Relevance, Feasibility, Scope and Conceptual Design Proposal for a Novel Venezuelan Micro-Satellite Platform

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***Abstract*—The Bolivarian Republic of Venezuela has made developments in the space field during the past decade and on, placing to successfully in orbit two satellites on the last 7 years, one in the Geostationary Orbit (GEO) and another in the Sun-Synchronous Orbit (SSO) in order to the peaceful use of outer-space resources. Currently the Bolivarian Agency for Space Activities (ABAE, for its acronym in Spanish) is finalizing to build a research and development center for design, assembly and test of small satellites. It is conducted an investigation over the relevance, feasibility and scope of the development of a novel platform within a Micro-Satellite dimensions and weights standard. This research focuses on the country capabilities in terms of its technological development, the average cost of such kind of satellites and the Venezuelan potentially growth in this area, furthermore it explores results of space agencies around the world using such platforms and the scope of its missions proposed. As a result of this research is presented a conceptual and systematic proposal of a new Venezuelan micro-satellite platform. It suggests novel ways to develop this new platform and its possible applications that will allow to expand new potentials. The Development of a Bolivarian Republic of Venezuelan's satellite platform, will allows the country to promote its own technological advances, and moreover to test new technologies and configurations.**

Keywords— Aerospace; Novel Platform; Develop; Space Technology; Micro-Satellite; Developing Country

I. INTRODUCTION

The scope of this research is to answer some questions that arise in our minds when we talk about the space field nowadays, like what is the investment tendency currently in space industry? It is true that so many countries are pointing to smaller satellites to cover their needs? What is the Bolivarian Republic of Venezuela capabilities to begin a new micro-satellite project? Moreover it shows some projects that use micro-satellite platforms and their characteristics, and it describes a conceptual proposal for a new micro-satellite platform for Venezuela

II. BACKGROUND

In the past ten years, different space agencies and space companies around the world are working in research and develop of novel low orbit satellite platforms in order to reduce cost and time of developing new programs; this kind of new platforms are ten to twenty times smaller than traditional spacecraft for low orbits applications.

According to Jie, Yanbin, Shihong and Lijun, (2013) during the years 2003 to 2012 were launched 117 satellites with platforms of 10 to 150 kg, representing 13.3% of international market, and 93 platforms between 150 to 500 kg were placed in orbit during the same period, representing 10.6% of the market. In total during these nine years the micro-satellites platform represents almost one quarter of total launches.

Nowadays many space agencies and companies have micro-satellites in orbit, as shown in Buchen and DePasquale (2014). For satellites between 1 and 50 kg only in 2013 were launched almost 100 missions and there are estimations over 150 launches for this year. The main participation in the last years in this kind of missions is from civil investments, but that condition is changing. Nowadays more and more governments and commercial institutes are participating; the estimation is that these two groups of investors will have more than 65% holding in the next 3 years.

In the early years, the smallest satellites were used only for research or education scopes, but nowadays with the improvement of integration scale and technological capabilities on space activities, it is possible to reach the highest requirements in almost all kind of missions, especially in low earth orbits.

In addition using the development of a micro-satellite for research and technologies development is a method widely implemented, however at the same time the outright spacecraft could be used as platform for a particular mission. The advantage of using this kind of platform whether for research, developing or final application is its lower cost in comparison to large satellites (> 500kg).

For micro or mini satellites it is possible to use COTS components even in flight model. This peculiarity is the first reason why many countries are investing in this field of study; developed countries are using their knowledge and resources to growth faster new micro-satellites platforms and developing countries are using this field of study to improve their technologies for space activities while venture into applications missions to meet their needs Jie, Yanbin, Shihong and Lijun, (2013). A second reason of incursion in micro-satellites technologies is the development time of projects, which is shorter than those of large satellites; sometimes they are even 3 times less.

Venezuela as explained above, began to take part of the countries involved in the international space sector; actually Venezuela has two satellites in orbit and is building a research and development center in its territory. With this actions Venezuela is promoting the national development based in the science and technologies. As explained by (Hernández, Acevedo, Varela and Otero, 2013) Venezuela has nowadays the capabilities to work actively in the space industry at different levels.

III. Discussion

Table I shows a sample of different countries and their micro-satellites projects. It can be considered as a micro-satellite platform projects from 10 kg up to 100 kg according to the rule, but considering what expressed in Jie, Yanbin, Shihong and Lijun, (2013) we can take into account and include satellites up to 200 kg as micro-satellites.

TABLE I. Micro-satellites Projects

Country[a]	**Mission**		
	Satellite	***Mass (Kg)***	***Scope***
Canada	NEOSSAT	~74	AstroTelescope
Canada	MOST	54	Stellar Photometry
Canada	SCISAT	150	Scientific Measurements
Canada	M3MSAT	85	Maritime Surveillance
Japan	Micro Lab-Sat	~50	Remote Sensing
Japan	REIMEI	60	Technology Demonstration Experiment
France	MYRIADES	70 (<130)	Different Missions
United Kingdom	TOPSAT	~115	Earth Observation
France	DEMETER	100	Scientific Objectives
Turkey	RASAT	97	Earth Observation
Korea	STSAT-1	106	Earth Observation
Korea	STSAT-3	150	Earth Observation
Nigeria	NigeriaSat-X	~87	Earth Observation
United Arab Emirates	DubaiSat-1	~200	Earth Observation
Germany	DLR-TUBSAT	45	Earth Observation
Morocco	MAROC-TUBSAT	47	Earth Observation
Indonesia	LAPAN-TUBSAT	56	Earth Observation

a. Sources: [3], [5], [8], [9], [10], [14], [12], [15], [16], [17]

In Table I can be seen that different developed and developing countries are using micro-satellites, obtaining excellent results. This kind of platforms allows to install one or more different payloads with diverse purposes, giving to each one the conditions required. Currently it is possible to reach same performance as large satellites with small ones but assuming only 5% of the first one cost. Evidently, choosing micro-satellites instead of large satellites have a compromise with other characteristics in satellites projects, like a shorter lifetime in some cases, but the benefits normally are huge compared with the drawbacks.

Historically the large satellites were related with the national space agencies and major companies in this field, and vice versa, but now they are pointing to smaller satellites due their lower costs. The facilities that are used to build a large satellite can be adapted for small satellites, and the basic knowledge are similar for both kinds of satellites. The experience building large satellites could be very useful for small satellites but no essential.

So, why a developing country needs to do a huge investment to begin the development of a large platform? When it is possible to cover the country's needs with a lower investment using micro-satellites. Why do they have to expend a lot of time to access useful space applications? When it is realistic to think into develop shorter projects' schedules with same results doing micro-satellites.

The Bolivarian Republic of Venezuela has been developing many industrial areas in the past years, but still depending at different levels of foreign countries to get diverse products. The space activities require a lot of investment in many industrial areas, but if dimensions of the products that these companies have to manufacture are smaller, thereupon the investments needed to develop the national industry are lower. During these years Venezuela has installed new facilities to design, integrate and test small satellites, with no more than 1-ton weight, these facilities are useful to develop micro-satellites and can be supported by other companies and institutes in the country.

FIGURE I. Difference between dimensions of satellites and facilities, each square represents the area that it is needed to place each kind of satellite (Large, Micro and Nano satellite respectively) [13]

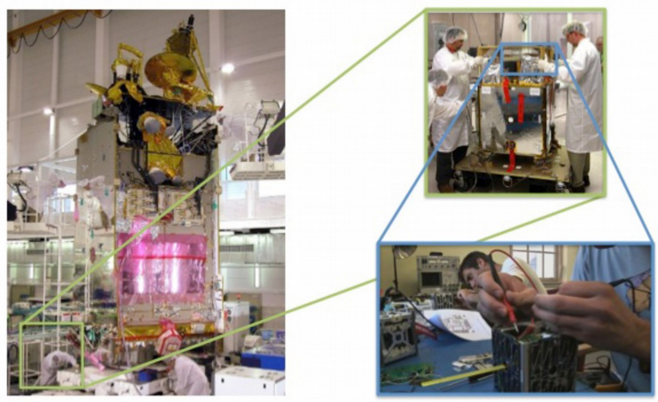


Fig. I shows that the different needs regarding to physical dimensions in the facilities where different kind of satellites should be integrated and tested are directly related with the needs of the different equipment in each kind of facilities. Therefore it is possible for Venezuela to use its new facilities to build micro-satellites, being a promising investment to begin the development of a novel platform for satellites no heavier than 120 kg, considering that usually the platform represent the 60% of the satellite's weight.

IV. Elements of Small Satellites (State of Art)

This section shows the actual state in space industry of the different subsystems in a satellite, even some equipment. NASA performed a research and technical report about the state of art of different technologies, equipment and systems of Nano and micro satellites. In NASA/TP–2014–216648 is listed and explained the main components of the different system of Nano and micro satellites. Based in this and other documents, there has been identified for the present work, many elements, providers and novel technologies for micro-satellites, it was leave aside the components listed for nanosatellites or other small satellites.

A. Attitude and Orbit Control System

This system is normally one of the most complex systems in an average satellite, it contains a lot of equipment and components, and normally it is conformed by five subsystems: Propulsion, Attitude, Orbit, Mechanical Actuators and Main Computer.

1) Propulsion

Historically this subsystem has not been used in very small satellites, but the grown of technologies in different areas like MEMS, NEMS, 3D printers, materials and others, has allowed the new developers to include and provide propulsion subsystem for orbit and attitude control. Nowadays there are many companies like SSC group (Sweden), ATK (USA), Busek (USA) or Polyflex Aerospace LTD (UK), which have developed propulsion units for micro-satellites. Therefore it is possible to include this subsystem in a micro-satellite, from hundred of grams to some kilograms of mass and from units of watts to hundred of watts of consumption.

2) Reaction Wheels

These components are often used in missions that require precise attitude stability, in some cases it is difficult to accommodate the reaction wheels necessary to have a good control; but a lot of companies are working in miniaturization of all its components to solve those cases.

Surrey Satellite Technology (SSTL) (UK), Astro- und Feinwerktechnik (Germany), Mitubishi Precision (Japan) and Sinclair Interplanetary (Canada) are some of the companies with proved experience designing reaction wheels for micro-satellites. At present it is possible to find reaction wheel from 2 mNm to hundred of mNm of torque.

3) Magnetotorquer

The Magnetorquers are widely used in small satellites, large satellites do not use them for two main reasons: first normally large satellites are destined to be placed in GEO orbits, and second is because their sizes are prohibitive to be controlled by magnetorquers.

The technologies for these components are widely developed; ZARM (Germany) and SSBV Aerospace & Technology Group (UK) are two companies with a lot of experience. The range of weight could be from 200g to 11kg.

4) Star Tracker

In order to have a high precision in attitude determination it is possible to allocate star trackers into the micro-satellites, nowadays these equipment may provide a pointing accuracy up to 0.0001 degrees with weights lighter than 1 kg. Technical University of Denmark (DTU) developed a series of star trackers used in different commercial and government projects. Another examples of star trackers developers of micro-satellite are VECTRONIC Aerospace (Germany), and Berlin Space Technologies (BST) (Germany).

5) Digital Sun Sensor

These components are also widely used in spacecraft to determine their attitude; Sinclair Interplanetary (Canada), DTU (Denmark) and TNO (Netherlands) have proven experience producing digital sun sensors for small satellites.

Sun sensors are not usually so heavy; in fact for micro-satellite applications they are not heavier than hundred of grams and their energy consumption is not beyond the units of watts. The most important parameter to select a digital sun sensor (DSS) is the accuracy and it shall be no greater than 0.1 degree.

6) Angular Rate Sensor

The most used sensor to measure the angular rate in a satellite is a gyroscope. Conventionally there are used at least five gyros to have the proper accuracy. It is possible to obtain all angular information of the satellite by processing the sensors' data using proper software, and combining the data from Gyroscopes and Star Trackers allows the satellite's attitude determination with high accuracy.

Northrop Grumman LITEF GmbH (USA/Germany), Advanced Engineering Services Co.,Ltd (Japan), Analog Devices (USA) and KVH Industries (Multinational) are some companies that produce useful gyroscopes for micro-satellites. At present the technology allows a maximum bias instability between $\leq 0.1^{\circ}$/h to tens of $^{\circ}$/h, using fiber optics or MEMS devices.

7) GPS Receivers

These equipment are often used in Low Earth Orbits (LEO) applications, because they provide a better orbit determination accuracy than using the Doppler method, obviously it is possible to combine both to determine on ground the orbit parameters.

A lot of companies around the world produce and sale, GPS receivers and antennas ready to be integrated in small satellites, but even some space agencies often develop their own equipment, doing an integration project of commercial components.

SSTL (UK), SpaceQuest (USA), DLR (Germany) and NOVATEL (Canada) are some companies which sale these kinds of components. The normal accuracy is 10 m but can reach till 1.5 m.

B. Power Supply System

It is possible to divide this system in three subsystems [13]: Generation, storage and distribution.

The most used method to generate energy in outer space, near to the earth is to use solar panels; there also exist different chemical units able to generate energy, but normally they are dangerous and pollutant, therefore those chemical methods are not often used in near earth orbits. Batteries are used to storage energy, for micro-satellites application there are available at least two kinds of batteries: Nickel Cadmium (Ni-Cd) which have high experience in orbit and Lithium ion (Li-Ion) which is considered as novel technology in space applications, but with highest performance and specific energy (Wh/kg). Finally, power distribution subsystem is conformed by power switches and regulators; the power bus may be designed to use 5.5 V up to 30 V (commercials values)

The solar panels efficiency are still low compared to other energy generation methods, arriving till 29% with high experience in orbit, mean while some researchers are proving new technologies that arrive even to 44%. Solar cells have a lot of advantages in space application, they are not heavy nor pollutant and can be used by other subsystems, for example as protectors of the satellite's structure and even in temperature control of the spacecraft.

1) Solar Cells

It is possible to find a lot of companies that produce or assembly solar cells for missions destined to outer space. Usually the process to select the solar cells is difficult because it depends on many factors. Micro-satellites have the capability to use solar panels as wings or attached to the structure, but these two approaches can change the substrate materials and the solar cells itself; other important constraint is the power needs, it will influence the decision to use wings or not and at the end it will be necessary to review the thermal control system and the mass budget.

Azur Space Solar (Germany), Clyde (UK), Pumpkin (USA), SpectroLab (USA) and Emcore (USA) are some of most important companies available in the market.

2) Batteries

In case of batteries, the predominant factor is the energy density to mass ratio; reliability is the second important thing to take care during batteries selection. Ni-Cd and Li-ion are normally the main two options in the market, but there are also available Li-Polymer, Li-Phosphate and Ni-H2. Clyde Space Ltd. (UK), Saft SA (France/ USA) and Sony (Japan) are some companies which provide batteries cells.

It is a common usage from different satellites' manufacturers to qualify by themself the batteries array and be generating heritage and reliability database of the selected batteries. It is a long process but it is the best way to have a good basement in energy storage components information.

3) Power distribution and Control

This subsystem is conformed by numerous components; usually it is integrated with the whole satellite, at least the harness and some switches. The control or management computer could be designed also by the same space agency and bought based in that design. Some companies provide the design service, and other sale distribution management units already integrated.

SpaceMicro Inc. provides a list of components radiation-hardened to be implemented in this kind of projects. [7], [13] Clyde Space Ltd (Scotland) provides service of design and also has some systems developed and ready to be integrated in a satellite.

C. Structure and Materials

A principal goal in satellite design is to reduce the weight reaching all the mission requirements, one way to do that it is to improve the spacecraft structure, the challenge is even more difficult to get when the structure of a satellite needs to be stiff, stable, cheap, ease to manufacture and able to support deployable mechanisms. Therefore over the years companies and space agencies have been developing different materials and shapes of structure.

The most used shape is the cube and the material is the aluminium alloy, but the designers always review the shape for each mission and also the materials technologies, doing their improvements and researches, getting good materials for space applications; such as composites of carbon fiber, titanium and others more.

D. Thermal Control System

This system is also very complex, because the design will depend on the Systems layout. Thermal control system is distributed all around the spacecraft, and it can use heater pipes to transfer the heat from equipment to radiators; heaters and multilayers isolators to control the temperature in the satellite and sensors to know all the temperatures status in the satellite.

It is possible to list some important companies that can provide those elements to be integrated by the micro-satellite manufacturer. Dunmore (USA), MAP (France), Akzo Nobel Aerospace Coatings (Netherlands), Advanced Cooling Technology, Inc. (USA) and AZ tech (USA) are some of the companies available for thermal control products and services.

E. On Board Data Handling

The on board data handling (OBDH) system is responsible of getting all the satellite's information and to communicate all the systems between each other, it will also prepare the telemetry packages and process the telecommands to and from ground station. It can be included as OBDH's subsystem the modulation and demodulation system (Telemetry, Tracking, and Command TT&C). The principal components of OBDH are microprocessor and memories; these two will mark the entire requirement during the design.

Nowadays exist a lot of companies that produce both, processors and memories, intended to space applications. AeroFlex, EverSpin, Innoflight, SSTL, Texas Instruments, Xiphos Technologies, Hitachi, Thales Alenia Space, COM DEV EUROPE, GOMSpace and Amtel are some companies which offer products and services, but it is possible to use in some kinds of missions commercial off-the-shelf (COTS) components, using different approaches to ensure the correct storage and handled of data on board.

V. Venezuelan Capabilities and a Micro-satellite Conceptual Proposal

As it was mentioned before, Venezuela has relevant developments in space activities; it began with the launch of its first satellite and with strategic international cooperation. Venezuela during the last 10 years has been taking important decisions to improve its professionals' knowledge and skills and is doing great investments to build the necessary facilities for space industry, to have an active participation in this field.

As is explained in ("unpublished", Acevedo and Becerra, 2014) and discussed above, Venezuela at present have many international partners in space industry, and will have soon the "Research and Development Center for small satellite technologies (R&D)"; where it will be possible to design, assemble, integrate and test small satellites not heavier than 1000 kg.

The regional conditions and Venezuela's evolution in space activities allow to aim new projects, and as it is shown in this research, a micro-satellite is a good goal to boost fundamental knowledge and local industry that in the future can be the basement for a solid and productive space industry, framed in the principles and objectives of this socialist and developing country.

It is important to list some knowledge acquired by ABAE-Venezuela in the last years (Hernández, Acevedo, Varela and Otero, 2013), it is shows in Table II:

TABLE II. CAPACITY BUILDING TO DEVELOP SATELLITE [5]

Field	Country	Institution	Professional Number
Space Management	France	ISU [b]	2 (1 in process)
Space Project Management	Venezuela-France	ABAE- EADS / ASTRIUM	41
Satellite engineering and design	Venezuela-France	ABAE- EADS / ASTRIUM	41
Satellite engineering, design and assembly	China	CAST Shenzhou Institute	70
Space Project Management	China	CAST Shenzhou Institute	20

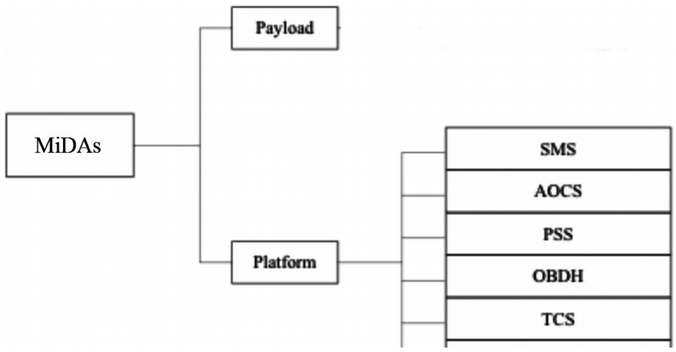
b. International Space University

A. Micro-satellite Conceptual Proposal

As it was announced above, this proposal considers a 120 kg weight budget for the platform; knowing that usually the satellite platform comprehends between 60 to 70% of all weight budget, it is predictable that with this proposal will be possible to build micro-satellites up to 200 kg. The proposal that is shown below is open to modifications after the required preliminary design phase, when it can be explored in depth if it is necessary a maximum budget of 120 kg or if it is feasible to reduce it.

In Fig. II it is shown the subsystems configuration for the platform "Micro-satellite Developed by ABAE (MiDAs)", the subsystems requirement and limitations are breaked down based on that configuration.

FIGURE II. PLATFORM MIDAS SUBSYSTEMS CONFIGURATION



1) SMS

The structure of MiDAs shall support and protect the other subsystems; the internal and external panels will be made in Aluminium Alloy or in Honey Comb. External panels also can be in thin Aluminium Alloy tiles or it could be designed as plates in Aluminium with truss hollows configuration, but the external face needs to be uniform, and it will have a minimum thickness of 10 mm. In case that external faces have been designed in aluminium, it shall be anodized.

MiDAs will have one solar panel pointing along the perpendicular axis to orbital plane; SMS will have a mechanical element that allows the Solar Panel to rotate on its own longitudinal axis. The SMS will provide a one shot deployment module.

MiDAs' basic shape will be a cube, and SMS weight budget will be ≤ 40kg (Including the solar panel).

2) AOCS

The AOCS of MiDAs shall provide three axis stabilization with a pointing accuracy ≤ 0.03 @3σ using star tracker and ≤ 0.25 @3σ in other cases [2]. The satellite's intrinsic axes will be orientated as follow: Z^+ pointing to earth, X^+ pointing flight direction and Y^+ in accordance with the right hand rule. MiDAs will have a GPS orbit determination. The AOCS weight budget will be ≤ 20kg

3) PSS

The power supply system will provide 80 W at the end of life (EOL); the batteries could be Li-ion with a regulated bus. The PSS weight budget will be ≤ 40kg

4) OBDH

The MiDAs' OBDH shall be able to process at least 5 Mips, and provide a standard internal communication bus to interconnect with other systems. The OBDH weight budget will be ≤ 8 kg.

5) TCS

The MiDAs' TCS will be designed to ensure the right temperature of all internal equipment. The TCS weight budget will be ≤ 2 kg.

6) TT&C

The MiDAs' TT&C will provide down link and Up-link connection using unified S band standard (USB), this system will be compliant with CCSDS standard and it will also perform the GPS link. The downlink will be designed to have a cold redundancy configuration and the up link will have hot redundancy configuration. The TT&C weight budget will be ≤ 10 kg.

7) Overall Characteristics

The platform will be designed to provide a lifetime between 3 to 5 years with a reliability of 0.8 to 0.9. It is obvious that all the final characteristics will be closed after in-deep design.

VI. Conclusion

It was shown that nowadays more and more countries are pointing to invest in micro-satellites or even smaller satellites; it was reviewed the present capabilities of the Bolivarian Republic of Venezuela, and it was proved that it is convenient for a country with its characteristics to invest in a new micro-satellite project. Based on other experiences, it is possible to predict a great successful for Venezuela, if it decides to invest in a micro-satellite project. One conceptual proposal and some systems characteristic and suppliers were provided. The proposal can be developed by ABAE with the participation of its partner countries which it has bilateral agreements or it can undertake new agreements with companies or agencies from others developing countries to work up on the proposal.

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