

MISSION ANALYSIS AND PERFORMANCE IMPROVEMENT OF THE BRAZILIAN LAUNCH VEHICLE VLS ALFA

Paulo Moraes Jr.

Adilson de Jesus Teixeira, Avandelino Santana Jr., Danton José Fortes Villas Bôas,

Domingos Salvio Carrijo, Mauro Kochi Yamamoto

**CTA, Institute of Aeronautics and Space, Space Directorate*

12228-904 São José dos Campos – SP, Brazil, paulo.moraes@iae.cta.br

ABSTRACT

With the aim to continue the development of satellite launch vehicles according to the National Program of Space Activities (PNAE) of the Brazilian Space Agency (AEB), a new launch vehicle program has been established and announced in year 2005. The new program, denominated *Cruzeiro do Sul*, is comprised of five new vehicles to be developed and qualified in the next years. The Brazilian satellite launch vehicle VLS Alfa, first component of the *Cruzeiro do Sul* program family is designed to accomplish Brazilian space missions already stated in the PNAE, concerning the transport of small satellites to equatorial orbits from *Alcantara Launch Space Centre* in Brazil. Furthermore, and in order to make VLS Alfa more attractive for governmental and private investors, an attempt is made to improve its performance and capability of transporting small satellites into sun synchronous orbits. The paper describes the proposed vehicle, its actual performance and mission capability.

1. INTRODUCTION

In the almost last three decades the Institute of Aeronautics and Space (IAE) of the former Aerospace Technical Centre, actually Department of Aerospace Science and Technology (DCTA), was engaged in the development of a satellite launch vehicle, shortly VLS-1, and the associated technologies and infra-structure.

Two prototypes of this vehicle have already been started, unfortunately with failures, so that the vehicle could not be qualified up to now. An accident occurred during the launch campaign of the third prototype in the year 2003 has provoked a considerable delay in continuing with the efforts of preparing the next steps of the project, and in qualifying the vehicle. Nowadays a fourth prototype is being prepared to be launch in 2012.

The VLS program was established in the year 1979, and started five years later with the main objective to develop the capability of launching small payloads into Low Earth Orbits from the Brazilian launch center Alcântara.

Despite the time elapsed for concluding the project and so to qualify VLS-1, which were mainly related with economic, political, and financial difficulties during the last years, the Institute of Aeronautics and Space has proven to be capable of developing own space vehicles, as for instance a complete series of sounding rockets of small and medium size, propellants, rocket motors, materials, engineering, laboratories, and so far, almost the necessary knowledge and expertise in dealing with so sophisticated matter.

The Institute of Aeronautics and Space is the prime contractor for the space transportation segment of the Brazilian Space Agency (AEB). All the present and future activities are then proposed, planned, and presented in a document called “National Program for Space Activities” (PNAE - Programa Nacional de Atividades Espaciais), issued by AEB and revised every 4 years [1].

Looking for a wider horizon and so for the future, and considering a natural question of “what will come beyond VLS-1”, a group of experts of the Space Systems Division of IAE/Space Directorate, worked out in the year 2004-2005v a proposal for a new launch vehicle program, which receives the denomination of “*Cruzeiro do Sul*”^[1].

^[1] Southern Cross : a constellation in the Southern Hemisphere near Centaurus and Musca. Also called *Cruz*.

The Brazilian satellite launch vehicle VLS Alfa, first component of the *Cruzeiro do Sul* program family, is composed of the lower part of the also Brazilian first satellite launch vehicle VLS-1, solid propellant first and second stages, and a liquid engine as third stage.

The VLS Alfa is designed to accomplish all Brazilian space missions already stated in the PNAE (Brazilian National Program for Space Activities), concerning the transport of small satellites to equatorial orbits from *Alcantara Launch Space Centre* in Brazil.

The study firstly concerns the mission analysis and system requirements for VLS Alfa with the aim to prove its capability in attending the basic missions, e.g. insertion of small satellites into low earth orbits.

Furthermore, and in order to make VLS Alfa more attractive for governmental and private investors, an attempt is made to improve its performance and capability of transporting small satellites into sun synchronous orbits.

So, some new requirements are imposed regarding trajectory optimisation, aerodynamics, mass minimisation through use of lighter materials, optimisation of staging events, eventually use of an apogee motor, reduction or simplification of on board subsystems or devices, etc.

The paper describes the proposed vehicle, its actual performance and mission capability.

2. LAUNCH VEHICLE PROGRAM CRUZEIRO DO SUL

The Cruzeiro do Sul Program effort is to evolve the current SLV, called VLS-1, and some of its components and sub-systems, into a family of small, medium and heavy lift launchers to perform missions currently not conducted by VLS-1. A wide variety of concepts has been considered in the studies which converged to a family of five new vehicles, [Figure 1](#).

During the project of the VLS-1 one of the main goals achieved by the engineers and technicians of IAE was the development and qualification of medium size solid propellant rocket motors. The use of these already qualified technology and motors was a basic premise for future developments [2].



Figure 1: CRUZEIRO DO SUL LAUNCH VEHICLES

Also the space missions planned and proposed in the “National Program of Space Activities”, mainly coordinated by the Brazilian “National Institute of Space Research” (INPE-Instituto Nacional de Pesquisas Espaciais) shows a demand for launching micro, mini and medium size satellites into low inclination as also in polar orbits. In the far future also the transport of geo-stationary satellites would complete the envelope of missions to be accomplished.

Brazilian space vehicles are powered by solid propellant rocket motors, and as a result the performance envelope is nearly exhausted. It was obvious that the only use of solid propellant motors would later impose a limit to the launch capacity of the vehicles.

Liquid propelled rocket motors should be considered if the target of the program is committed with the improvement of the launch capability up to the transport of geo-stationary satellites.

3. THE LAUNCH VEHICLE FAMILY

Taking the low segment of VLS-1, comprised of four solid propellant S43 rocket motors as first stage, followed by an altitude adapted S43 motor as second stage, the first vehicle of the new family should be designed.

The main reason to establish this approach was the use of already developed and qualified motors and systems, as for instance stage separation devices. Also the fact to have the parts of a vehicle already qualified should shorten the development time and keep the costs low.

Only current technology, or that which can be demonstrated within the next few years will be considered. Foreign rocket motors and technologies may be used, specifically new liquid propulsion system designs may well come from abroad, though the hardware would be built in Brazil. Therefore, the use of foreign technology should be consistent with the Brazilian Space Agency (AEB) policy, and the Brazilian space industry should be an important actor and partner in the program.

One specific goal of the Cruzeiro do Sul LV Program is to reduce development and operational cost of the launchers, as also the development time. Design concepts will cover the entire system, not just the launch vehicle, including also changes in facility and range interaction. Also some premises related to environment protection are established so that non toxic propellants should be used.

Although the Cruzeiro do Sul LV Program is not envisaging at now to compete in the global launcher market, due to its mean strategic goal of developing autonomous launch capability in Brazil, the launchers can be in the future offered to foreign customers if they become competitive.

The VLS-1 is capable of transporting small satellites (up to 150 kg) into 750 km low inclination orbits. An improvement of this capacity in order to attend missions established in the PNAE was a first approach to establish the configuration of the forthcoming launcher. A nominal launch capability of 250 kg in 750 km or 400 kg into 400 km low inclination orbits was then established.

So, with this first approach and looking forward to develop the capacity of transporting heavier satellites into GTO, and considering the need of liquid propelled rocket motors, a family of five new expendable vehicles was proposed to be developed.

The proposal of developing the five vehicles, building a family, has considered a strategic step by step progress using already proven technologies, systems and sub-systems, as also the transport capability improvement making use of boosters, when necessary.

4. VLS ALFA

The first vehicle of the family is denominated VLS ALFA, [Figure 2](#).

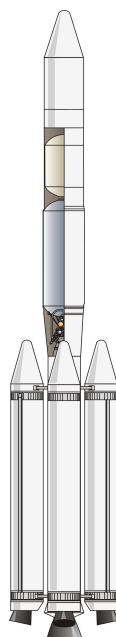


Figure 2: VLS ALFA

VLS ALFA is a three stage launch vehicle with an expected capability of transporting up to 400 kg payload into low inclination orbits of 400 km altitude. The low part of the vehicle, first and second stages, is identical with the low part of the previous VLS-1. Four S43 solid propellant motors, building the first stage, are placed around the central core, second stage, which also makes use of an altitude adapted S43.

The previous third and fourth stages of VLS-1 are then being replaced by a new liquid propellant motor with estimated 75 kN thrust.

Recently a concept review of the proposed configuration for the VLS ALFA has been started with the aim to confirm the attendance of Brazilian satellite missions and to elaborate system requirements.

Presently the Phase Zero, related to Mission Analysis of VLS Alfa, has been concluded and a Development Plan is under work.

The development of VLS ALFA will be carried out in parallel to the final qualification of VLS-1, and it is expected to perform its maiden flight at the end of 2015.

5. VLS ALFA LAUNCH CAPABILITES

The Brazilian Space Activities Program considers the development, launch and insertion of small scientific/technological satellites into low earth orbits. Furthermore it also considers satellites for remote sensing applications placed in sun synchronous orbits at around 500 to 600 km altitude, [Figure 3](#).

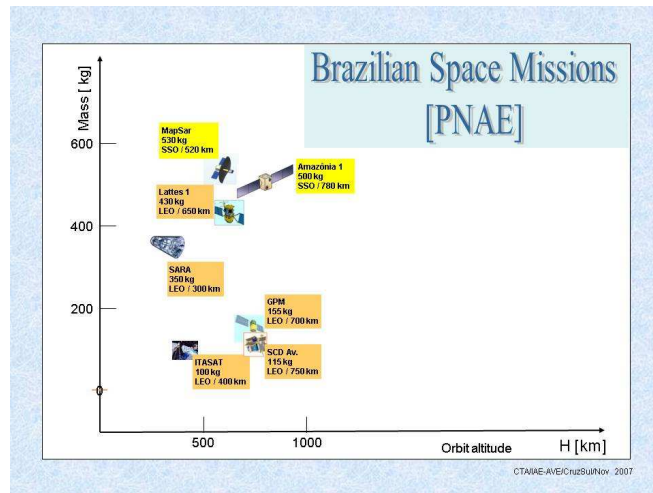


Figure 3: BRAZILIAN SPACE MISSIONS

The previous configuration of VLS Alfa, defined during the preliminary studies, was able to accomplish all the low altitude and low inclination orbit missions, using either a high or a low performance upper stage, as can be seen in Figure 4.

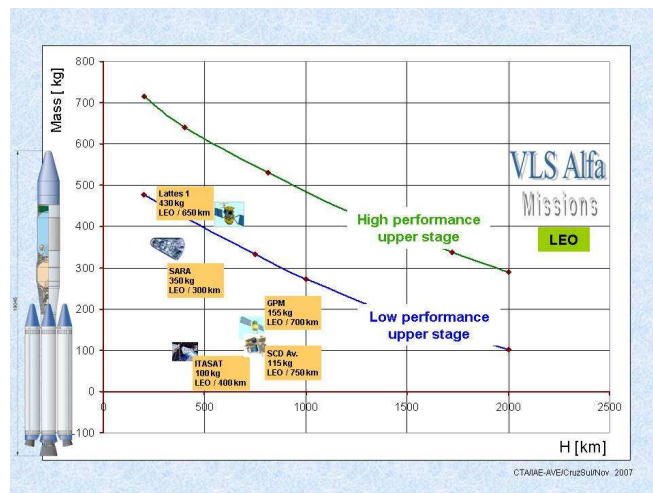


Figure 4: VLS ALFA & LEO MISSIONS

If sun synchronous orbit missions have to be accomplished the simple use of a high performance upper stage will be not sufficient to achieve this goal, [Figure 5](#).

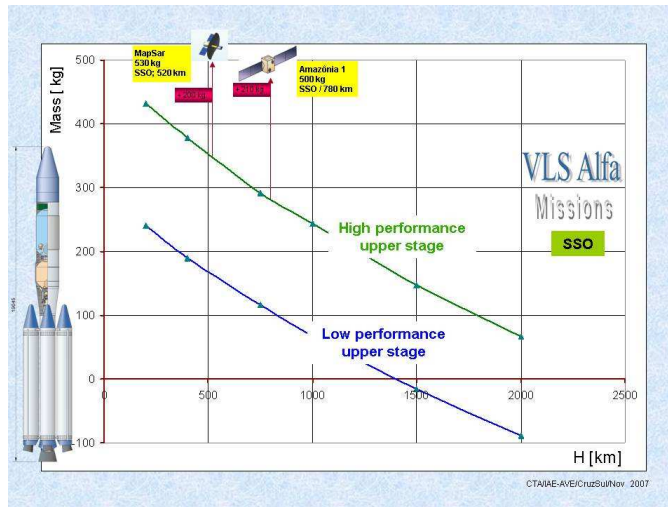


Figure 5: VLS ALFA & POLAR MISSIONS

Considering the fact that the already specified propellant pair for the upper stage (third stage), based on liquid oxygen and kerosene, will be used, the sun synchronous missions can only be performed if a kick motor of around 400 N thrust should be attached to the satellite bus, giving the necessary last energy impulse to achieve the desired orbit.

Another approach is to replace the low stages of VLS-1, built with four S43 as strap-on boosters and a S43 as second stage, by a single solid propellant motor of the 150t thrust class.

With such configuration, not only aerodynamic losses will be minimized due to overall common maximal diameter, but also due to the fact that the new motor case will be made by composites. Furthermore the optimization on avionics, pyrotechnical and mechanical sub-systems and equipments will also help to maximize the performance of the vehicle.

[Figure 6](#) shows the possible configuration for a two stage VLS Alfa.



Figure 6: VLS ALFA IMPROVED CONFIGURATION

With the two stages configuration and a small third stage (as apogee motor) the VLS Alfa will be able to accomplish also the Brazilian sun synchronous space missions.

5. FINAL REMARKS

The CRUZEIRO DO SUL Launch Vehicle Program and the family of launch vehicles that constitutes it show the roadmap for development of launch capability in Brazil.

The program is, as stated before, a strategic way to develop launch technologies and space transport capabilities in Brazil, making use of already developed systems and technologies, with the challenge of developing new technologies and systems. The program was proposed based on the premises of the Brazilian National Space Program, and should firstly attend the space missions contemplated within this program.

Due to the most adequate geographical location of Alcantara Spaceport for launching of spacecrafts into almost all types of orbits, and the purpose of the Brazilian Space Agency, Space Institutes and Industry to play an important role in the space transport branch, the CRUZEIRO DO SUL Launch Vehicle Program is right sized to aggregate all the efforts and so achieving relevant results in the next years.

The first launch vehicle of the Cruzeiro do Sul family, the VLS Alfa, is being developing to guarantee the accomplishment of all the low inclination Brazilian satellite missions.

With the improvement of VLS Alfa, by replacement of the low part of VLS-1, first and second stages, by a sole solid propellant motor, its performance will be increase substantially, allowing it to accomplish all the sun synchronous missions.

REFERENCES

- [1] PNAE-Programa Nacional de Atividades Espaciais 2005-2014 (*National Program of Space Activities, 2005-2014*), AEB, Brasília-DF, Brazil, www.aeb.gov.br
- [2] Paulo Moraes Jr., & all, “An Overview of the Brazilian Launch Vehicle Program *Cruzeiro do Sul*”, 57th International Astronautical Congress, Paper IAC-06-D2.1.08, Valencia, Spain, october 2006

ACKNOWLEDGMENTS

The first author would like to acknowledge the *Foundation for Space Science, Technology and Applications* (FUNCATE) for sponsoring his participation at the *European Conference for Aero-Space Sciences – EUCASS 2011*.