R&D and Plans for Small Satellite Missions

Ricardo Galvão

11th September 2018
“Modern microsatellites revolutionized space in the same way that the personal computer (PC) revolutionized computing. The low cost of entry to space afforded by small satellites and their growing capabilities enabled any nation, government department, small companies, and individual universities to access space directly in an affordable and low risk manner.”

“There is no doubt that nanosatellites and especially the CubeSat standard has greatly increased access to space for smaller organizations and especially educational establishments; however, there has been a very high failure rate.”

“Small satellites have become fashionable and form a major component of the so-called “NewSpace” environment that tends to imply initiatives led by business and industry with private funding, rather than the more traditional model led by government agencies.”


In this scenario, what role should be played by a large government research institute like INPE?
Routine Space Technology Activity in INPE

Medium (500 to 1000 kg) and Large Satellites (> 1000 kg)

CBERS 4A
Amazônia 1
Routine Space Technology Activity in INPE LABORATORY OF INTEGRATION AND TESTING
Should INPE develop its own general program on small satellites?

“Constructive” Alternatives

- Capacity building
- Play the role of open installation giving specialized support to more ambitious projects
- Develop a program concentrated on special relevant applications or advancement of small satellite technology
- Develop a program focused on scientific applications of small satellites

“Hindrance” Policy

- Develop a program that competes with those suitable for development in universities and startup companies.
Kleber Naccarato - 2017 Symposium

BRAZILIAN’S CUBESATS’ INITIATIVES

- **NANOSATC-BR1 (UFSM / INPE)**
  - 2014, 1U Architecture, 600km Altitude, [http://www.inpe.br/crs/nanosat/](http://www.inpe.br/crs/nanosat/)
  - Assess data from South America Magnetic Anomaly & Brazilian’s Ionospheric Electrojet

- **SERPENS-1 (AEB)**
  - 2015, 3U Architecture, International Collaboration
  - UnB, Univ. Vigo, Sapienza, Cal Poly, Morehead, UFSC, UFMG, UFABC, IFF

- **CONASAT**
  - First CubeSat constellation (in development)

- **Tancredol (UbatubaSat Project)**
  - 2017, TubeSat (~10x13cm), [http://www.ubatubasat.com/](http://www.ubatubasat.com/)

- **ITASat-1 (ITA)**
  - 6U Architecture (in development)

- **AESP-14 (ITA / LIT-INPE)**
  - 2015, 1U Architecture, 400kn

- **NANOSATC-BR2 (2U)**
  - Langmuir Probe (CEA / INPE)
  - Magnetometer (UFSC/UFRGS)
  - Altitude Control System (INPE / UFMG / UFABC)

**SPORT - Scintillation Prediction Observations Research Task**

- International cooperation: NASA / AEB / CEA-INPE / ITA
- To study ionosphere plasma bubbles, which severe compromise / block satellite signal transmissions from / to Earth
- Scientific payloads: Ion Velocity Meter, GPS Occultation Receiver, Electric Field Probe, Langmuir Probe, Fluxgate Magnetometer and Swept Impedance Probe

- **ITASat-2 (ITA)**
- **SERPENS-2 (AEB)**
- **FloripaSat (UFSC)**
- **14BISat (IFF)**
- **Tancredol-2 (UbatubaSAT Project)**
“Although microsatellites are physically small, they are nevertheless complex vehicles that exhibit virtually all the characteristics of a large satellite. This makes them particularly suitable as a focus for the education and training of scientists and engineers by providing a means of direct, hands-on experience at all stages and in all aspects (both technical and managerial) of a real satellite mission—from design, production, test, and launch through to orbital operation.”

1º CubeDesign
SmallSats, big ideas
Tragam seus satélites e mostrem que são os melhores Engenheiros Espaciais!
Winter Contest on Cube Satellites
Winter Contest on Cube Satellites
Outreaching Activities
2018 Meeting of the Brazilian Society for Advancement of Science
Open Support Infrastructure for Advanced Projects
Space Engineering and Technology

CPRIME

Center for Integrated Projects of Space Missions

(improved phase zero analysis $\rightarrow$ decrease failure rate)

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<th>Systems</th>
<th>Telecommunication</th>
<th>Ground Systems</th>
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<td>Operations</td>
<td>Power system</td>
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<td>Orbit analysis</td>
<td>Layout</td>
<td>Launching alternatives</td>
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<td>Payloads</td>
<td>Mechanisms</td>
<td>Development approaches</td>
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<td>Altitud and Orbit Control</td>
<td>Structures</td>
<td>Risk analysis</td>
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<td>Propulsion</td>
<td>Thermal control</td>
<td>Cost analysis</td>
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<tr>
<td>Inboard supervision</td>
<td>COTS analysis</td>
<td></td>
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</table>
CPRIME

Momentos de um estudo no CPRIME, 2016.
Integration and Testing - LIT

Vibration/Mass properties Interface developed by AESP-14 Team

MGSE for 1U (Developed by AESP-14)

ISL/ISIS 1U Vibration Test-POD
NANOSATC-BR1 (1U) Assembly, Integration and Tests

- Vibration tests
- Thermal Vacuum Test
- Bake-out procedure
- Mass Properties (mass, MOI and CoG)

With support of LSIS/LIT staff for Flight Model integration and testing specifications.
SUCHAI (1U - Chile) Environmental Tests

- EM and FM environmental testing
- Vibration tests
- Thermal Vacuum Test
- Mass Properties
Program concentrated on special relevant applications or advancement of small satellite technology
CONASAT PROJECT - CRCRN

Develop a low cost solution for the Brazilian System of Environment Data Acquisition

Brazilian System of Environmental Data Collecting Platforms
CONASAT PROJECT - CRCRN

SCD-1 (1993)

SCD-2 (1998)

1m × 1.5m; 115kg
25°, 750 Km Circular orbit
14 revolutions/day

Constelation of CubeSats

CONASAT - 1

8U CubeSat
CONASAT PROJECT - CRCRN

www.crn2.inpe.br/conasat
NANOSAT PROJECT - CRCRS

Get data from South America Magnetic Anomaly & Brazilian Ionospheric Electrojet

Offer hands-on training for Aerospace Engineering students of University of Santa Maria

NANOSATC-BR Ground Station – GS

GS(CRCSR) Santa Maria, RS

GS(CRCSR) São José dos Campos
NANOSAT PROJECT - CRCRS

Get data from South America Magnetic Anomaly & Brazilian Ionospheric Electrojet

NanosatC-BR1
Operating for over four years

http://www.inpe.br/crs/nanosat/
EQUARS
Equatorial Atmosphere Research Satellite
(Low-High atmosphere coupling processes leading to plasma bubbles)

~120 kg; equatorial orbit; 15° inclination; 635 km
3 axis stabilized platform; NADIR pointing
**EQUARS**

Equatorial Atmosphere Research Satellite

(Low-High atmosphere coupling processes leading to plasma bubbles)

- **GROM**
  - GPS receiver to employ the radio occultation method

- **IONEX**
  - HFC – high frequency capacitive probe receiver
  - LP – Langmuir probe
  - ETP – Electron temperature probe

- **ELISA**
  - Electrostatic Energy Analyzer
  - 1 to keV

- **APEX**
  - Alpha, Proton, and ElectronfluXes
“CubeSat-derived NanoSats would hit significant challenges as they begin to work in deep space. Radiation tolerance on CubeSats has always been hit-or-miss. But as science missions require certain lifetime guarantees, radiation tolerance has become more of an issue.”

Heavy-ion damage tests of FPGA-based SpaceWire component in the Pelletron Accelerator of USP
“Deep” Space Research

NASA Research Announcement

Astrophysics Science SmallSat Studies

Solicitation: NNH18ZDA001N-AS3

Dates
Release
AS318 Proposals Due

Feb 14, 2018
Jul 13, 2018

Announcement Documents

▷ DUE DATES: Table 2 lists all program elements in due date order (.HTML)
▷ DUE DATES: Table 3 lists all program elements in appendix order (.HTML)
▷ ROSES 2018 Summary of Solicitation (.PDF)
▷ Complete ROSES 2018 NRA as amended and clarified as of August 24, 2018 (.PDF)
▷ D.1 Astrophysics Research Program Overview (.PDF)
▷ D.15 Astrophysics Science SmallSat Studies corrected April 18, 2108 (.PDF)

Other Documents

▷ Frequently Asked Questions as of June 12, 2018 (.PDF)

Program Element Information

▷ Research Opportunities in Space and Earth Sciences 2018 (ROSES-2018)
“Deep” Space Research

Small Satellites: A Revolution in Space Science 2014

New mission concepts:
“Identify new concepts uniquely enabled by the small satellite platform”

Many relevant questions in astrophysics, heliophysics, and planetary science require

“new observation approaches such as spacecraft constellations, and/or continuous all-sky observing coverage, or sensors that are in-situ and/or in extreme environments that are simply not feasible via stand-alone large and expensive missions”
How to Boost the Brazilian Space Program?

“Deep” Space Exploration!
The ASTER Mission:
Exploring for the first time a triple-system asteroid

- Elbert E. N. Macau
  - Instituto Nacional de Pesquisas Espaciais – INPE

- Othon C. Winter
  - Univ. Estadual Paulisat – UNESP

- Haroldo F. Campos Velhos
  - INPE

- ASTER Technological Development Team

- Brazil
The Goal: A Near Earth Asteroid!

- Asteroids are believed to have formed early in our solar system's history—about 4.5 billion years ago—when a cloud of gas and dust called the solar nebula collapsed and formed our sun and the planets.
- By visiting them we can look for answers such as:
  - how did the solar system form?
  - where did the Earth's water and other organic materials such as carbon come from?
- We may learn more about past Earth impacts and possibly find ways to reduce the threat of future impacts.
Target: triple asteroid system 2001 SN263

- It is the only C-type triple NEA known;
- C-type asteroids hold clues to the origin of the solar system, formation of planets, origins of water and life on Earth;
- C-types are dark, with low albedos, and so difficult to study from Earth.

In February 2008, radar images taken at the Arecibo Observatory revealed the first near-Earth triple asteroid system.

Orbital and physical elements.

<table>
<thead>
<tr>
<th>Asteroid</th>
<th>Orbit</th>
<th>a</th>
<th>e</th>
<th>I</th>
<th>Period</th>
<th>Diameter</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sol</td>
<td>1.9887 UA</td>
<td>0.4779</td>
<td>6.6889°</td>
<td>≈2.8 años</td>
<td>2.8 km</td>
<td>M₁ ≈ 1.1494 × 10¹³ kg</td>
</tr>
<tr>
<td>2</td>
<td>Asteróide 1</td>
<td>17 km</td>
<td>*</td>
<td>*</td>
<td>≈147 horas</td>
<td>1.1 km</td>
<td>M₂ ≈ 7.9 × 10⁻² M₁</td>
</tr>
<tr>
<td>3</td>
<td>Asteróide 1</td>
<td>4 km</td>
<td>*</td>
<td>*</td>
<td>≈46 horas</td>
<td>0.4 km</td>
<td>M₃ ≈ 5.7 × 10⁻³ M₁</td>
</tr>
</tbody>
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Aster spacecraft

- To be developed, integrated and test in Brazil;
- Collaboration with IKI – Space Research Institute of Russian Academy of Science;
- Other international collaborations are welcome.

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<tbody>
<tr>
<td>Initial wet mass</td>
<td>152 to 157 kg</td>
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<tr>
<td>Scientific payload</td>
<td>30 to 35 kg</td>
</tr>
<tr>
<td>Propellant (Xe)</td>
<td>66 to 71 kg</td>
</tr>
<tr>
<td>Nominal power</td>
<td>2.1 kW</td>
</tr>
<tr>
<td>Area of solar panels (As-Ga):</td>
<td>5 m²</td>
</tr>
<tr>
<td>Thrust of 1 thruster</td>
<td>80 to 90 mN</td>
</tr>
</tbody>
</table>
ASTER: subsystem development made by Brazilian companies

- Intelligent material: antenna and magnetometer;
- Star sensor
- Electric propulsion:
  - Kaufman-type ion thruster (PION): station-keeping
  - Permanent Magnet Hall Thruster (PMHT): main propulsion
- On-board computing system
- Laser Range Finder
- Infrared Spectrometer
- Multi-Band Imaging Camera
- Plasma e astrobiological experiment
Pre-Symposium Hands-on Workshop