FORTY YEARS OF COOPERATION BETWEEN DLR/MORABA AND CTA/IAE

Ariovaldo Felix Palmerio(1), **Mauro Melo Dolinsky**(2), **Peter Turner**(3)

(1) General-Command of Aerospace Technology/Institute of Aeronautics and Space (CTA/IAE), Praça Mal. Eduardo Gomes, 50, Vila das Acácias, 12228-907 São José dos Campos, SP, Brazil, palmerio@iae.cta.br
(2) General-Command of Aerospace Technology (CTA),Avenida Brigadeiro Faria Lima, 1941, Parque Martim Cererê, 12227-000 São José dos Campos, SP, Brazil, dpj2@cta.br
(3) Deutsches Zentrum für Luft- und Raumfahrt e.V., (DLR/MORABA), Postfach 1116, D-82234 Wessling, Germany, peter.turner@dlr.de

ABSTRACT

During forty years of cooperation, DLR/MORABA and CTA/IAE evolved into a level of intimacy, in the operation of sounding rockets and their payloads, that a virtuous circle is formed in the sense that new opportunities are constantly keeping the two organizations in the same track.

The purpose of this article is to comment on the major milestones of the past and future of this cooperation, by also recognizing the effort of those, who, through the years, had the vision to keep up with the good work.

1. INTRODUCTION

On June 09, 1969, the Brazilian and German governments signed an umbrella agreement to cooperate in scientific research and technology development. On November 19, 1971, then the Aerospace Technical Center (CTA), and now General-Command of Aerospace Technology, and then the German Institute of Research and Air and Space Navigation Testing (DFVLR), now the German Aerospace Center (DLR) signed a Special Agreement in Bonn. At that time, Brazil was in its first steps into the sounding rocket development and Germany needed access to space for its scientific atmospheric physics research. The Institute of Space Activities (IAE) was the executive arm of CTA for the purpose of the cooperation Up front, this may have seemed an odd association, but time would show that its fruits would surpass the most optimistic prediction.

In 2007, IAE signed a new cooperation agreement with DLR, being the former now an independent organization, just as a formality, since the joint work proceeded steadily.

In the following sections, the most significant achievements of the cooperation are reported in three time frames: the past; the contemporary times and the near future. The reader will have the opportunity to understand that there is good reason to celebrate these four decades, during the 19th ESA PAC – Symposium, in these unique Bavarian grounds, in the company of such a small community, but fiercely hardworking toward high achievements.

2. THE PAST

2.1 Sounding rocket payloads

The first mission performed by MORABA in the Barreira do Inferno launch range (Natal) was in 1969, to launch a Javelin, a four stage vehicle composed of the motors: Honest John, at the first stage, two Nikes in the second and third stages and an Altair X248 at the fourth stage. This was a training mission for MORABA under NASA tutoring.

In January 26 and 30, 1970, two more Javelins flew from Natal. The experiments were made by the Max-Planck Institute, for Extraterrestrial Physics, to measure electron densities at high altitudes.
In October 1970, six Nike-Apache launched the Ionosphere Plasma Experiments for the University of Braunschweig.

Two Black Brant V sounding rocket launches occurred in March and April, 1972 in order to perform measurements and test the Aeros satellite instruments, prior to their injection into orbit.
For the same purpose, three Black Brant V flew in February 1973.

In October 1979, the rocket payload ASTRO-HEL was lofted by a Skylark 12. The experiment consisted of one helium resonance-cell extreme ultraviolet photometer instrumentation for the high resolution spectral analysis of He-I 58.4 nm and He-II 30.4 nm radiation. In addition two Nike Orion vehicles were launched to test new instrumentation. There were also two scientific instruments on board from the University of Graz.

The Interzodiak project obtained solar wind flux in a region where existing technologies did not offer any access, between the solar corona and the perihelion of Helios spacecraft at .29 AU. Means were developed for constant monitoring of the solar particle output in this region by using the planned instrumentation, after successful rocket flights, on Earth-orbiting platforms; providing dust density distribution measurements entirely independent of optical zodiacal light observations, and also giving dynamical parameters of the orbiting dust grains. The rocket used was the Skylark 12, in March 1985.

In February, prior to the main launch, MORABA tested new Orion hardware using carbon fiber for the fins, for the parallel payload and the nose cone.

The separation and ignition of the 3rd stage had a problem and thus the anticipated flight trajectory was not obtained. It was decided to repeat this experiment with a second flight. The Interzodiak 2 flew in September 1988, also with the Skylark.
A sequence of flights from Natal was performed, as listed in Table 1

Table1.Early European missions in Natal

Rocket/Experiment	Date
DVL-OP	January 1970
Braunchweig University	October 1970
Aeros	Feb. – March 1972
Aeros	February 1973
Astro HEL, NO test	October 1979
Orion carbon fiber fins	February 1985
Interzodiak 1	March 1985
Interzodiak 2	September 1988

Proc. '19th ESA Symposium on European Rocket and Balloon Programmes and Related Research, Bad Reichenhall, Germany, 7–11 June 2009 (ESA SP-671, September 2009)

The reader can find additional and colorful information on these campaigns in [1]
When the cooperation started, Brazil was developing the SONDA II sounding rocket, the first development entirely done at IAE, consisting of a monostage with a fairly small payload compartment.
In 1977, flew the first SONDA III. This is a two stage rocket, in which the second stage motor is the S20, developed for the SONDA II, and the first stage booster is the S30 motor. The Figure 2 illustrates its profile and Table 2 informs its main data.

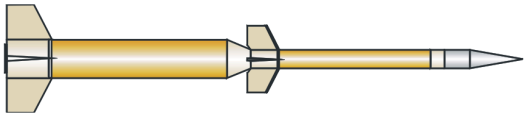

Figure 2. SONDA III
Table 2.SONDA III

First stage motor	S30
External diameter (mm)	557
Action time (s)	29
Thrust in vacuum (kN)	95
Second stage motor	S20
External diameter (mm)	300
Action time (s)	22
Thrust in vacuum (kN)	32
Vehicle with 60 kg payload	
Take off mass (kg)	1615
Total length (mm)	6717
Apogee (km)	700
Number of flights	31

Two flights of the SIII, in September 1982, carried European payloads (Coulored Bubbles Experiment, from the Max Planck Institute). In the same Cruzeiro do Sul Campaign, performed at Barreira do Inferno range (Natal), another two SONDA III and two Nike-Brant VC were launched as part of the BIME experiment (Brazilian Ionospheric Modification Experiment) involving several scientific organizations, under the leadership of an American governmental institution, the Air Force Geophysics Laboratory (AFGL). More than a hundred Brazilian, American and German scientists and technicians participated in this campaign.
The importance of this vehicle for the cooperation with MORABA is the extensive use of its first stage, including the S30 motor, fins and tail can, in rockets that carried European payloads in Brazil, Norway and Sweden.

2.2 Other activities

Brazilian and German engineers and scientists had the opportunity to spend time in Germany and in Brazil, in order to cooperate in the areas of:

- sounding rocket trajectory modeling;
- payload recovery systems;
- satellite launcher trajectory modeling;
- design and fabrication of composite structures;
- solid propulsion;
- propellants and related materials;
- dynamics of booster separation;
- telemetry and check-out system;
- control system (Sonda IV)

Five workshops were held in Brazil, from 1973 to 1986, when German DLR and ICT-Berghausen and Brazilian IAE specialists exchanged their experience in Solid Propulsion, Chemistry of Propellants and Explosives, Weight Balance for Wind Tunnels, Electronics and other subjects.

2.3 Discontinuity

Around 1987, due to restrictions imposed by the Missile Threat Control Regime (MTCR), there was a discontinuity in the space cooperation between DLR and IAE. Sensitive areas, like rockets and their items, were not allowed in the cooperation. However, the partnership with DLR stayed in force in less sensitive areas. In 1995, with the adhesion of Brazil to MTCR, the cooperation in the area of rockets was reestablished.

3. THE CONTEMPORARY TIMES

3.1 VS-30 and VS-30 Imp. Orion

In the year 1996, DLR-MORABA consulted IAE about the performance and other characteristics of the SONDA III. The idea was to use the rocket in the European microgravity program and others experiments. After a joint analysis, two new sounding rockets were in the market: the VS-30 and the VS-30/Orion.

The VS-30 is a monostage vehicle essentially composed of the first stage of the SONDA III and a payload. The combination with the motor Improved Orion, in the second stage, the VS-30/Orion, also showed the desired performance for a class of payloads. The following missions were accomplished by these rockets:

Table 5.VS-30 and VS-30/Imp Orion missions

Vehicle/Payload	Range	Date
VS-30/Dummy (a)	Alcântara	April 1997
VS-30/RONALD-1	Andoya	October 1997
VS-30/RONALD-2	Andoya	January 1998
VS-30 (b)	Alcântara	March 1999
VS-30/Space Mail	Alcântara	February 2000
VS-30/Orion (c)	Alcântara	August 2000
VS-30/Orion (d)	Alcântara	November 2002
VS-30/Orion/SHEFEX 1	Andoya	Oct – Nov 2005
VS-30/Orion/HotPay2	Andoya	January 2008
VS-30/Orion/ICI-2	SvalRak	Nov - Dec 2008

(a) Operation Santana: test flight of the VS-30. This launch was meant to qualify the new vehicle VS-30 proposed by MORABA. The rather heavy dummy payload (~400kg) should reach an apogee of 120km, in preparation for the launches of the Ronald project, to be lofted from Andoya. On board there was also an experiment from the University of Stuttgart, measuring oxygen concentration in the atmospheric layers.
(b) Operation São Marcos: the payload carried Brazilian experiments and a flight parameter measurement module built by MORABA.
(c) Operation Baronesa: this was the first flight of this bi-stage rocket. In this test flight, the dummy payload was equipped with a flight parameter measurement module built by MORABA.
(d) Operation Pirapema: the payload carried Brazilian experiments and a flight parameter measurement module built by MORABA.

3.2 VSB-30

In the year 2000, DLR invited IAE and the Brazilian Space Agency (AEB) for a meeting in Oberpfaffenhofen to propose two developments: the VSB-30 and the VS-43.

The VS-43 was meant to fly the MAXUS payloads, in substitution for the Castor IVB motors. Some months later, Astrium decided to keep the configuration, and the design of the VS-43 stopped.
The VSB-30 was meant to substitute the Skylark 7 in the TEXUS program, and it came out to fulfill this role. The design of the rocket was shared by IAE and MORABA [2, 3] from the beginning. The qualification flight occurred in October 2005, in Alcantara.
The profile of the VSB-30 is seen in Fig. 3 and its main data are given in Table 3. The second stage motors is the S30, as described in Table 2.

Table 3.VSB-30

First stage motor	S31
External diameter (mm)	557
Action time (s)	14
Thrust in vacuum (boost phase) (kN)	255
Vehicle with 400 kg payload	
Take off mass (kg)	2500
Total length (mm)	12583
Apogee (km)	250
Number of flights	7

Up to now, the missions accomplished are listed in Table 4.

Table 4.VSB-30 missions

Payload	Range	Date
Dummy	Alcântara	October 2004
TEXUS 42	Kiruna	December 2005
TEXUS 43	Kiruna	April – May 2006
CUMÃ II	Alcântara	Jun – Jul 2007
TEXUS 44	Kiruna	Jan – Feb 2008
TEXUS 45	Kiruna	Jan – Feb 2008
MASER 11	Kiruna	April – May 2008

3.3 Other Joint Works

Training rocket

The Alcântara and Barreira do Inferno (Natal) ranges decided to have rocket launches in order to keep the ground systems and the personnel trained. MORABA offered to do two demonstration flights with Improved Orion (ImpO) as training rocket equipped with a payload carrying sensors and telemetry. In 2008, eleven ImpO motors were delivered to Natal. One of these motors was bench tested at IAE to get thrust information for flight calculation. The first launch took place in October 2008, in Natal, and the second in Mary 2009 in Alcântara. The Brazilian ranges intend to fly, each year, two of these rockets from each range.

SHEFEX II

The SHEFEX II mission requires a longer hypersonic flight, if compared to the SHEFEX. MORABA chose two Brazilian motors, the S40 and the S44, to boost the payload. The S44 was developed for the fourth stage of the Brazilian Satellite Launcher (VLS-1) and is fully operational and flight proven, after two flights as a second stage motor of the VS-40 sounding rocket. As of now, the flight motor is ready for flight, and awaits the shipment to the launch range.
The S40 has a longer story. It was first developed for the SONDA IV sounding rocket that successfully flew four times. It also worked in the first stage of the VS-40 sounding rocket. It was modified to fly in the third stage of VLS-1, by modifying the solid propellant internal geometry, the motor case interfaces, the closure of the aft dome and the nozzle. At a certain moment, it was decided to have just one motor case for the sounding rockets and VLS-1. The version in use in VLS-1 is now standard and all design modifications for the sounding rocket use are complete and are under production.
Due to the time required to produce the motor cases in 300M steel for VLS-1 and the low stock available, it was decided to build them in Maraging steel, for the application on sounding rockets. MORABA bought the steel sheets in Austria, and will send them to Brazil in the near future. Four motor cases will be built for the fabrication process and structural qualifications. Meanwhile, a ground firing test of the S40, using a 300M steel motor case designated for ground tests, will be performed, qualifying the changes applied. If a qualified motor case in Maraging steel is ready in time, it will be filled and delivered for flight. If not, a 300M motor case will be filled and delivered. The flight motor is expected to be ready by the end of 2010. The mission is planned for 2010, in Woomera, Australia. The concept of the vehicle is led by MORABA. IAE will deliver the motors, the interstage with separation system. and the second stage destruct system.

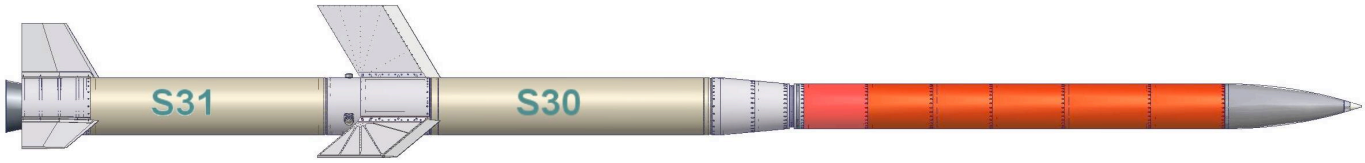

Figure 3. VSB-30

MICROG

All microgravity missions of the VSB-30 used the service module and recovery system developed and produced by MORABA. IAE asked MORABA permission to build those items in Brazil, but using a Brazilian company to execute the task, under a grant of FINEP, a federal government fostering agency of the Brazilian industry. A first meeting involving IAE, that company and MORABA occurred in July, 2008 in Oberpfaffenhofen.

Falcon

MORABA and IAE worked together in many launch operations in Brazil and in Scandinavia. The flight safety and trajectography specialists of both organizations decided to put together their experiences and build a software that would enhance their operational capabilities during the launch campaigns. The Falcon computer program is the tool developed by the two teams during three years of work. It features a user friendly interface to perform trajectory analysis under wind conditions close to the liftoff.

4. THE FUTURE

In the rocket activity, the major plans are:

TEXUS and MASER

The business plan for the VSB-30 is to fly TEXUS46 and 47 at the end of 2009; TEXUS 48 and 49 at the end of 2010; and MASER 12 in 2010. The improvements on the VSB-30 are constant in order to increase the operational safety and also in order to converge to minimal changes when the launch operation is in Alcantara. As significant examples of new developments, the first one consists of the igniter initiators with 1A/1W/5min nonfire characteristics that will be installed starting this year. The second example is the manual Safe @ Arm devices that are already present in the ignition system of both S30 and S31 motors. The development of remote controlled S&A devices is already under way.

HiFire

MORABA won the bid proposed by the Australian authorities, to provide the launch vehicle and launch support for the indigenous hypersonic experiment known as HiFire. MORABA proposed the delivery of VSB-30 and VS-30/Orion vehicles. The program will require two VSB-30 and two VS-30/Orion for launches in 2010.

In a more distant scenario, two possibilities for joint work may take shape, as follows.

SHEFEX III

At the beginning of this year, MORABA presented to IAE the basic requirements for this mission on what concerns the rocket:

- the payload must be delivered at 6.5 km/s;
- the delivery altitude is 100 km; and
- the payload mass is in the range of 300-500 kg.

A feasibility study started with the priority of determining the combination of available Brazilian solid rocket motors that could fulfill the mission energy wise.
The study is expected to be closed in 2009, when a number of hard points is assessed like:

- availability of motors;
- required development effort on motors;
- availability of thrust vector actuators (TVA);
- availability of guidance and control hardware;
- controllability;
- trajectory profile;
- required development of auxiliary systems.

The preliminary launch is foreseen for 2015.

VS-43

MORABA and IAE may decide to work on a test flight of the VS-43, such that the Brazilian side would provide the S43 motor equipped with thrust vector control actuators and the European side would provide an equipped dummy payload that would control the motor, the microgravity environment of the payload and the recovery system. Although the performance of this vehicle is slightly lower than the present MAXUS configuration, it promises to be a suitable carrier for the extension of that European program.
This topic is presently under negotiation.

5. CONCLUSION AND REMARKS

The forty years of ever growing cooperation between MORABA and IAE leave no doubt about what the true cooperative spirit means. The two so different organizations were able to find common objectives and pursue them together by giving and taking, and by mutual understanding of their strong and weak sides.
The reward is the achievement of a great number of successes and the learning experience of some losses. For those who experienced it, their lives were enriched by deep friendship and professional accomplishment.
It is the hope of the authors that the cooperation will be always renewed by jointly taking new challenges and by keeping the bridge between two countries, two technical bodies in the same spirit that sustained the past years.

6. ACKNOWLEDGEMENTS

Our deepest appreciation goes to our sponsoring organizations: the Aeronautics Command (COMAER), the Brazilian Space Agency (AEB) and the foundation FUNCATE for their financial support; and Deutches Forchung für Luft-und Raumfahrt (DLR) and the European Space Agency (ESA) for the cooperative work.

7. REFERENCES

1. Turner, P. E., Einmal ins All und zurück, Köln, 2007.
2. Palmerio, A. F., et. al., The Development of the VSB-30 Sounding Rocket Vehicle, *Proceedings of the 16th ESA Symposium on European Rocket and Balloon Programmes and Related Research*, St. Gallen, Switzerland, June 2003.
3. Palmerio, A. F., et. al., Results from the First Flight of the VSB-30 Sounding Rocket Vehicle, *Proceedings of the 17th ESA Symposium on European Rocket and Balloon Programmes and Related Research*, Sandefjord, Norway, June 2005.