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SMALL SATELLITES

FOR LATIN AMERICA

Report of a Workshop of
the International Academy of Astronautics
held at INPE, Brazil, on June 20-23, 1994

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1. INTRODUCTION

1.1. Purpose

The purpose of this document is to provide the results and the recommendations of the Workshop on Small Satellites for Latin America held at the National Institute for Space Research (INPE) in São José dos Campos, Brazil on June 20-23, 1994. This Workshop was convened after recommendations of the Sub-Committee on Small Satellites for Developing Nations which met in Graz (Austria) in October, 1993.

This document is addressed to all members of the International Academy of Astronautics (IAA), to the members society of the International Astronautical Federation (IAF), to the officials of all Latin American Countries and to the Office of Outer Space Affairs of the United Nations.

1.2. Background

The interest to constitute a Sub-Committee on Small Satellites for Developing Nations arose after the previous workshops carried out by the IAA on the subject of small satellites, with the purpose of identifying the concepts and processes needed to initiate, manage, acquire and launch small economical satellites. It was understood that small satellites could serve a wide range of purposes, including learning high technology and management of space programs, increasing the world's scientific knowledge, providing a country with application systems such as communications or earth observation, and enhancing the education of its people.

This workshop is the first one carried out within the scope of the Sub-Committee, which has as a long term goal the promotion of the concept of small satellites for the benefit of developing nations. The Sub-Committee has decided that the assessment of these benefits would be made on a regional basis through its members and representatives from interested developing countries.

1.3. Participants

Four Latin American countries were represented in the workshop: Argentina, Brazil, Chile and Mexico. Each of these countries has already initiated independent national space programs through the development of small satellites. These programs are briefly described in Section 3. The complete list of participants, totalling 30, is attached as an annex to this report. In addition to Latin American participants, the Workshop was also attended by representatives of Canada, France, Germany, Ireland, United Kingdom, and United States. The participants were representing space agencies, governmental institutions, private space companies, research centers, and universities.

1.4. Objectives

The objectives of the workshop have been defined in conformance with the terms of reference of the Sub-Committee on Small Satellites for Developing Nations, to meet the specific needs of Latin America.

The specific objectives of the workshop consisted therefore in the identification of:

- the needs of Latin American Nations, which can be met by the use of small satellites;
- the plans and objectives of current and future programs in Latin America;
- the expected benefits and anticipated difficulties;
- the needs and opportunities for international cooperation within Latin America and with other countries.

1.5. Outcome of the workshop

The participants have worked along these objectives and tried to identify needs, priorities, benefits and difficulties.

As a result of the presentations and discussions which took place during the workshop, it can be said that there is an agreement on the general needs as they are presented in section 2 of this report. It was agreed that local problems and specific characteristics of a country or a region could be the drivers in designing scientific or application missions. It was also agreed that small satellites are a driving force for developing countries, to initiate a space program, to train their personnel and to develop their infrastructures. The low cost access to space was found to be an issue and is discussed in some details in this report. There have also been lot of discussions on the subjects of the technology transfer, the international cooperation and the funding of the projects.

Despite the inherent advantages of small satellites as they have been highlighted in previous reports, the participants to the workshop therefore identified several difficulties common to many of the Latin American countries:

- The countries with established space programs frequently do not understand the scope of problems within the developing Latin American countries.
- There is often no national consciousness of the benefits to the country of a space program.
- There are difficulties to obtaining low cost access to space, due to availability and cost of existing launch services.
- There is a lack of adequately trained local personnel.
- There is non-existent or insufficient funding for space activities and associated infrastructure.

All these difficulties have been reviewed by the participants to the workshop, and are discussed in the following sections (sections 4 to 7) of the report.

Finally recommendations were established, reviewed and approved by all participants. They are included as part of the conclusion of this report.

2. NEEDS AND POSSIBILITIES

In Latin American countries, as in most developing countries of the world, one can identify at least two categories of needs for which small and micro-satellite systems may provide alternative solutions.

The first group may be classified as direct needs, and relates to social and economical problems which may benefit from the various applications of space technology, particularly those associated with small satellites. Direct needs are discussed in section 2.1 and summarized in Table 1.

The second group of needs has an indirect nature, and deals with attaining the condition of taking full advantage of the country's investments in the acquisition of space systems and services. This concept will be further developed in section 2.2.

2.1. Direct Needs

The direct needs for Latin American Nations can be classified in several ways. For instance, they can be classified by the geographical location, by the types of services and products, or by the types of applications. Also, Latin America presents some more developed areas where the needs are very similar to those of developed nations. For the purpose of this Workshop, however, it was more significant to focus on problems that are more typical of the Region such as communication and monitoring of remote areas, agricultural land use, and environmental protection.

Product / Service		Market/Demand	Offer/Specific Need
Telecommunication	Fixed Remote Mobile Remote	-Health services support -Transportation systems support -Government -Agriculture -Aeronautic and maritime traffic control -Localization services	-Nowadays high cost -Cost should be reduced to allow a widespread use
Earth Observation		-Meteorology -Agriculture -Government -Mineral resources -Environment control -Deforestation -Fishery -Disaster prevention & control	-Offer of centralized systems -Necessity of a decentralized approach -Collection of data of specific meteorological phenomena -Needs for a better distribution of fishery, mineral resources & meteorological data
Science		-Local geophysical phenomena -Use of privileged position to astronomical observation	-Offer of general purpose experiments and orbits -Need for specific orbits & experiments

Note: All those needs can be satisfied making use of small satellites.

TABLE 1: DIRECT NEEDS

Even for the needs that are typical to the Region, however, Latin America is not homogeneous at all. In fact, it is important to note that it spreads from zero to polar latitudes, from extensive sea level to high mountain regions, not to mention the extensive rain-forest areas. It is possible to say, nonetheless, that Latin America has definite needs in Telecommunications, Earth Observations, and Science that might be satisfied by the systems currently available or proposed by developed countries if it were not for some unique requirements. Those relate primarily to technical and price considerations. The following sections explore these unique Latin American needs in greater details.

2.1.1. Direct Needs in Telecommunications

Telecommunications is a wide field for debate. It could be started with the high load needs in data, voice and TV provided by the national and international satellites. These issues may not be fully resolved yet, but Latin America has been able to stand the present service levels. Nowadays new systems are being proposed for direct broadcast, teleconference; small GEO (Geostationary Earth Orbit) satellites are also proposed for specific private services. It can be considered, that in these areas, Latin American needs and problems would follow the tendency of developed nations. So it seems more interesting here to focus the discussion on the remote and mobile communications using small satellites at low orbit.

The use of Low Earth Orbit Communications (LEOCOM) Systems is being proposed to provide remote and mobile communications. The LEOCOM system is being devised to allow many services; the major service is the communication between a portable terminal, similar to the one employed in cellular communication, and a normal telephone of the existing fixed telecommunication network. In this case, the two users may be located anywhere in the territory. The communication between two mobile users anywhere in the coverage region is also possible. On the other hand, communication is also feasible between a mobile user in Brazil and a user of the fixed network system anywhere in the world. In this case, the final connection is completed through the existing network system.

The use of automatic Data Collecting Platforms (DCPs), similar to the ones presently employed with Data Collecting Satellites (DCS), such as the Brazilian SCD1, allows the installation of a data collection network which features a wider coverage than the DCS and provides real-time service. In addition, due to the two-way characteristics of LEOCOM, it is possible to send commands from a central station in response to the received data, or for distant monitoring and control. In this case, aircraft's equipped with automatic location receivers could be controlled by a central station that would receive the data through the LEOCOM system.

Due to the LEOCOM satellites *motion* relative to Earth, the gateway can provide the location of any user of mobile terminals. The location accuracy, in the hundred meter range, is adequate for most applications as, for instance, tracking of ships. In the event a better accuracy is required, a GPS receiver at the mobile terminal would transmit its actual location. The LEOCOM mobile terminal can also be coupled to a facsimile machine for the transmission of graphical data. Thus it will make it possible to send for instance a fax of an electrocardiogram in the case of a medical emergency in a remote area.

Telemedicine will increase efficacy of medical services by allowing the transmission of information obtained by cheap and simple sensors directly to complex processing units in large medical centers where it might be properly interpreted by specialized physicians. This makes possible powerful and effective emergency services to reach poor and undeveloped areas, saving many lives and avoiding unnecessary displacement of patients.

To increase immunity to failures under disaster conditions, mobile communications may also play an important role in the case of big natural disasters, allowing for help to reach the disaster victims earlier and providing the logistic support to the rescue teams.

The LEOCOM could be the solution of communications for large remote areas in developing nations. However, it is necessary to direct efforts in this direction. The currently proposed LEOCOM systems are oriented for the big and sophisticated market in developed nations. The cost to end users can become unrealistic for the Latin American remote areas. Sometimes, technical aspects also represent limitations. Some of the currently proposed systems in fact require ground support not available in undeveloped areas.

The conclusion is that LEOCOM systems can be of value but the developing nations need to work to have access to this new technology. The prospects for developing nations, in particular Latin America, are excellent. To take an example, Brazil has around 2.5 million of productive farms. Only 20% of these farms have telephone services. Analyses made by Brazilian and international companies have shown that 160.000 voice terminals could be implemented only in Brazil and for agricultural applications. Of course this market increases substantially as other applications are included.

The Latin American Nations have many options, but they must make a significant effort to properly define their needs. The LEOCOM business is very large and competitive and is just starting. This creates the opportunity to negotiate the conditions and the appropriate level of participation, and to warrant access to the frequency spectrum, a definitely limited resource.

2.1.2. Direct Needs in Earth Observation

The Earth Observation applications considered here cover the several aspects related with data collection and imagery. Similarly to telecommunications, Earth Observation could be focused from different points of view. Even in Latin America, different unique scenarios of applications can be identified.

Latin America had an early access to the benefits of satellite remote sensing, with the launching of the first Landsat (early 70's). Since then many offerings have appeared, including modem Landsat's, SPOT's and, recently, the microwave satellites Radarsat and ERS. Meteorological satellites such as GOES and Meteosat should also be mentioned.

Latin America has still a long way to go in order to maximize the benefits allowed by the existing capabilities. There are, however, unique needs at both national and regional levels that demand new solutions. Brazil, for instance, is already developing two new satellite programs (SSR and CBERS) to address specific needs. Latin America and other developing nations require special capabilities related to sensor parameters such as spectral bands, spatial resolution, time resolution, cost of image, investment level in ground equipment, and expertise required for utilization.

During the United Nations Conference in Rio de Janeiro in 1992, sustained development and biodiversification were terms included and defended in every speech made by the Heads of States. However the developing nations are focused on their economic troubles and especially concerned with resolving environmental issues while enhancing agricultural production to improve the quality of life for all. A potential solution for these sometimes conflicting goals may include the sustained development of interior regions including the Amazon. This careful development can only happen with provision for local monitoring and control of natural resources usage. Remote observations from satellites and distribution of the remote sensing data will help slow the depletion of natural resources including the rain forest. It is also important in sustained development that the logistics necessary to support settlement and employment be considered.

Remote sensing with portable ground stations and low cost space systems has an important role to play. The key feature of the space system is direct down-linking to numerous small ground stations, eliminating the need for a centralized processing and distribution system. The advantages are real time access to observations, smaller data bases and ease of information distribution - even in areas not well served by communication systems. In some cases monitoring in real time and decentralization is mandatory. Some examples of this are: forest and brush fires, pollution, fishing, storms. Remote mobile communications will permit logistic support to police in their fight against drug traffic in frontier regions. Using polar orbits, the space system would be capable of servicing users world-wide.

In the area of disaster prevention, there are clear demands for earthquake forecasts, early detection of tropical storms and anticipation of volcanic activity. Scientific and system design activities should be carried out in these areas.

2.1.3. Direct Needs on Science

The present discussion concerning the use of small satellites by developing nations should emphasize the necessity of better understanding the near-Earth space environment in the southern hemisphere. This unique local environment is understood to be represented by the upper atmosphere-ionosphere-magnetosphere system domain and the interplanetary medium.

During the last decade there has been considerable progress in understanding the global behavior of upper atmospheric regions and their relationship with the interplanetary medium. Such studies, however, have been drastically concentrated in the northern hemisphere of the Earth's globe as opposed to the southern hemisphere. This fact most probably has to do with the lesser scientific and technological capabilities of developing countries which geographically dominate the southern hemisphere, and also with the much larger oceanic areas in the South.

It seems highly advisable, therefore, that developing nations, which physically exist primarily in the southern hemisphere and in particular in the tropical zone, should join the global effort towards improving the knowledge of their own space environment. It does not make sense that such important environmental studies which are for the benefit to the whole humanity should be restricted to the Earth's northern hemisphere. Developing nations certainly have the necessary human resources, potential skills and motivation to carry out such studies.

As a consequence of the relative lack of space science studies in the southern hemispheric region, several natural phenomena which occur in upper atmosphere regions in the tropical and southern hemisphere zone are not adequately understood: for example ionosphere plasma depletion's, or bubbles, which occur over the South American sector and strongly interfere with radio communications as in nowhere else in the low latitudinal region of the globe; or the South Atlantic Anomaly which is well known for the occurrence of energetic precipitating particles stemming from the inner Van Allen radiation belt, causing severe physical damages or even the complete destruction of satellite instrumentation (such as sensors in general, solar cells, photometry devices, etc.)

In the event that anthropogenic ionized radioactive particles get trapped in the internal radiation belts, those potentially harmful particles to humans can be poured over the South Atlantic region, resulting in radioactive pollution and ecological disaster over that region.

The ionosphere-thermosphere system has been extensively studied in the Brazilian zone in the past two decades by INPE and other international research institutions as well such as the Max-Planck Institute (Germany), NASA (USA), etc. Several rocket experimental campaigns have been conducted for that purpose since 1972 by the Max-Planck Institute and NASA in collaboration with INPE and the Brazilian Air Force. Ionosphere studies over the African continent have also been carried out by European and African nations in the last few decades. The same is true of with Australia and Asian countries in the Asian sector.

The southern hemisphere region is an important region for studies in the field of astrophysics especially for the studies of sky regions which cannot be directly accessed from the northern hemisphere. Many developing countries located in the southern hemisphere have been engaged in astrophysical studies in the southern hemisphere in the past few decades. Satellites would be an important means of complementing the ground-based studies which have been performed so far by developing countries and of course for future studies.

2.2. Indirect Needs

The workshop debate on indirect needs has been able to detect two major points which are stated and discussed below:

1) ***To gradually internalize expensive investments made for accessing space services.***

For decades now, Latin American Nations have been users of space systems and services, mostly in the field of satellite communications but also, with growing interest, in other areas like remote sensing.

Space systems are indeed expensive. Brazil, for instance, is paying over 300 million dollars for the second generation of its Brasilsat communication satellites; Mexico has paid 570 million for its system. Considering that those satellites will have to be replaced within an 8 to 10 years time horizon, the total amount of investment is expensive, particularly from the stand-point of a developing country.

Another key point to be kept in mind is that the international experience has shown investments in the space sector to have a very high multiplier effect on the GNP (a factor around 7 has been suggested in the literature).

Accordingly, it would be highly desirable for Latin American Nations to be able to maintain within their borders growing portions of their investments in commercial space systems and services. However, this can only be achieved through the increasing participation of the national industry in the international contracts for the provision of systems and services. This, in turn, is not only a matter of governmental policy but also, necessarily, of existing local capability.

Projects to develop small and micro-satellite systems, for their reasonable costs and shorter duration, can be the best strategy towards acquiring the expertise which is considered necessary to internalize parts of the governmental investments in commercial space systems and services.

2) To increase the level of indigenous expertise in space science and technology available in Latin American Nations, so as to guarantee, at least, the proper specification of the systems required to satisfy national needs.

Too often, the lack of appropriate knowledge and training have resulted in developing countries deciding upon approaches that are not the best to suit their needs. Education programs and formal training are necessary steps to acquire the desired capability, which, incidentally, may be negotiated as part of contracts for the acquisition of space systems. Formal training, however, is not a substitute for the experience and maturity acquired by working in space projects and, as noted earlier, small or micro-satellite programs may prove to be an affordable initial step for developing countries.

A coordinated interchange of information among the Latin American countries might be a proper way to increase the expertise in space programs needs and definitions. In-depth studies to evaluate the actual needs of Latin America can increase the chances that every country will choose the best alternative to suit its unique and changing needs.

3. DESCRIPTION OF CURRENT AND FUTURE PLANS

This section provides a description of the current and future programs in Latin America, and an overview of the plans and objectives set for the development of space activities through the development of small satellites.

3.1. Argentina

Argentina is presently involved in the SAC program, based on an international cooperation between CONAE (Argentina) and NASA (USA). While CONAE is responsible for designing and building the spacecraft and part of the scientific instrumentation, NASA will provide the launch, initial orbit monitoring and the rest of the scientific instruments.

At present, CONAE is in the final stages of building and testing the SAC-B satellite at system level. SAC-B is a satellite of 188 kg, designed for an elliptical orbit (510 km x 550 km), 38° inclined to the equator, carrying four scientific instruments, that will be launched in April 1995. The Italian Space Agency (ASI) is also taking part in this project by providing the solar array and one instrument. In addition, INPE of Brazil provides its facilities and technical assistance for the spacecraft system qualification.

The second part of the SAC Program, the SAC-C satellite, is in the early engineering stages. This is a satellite of 260 kg approximately, to be launched into a sun synchronous polar orbit at about 500 km altitude. It will carry scientific instruments, and a multispectral medium resolution scanner for Earth observation, which is being developed by CONAE. The launch is planned for 1998.

Towards the end of 1994, the Argentine Space Program, which is currently being elaborated, will be presented to the national authorities. The lines to be followed in the future will be specified in that document, specially relating to satellites, communications, remote sensing, etc...

The national authorities have recently declared their decision to create a Center for Space Studies in the province of Cordoba, which will include an Integration and Test Laboratory for subsystems and spacecraft.

3.2. The Brazilian Space Program

3.2.1. A brief historical overview

In the sixties, besides intense recruiting and training, space activities in Brazil consisted in theoretical and experimental investigations, basically concentrated in the area of space and atmospheric sciences. In the seventies, INPE, while continuing its activities in space and atmospheric sciences, gave emphasis in establishing competence in two promising fields of the applications of the space technology: remote sensing and meteorology. Meanwhile the recruiting and training of human resources were extended to a broad spectrum of space related fields.

The eighties were envisioned as the decade when Brazil would acquire basic competence in the design and development of space systems. The Brazilian Complete Space Mission (MECB) was approved by the Federal Government in 1979.

Finally, the Brazilian Space Agency was created in early 1994.

3.2.2. The MECB Program

The MECB program was approved to achieve:

- the development of four small satellites, two for data collection and two for remote sensing;
- the development of a compatible small Satellite Launch Vehicle (VLS);
- the construction of the launch complex of Alcantara.

The Data Collecting Satellite (SCD-1) was launched in February 1993 to provide capabilities for reception and re-transmissions of the environment data. The satellite flies in a circular orbit, inclined about 25°; at an altitude near 750 km. During the passes visible from the Cuiaba tracking station, any Data Collecting Platform (PCD) within the coverage angle of the satellite payload antennas has its UHF signal relayed by the satellite in S-band. The SCD-1 can support up to 500 PCD's operating at arbitrary locations in Brazil. The 115 kg spacecraft is spin stabilized by the rotation imparted by the last stage of the launcher prior to the injection. The attitude control subsystem is equipped with a magnetic torque coil to operate spin axis maneuvers. The second Brazilian satellite, SCD-2, is similar to the SCD-1 apart from some upgrades in the torque coil capabilities. The functional tests on the qualification model of the SCD-2 are completed, and the assembly, integration and tests of the flight model are now initiated at the LIT (Integration and Test Laboratory) at INPE. This phase shall be finished by the end of 1994, and SCD-2 will be ready for launch at the beginning of 1995. The COBAE (Brazilian Commission for Space Activities) has approved recently the inclusion of a new satellite in this program, the SCD-3, that shall be similar to the ECO-8 with an additional data collection payload similar to the one of SCD-1; it shall work as a concept test for the ECO-8 system. This satellite is in the design phase and its launch is scheduled to happen by July 1996.

The Remote Sensing Satellite (SSR) of the Brazilian space program is to provide a permanent and highly repetitive monitoring of the country's agricultural and forest phenomena through space borne imagery. To accomplish its goals while subject to the constraints imposed by the planned Brazilian VLS launcher, the SSR will be a three-axis stabilized spacecraft operating in a low, sun synchronous Earth orbit, with a total mass at launch limited to 170 kg. The satellite payload is a solid state pushbroom camera which provides two channel imagery in the visible and near infra-red spectral bands, with a spatial resolution of 212 m.

The SSR orbit is sunsynchronous and the orbit parameters are such that the complete coverage of the Brazilian territory is repeated every four days. The operational equator crossing time is 9:30 a.m. The spacecraft structure is made of aluminium honeycomb panels which house the equipment units around a central compartment where two hydrazine tanks are located. Three solar panels are deployed in orbit by means of simple torque storage mechanisms and remain fixed in the orbital plane. Basically passive thermal control is used to keep the equipment units within their operating temperature range.

The SSR is three-axis stabilized through an attitude control system based on the momentum bias provided by a fixed momentum wheel and on control torque's provided by three mutually orthogonal magnetic torque rods. A dedicated computer controls the operation of the spacecraft sensors and actuators. Initial orbit acquisition and orbit maintenance are performed by a propulsion system consisting of hydrazine thrusters.

The SSR is designed to operate in a circular, sun synchronous, near polar orbit at an altitude of 640 km. The local solar time at the north to south equatorial crossing is 9:30 a.m. +/- 15 minutes; a compromise between the fixed solar array performance and the average time of fog dissipation over most of the Brazilian Amazon region. The orbit will be such that there will be 14 3/4 periods per day. The satellite ground trace repeats its Earth coverage every 4 days with a 680 km wide interface at the Equator

3.2.3. The CBERS Program

The general objective of the program, which is developed jointly by Brazil and the Peoples Republic of China is the development and in-orbit operation of two complex spacecraft for the observation of Earth resources. This program will develop the experience in designing and implementing a space segment with the necessary ground base data reception, processing and interpretation system, and in integrating the satellite based remote sensing data with conventional data systems for resource management. It will pave the way for taking up an operational remote sensing program for both countries.

The unique characteristics of the CBERS program which differ from the existing remote sensing satellites is its multisensor imaging payload with different spatial resolutions. The three imaging sensors aboard the spacecraft are the Wide Field Imager (WFI), the High Resolution CCD Camera(CCD) and the Infrared Multispectral Scanner (MSS). The WFI has a wide swath width which gives a synoptic view with low spatial resolution. On the other hand, the CCD and the MSS sensors provide detail information of a sampled area inside the WFI scene. In addition, the CCD has an off-axis pointing capability and thus, any phenomenon detected by WFI may be "zoomed" by the oblique view of the CCD with a minimum time lag of three days. These multi-sensor data are specially interesting for ecosystem monitoring where high frequency information are required.

3.2.4. The scientific satellite

A project for scientific micro-satellite around 60 kg, that shall fly as a piggyback with the first CBERS satellite, is in the planning phase. An Announcement of Opportunities is already prepared to receive proposals, [illegible] scientific experiments to fly on this satellite. It is only waiting the [illegible] NEP (Financial Studies and Projects) for the release of the

Announcement of Opportunities. In the mean time, the engineering tasks directed to the micro-satellite design are under way at INPE.

3.2.5. The future missions

Remote and mobile communications - ECO-8

The particular characteristics of the ECO-8 system is to explore an equatorial lightsat constellation. It can provide real time communications capability involving only eight satellites. The system responds to an important demand for low orbit communications in equatorial countries. Part of the world as Amazon region, Africa, Australia and many other important regions are included.

The system is designed to service a low density user environment. The system can benefit one million of intermittent users and can provide logistic support for professionals who look after frontiers, forests or who develop medical or scientific missions. The system will provide digital and voice communications with low cost small user units.

The system is composed of the equatorial constellation of eight small satellites, the ground station and control center facilities, and the telecommunications mission stations. It can be observed that the area between 30° south and 30° north can be served with permanent real time communications. The major objective is to supply intermittent communications for a high number of users at low cost. It provides capability for communications among users who are not necessarily located in the same satellite antenna footprint. The Brazilian market for remote voice and message communications is large and is supposed to attract rural transport and country travellers. The estimates for medium demand rates per user are 60 min./month for real time voice, 300 pages /month for telex and fax messages in a storage forward scheme, and 500 messages/month for pager users. The main satellite load is expected for voice with 100,000 users.

The mission control stations receive and send the feeder data to control and switch the telecommunication network. The equipment of the user on ground is assumed to be portable and low cost. A typical user equipment comprise a simple non-tracking antenna, receiver, transmitter, and interfaces.

The relevant parameters of the system and the satellites are:

- eight operational satellites;
- equatorial orbit at 2000 km;
- virtual link between satellites;
- satellite of 250 kg and 80 W (RF-payload).

Remote sensing - WOM-8

The World Observation and Monitoring (WOM-8) system involves the use of 8 satellites in two orbital planes. The system has a high temporal resolution with two full Earth coverage's every 12 hours. The spatial resolution and the spectral bands are designed for monitoring forests, fires, pollution and biomass; the payload is a CCD camera with a wide field imaging capacity.

A particular feature of the system is the direct down link to numerous users with small ground stations, thus allowing real time access of end users to the data. This requires on-board compression, with techniques already tested at INPE. The associated low cost of the small ground terminals should enlarge the use of remote sensing in general, and in particular the participation of undeveloped countries.

3.2.6. The Brazilian space infrastructure

Integration and Test Laboratory (LIT)

Specially designed and built to satisfy the needs of the Brazilian space program, the LIT includes a 450 m^2 satellite integration area and a 1600 m^2 environmental testing area; this includes thermal vacuum and climatic chambers, vibration and shock, and electromagnetic compatibility test facilities. The satellite check-out station and the test control rooms are adjacent to the clean areas, with a full unobstructed view over all activities. In addition, the LIT includes also a sensor calibration laboratory, and a reliability laboratory used for the reception, inspection and qualification testing of electronic components.

In addition to serving the national Brazilian space program, the LIT is also used for international cooperative programs as it has been the case for the SAC-B Argentinean satellite.

TT&C and Control Center

The INPE Ground Control System is made of a Satellite Control Center (SCC) located in Sao José dos Campos, and Ground Stations located in Cuiaba and Alcantara. Both Ground Stations can operate the spacecraft in a degraded mode. A Communication Network connects all three sites.

Alcantara Launch Center.

The Alcantara Launch Center (CLA) is located very near of the Equator and can accommodate launching in any inclinations. The CLA is located in an unpopulated area with total security for the nearest small villages. The CLA can be accessed by plane or by boat from Sao Luis, capital of the Maranhao State.

The unique and dedicated launch complex is equipped with all sorts of facilities to permit sophisticated missions. The facilities which could be distinguished are the following:

- the Technical Center, in a building with more than 10,000 m^2, includes the direction offices, the administrative division , and all the logistic support for the operations;
- the Control Center, where all the telemetry data are processed and the commands are generated. It involves modem installations and computer capabilities;
- the Telemetry Station, where the data are received and pre-processed;
- the Meteorology Station for weather monitoring and analysis before, during and after launch operations;
- the sector for preparation of the payloads to be launched;
- the tracking stations with high precision radar's and signal processing equipment to permit multiple follow-up of the launcher and stages when they are separated during the flight.

3.3. Chile

The Chilean Space Program is developed to accomplish the following objectives:

- to incorporate at a national level the necessary technological basis for the development of space activities;
- to develop the Chilean own satellite capability that would allow the reduction of their conditions as users;
- to share the achievements of space development with the national scientific and academic communities.

The current program is in an experimental stage with the development of the first micro-satellite named FASat- Alfa. It is a 50 kg spacecraft to be launched in 1995 in a low polar orbit at 800 km. It will carry experiments such as a camera for imaging the Earth, a sensor for ozone layer measurements, experiments using the GPS system, and communications and data transfer. The following objectives should be achieved within the development time of 2 years:

- to prepare an integrated team of engineers in all disciplines of space development;
- to develop low cost technology with emphasis on the use of miniaturization, informatics and electronics;
- to use the technological experiments to initiate a scientific basis in order to develop more complex space programs in the future.

After FASat-Alfa, Chile plans to carry out the following space program:

- In a 10 years term, development of a mini-satellite for communications and detection of natural resources.
- In a 15 years term, development of a geostationary satellite that would allow the complete satisfaction of domestic communications, making intensive use of international agreements on cooperation in scientific activities.

3.4. Mexico

In Mexico, activities related to space sciences and technology were formally initiated in the frame of the International Geophysics Year; subsequently, in 1962, the National Outer Space Committee (CONEE) was created as a technical specialized organization depending from the Communications and Transport Ministry with the aim to coordinating and promoting subjects related to the peaceful research, exploitation and utilization of outer space. Its main mission was to develop high atmosphere research programs, sounding rockets and balloons, and to study the national territory by means of remote sensing techniques. Some collaboration agreements were signed with similar agencies.

The CONEE disappeared in 1977, but it marked the way for the involvement of some research and academic institutions in space related fields.

Astronomy is a space activity with a great tradition since the prehispanic era and is carried out mainly by UNAM's Astronomy Institute and the INAOE (Instituto Nacional de Optica, Astrofisica y Electronica), covering a large number of research areas, and making a wide use of spacecraft data. To promote these activities, Mexico organized the second Latin-American Conference on Space Geophysics at the University of Guanajuato at the time of the solar total eclipse in July 1991. This was also the opportunity to establish a small sounding rockets launch base in the State of Nayarit.

In the field of Earth Observation, there exists a great quantity of groups and entities that use satellite imaging for applications such as the quantification of natural resources, pollution, agriculture, geology, oceanology, fishing, hydrology, meteorology, city planning and road tracing. In order to benefit from these developments, the involved institutions have established a national remote sensing development plan: all the development phases are covered, from sensor technology to applications and the promotion of users.

In the field of telecommunications, Mexico joined the International Satellite Communications Organization (Intelsat) in 1966, allowing access to intercontinental satellite links. In 1981, Mexico became one of the first countries to get approval from Intelsat to use their satellite system for domestic applications. Based on the experience gained with using the Intelsat system a national system of communications by satellites was established: two Morellos satellites were launched in 1985, and they are followed by a second generation of satellites called Solidaridad, the first of which has been launched in November 1993. As a part of the Solidaridad program, it was included the academic and practical training of Mexican scientists and technicians by the satellite constructor and the launch agency, as well as some kind of technology transfer.

In general, satellite communications in Mexico have permitted the impulse of programs on education, health, agriculture, energy and informatics. Similarly, they have helped population decentralization and have amplified the use of telephone, television, and data transmission.

Taking into account the importance that represent space activities, the Communications and Transport Ministry organized in 1989, through the IMC and in cooperation with the European Space Agency and the French Embassy in Mexico, the Euro-Mexican Days on Space Affairs which contributed to reactivating the interest in Mexico for such activities and led to the creation of the University Research and Development Space Program (PUIDE) in the UNAM, and lately the Space Projects Direction in the Instituto Mexicano de Comunicaciones (IMC).

Space technology development is carried out mainly in research institutions and universities. Research in electronics and communications is carried out by the National Autonomous University of Mexico, the National Polytechnic Institute, the Center for Scientific Research and High Level Education of Ensenada, and the Astrophysics, Optics and Electronics Institute. Their effort includes the development of high frequency equipment, optical communications equipment, parabolic antennas, remote sensing and the equipment evaluation for rural use. These institutions have incorporated topics on these technologies in their graduate and under graduate programs. These same institutions make research and development also on areas such as structures, materials, mechanisms, flight mechanics, and propulsion systems.

Two micro-satellites are under development, one by the PUIDE that will be launched in 1994, and the other one promoted by the IMC with the participation of some of the above mentioned institutions. This second satellite, named SATEX-1, is an engineering test satellite of 50 kg to be launched in a low altitude polar orbit; it will carry several payload equipment such as a CCD camera, a Ka-band receiver, a data collection system and a GPS receiver. Both satellites are experimental and pretend to summarize the practical experience in space technology. Additionally, conversations with the INTA of Spain are sustained to collaborate in the Hispano-American Minisatellite Project that was born in the context of the America's Space Conference.

4. ACCESS TO SPACE

4.1. Introduction

Small satellites can be seen as a feasible way for the developing Latin American nations to acquire up-to-date technology at costs fitting their budgets, mainly considering launch costs and technical capabilities. From this viewpoint, a natural way to establish a sound technological base is through the investment in small (micro) satellites, with an initial focus on spacecraft masses in the range of 10 kg to 50 kg. The availability of subsystem components in the international market and the possibility of low cost secondary (piggyback) launches on medium/large launchers makes microsatellites affordable to developing Latin American Nations.

Another attractive option is the possibility of international cooperation, where more than one country/institution having common interests jointly develop a mission. Each partner participates by providing specific components, experiments, expertise and a launch, all aiming at lowering costs of the total mission.

This kind of approach is very convenient to facilitating the spread of technology amongst all the participants and contractors (universities, research centers, and industries) in all phases of the development of the spacecraft and required space infrastructure.

Once acquired, this technology base enables further expansion of programs, either from the technological or products point of view, even comprising multi-purpose platforms, leading to development of payloads up to 200 kg, and dedicated launches, preferably with available low-cost launchers.

It seems evident that cost is the main issue concerning the access of developing nations to space.

4.2. Opportunities for launch of small satellites

Launch opportunities for small satellites include a number of alternatives: launch as a secondary or piggyback satellite on a large ELV (Expendable Launch Vehicle); launch on dedicated ELV; or as one of two spacecraft launched on a dual mission on a single ELV; or carried in one of the small satellites services offered by the Space Shuttle. The choice of one of these alternatives involves an assessment of the unique mission requirements against the capabilities, costs and constraints of the launch options.

4.2.1. Secondary/Piggyback launches

In an effort to reduce the cost of access to space and to make use of surplus performance capabilities, larger ELV manufacturers are interested in offering the small payload community the option of flying as a secondary or piggyback payload on those missions where the primary payload does not fully utilize the vehicle's capability. The primary payload schedule and reliability remain unaffected by the companion payload, and the small payload owner is provided with a potentially cost-effective alternative to the purchase of a dedicated small ELV.
A primary payload owner purchases a dedicated launch service on an ELV to achieve the primary payload mission objective, which in turn drives the vehicle configuration, orbital trajectory, launch schedule, and security requirements of the mission. The primary payload owner incurs the price of the launch service. An experiment, sensor, instrument or fully integrated payload whose mission objective is different from that of the primary payload may gain access to space as a secondary or piggyback launch on that ELV. In a piggyback launch, the secondary payload owner utilizes excess capacity on the ELV once the primary payload requirements are satisfied. The secondary payload is constrained in weight, size, orbital trajectory, vehicle configuration and launch schedule by the primary payload when purchasing a piggyback launch. However, the piggyback launch costs may be only a very small fraction of the launch service price plus the cost of integrating the secondary payload into the ELV.

NASA has a history of successfully flying secondary payloads on Delta and has recently initiated a program to continue similar flight opportunities on Delta II. Arianespace also offers launcl opportunities for secondary payloads. Secondary flight opportunities on Long March, Proton and H- may be viable options in the future for small payload owners to consider and explore. Additional futu options include launch on the Ultra-Lite and Med-Lite ELV services currently in procurement l NASA. At this time, secondary launch opportunities are available primarily on Ariane and Delta II. T US Space Shuttle is also mentioned briefly; however, actual flight opportunities are sparse at this time.

Arianespace is offering secondary flight opportunities for up to six satellites, each weighing up to 50 kg, on a circular platform called Ariane Structure for Auxiliary Payloads(ASAP). The ASAP carrier ha: been designed for use on Ariane missions with a single primary payload; it has been used and i: intended to be used to place satellites into a polar Low Orbit or a Geostationary Transfer Orbit Approximately five Ariane 4 missions currently scheduled through the mid- 1990's offer the potentia use of the ASAP carrier into polar orbits. Arianespace has set a price for launch of the ASAP platform which may be split among as many as six different small satellite customers. Arianespace has alread identified a number of candidate secondary payloads interested in taking advantage of the ASAP carric for upcoming flights.

McDonnell Douglas Aerospace is offering piggyback flight opportunities for experiments/payloads tha are small and light enough to fit on the Delta II second stage. The Delta II second stage avionic package can provide limited command, power, telemetry and attitude control services to the secondar payload. Based on current contracts, secondary flight opportunities are available on Delta II (7920 or 7925 models) developed to launch the US Air Force Global Positioning Satellites (GPS) beginning in early 1990. GPS launches in 1996 and beyond will be launch-on-demand; therefore, the secondary payload project cannot plan for a scheduled launch date for GPS primary missions. Sufficient excess performance margin is not available on any of the commercial Delta launches currently under contract; hence, the only flight opportunities are on government launches. NASA is identified as the appropriate point of entry for any civilian/ educational/ non-profit/ international organization interested in reserving an available secondary flight opportunity and has developed a Delta II secondary pay load user's guide. Integration costs, additional range support and any costs associated with additional security requirements are paid by NASA. NASA has launched a series of four piggybacks since July 1992 and is planning three additional launches by January 1996. The average cost of these missions is 1 to 2 M US dollars.

National space policy directives preclude NASA from providing Shuttle launch services to commercial communications satellites or other commercial payloads unless they require the Shuttle's unique capabilities or manned intervention. NASA's Office of Commercial Space Programs has established several types of joint arrangements that offer flight time on the Space Shuttle for applied research until the commercial potential of a product has been established. Shuttle secondary payload flight opportunities are available for a variety of users: US Government, domestic/international research or technology ventures. Flight assignments for secondary payloads can be made as much as 19-20 months or as late as 5 months prior to launch. The number of available secondary flight opportunities on any single Shuttle mission is highly variable and dependent on the primary mission objectives and requirements.

4.2.2. Dedicated launches

During the past thirty years, many countries have invested in the development of indigenous launch vehicle capability, pursuing the lucrative commercial market or strengthening their own civil and national defense. International space policies and programs are emerging with developments in commercial and advances in related technologies.

The small class of ELV's is the most dynamic one and has experienced the largest entry of commercial entrepreneurial activity both in the United States and abroad over the past few years. Small class ELV's can deliver payloads weighing from as little as 25 kg to as much as 1500 kg to Low Earth Orbit. Until 1989, the only flight demonstrated vehicles in this class were the United States Scout, Atlas-E/F and Titan II; the Japanese Mu-3IIS; and the Chinese Long March 1. All these vehicles were developed under government contracts to meet specific government requirements.

With the emergence of a potential commercial small class market in the late 1980's, industry has responded by offering a range of new services. Currently there are a number of US ELV Companies interested in servicing the small launch service market. These include, but are not limited to, the following vehicles: Pegasus, Taurus, Conestoga and Orbital Express. Of these, only Pegasus has any orbital flight history. Pegasus has had five flights from 1990 to June 1994. Scout, the United States workhorse small launcher was phased out in May 1994 when the last Scout booster in NASA's inventory was launched. Although there has been much industry interest in offering commercial services in this class, a real commercial customer base has not yet materialized. A dedicated launch service on one of these small ELV's ranges from between 10 to 20 million US dollars. A dedicated launch at this price is a luxury few scientists, universities, radio amateurs or other commercial entrepreneurs can afford. Tables 2 and 3 provide a summary of the availability, performance capability and costs quoted for both US commercial and international ELV's. Payload operators considering launch on a non market vehicle must take into account technology transfer and trade constraints.

Each vehicle should be considered from a total launch system perspective with an understanding of both the hardware's performance capability and the attendant operational launch constraints. Launch pad location and availability have a direct impact on the performance capability achievable by a specific vehicle to accomplish unique mission objectives.

Available launch azimuths dictate the range of orbits a vehicle can perform, with or without dogleg maneuvers. Pegasus has unlimited launch site opportunities, since it begins its flight on an aircraft, and can also accommodate twelve missions a year to a range of orbits. The payload fairing diameter dictate the physical payload size that each vehicle is designed to accommodate. Individual vehicle user manuals should be consulted to compare other critical environmental constraints (e.g., acoustics, loads Launch site location is a factor that also requires consideration since campaign costs associated wi launches from international sites can pose a financial burden on small payload operators.

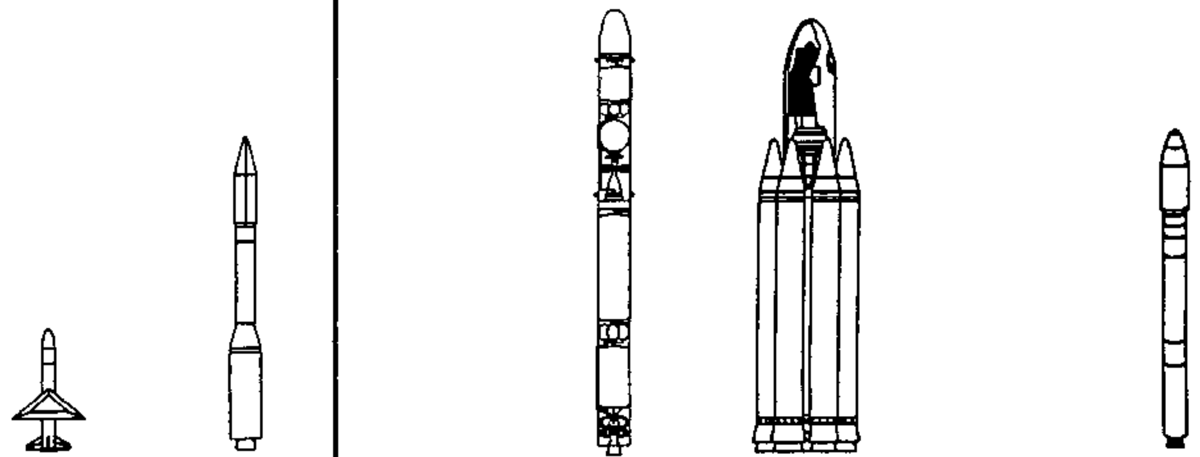
4.2.3. Dual Manifesting

Launch as one of two small satellites on the same ELV (dual manifesting) is another alternative. NASA is planning to launch two small satellites, the Argentine Satelite de Aplicaciones Cientificas-B (SAC-B) and the High Energy Transient Explorer (HETE), on a Pegasus vehicle in April 1995. To allow this dual manifesting on Pegasus, NASA developed a Dual Payload Attach Fitting (DPAF). The Pegasus dual capability supports spacecraft in the 100 to 180 kg range, depending on orbit requirements. In addition, specifications for the Ultra-Lite and Med-Lite vehicles currently in procurement by NASA w include provisions for dual manifesting.

U.S. SMALL EXPENDABLE LAUNCH VEHICLES

EXISTING | *PROPOSED - IN DEVELOPMENT*

(DRAWINGS ARE NOT TO SCALE)



VEHICLE / MANUFACTURER	Pegasus / Orbital Sciences	Taurus / Orbital Sciences	Ultra-Lite	PacAstro	Conestoga / EER Systems	Med-Lite	Lockheed Launch Vehicle
PERFORMANCE TO 185 KM (INCLINATION) (CONFIGURATION)	360 Kg (28.5°) (Standard)	1,400 Kg (28.5°) (Standard)	TBD	N/A	1,200 Kg (28.5°) (1620)	TBD	1,050 Kg (28.5°) (LLV-1)
PAYLOAD FAIRING DIAMETER (OUTER)	4.2 ft (128 cm)	5.25 ft (160 cm)	TBD	72" (183 cm)	72" (183 cm)	TBD	92", 120", 141" (234 cm, 305 cm, 358 cm)
LAUNCH SITE(S) (LATITUDE, DEG)	WFF, VAFB (37.9°, 34.7°)	CCAFS, VAFB, (28.8°, 34.7°)	East & West Coast Capability	WFF, VAFB, (34.7°, 37.9°) Andoya	WFF, CCAFS, (37.9°, 28.5°)	CCAFS, VAFB, (28.5°, 34.7°)	CCAFS, VAFB, (28.5°, 34.7°)
STATUS	Operational	1 Flight 1994	NASA Procurement 1994	Proposed	In Development	NASA Procurement 1994	In Development
INITIAL AVAILABILITY	--	–	1999	1996	1994 (1620)	1998	Nov 1994 (LLV1)
PROJECTED COMMERCIAL LAUNCH COST (94$)	$13-15M	$18-20M	$5-6M	$5-6M	$18-24M	$25-30M	$15-26M

*NOT AVAILABLE

TABLE 2 - US SMALL EXPENDABLE LAUNCH VEHICLES

4.3. Constraints on access to space

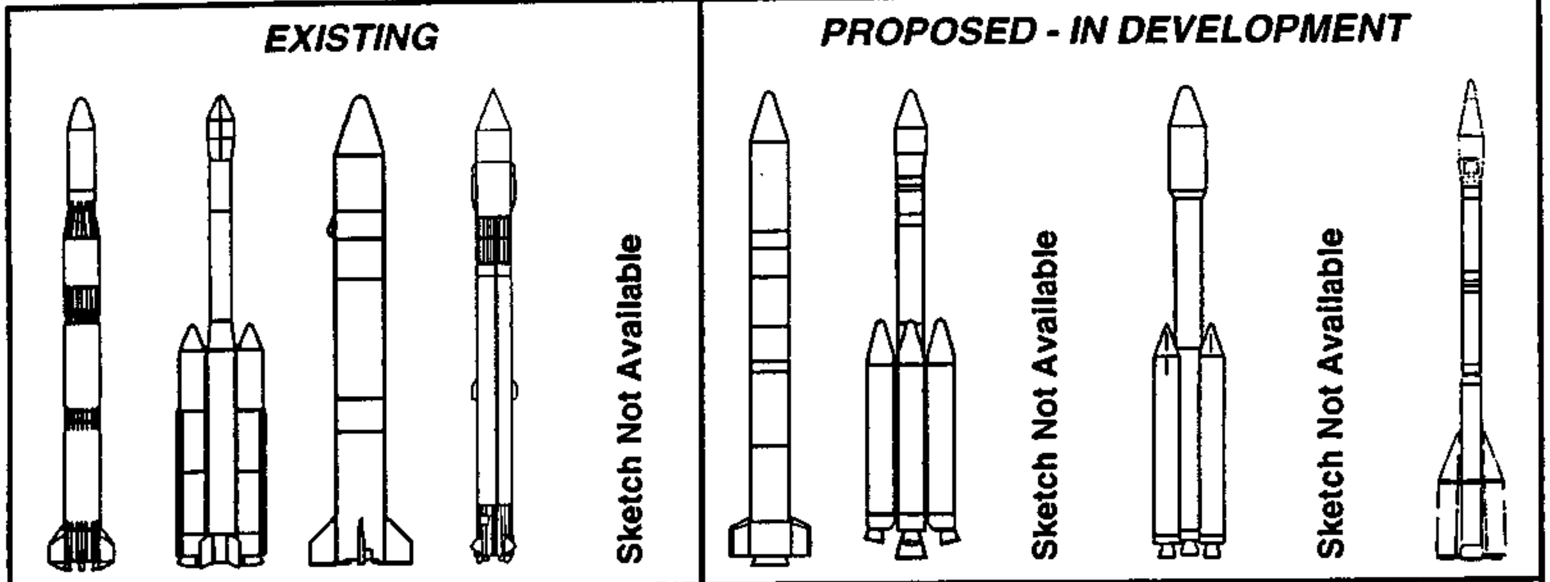
Constraints on obtaining accommodation on a launch vehicle include cost and availability of a vehicle of suitable capability in terms of spacecraft volume and spacecraft mass to the required orbit. For small spacecraft launching as secondary payload, additional constraints may be imposed by the primary mission requirements.

Ariane secondary payloads are limited in mass to 50 kg, including adapters, and in volume to a 45 cm^3. Mechanical and electrical interface information is available in the ASAP User's Manual. Secondary payloads launched on Ariane cannot specify a separation attitude and must accept the primary mission orbit.

Delta secondary payloads are limited in mass by the primary mission mass margin and, for separating payloads, by separation system constraints. Typical masses of 50 to 60 kg for separating payloads and 50 to 80 kg for attached payloads. Envelopes for Delta secondary payloads depend on the vehicle configuration (fairing size, number of stages, primary attach fitting) and are defined along with mechanical and electrical interfaces, and other constraints, in the Delta Launch Vehicle Secondary Payload Planner's Guide for NASA Missions, available from Goddard Space Flight Center. One dimension must be less than 31 cm for separating payloads or 38 cm for attached payloads. A considerable constraint for secondary payloads is availability of suitable primary mission opportunities.

For dedicated launches, additional constraints may be imposed by the launch constraints applicable to the specific vehicles. Launch site location, with the attendant range safety restrictions on launch azimuth, may limit the minimum inclination available. For example, Kourou and Alcantara are most suited to launch of very low inclination missions. Launch site latitudes are shown in Tables 2 and 3.

INTERNATIONAL SMALL EXPENDABLE LAUNCH VEHICLES



	EXISTING					PROPOSED - IN DEVELOPMENT					
VEHICLE	Long March 1D (China)	ASLV (India)	Shavit (Israel)	COSMOS (Russia)	START-1 (Russia)	M-5 (Japan)	VLS (Brazil)	ALV (Australia)	SMS (Italy)	ESL (Europe)	BB 2000 (Canada)
PERFORMANCE TO LOW EARTH ORBIT (kg)	789 345 km circ, 57° incl	150 400 km circ, 43° incl	159 185 km circ, 143° incl	1,361 593 km circ, 51° incl	499	1,950 250 km circ, 31° incl	275 500 km equatorial	907	998 185 km equatorial	450 760 km circ, 90° incl	140-250 740 km polar, circ orbit
PAYLOAD FAIRING DIAMETER	204 cm (6.7 ft.)	100.6 cm (3.3 ft.)	119.4 cm (47 in.)	240.8 cm (7.9 ft.)	N/A	249.9 cm (8.2 ft.)	~120 cm (~ 3.5 ft.)	N/A	165.1 cm (65 in.)	220 cm (7.2 ft.)	117 cm (46 in.)
LAUNCH SITE(S) (LATITUDE, DEG.)	Jiuquan (40.7°)	Sriharikota (13.9°)	Negev (31°)	Plesetsk, Kasputin Yar (62.8°, 48.4°)	Mobile	Kagoshima (31.2°)	Alcantara	Woomera, Cape York	San Marco (2.9°)	Kourou (5.2°)	Vandenberg Wallops I., (34.7°, 37.9°) Andoya
STATUS	Not Available	Operational	Operational	Operational	In Develop-ment	In Develop-ment	In Develop-ment	Proposed	Proposed	Proposed	Risk Reduction Phase (Co-Funded CSA, BAL, MB Gov't)
INITIAL AVAILABILITY	1971 (Long March 1)	1987	1988	1964	1994	1995	1997	N/A	TBD	1999	1998 (Qual. 1997)
COMMERCIALLY AVAILABLE	No	No	No	Yes	Yes	No	1997	TBD	TBD	TBD	1998 (Qual. 1997)

TABLE 3 - INTERNATIONAL SMALL EXPENDABLE LAUNCH VEHICLES

4.4. Considerations for launch vehicle selection

Spacecraft owner needs to critique each launch vehicle option with respect to the following considerations prior to making a launch vehicle selection decision. The most important consideration is the spacecraft value; it requires an assessment of the profit potential and the cost associated with its replacement. How many payloads will be launched? Is this a one-of-a-kind spacecraft?, or a low-cost series of identical payloads?

A second consideration should be the potential launch vehicles reliability record of flight history. A series of low-cost payloads may be willing to take the risk of a new lower cost launch vehicle with an unproved record.

A third factor in the selection process is an assessment of launch service costs when compared to the anticipated commercial return on investment, value of the payload at risk, and the associated vehicle reliability record. Schedule uncertainty is important to most payload owners with a commercial product in mind, but may be of less importance to a scientific experiment where time is not a primary driver. Corporate stability and long-term viability of the launch vehicle manufacturer is a critical factor all customers would be advised to consider. Once a commitment is made to a particular vehicle, the spacecraft and its payload will typically require some modifications if it is necessary that it be launched on a vehicle different from the one for which they were originally designed.

The insurance requirements of a given launch vehicle and the insurance package included in the launch service price should be closely examined. Although insurance costs for small ELV's are significantly lower than those attributable to larger ELV's, the total launch service costs can fluctuate widely between vehicle manufacturers based upon the insurance package each one has negotiated.

Any customer looking to launch a payload with US component technology on an international EL would be wise to consider the applicability of technology transfer export regulations. At present, the State Department is reviewing applications to allow US payloads to be launched on Chinese Russian launch vehicles on a case-by-case basis.

4.5. Launch cost considerations

Reducing the cost of transporting payloads to orbit has been an elusive but much touted goal of every proposed launch system since the early Space Shuttle days as a necessity to develop commercial space goods and services. The cost quoted by the commercial launch service supplier may not always include all the components of cost associated with launch of a payload into a specified orbit. A brief list of the major components of cost are presented in Table 4.

In addition, some large commercial spacecraft manufacturers make launch reservations on more than one vehicle to provide schedule insurance, should one of the vehicles experience a failure or become unable to provide a launch as requested by the customer. This option is probably too costly for most payload customers to consider. The launch campaign costs associated with a launch from a remote launch site (Australia/San Marco/China) may, in some cases, pose an additional financial burden on the small payload customer. When it comes to launch selection, the total value of the resources at risk drives the cost/reliability trade-off ultimately made by the payload owner.

LAUNCH SERVICE	• Vehicle • Range Services • Spacecraft Processing • Propellants
MISSION UNIQUE REQUIREMENTS	• Upper Stage
LIABILITY INSURANCE	• Third Party • Damage to Government Property
REFLIGHT INSURANCE	
DUAL COMPATIBILITY	• Schedule Insurance
CAMPAIGN COST	• Remote Launch Sites

Table 4 COMPONENTS OF COST

4.6. Ways to obtain launch access

4.6.1. Acquisition of launch services from the international community

Acquisition of launch services from international commercial sources is sometimes preferable to cooperative arrangements, due to difficulties in finding an appropriate exchange opportunity. In particular, countries seeking their first launch may find a commercial acquisition the most effective route open to them.

Brazil has experience in acquiring a Pegasus launch from the US firm Orbital Sciences Corporation for the SCD-1 mission, successfully launched on February 9, 1993. As of the writing of this report, Chile and Mexico were actively seeking commercial piggyback launch opportunities to support the launch of their respective first national satellites.

Acquisition of launch services should be planned as an integral part of the country's long term planning of their space program. A country newly embarked on satellite activities, and seeking to develop a national infrastructure (government and/or industrial) must also establish priorities for the development of expertise in managing launch activities.

Some guidelines for acquiring launch services are provided below:

1. Planning should begin with preliminary discussions with the agencies of other countries as well as private companies offering launch services to understand what is available.
2. Preparation of a preliminary budget and organization plan early is very useful.
3. Outline desirable contract terms for the satellite options under consideration.
4. Release a statement of launch requirements to the industry.
5. Negotiate and sign a launch contract.

The launch acquisition strategy should include progressive training and development of their staff.

It can be expected that new, financially constrained, programs will start with small satellites (such as SATEX, FASat) whose reliable development may be accelerated considerably by careful selection of contracted support, training and development of the launch management team, as well as the satellite development team. Such support may include guidance on launch selection.

Once the overall strategy is generally determined, the usual array of factors should be assessed before a candidate list of suppliers is compiled, and contract discussions, and ultimately negotiations, begun; i.e.

- spacecraft value, profit potential and desire for reflight potential/requirement;
- commercial versus science payloads; a commercial satellite delivered in orbit should greatly reduce national infrastructure requirements;
- follow-on payloads, and potential cost reductions for a series;
- stability of supplier is critical if a continuing relationship is desired;
- insurance flight, reflight requirements;
- the suppliers willingness to train staff, transfer technology, and provide in-depth knowledge through training (on the job, classroom, etc.).

Once an initial national policy and approach to launch provision has been agreed, a contracting team with technical, financial, legal and policy specialists should prepare a comprehensive list of questions, visit prospective suppliers, and prepare a short list of suppliers. Consultation with other users should be followed by follow-up visits, to design, production and launch sites. The contract form should be finalized, best and final offers requested, and then detailed negotiations completed with the supplier selected.

It must be emphasized that contracting should be done by a team to develop expertise; members should be chosen for both specialist expertise and communications skills in an international setting.

4.6.2. Participation in international cooperatives

The space faring nations have often pursued space missions by combining unique skills, products and capabilities from each country into a single cooperative mission. Cooperative missions may be considered when a clear programmatic benefit is shared by more than one country with a mutual desire to maximize their unique national resources and available funding. Unique national skills can include any/all of the following:

- scientific/technical expertise;
- specialized instruments;
- space infrastructure (ground stations/processing facilities, launch pads);
- technological advances;
- launch services.

Summarized below are some steps a Latin American country seeking to participate in an international cooperative mission, where a space launch is contributed by a foreign partner, should consider:

1. Assessment of your country's unique national resources you could contribute to the mission.
2. Develop clear and specific mission objectives:
   - training in space activities;
   - scientific exchange;
   - technological advancement.
3. Assessment of which space-faring nations have launch capability and may share your objectives.
4. Contact the space organization in the country (countries) where you may have shared mission objectives.
5. Negotiate and consummate terms of each partners responsibilities in an agreement.

International cooperative agreements vary from mission to mission and country to country, most require each country to assume full financial and technical responsibility for its portion of the cooperative effort. In addition clean and distinct managerial and technical interfaces are detailed in agreements.

Both Argentina and Brazil have entered into international cooperative agreements which included, launch of national spacecraft on launchers provided by foreign partners. Argentina and NASA have entered into an agreement to support the 1995 launch of the first Argentine spacecraft aboard a dual launch on a Pegasus. Brazil and China have also entered in to a cooperative agreement, whereby the joint China-Brazil Earth Resources Satellites (CBERS) will be launched by Chinese Long March rockets.

4.6.3. Development of a new low-cost small launcher

As previously stated, low cost access to space is a critical enabling capability, particularly for developing Latin American countries with limited resources to expend on initial space activities. If low cost, routine access to space is not readily available in the international market place, a country may consider development of an indigenous launch capability. A driving force in pursuing this approach is the lack of available low cost launchers and an inability for a country to meet their launch requirements on a timely basis, especially if the country views access to space as critical to their national development and requires the benefits of space, such as understanding of natural resources, cheap communication to remote areas and the overall educational benefits to the local population.

5. TECHNOLOGY TRANSFER

5.1. General

A successful technology transfer in the development of the small satellite activities implies a process by which a team acquires sufficient momentum to be able to produce the next generation of a small satellite. To be successful, the transfer should be a transfer of understanding, not the transfer of a technology package (know-why as well as know-how).

5.2. Basic mechanisms for technology transfer

There are several mechanisms whereby technology transfer can be achieved. Some examples of technology transfer processes between a more developed country and a less developed one are described below:

1) Bilateral agreements between governments

• Development of specific protocols of cooperation on space activities in order to assure political support for the total duration of the program. These programs must involve the training of personnel and the technical, financial and scientific support for projects proposed by the developing country during the total duration of the program. The benefit for the developed country is its influence on the definition of the project details and the great possibility of becoming a supplier of services and products.

• Assistance in setting up ground equipment to support space activities in Latin America. The Latin American country provides the location and the civil infrastructure for the equipment. The supplier provides all the key equipment units, the training of personnel and the clearance for the use of the equipment also by the host country. The benefit for the supplier is the use of a foreign territory and the reduction of the implantation, operation and maintenance costs of the infrastructure.

• Provision of training of personnel provided by the most developed country together with joint development programs of space projects. This type of interchange usually happens between government institutions with common goals.

2) Agreements or joint ventures between research institutions and private companies.

In this case both partners develop a joint project; each one pays part of the costs and works on its areas of expertise. The final results are shared by both partners. The participants can benefit from the reduction of costs and the opportunities for the development of other common projects.

3) Purely commercial agreements.

In this case a technology (a process, an equipment, a system etc.) is bought to supply a specific project. Even in this case the participation of technical personnel of the country that is buying the technology is mandatory during preliminary negotiations, the approval of the general technical specifications and acceptance tests.

4) Academic interaction

Scientific experiments can be developed and jointly flown on small satellites by university partners in different countries. Personnel and student exchange as well as data analysis and joint publication of results are typically involved. Participation in international meetings/colloquia/workshops/etc.. can also be considered as possibilities for exchanges.

5.3. Basic conditions for technology transfer

Considering that all technology transfer processes typically involve people from different countries, it is necessary to assure *some minimum conditions* for its successful implementation:

- successful technology transfer can only be made to persons of sufficient technical and scientific background;
- access to appropriate infrastructure to support the application of the technology should be available;
- a long term development plan with scheduled objectives and proper financing should be in place, in particular because technology transfer is a long term process.

5.4. Advantages

The following advantages of technology transfer render it desirable:

- it lowers the costs in the long term;
- it promotes a quick entry into space;
- it promotes international cooperation;
- it promotes technological spin-offs;
- it contributes to create high quality jobs;
- it contributes to enhancing the technological standing of the nation.

Technology transfer, when appropriately undertaken, is achievable and provides the key to accelerate access to space for those countries which elect to implement such a program.

6. INTERNATIONAL COOPERATION

6.1. Background

According to those tenets established by the charter of the United Nations and other agreements concerning international cooperation for the exploration and peaceful uses of outer space, there is a right for each country to have the opportunity to participate in space activities. In addition, there is an obligation for each country to cooperate in these efforts and to share existing information and adequate technology in order to plan, develop, launch and operate satellites.

Although cooperative space activities have existed for a number of years, particularly as specific scientific endeavors, they are only now beginning to include small satellites for Latin American countries. Therefore, it is highly desirable to define opportunities to widen the scope of cooperative efforts so that more countries in Latin America could have access to space and the resultant benefits to be derived from space technology.

6.2. Objectives

The objectives of Latin American participation in small satellites are to allow the nations within this region to have easier and lower cost access to space activities. This will provide them with valuable tools that can contribute to their sustained technical and economic development, which could result in improved quality of life, protection of their environment, and other benefits derived from the use of advanced technology and new management techniques. The spin-offs from space technology can facilitate and accelerate the internal development of new and advanced national technologies that would improve their competitive positions in the world market.

6.3. External cooperation for Latin America

Recently agreements have been made by Argentina and Chile for cooperative programs:

Argentina is building its own small scientific satellite (SAC-B), which will be launched with a small US scientific satellite (HETE) by an American launch vehicle (Pegasus). Under the terms of the agreement with NASA, Argentina will receive a free launch, technical expertise in spacecraft development, and suggestions for sources of spacecraft components. In return, there is reserved adequate mass, volume and support for US instruments on board SAC-B. Additionally, Argentina and the United States will both have access to all of the data acquired by SAC-B. There is no exchange of funds under this agreement.

Chile is taking a different approach. They have contracted with Surrey Satellite Technology Ltd., for a microsatellite (FASat Alfa) and the training required to build another one themselves. The training will also include ground operations.

Clearly, either of these approaches can be used by other countries in Latin America as an entry into space activities. Other possibilities include cooperative activities for one or more scientific instruments that could be flown on the small satellites of other countries. Such instruments could reflect science or applications of special interest to the particular country. Agreements can be made between governments, academic institutions and private industry in any of a number of different countries.

Specific spacecraft subsystems and/or software could be built and provided to other countries in return for scientific data or other benefits.

6.4. Cooperation internal to Latin America

Brazil has assembled excellent satellite test facilities, which Argentina has used for the qualification of their SAC-B spacecraft. Not every country can afford, nor does it need, the infrastructure required for such extensive test facilities. With its central location in South America, INPE in Sao Jose dos Campos, could provide this service for the entire continent.

As an other example, Brazil, Argentina and Chile are working together to gather and analyze data on the origin and nature of the unique equatorial plasma bubble phenomena that interfere with communications, particularly in lower frequency bands. Brazil's cooperation in this field of scientific endeavor exists also outside of Latin America. For instance, Germany and the United States have been studying the physics of equatorial plasma depletion's which occur in ionosphere domains (plasma bubbles) over South America using sounding rockets launched from the Brazilian rocket launching facility at Barreira do Inferno. Ionosphere sounding rocket experiments have also been launched from Peru. From August to October 1994, NASA plans to launch 33 sounding rockets from Alcantara to study the ionosphere-thermosphere system.

Until now, Brazil has worked independently to build its own satellites and is developing its own launch vehicle. Mexico has built a nanosatellite and is executing a plan involving various universities and other internal institutions to build a microsatellite for experimental data communications. It is conceivable that, in the future, cooperative efforts could involve several Latin American countries in order to exchange information and execute larger programs at a reasonable cost for each country involved. One benefit of such cooperation would be to avoid the duplication of efforts among the countries.

7. FUNDING

7.1. General

Members of the Workshop note that national space programs have always started based on government plans and initiatives. However, in the current fiscal climate, it is noted that the budgets of developed space countries are under such pressure that increasingly those governments are seeking industrial support for new initiatives as there are some areas that could be developed in cooperation with industry or service companies. Hence their programs and planning increasingly emphasize on commercialization. Aiming to reduce funding difficulties and to justify governmental investments, the projects could be included at least in one of the following categories:

(1) with clear impact on science or R & D;
(2) to cover governmental demands on infrastructure;
(3) market oriented with financial feasibility.

Realizing the potential for future wealth generation, the nations of Latin America should seek ways to involve their industries in future programs. The involvement of local industry in space technology production depends on economic feasibility which could be achieved in at least two ways:

1) joint ventures with international companies, thus opening the international market;
2) long term continuous missions, such as ECO-8 and WMO-8, assuring a continuous demand from internal and international markets.

The particular situation in each of the four Latin American countries involved in the workshop is presented hereafter:

7.2. Argentina

Space activities in Argentina are sustained by national funds. In the future Space Program, special emphasis will be put on those activities that may interest the private sector involved in different activities, such as communications, agriculture, deforestation, fishing, localization services, etc., and consequently would receive economic support from it.

7.3. Brazil

The funding of the satellite development has been concentrated in the Government. Until now this can be justified by the benefits related with developing scientific and technological capabilities. Important results were obtained, including infrastructures; a reasonable space industrial sector; around 2000 scientists and technicians with a broad spectrum of expertise; the manufacture of satellites. Investments in space technology and space science is expected to continue. Therefore satellites may generate clear direct benefits to justify continuation.

The Brazilian space program includes projects which can fit within the three categories defined in section 7.1, i.e. respectively:

- the scientific satellites and the SCD satellites;
- the remote sensing missions SSR and CBERS;
- the planned telecommunication mission ECO-8.

There is a tendency in the whole world to involve private companies even for missions with application for public interest. Therefore the future missions like SSR and CBERS are being discussed in terms of products and prices in an open and competitive market. This does not mean that the final user will pay all the account. Governments are expected to subsidize environment and agriculture projects. The project administrator decides the most fruitful way to spend the money. There are applications which can be fully commercial, as for example mineral/petroleum exploration, commercial fisheries, mineral industries, mapping, and GIS.

The CBERS and the SSR satellites are being designed to prove their competitiveness. The first generation of both programs have been fully government supported. The economic feasibility of these programs has to be considered in different ways. The CBERS program can provide powerful imagery with unique character and performance. This program is being developed in a joint venture between Brazil and China ; these two countries together already imply quite a large market to start. The SSR satellite with the WFI imagers can become a good option because of small size, low cost and they can supply a niche of high temporal resolution images.

The ECO-8 system implementation is being considered because of its commercial feasibility. However, concerning the funding, commercial and strategic interests are being considered simultaneously. The customers, represented by the operator companies are responsible for the implementation costs. Otherwise the Brazilian government is considering parallel investments in key technologies related to the project. The idea is to combine strategic technological interest and competitiveness necessary for a market oriented mission. The R&D will represent in this scenario an additional cost to be supported by public funding. However, the most part of the costs and the guarantee of a continuous program will be funded on a commercial and price basis from the market.

7.4. Chile

The current space program of Chile receives funding from two organizations of the Chilean government: the Air Force and the Bureau of Civil Aviation.

At present, the program is being developed jointly with the University of Surrey (UK).

7.5. Mexico

Something has been done in the way to consolidate and develop space technology, but big efforts remain to be done to tighten cooperation, especially in the formation of the indispensable "critical mass" that gives viability and efficiency to the projects. To accomplish it, the participation of all the interested people and entities will be required.

All the activities of the Mexican space program represent a significant investment, supported by a wide range of organisms.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. General benefits from small satellites

From the previous studies prepared by the IAA on the subject of small satellites, and from the results of this workshop, it can be recalled that small satellite systems offer the following benefits:

- An independent national space program can be developed within a short period of time and at relatively low cost, allowing quick entry to the space sector. The study and development of space instrumentation, spacecraft components, sounding rocket programs, individual small satellite programs, and cooperative small satellite programs are low cost opportunities to commence space activities.

- Fairly sophisticated scientific and technology experiments can be flown in space at modest costs, including space physics, astronomy, technology demonstrations, communications experiments, and acquisition of Earth resources data, including disaster information.

- Small satellites present an opportunity for training engineers and engineering students in all of the engineering disciplines, including software development for on-board and ground computers, and in the management of sophisticated technical programs.

- Opportunities are available for national and international cooperation, to acquire advanced technologies and upgrade the nation's technical expertise in new areas.

- Small Low-Earth Orbiting (LEO) satellites offer the promise of inexpensive telecommunications services, and opportunities for international cooperation. Such services could include mobile communications for ships, aeroplanes, and land transportation, and for personal communications.

- Small satellite systems provide the opportunity to invest limited resources to increase gradually a nation's space infrastructure.

8.2. Expected returns to the deprived populations of Latin America from small satellite missions

Beyond those general benefits, it is important to insist on the expected returns to the deprived population of Latin America from small satellite missions:

- Improvement of agricultural and animal productivity in medium to large size rural properties due to better weather predictions, identification of soil characteristics, improvements in communications and transportation.
- Lowering of transportation cost, made possible through the optimization of truck, bus and ship routing, location and early robbery detection, with favorable impacts on prices of goods.
- Provision of communications for the basic needs of small rural settlements in remote areas.
- Expansion of availability, thus decreasing prices, of better technology for everyday electric and electronic goods and materials, an indirect effect of the industry participation in quality demanding space projects.
- Improvements in natural disasters detection and relief, made possible by systems that integrate scientific, communications and remote sensing satellite networks.
- Educational programs for remote areas populations.
- Job creation in the space industry and ground facilities.
- Overall improvements in the quality of life of populations living in areas neighboring the ground facilities that support space activities.

8.3. Recommendations

Finally, in view of the general benefits, and of the expected return to the populations, but also considering some the difficulties experienced to-day, the following recommendations are made:

(1) The Latin American nations should jointly detail their needs in remote/mobile communications. It is recommended that the Agência Espacial Brasileira (AEB), Brazil, initiate the actions to coordinate these activities.

(2) The Latin American nations should jointly define their specific requirements for a remote sensing satellite system with direct down-link to users so as to respond to their local needs. It is recommended that the Comision Nacional de Actividades Espaciales (CONAE), Argentina, initiate the actions to coordinate these activities.

(3) It is recommended that Latin American nations jointly participate in global studies of space sciences with emphasis on studies of the tropical and southern hemisphere region.

(4) Each Latin American nation should take the steps necessary to make the public and the policy-making government officials aware of the importance and benefits of a national space program so that funding for space activities will be included in the national budget on a sustained basis.

(5) Each Latin American nation which is or wants to be involved in a space program, should develop and publish its national space policy so that areas of cooperation can be identified.

(6) It is recommended that Latin American industries take initiatives and play a more active role in investing in the development of increased national space activity.

(7) Any sensitive technologies involved in technology transfer should be identified in advance by the countries involved, and related barriers overcome.

(8) The Latin American nations should identify and propose mechanisms to improve access to available technologies for scientific applications.

(9) Representatives of Latin American nations should participate in seminars, professional society meetings and other similar forums for the exchange of the latest technical data.

(10) Latin American nations should attempt to find a market for existing national expertise to sell space hardware and software to other countries for their space programs, using national academic and industrial facilities

(11) In order to facilitate developing nations access to space, particularly through easy access and availability of piggyback and dual-manifestation missions, the international launch community should periodically publish and distribute notice of potential low cost launch opportunities.

ANNEX - LIST OF PARTICIPANTS

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