Two paradigms of scientific and Technological politics: continuity and change brazilian Space Program: actors, strategies and lessons

Jorge R. B. Tapia

Instituto de Economia (IE)
Universidade Estadual de Campinas (UNICAMP)
E-mail: bitapia@eco.unicamp.br

Introduction

The purpose of this paper is to examine the development process of a complex product – satellites – in the Brazilian space industry. Therefore, it is necessary to analyze the Brazilian Space Program through the reconstruction of its operational framework, characteristics and different degrees of efficiency and effectiveness of implementation of policy formulations with reference to its main “programs”.

This work draws from a survey of information sources and fits within the broader context of a field-based empirical study of the Brazilian experience in satellite production. The analytical perspective adopted here articulates theoretical elements explored, over time, by Rush (1993) and Miller, Hobday et al (1995) regarding Complex Product Systems (CPS) and those involving policy analysis centered heavily on the notion of actor networking. The work by Miller, Hobday et al examines the process of generation and diffusion of innovation of a new product – the flight simulator. Our analysis focuses mainly on technological-managerial assessments and institutional learning processes in the satellite production environment, based on the specific (technological) innovation logic and (dynamics) of complex product systems. To position accurately the contribution of the stated work on the ongoing complex product systems debate stands as an important attribute of this analysis.

The common characteristics concerning the development of complex products allow the examination of the Brazilian experience. It does not encompass rigorously the development of an entirely new product (major innovation, see Utterback, J. H. et Christopher,T. Hill, 1983) but rather an assessment and learning process integrated in specific phases of the satellite development process.

We have found that the pattern of technological innovation in this industry is not well characterized by previous existing models, which, for this reason, see this sector with a unique specificity with regards to Brazilian public-private market relations.

The pertinence and usefulness of this analytical perspective is to allow, on one hand, the identification of critical dimensions of the satellite development process, and on the other hand, the rescue of the role of the actors involved. They are generally neglected, or, at the most, submitted to monocausal, simplified explanations which privileges exclusively specified groups of factors: inaccurate goal definitions, lack of financial and adequate human resources etc.
The central hypothesis holds that the implementation was strongly conditioned and orientated on behalf of institutional factors, by strategies “adopted” by different players and by its interactive nature throughout the products process development.

In the complex product system development three associated dimensions are outlined all together.

1. The degree of coordination among the institutional and industrial dynamics;
2. The level of cooperative strategies predominance among different agents;
3. The institutional, technological and social acknowledgment capabilities.

The analytical perspective engaged – and acknowledged here – seeks to cover these essential dimensions in accordance with suitable criteria of evaluation. First, the reconstruction of the directives and logic of action of the parties involved in satellite development in Brazil. Second, the characterization of the type of structure built along with mechanisms and forms of articulations adopted. Third, the identification of different types of available resources (financial, organizational and technological) with regard to the “forms” in which they were congregated. Fourth, the exam of deciding rules and mechanisms “used” in the various phases of satellite manufacturing. And lastly, the analysis of problems, solutions and difficulties (on the subject) of project management operability.

The Satellite as a CPS

The Complex Product Systems are mostly identified with customized products, where scientific and engineering know-how are intensively conducted. In addition, these products “incorporate” a great number of subsystems and adaptable components that allow and require full system interoperability and interconnectivity. If all of these conditions hold, the final product is capable of accomplishing its functions (Rush, 1993; Hobday et al., 1995).

---

2. *Drawn* out heavily on Miller, Hobday, Leroux-Demers and Olleros (1995) properly point out that complex product systems are large item, customized, engineering intensive goods which are unlikely to be mass produced. Complex Product Systems embody practically three general characteristics: 1. They are built of interconnected-often customized elements; 2. They exhibit non-linear and continuously emerging properties; 3. There is a high degree of user involvement in the innovation process, coexisting with economic environment “changes” leading to continuous and constant innovation process along with long duration production. Continuously emerging properties might also result in changes in systems form and structure in production’s assembly. It means that the growth of CS is often accompanied by changes in its form and structure. These works in parallel with the high degree of direct user-buyer involvement in the innovation process and throughout the product’s development as well as in re-innovation circumstances. This phase requires considerable degree of management flexibility and interoperability among the parties. Users are heavily involved in complex product development due to multi-users price-quality combination of strategic market analysis and service forecasts along the competition dynamics changeovers. Under this assumption, it is possible to identify a verified intensification in the user-buyer reciprocal relation, that is a major and enhanced variable in CPS performance.
There is a crucial difference between most conventional mass-market commodity product models of production and those involving Complex Systems (CS). Moreover, CS are identified widely with the product and supply industry, and the terms complex product system and complex product refer only to the product.

Being at the same time a sustainable user and integrator of complex systems is a very striking characteristic of the space sector. In more general wording, satellites are composed of two basic parts: the platform and the payload, which follow respectively different reasoning to the extent of industrial and technical dynamics generating compound difficulties to the industrial subsystem integration. While in the platform production the “integrators” apply a patterned manufacturing logic in order to maximize scale production, the payload orbit modus operandi tends to assume an industrial strategy based on adaptability to the users’ requirements and specifications.

To a sufficient degree, in satellite manufacturing process there is a permanent asymmetric tension between standardization concepts and the variety of purposes created as a result of users’ requirements. The final technical quality of the satellite depends largely in pay-loads specification phase, to which the manufacture-user interaction is fundamental. Putting into other words, the learning by interacting process will determine the outcome quality of the final product.

With reference to technological requirements, satellite manufacturing, in its turn, is submitted to reliability and durability exigencies associated with intrinsic tension between two imperatives: the non-reparability of components in “real-use” conditions, and the integration of highly sensible and complex components.

The savoir-faire specificity in the satellite case stands within the complex system concept domain capability. It is strongly integrated in the stringency of “adopted” procedures in order to presume the space vehicles liability. It should not bypass, therefore, the proper selection of severe tests, components, equipment and subsystems, which refers back to the system as a whole (Bés, 1993).

Finally, the specificity also depends directly on project management, in order to assess the extent to which deadlines and costs are plausibly assumed and in accordance with desired objectives.

We sustain that project management should also play an obvious key-role in policy implementation supervision, given the imperative of establishing a properly functioning project framework.

Glancing at the European experience, its success in the development of a consistent scientific-technical and industrial capacity-building in the space arena is strictly associated with organizational and political/strategic aspects, all embracing the survivability concept. Thus, the existence of an innovation structure endowed of efficient group and activity coordination mechanisms along with operational flexibility bearing on partial project results also contributes to this success.

Two lessons seems important:

(1) European space autonomy has come about successfully due to cooperative fine-tuning between public and private institutions which has permitted a learning process feasibility based on interaction among the actors.

(2) Institutional and industrial dynamic coordination is essential to any program regarding complex innovation.

Hence, we must note with close attention that the challenge for public institutions (mainly scientific agencies) consists of the far-reaching ability to maintain adaptable capabilities, that is, the capacity to reformulate objectives and intervention methods over market changeovers.

**Brazilian Space Activities**

- **Brazilian Space Program:** Characteristics, Aims and Mechanisms

  It is possible to identify in Brazil a group of programs and projects in the space sector engaged with satellite development, which has emerged since the late 70s. These initiatives encompass the Brazilian Space Program, which started initially with the Brazilian Complete Space Mission – (MECB). Later it has enlarged its directives towards the China-Brazil Earth Resources Satellite Cooperation (CBERS) and to proposals like the ECO-8 low orbit communication system, together with a French-Brazilian agreement for a scientific satellite.

- **Brazilian Complete Space Mission (MECB)**

  The Brazilian Space Programs genesis goes back to a group of military government programs nurtured throughout the 70s. Regarding the space program, we identify a convergence of interests between the Air Force and scientific community sectors. It was expected then that there were sufficient industrial support and techno-scientific assessment capable of implementing a total space-orientated effort.

  Between 1976 and 1988 two directions were pointed out in the Brazilian space program’s orientation. First, the proposal of widening the scope of satellite applications emerged rather firmly, instead of scientific satellites only. Originally, it was established the production of four satellites: two data-collecting satellites (SCD1
and SCD2, scheduled for 1986) and two remote sensing satellites (SSR1 and SSR2\textsuperscript{6} scheduled for 1988). A third data collecting satellite SCD3 has been included in the MECB program.

Second, the national interests in developing space vehicles became evident – the so-called Satellite Launcher Vehicle (SLV) – contextually referable to ballistic missile technology development.\textsuperscript{7}

Although the main argument to justify the program had been the applied satellite development, the main directive was truly orientated towards the SLV, due to its strategic-military importance and priority.

The French-Brazilian cooperation, initiate in 1976, showed signs, in 1979, of asymmetrical unsustainability among the parties, Brazilian military orientation pledged goes the solid propellant rocket technology, differing from French liquid propellant’s technology, which would be available goes technology transfer.

Therefore the French-Brazilian cooperation was abandoned, in 1979. An exclusive space program named Missão Espacial Completa Brasileira (MECB) was put into motion under the supervision of a bureaucratic-military commission, the Comissão Brasileira de Atividades Espaciais (COBAE) or Brazilian Commission for Space Activities. COBAE was recently dismissed and replaced by the newly created Agência Espacial Brasileira (AEB) as from February 1994.

The Brazilian Space Program inherited since its birth an ambitious project framework, which sought technological assessment in the space environment. This “complete” space program embraces satellite segments and ground segments (satellite controls and launching facilities) (Nascimento, 1984).

MECB’s main scope embodies project activities, development, manufacturing and launching of Brazilian satellites using a national space vehicle (SLV)\textsuperscript{8}. With explicit military characteristics, the program aimed the acquisition of technological, industrial and managerial-operational assessment in the space industry, based exclusively on national efforts.

From an institutional point of view, the program had two distinctive tasks. The Instituto Nacional de Pesquisas Espaciais (INPE) became responsible for the project, development, manufacturing and ground control of the satellites (SCD1, SCD2, SSR1 and SSR2). INPE – as a civil and federal organism – has also been responsible for the ground systems, data collecting platforms for environmental data, system integration, test and orbit operation. The Centro Tecnológico da Aeronáutica (CTA) became responsible, through the Instituto de Atividades Espaciais (IEA), for

\textsuperscript{6} Remote sensing satellites capture images of the Earth, using on-board cameras, while data-collecting satellites receive and transmit environmental data.

\textsuperscript{7} The Brazilian SLV would be a by-product of the Sonda rocket family. It is quite interesting to note that most countries with missile technology first developed ballistic missiles for military purposes, and only after this technology was transferred to space/civil/ space vehicles. The Brazilian experience shows a twin development, since its solid propellant fuel technology aimed at developing ballistic missiles in parallel with space vehicles (SLV’s).

\textsuperscript{8} SLVs in this conception excludes manned space vehicles.
the overall launching activities, that is, the construction of the SLV and the operations of the Centro de Lançamento de Alcântara (Alcântara Launching Center). From MECB’s original conception, the SLV would be a by-product of the Sonda rocket family’s development, employing national solid propellant technology. The option of developing a solid propellant vehicle instead of a liquid or liquid-solid propellant vehicle engendered innumerable doubts and polemics regarding to MECB’s true objectives in the rocketry arena. It became quite clear to the international scientific community SLV’s pivotal role in Brazilian space activities. It is important to mention that there are practically no technological dissimilarities between space vehicles (SLV) and ballistic missiles. The main difference addresses to its “trajectory” and destiny. One carries military warheads, the other carries satellites.

The first phase of MECB’s development (1979 to 1984) experienced budget restrictions, problems with human resource formation and a lack of effective project engineering. For this reason, MECB entered a second phase, which meant institutional reorganization and project management changes within INPE in order to effectively put in motion activities related to SCD1’s conception and development. New forms of management were established with respect to MECB’s institutional structure framework execution.

Although INPE was able to achieve, with some delays, its objectives, the program, as a whole, was put into jeopardy due to SLV’s unsuccessful development. CTA was unable to build the SLV as intended, and it still faces numerous difficulties to consolidate the national SLV.

Successive delays altered the program’s schedule: the Brazilian SLV dismissed, the SCD1 was launched, in 1993, by an American SLV – named Pegasus – from the wing of a B-1 bomber, and SCD2 is completed and waiting for SLV bidding.

It is evident that MECB faced consecutive delays and difficulties along the 80’s. The most widely accepted interpretation about the problems involving MECB and the reasons for degrees of failure, privileges two orders of factors: the scarcity of financial resources (funds) and international pressure – most evidently attributed to the SLV’s development. Acknowledging the assured importance of these two factors, the doubt stands in the argumentation if these two factors were the only variables responsible for MECB’s problems. Therefore, we must assess and interact with the possibility of a formerly more complex sum of problems related to MECB’s development.

• Financial Difficulties

Probably the most notable aspect of MECB proved to be its erratic movement in financial resource allocation, varying with successive budget restriction. Figure 1
shows allocated resources and effectively released resources between 1980-1994 for MECB.

**Figure 1**

![Graph showing allocated resources and effectively released resources between 1980-1994 for MECB.](image)

**Source:** Source: INPE – Activities report 1991/1995.

In MECB’s implementation, scarce financial resources assumed two magnitudes: insufficiency of resources and erratic releases. The insufficiency of resources brought forward problems related to the establishment of unrealistic goals and project viability. Insufficient resources – lower than program’s necessities – became the major obstacle for project decision-making in what was truly potentially viable. From the operational aspect, delayed or erratic released resources symbolized losses in determined sequential project implementation, contributing to the nonobservance of program’s prime schedule.

Although financial adversities have affected MECB’s implementation, they should only be identified as a conditioning process, not as its causal element.

**Strategic Dilemma and the importance of management dimension**

As a consequence of the difficulties in implementing MECB’s original schedule, a politically determined “strategic dilemma” situation took over the program from 1985 to 1989.¹⁰ This dilemma expressed itself either by the option of a) maintaining the original goals or b) reviewing them in order to accomplish assessment within the original schedule programming along with technical assessment acquisition, even if that meant abandoning certain objectives.

The second proposal was rejected by the majority of INPE and CTA members. The original concept was maintained in its essence, thereby consolidating the idea of MECB’s effective viability. Nevertheless, it was imperative to find an answer to the strategic dilemma. How to successfully fulfill the aspired goals, considering schedule deadline and the adverse scenario for the program?

---

¹⁰ Period that comprehends the Nova República - New Republic - following the end of the military regimen (1964-1985).
The refusal to accept the second proposal — MECB’s revision — cannot be attributed entirely and exclusively to military interference extremely interested in the VLS’s long-lasting development. INPE and CTA’s behaviors should, in this matter, be explained — at least in part — by reasons strictly related to its own institutional consolidating strategies. For them, MECB’s existence worked as an open door opportunity to increase and create new areas of research and toward the construction of new facilities. In addition, commitment relations within MECB would grant political prestige and help the access to decision-making instances within the state apparatus.

To sum up, some of INPE and CTA’s option were affected by their respective institutional interests and agency logic and cannot be charged exclusively to the existence/presence of nationalist ideology and the role of military forces ruling MECB.

The adopted strategy concentrated technical and operational efforts in the first satellite (SCD1), while the other three engendered a “stand-by” preliminary execution situation. The priority was to “put the first Brazilian-made satellite in orbit”. Further satellites would be a natural consequence of SCD1’s success. With this philosophy in mind, implementation operations became technologically simplified. This strategy showed successful results. The SCD1 – first Brazilian-made satellite – finally reached its orbit in 1993. This experience demonstrates how certain obstacles can be overcome through flexible managerial decision-making implementations. This experience exhibits the importance of the managerial dimension, its relevancy in technological program implementation as to complex product development, and in its chances to achieve the desired goals.

Coordination Deficiencies

In the numerous levels of MECB’s machinery it is possible to identify problems of coordination, of diverse nature.

(a) Horizontal articulation deficiencies — INPE faced many difficulties regarding communication with superior decision-making organisms, in particular with COBAE. We must say that not always there was an interest of INPEs “fine-tuning” with COBAEs’ interests, since COBAE was only a regulatory bureaucratic-military-conceived agent, with a scant overview of the program’s operational problems. The lack of “tuning” between research groups and national bureaucratic-military ranks contributed to the non-success of efforts of reorientation procedure, reducing liberty degrees of most project executors.

Certainly, the optimist nationalist world-view of “Brazil, Great Power”, cherished by high military decision-making ranks — could have contributed to

11. High military branches, especially from the Air Force and Defense Office (Aeronáutica e Estado Maior das Forças Armadas - EMFA) promptly rejected the revision proposal.
12. The simplification option could have put into jeopardy the technological capacity-building goal. This strategic decision may have sacrificed de learning capability related to complex product and system development.
increase communication deficiencies. Indeed, the expectation created on behalf of MECB’s utmost success was also related to this nationalist ideology. Yet, to a certain extent, the problem proved to be more complex and sinuous in the long-run. To this point, the lack of managerial and technical assessment from superior ranks inside MECB is pointed out as a fundamental factor in the outcome of this subject.

The low capacity of monitoring MECB’S implementation engendered a paradoxical situation. The lack of evaluation capability over technical viability frequently helps, from one side, the approval of certain projects. It reinforces, in a sense, both the scientists and researchers position thanks to their knowledge and produces a relation of competence based upon their core competence. From another point of view, however, it hinders the comprehension of problems encountered along the innovation process.

MECB seemed to have experienced these problems. The innovation process’ dynamics confronted adaptability inflexibility, causing serious losses with reference to the satellite’s project execution.

The greater the difficulties encountered by a project, more imperative become the importance of communication links among the various decision-making levels within a given innovation structure. The absence of fine tuning among research staff and high military-bureaucratic branches intensified the level of difficulty in reorienting goals and changing procedures, again reducing the degree of freedom of project executors. This seems to be the case of VLS – the most problematic aspect of MECB.

(b) Vertical articulation deficiencies – A low level of cooperation mechanisms between research groups from INPE and CTA was established throughout MECB’s development. Innovation process, mainly learning-by-interacting, were almost never practiced since the beginning.

In a more formal plan, there were practically no mechanisms of coordination, either to solve common problems or to stimulate systematic exchanges of experiences. Undeniably, this institutional deficiency hindered the technological and institutional learning process itself, to the extent that the interaction between research groups never reached the desired levels. Due to MECB’s framework itself, and to the acknowledged importance of learning by interacting processes to the achievement of the innovation process, since the start cooperative teams should have been institutionalized. They should have met regularly to exchange major information regarding MECB’s technological interfaces, to discuss technical specifications, unexpected problems, possible solution and so on.

This conceptual institutional deficiency was only partially overcome, by means of informal links and the establishment of network created by the good relationship between research staff from INPE and CTA.

---

13. An example is the attitude towards eventual failures. Common in any venture of this nature, they should be understood as part of the learning process, but are frequently interpreted as synonym of failure.

14. See Lundvall (op. cit.).
International Pressure

The major argument for the SLV’s failure refers to the international pressures concerning ballistic missile technology restrictions. In 1987, military-space technological auto-sufficient nations’ decision to stop Brazilian access to materials and technology related to ballistic missiles became official.

INPE and the Private sector in MECB

The interface between INPE and the private sector flourished gradually, with challenges put forward as to the maintenance of satellites achievement without deviating technological assessment goals. Considering schedule delays, one alternative was to reach the desired goals through imported subsystems; another alternative pointed INPE as totally capable of successfully accomplishing subsystems manufacturing and integration.

The program mainstream strategy neglected extreme alternatives, aiming at stimulating national private participation – through cooperative contracts –, whenever those contracts wouldn’t put into jeopardy the programs main schedule. For this reason, national industries participation was to be achieved gradually, and a great number of components and equipment were imported.

The level of industrial participation – private participation – was particularly dependent upon project managers degree of uncertainties attributed to national industry’s effective capabilities. For the first satellite – SCD1 – managers decided not to attribute crucial responsibilities to the emerging Brazilian space industry, and, therefore, delegated only a small percentage of contracts to this sector. Nevertheless, industrial participation in SCD2 increased 15% in relation to SCD1. This enabled INPE to be fully capable of establishing an international joint-cooperation with China in 1988/89 (to build a ten-times bigger satellite than the previous SCD1 and SCD2).

INPE’s participation as institutional coordinator progressively promoted paths of integration with the industry. Given the private sector’s lack of experience and its relative fragility, MECB’s management sustained a “pro-active” behavior. This pro-active conduct is fundamental to this analysis because it specifically characterizes and demonstrates, accordingly, the institutional-industry interface and stylizes its cooperation specificity. INPE not only transferred component specifications but

15. Technological Missile Regimen Control.
16. See Karp (1986). It is important to mention that Brazil was a major missile exporter to many countries in war, mainly to Middle East nations (Iran-Iraq War) during the 80’s. The main question remains: How did the Brazilian private industry become technologically successful in military missile production? Was this particular industry favored from MECB’s public funds for the SLV’s development? This paper favors a positive answer to the latter.
17. Two examples of imported parts were the solar cells and batteries.
18. The SCD2 is ready for launch and undergoing final tests at the Laboratório de Integração e Testes (LIT) - Integration and Test Laboratory, waiting for the final launcher to be chosen from international bidding.
assigned qualified project engineering staff to work directly within the industries operational framework.\textsuperscript{19}

Adopted procedures had its modus operandi, based, therefore, not entirely on institutional deficiencies, but also upon INPE’s inexperience regarding technological institutional-industrial transferring and basic contract management.

Although SCD1 was manufactured almost entirely by INPE, MECB today has a great industrial involvement. All of SCD3 and SSR satellite series subsystems will be manufactured by national private industries.

China- Brazil Earth Resources Satellite Cooperation – CBERS

The Brazilian space program expanded thanks to a Chinese-Brazilian scientific-technological cooperation to manufacture and operate, initially, two remote sensing satellites – named China-Brazil Earth Resources Satellite (CEBERS1 and CBERS2). The cooperation was signed by both governments in July of 1988, opening a totally new frontier and global challenge for INPE’s researchers and program managers.

Of the financial point of view, in the development of the satellite and of the vehicle thrower, China fit to arch with: 70% of the satellite (cost and construction), being Brazil with the remaining 30%.

Objectives and Technical & Operational Aspects

CBERS’s prime goals are to develop remote sensing satellites, to manage, develop and monitor Chinese and Brazilian terrestrial resources in agriculture, forestry, geology, hydrography, cartography, meteorology and environment, among others.

The CBERS satellites are designed for global coverage and they include cameras to make optical observations and data collecting systems to gather environmental data. They are unique systems due to the use of on-board sensors, which combine features that are especially designed to solve the broad range of space and time scales involved in the monitoring of ecosystems. A unique characteristic of CBERS is its multi-sensor payload with different spatial resolutions and data collecting frequencies. It is composed of two modules. The payload module houses the optical and electronic systems used for Earth observation and for data collecting; the service module incorporates the equipment that ensures the power supply, control, telecommunications and all other functions referable to the satellite’s operation.

CBERS has a synchronous solar orbit at an altitude of 778 km, doing approximately 14 daily revolutions in a 98.504° inclination with a period of 100.26 min.

\textsuperscript{19} It is important though to mention that the majority of industry researchers and engineers were former INPE’s employee, contracted to exercise the very same activities, but with higher wages.
The central hub for all operations related to the CBERS satellite and its mission control is the Satellite Control Center. The TT&C stations provide the link between the satellite controllers and the satellite itself, besides being the stations used to collect the raw data of the CBERS environmental data collecting system, in S-band. Stations in other countries may be established to extend the CBERS coverage potential.

CBERS Development

Indeed, CBERS offered advantages as to MECB, considering main aspects like technology transfer, degree of technical-scientific complexity; private sector’s participation and international cooperation involvement.

From one point of view, this project would virtually allow and enhance the Brazilian space program’s long-term continuity, even if MECB’s prime goals, latu sensu, were not accomplished as originally planned. From another, considering the budgetary restraints along with the costs for the remaining satellites that would be manufactured under MECB’s original program, the cooperation with China would enable INPE to be fully independent from military bodies and continue its original character as a civil-federal organism with lower estimated costs vis-à-vis MECB’s costs for the SSR series.

Both parties foresaw advantages in the cooperation. From the Chinese side, cooperation with Brazil constituted a total breakthrough from its isolationism. China would be able to open a “door” to western patterns of techno-scientific coordination and management; from an economic stand-point it meant cost-reducing benefits, technology transfers and revenues from launching services, among others.

Brazil initiated its remote sensing operations in 1972 with the Cuiabá Satellite Control Station receiving Landsat’s data. As for today, INPE receives, processes and delivers images from LANDSAT, SPOT and ERS-1. It also receives data from environmental satellites – TIROS-NOAA, GOES, METEOSAT and SCD1. In this sense, Brazil has played a leading role in remote sensing applications. For this reason, INPE’s twenty-five-years remote sensing image operation experience is, in fact, an object of Chinese interest, so this experience should be transferred to them.

From the Brazilian viewpoint, this cooperation meant a whole new sphere of attributes, from technological-operational acknowledgments, techno-scientific

---

20. Between 1987-1991, political-institutional-military conflicts surfaced when the SCD1 was ready for launching and Brazilian VLS was far from being an operational reality. For this reason, it was necessary at the time to contract external launching services for the SCD1 - this was INPE’s view -, which encountered indirect opposition from military ranks within COBAE and CTA/IAE - which were responsible for the VLS’s manufacturing.

21. MECB’s original concept for satellites determined the manufacturing of two data collecting satellites (SCD1 and SCD2) and two remote sensing satellites (SSR1 and SSR2).

22. The satellite image data are received at the Cuiaba TT&C (Tracking, Telemetry and Control) Control Station, and sent to the Cachoeira Paulista Space Center to be processed.
learning procedures\textsuperscript{23} and auto-sufficiency in remote sensing services\textsuperscript{24} to governmental budgetary enlargement and cost-reduction benefits. For both parties, it meant the possibility to commercialize remote sensing services and to become definite players in the remote sensing ‘ballgame’, considering growth forecasts prognosis for these particular services.

Free of military intervention, CBERS’ is conceptually aligned to effort Brazilian technological and industrial assessment in the space scenario. MECB, though, is a program seeking technological assessment, but not CBERS. CBERS basically is an operational program and its continuity stands within commercial-operational competitiveness ideals. MECB’s remote sensing satellites (SSR series) are small and less complex, varying from 145 to 170 kg. The CBERS satellites are extremely complex (1,450 kg, 10 antennas and 3 cameras) engender extreme up-to-date technologies, aggregated to LANDSAT and SPOT simultaneously, which means a great step towards state of the art remote sensing operational-technological satellite capabilities.

In accordance with this model, the responsibilities for the stimulation and consolidation of national private companies remain within federal instances by means of INPE.

CBER’s operational management consists of an executive committee composed of Brazilian and Chinese researchers and project managers. The executive committee’s framework is divided into two groups, the Engineering Management Group (EMG) and the Engineering Technical Group (ETG) working in cooperation.

EMG responsibilities involve the program’s planning product’s safety, administrative coordination, financial management, contract observance, the establishment of interface mechanisms between and among industries engaged in subsystems manufacturing, crucial trade-off-schedule decision making and represent program’s interests within political, social and economical parties, among others.

ETG is ultimately responsible for both the functional systems: mission analysis, orbit conception, configuration’s design, assembly and interface with launcher; and the satellite as a whole: structure, altitude and orbit systems control, ground and orbit energy supply systems, thermal control, on-board data processing, circuits and total payload.

The development, conception and launching of the satellites are organized in five basic phases, under conduction and supervision of management’s (ETG and EMG) subordinated groups.

Table 4
CBERS Main Schedule Plan

\textsuperscript{23} Mainly those learning procedures - learning-by-doing, learning-by-using, learning-by-interacting (learning-by-producing and learning-by-operating) - respectively described by Arrow (1962), Rosenberg (1982) and Lundvall (1985).

\textsuperscript{24} Considering Brazil vast geographical territory, the use and operation of remote sensing services is evidently an outmost necessity. INPE has been using for more than 7 years, American and European remote sensing services. Therefore, the auto-sufficiency - if achieved - in remote sensing services would promptly cease those services costs.
Phase Goals

<table>
<thead>
<tr>
<th>Phase</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase A Concept phase</td>
<td>• Mission specification phase, among others.</td>
</tr>
<tr>
<td>Phase B Definition</td>
<td>• Definition of satellite’s system scheme and systems technical</td>
</tr>
<tr>
<td>phase</td>
<td>specifications.</td>
</tr>
<tr>
<td></td>
<td>• Definition of subsystem’s preliminary scheme and subsystem’s</td>
</tr>
<tr>
<td></td>
<td>technical specifications.</td>
</tr>
<tr>
<td>Phase C Design phase</td>
<td>• Determine system’s/subsystem’s scheme and technical specifications.</td>
</tr>
<tr>
<td></td>
<td>• Determine equipment’s preliminary scheme design.</td>
</tr>
<tr>
<td></td>
<td>• Develop subsystems equipment.</td>
</tr>
<tr>
<td></td>
<td>• Integrate and test of Structure Models (SM), Thermal Model (TM) and</td>
</tr>
<tr>
<td></td>
<td>electric-electronic Model (EM).</td>
</tr>
<tr>
<td>Phase D Construction</td>
<td>• Have ready equipment schemes and its technical specifications.</td>
</tr>
<tr>
<td>phase</td>
<td>• Construction/manufacturing of the Flight Model (FM) subsystem’s</td>
</tr>
<tr>
<td></td>
<td>equipment.</td>
</tr>
<tr>
<td></td>
<td>• Integrate, test and launch the Flight Model.</td>
</tr>
<tr>
<td>Phase E Flight Model</td>
<td>• Mission’s management through normal operation, “in” and “post”-orbit</td>
</tr>
<tr>
<td>(Module) phase</td>
<td>injection.</td>
</tr>
<tr>
<td></td>
<td>• In-orbit tests.</td>
</tr>
</tbody>
</table>

Source: INPE/CBERS.

In order to promote a better understanding and effective identification of the evolution of the objectives, activities, changeovers and problems emerged in CBERS’s implementation process, we have divided its history into four different temporal periods.

Basically the CBERS Program can be divided into three distinctive periods: Organizational Period (1988-1990); Restriction Period (1990-1992) and Resurgence Period (1992-1995).

- Organizational Period (1988-1990)

In this period, mutual working staffs were created among and between both parties to formulate – give form to – the cooperative agreement, and to establish a development plan for both CBERS1 and CBERS2. With the agreement put into motion between the two countries, CBERS’s managerial-administrative structure was created and the development plan was thereafter executed. Afterwards, phase A was initialized.

Nevertheless, it is imperative to recognize a group of social-cultural obstacles – other than those purely technological – which brought forward numerous communication and operational difficulties, that had to be overcome in the short run. One of them was the language. Not many of the Chinese managers spoke English – most of them spoke Russian\(^{25}\) – due to their political-economical isolation from western economies.

Another main difficulty embraced a techno-cultural aspect of managing, operating and specifying systems, subsystems and equipment. Chinese technical

\(^{25}\) The Chinese aerospace development - that was born in the 60’s - was originally conceived and consolidated through a Soviet-Chinese cooperation in a cold war environment. For this reason, the majority of Chinese space managers were able to speak Russian quite fluently.
procedures for conception, specification, design and development of engineering attributes were largely different from those which Brazilian managers were familiar with. Chinese procedures are characterized by a simplified-more-robust conception of engineering and design that permitted an effectiveness of success. It was necessary, therefore, to determine, at first simultaneously common integrated procedure methods.

In this field – procedure methods – INPE had reached a suitable level of success, being able to guide and determine cooperatively the paths to patterns of engineering design, concept and scheming of systems, subsystems and coordinating variables.

By the beginning of 1990, CBERS program was no longer considered – by federal government – a national priority. Budgetary funds were drastically reduced and became scarce for most national Research and Development (R&D) institutions. Resulting from delayed funds came the impossibility to qualify and contract national (Brazilian) companies to supply CBERS’s development as to equipment, systems, subsystems and components, which led to schedule delays.

- Restriction Period (1990-1992)

Budgetary restrictions did not only refrain the project, they incapacitated INPE to meet its attributed responsibilities concerning project execution and development. Furthermore, it also implicated on the non-observance of contractual clauses. These brought forward negative consequences to CBERS as a whole, along with discredit among chines managers as to the project’s continuity. Figure 2 clearly highlights the financial situation between 1989 and 1992.

![Figure 2: CBERS Financial schedule](image)

Source: INPE

---

26. This scientific-technological budgetary restriction policy was enacted by President Fernando Collor who was elected in 1989 but resigned trying to avoid his impeachment conducted and voted by Brazilian Parliament.
Within this specific period, two major achievements were accomplished from the Brazilian scope. The first one was to enhance explicit technology transfer. The second proposal was that both satellites (CBERS1 and 2) would be integrated and tested in the Integration and Test Laboratory (LIT) at INPE along with Brazilian participation in satellite’s control and track activities. All of these proposals have been approved mutually in a 1995 contract agreement, together with the precise conditions in which they are to be implemented.


CBER’s pending affairs started to be solved in 1993, so the eminent threat of program’s interruption ceased. In March of 1993, the CBERS regained its priority importance due to management-diplomatic efforts from both parties (executive committees). The previous schedule was postponed, and CBERS1 was planned to be launched from a Chinese Long March rocket in September of 1997, and CBERS2 is scheduled for 1999 – which means a three year overall delay in the program.

CBERS’s financial outflows were restored throughout 1993, with special governmental financing derived from federal privatization policy. These financial resources were intensively employed on new company’s contracts, together with the maintenance of former undergoing contracts.

CBERS1 is at this moment (1999) at phase E, and its structural model has gone through dynamic tests at INPE and shipped to China for coupled tests with Long March vehicle, undergoing preparations to start integration and test of the flight module in China.

CBERS’s original cost structure estimated a US$ 150 million total average expenditure. The Brazilian share summed-up US$ 45 million of the absolute gross, 30% of the total amount. Out of these, US$ 30 million were funneled to manufacturing and development activities, and US$ 15 million designated to cover launching services. The majority of these resources are aimed at developing industrial capabilities among the private sector.

Successful, well-matured project expansion negotiations brought about increasing cost figures. CBERS gained new attributes: first, CBERS2 integration and test in Brazil (estimated US$ 10 million); second, cooperative as to track and control both CBERS satellites together with ground segment competencies (US$ 15 million); third, specific satellite structure responsibilities handed over to China (US$ 8 million); fourth, assembly into both satellites of Wide Field Imager (WFI) Brazilian-made cameras. Therefore, these extra expenses added an additional US$ 39 million to the programs total cost.

---

27. These endowed resources - cross-subsidies - were released under an agreement between the Science and Technology Ministry (MCT), Banco do Brasil (Brazilian official federal bank) and the Project and Research Financing Agency (FINEP).

28. An offset-financial compensation agreement was established between INPE, FINEP and China Great Wall Industry (satellite launching company) to assure 100% commercial compensation. China would buy the equivalent of US$ 15 million of Brazilian products, giving special preference to aerospace products.
• Last Period (1997-1999)

This period is characterized by the development of the activities of integration of the satellite and of final tests. The contribution of resources was around of R$ 15 million, considered appropriate to the need of the second project some analysts (Furtado et al., 1998).

Along the project CBERS (1988-1999) the Brazilian government spent R$ 160 million, of the which R$ 70 million, or about 44% of the total resources, pagos or reviewed the inputs to national suppliers.

CBERS- Industry interface

The industrial involvement within MECB (today) and CBERS has been deliberately undertaken in a gradual, limited extent, conditioned by available budgetary endowments, by industries’ managerial qualifications and by technological assessment. All of the Brazilian responsible subsystems are to be developed and manufactured, if possible, by national private industries in accordance with INPE’s coordination.

The type of industrial participation has been dependent upon the companies technological and managerial assessments: in some cases industries participate only in the manufacturing process, leaving project and engineering specifications to INPE; others are responsible for both project, manufacturing and integration of subsystems. Nevertheless, the INPE/industry interface confronted management and technological problems strictly related to relative fragility of emerging industries.

First, the non-observance of delivery of on-board equipment and subsystems manufactured by national firms contributed to schedule delays, elevating management costs and creating a “control posture” conducted by INPE’s managers to avoid future cumulative setback. Second, the situation of industries financial insolvency during the president Collor’s regimen was aggravated by scarce governmental funds.

The main elaborate that have participated in the CBERS and MECB projects it plows: ESCA, Elebra, Aerodynamics, Digicon, TECNASA, ADE, INB, COPESP, D.F. Conele, EMBRAER, MECTRON and Composite.

During the eighties, the strategy adopted by INPE it was internalizar most of the linked activities to the production of satellites. The complexity involved in the production of satellites and the lack of experience of the private section they went the main reasons to the adoption that strategy. In the project CBERS, INPE tried to adopt a closer strategy of that used by the European and American programs.

Like this, the Institute has been looking for to review a growing number of tasks and responsibilities for the national supplying companies. Actually, INPE tries to establish a new organization in the implementação of CBERS, redefine the functions between the public section and private osetor. In the new drawing INPE would be entrusted from the linked activities to the technical specifications and the
one of integration of the satellites, while the production, assembly and the tests
would be of responsibilities of the national industries.

Following the new orientation INPE has been hiring complete subsistemas
close to the national companies. There are two types of suppliers in the program
CBERS. The calls suppliers of 1st line that plows companies and consortia negotiated
to it executes the specific project. The other category of companies is the suppliers of
2nd line, subcontracted to develop parts of the projects executed by the of 1st line.

The suppliers of first line are directly the contracted companies for INPE, in
CBERS they form a group of 5 companies: AEROELETRÔNICA, AKROS,
DIGICOM, ELEBRA, ESCA, TECNASA/TECTELCOM. Three of them associated
(AKROS, DIGICON and ESCA) and they formed the consortium ADE,
AÉROELETRÔNICA, AKROS and DIGICON also acted the suppliers of second
line.

The suppliers of 2nd line specific are nineteen companies (to see picture), and
three of them, R - CUBED, FOR AND HOLLOW, they are foreign. The largest
participations are of Neuron with 8 contracts and of Fibraforte with 5 contracts.

<table>
<thead>
<tr>
<th>COMPANIES NEGOTIATED DIRECTLY BY THE INPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEROELETRÔNICA, ADE CONSÓRCIO (AKROS, DIGICON, ESCA), DIGICON, ELEBRA SISTEMAS DE DEFESA LTDA., ESCA, FUNCATE, TECNASA ELETRÔNICA PROFISSIONAL LTDA./TECTELCON,</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPANIES ONLY SUBCONTRACTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANVIAL CASE, CCG, CDT/ETEP, COMPIS, CONQUALIT, EMBRAER, FIBRAFORTE, GALVANUM G. RUSSEF, INDUSMEC, LEG, MICROELETRÔNICA, MICROELETRÔNICA INDUPAR, MECTRON, MICROMAX, NEURON ELETRÔNICA, OCA, PRA, R-CUBED, TAUNNUS.</td>
</tr>
</tbody>
</table>

Source: Furtado et al. (1998).

INPE was responsible for the organization and coordination of the conception
phases, production and the control of the reliability of the subsistemas of collection
of data, imageador of wide field (useful load or of observation and it collects of
data), supply of energy, service telecommunications, equipments of electric support
(necessary service to the operation of the satellite) and the structure of the satellites.
He also collaborated in the production of equipments embarked as board supervision,
of altitude-orbital control and in the amplifier of potency of the transmission of data
of the scanner infravermelho.desenvolvidos for China. Besides, it assumed the
integration and the test of the relative subsistemas to the national satellite.

Concluding Remarks: lessons of the Brazilian experience

It is crucial to realize that the projects in the Brazilian space industry have
dealt continually with chronic political, financial and institutional problems. Overall,
both MECB and CBERS have suffered from lack of financial resource, which has
been responsible for group discontinuities, schedule delays and fallbacks, and even
endangering the project’s own continuity.
Regarding the space program’s structure and mechanisms, the Brazilian experience reveals distinguished problems. First, we should note the lack of articulation mechanisms inter and intra political decision-making instances and faculties and research groups. This lack of coordination was associated with COBAE’s technical preparation shortage to act as the executor of project supervision and monitoring. Indeed, it also failed to handle, redirect and redefine core goals related to the concrete difficulties faced throughout the implementation process.

Second, the absence of a stern direction resulted in fragmentation along the conduction of space projects. This situation favored the adoption of concurrent procedures/strategies within the same innovation structure, and therefore, influenced negatively the project’s overall development.

In situations where does not exist clear attributes of responsibility between the parties involved, the competence to overcome problems in the program’s interface is largely reduced, avoiding product damage and the risks of institutional conflicts and disruptions. In these cases, the risk of situations where concurrent strategies and uncompromising disputes prevail over cooperative strategies and with high synergetic potentials, should be dealt promptly.

A third problematic aspect was the unsatisfactory response given by the major enterprises directly involved with these projects. The overall difficulties to ensure the fulfillment of schedule deadlines and, in a more general wording, to successfully meet with demand specifications, exemplify – to a sufficient degree – the relative fragility of the Brazilian private industrial space sector. Strictly speaking, this fragility cannot be entirely and exclusively explained by scarce financial resource and by the unstable macroeconomic environment prevailing during the 70’s and 80’s in the Brazilian economy. Since there is a great deal of heterogeneity in the industrial sector, the learning process itself is strongly dependent upon the nature of interaction between the agents. This has brought difficulties towards the consolidation of technological trajectories between enterprises, capable of allowing long-lasting and consistent learning process.

In terms of the architecture of the development projects in the satellite sector, on one side, there is a need to adopt a market-oriented conception, incorporating economic and industrial aspects in the center of project strategies; on another, the need to proper delimit the tasks of the various agents involved. In other words, it is imperative to realize that the introduction of a market-oriented guidance would undoubtedly lead to cost-cutting, dynamism in technological innovation, improved services, provision, learning capabilities etc.

At the same time, there has been significant advances in the institutional, technological and in the negotiation capacity regarding cooperation agreements. Despite all the difficulties mentioned, MECB and CBERS’s experiences have revealed a significant institutional learning regarding complex product systems management.

Concerning this subject, this paper has led to another research centered on the interface between Space Agencies, Federal Government and Space Industries, which delineates precisely the Brazilian private sector’s involvement with space activities, which will be available in 1997.
Two major aspects deserve special attention. From one side, INPE, although caught in adverse conditions, was capable of effectively developing satellites SCD-1 and SCD-2. From another side, project’s management negotiation capability has successfully advanced towards high-levels of overall performance, which explains the successful results obtained in the CBERS cooperation agreement extension. Considering the central role of scientific and technological cooperation in the space arena, this learning is sure to allow – at an optimal level – the negotiation of future agreements in more favorable terms.

Bibliography

GAZETA MERCANTIL, vários números.


INPE (s.d.) *Relatório Interno sobre o Programa CBERS*. São José dos Campos, mimeo.

INPE/CBERS (s.d.) *Documento Interno*. São José dos Campos. Comitê Conjunto do Projeto CBERS (JPC), mimeo.


ISTO É, vários números.


Aalborg University Press.


O ESTADO DE SÃO PAULO, vários números.


