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# *Toward Fusion of Air and Space*

## *Surveying Developments and Assessing Choices for Small and Middle Powers*

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## DILEMMAS IN SPACE STRATEGY FOR REGIONAL POWERS: A BRAZILIAN PERSPECTIVE

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### Introductory Remarks

**An Historical Overview.** Brazil was among the first countries to officially include space activities within its government program back in 1961 with the establishment of GOCNAE, the Organizing Group of the National Commission for Space Activities, placed under the National Research Council (CNPq). It is worth mentioning that, despite being a civilian organization, GOCNAE received staunch support from the Ministry of Aeronautics, which provided a site in São José dos Campos, São Paulo, and personnel to compose part of GOCNAE's initial staff.

In 1966, the Ministry of Aeronautics established the Executive Group for Space Projects Activities and Studies (GETEPE) which, in 1969, created the Institute of Space Activities (IAE). These activities were consolidated in 1971 under COBAE, the Brazilian Commission of Space Activities, a coordinating interministerial body under the head of the Joint Chiefs of Staff of the Armed Forces (EMFA).

In 1971, GOCNAE became INPE (the Institute of Space Research); and from 1985 on INPE (which since 1990 became the National Institute for Space Research) reported to the Ministry of Science and Technology.

INPE's activities, initially focused on aeronautics research, expanded in the '70s to include space applications such as remote sensing and meteorology. Actually, Brazil was among the first countries in the world to install a complete Landsat Satellite Ground Station in 1972, right after the United States and Canada.[2] From there it went into space technology (satellites and associated ground systems). Meanwhile, the IAE concentrated its efforts on the development of sounding rockets and, more recently, launch vehicles.

The Ministry of Aeronautics also set up the Launch Centers of Barreira do Inferno (CLBI) and Alcântara (CLA). The former has been in operation since 1965, providing facilities for launching and tracking Brazilian and foreign sounding rockets, aiming not only at the development of the country's capability in sounding rockets and

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[1] This paper is coauthored with M. N. Barbosa, former director of INPE, president of IAF, now adjoint general director of UNESCO. The authors are indebted to General of the Air Force Reginaldo dos Santos, chief of DEPED, the Brazilian Air Force Department of Research and Development; Dr. Luiz Gylvan Meira-Filho, president of AEB, the Brazilian Space Agency; Ambassador Carlos José Prazeres Campelo, chief of the Department of Space Cooperation, AEB; Dr. Lauro Tadeu Guimarães Fortes, chief of the Department of Planning and Coordination, AEB; and Rear-Admiral Hélcio Blacker Esposel of the Ministry of Defense, for their valuable counsel and suggestions.

[2] M. N. Barbosa and D. Bastos-Netto, "The Brazilian Satellite Remote Sensing Program," *Remote Sensing for Development, Part II,* Jörg Albertz and Rüdiger Tauch, eds. (Berlin, Germany: DSE, 1989), pp. 23–32.

launch vehicles but also for the research in space and atmospheric sciences. CLBI has successfully handled well over 2,000 launchings to date.[3]

In 1979, the government established the Complete Brazilian Space Mission (MECB), the first long-term space project which aimed at the development of small application satellites (environmental data collecting and remote sensing) and a launch vehicle to do the job properly, along with their ground infrastructure. This led to the building of the CLA in the state of Maranhão. The CLA is in use for suborbital launches. Its location, close to the equator, renders it an internationally competitive center for satellite launches.

Brazil pursued enhanced cooperation with other countries, in addition to maintaining the MECB project during late 1980s. Political changes plus the world scenario led Brazil to substitute COBAE with a new institution conceived to exert an ampler role in this country's space affairs, emphasizing not only its civilian role but its purely pacific nature during early 1990s. Hence, the Brazilian Space Agency (AEB) was created in 1994 as a civilian organization under the Presidency of the Republic (since last year, AEB has been put under the Ministry of Science and Technology). This has been kept this way, regardless of the statements and forecasts published in a RAND report back in 1993.[4] It is also worth mentioning that Brazil signed the Missile Technology Control Regime (MTCR) agreement in 1998.

**A Review of the Present Situation.** Today, Brazil has nearly 300 Ph.D. scientists, 800 researchers and engineers, and 2,000 technical people from different fields engaged in space activities under the overall coordination of the AEB.

Infrastructure, space technology, and systems are the concentration areas of investment, for they are basically more expensive than scientific research and the application of proven technologies.

Brazil has matured in the fields of remote sensing and meteorology.

It also has a reasonable foundation in space technology and engineering. Besides the Alcântara (CLA) and Barreira do Inferno (CLBI) launch facilities, the space community in Brazil has succeeded in building other basic infrastructure items for space R&D such as the Integration and Test Laboratory (LIT), the Satellite Tracking and Control Center (CRC), the Colonel Abner Propellants Utility (UCA), and, more recently, the Satellite Thrusters Test Facility with Altitude Simulation (BTSA).

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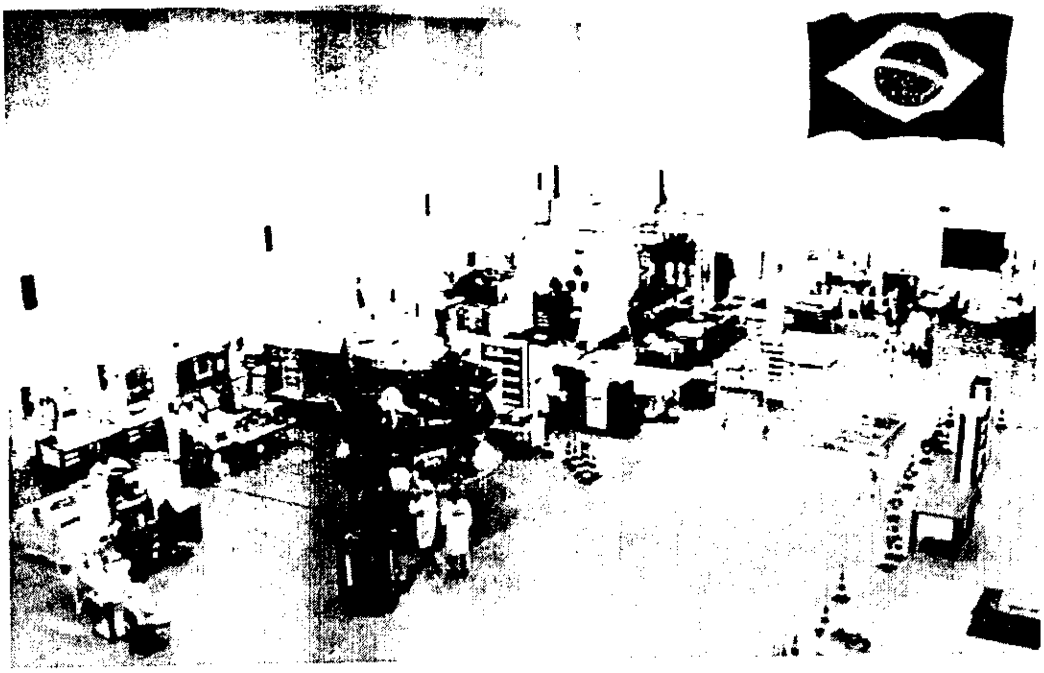
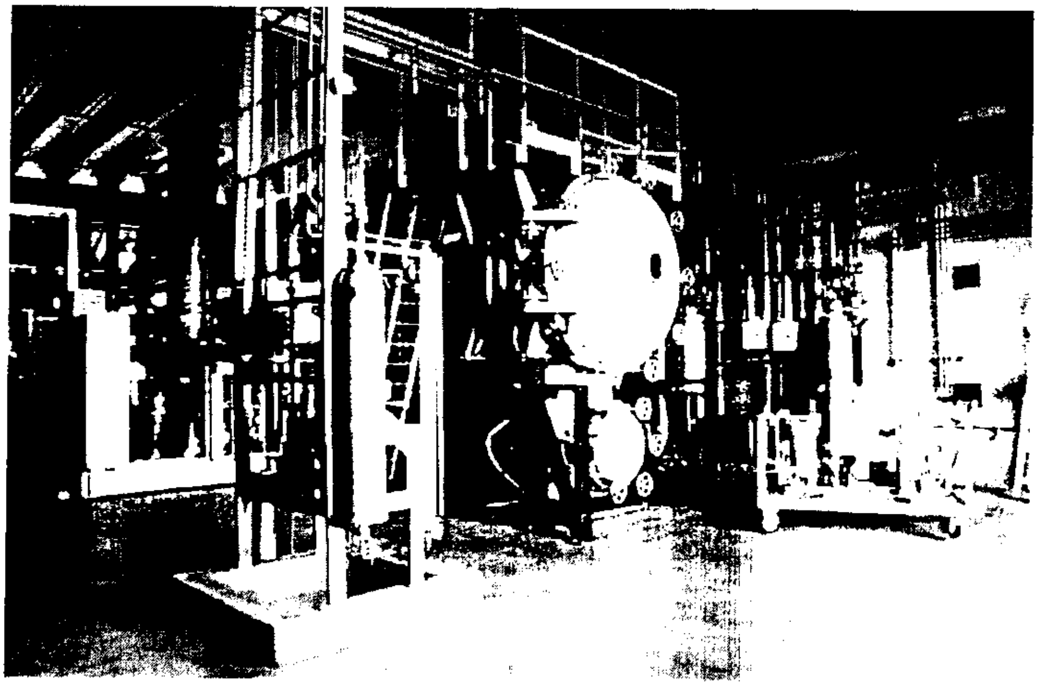
[3]A. G. Mota, "Esboço Histórico da Pesquisa Espacial no Brasil," Publ. INPE 3938 -RTR/088, INPE, São José dos Campos, SP, Brazil, 1986 (in Portuguese).

[4]B. G. Chow, *Emerging National Space Launch Programs: Economics and Safeguards* (Santa Monica, Calif.: RAND, R-4179-USDP, 1993).



Integration and Test Laboratory (LIT)


Satellite Tracking and Control Center (CRC)



**Satellite Thrusters Test Facility with Altitude Simulation (BTSA)**

*Scientific Production:* The Brazilian scientific body in space activities dwells in the fields of space sciences, meteorology, oceanography, earth sciences, thematic applications in remote sensing, global change, materials science, plasma, combustion and propulsion, orbital mechanics and control, mathematical modeling, and computation sciences.

This group presents a high level of productivity—with publication levels comparable with those found in other industrialized countries—and an active program of international collaboration.

*Space Applications:* A long-term program aimed at the establishment of proper infrastructure, human resources, and adequate methodologies and tools is under way and it has yielded significant dividends. Activities on remote sensing, for instance, have been incorporated into daily chores of social–economic weight and generated private enterprises that offer services to the general public. As far as meteorological activities are concerned, the Weather Forecasting and Climate Studies have been implemented at INPE to provide up to five-day lead time numerical weather predictions and climate forecasts on an operational basis. These services are freely available on the Internet.

*Space Engineering and Technology:* The first two satellites conceived, designed, developed, manufactured, and fully tested and qualified in Brazil were successfully placed into orbit. The SCD-1, the first data-collection satellite, was placed in orbit eight years ago and it is still operational, despite the initial planned lifetime of 18 months. The SCD-2 was launched in October 1998 and is also showing a good performance. Both satellites receive and relay information from nearly 400 data-collection platforms scattered around Brazil, neighboring countries, and over the continental shelf.[7]

The Chinese–Brazilian cooperation for the development of remote sensing satellites has led to the successful October 1999 launching of CBERS-1 (now in operation). The launching of CBERS-2 is scheduled to take place early next year.

The country has developed (with an expressive contribution from the Brazilian industry) a series of sounding rockets (designed, integrated, tested, and qualified by IAE). The launching of Sonda Sounding Rockets II, III, and IV have enabled scientists from Brazil and abroad to carry out many suborbital scientific experiments. Well over 60 scientific technological payloads have been flown with success. Now the country is in the final phase of the development of its first launch vehicle, scheduled for late this year. This vehicle, VLS-1, was designed for the MECB program, i.e., for the launching of satellites up to 200 kg into 700–800-km orbits only.

*Industry Contribution:* Brazilian industry participation in space projects has been steadily growing. This can be evaluated using the ratio of the worth of industrial contracts to the overall system cost: It was 9 percent for the SCD-1 satellite, and increased to around 20 percent for the SCD-2 satellite. As for joint international ventures, it was 42 percent for the Brazilian segment of CBERS-1 satellite and it is expected to go up to 90 percent for the next ones in the CBERS series. It is estimated that the development of the VLS-1 vehicle will elicit around 70 percent of industrial participation.

The Brazilian Aerospace Industries Association (AIAB) has been created as a result of the importance of these recent activities in Brazil. It is well-known that EMBRAER, the largest Brazilian industry in this sector, has shown the highest net profit among all industries in the country last year. As the representative of the private sector, the AIAB is part of the National System for the Development of Space Activities (SINDAE).

## International Scenarios

The changes following the end of the Cold War have altered the courses of space programs everywhere. Modernizing policies have led to frequent revisions of ongoing projects and changes for future plans. The end of the Cold War also allowed civilian space programs to benefit from technologies developed for military applications (such as, for example, the high-resolution and imaging techniques that opened new marketing opportunities for remote sensing applications).

These developments have fostered support for programs that lead to immediate returns for society, i. e., application programs. This suggests priority to Earth observation and telecommunication systems for which the space environment is used in developing new processes (such as microgravity experiments). Another trend easily

[7] AEB, *The National Space Activities Program, PNAE 1998–2007*, Brasilia, DF, Brazil, 1998.

noticed is the worldwide tendency to replace long, expensive missions by large numbers of smaller and shorter ones, using off-the-shelf platforms, components, and even standardized design.

Therefore, it can be stated that most of the space programs today possess the following characteristics:

- They give priority to application areas, e.g., telecommunications, remote sensing including microwave bandwidths), meteorology, and microgravity.
- They keep the schedule of the International Space Station (ISS) program and of those programs aimed at providing space infrastructure in support of scientific and technological payloads.
- They develop non- or partially reusable launch vehicles along with the development of reusable ones to reduce launch costs.
- They strive to increase the deployment of mini- and micro-satellites (recoverable or not) for scientific and technological experiments.

## Dilemmas for the Country—
## Space Development Priorities and the Brazilian Space Program: Its Reasons and Principles

It is known that, except for communication satellites, space programs do not offer a direct return to the investment made on them. On the other hand, as a developing country, one of Brazil's most important policies, regardless of other nations past experiences, is the high priority lent to its social chores and toward the protection of its environment.

This poses the following dilemma:

1. Should the government yield to the immediate political pressure and give up its space activities, reducing them to an absolute minimum? (Notice that this kind of pressure is not internal only, for Brazil is too big in surface and population to be fully welcomed among the developed space-oriented nations.)
2. Or should the country take the road of common sense and look beyond the horizon, believing that, as happens with any high-tech activity, it will pay off several times over (in the medium range) the investment made on it?

Brazil cannot ignore its position in the cadre of South America countries either, and thus it has to be prepared to share its knowledge and acquired expertise with its neighbor nations, for the common well-being. This is specially true within Mercosur community countries.

Therefore Brazil has chosen the second option:

Although the total investment in the sector is quite modest (this year around 0.025 percent of its gross national product), Brazilian space activities will follow within this decade a well-defined program aimed at increasing of the return to society of the investment made in this area.

A comprehensive investigation of the reasons for the existence of space programs points out two major conclusions. (1) As mentioned above, these programs usually do not offer a complete and direct return of the overall investment (i. e., they do not cover the costs of design, development, construction, launch, and operations), with the exception of communications satellites. This is true even for the United States and the ESA countries. On the other hand, these programs still have a long way to go, as it is the case, for instance, with microgravity, which might turn out profitable in the future. This is the main impetus for a sizable part of the investment in the area. (2) The results of space programs, mainly those linked to Earth observation, are of government interest. This is so with systems for investigating large-scale phenomena covering large areas, such as environmental monitoring, data collections for weather forecast, geological and cartographic surveys, among others of direct benefit to society. Although these activities might even offer some financial returns, it is not expected that all necessary funds be provided by the private sector.

For Brazil, the lines of action follow these basic principles:

A. *To find and to fill niches of interests for the country in the field of space activities.* These niches may be a result of our own particularities, such as location and internal needs, which might not generate strong interest among the industrialized nations. For example:

1. Constellation of small, low-cost communications satellites in low equatorial orbit, to be used for the integration of remote regions and which may be of interest to other equatorial countries;
2. Small, low-cost, low-orbit remote sensing satellites capable of relaying images directly to small ground stations within each satellite-covering area for real-time monitoring of land use (i.e., for deforestation control or, if high resolution is available, frontier surveillance). It is important to note that, in the near future, SIVAM (Amazon Surveillance Integrated System) activities will rely heavily on space technology.
3. Broadcasting satellites that run educational TV systems to assist remote regions.
4. Other niches for Brazil are, for example, in the area of scientific research: the Equatorial Electrojet and the South Atlantic Magnetic Anomaly. In addition, the ocean–atmosphere interaction in the South Atlantic and the climate of the Amazon are scientific themes of regional and global importance.

B. *To enhance integration with international programs through scientific and technological cooperation.* As space activities and its by-products have been shown to have a significant impact on society (or to possess potential, not yet fully exploited benefits), the main target of a national space policy for Brazil should cover a wide range of interests that engages, whenever possible or acceptable, private organizations. This way, progress can be foreseen in space applications (remote sensing, meteorology, oceanography, geodesy, and navigation), in space systems and its technologies (satellites and launch vehicles), and in space sciences.

## Objectives of the National Policy for the Development of Space Activities (PNDAE)

The main aim of the PNDAE is "to advance the capacity of the country according to appropriate criteria, to utilize space techniques and resources in the solutions of national problems and in benefit to Brazilian society."[6]

For this aim to be achieved, the following specific objectives have been identified:

A. *The establishment in the country of a technical scientific competence in the area of space, which would permit a genuine autonomy of action in*

- the selection of alternative technologies for the solution of Brazilian problems;
- the development of in-house solutions for problems specific to our territory or society, wherever more economical alternatives are either unavailable or cannot be guaranteed;
- the effective use of information of interest to Brazilian society, provided by space techniques; and
- international negotiations, accords, and treaties, involving material pertinent to space activities or capable of benefiting from knowledge based on such activities.

B. *Advancement of the development of space systems, together with the corresponding means, techniques, and ground-based infrastructure, making necessary or desirable services and information available to Brazil.*

C. *Qualification of the Brazilian industrial sector to participate and become competitive in the supply of products and services related to space.*

To achieve the above-mentioned objectives, the PNDAE also establishes the following guidelines to be observed, most of them self-explanatory:[7]

1. Priority for the solution of national problems
2. Concentration of efforts in high-profile projects
3. Scope defined by final results
4. Critical analysis of the investment[8]

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[6]AEB, *The National Space Activities Program, PNAE 1998–2007*, Brasília, DF, Brazil, 1998.

[7]Ibid.

[8]That is, prioritizing initiatives involving a balanced temporal distribution of results with guaranteed returns in short and medium terms and submitting program investment proposals to cost-benefit analysis.

5. International cooperation of consequence[9]
6. Incentives for industrial participation
7. Optimized use of resources
8. Development of capability in strategic technologies[10]
9. Pragmatism in the conception of new space systems
10. Importance of scientific activities
11. Emphasis on space applications[11]
12. Coherence between autonomous programs
13. Matching technological objectives with scientific aims and application goals[12]
14. Dual-use technologies[13]
15. Other guidelines. In addition to the items mentioned above, one should also include activities promoting (a) the generation and training of highly qualified human resources; (b) international cooperation at all levels; (c) greater integration between the university and the industry; (d) with priority, the development of space systems; and (e) the development and dissemination of space applications. It should promote and encourage commercial participation in sponsoring of space systems for commercial services; it should also encourage the commercial exploitation of space activities–generated services and products, giving priority to the private sector.

It should complete and maintain adequately the needed infrastructure for space missions of national importance including development, integration and tests of space systems, laboratories, tracking and control centers, and launch facilities. Finally, it should also promote the dissemination and the effective use of space-related information with emphasis on that of normative nature.

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[9]In the context that information sharing is limited to that strictly necessary to achieve the common objective and due to the fact that in the technical area international cooperation is not usually characterized by a free interchange of valuable information, the following items should be observed: Benefits should be stated clearly and pragmatically; cooperative scientific projects should be encouraged that seek to establish favorable conditions for personnel, equipment, and data exchange, and to ensure beneficial participation in major international scientific programs; opportunities for cooperation in space engineering, technology, and systems should be taken whenever possible within the interests of the country; cooperative initiatives with countries with similar problems should merit special attention; the establishment and adoption of international standards should be adopted.

[10]Given the importance in dominating techniques considered strategic for the country, this guideline should consider the following criteria: their importance for space systems or services of major interest; difficulties with their importing; their potential commercial value for Brazilian concerns; and the competence and facilities available in the country to make state-of-the-art contributions.

[11]For a country with the geopolitical characteristics of Brazil, the application of space technology to the solution of national problems constitutes the main justification for government investments in the area.

[12]This should be taken as fundamental in programming the development of space activities; the scientific and application objectives, respectively, should be directed toward the advancement of universal knowledge and to the solution of problems of national scope or of interest to the country.

[13]A significant part of the technologies used in space applications can be termed as such. Therefore, the national space activities program should take into account the government policies and legislation on export controls on dual-use material and related services, seeking, where applicable, proper coordination.

## Strategy to Fulfill the Objectives of the PNDAE

Given the directives of the PNAE through its objectives and guidelines, PNAE has established a ten-year plan, organized in major programs, which, in harmony with those directives, also took into account the peculiarities of the various sectors and were consistent with the policies of the ministries responsible for the country's position in the international arena. These major programs, fully taken from AEB's *National Space Activities Program, PNAE 1998–2007*, are listed next along with some of their main specific objectives and some considerations:

1. *Space Applications*—To create the tools for society to best use the data generated by application satellites, mostly in the fields of remote sensing, meteorology, oceanography, telecommunications, geodesy, and navigation.

2. *Satellites and Payloads*—To generate the capability for the conception, design, development, construction, and use of satellites and their subsystems. These activities include

   - data-collection satellites (SCDs);
   - Earth observation satellites (the SSRs [Small-Scale Remote Sensing Satellites] and CBERS series);
   - scientific and demonstration satellites (small, low-cost satellites for short missions, such as the SACI series and the SFB, the French Brazilian Scientific micro-satellite under development by CNES and INPE);
   - telecommunication satellites (aimed at establishing, in the long range, autonomy in the conception and design of systems to exploit alternatives of specific interest to the country as well as to enable national enterprises to increase the share in the telecommunications satellite subsystems market)
   - Payloads and Complementary Initiatives (experiments with foreign space agencies, e.g., CIMEX and HSB with NASA and the PSO [Sub-Orbital Stabilized Platform]; and, last but not least,
   - the International Space Station (ISS).

3. *Launch Vehicles*—To give the country the capability to design, develop, and build launch vehicles for suborbital payloads and satellites. It includes three subprograms: sounding rockets, launch vehicles for small satellites, and launch vehicles for medium satellites.

4. *Space-Related Infrastructure* —To expand and keep up the existing facilities that constitute the mainstay of the space activities in Brazil and to set up new units deemed necessary. This consists of four subprograms:

   (a) Support infrastructure for satellite development (with the integration and tests Laboratory, LIT [see page 123], the Satellite Tracking and Control Center, CRC [see page 123], and the Satellite Propulsion Laboratory, BTSA [see page 124]).

(b) Support infrastructure for the development and launching of space vehicles, with the following facilities in operation: the Alcântara Launch Center (CLA), the Barreira do Inferno Launch Center (CLBI), and the Colonel Abner Propellants Utility (UCA), as well as the following planned facilities: a satellite launch vehicle tracking and control network, a rocket motor propulsion laboratory, an acoustic tests laboratory, a carbon-carbon research and production unit, and a transonic wind tunnel.

(c) Support infrastructure for research in space and atmospheric sciences (including facilities such as the Itapetinga Radio Observatory, the São Luiz Equatorial Space Observatory, the Balloon Launch Unit, and the southern regional Space Research Center).

(d) Support infrastructure for space applications (with satellite data receiving, processing, and distributing systems for remote sensing satellites such as the Landsat, SPOT, and CBERS series and for meteorological satellites such as Meteosat and Geostationary Operational Environmental Satellites (GOES), as well as for polar orbit NOAA series and the Weather Forecasting and Climate Studies Center [CPTEC], which generates and disseminates numerical weather and climate forecasts for Brazil with lead times and reliability similar to those of other first-rate centers). An Integrated Space Data Center (CIDE) will be installed in the near future, to allow access to all space data archives.

5. *Research and Development*—To foster, coordinate, and support projects on basic and applied research in space science and technology. It consists of six subprograms: (a) space and atmospheric sciences; (b) meteorological sciences; (c) global change; (d) microgravity; (e) space technology; and (f) related areas, including R&D in fields associated with space activities such as material physics, mathematical modeling, scientific computation, and plasma physics.
6. *Human Resources*—To establish in the relevant fields the trained human resources needed for carrying out the PNAE.
7. *Development of National Industrial Capability*—To establish industrial competence among the Brazilian companies to participate in the supply of space-related services and products within the country and abroad.

## Concluding Remarks

The Brazilian policy in space activities has been always transparent and keeps it that way, even in the quite sensitive area of launch vehicles development. This was detailed in a RAND report back in 1993,[14] which offered the primary reason for selecting Brazil as a case study to be extrapolated to other countries: "economic data on emerging national space launch programs are generally closely held, but Brazil's data are available."

[14] B. G. Chow, *Emerging National Space Launch Programs: Economics and Safeguards* (RAND R-4179-USDP, 1993).

Brazil has been collaborating with its neighbors in South America and countries abroad: It has started the development with Argentina (and lately with Spain) of a remote sensing satellite, the SABIA, for applications in water resources, agriculture, and the environment. Its presence in the ISS will bring to the country the opportunity to hold experimental activities in earth observation, biotechnology, material sciences, and combustion microgravity, and the ability for its industry to improve its competitive level in the international high-technology market. A platform for scientific micro-satellites is under joint development with CNES. The association with China has led to the successful launching of CBERS-1, the first of a series of remote sensing satellites. CBERS-2 is scheduled for early next year.

As for the dual-use technology implications, everybody knows it is nearly impossible to split them clearly for this or that utilization. Just recall the many items which, within our life span, drifted from the ultrasecret realm into everybody's house.

The Brazilian company EMBRAER, the largest aerospace private enterprise in the country, presented in 2000 the stock market's largest investment return, so space development (launchers included) is not only a matter of national pride but also one of sheer economic common sense.