RECENT DEVELOPMENTS AT INPE´S SMALL SATELLITES DIVISION

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Small satellites applications nowadays are in high demand as in some cases this approach may be effective in performance and costs. INPE has recently started a series of contributions in the small satellites area and has in fact assigned a division (DIPST) on its structure to tackle just small satellites and all the concerns arising from them. This work briefly introduces a snapshot of the current activities being performed by DIPST and also where it is heading to in near future. Therefore, DIPST is assigned to: (1) Develop activities, technical consultancy and dissemination of knowledge; (2) Design cost-competitive space missions; (3) Develop of applications embedded in small satellites, suborbital flights, drones or stratospheric balloons and (4) Validate COTS com-ponents and alternatives for cost reduction. DIPST will be managing: (1) Life cycle stages, development and qualification of standard platforms and qualification of pay-loads and (2) Support the development cycle of new technologies to reach the maturity level. Finally, DIPST will participate in: (1) Actions for the Brazilian technological autonomy in the development of small satellites, their subsystems and components and (2) National and international cooperation. Concerning current projects, DIPST is taking part and supporting many nanosatellites initiatives like: (1) SPORT (Scintillation Prediction Observations Research Task) a 6U-cubesat in partnership with NASA, AEB, ITA to study the preconditions leading to equatorial plasma bubbles in the ionosphere. Mission operations will be done by INPE through its ground stations and INPE will receive, archive and distribute mission data at the Brazilian Monitoring and Study of Space Weather Program (EMBRACE) facilities and disseminate the processed data to the scientific community. (2) GOLDS-UFSC – a 2U cubesat for GOLDS Constellation (Global Open coLlecting Data System) developed by the academic sector and carrying an environmental data collecting payload from INPE´s northeast site. (3) BiomeSat – a 6-U nanosatellite for forest´s health monitoring looking at photosynthesis activity from chlorophyll fluorescence and part of a multi-mission nanosatellite platform named P10 reused in future demands. (4) BalloonSat – a balloon carrying a nanosatellite for rapid prototype developments which 1st mission is being undertaking with an educational institution as part of DIPST outreach effort. Future projects are also described like the P30 - a 30Kg small satellite, and P100 platforms - a 100Kg microsatellite bus. TuriSat, a small satellite for forests fires in Amazonia will use the first P30 platform targeted.

1. Introduction

Currently many space programs in the world have already a development on smallsats besides the traditional bigger satellites [1]. Following this trend, INPE has recently created a special division, named DIPST, dedicated to this category of satellites. DIPST is responsible for conducting the activities of development, technical support, and knowledge dissemination of technologies and capabilities for small satellites in space programs, with the academic and industrial sectors. DIPST works transversally with the other Divisions and Service of INPE´s General Coordination of Space Engineering, Technology and Science (CGCE) in order to create synergy among various areas of knowledge of this Coordination.

The main role of DIPST is the development of nanosatellites and microsatellites (up to 100kg) intended for space science and Earth science applications, including technological demonstrators. For the development, DIPST seeks to improve the quality and reliability of these satellite artifacts using INPE's experience acquired in the development of larger satellites, such as the SCD, CBERS and Amazonia-1 families. Similarly, small satellites can prototype exploratory solutions that will be used in larger missions as well as being a complement to INPE's larger remote sensing satellites like Amazonia and CBERs series.

Missions with small satellites may include several possible alternatives ranging from a single small satellite, missions with several small satellites flying in constellation or swarm, and missions together large satellites. DIPST division is gathering laboratories and qualified personnel for the development of nanosatellites and microsatellites, including initial assembly, integration and tests. As an example of contribution, INPE will provide the ground segment for the SPORT nanosat [2] to study the preconditions leading to equatorial plasma bubbles in the ionosphere, receive, archive and distribute mission data EMBRACE disseminating the processed data to the scientific community.

This paper is organized as follows: Section 2 presents some nanosat missions using the P-10 platform; Section 3 talks about prototyping missions using the BalloonSat concept; Section 4 introduces the P-30 platform and small-satellites missions derived from it; similarly, Section 5, presents micro-satellites missions in the P-100 platform; Section 6 describes some nanosatellite constellations for environmental data collection and Section 7 concludes this paper.

2. Nanosatellites Missions in the P-10 Platform

DIPST is planning two key nanosatellites mission that will use the P-10 platform [3]: (1) BiomeSat [4] - a 6U nanosatellite proposal for providing information on forest conditions in Brazil, with a level of spatial and temporal detail useful for monitoring and (2) RaioSat [5] – this mission will have, as a space segment, a prospectively 6U-cubesat with a mass of 10 kg, with an on-board computer and an attitude control system to meet the requirements for lightning flashes images.

2.1 BiomeSat Mission

Forest conservation in Brazil is important for several reasons. Forests are home to a high number of plant and animal species, and high values of water and carbon stocks and flows between the land surface and the atmosphere, thus having a substantial impact on climate, biodiversity and the availability of natural resources. Due to the large territorial extension, remote sensing is essential for monitoring forests in Brazil.

Thus, to contribute to the forest observation programs in the country and agricultural monitoring, it is intended to generate information on the conditions of these areas using the collected data. Specifically, it is intended to collect data on the state of forests and agricultural crops using vegetation indices, which can aggregate the effect of various disturbances such as droughts, deforestation and fire, and present less complexity for data acquisition and calculation.

BiomeSat will be implemented around a 6-U cubesat platform as shown in Figure 1. The proposal for mapping forest conditions and agricultural monitoring considers the use of vegetation indices based on images collected in bands of electromagnetic waves corresponding to the visible and infrared spectrum. Some examples of these indices that use data in the red (R), green (G), blue (B) and near-infrared (NIR) ranges include, among others, the Visual Normalized Difference Vegetation Index (Visual NDVI), the Green Leaf Index (GLI), the Visual Atmospheric Resistance Index (VARI), as well as the Normalized Difference Vegetation Index (NDVI) and similar ones. These indices are related to chlorophyll content, differences between plants, exposed soil and non-vegetable material and are therefore appropriate for estimating vegetation conditions and agricultural crops.

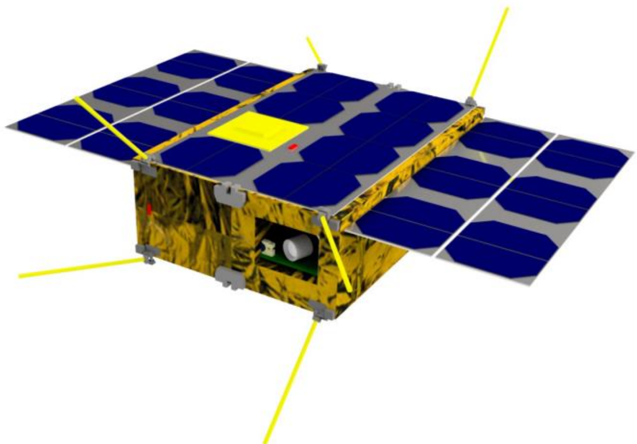

Figure 1: BiomeSat artistic view for forest health monitoring.

The BiomeSat mission intends to continue monitoring environmental changes, deforestation and forest degradation, as well as supporting applications in agriculture in order to obtain several benefits in different areas:

- Vegetation: monitoring of deforestation, degradation, and state of vigor of forests.
- Agriculture: estimate of planted area, vegetative vigor of crops, forecast of agricultural production, determination of areas of preservation of springs, forest reserves and agricultural areas, pointing out errors in fertilization, irrigation and soil preparation processes, regions with greater potential of production.
- Environment: assessment of the impact of fire, deforestation and drought on a given area, allowing a good rate of monitoring of environmental degradation, delimitation of continental water bodies, support for coastal management.

- Education: generation of material to support educational activities in geography, environmental sciences and other disciplines and generation of data and information for the development of scientific studies.

The initial conception is planned to carry a set of payloads, namely: (1) a remote sensing camera for forest health monitoring which is the primary mission, (2) a data-environmental collecting transponder (EDC) which was developed by INPE ´s Northeast site, (3) an AIS transponder for monitoring vessels in the Brazilian maritime authorities and, (4) a space-weather monitor (SEM) or tracking space environment mainly TID (Total Ionizing Dose) and SEE (Single Event Effects). The nanosatellite bus is envisaged to be a multi-mission platform for other future missions and serves as a complement to INPE's larger remote sensing satellites like Amazonia and CBERs series.

2.2 RaioSat Mission

Extreme weather events are increasingly common in Brazilian territory, and to assist in the study and generation of meteorological forecast models, the monitoring of lightning occurrences becomes extremely important [6]. The Atmospheric Electricity (ELAT) group of the Earth System Science Center (CCST) together with the Small Satellite Division (DIPST) proposed the RaioSat mission, to assist the existing ground network, for monitoring lightning occurrences.

The RaioSat mission will have, as a space segment, a 6U-cubesat as shown in Figure 2, with a mass of 10 kg, with an on-board computer and an attitude control system to meet the requirements for lightning flashes images and having the following payloads: Camera in the IR range (infrared) with sensor and optical filter, a GPS (Global Positioning System) for low orbit applications, VHF SDR (Software Defined Radio) receiver operating in the 30 - 100 MHz band, to record the electromagnetic signatures and validate the lightning detections acquired by the IR camera.

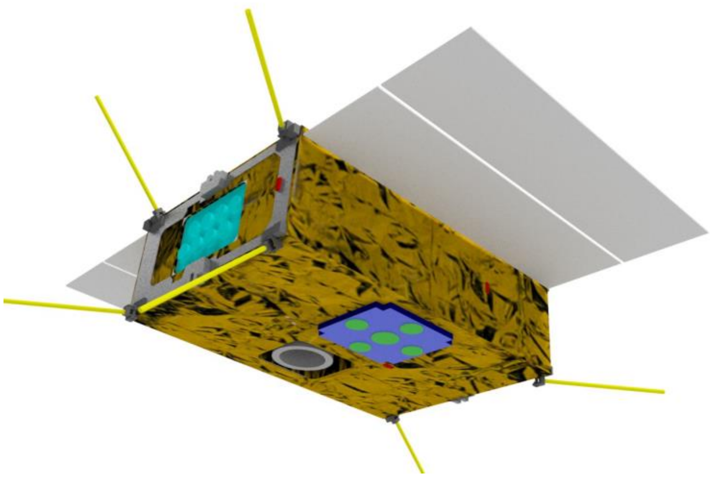

Figure 2: RaioSat artistic view for lightning events monitoring.

The RaioSat mission will complement the BrasilDat network for monitoring atmospheric electrical discharges, and assist in the Brazilian civil defense and risk and disaster management system. This mission will be fundamental for the short-term weather forecast for disaster prevention actions by storms and electrical discharges and assist in risk and disaster management and civil defense.

3. BallonSat - Multi-Mission Platform for Stratospheric Balloon

DIPST will soon launch its first experimental Multi-Mission Platform for Stratospheric Balloon (PMBE) which was developed to be used as a telemetry, remote controls and georeferencing system that, coupled to a stratospheric balloon, can help in the testing and evaluation of technological systems and scientific experiments that use stratospheric flights [7].

The stratosphere has peculiar conditions, such as low pressure and temperature, in addition to a relatively long and free link distance, which can be favorable for certain tests and experiments. The evaluation of some subsystems that are developed for nanosatellites, using CubeSat architecture or not, can use this platform, as depicted in Figure 3, since the costs would be extremely low especially when compared to those performed in orbit tests.

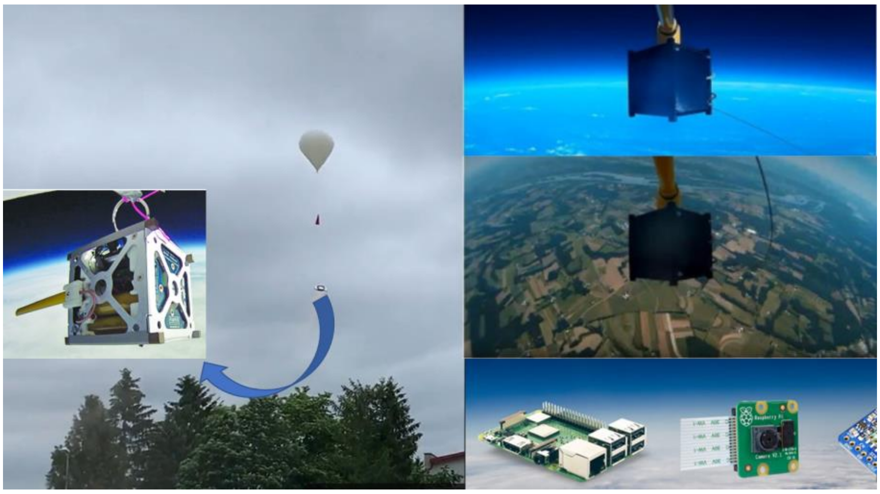

Figure 3: Multi-Mission Platform for Stratospheric Balloon (PMBE).

The PMBE is based on a CubeSat architecture. It weighs under 500g and is built with low-cost components and power consumption. Its subsystems have dimensions of 10 x 10 cm and are coupled through a PC104 connector. It consists of an onboard computer, OBDH, with integrated GPS, a subsystem for sending telemetry and receiving telecommands, TM/TC, and a power subsystem. The TM/TC is suitable for the type of mission, and its operating parameters may vary, such as transmission and reception frequencies, power, data rate and type of modulation used. It works primarily on UHF frequencies, between 400 MHz and 433 MHz, and on sub-Giga Hertz frequencies, between 900 MHz and 930 MHz. According to the configuration of the parameters of the TM/TC subsystem, it is possible to close a link of up to 900km. In addition to the subsystems mentioned, the PMBE is also composed of the structure and thermal control subsystem, for mechanical support and temperature control, containing standard analog and digital interfaces for connecting sensors, cameras and experiments.

4. Small-satellites Missions in the P-30 Platform

DIPST is designing a small satellite platform weighting 30 Kg named P-30 [8] in order to enable more demanding missions which would be instantiated into a the Turi-Sat mission. It aims to contribute to the programs of observation and preservation of forests in Brazil by generating information on the location of fires, enabling the competent authorities to act in the early stages of fires.

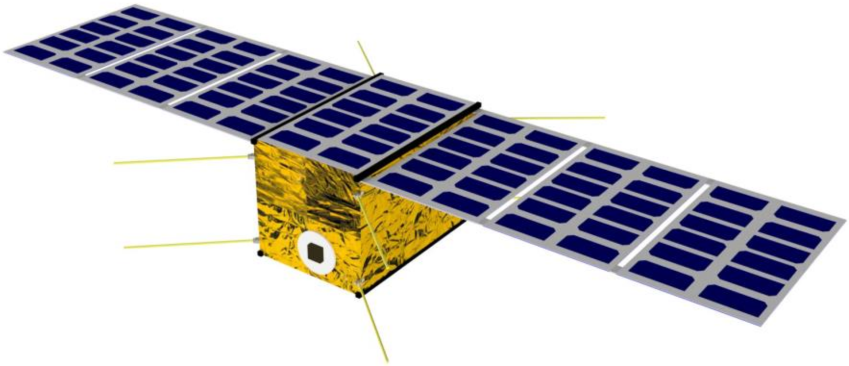

Figure 4: The TuriSat, a 30Kg small-satellite mission.

Fire fighting in forest regions has been the subject of research by several groups in international agencies. An important tool for fighting fire is the use of remote sensing techniques to identify and locate fire outbreaks, thus making it possible to extinguish the fire at an early stage, when the damage caused to the environment is still small.

The TuriSat microsatellite, class 30kg, will have three optical imagers, with appropriate characteristics, and a data collection system. It will have 3-axis control and propulsion subsystem. With this, it will be able to operate at higher altitudes and will be aligned with good practices for the rational use of space. Techniques will be used to mitigate the effects of cosmic radiation in order to extend its useful lifetime.

5. Micro-satellites Missions in the P-100 Platform

In order to meet the requirements for science mission like space weather, DIPST is envisaging a micro-satellite platform bus weighting 100 Kg named P-100 [9] which would accept another 100 Kg module for carrying the scientific payload instruments. EQUARS [10], shown in Figure 5, is the first P-100 target mission.

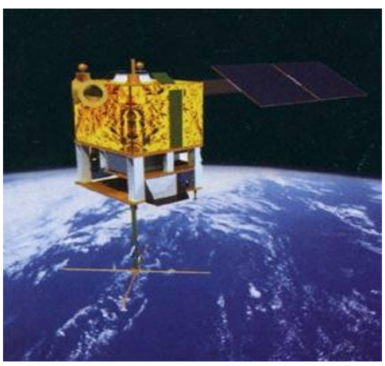

Figure 5: The EQUARS [10] mission will be using the P-100 bus platform.

6. Nanosatellite Constellations for Environmental Data Collection

Nanosatellite missions have much of their life cycle shortened as they use commercial components (COTS). The standardization achieved with nanosatellites using on the cubesat platform has allowed drastic cost reductions by enabling scientists and engineers to design small artifacts and coordinate networks of multiple cubesats (known as “cubesat constellations”) that provide a wide variety of new technologies. resources in orbit. DIPST is currently supporting of two initiatives: (1) The CONASAT Project [11] and the (2) GOLDS Constellation [12] which are described in details hereafter.

These first constellations will support mainly the Brazilian Environmental Data Collection System (SBCDA). Currently, the SBCDA is a Brazilian satellite-based environmental monitoring system developed and operated by the Brazilian Institute for Space Research (INPE). Currently, SBCDA consists of 5 Low Earth Orbit (LEO) satellites (SCD-1, SCD-2, CBERS-4, CBERS-4A and Amazonia-1); two control and data reception stations and a network of approximately 500 automated Environmental Data Collection Platforms (DCP), most of them scattered throughout the national territory and some oceanographic buoys. Today the SBCDA work as follows:

- The data are collected through sensors coupled in the DCPs that transmit them to the satellites in the frequency of 401MHz, in short-burst signal, in a unidirectional and asynchronous communication;
- LEO satellites relay the signals of the DCPs back to the Ground Receive Stations located in Alcântara and Cuiabá;
- The DCP data received at Ground Stations are sent to the mission center located in Natal, where a software-based system named SINDA (Integrated System for Environmental Data);
- SINDA processes, stores and make data available to the end users and
- The users’ access to SINDA is free through the Internet.

6.1 The CONASAT Project

The CONASAT Project (Constellation of Nanosatellites for Data Collection Environmental) [con], based on the concept of “fast and cheap access to space” using the CubeSat standard, aims to offer a technologically updated option, incorporating recent advances in microelectronics, telecommunications, embedded systems and sensors using MEMS technology. The project can be seen as an evolution of the SBCDA employing a constellation of CubeSats, aiming to improve the quality of the service, in terms of capacity, geographic coverage and shorter revisit times.

The project aims to provide the country with its own capacity in the development of the life cycle of space systems and in this context, it consolidates the application of technology from the development, operation and offer of products through a satellite system, totally designed in the country. The project operates along the following lines of Sustainable Development Goals (SDGs) - UN 2030 Agenda:

- SDG15: The project will enable effective actions in environmental management through the collection of environmental data.
- SDG14: The project may contemplate the development and immediate application through the collection of environmental data provided by oceanic buoys.

In order to ensure the continuity of the SBCDA and meet the new demands of environmental monitoring, providing new services and improving its performance, INPE, through the Northeast Spatial Coordination (COENE), is conducting the CONASAT project, which aims to offer an innovative solution in the space segment. The solution is based on a constellation of nanosatellites, which allows for a cost reduction while providing an improvement in the quality of service, in terms of capacity, geographic coverage and shorter revisit time.

The payload will be a transponder for collecting environmental data called EDC (Environmental Data Collector) onboard a cubesat developed and qualified by INPE. The ground and application segments will also have their capability enhanced with these missions.

Currently, CONASAT-1 is the first satellite of the CONASAT/GOLDS constellation, it is a Cubesat 1U standard satellite which objective is to test in flight the EDC transponder developed by INPE, which decodes in flight the signals received from PCDs (Platforms for Data Collection) belonging to the SBCDA. The CONASAT/GOLDS constellation aims to update and expand the SBCDA, which is a message forwarding system developed by INPE, in operation since 1993, based on low-orbit (LEO) satellites.

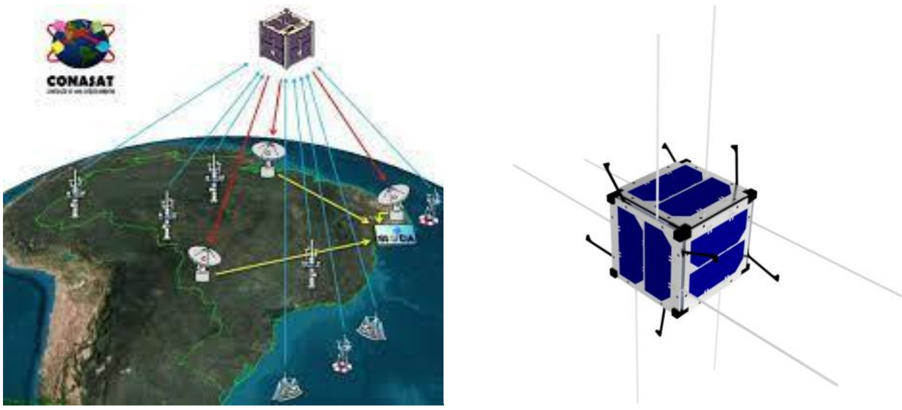

Figure 5: CONASAT-1: the 1st nanosat for data collection constellation [11].

The main results expected with CONASAT are: (1) Guaranteed operation of the SBCDA. (2) Increase in SBCDA's revisit capacity. (3) Increase in the number of SBCDA stations (PCDs) installed in the national territory and (4) Improvement of the environmental data collection service offered by the SBCDA.

6.2 The GOLDS Constellation

The GOLDS Constellation stands for “Global Open coLlecting Data System” and it is a collaborative nanosat constellation for environmental monitoring which will provide data for scientists, government institutions and private companies in the country. GOLDS gathers initiatives on the modernization of the SBCDA (Brazilian Environmental Data Collection System).

The purpose of this monitoring system is to provide data for scientists, government institutions and private companies in the country being used in a wide variety of applications, related to environmental protections, awareness, study or protecting human life, such as weather forecasting, studies of ocean currents, tides, atmospheric chemistry, agricultural planning, monitoring of the watershed, river and rain gauge data, monitoring fishing vessel route, among others.

The cubesat-2D GOLDS-UFSC will soon compose the GOLDS. The constellation will reduce the costs to provide quality of service with regards to capacity, geographic coverage and revisit times. Finally, GOLDS will support in different applications: weather forecasting, studies of ocean currents, tides, atmospheric chemistry, agricultural planning, monitoring of the watershed, river and rain gauge data, monitoring fishing vessel route, etc. It will open several possibilities for business and science cooperation in space Applications.

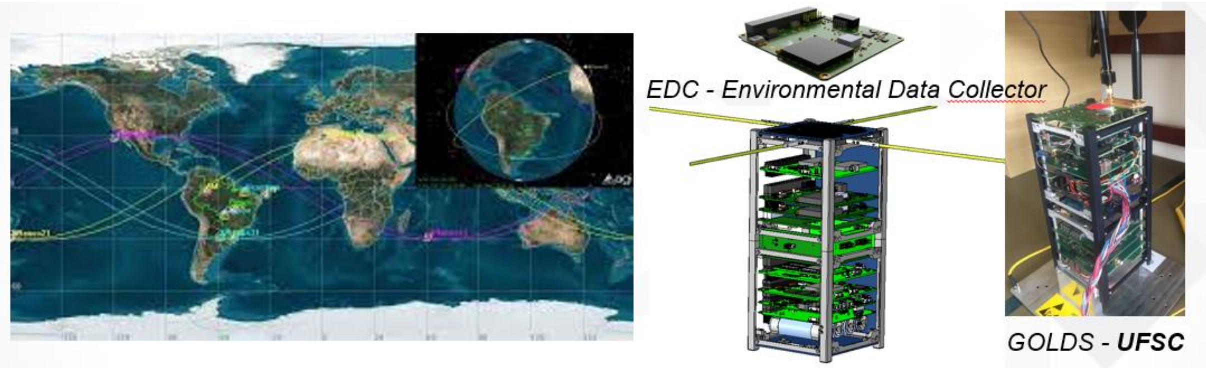

Figure 6: GOLDS Constellation [13] - "Global Open coLlecting Data System"

7 Conclusions

As the demands and opportunities for small satellites applications are increasing rapidly, INPE has decided to start a dedicated division, named DIPST, for strengthening the small satellites area as well benefitting from it towards major satellite challenges. This work presented the current and prospective projects / activities being performed by DIPST: technical consultancy and knowledge dissemination; lower the risks and costs on space missions; prototyping with stratospheric balloons flights in the BalloonSat concept and lowering the risks on COTS components. A key DIPST task is supporting the development cycle of new technologies to reach the maturity level so that they may be incorporated in larger satellites.

DIPST is involved in a myriad of initiatives such as: (a) the SPORT nanosat ground operations which launch is due very soon; (b) environmental data collection nanosats constellations like GOLDS and CONASAT; (c) climate change-related nanosatellites like BiomeSat, for monitoring forests health mainly and RaioSat, for monitoring lightning event, using a multimission platform P-10; (d) larger platforms as P-30 and P-100 which will be used in, respectively, the TuriSat for forests fires in Amazonia will use and EQUARS, a space weather science mission.

We believe if we succeed in gathering all the resources for the completion of these projects, the coming years will be quite challenging but with a singular opportunity to create new frontiers to the country´s space engineering and cater for their underlying applications.

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