# KNOWLEDGE AND TECHNOLOGY MANAGEMENT IN A SYSTEM APPROACH, FOR A NEW SATELLITE SYSTEM PLANNING

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## ABSTRACT

After four decades of a continuous development in services, applications and technology, now a satellite is considered as one of the most important communication systems. In spite of having many different options for telecommunication services, the satellite service is competitive and is increasing with high rate of traffic.

As the satellite system is not perennial, sooner or later has to be replaced. The satellite replacement task is complex because there are many technical, economic and political factors and to be considered. From the national point of view there are also development criteria to achieve goals in term of the support to the whole economic system and to the specific economic activities related to industry, education, government and business.

From the systemic point of view, it is necessary to consider several disciplines. In that multidisciplinary problem we propose to include Knowledge Management, Technology Management, Communication Engineering, Economics, Physics and Information Systems besides of System Engineering and System Science.

A satellite communication system has to be planned several years before the date when it should be launched into space. Due to this situation, a system approach is needed to achieve the whole purpose and the partial objectives. The first activity is to define the system frontier, the supra system and the subsystems, the second activity is to classify them in a hierarchical order to identify the main relationships among them.

When a great scale system is designed there is an interest to achieve all the possible improvements of the previous system, incorporate the advantages of new knowledge, new technology, new public policies, reinforce the regulatory frame and satisfy the new needs through the new services. Knowledge Management, Technology Management and Systems Science help us in this purpose.

In the Mexican case it is also desirable correct the main mistakes that were made in past experiences. For this reason it is necessary to apply the concepts, schemes and methodologies of the Knowledge Management.

Keywords: System Approach, Knowledge Management, Technology Management, Satellites, Communication, Systems.

## KNOWLEDGE AND TECHNOLOGY MANAGEMENT

## INTRODUCTION

The Mexican new satellite is a great scale system. It should be designed with all the possible improvements of the previous system incorporating the advantages of new knowledge and new technology. For achieving this purpose new public policies should be added and present regulatory frame modified.

Only if System Engineering, Project Engineering, Knowledge Management, Technology Management and Systems Science are properly used the new satellite can fulfil the demand requirements. For this reason it is necessary to apply concepts, schemes and methodologies taken from the mentioned disciplines and combine them in an integrate methodology.

In the Mexican case it is also desirable correct some mistakes that were made in the past experiences. Mexican Government is charge of the Mexican satellite system.

Now for having a new satellite it is necessary to face a relative saturation of the geostationary orbit, to negotiate with international entities, contract specialized companies for several activities and create an enterprise to operate the satellite once it is located into the space. Good marketing and enough financial productivity are necessary conditions for that enterprise.

There are many different specialists involved in a satellite planning. Most of them are related to communication engineering, but others belong to disciplines like strategy planning, financial activities, marketing and technology management.

## SYSTEM DEFINITION

In this part of the paper we select the elements of the system to mark the difference respect with those which are out of it, in this way we are defining the system limit. The intent is to provide a conceptual understanding of systems approach and system engineering to the problem of building a new satellite system or replacing the old one which is going to be out of service. Also the purpose is to provide an analytic structure through which a new satellite decision making can be performed.

It is based upon the system concept. Defining system as an aggregation of elements united by some form of interaction, to form an integral whole to function in obedience to some main objective and control. Of course the focal point of this system approach is directed toward a new design which takes into consideration all available knowledge in this matter and new technologies.

After applying a system definition for our problem of planning a new satellite, we obtained the following figure.

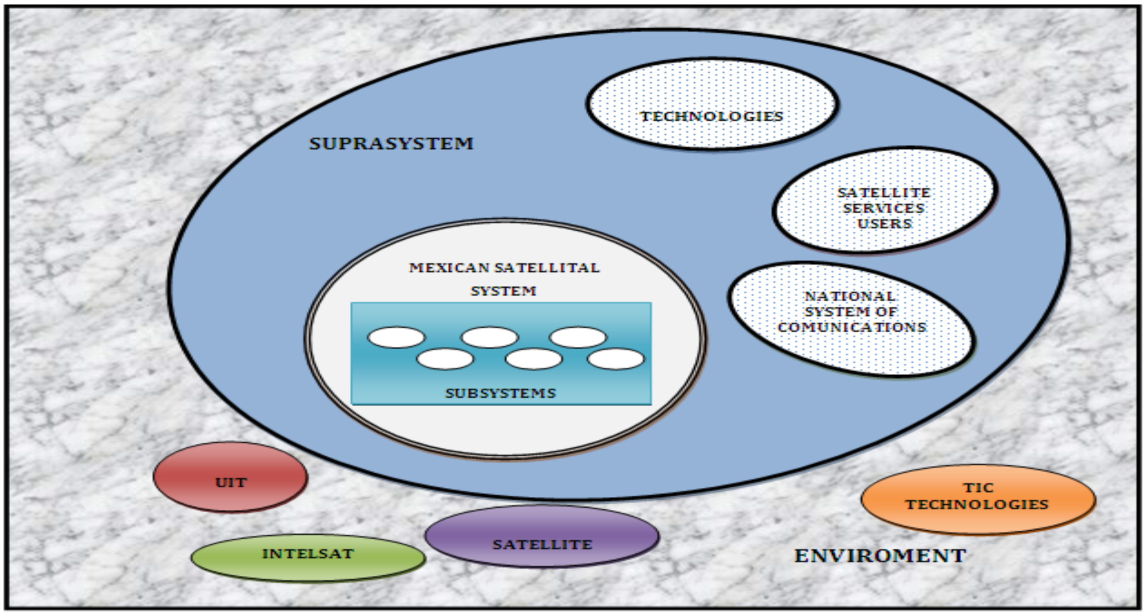


**Figure I. System Definition**

**Suprasystem**

- International Satellite Systems
- Satellite Technologies
- TIC Technologies
- UIT/ Intelsat
- National Political System
- National System of Telecommunications
- International Providers

**Subsystems**

- Subsystem 1. Technical Subsystem / Engineering Subsystem
- Subsystem 2. Regulatory Framework Subsystem
- Subsystem 3 . Marketing Subsystem
- Subsystem 4. Services Subsystem

## KNOWLEDGE AND TECHNOLOGY MANAGEMENT

Two points of view are considered in this definition, the traditional design terminology and the new one related to systems terminology that has recently come into vogue. There are many recent advances in technology. So, now there are many satellite designers so specialized that it is necessary to use the fundamental concepts of system engineering into the design of any new satellite. Today a communication engineer does not design a total new satellite. Most large design projects like aircrafts, refineries, airports, and also satellites are broken in smaller design tasks made by different companies, but it is common that one of them has the total control of the new design, managing the organization of all these individual projects.

## SYSTEMS ENGINEERING APPROACH

Analysis is necessary to separate the whole into its constituent elements. In the opposite sense, it is necessary synthesis, which is the combination of those parts into a complex whole. The new satellite system approach requires an interdisciplinary coordination of activities to design each component and subsystem of the system to obtain an optimal design. Systems engineering requires of many specific analysis and synthesis are required to take apart and study each part individually.

System engineering is applied to obtain the following ideals:

- The study and evaluation of all parts of the defined system.
- The analysis of the system to study the effects of each part has upon the operation of every other part and has upon the whole working of the system
- The synthesis of all parts once partially studied to define the total effect upon the system
- The optimization of the total system.

In this way, System Engineering is the application of System Science to achieve the improved functioning of a large scale system design.

There are a variety of system approaches presented in the literature. In this case we prefer a scheme which defines a general step-by-step procedure to solve the problem, emphasizing the required decision making.

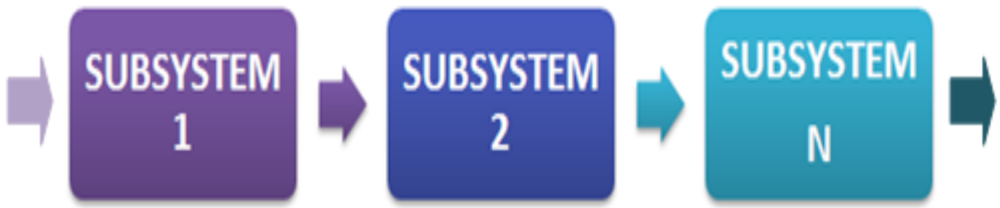


**Figure II. Subsystems**

**System Objective**

The objective is to build a new satellite for this era, after several experiences in the last thirty years. When Mexican needs have increased, technology has changed and the enterprise in charge of services has had many administrative and financial problems.

It is needed a suitable geo stationary Satellite -positioned in a proper orbit to cover the Mexican territory and other near areas to make possible offering the needed services for the country. This new satellite has to be created after a gestation period which should begin in 2012 by Mexican Government by means of the setting a group of experts to consider the technical, operational and administrative aspects to introducing the satellite communication services for many applications in the country according to present demand. It is expected the satellite be operational in two years
As the satellite which is going to be designed is a Mexican Government property and as it is operated by the state, the entire practical details about it performance depend on by Mexican norms and Mexican polices.

There are two general Earth orbital configurations: the geostationary orbit (GSO) and the non- geostationary orbits (non-GSO). In last two decades most satellites have been of the GSO type in national, regional and international. Only in the few last years the non-GSO satellites have become the focus of new developments.

**Functions associated with the technical subsystem**

This system is constituted by two main parts: The Space segment and the earth segment constituted by a set of earth stations.

*The Space Segment. Subsystem 1A. Level 2*

The main parts of the technical subsystem 1A of a communication satellite are: the space platform, the power generating system, the environmental control, the orbital control and the communication payload. These components can be considered level 2 subsystems of the subsystem 1.

A good performance of the technical subsystem requires:

- A high degree of station-keeping accuracy and attitude control
- A high antenna pointing
- Long time in the nominal orbit position
- Reliable electric power supply
- Effective thermal control of electrical components
- Operation during solar eclipse
- Launch vehicle capable of insertion into GSO orbit

Following a list of the main physical components with its respective functions is presented:

- The Platform structure
- The thermal control system
- The power supply system
- The attitude and orbit control subsystem
- The telemetry , command and ranging system
- The apogee motor

*Function 1. Determining the Position and Path of a Satellite*

The first function to be accomplished by a satellite is to be positioned and follow a precise path. The problem of determining this position and path is the field of interest of many scientists. During the last two decades commercial communication satellites networks have utilized geostationary satellites so several portions of the geostationary orbit are crowded and coordination between satellites is an additional technical problem. That is why the non_geostationary satellite systems have grown in importance as a technical issue that because of their Earth coverage capability,

In this paper we consider that the orbit issue is a part of Knowledge and Technology aspects included in the general management of a satellite project. That is why both aspects should be considered in the Satellite Project Engineering.

*Function 2. Satellite Ground Track and Coverage*

The satellite ground track is the trace of the points of the Earth overflown by the satellite. 1 when it moves along its trajectory. There is a specific knowledge respect calculus to obtain this parameter.

*Function 3. Satellite Structural Design. Subsystem Component Level 2 Number 1*

The satellite structure is designed to house, support and protect its various elements during its lifetime. The greatest inertia, dynamic stresses and strong vibration occur during the launch activity. The spacecraft is protected during this aerodynamic phase with an enclosure or"nose cone" to survive the thermal and inertial stresses of the additional propulsion until it is finally inserted into its proper orbit. After this activity, the structure must protect the satellite equipment from the environment of space.

Other important function is to test the structure, with actual or simulated components and environments in order to have a successful design.

Two principal structural types are there in the design of satellites: the spin stabilized spacecraft and the three-axis body stabilized spacecraft. The first one is usually shaped like drums. Part of the drums rotates and the other part allows that the antenna mounted in it and is always facing the Earth. The spinning part is covered by solar cells and its spin axis is oriented perpendicular to the Sun for providing maximum energy to the solar cells.

The stabilized structures are shaped like a box with rectangular sides and with external attachments to collocate all the components that need to function outside the enclosure.

The aircraft appears fixed to an observer on the surface of the Earth, but really the box rotates once for every circling of the Earth so the external mounted antennas always face the Earth. Energy is supplied by a set of solar panels oriented with a North –South axis which rotate once per orbit revolution.

As it is necessary to have a low mass in the spacecraft structure, the main frame is comprised of strong lightweight metals, such as aluminum or magnesium alloys and other structures made of special plastic. Other auxiliary structures for solar panels, antennas and special equipment require several advanced structural designs and materials as carbon fibres and epoxy resins.

*Function 4. Thermal Control. Subsystem Component Level 2 Number 2*

The Thermal Control Subsystem (TCS function is to assure that the equipment in and about the spacecraft structure is maintained within a temperature range to allow a successful satellite operation. A TCS design takes into account the different thermal environment that exists in space where convection, conduction and radiation define heat transfer.

There are several techniques for controlling thermal radiation exchange of the spacecraft. Besides of that, the main structure of the satellite is constructed with a combination of thermal insulation and conductive materials. Most equipment can tolerate a wide range of temperatures in order to function but life expectancy and reliability require more strict limited temperature ranges.

Heat generated from power amplifiers, motors and heaters must be conducted to the outside surfaces where it can be dissipated. External structures require special designs.

*Function 5. Satellite Attitude and Orbit Control Subsystem Component Level 2 Number 3*

Technology has changed in Earth to maintain attitude and orbit location .Now the overall design trend for this kind of systems is to automate the control functions so that a small group of controllers can perform the ground operations.

The attitude and orbit control component is maintained the antenna RF beam pointed to the intended areas on Earth. There is a lot of detailed engineering and experiences respect this function.

On-board propulsion requirements for satellites account for a significant part of the mass of a spacecraft. Given the importance of this issue there are several research and development programs to improve performance. Several innovations have been includes as advanced solar electric propulsion system, different chambers for chemical propellant.

The objective of orbit control is to maintain the space craft inside the allocated position in latitude/longitude.

*Function 6. Power Supply Subsystem Component Level 2 Number 4*

Electric power requirements for communication satellites have increased considerably during the last 20 years, as launch system have become more powerful to insert payloads into orbit from 2000 to 5000 kg. Now a large number of transponders have to be accommodated on a single spacecraft.

The power supply system of a communication satellite has as main components: power generators, usually solar cell arrays, located in the spinning body; electric storage devices, the electric harness for conducting electricity to the equipment demanding power, converters and regulators and electric control and protection subsystem of the telemetry system.

The equipment which require electric power are : the communication system in which transponders demand 70% of the total power., battery charging, about 5%, thermal control about 10%, tracking, telemetry and control and attitude control.

The solar arrays design assure that the sufficient surplus capacity exists initially so that end-of-life performance has the communication mission requirements.

In case of eclipse periods, it is necessary to store energy by means of electrochemical generators. All telecommunications satellites are equipped with nickel-cadmium batteries.

*Function 7. Telemetry, Command and Ranging TCR. Subsystem Component Level 2 Number 5*

The functions of a TCR are: Reception and demodulation of command signals intended to keep the satellite operational; collection, shaping and emission of telemetry signals for the permanent control of the whole satellite; transfer after demodulation and remodulation of signals used for ranging. The TCR system must function reliably through all the phases of a satellite's life.

*Function 8. The Apogee Motor. Subsystem Component Level 2 Number 6*

There is the option either a direct insertion into final orbit from a single launch system or the use of a transfer orbit, after which an apogee motor is used to place the satellite into its final orbit.

There are two types of technology for the apogee motor: traditional "solid propellent apogee motor that has been used up to now for most satellites; the second one is the current trend towards "bi-liquid propulsion ".

*Function 9. The communication payload. Subsystem Component Level 2 Number 7*

The subsystem Communication Payload is comprised of the communication transponders, antennas and associated equipment involved directly in the receipt and transmission of radio signals from and to earth station networks. Most transponders are transparent at the present time, they simply translate the frequency of received signals, amplify them and route them to the appropriate transmitting antennas. More advance transponders contain switching elements that transfer signals between multiple satellites beams and more advance transponders have other technological advances.

*Satellite Earth Segment. Subsystem 1B. Level 2*

The earth station is the transmission and reception terminal of a telecommunication link via satellite- This station consists in the following elements:

- The antenna
- The receiver amplifiers
- The transmitter amplifier
- Frequency converters and modems (telecommunication equipment)
- The multiplexing/ demultiplexing
- The equipment for connection with the terrestrial network
- The auxiliary equipment
- The power-supply equipment

- The general infrastructure

An earth station with multiple access links comprises two categories of subsystems: RF system (those which are common to the links, antenna and transmit and receive equipment) and the second category which are specific to a particular link.

The first category includes primarily the antenna system, the input low noise amplifiers and the transmitter power amplifiers. These amplifiers are backed up by hot, automatically switched, stand by units. The second category includes telecommunication equipment, multiplex units when the configuration of the station , the link distribution and also the MTTF of the unit allow it, those subsystems may possibly provided with one-for-n type redundancy .

The components of the earth station are described following.

*Function 10. Satellite Antennas. Subsystem Component Level 2 Number 8*

The antennas of earth stations are the most impressive equipment, common to transmission and reception, according with the performance requirements:

- High gain for transmission and reception
- Low level of interference and of sensitivity of interference.
- Radiation with high polarization purity
- For reception, low sensitivity to thermal noise due to ground radiation.

The antenna system consists of the mechanical system, comprising the main reflector, the pedestal, the driving gear and servo-system; the primary source, comprising the illuminating horn, the associated mirrors and non radiating components; and the receiver of the automatic tracking device.

It is very common to classify earth stations for 6/4 GHz and 14/11-12 GHz bands only according to the size of their antennas:

- Large stations: antenna dimension more than 15 m
- Medium sized stations: antennas from 15 m to 7 m
- Small stations: antennas 7m to 3m, or less
- Micro stations for VSAT: 4 m to 0.7 m

This is a broad classification which also covers the complexity of other subsystems.
*Function 11. Amplifiers. Subsystem Component Level 2 Number 9*

The low noise amplifiers (LNA) are used to receive the very weak signals from a satellite, for this service the earth-station antenna must be connected to a highly sensitive receiver, one with very low inherent thermal noise. This kind of amplifier is always used as a microwave preamplifier in the reception chain of the earth station and is usually wideband; it amplifies all the carriers emerging from the receiver port of the antenna diplexer. There are many variations of coolers that should be studied for achieving good noise temperature performances and low costs.

Power amplifiers are required in earth stations. The two main types of microwave tube used in earth-station power amplifiers are travelling wave tubes (TWT) and klystrons, In the case of small stations, solid-state power amplifiers are more and more used. Following a description of these amplifiers is given:

- Travelling wave tube (TWT) amplifiers. They are wideband amplifiers covering the entire usable band of the satellite with the necessary uniformity. The TWT appears to be the ideal power amplifier for earth stations. It allows several carriers to be transmitted simultaneously with a single tube irrespective of the repeaters and the frequencies allocated to these carriers.
- Klystron amplifiers. They are essentially narrow pass band devices that are generally more economical than TWT amplifiers with several advantages: high efficiency, very simple power supply, great sturdiness and long working life with reduced power consumption.
- Solid-state amplifiers. They are used in case of low-capacity stations, normally with field effect transistors. Solid-state power amplifiers are very reliable and economical and may provide an ideal solution for small earth stations.

In the case of large stations it is necessary to use several amplifiers, either klystrons or TWTs. The klystron amplifiers as many as transmitted carriers; in the case of TWT amplifiers, the output power of a simple amplifier may be sufficient. One or more stand-by amplifiers are usually provided to ensure the necessary availability.

*Function 12. Telecommunication Equipment. Subsystem Component Level 2 Number 10*

Besides of that, it is necessary to have telecommunication equipment which modulates the very high frequency carrier with low frequency signals for emission and extracts this low frequency on reception. It comprises frequency converter equipment, modulating and demodulating equipment and signal-processing equipment.

*Other Subsystems*

Besides Technical Subsystem Number 1, there are three other subsystem which are going to be studied later when more information be available : Subsystem 2 Regulatory Framework , Subsystem 3 Marketing and Subsystem 3 Services Enterprise

## KNOWLEDGE AND TECHNOLOGY MANAGEMENT IN A SYSTEM ENGINEERING APPROACH

Planning a new satellite requires put together a system approach that includes the criteria and techniques taken from three fields: SYSTEM ENGINEERING for completing the detailed design, KNOWLEDGE MANAGEMENT for taking into account all previous and present knowledge about satellites and TECHNOLOGY MANAGEMENT for integrating the selection of the best practices and technologies about satellites.

For this reason in this paper it is proposed to apply four main methodological schemes

The first one is for integrating the Part I of the System Engineering Approach for planning a new satellite Strategies Formulation and Regulatory Framework Modification (Figure 3), the second one is the part II of the same System Engineering Approach, focussed to Design Basis Figure 4; the third one is for integrating criteria from different fields( figure 5) and the fourth one is for making possible coordination and cooperation of many people related with this task : officials, experts, specialists and society. (Figure 6)

### System Engineering Approach

The system engineering process to design a satellite system requires a system approach to have a qualitative method of solving the most important design problems. Before beginning the work, it is necessary to have a precise definition of a comprehensive set of objectives. It is necessary that these objectives be realistic and to have a practical measure of effectiveness, associated with the main satellite performance characteristics. In this stage it is not necessary getting into detail but is convenient to be enough specific and measurable.

For the team which is designing the system, in this step, is convenient be involved in the exact meaning of each objective. Once a tentative set of objectives was defined after purified it has to identify the functions related to each objective. Functional specification of the system is the first part of the analysis procedure.

If certain objectives or functions are seen unfeasible it is convenient to eliminate them. A clear definition of objectives free of contradictions and unrealistic statements will be used for further design. Strategic issues should be considered before to finish this part.

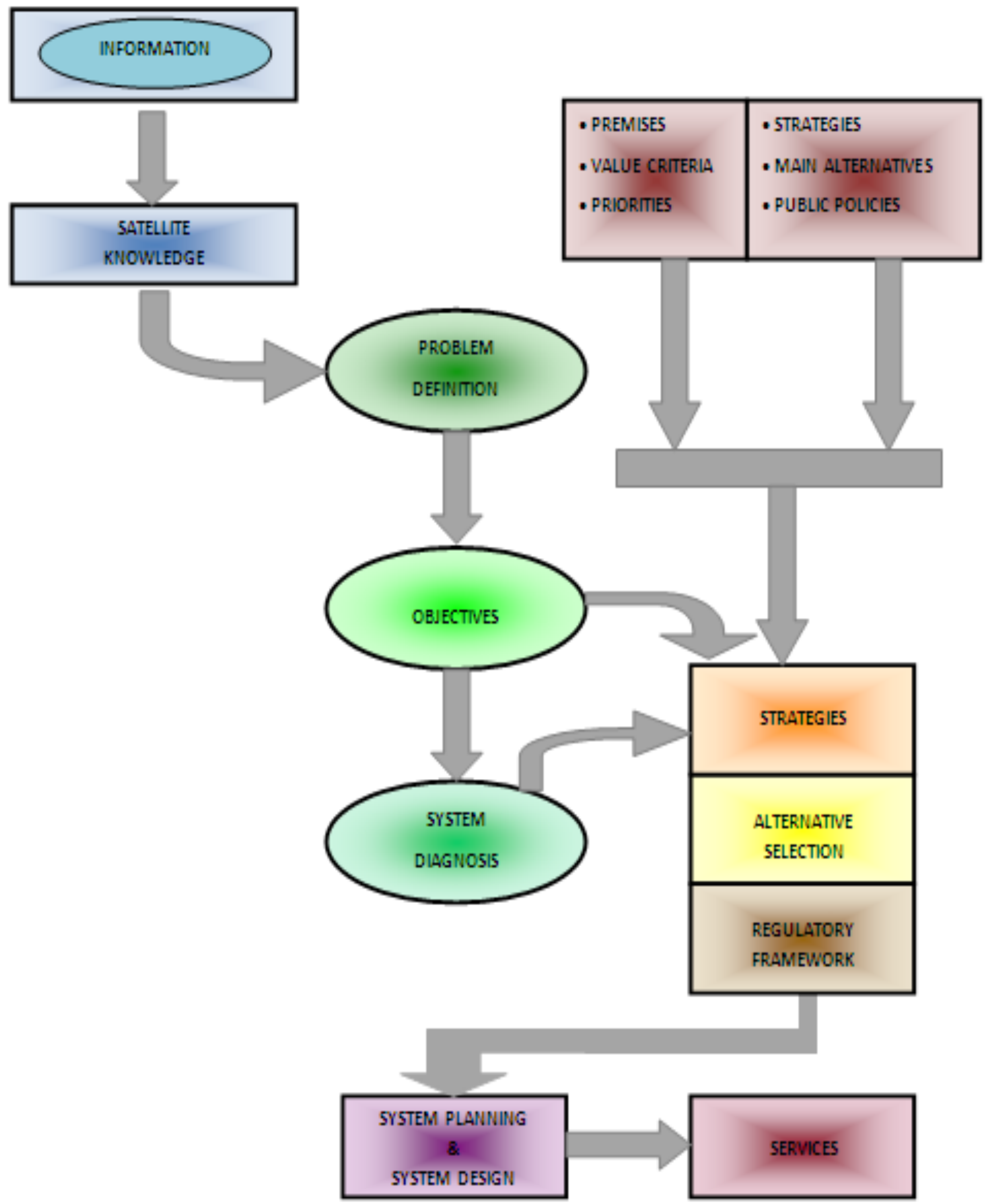


**Figure III. System Engineering Approach for Planning a New Satellite, Part I Strategies Formulation and Regulatory Framework Modification.**

The second level of system engineering approach has as a main activity consideration and evaluation of alternatives to complete the subsystem approach. In the last part of this approach the purpose is to have all elements of the detailed designed system just before to build it.

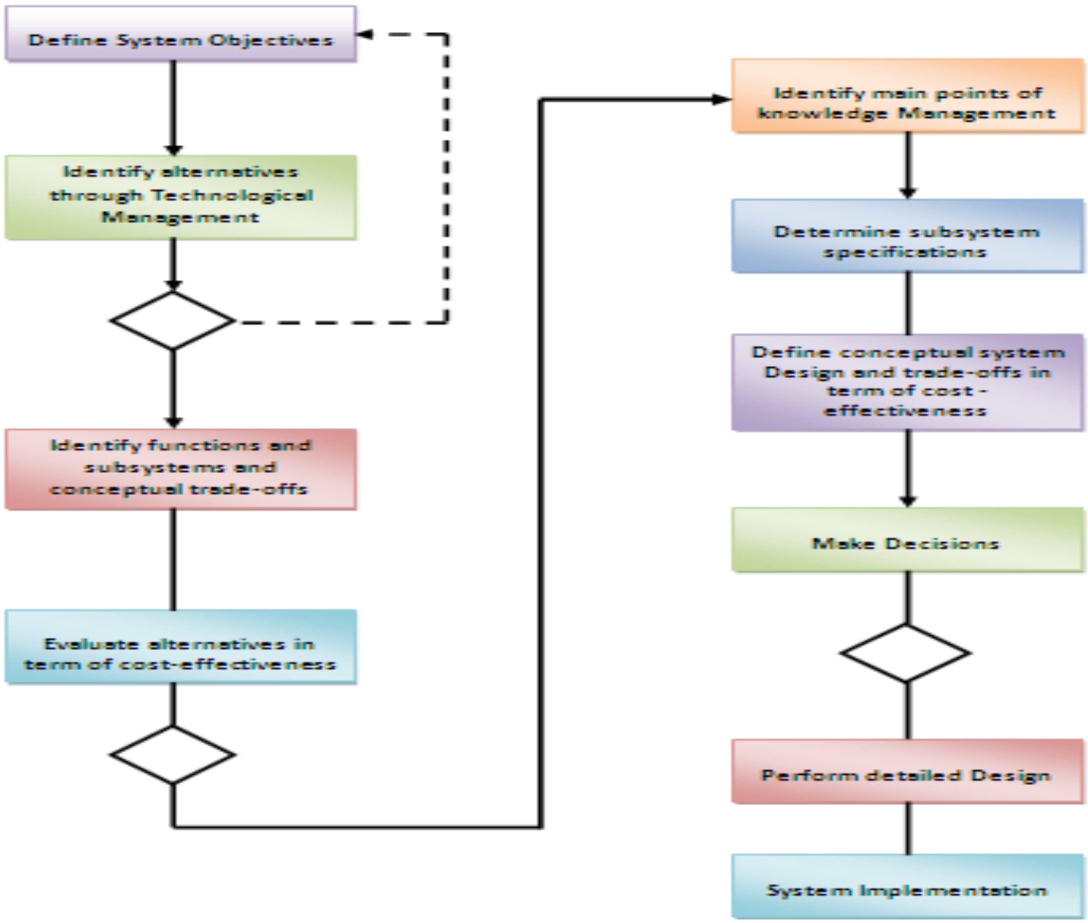


**Figure IV. System Engineering Approach for Planning a New Satellite Part II Design Basis**

**Knowledge Management applied to a New Satellite Planning**

Knowledge Management is a new field that can be applied to different objectives, contexts and situations. It is possible to apply this subject to complex projects, planning processes, institutional planning organizational interactions and scientific and academic activities. In this way the present telecommunication system (TCS) is improved.

In this part we propose a methodological criteria to modify the present Mexican satellite system (MSS), applying Knowledge Management to obtain the biggest increase in value of this system for its community.

In this case we propose to utilize the third generation knowledge Management model in order to organize the communities to learn. The communities are integrated by specialists and experts.

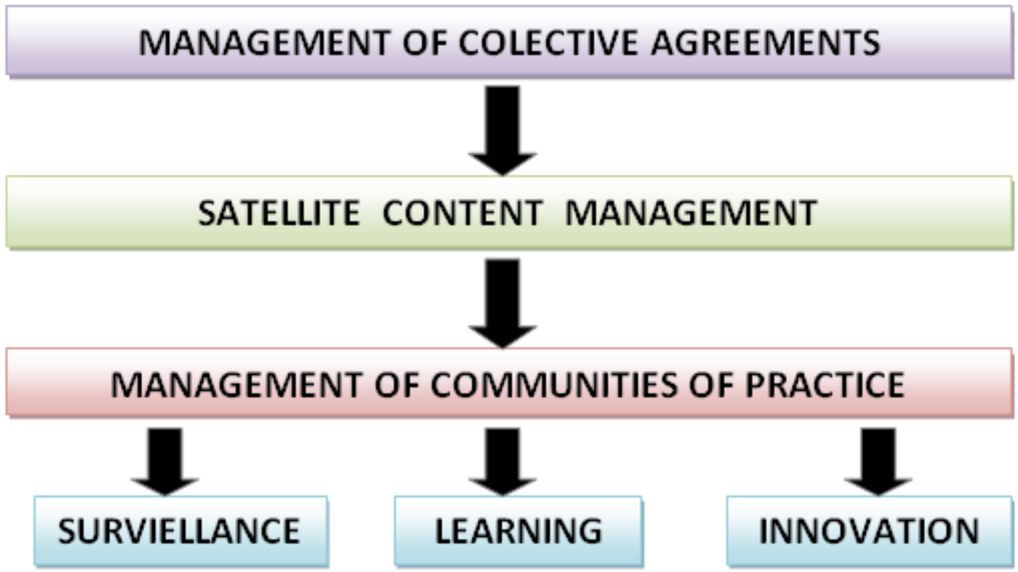


**Figure V. Knowledge Management Applied to Learning and Innovation when a new satellite is planned**

The Knowledge Management levels are: Acquisition, Generation, Technological evolution and achieving an evolutionary system. In this moment it would be convenient to consider the possibility to have a proper technological evolution of the Mexican satellite system.

After applying a normal SWOT analysis to the problem threads, opportunities, strengths and weakness were identified. Then, the methodology considered the following key points:

1. Identify benefits,
2. Value creation definition,
3. Strategy formulation ,
4. Define key success factor,
5. Identify key and performance indicators,
6. Governmental processes analysis
7. Alignment of strategy with national policies.

Once this process is finished Knowledge strategies can be integrated to strategic planning.

The obtained results from a holistic point of view are more valuable than those corresponding to other traditional options that only take into account technical and economic aspects.

**Technology Management**

Technology Management has the following specific objectives: Identify and evaluate the technological options; manage the R&D function if it were necessary, evaluate the feasibility of the new satellite project¸ integrate and transfer the new technologies required for the new satellite operation: and develop the technological training of involved personnel.

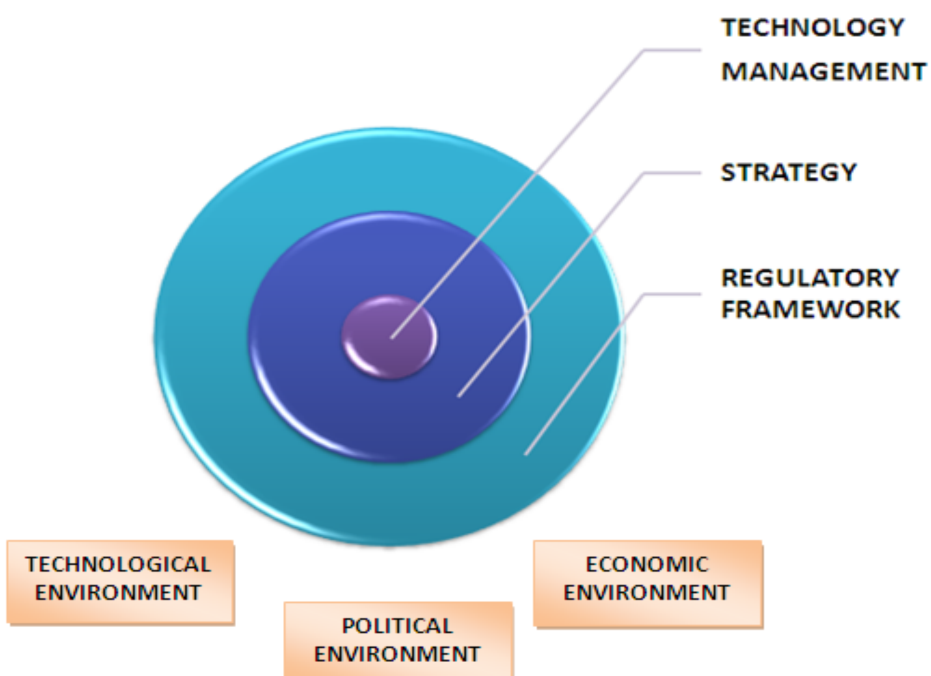


**Figure VI. Integration of Criteria from Different Fields**

*Technology management applied to a New Mexican satellite*

Technology Management is the discipline to put together the different branches of engineering, sciences and management for planning and executing the technological changes according with strategic objectives of the organization. The organization is the Mexican Government which is the entity who has the responsibility of designing and launching the new satellite.

## SPECIFIC METHODOLOGY FOR APPLYING KNOWLEDGE MANAGEMENT TO THE MEXICAN SATELLITE SYSTEM

1. Reviewing of the planning efforts made in the past. (Objectives, Strategies, Goals, and Results.)

2. Knowledge Strategies Formulation. ( Mission, Vision, Specific Objectives, Institutional Planning model )

3. Selection and Integration of the team. Selection of external and internal elements.

4. Value Criteria Definition. Selection of value criteria. Procedure for definition of partial or integral values of existing system and new options.

5. Knowledge Management Operation, Meetings, Conversation, Integration of documents.

6. Evolutionary System Design and Operation.

## CONCLUSIONS

Long scale systems, as a satellite, are designed to incorporate all the possible system improvements to have a good performance. It is necessary to incorporate the advantages of new knowledge, new technology and the appropiate public policies, under a regulatory frame to match the needs.

Knowledge Management, Technology Management and Systems Science help to achieve these purposes.

These disciplines have to work together within a system engineering approach and with the best existing practices to make the telecommunication services are available and be competitive.

It is very convenient to apply a normal SWOT analysis before a specific methodology to obtain the strategy formulation according to the value creation and performance indicators.

## KNOWLEDGE AND TECHNOLOGY MANAGEMENT

Technology Management is a very successful task after formulating the Knowledge strategies and selecting a good team of experts.

Technology Management fulfils the following objectives: Identify and evaluate the technological options; evaluate the feasibility of the new satellite project and integrate and transfer the new required technologies.

Once the main strategies are defined, the process finishes integrating the Knowledge and Technological strategies. Then the project engineering follows the normal rules for complex and great scale systems.

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