7	9,8
Germany	82	0,0	32.680	10,4	76,6	3.328	34,0		7,1	16,2
Italy	59	0,2	28.970	9,0	77,1	2.623	37,0	72,0	15,0	27,7
Japan	127	0,0	32.840	7,9	82,2	2.514			40,1	96,6
Mexico	105	1,0	11.990	6,2	43,3	756			1,4	3,5
Russia	143	-0,5	12.740	5,8	63,2	638	43,0	85,0		
Spain	44	1,1	28.200	8,1	72,5	2.388		76,0	8,1	13,5
United Kingdom	60	0,4	33.650	8,4	87,4	2.784			5,4	7,5
U S of America	302	1,0	44.070	15,3	45,8	6.714			30,0	36,0



(13.2.- Market study and international comparative data)

Will start with the calculation of the number of tests of diagnostic imaging department integrated into a newly-built hospital. Data from exams and attendance number were provided by the public authorities, and located in the area are to the left of the figure below, which summarizes the calculation process and additionally integrates data on the situation of machinery in the area where is located the hospital. There are also data from hospitals in the area and operation planned for the center, such as days, hours of operation, etc. The result is the baseline data for the calculation of the number of rooms.

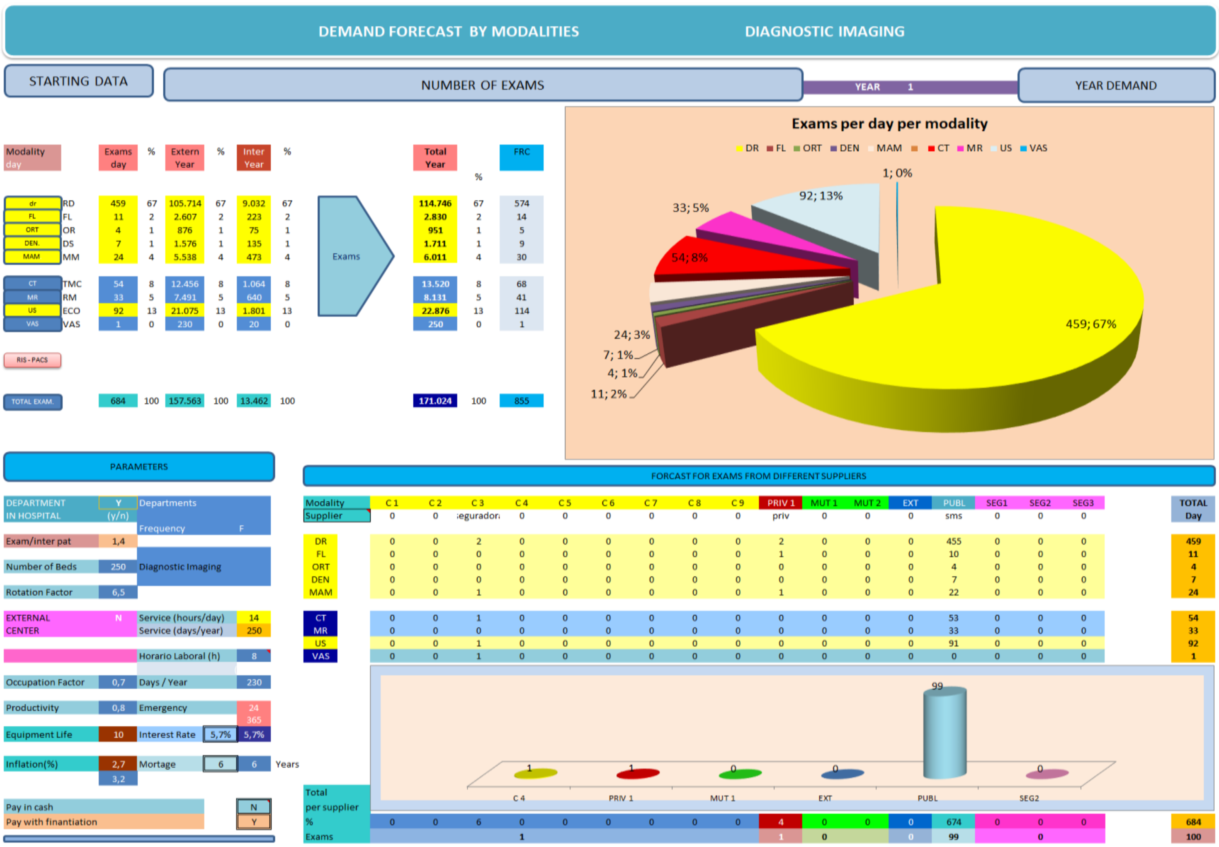


(13.3.- Calculation of the number of tests in an image department of a public hospital)

The graphic used responds to a special in Excel, but can be simplified by the user in a personal way according to the form to want display the data. Once there are a few baseline data, which are the number of exams that are envisaged for the department, the next step is to calculate the distribution of these tests in line with the type of center:

- Patients internal and external
- Working hours and days per year
- Emergencies
- Special data; for densitometry, pediatrics and interventionism, dental, etc.

In the chart below are shown these details and the configuration of the patients to advance in the calculationof the number of rooms needed to provide the service.



(13.4.-Starting data)

In the same way the data is presented for a molecular imaging department.

DEMAND ANALISYS — MOLECULAR IMAGING DEPARTMENT

REGION / DEPARTMENT FORECAST

Modality	Total	%	Patients/day	%	Exams	%	Total/Year	%	Frequency
GAM-G	16.965	65,0	17	65	4.323	65,0	4.323	65	12
GAM-C	3.915	15,0	4	15	998	15,0	998	15	3
SPECT CT	1.305	5,0	1	5	333	5,0	333	5	1
PER CT	3.915	15,0	4	15	998	15,0	998	15	3
LAB	22.185		23		5.653		5.653	85	16
Ciclotron	3.915		4		998		998		3
Radiopharm.	3.915		4		399		399		1
TOTAL	26.100	100	27	100	6.650	100	6.650	185	19

FREQUENCY: 18

CALCULATION DATA

Frequency: Y (y/n)

Contracts

STARTING DATA

REGION / CENTER AREA

Region	
Population	1.450.000
Hospitals	18
Beds	3.200
Nuc. Doctors	130
Rot/bed	7,2
Occup Index	85
Productivity	70
Shifts	7
Emergncy	24

Growth	%
Population Last 5 Years	2,0
Forecast next 10 Years	1,0
FREQUENCY	19

,1000

Serv.(hours)	7
Serv.(days)	250

POPULATION	%
< 15 Years	17
>15 < 65	68
> 65 Years	15
	100
G last 5 Y	2,0
Forc. next 10 Y	1,0

HOSPIT. (Beds)		Phys. I M	
N.S.del Rosell	950	Public	0
H. Mar menor	350	Privates	0
H.Tentegorra	200	Pu/Pr	0
H. Privado	120		

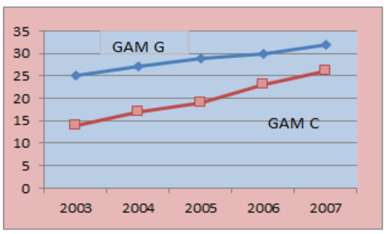
Center area	
Population	350.000
Hospitals	4
Beds	1620
Spec IM	0
Rot/bed	6,8
Occup Index	95
Productivity	70
Shifts	7
Emergencies	24

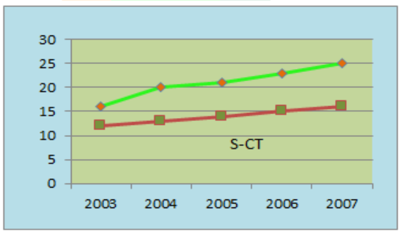
MOLECULAR IMAGING TECHNICS GROWTH

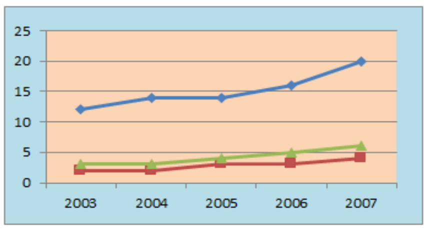
	GAM G	GAM C	%
2003	25	14	
2004	27	17	21,43
2005	29	19	11,76
2006	30	23	21,05
2007	32	26	13,04

		SPECT-CT	%
2003	16	12	
2004	20	13	8
2005	21	14	8
2006	23	15	7
2007	25	16	7

	PET-CT	CIC	RAD
2003	12	2	3
2004	14	2	3
2005	14	3	4
2006	16	3	5
2007	20	4	6







(13.5-Demand in molecular imaging)

(13.6.- Demand by modality in molecular imaging)

And exactly the same in a radiotherapy facility. However here the concept of **frequency** is changed by the **incidence** and the number of tests by the number of **sessions.**

(13.7.- Radiotherapy sessions demand)

XIII.II.- ROOMS AND SURFACE

Department surface calculation was shown in Chapter IV. The procedure is not repeated. Only estimates are presented in the 1 year of operation of the department and in year 10. In molecular imaging and radiation therapy, the procedure is the same and only is shown the year 1 to avoid reiterations. The last columns of the worksheet give a reference of the surface in 10 years according to the expected growth in the examinations demand patterns and population to serve.

DEPARTMENT SURFACE CALCULATION — IMAGING DIAGNOSTIC

Populat.	Frequency	Modality	%	Exams	t exa	Producc. Medium	R	R	Average surface	Total surface	Population growth	R	R	Modalities Growth	R	R	Total Surface	Number of exams
Population	Exam/1000				min	Exams			m2	m2							m2	10
200.000	574	DR	67	114.746	4	36.750	3,1	3	20	60		3,4	4	1	3,8	3	60	138.481
	14	FL	2	2.830	15	9.800	0,3	1	25	25		0,3	1	2	0,4	1	25	3.732
	5	ORT	1	951	6	24.500	0,0	1	8	8		0,0	0	1	0,0	1	8	1.148
Frequency total area	9	DEN.	1	1.711	15	9.800	0,2	1	15	15		0,2	1	3	0,3	1	15	2.463
	30	MAM	4	6.011	10	14.700	0,4	1	12	12	1,1	0,4	1	3	0,6	1	12	8.655
912	68	CT	8	13.520	15	9.800	1,4	1	30	30		1,5	2	4	2,2	2	60	21.234
	41	MR	5	8.131	25	5.880	1,4	1	35	35		1,5	2	9	3,3	3	105	19.486
	114	US	13	22.876	15	9.800	2,3	2	15	30		2,6	3	5	4,0	3	45	39.160
	1	VAS	0	250	60	2.450	0,1	1	35	35		0,1	1	4	0,2	1	35	393
	855		100	171.024				12		250			15			16	365	234.750

NET EXAM SURFACE	250		365
TOTAL DEPARTMENT GROSS SURFACE — HOSPITAL	1.750	More surface: * Population growth * Modality growth	2.555

CALCULATION PARAMETERS

Service (hours/day)	14	Working (h)	8	Emergencies	24
Service (days/Year)	250	Days / Year	230		365

Occupation Factor	0,7
Number of beds	250
Aver. Stay in hospital	6,5
Population growth (%)	1,1
Years for calculation	10

Operation time of modalities	(h)
RD-FL-MAM-ORT-DEN-US	14
CT - MR - VAS	14

Exam times			
RD	4	TMC	15
FL	15	RM	25
ORT	6	ECO	15
DEN	15	VAS	60
MAM	10		

Modalities growth			
MR	9	DR	1
CT	4	FL	2
US	5	MAM	3
VAS	4	DEN	3

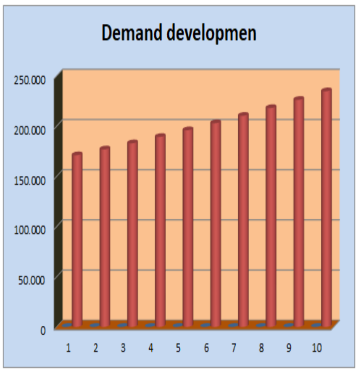
(13.8.- Calculation of the surface of the imaging department)

ROOMS CALCULATION DIAGNOSTIC IMAGING

Number of exams

		1			S1	2		S2	3		S3	4		S4	5		S5	6		S6	7		S7	8		S8	9		S9	10		S10
DR	67	114.746	3,1	0	3	117.168	3,2	3	119.641	3,3	3	122.167	3,3	3	124.746	3,4	3	127.379	3,5	3	130.068	3,5	3	132.814	3,6	3	135.618	3,7	3	138.481	3,8	3
FL	2	2.830	0,3	0	1	2.918	0,3	1	3.009	0,3	1	3.103	0,3	1	3.200	0,3	1	3.300	0,3	1	3.403	0,3	1	3.509	0,4	1	3.619	0,4	1	3.732	0,4	1
ORO	1	951	0,0	0	1	971	0,0	1	991	0,0	1	1.012	0,0	1	1.034	0,0	1	1.056	0,0	1	1.078	0,0	1	1.101	0,0	1	1.124	0,0	1	1.148	0,0	1
DEN.	1	1.711	0,2	0	1	1.781	0,2	1	1.855	0,2	1	1.932	0,2	1	2.011	0,2	1	2.095	0,2	1	2.181	0,2	1	2.271	0,2	1	2.365	0,2	1	2.463	0,3	1
MAM	4	6.011	0,4	0	1	6.260	0,4	1	6.519	0,4	1	6.788	0,5	1	7.069	0,5	1	7.361	0,5	1	7.665	0,5	1	7.982	0,5	1	8.312	0,6	1	8.655	0,6	1
CT	8	13.520	1,4	0	1	14.215	1,5	1	14.946	1,5	1	15.715	1,6	2	16.524	1,7	2	17.374	1,8	2	18.267	1,9	2	19.207	2,0	2	20.195	2,1	2	21.234	2,2	2
MR	5	8.131	1,4	0	1	8.960	1,5	2	9.874	1,7	2	10.881	1,9	2	11.990	2,0	2	13.213	2,2	2	14.561	2,5	2	16.046	2,7	2	17.682	3,0	3	19.486	3,3	3
US	13	22.876	2,3	0	2	24.284	2,5	2	25.778	2,6	2	27.365	2,8	3	29.049	3,0	3	30.837	3,1	3	32.735	3,3	3	34.750	3,5	3	36.889	3,8	3	39.160	4,0	3
VAS	0	250	0,1	0	1	263	0,1	1	276	0,1	1	291	0,1	1	306	0,1	1	321	0,1	1	338	0,1	1	355	0,1	1	373	0,2	1	393	0,2	1
		171.024			12	176.820		13	182.890		14	189.254		15	195.929		15	202.936		15	210.297		15	218.035		15	226.177		16	234.750		16
Increment in the number of rooms in the period								1			1			1			0			0			0			0			1			0
								Increase			Increase			Increase			Constant			Constant			Constant			Constant			Increase			Constant
								Review and go			Review and go			Review and go			Review and go			Review and go			Review and go			Review and go			Review and go			Review and go

VARIABLES DE CALCULO



Service (hours/da	14	Working (h)	8		24
Service (days/yea	250	Days/ year	230		365

Occupation Factor 0,7

Number of Beds 250

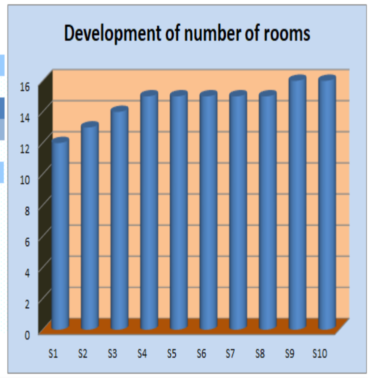
Aver. Stay 6,5

Population growth (%) 1,1

Yeards of calculation 10

Modalities growth

MR	9	DR	1
CT	4	FL	2
US	5	MAM	3
VAS	4	DEN	3



(13.9.- Evolution of the number of rooms of the diagnostic imaging department based on the number of tests in 10 years)

Following are the calculations of surface for molecular imaging and radiotherapy departments. The calculations are not exposed to 10 years because are applied the same guidelines that the calculations submitted for diagnostic imaging. First look at the calculation variables in molecular imaging.

Service (hours/day)	7	Working h.	7	Emergencies	0
Service (days/Year)	250		230		0

Occup. Factor	0,7

Number of beds	350
Averag. Stay	7,5

Population Growth (%)	1

Years for growth calculations	10

Modalities working time	(h)
GAM-G;GAM-C;SPECT-CT:PET-CT; LAB	7
Cyclotron-Radiopharmacy	7

Exam time	
GAM-G	15
GAM-C	30
SPECT CT	20
PET CT	20
LAB	5

Modalities growth	
GAM-G	4
GAM-C	2
SPECT CT	5
PET CT	8
LAB	

Dose production	
CyCLOTRON	7
RADIOPAHRMACY	7

SURFACE CALCULATION MOLECULAR IMAGING DEPARTMENT

Populat.	Frequency	Modality	%	Exams	t exa	Product. Average	R	R	Average Surface	Total Surface	Population Growth	R	R	Modality Growth	R	R	Total Surface	Number of Exams
Population	1000				min	Exams			m 2	m 2							m 2	10
350.000	14	GAM-G	49	5.073	15	4.900	1,0	1	25	25		1,1	1	4	1,6	2	50	7.896
	4,3	GAM-C	14	1.498	30	2.450	0,6	1	25	25		0,7	1	2	0,8	1	25	1.936
	3	SPECT-CT	10	1.083	20	3.675	0,3	1	40	40		0,3	1	4	0,5	1	40	1.685
Frequency Area	8	PET-CT	26	2.748	20	3.675	0,7	1	40	40		0,8	1	8	1,6	3	120	6.007
		Cam.Cal.		7.653	5	14.700	0,5	1	25	25		0,6	1	5	0,9	1	25	12.984
											1							
19		Cyclotron		2.748	dosis	8.575	0,3	1	35	35		0,3	1	8	0,7	1	35	6.007
*(1000)		Radiopharm		2.748	dosis	8.575	0,3	1	40	40		0,3	1	8	0,7	1	40	6.000
	30		100	10.400				7		230			7			10	335	42.515

NET EXAM SURFACE	230	335

DEPARTMENT TOTAL GROSS SURFACE	Hospital	1.380	MORE SPACE FOR: * Growth of population * Modalities growth	2.010

SURFACE CALCULATION									RADIOTHERAPY DEPARTMENT									
Populat.	Frequency	Modality	%	Sessiones	t ses	Average Production	R	R	Average surface	Total surface	Population growth	R	R	Modality growth	R	R	Total surface	Number of Sessiones
Habitants	Incidence/ 1000				min	Sessions			m 2	m 2							m 2	10
530.000	56	LINAC	97	29.501	8	18.375	1,6	2	70	140		1,8	2	7	3,2	3	210	59.318
	0,3	Steeotaxy	0	134	60	2.450	0,1	0	70	0		0,1	0	5	0,1	0	0	221
Incidence Area	1	BRQ	2	687	15	9.800	0,1	1	50	50		0,1	1	7	0,1	1	50	1.381
		PLAN-LINAC		1.764	50	2.940	0,6	1	15	15		0,7	1	7	0,1	1	15	229
		PLAN-BRQ.		229	50	2.940	0,1	1	15	15	1	0,1	1	7	0,2	1	15	460
2,3		SIM.		1.061	50	2.940	0,4	1	30	30		0,4	1	7	0,7	1	30	2.133
*(1000)		Blocks		329	25	5.880	0,1	1	20	20		0,1	1	0	0,1	1	20	360
	57		100	33.704				7		270			7			8	340	64.102
NET SURFACE AREA										270							340	
TOTAL GROSS DEPARTMENT SURFACE					Hospital					1.620	MORE SPACE NEEDED FOR: * Population growth * Modality growth						2.040	

(13.10.- Surfaces of molecular imaging and radiotherapy)

And then the calculation variables are presented in radiotherapy. They are usually in a single worksheet in Excel, but it is separated because of the format of the book.

Service (hous/day)	14	Labor time	7	Emergencies	0
Service (days/Year)	250		230		0

Occupation Factor	0,7	Number of beds	280
		Rotation Factor	6,5 d/cam

Population growth (%)	1
Claculation Years	10

Modalities working time	(h)
PLAN-LINAC; PLAN-BRQ	14
LINAC-ESTR-BRQ-SIM-BLOCKS	14

Treatment time	
LIN	8
Ester	60
BRQ	15
PLAN	50
SIM	50

Modalities growth	
LINAC	7
BRQ	5
PLANF	7
SIM	7
BLOCKS	0

Sessions per treatment	
LINAC	25
BRQ	3

Other parameters	
Simulations %	80
Blocks %	30

XIII.III.- ZONES DISTRIBUTION

A modular distribution in zones can be done starting from the medium surfaces described in chapter IV final graph, adding the surfaces of the room modules and the same for each of the dependencies, corridors, etc. will arrive to a representation as the figure of below. It is an estimate only of reference, since the zonal distributions come out of the final department design, and now is working only with average and primary information. Here there is one example of a distribution of the calculated surface and it has been done with the approximate dimensions of the modules already commented. Therefore only serve as reference and will be made a determination when finishing the complete design of the department once has been completed the design stage.

SPACE DISTRIBUTION — DIAGNOSTIC IMAGING

MODALITY	EXAM DISTRIBUTION TOTAL	%	EXTERN	%	INTERN	%	T.EX. min	Room nº	RECEPTION	WAIT EXTERN	WAIT BEDS	CORRIDOR EXTERN	CORRIDOR INTERN	CORRIDOR PERSONNEL	TOILETS	ROOM DIAGNOST.	CABINS Prepart.		OFFICES OTHERS	TECHNOLOGY
DR	114.746	67	105.714	67	9.032	67	4	3		59					18		12	a	24	
FL	2.830	2	2.607	2	223	2	15	1		17					4		6	b	12	
ORT	951	1	876	1	75	1	6	1		19					0		5	c	13	
DENS	1.711	1	1.576	1	135	1	15	1		22		98	4		3		0	d	10	
MAM	6.011	4	5.538	4	473	4	10	1		12					0		5			
									58		34	168	0	159	6	72				79
CT	13.520	8	12.456	8	1.064	8	15	1		17					9		16	lec	34	
MR	8.131	5	7.491	5	640	5	25	1		29					2		14	ofic	16	
US	22.876	13	21.075	13	1.801	13	15	2		40					9		8	alm	31	
VAS	250	0	230	0	20	0	60	1		20					3		15	vest	26	
																		bibl	30	
	171.024	100	157.563	100	13.462	100		12	58	236	34	168	0	159	55	72	69		195	79

ZONAES - SPACES NET AND GROSS

ZONES	m2	%
PATIENT ZONE	585	37
EXAM ZONE	472	30
DIAGNOSTIC ZONE	152	10
PERSONNEL ZONE	275	18
TECHNOLOGY ZONE	79	5
TOTAL ZONE SURFACE	1.563	100
losses	187	10,7
TOTAL GROSS SURFACE	1.750	

PARAMETERS

HOSPITAL		DIAGNOSTIC IMAGING DEPARTMENT	
Number of beds	250	Service (hours/day)	14
Averg. Stay	6,5	Working time(h)	8
Occup Factor	0,7	Days / year	230
Dept. surface	1.750	Emergencies	24
D1 - I 70,0	25		365

FIXED SURFACES

RECEPTION			CORRIDORS	
Desk	14		Estern	168
Hall	34		Intern	
Office	10		Personnel	159
			Toilets (m2)	6
OFFICES			Others	
Chief	24	a	Reading	34
Supervisor	12	b	Office	16
Administrato	13	c	Library	30
Computing	10	d	Storage	31
			Vest	26
TECHNOLOGY				
Servers	11		Tech rooms	41
AC + Electrc.	20		Others	6

(13.11.- Modular spaces distribution)

XIII.IV.- PERSONNEL

With the calculation of the staff we ended up the department planning process. Successive graphics presents a way of doing it based on the production of the personal for every modality depending on hours worked and the objective of productivity that is pursued. It is not an exclusive way. Many calculates based on parameters for room and shift, considering other factors as labor days of work and working days of service and participation or not in the emergency guards.

Modality	Exams Total	%	t exam min	Rooms nº	Radiol.	Tecnic.	Nurses	Auxil	Carttak.	Adm.	Comp.
DR	114.746	67	4	3	4,8	15,5					
FL	2.830	2	15	1	0,5	0,5	0,2				
OR	951	1	6	1	0,0	0,1					
DEN	1.711	1	15	1	0,1	0,2					
MAM	6.011	4	10	1	1,0	1,0					
									3,0	10,0	1,8
CT	13.520	8	15	1	2,3	2,3	1,4				
MR	8.131	5	25	1	1,4	1,8	0,5	0,9			
US	22.876	13	15	2	3,9			3,9			
VAS	250	0	60	1	0,2	0,2	0,1	0,2			
	171.024	100		12	14,2	21,7	2,1	5,0	3,0	10,0	1,8

		Year 1	Year 10	% Variation
		1		
Radiologists		14,2	21,7	52,8
Technicians		21,7	29,4	35,4
Nurses		2,1	3,7	72,9
Auxiliaries		5,0	9,2	83,1
Carttakers		3,0	3,0	0,0
Aministrators		10,0	13,7	37,3
Computing		1,8	2,4	37,3
Total Personnel		57,9	83,2	43,7
Increase				
Des+Holid+	12%	64,86	93,22	43,7

HOSPITAL	
Number of beds	250
Rot. Factor	6,5
Occupation Factor	0,7
Productivity	0,8
Emergencies	24
	365

DIAGNOSTIC IMAGING		
Service(hours/day)	14	14
Service (days/year)	250	
Working hours (h)	8	
Daus/Year	230	

Radiologists		Nurses		Administr.	
DR	35.000	FL	19.320		
US	6.440	US	0	Administr.	96.600
CT	6.440	CT	10.304	Reception	48.300
MR	6.440	MR	19.320		
VAS	1.127	VAS	3.220		
FL	6.440	**Auxiliaries**		**Carttakers**	
Technicians		US	6.440		
DR	8.782	FL	13.800	Cartt.	4.830
US	0	VAS	1.208		
CT	6.440	CT	0		
MR	4.830	MR	9.660		
VAS	1.208	**Computing**		**Maintenance**	
FL	6.440	Adm.aplic	241.500		
MAM	6.440	sistem	193.200		

(13.12.- Calculation of staffing requirements)

The experience in many hospitals in Spain indicates that the number of radiologists is somewhat lower than the calculated, for the number of requested examinations. Not in all departments. In those where all tests are diagnosed the figure is correct, but consider that many radiographic examinations are not diagnosed in the image department, but pass directly to the petitioner doctor. Much happens in the explorations of traumatology.

Also the ratio of two technicians per radiologist is met if we add technicians, nurses and auxiliaries. In many centers nurses perform radiological scans in the same way as a technician. Also indicates the needs to 10 years according to the growth parameters that have been set. It is a very important fact for the planner.

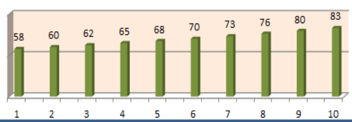
DEPARTMENT PERSONNEL CALCULATION DIAGNOSTIC IMAGING

EXAMS | PERSONNEL | YEAR 10

Modality	Exams Total	%	t exam min	Rooms nº	Radiol.	Tecnic.	Nurses	Auxil	Carttak.	Adm.	Comp.
RX DIGITAL	138.481	59	4	3	5,6	18,5					
RX FLUORO	3.732	2	15	1	0,6	0,6	0,2				
ORTOPANTO	1.148	0	6	1	0,0	0,1					
DENSITOM.	2.463	1	15	1	0,1	0,3					
MAMOGRAF	8.655	4	10	1	1,5	1,5					
	0								3,0	13,7	2,4
TAC MULT.	21.234	9	15	2	3,6	3,6	2,3				
R ES. MAGN.	19.486	8	25	3	3,3	4,4	1,1	2,2			
ECOGRAFIA	39.160	17	15	3	6,7			6,7			
VASCULAR	393	0	60	1	0,4	0,4	0,1	0,4			
	234.750	100		16	21,7	29,4	3,7	9,2	3,0	13,7	2,4

PERSONNEL EVOLUTION

YEAR	Total	Radiolog.	Technic.	Nurses	Auxil.	Carttak.	Admin.	Computing
1	58	14,2	21,7	2,1	5,0	3,0	10,0	1,8
2	60	14,9	22,4	2,3	5,4	3,0	10,3	1,8
3	62	15,6	23,1	2,4	5,7	3,0	10,6	1,9
4	65	16,3	23,9	2,6	6,1	3,0	11,0	2,0
5	68	17,1	24,7	2,7	6,6	3,0	11,4	2,0
6	70	17,9	25,6	2,9	7,0	2,9	11,8	2,1
7	73	18,8	26,4	3,1	7,5	3,0	12,2	2,2
8	76	19,7	27,4	3,3	8,0	3,0	12,7	2,3
9	80	20,7	28,4	3,5	8,6	3,0	13,2	2,3
10	83	21,7	29,4	3,7	9,2	3,0	13,7	2,4



PERSONNEL EVOLUTION

		Year 10	Year 1	% Variation
Radiologists		21,7	14,2	52,8
Technicians		29,4	21,7	35,4
Nurses		3,7	2,1	72,9
Auxiliaries		9,2	5,0	83,1
Carttakers		3,0	3,0	0,0
Aministrators		13,7	10,0	37,3
Computing		2,4	1,8	37,3
Total Personnel		83,2	57,9	43,7
Increase				
Des+Holid+	12%	93,22	64,86	43,7

PARAMETERS

HOSPITAL		DIAGNOSTIC IMAGING		
Number of beds	250	Service(hours/day)	14	14
Rot. Factor	6,5	Service (days/year)	250	
Occupation Factor	0,7	Working hours (h)	8	
Productivity	0,8	Daus/Year	230	
Emergencies	24			
	365			

AVERAGE PERSONNEL PRODUCTION

Radiologists		Nurses		Administr.	
DR	1.127	FL	3.220		
US	6.440	US	0	Administr.	0
CT	0	CT	0	Reception	0
MR	8.782	MR	0		
VAS	0	VAS	6.440		
FL	6.440	Auxiliaries		Carttakers	
Technicians		US	9.660		
DR	1.208	FL	0	Cartt.	0
US	6.440	VAS	0		
CT	6.440	CT	0		
MR	0	MR	0		
VAS	Set	Computing		Maintenance	
FL	selected	Adm.aplica	0		
MAM	value	sistem	0		

(13.13.- Long term evolution of the staff)

The calculation made adjustments based on the number of the rooms working hours. There are rooms that work for 7 hours (one shift), 14 hours (two shifts) and the emergency is working continuously during all the days and year.

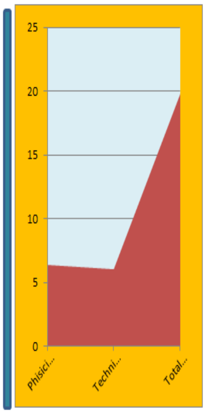
Then presented the same graphics for molecular imaging and radiotherapy, not presenting graphics to 10 years, that although they are very important for the planner, are similar to the diagnostic imaging, described above, and avoid redundancies that they do not provide news to the description of the planning that will be finished with this calculation process.

PERSONNEL MOLECULAR IMAGING

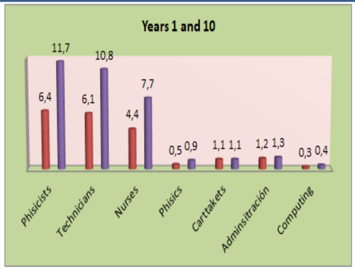
EXAM DATA / PERSONNEL

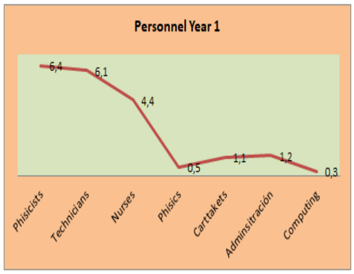
Modality	Exams TOTAL	%	T. EX min	Rooms nº	Phisicians	Tecnic.	Nurses	Phisics	Cartak.	Adminis	Comput.
GAM-G	5.073	49	15	1	2,1	2,0	1,8	0,1			
GAM-C	1.498	14	30	1	0,6	0,6	0,5	0,0			
SPECT-CT	1.083	10	20	1	0,6	0,6	0,4	0,0			
PET-CT	2.748	26	20	1	1,6	1,1	1,4	0,1			
Cam.cal.	7.653		5	1		0,7		0,1			
									1,1	1,2	0,3
Cyclotron	2.748		dosis	1	0,8	0,5		0,1			
Radiofarm.	2.748		dosis	1	0,8	0,7	0,2	0,1			
	10.400	100		7	6,4	6,1	4,4	0,5	1,1	1,2	0,3

Year 1



PERSONNEL IN THE FIRST YEAR





PERSONNEL DEVELOPMENT

		Year 1	Year 10	% Variatión
Phisicists		6,4	11,7	83,7
Technicians		6,1	10,8	78,4
Nurses		4,4	7,7	76,8
Phisics		0,5	0,9	93,0
Carttakets		1,1	1,1	0,0
Adminsitración		1,2	1,3	9,9
Computing		0,3	0,4	68,5
Total Personnel		19,8	34,0	71,7
Increse for Desease+...	12%	22,18	38,07	71,7

PARAMETERS

HOSPITAL		IMAGING MOLECULAR DEPARTMENT		
Number of beds	350	Service (hours/day)	7	7
Rotation Factor	7,5	Service (days/Year)	250	
Occupation Factor	0,7	Working hours	7	
Productivity	0,8	Days/Year	230	
Emergencies	0			
	0			

AVERAGE PERSONNEL PRODUCTION

Phisicists	exam	Nurses	exam	Administr.	exam	exam
GAM	3.091	GAM	3.864			
SPECT-CT	2.208	SPECT-CT	3.864	Administr.	77.280	Set value
PET-CT	2.208	PET-CT	2.576	Reception	38.640	
CYCLOTRO	4.500	CYCLOT	15.456			
RADIOFPH	4.500	RADIOPH	15.456			
		Phisics	exam	Carttakers	exam	
Technician	exam	GAM	38.640			
GAM	3.513	SPECT-CT	38.640	Carttakers	1.500	1.500
SPECT-CT	2.576	PET-CT	38.640			
PET-CT	3.513	CYCLOT	15.456			
CYCLOTR	7.728	RADIOPH	19.320			
RADIOPH	5.000	Computing	exam	Maintenan	exam	
LAB	15456	Admin	100.000			
		System	200.000			

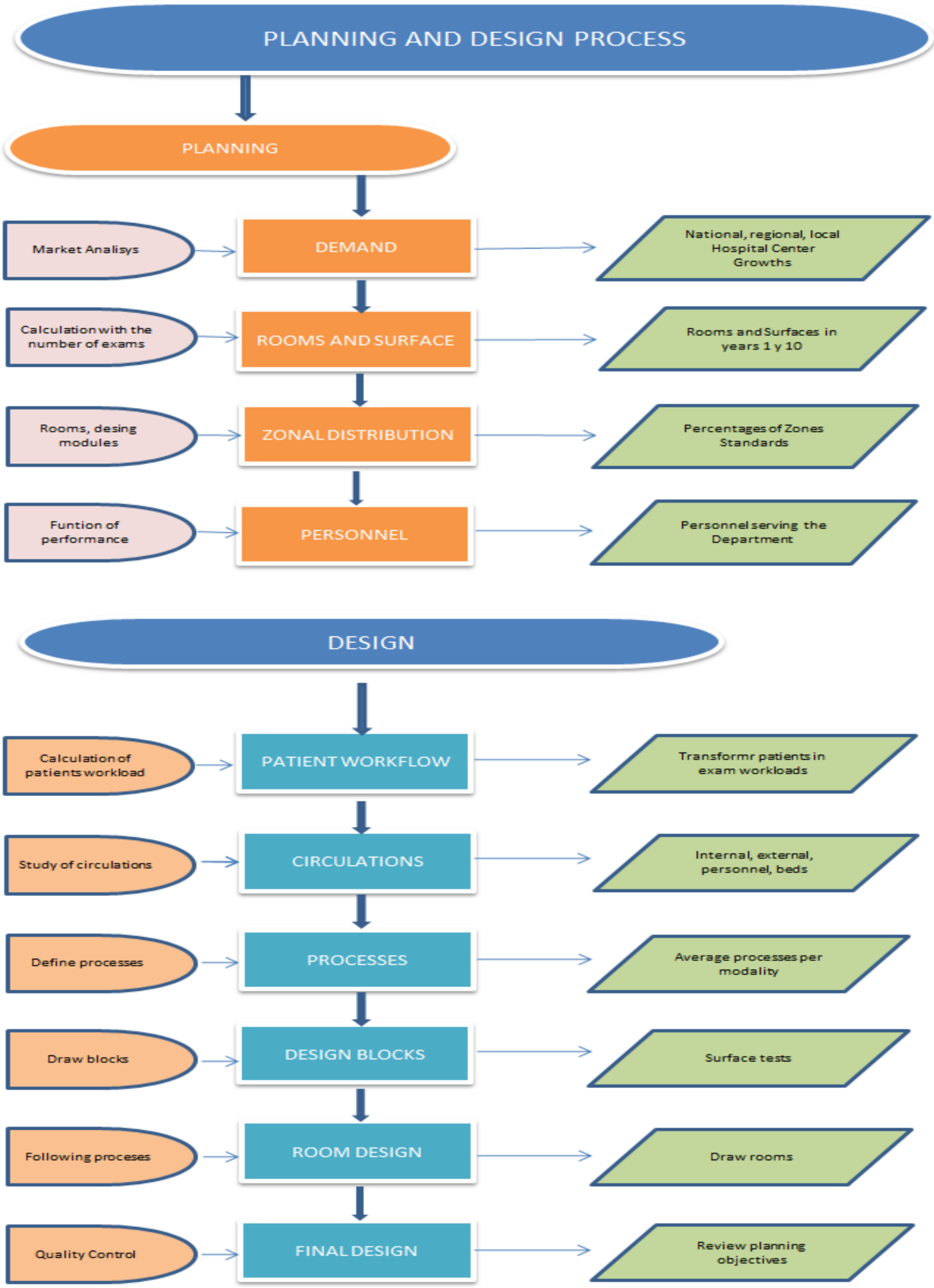
(13.14.- Personnel in molecular imaging and radiotherapy)

XIII.V.- DESIGN

In summary, with the planning actions made, has been reached the point where obtained:

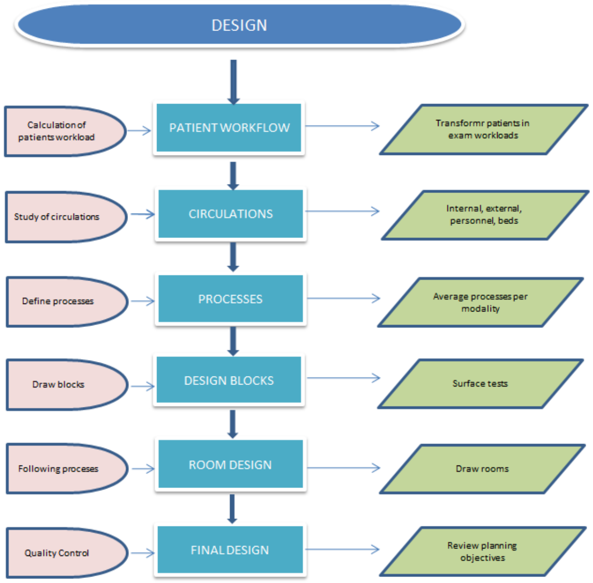
- The number of tests or treatments that are expected to perform in the department.
- Determined the required surface of the department and the number of rooms required.
- An approximate distribution of zones and the personnel that is going to be needed.

And an assessment of the needs of 10 years, with a few parameters of population growth and growth in demand for modalities that will exist in the department.



(13.15.- Planning and design processes)

XIV.- THE DESIGN PROCESS



I. PATIENTS WORKFLOW

II. CIRCULATIONS

III. CLINICAL PROCESSES

IV. DESIGN BLOCKS

V. ROOMS DESIGN

VI. DEPARTMENT DESIGN

"Design is not just what you see, is how it works"- Steve Jobs

XIV.- THE DESIGN PROCESS

According to some sources, the word comes from the Italian "*disegno*" which refers to a sketch, sketch or outline which is performed on a material support before realized production of something. In this general way it can be used in virtually all forms in which today is subdivided the field of design: artistic, graphic, industrial, etc., or by activities, such as fashion, jewelry, automobiles, etc. Some paragraphs expressed by various authors in connection with the concept of design are collected below.

The concept of design is often used in the context of the arts, architecture, engineering and other disciplines. “The design moment involves a mental representation and the subsequent depiction of this idea in any graphic format (visual) to display how will like the concept that is to be planned. Design, therefore, may include a drawing or layout that anticipate the characteristics of the work".

“When designing, the person not only takes into account aesthetic aspects, but also functional and technical issues. This requires designer studies, research and modeling tasks enabling to find the best way to develop the object intended to create".

In addition to fashion, another field that has acquired great evolution and growth in recent years is the known interior design thanks to which the rooms of a house or a building specifically manage to show a spectacular image thanks to the study that the professionals that perform this woks take into account factors such as the architecture and environmental psychology. The professionals performing these tasks works in internal spaces to ensure better security, and this treatment makes the functionality 100% offering an attractive and aesthetic place to obtain a flawless work interior design.

The interior design despite being an inside job, it requires dedication and optimism. So should be selected the best combination in colors, floors, furniture, lighting and all the necessary elements to carry out some work. Interior designers also project his ideas through a design software to provide information over their techniques to engineers, architects and builders who give life and show how their new designs will be"."

The industrial design is a type of design that includes from screws to large mechanical parts, devices prefabricated for the reconstruction, and the furnishings of each type of machine. Through large specialized engineers are accomplished the design and executed any technological device. Giving life to the appliances, cell phones, bicycles and cars among many other objects.

Artistic design is understood a more rational and sensitive approach to certain human products that must not necessarily be beautiful and since long time they are considered works of art.

Design as the act of creating something material, concrete, two-dimensional or three-dimensional, until the structuring of space, image, or virtual and intangible objects.

In our field of diagnostic imaging and radiotherapy we could define design in the following way**:**

It is the last creative link that comes from a systematic process of planning and from which is get a graphic result capable of representing the functionality of a simple room or a department, and from which is generated an architectural project and a business plan.

It is creative, because not only is required to follow certain steps of a programmed process, but that they require imagination, knowledge and dedication to obtain a satisfactory result that meets pre-set goals.

It is needed to fix as precisely as possible, in the planning phase, the objectives that want to be achieved in the business plan that will come after the design phase, and it will take data from design to completion and be approved by the project manager. Data such as the costs of projects, construction costs, installation costs, consumption of energy, etc., are very detailed behind the design and can be used in the business plan, which clarify the viability of the project and its implementation underway.

Will go deeper in the analysis already made in the previous chapters of the book in relation to the needs for design, such as the study of the flow of patients, circulations, processes and final design of the department and enter into a practical analysis of these issues which outline the final design of the room, assembly of rooms or department. How many people per hour will move along a corridor, define their dimensions, in the same way that after the study of the process is concluded that for reasons of activity, type of patients, etc..., a room of preparation in CT that host a particular preparation, such as monitoring and anesthesia equipment is required. It is not necessary in all the CT rooms but it is in many of them. This changes the design of the CT room and therefore the costs of construction, but also the room productivity. Will be reviewed the concepts already learned in the chapters of design of the book with visual examples that will help in the design tasks.

XIV.I.- PATIENTS WORKFLOW

Known the patients than are expected to go to a room per hour, also can be estimated the number of people who will be in the waiting room during a determined time, and this may be information needed to set up the size of the waiting room.

Most of the times in a design is fixed the space for reception. But the question is which space is this. Normally it is known the number of tests per year, but the number of people per hour is not calculated, or the hours of increased inflow based on citation, or there is no citation, as even happened in some centers. Data are needed to determine the reasonable dimensions of a reception, and this come with the number of people per hour that are arriving the department, in another words calculating the flow of patients.

In the following table, is breaking down the calculation of patients per hour going to each room, at the time of opening of the department, year 1, and ten years later with a few assumptions of growth, both population and demand of modalities.

Service details are at the bottom of the sheet, in hours and days per year that such service will be provided. The annual increase in population data are also set, that it is the obtained from local or national statistics and the growths, or decreases, in the modalities can be obtained from local health statistics.

With all of these assessments already are set the first step for the beginning.

The second step is to turn patients into people per hour. This depends on the type of facility. A companion per patient is normal on most of the centers. More in the pediatric. In these, it is normal to apply the factor 2.5 to determine the flow of people who come to the department and are distributed through the rooms, because many times there are two people going with the patient.

Emergencies should be considered according to the objectives of the project. Although the rooms are integrated in the imaging department they should have separate access. The patients come from the emergency department, and normally the accompanying people stays in the emergency waiting room, which is not in the image department. In radiation therapy there is not, in general, emergency. The workflow is scheduled.

With these data could already be done the design sizes of waiting rooms. Only have to know the average duration of the exams to set timeouts and according to these how many patients are going to be waiting in the waiting rooms for examinations in the modalities. When these special waiting rooms do not exist and there is a general one for all patients, as unfortunately happens in many centers, the detailed calculation is more difficult, although it could be done a table to weigh the number of patients per hour. If the citation does not exist there is still more the difficulty for the calculations of the size, and many times the only solution is over dimensioning to avoid later reclamations. Probabilistic techniques may be used.

(14.1.- Number of patients per hour in the short and long term)

STARTING DATA

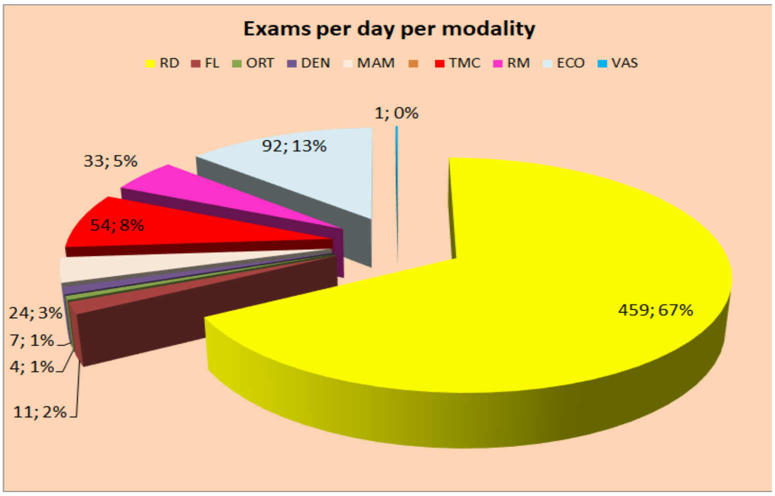
PATIENTS AND PEOPLE FLOW

Modality		Exams day	%	Exterm Year	%	Inter pat.	%	Ext hour	Int hour	People hour	Number Rooms	People Room hour	Total Year
DRL	RD	459	67	105.714	67	9.032	67	7.551	645	66	3	21,9	114.746
FL	FL	11	2	2.607	2	223	2	186	16	2	1	1,6	2.830
ORT	OR	4	1	876	1	75	1	63	5	1	1	0,5	951
DEN.	DS	7	1	1.576	1	135	1	113	10	1	1	1,0	1.711
MAM	MM	24	4	5.538	4	473	4	11	34	3	1	3,4	6.011
CT	TMC	54	8	12.456	8	1.064	8	890	76	8	1	7,7	13.520
MR	RM	33	5	7.491	5	640	5	535	46	5	1	4,6	8.131
US	ECO	92	13	21.075	13	1.801	13	1.505	129	13	2	6,5	22.876
VAS	VAS	1	0	230	0	20	0	16	1	0	1	0,1	250
RIS - PACS													
TOTAL EXAM.		684	100	157.563	100	13.462	100	10.870	962	98	12		171.024

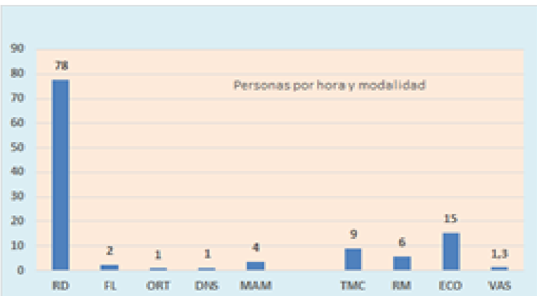
PARAMETERS

npanicmpañantes		Geneal	2,0
		Pediatrics	2,5

DEPARTMENT IN HOSPITAL	Y (y/n)	Departments Frequency	F
Exam/intern pat.	1,4		
Number of beds	250	Diagnostico por Imagen	
Rotation Factor	6,5		
EXTERNAL CENTER	N	Service (hours/day)	14
		Service (days/Year)	250
		Labor Hours(h)	8
Occupation Factor	0,7	Days / Year	230
Productivity	0,8	Emergencies	24 365
Equipm. Life	10	Int. Rate	5,7% 5,7%
Inflation(%)	2,7 3,2	Mortage	6 6 años
Pay in cash			N
Purchase with finantiation			Y



(14.2.- People per hour and modality)



(14.3.- People per hour and exam room)

XIV.II.- CIRCULATIONS

In a previous Chapter has been presented the way to start with its analysis. Only intends to expand details of the importance of their proper establishment. In the example that follows, a design by the year 2013, are clearly defined the circulations:

1.- **Patients, in yellow** and entering wait rooms in blue. Waiting rooms by modalities in its majority.

2.- **Personnel**, which circulates primarily in blue corridors, without in-patient interference in work.

3.- **Inpatient** in beds and wheelchairs and staff, mainly technical.

An alternative, composed by a mixed circulation of internal staff and patients, has been superimposed with lines on this design, present the following problems:

- **Loss of productivity** by continuous collisions of staff with internal patients; easy to calculate as was shown in the previous section the way to calculate the number of in-patients per hour which will circulate through this same corridor. Also is known what is the staff and their movements, so the mixture with internals is negative for the work in the department.

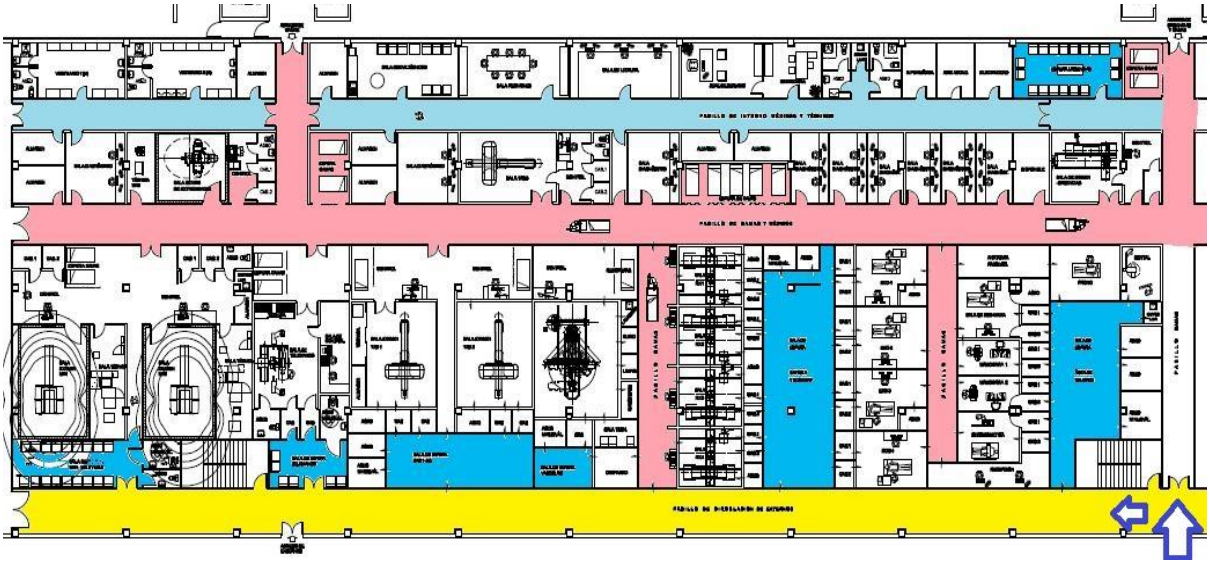
- **Greater loss of the gross area** of the department, because if it is added the access corridors to rooms, purple color, along with the new waiting for patients, yellow, can be seen more space (square meters) lost by an inadequate circulation.

- **Higher construction costs**. More corridors, worst distribution.

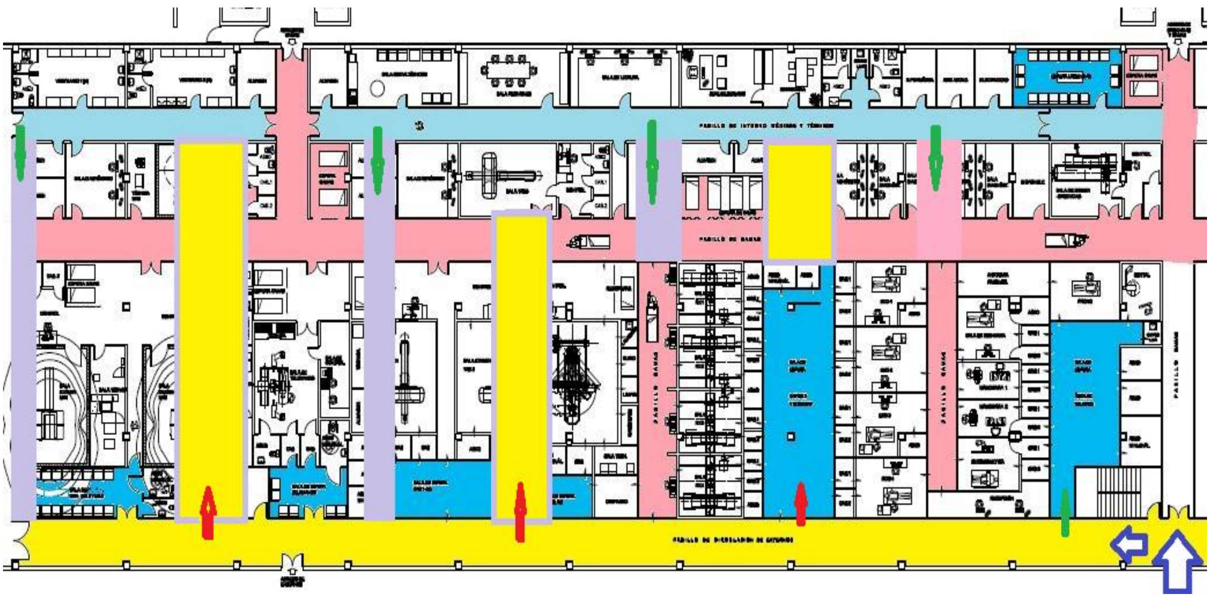
- **Less comfortable patients waits**, then will no longer be modality, but for several modalities. Less privacy, more noise.

The analysis of the circulation in a very important part of the design process, and see that it does not bring, in general, great difficulties.

There are habits that are not always easy to change in designs of departments. Most designers have very clear defined the movement of patients, avoiding mixing with internal patients and personnel, but internal personnel circulation is rarely separated from the internal patients. If it is possible have to do the separation, because the real fact of loss of productivity is going to happen, and for many years, for avoid designing this type of separate circulation. Personnel with internal patient collisions are severe in hospitals where there are no consultations and there are less outpatients, and the increased workload comes from internal patients.



(14.5.- Circulations separated for external patients, technicians-beds and staff)



(14.6.- Alternative with a single corridor for internal beds: more space and less comfort)

Work in AUTOCAD or any graphic design program simplifies significantly the selection of circulations.

The example shown above is a simple graphic representation of all of this ideas about circulations and explain by itself why circulations is one clear step in the design process.

XIV.III.- CLINICAL PROCESSES

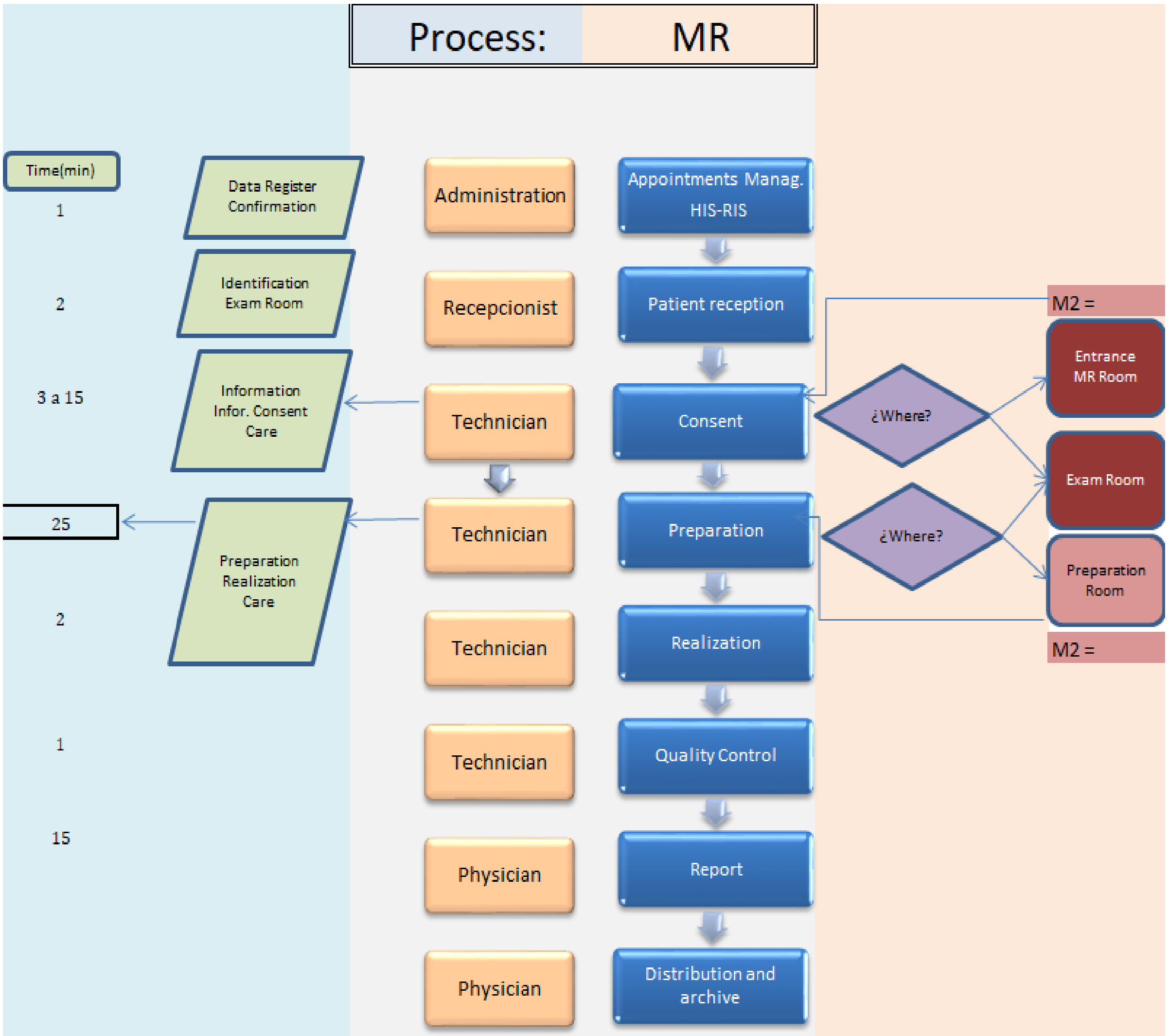
A medical image acquisition in diagnostic radiology, nuclear medicine examination, one radiotherapy treatment, can be represented by the different steps performed to be completed. i.e. the different steps carried out in the clinical process. Review the processes that are expected to develop in the department presents two types of contributions that are very valuable in the final design process:

- Know exactly the additional surfaces which would be used in advance in the process of design, because it happens that the relationship with the patient, or the process itself to facilitate its steps, may require additional dependencies, and at the end additional surface.

- Bring more clarity to the total time that a patient, and his companions, will stay in the department. The addition of the individual times gives us an idea of the total process time.

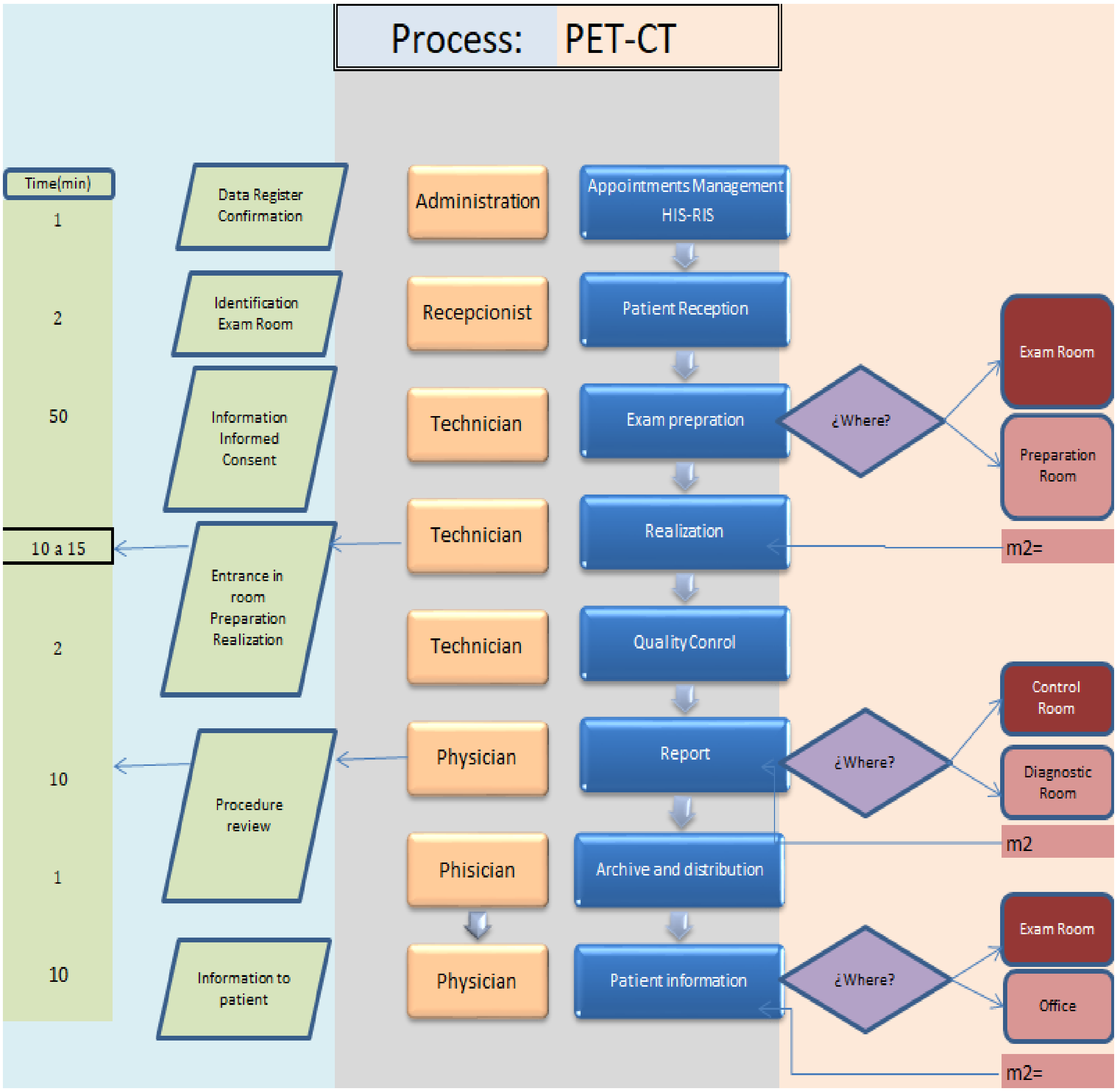
It is presented an MRI case where a decision is if preparation room will be placed for the patient and placing a room for the task of explanation of informed consent. In general all designs have both facilities in MR. But there are situations that offer a question. The surface is different, and it can be calculated at the design time.

It is the same case of an installation of angiography, although this may be more complicated. In some cases, resuscitation beside the examination room are needed. This further increases the surface.



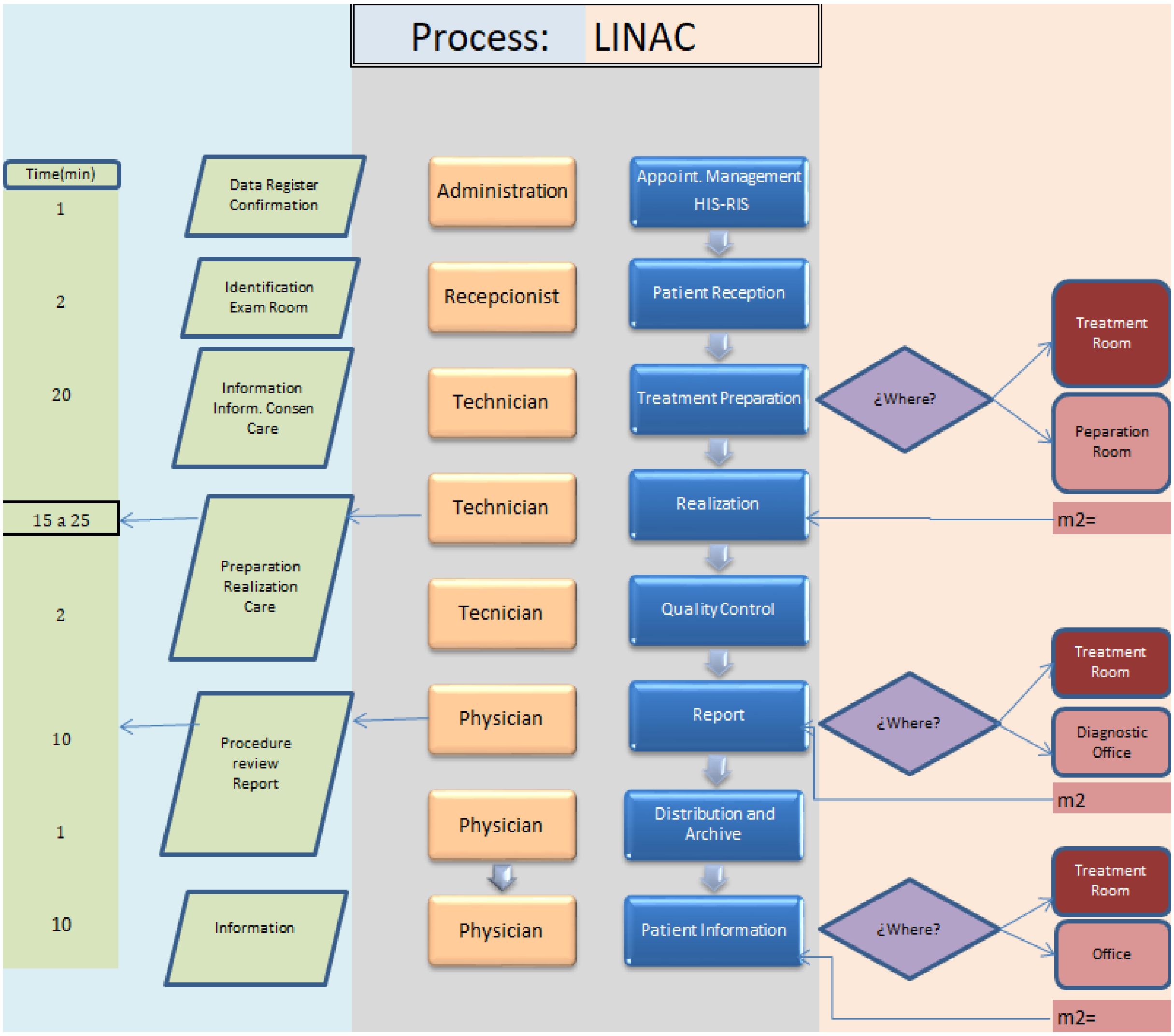
(14.7.- Clinical magnetic resonance imaging examination process)

In Molecular Imaging, there is the same way of contemplating the situation. A review process is exposed with PET CT, where can reduced the processing steps and measure their times and extra spaces, if it is need.



(14.8-Clinical process of PET-CT examination)

And in the same way is break down a LINAC treatment process, so can be seen its average times and spaces. Logically all the treatments do not have the same process, but the operation is with averages, and if a modality requires special care, as for example the case of stereotaxy, should be looked at the individual process to see what space requirements presents. This is the phase where doing this analysis, on the other hand simple and routine, facilitates the design and avoid the las time breaking comments where you have to add or reduce spaces, and in the worst case when the design is finished and a review of project is done to see the progress. It may cause many hours of extra work, as if it is needed to include an additional space for a preparation place it may lack surface for this room. And restart again.

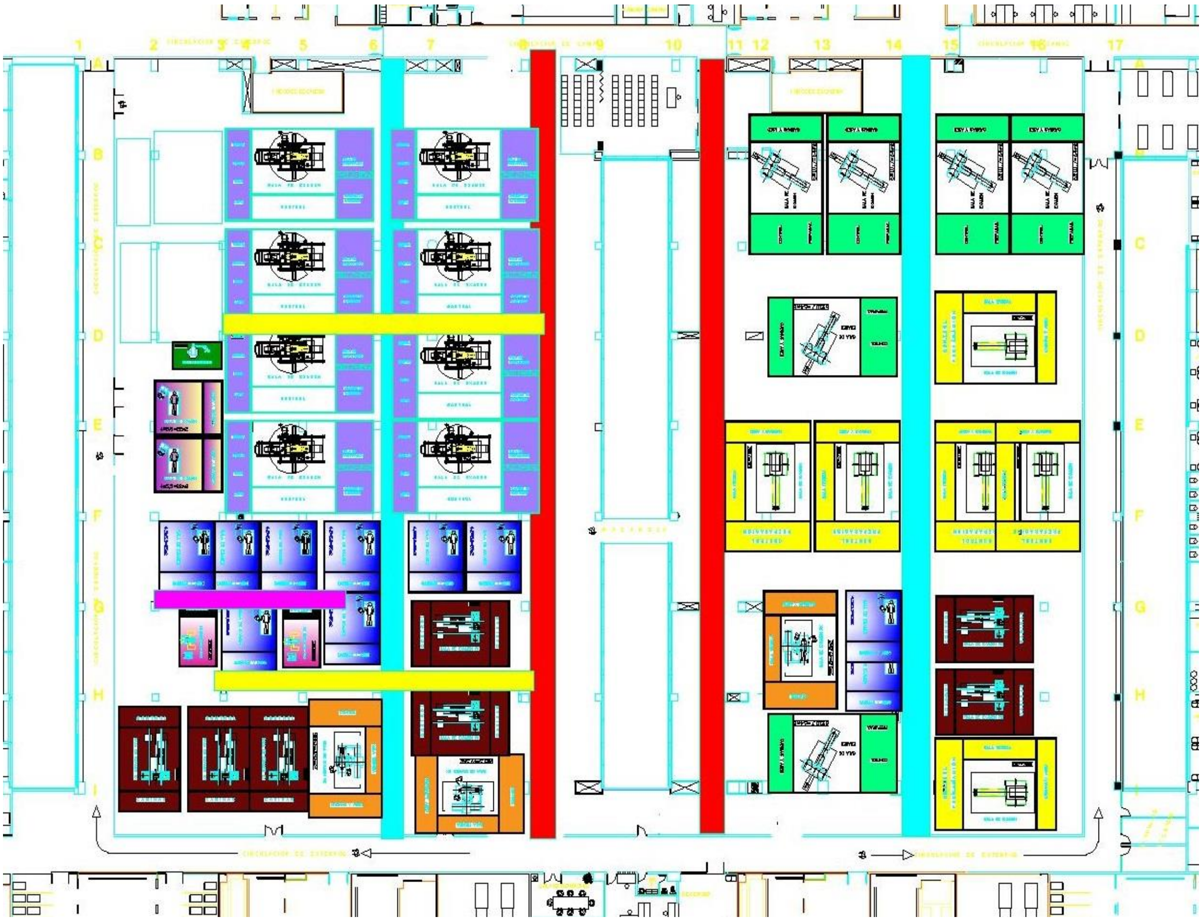


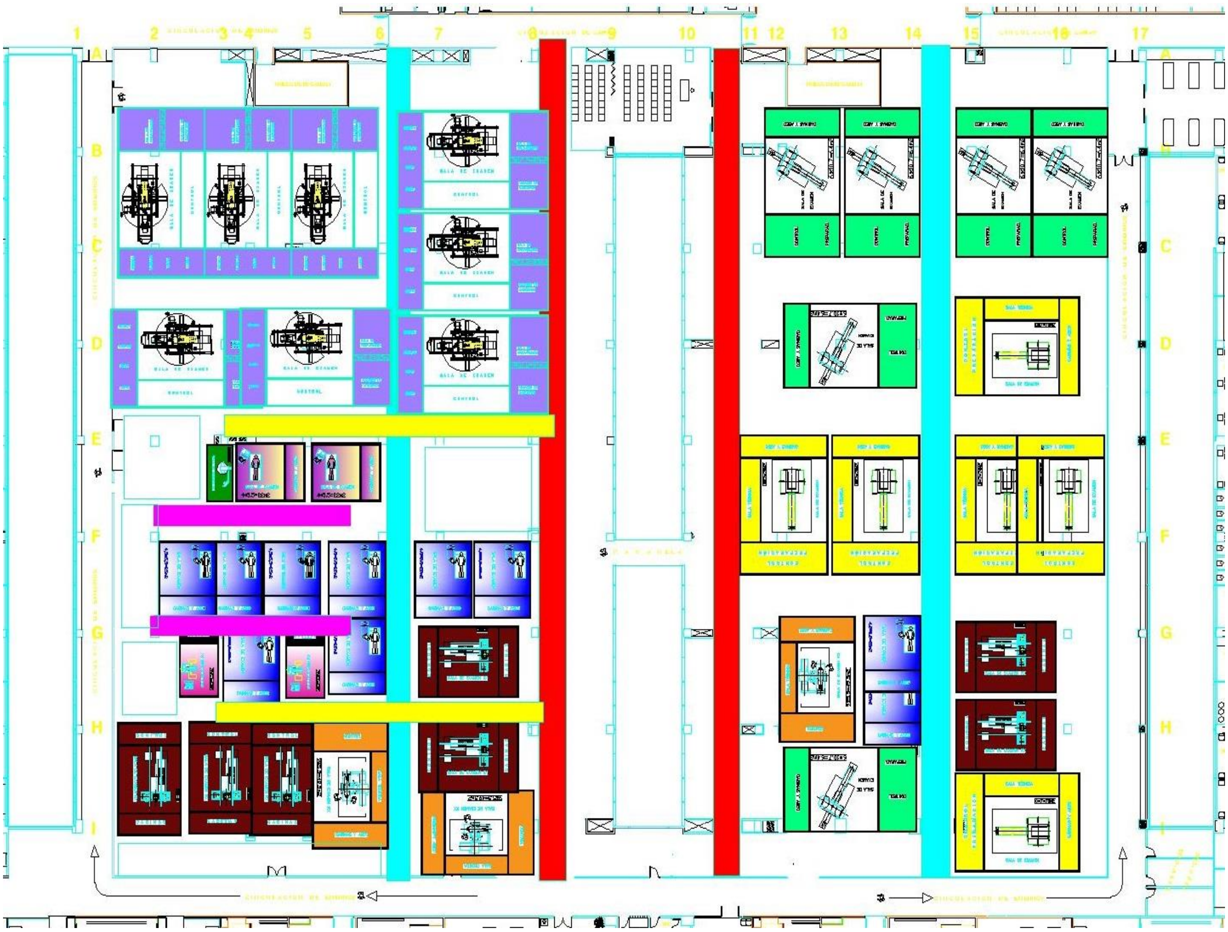
(14.9-Clinical process of a LINAC treatment)

XIV.IV.- DESIGN BLOCKS

Already has been seen in the chapters dealing with the modalities and Chapter 10 dedicated blocks of each modality design and how to fit them into a CAD program within the surface destined to the department.

It is not necessary to introduce new concepts in this connection. Only stress the great utility for the designer, once it acquires certain practices in the handling of blocks, he can make his own blocks with the pictures he want and with the dimensions already previously indicated. Only will be exhibited as a complex design can be changed in a short time to find a satisfactory solution for all design team.





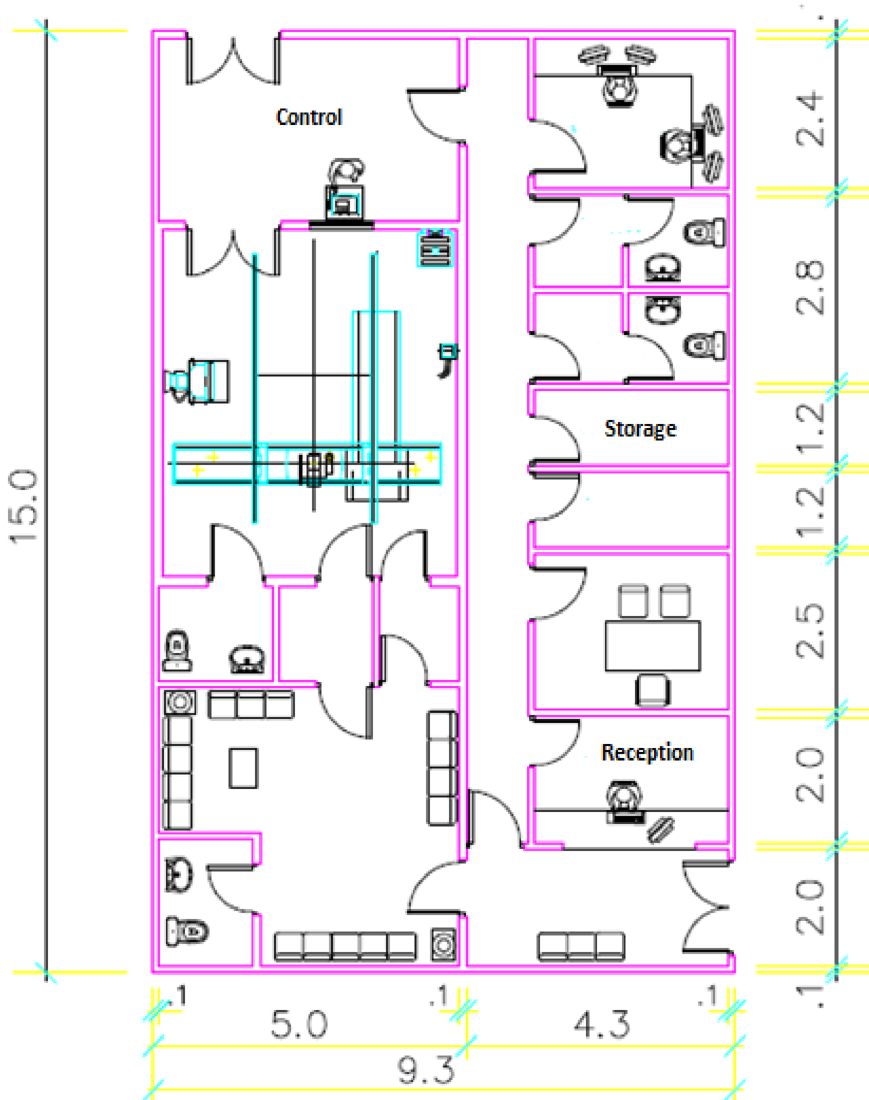
(14.10-Choices in designs with blocks)

Shown the changes in the angiography bock and cardio angiography in a very simple way that offers a view of a part of the design with blocks that changes the distribution of the rooms in a very short time. The design team can take very fast decisions and make adjustments based in this simple and rapid procedure.

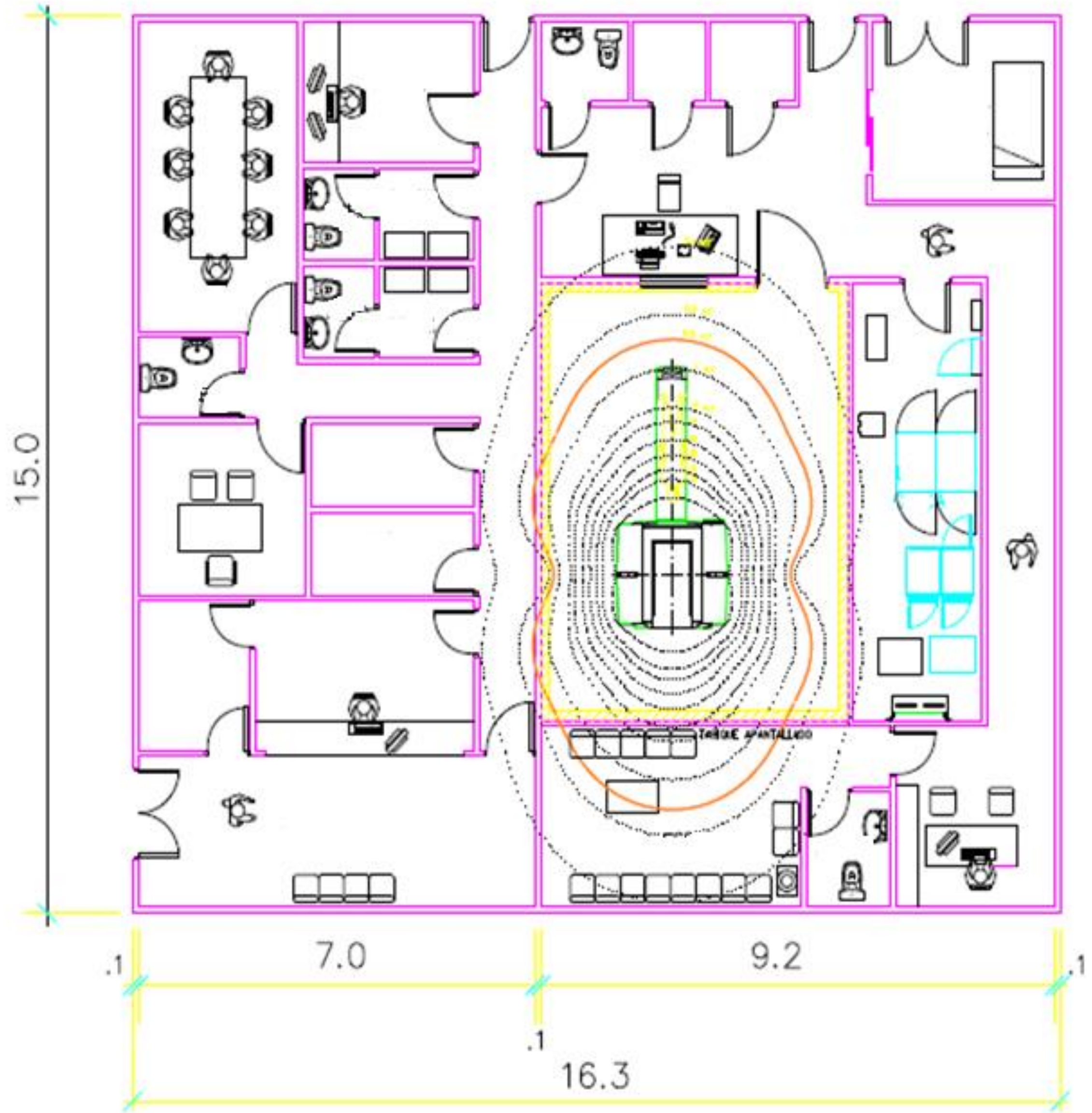
XIV.V.- ROOMS DESIGN

Design proposals of rooms following a modular system to integrate them into the design of a department is already showed in Chapter X.

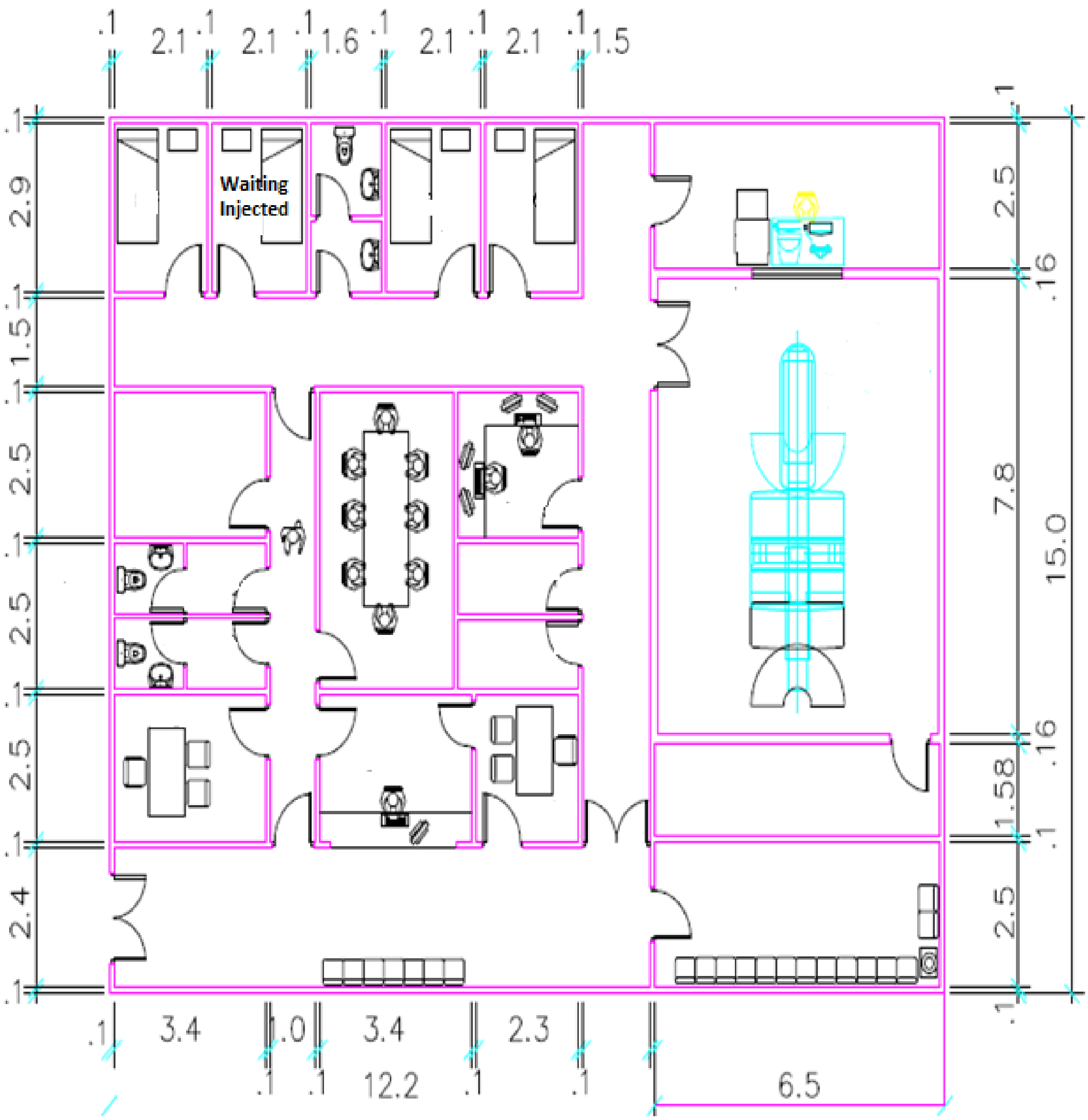
Below are proposals for rooms installed individually with the corresponding dependencies. Dimensions are in metric.



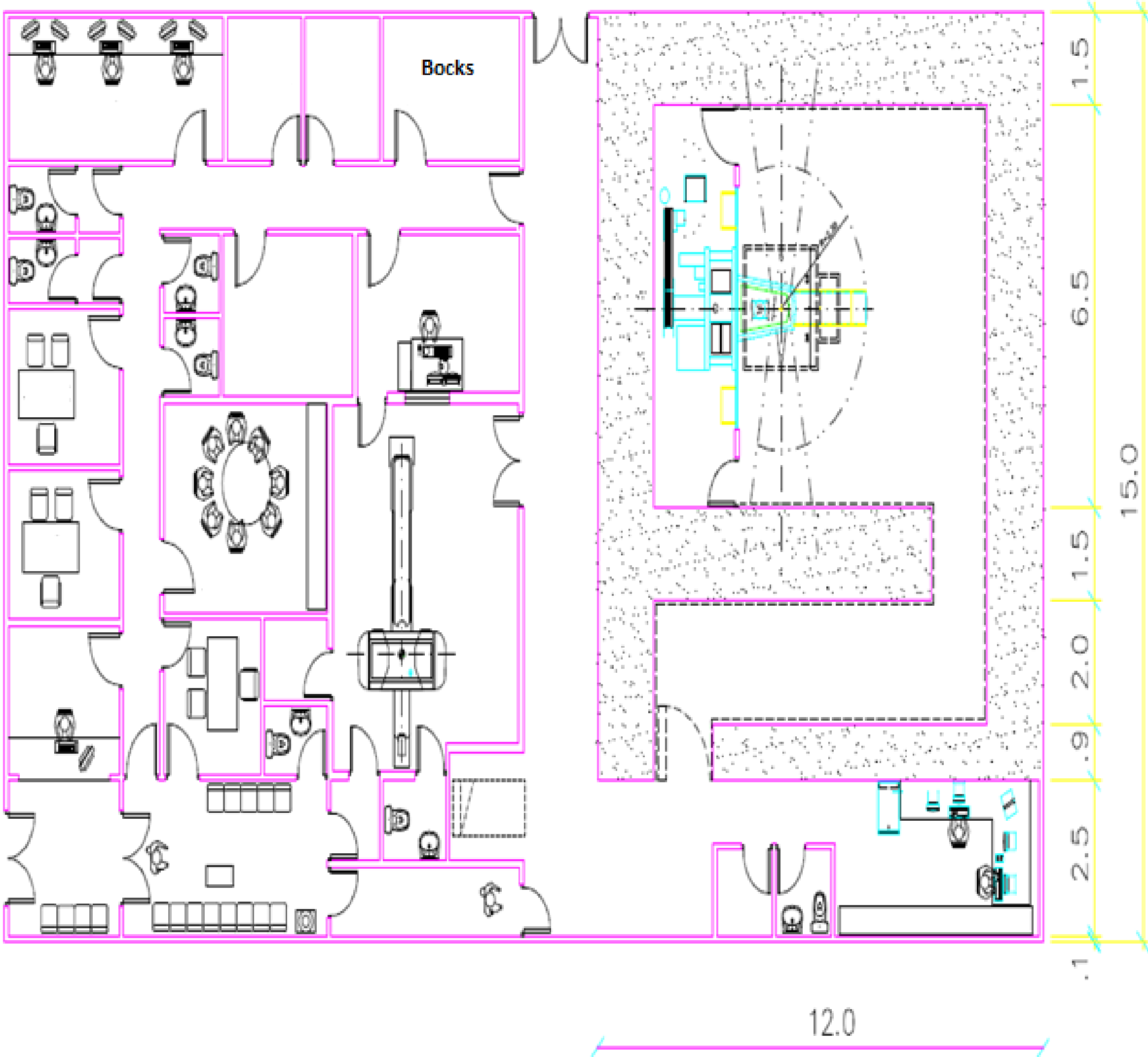
(14.11-X-ray digital room with its dependencies)



(14.12-Room of magnetic resonance and annexes)



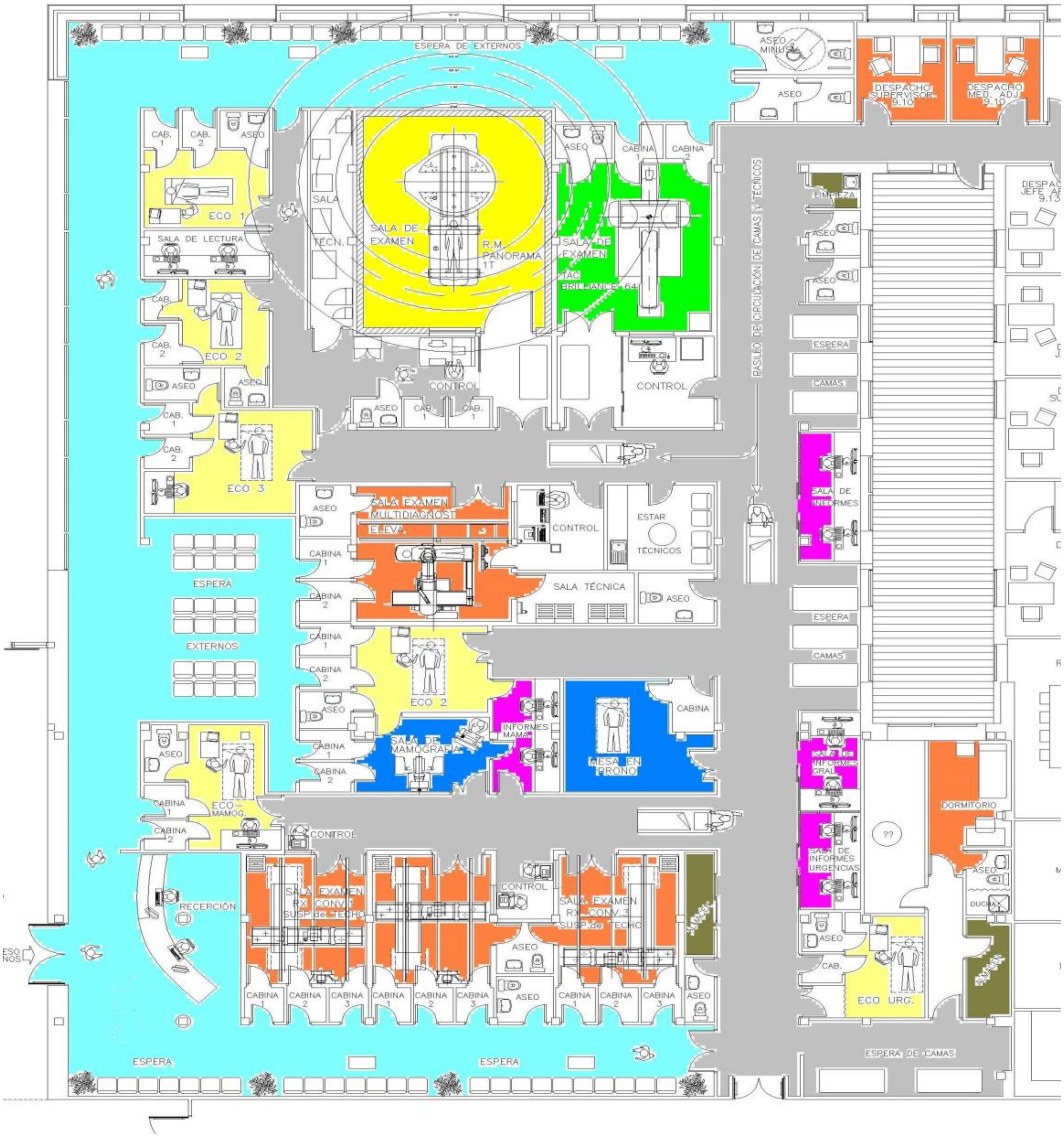
(14.13-PET CT as a single installation room)



(14.14.-LINAC room and dependencies)

XIV.VI.-DEPARTMENT DESING

Is the final step which has been already discussed and base of the corresponding architectural project that will serve as a basis for the department business plan.

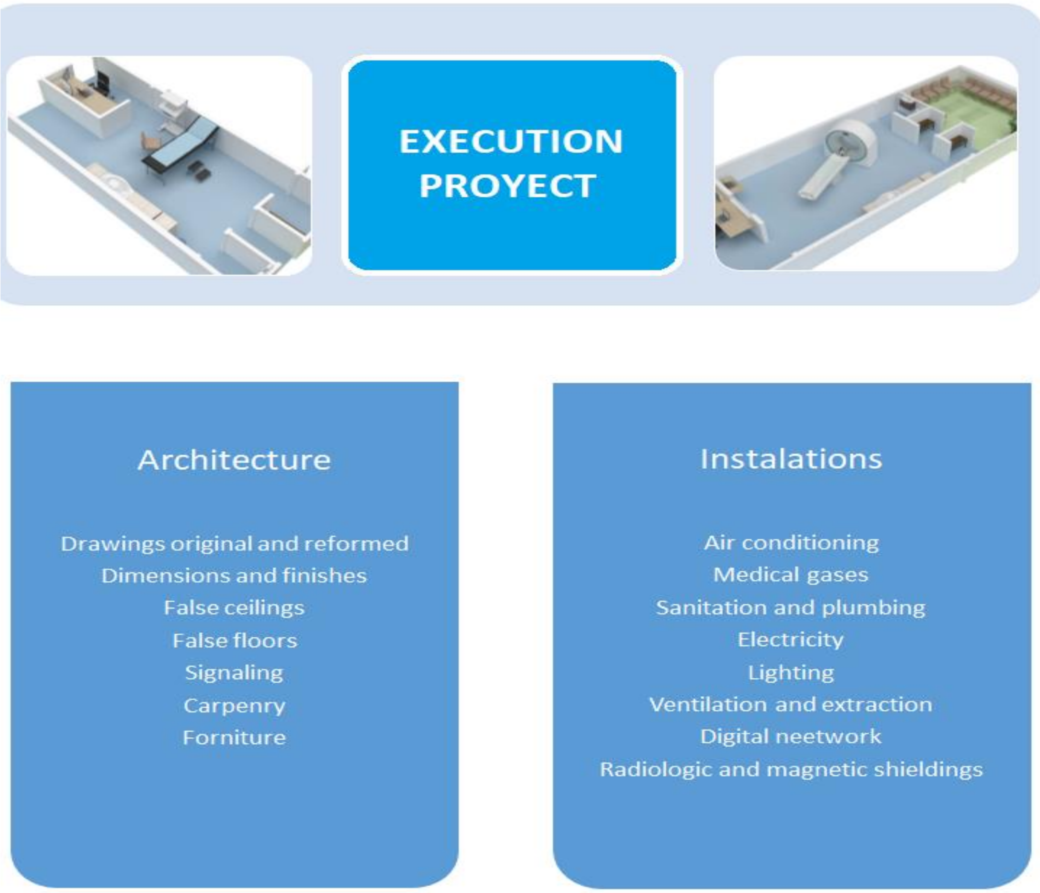


(14.15.- Department design)

Once the department drawing has been finished, the architect has the way cleared for drafting the project. The architecture team still has a substantial task until have defined all the details that turn it into a document capable of driving in a final construction. Must be calculated and written all sub projects that are expressed in the figure below so that the construction work can be done without difficulties.

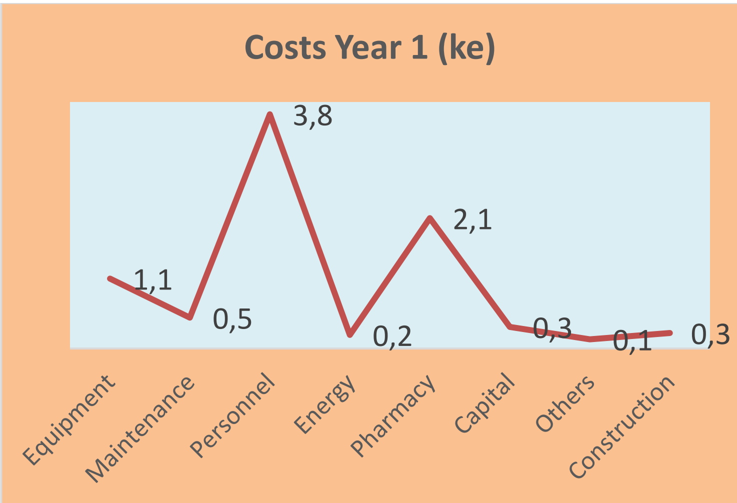
Under the direction of the architect, as director of the project, must be carried out by the relevant specialists a number of sub projects that allow to define from a blip until the placement of a digital network connection terminal, without which today does not work an diagnostic imaging or an radiotherapy department.

Describes the tasks to be carried out in the department's project, basis for the realization of the business plan, which will be briefly detailed in the next chapter.



(14.16.- Subprojects to develop for the full project)

XV.- BUSINESS PLAN



I. **INVOICING**

II. **COSTS**

III. **COSTS PER EXAM**

IV. **CASH FLOW AND RESULTS**

-

Long-term planning is not to think in future decisions, but in the future of present decisions.

Peter Drucke

XV.- BUSINESS PLAN

This chapter was deleted in the first edition on the basis that the many of the imaging and radiotherapy departments are integrated into hospitals, and there is no specific form of a business plan, in general, unique for each department or service of the hospital, but there is an overall plan for the hospital, culminating in a number of accounts covering all hospital activities, adding the individual costs of its components; building, projects, equipment, etc. At least thus takes place in public hospitals and not in all privates, making a business case prior to the investment, in many cases with detailed analysis of each department profitability. It is made on a global basis. It is believed that, at least in private, that in hospital centers and outpatient centers a substantial change is occurring and there is not built anything without a prior plan that ensures profitability. Also in public, are being carried out plans that at least provide one overlook to the cost per exam and modality that will be reached in the operation of the department.

The Business Plan is the document that with concrete economic magnitudes shows the activity is aimed to develop the department and it places the future project with one experience and a personalize entity on the day that is approved by the project committee. It tells us what to do, how it will be done and when should the events occur.

Must include the details of income, expenses, billing, payments and cash flow to end up in an account of results that can be zero in public centers or a fair profit to give back the investors in private entities. Let us not forget that public investors are the citizens that coast the center with their taxes.

Surely each one has their own software tools to insert the data that is available for the implementation of the plan, for this the graphics that arise in the next pages are a way of exposing the basic elements of the plan, which may be exposed and displayed in multiple ways.

The Business Plan is the tool that will allow the development of the project in accordance with stablished objectives and that will provide the expected department activities be numerically documented on a date very prior to the physical implementation of the project.

Will be shown in the following graphics in schematic and simplified form the most important steps.

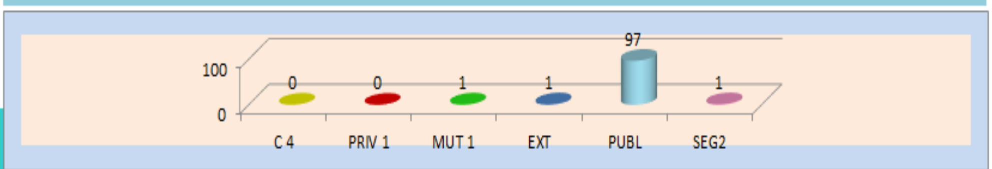
As are already known the number of exams or treatments, the surface, the rooms, staff and all investments, can start calculations of the plan. Will start by calculating expected revenue of the department. Public and private examination rates. Then will be calculated the costs of personnel, equipment, drugs, works, etc, expected payments and the cash flow, to finish with the result that is expected from the operation of the department.

XV.I.- INVOICING

First, how many patients per modality and then the average values of the existing rates of the insurance companies, private and public rates published.

FORECAST OF SENDING PATIENTS FROM DIFFERENT CLIENTS

Modality	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	PRIV 1	MUT 1	MUT 2	EXT	PUBL	SEG1	SEG2	SEG3		TOTAL
Client	Asisa																		
DR									1		1	1	5	636	2	2	1		649
FL									1		0	1	2	14	0	1	0		19
ORT												1		5	1	1			8
DEN													1	10					11
MAM											1			31					32
CT									1			1		74					76
MR													1	45			1		47
US														126	1		1		128
VAS												1	1	8	0	0			10



Total per client	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	PRIV 1	MUT 1	MUT 2	EXT	PUBL	SEG1	SEG2	SEG3		TOTAL
%	0	0	0	0	0	0	0	0	3	0	2	5	10	950	4	4	3		981
Exams				0						0	1		1	97		1			100

(15.1.- Tests provided by patient sender)

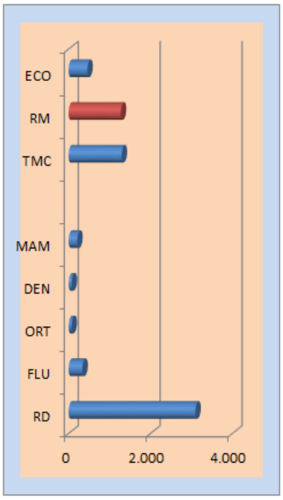
CLIENT EXAM PRICES (euros)

Modality	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	PRIV 1	MUT 1	MUT 2	EXT	PUBL	SEG1	SEG2	SEG3	Average
Client	Asisa																	
																		euros
DR									45	50	60	60	60	20	60	60	40	21
FL									83	99	90	90	90	71	89	89	90	75
ART									25	40	50	50	30	25	30	39	40	38
DEN									35	60	60	60	60	22	60	60	60	31
MAM									45	50	50	50	50	28	50	50	50	29
CT									100	130	120	120	100	73	100	100	100	74
MR									140	170	120	120	160	115	160	160	160	117
US									45	50	50	45	50	15	50	45	50	16
VAS									900	1.100	900	900	900	769	900	900	900	795
Pay delay	1	2	2	3	2	3	2	1	3	0	1	2	3	0	1	1	1	
Quarters	1	2	2	3	2	3	2	1	3	0	1	2	3	0	1	1	1	133
Max 3 Q					2					0	2	2	3	0		1		

(15.2.- Rates apply for each sender of exams and deadlines for payment to each sender)

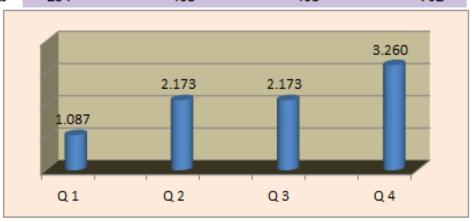
STARTING DATA

Modalities	Exams Total	%
DR	149.187	66
FL	4.466	2
ORT	1.912	1
DEN.	2.429	1
MAM	7.314	3
	0	0
CT	17.516	8
MR.	10.910	5
US	29.541	13
VAS	2.357	1
RIS - PACS		
OTHERS		
	225.630	100



INVOICING

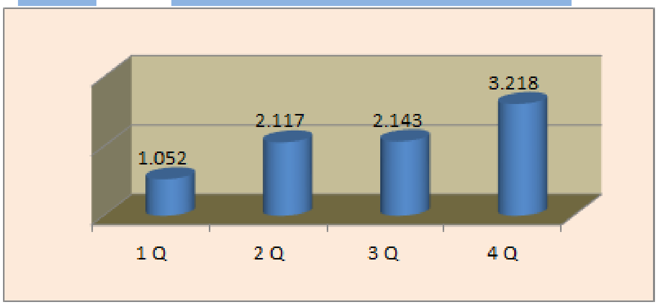
	Q 1	Q 2	Q 3	Q 4	TOTAL k euros
RD	387	774	774	1.161	3.095
FLU	42	84	84	126	337
ORT	9	18	18	27	72
DEN	9	19	19	28	76
MAM	26	52	52	79	210
TMC	162	324	324	486	1.296
RM	159	319	319	478	1.275
ECO	57	115	115	172	459
VAS	234	468	468	702	1.872
	1.087	2.173	2.173	3.260	8.693

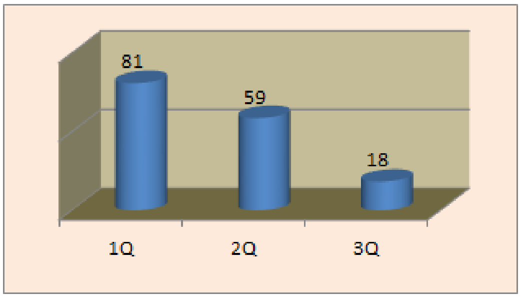


(15.3.- Invoicing per quarter in the first year of the department)

COLLECTING INVOICES

	Year 1					Year 2		
	1 Q	2 Q	3 Q	4 Q	TOTAL	1Q	2Q	3Q
	k euros				k euros			
DR	375	754	763	1.146	3.037	29	21	8
FL	41	82	83	125	331	3	2	1
ORT	9	17	18	27	70	1	0	0
DEN	9	18	19	28	75	1	1	0
MAM	25	51	52	78	206	2	1	1
CT	157	315	319	480	1.271	12	9	3
MR	154	311	314	472	1.251	12	9	3
US	56	112	113	170	451	4	3	1
VAS	227	456	462	693	1.837	17	13	5





1.052	2.117	2.143	3.218	8.530	81	59	18

(15.4,- Collections by modality and deferred to the next year based on the period of payment)

XV.II.- COSTS

The fixed and variable parameters are the operating data that have the department. Capital as well as basic advertising, training, office overheads, construction, equipment etc., and other fixed costs. Also have the costs of staff, projects, energy, drugs, water, services, etc.

FIXED AND VARIABLE PARAMETERS

HOSPITAL		DIAGNOSTIC IMAGING	
Number of beds	280	Labor hours	8
		Days / Year	230
Rotation Factor	6,5		
		Service (hours/day)	14
Occupation Factor	0,7	Service (days/Year)	250
Productivity	0,8	Emergency	24
			365
Equip. Life	10	Interest rate	5,5%
Inflation(%)	2	Mortage (Years)	5
	4		
Publicity	Training.	Office	Others
5	10	20	40

PROJECT AND CONSTRUCTION

	e/m2	ke
Architect	10,0	24,5
Physics (e/s)	500,0	7,5
Mag. Shield	2,0	4,0
Lighting	3,0	7,4
Elect.(e/kw)	3,0	4,4
A.C.	3,0	7,4
Fire prot.	2,0	4,9
Decoration	2,0	4,9
Total project		64,9
Construction	Year 1	Year 10
Price e/m2		
1.000	2.450	0
Interests	345	0

RESOURCES COSTS

					(precios)	años	tipo int	(Kva)
Personnel	keu/año	Energy		Equipm	k.euros	5	5,5%	Power
Radiolog	60	El (e/kw)	0,1	DR	200	28		100
Techinicians	25	Wat(e/m3)	2,0	FL	300	42		100
Nurses	30	Gas(e/m3)		ORT	50	7		2
Auxiliaries	17	Manager	50	DEN	50	7		2
Carttakers	17	Power	kW	MAM	230	32		5
Administrat.	20	Installed		CT 1	700	99		150
Computing	25	Equipm	1.093	CT2	700	99		150
Pharmacy	ke/año	Lighting	98	MR1	0	0		0
Cont. MR	30	A.C.	123	MR2	900	127		130
Cont CT	30	Computers	5	MR3	900	127		150
Other Cont.	20	Others	135	US	80	11		1
Linig	1	Total KW	1.453	VAS	700	99		150
Others	2			Ris+Pacs	2			
Catheter	500			Others	100	14		
Renting		euros/m2	Total/Year	Maintenanace		%		
m2				General		0		Value
2.450		10	24.500	Ultras.		0		Personal
				Building		20	e/m2	6

(15.5-Overview of staff, drugs, energy and equipment costs)

Modality	Exams Total	%	Room Nº	Personnel		Equipm 5 Years	Manten. k euros	Personnel	Energy	Pharm.	Capital 5 años	Constr.	Others	
DR	149.187	66	4	rad	25,9	160	0	1.551	0,62	149	23		5	pub
FL	4.466	2	1			60	0		0,22	103	8			
ORT	1.912	1	1	tec	41,3	10	0	1.032	0,03	6	1			
DEN.	2.429	1	1			10	0		0,08	2	1		10	train
MAM	7.314	3	1	nur	8,9	46	0	267	0,001	22	6			
											69	251		
CT	17.516	8	2	aux	13,2	280	0	224	43,79	315	79			
MR.	10.910	5	2			360	0		17,73	196	101		20	offic
US	29.541	13	3	cartt	4,7	48	0	79	0,74	89	7			
VAS	2.357	1	1			140	0		8,84	1.232	20			
											30			fint
				adm	9,2			184					90	sev
RIS - PACS				comp	2,3		451	56						
OTHERS						20	0		83,3		3		25	rent
					105,3		49		19,1					
				12%	12,6			407	42,9					
							(año2)		4,0					
	225.630	100	15		118,0	1.134	500	3.801	221,3	2.115	349	251	150	
						5.670								
						Investment								

(15.6.- Table of department costs year 1. There is no maintenance for equipment warranty)

Modality	Exams Total	%	Room Nº	Personnel		Costs	Radiol.	Tecn.	Nurses	Aux	Cartt	Admini.	Comput.	Total Personne ke
DR	149.187	66	4	rad	25,9	1551	10,3	23,4						1.204
FL	4.466	2	1				0,9	1,5	0,3					101
ORT	1.912	1	1	tec	41,3	1032	0,1	0,3						14
DEN.	2.429	1	1				0,1	0,4						18
MAM	7.314	3	1	enf	8,9	266,7	0,4	1,6						66
											4,7	9,2	2,3	320
CT	17.516	8	2	aux	13,2	224,2	2,6	5,7	2,8					385
MR.	10.910	5	2				2,0	5,4	2,7	6,8				453
US	29.541	13	3	cela	4,7	79,44	6,7			3,4				461
VAS	2.357	1	1				2,5	3,1	3,1	3,1				371
				adm	9,2	184,1								
RIS - PACS				inf	2,3	56,41								
OTHERS														
					105,3	3394								
				12%	12,6	407,2								
	225.630	100	16		118,0	3801	25,9	41,3	8,9	13,2	4,7	9,2	2,3	3.394

(15.7.- Personnel costs)

XV.III.- EXAM COSTS

One that all costs are calculated all, only requires establishing overheads and the weight of these general costs on the different modalities for the calculation of the cost by examination per modality.

The values below are average modality values and depending on the power of the computer system could be obtained the cost per exam or treatment in according with the catalog of the center. At this stage this data would be sufficient to know if the efforts in the plan has been correct or on the other hand, the value of the costs obtained make not feasible the operation of the department for getting economic amounts that can ballast the activities of other departments, or impossible to invoice later.

With these costs it could begin marketing activity of the department by a breakdown of the tests in each category and calculating the amounts in accordance with the expected numbers and rates to apply. It is a fact of great importance both for public and private centers.

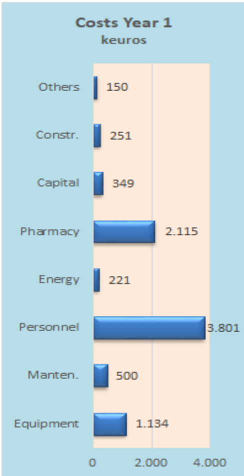
Modality	Exams		Room	Personnel		Costs	Equipment	Manten.	Personnel	Energy	Pharmacy	Capital	Constr.	Others	Gen Costs	TOTAL	Cost per Exam	
	Total	%	Nº													k euros	euros	
DR	149.187	66	4	rad	25,9	1551	160		1204	0,62	149	23		5	pub	1.537	DR	19
FL	4.466	2	1				60		101	0,22	103	8				273	FL	70
ORT	1.912	1	1	tec	41,3	1032	10		14	0,03	6	1				31	ORT	25
DEN.	2.429	1	1				10		18	0,08	2	1		10	for	32	DEN	22
MAM	7.314	3	1	nur	8,9	266,7	46		66	0,001	22	6				141	MAM	28
									320			69	251			640		
CT	17.516	8	2	aux	13,2	224,2	280		385	43,79	315	79				1.103	CT	71
MR.	10.910	5	2				360		453	17,73	196	101		20	ofi	1.128	MR	112
US	29.541	13	3	cartt	4,7	79,44	48		461	0,74	89	7				605	US	29
VAS	2.357	1	1				140		371	9	1.232	20				1.772	VAS	760
												30			fin	30		
				adm	9,2	184,1								90	var			
RIS - PACS				comp	2,3	56,41		451								451		
OTHERS							20			83,3		3		25	Alq	106	Medium Cost	
					105,3	3394		49	407	19,1					150	625		
				12%	12,6	407,2				42,9						43		38
										4,0						4		
	225.630	100	16		118,0	3801	1.134	500	3.801	221	2.115	349	251	150		8.522		
							5.670								1.900			
							Inicial Investment								General Costs			

(15.8.- Average exam cost per modality)

XV.IV.- CASH FLOW AND RESULTS

STARTING DATA

Modalities	Exams Total	%
DR	149.187	66
FL	4.466	2
ORT	1.912	1
DEN.	2.429	1
MAM	7.314	3
CT	17.516	8
MR	10.910	5
US	29.541	13
VAS	2.357	1
RIS - PACS		
OTHERS		
	225.630	100



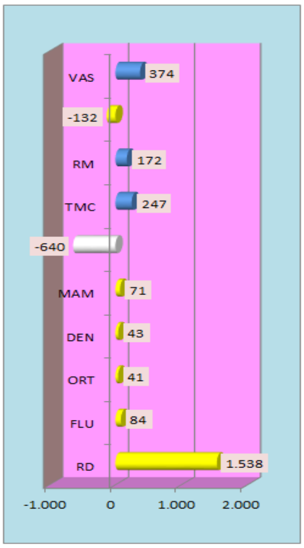
PAYMENTS BY QUARTERS

Year 1 1 Q	Year 1 2 Q	Year 1 3 Q	Year 1 4 Q	Year 1 TOTAL	Year 2 1 Q
347	384	384	384	1.499	37
43	68	68	68	247	26
6	8	8	8	30	1
7	8	8	8	31	1
30	35	35	35	135	5
160	160	160	160	640	0
197	276	276	276	1.024	79
233	282	282	282	1.079	49
129	151	151	151	583	22
135	443	443	443	1.464	308
8	8	8	8	30	
0	0	0	0		0
0	0	0	0	0	0
0	0	0	0		0
0	0	0	0		0
113	113	113	113	451	0
27	27	27	27	106	0
156	156	156	156	625	0
11	11	11	11	43	0
1,0	1,0	1,0	1,0	4	0
1.602	2.130	2.130	2.130	7.993	529

(15.9.- Payments Year 1)

SATARTING DATA

Modality	Exams Total	%
RD	149.187	66
FL	4.466	2
ORT	1.912	1
DEN.	2.429	1
MAM	7.314	3
CT.	17.516	8
RM.	10.910	5
US	29.541	13
VAS	2.357	1
RIS - PACS		
OTHERS		
	225.630	100



CASH FLOW BY QUARTERS

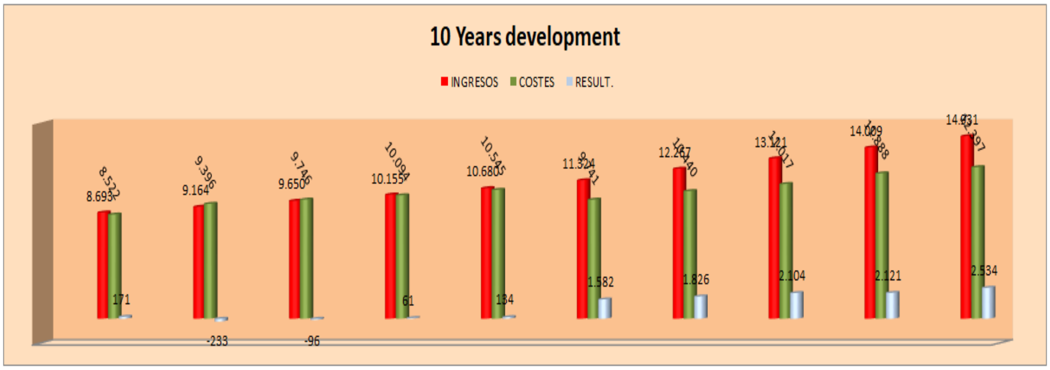
Q 1	Q 2	Q 3	Q 4 k euros		Cash Flow TOTAL k euros	Gen Costs	Costs TOTAL k euros
28	370	379	762	RD	1.538		1.537
-2	14	15	57	FLU	84		273
2	10	10	19	ORT	41		31
2	11	11	20	DEN	43		32
-4	16	17	42	MAM	71		141
-160	-160	-160	-160		-640		640
-40	40	44	204	TMC	247		1.103
-79	29	32	190	RM	172		1.128
-74	-39	-38	19	ECO	-132		605
92	13	19	250	VAS	374		1.772
-8	-8	-8	-8		-30		30
0	0	0	0		0		0
0	0	0	0		0		0
0	0	0	0		0		0
-113	-113	-113	-113		-451		451
-27	-27	-27	-27		-106		106
-156	-156	-156	-156		-625		625
-11	-11	-11	-11		-43		43
-1	-1	-1	-1		-4		4
-549	-14	13	1.087		537		8.522
5.670 Inicial In						1.900 Gen.Costs	

(15.10.- Cash Flow Year 1)

A summary of the calculation of profit loss account for 10 years is shown in the next graphic.

PROFIT LOSS ACCOUNT DIAGNOSTIC IMAGING

Modality	1	2	3	4	5	6	7	8	9	10	TOTAL keuros
DR	3.095	3.189	3.283	3.379	3.477	3.650	3.833	4.018	4.205	4.396	36.525
FL	337	347	358	368	379	398	417	438	458	479	3.978
ORT	72	74	76	78	81	85	89	93	97	102	846
DEN	76	80	84	90	92	99	105	112	120	127	985
MAM	210	223	236	250	271	285	307	330	354	378	2.842
CT	1.296	1.375	1.457	1.542	1.630	1.757	1.893	2.035	2.183	2.337	17.504
MR	1.275	1.393	1.515	1.643	1.776	1.955	2.148	2.351	2.564	2.789	19.410
US	459	497	536	577	619	677	739	805	873	946	6.727
VAS	1.872	1.987	2.105	2.228	2.355	2.419	2.736	2.941	3.154	3.377	25.175
INVOICING	8.693	9.164	9.650	10.155	10.680	11.324	12.267	13.121	14.009	14.931	113.993
COSTS	8.522	9.396	9.746	10.094	10.545	9.741	10.440	11.017	11.888	12.397	103.787
RESULTS	171	-233	-96	61	134	1.582	1.826	2.104	2.121	2.534	10.206



(15.11.- Results in 10 years)

Altea (Alicante), August 2009/Revision, translation and extension December 2018

WEB LINKS

1.- INTERNACIONAL ORGANIZATIONS

International Atomic Energy Agency

http://www.iaea.org

Organization for Economic Coop.and Development

http://www.oecd.org

Pan American Health Organization

http://www.paho.org

World Health Organization

http://www.who.int/en/

International Labour Organization

http://www.ilo.org

International Commission on Radiological Protection

http://www.icrp.org/

U.S. Food and Drug Administration

http://www.fda.gov

International Radiation Protection Association

http://www.irpa.net/

International Electrotechnical Commission

http://www.iec.ch/

International Organization for Standardization

http://www.iso.org/

Association for the Advancement of Medical Instrumentation

http://www.aami.org/

International Commission on Illumination

http://www.cie.co.at/

International Society for Magnetic Resonance in Medicine

http://www.ismrm.org/

National Electrical Manufacturers Association

http://www.nema.org/

CSN EURATOM

https://www.csn.es/normativa-del-csn/normativa-ue

2.- SCIENTIFIC ORGANIZATIONS

International Commission on Radiology Units & Measurements

http://www.icru.org/

National Council on Radiation Protection and

Measurements

http://www.ncrponline.org/

Academy of Radiology Research

http://www.acadrad.org/

American Cancer Society

http://www.cancer.org

American Healthcare Radiology Administrators

http://www.ahra.com/

American National Standards Institute

Centre for Devices and Radiological Health(CDRH)

http://www.fda.gov

Health Level Seven

http://www.hl7.org/

Institute of Electrical and Electronic Engineers (IEEE)

http://www.ieee.org/

Underwriters Laboratories, Inc. (UL)

http://www.ul.com/

Air-Conditioning and Refrigeration Institute

http://www.ahrinet.org

Integrating the Healthcare Enterprise (IHE)

http://www.ihe.net/

SCAR: Society For Computer Applications in Radiology

http://www.ansi.org/

Society for Computer Applications in Radiology

http://www.scarnet.org/

European Society of Radiology

http://www.myesr.org/

The Society for Pediatric Radiology

http://www.pedrad.org/

National Committee for Quality Assurance

http://www.ncqa.org/

NIH Biomarkers Consortium

http://www.biomarkersconsortium.org

3.- MEDICAL SOCIETIES

American Society for Therapeutic Radiology & Oncology

http://www.astro.org/

Society of Nuclear Medicine

http://www.snmmi.org/

Radiological Society of North America

http://www.rsna.org/

American College of Radiology

http://www.acr.org/

American Association of Physicists in Medicine

http://www.aapm.org/

American Brachytherapy Society

http://www.americanbrachytherapy.org/

American College of Nuclear Medicine

http://www.snmmi.org/acnm/index.aspx

American College of Radiation Oncology

http://www.acro.org/

American Institute of Ultrasound in Medicine

http://www.aium.org

World Molecular Imaging Society

www.wmis.org

Japan Radiological Society

http://www.radiology.jp/english/index.html

The Society for Pediatric Radiology

http://www.pedrad.org/

Sociedad Española de Física Medica

http://www.sefm.es

Sociedad Europea de Radiología

http://www.myesr.org/

Sociedad Española de Radiología

http://www.seram.es/

Italian Society of Medical Radiology (Società di Radiologia Medica)

http://www.sirm.org/

Société Française de Radiologie

http://www.sfrnet.org/

British Institute of Radiology

http://www.bir.org.uk/

Deutsche Röentgengesellschaft (G)

http://www.drg.de/

Association for medical imaging management

http://www.ahraonline.org

4.- PUBLICATIONS RELATED WITH DIAGNOSTIC IMAGING AND RADIOTHERAPY

Diagnostic Imaging

http://www.diagnosticimaging.com

Radiographics

http://radiographics.rsnajnls.org

American Journal of Radiology

http://www.ajronline.org/

Radiology

http://radiology.rsnajnls.org/

Aunt Minnie

http://www.auntminnie.com

British Journal of Radiology

http://www.bir.org.uk

European Radiology

http://www.myesr.org

Imaging Technology

http://www.itnonline.com

The International Journal of Radiation Oncology*Biology*Physics

http://www.astro.org

5.- MANUFACTURERS AND SUPPLIERS

Agfa Healhtcare

http://www.agfa.com

Fujifilm

http://www.fujifilm.eu/

GE Healthcare

http://www.gehealthcare.com

Hitachi

http://www.hitachi-medical-systems.com/

Frost And Sullivan

http://www.frost.com/prod/servlet/frost-home.pag

Sedecal

Philips Healthcare

http://www.healthcare.philips.com/

Siemens

http://www.medical.siemens.com

Toshiba

tp://www.toshiba-europe.com/medical

IMV

http://www.imvinfo.com

Varian

http://www.varian.com

http://www.sedecal.com

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Population	Frequency	Modality	%	Exams	t exa	Medium Production	R	R	Medium Surface	Net Surface	Population Growth	R	R	Modality Growth	R	R	Total Net Surface
Population	Exam/1000				min	Exams			m 2	m 2	%						m 2
160.000	1.000	DR	34	54.400	3	26.250	2,1	3	20	60		2,5	3,0	0	2,5	3	60
		FL	3	4.800	15	5.250	0,9	1	25	25		1,1	1,0	0	1,1	1	25
		ORT	1	1.600	6	13.125	0,1	1	8	8		0,1	1,0	0	0,1	1	8
		DEN	1	1.600	15	5.250	0,3	1	15	15		0,4	1,0	4	0,5	1	15
		MAM.	3	4.800	10	7.875	0,6	1	12	12		0,7	1,0	4	1,0	1	12
		CT	6	9.600	15	10.500	0,9	2	30	60		1,1	1,0	4	1,5	2	60
		MR	8	12.800	25	6.300	2,0	2	35	70		2,4	3,0	5	3,7	4	140
		US	8	12.800	15	5.250	2,4	2	15	30		2,9	3,0	5	4,4	5	75
		VAS	1	1.600	60	1.313	1,2	1	35	35	2	1,5	1,0	5	2,2	2	70
160.000	1.000	US	3	4.800	15	26.280	0,2	1	15	15		0,2	1,0	5	0,3	1	15
		DR	30	48.000	3	131.400	0,4	1	20	20		0,4	1,0	0	0,4	1	20
		CT	2	3.200	15	26.280	0,1	0	35	0		0,1	0,0	4	0,2	0	0
			100														
0	0	DR	67	0	8	19.688	0,0	0	20	0		0,0	0,0	0	0,0	0	0
		FL	7	0	30	5.833	0,0	0	25	0		0,0	0,0	0	0,0	0	0
		US	10	0	20	5.625	0,0	0	15	0		0,0	0,0	5	0,0	0	0
		CT	8	0	25	6.300	0,0	0	30	0		0,0	0,0	4	0,0	0	0
		MR	8	0	60	2.625	0,0	0	35	0		0,0	0,0	5	0,0	0	0
			100														
				160.000				16		350			17,0			22	500

NET EXAMINATION SURFACE — 350 — 500

DEPARTMENT GROSS SURFACE — 2.100 — 22.604 ft2

GREATER NEED OF SPACE BECAUSE:
* Population Growth
* Modality Demand Increase

3.000 — 32.291 ft2

PLANNING properly the needs of diagnostic imaging and radiotherapy of a community is a complex task that requires experience and specialization and a lot of creativity for the next task that is the design.

DESIGN the department properly is the next stage which leads to many years of good performance, productivity in the work of the personnel and satisfaction in the care of the patient.

Facilities that provide the correct diagnosis and treatment to patients are the target of this book, and through its pages can will know techniques and procedures with which health managers, medical administrators, medical doctors, radiologists, oncologists, engineers, physicists, architects and other professionals in the sector can perform their task with satisfaction and efficiency, so patients will find, once the departments are in operation, safe and comfortable.

And its final goal is to have diagnostic imaging and radiotherapy departments that ratify the patient in their dignity as a person.

J.A. GARCIA