



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

CUBESATS, A MISSÃO NANOSATC-BR E ALÉM

Danilo Pallamin de Almeida - INPE

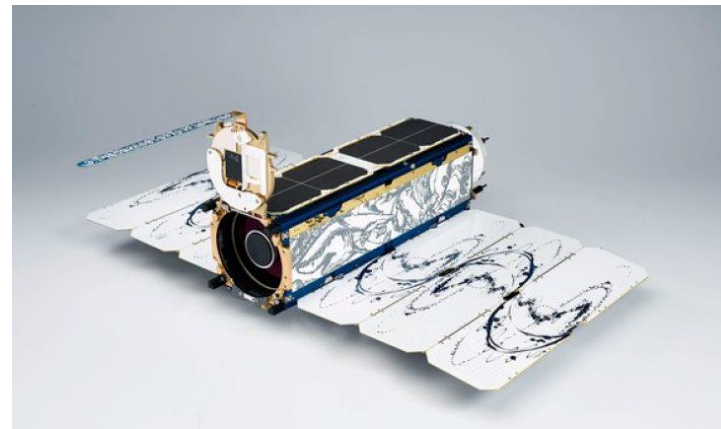
Dr. Otávio Durão – INPE

Marcelo Essado - EMSISTI

Curso de Inverno; INPE; Jul. 2018.

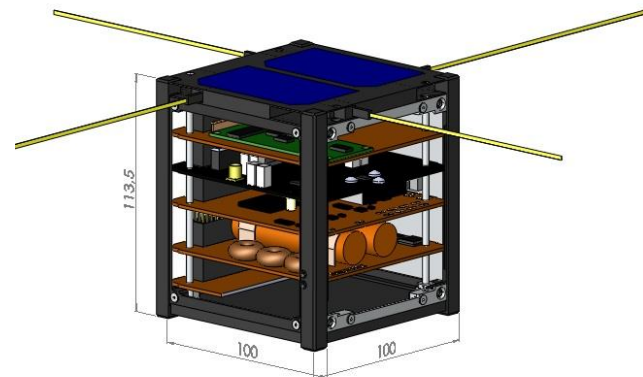
O que são CubeSats?

- Histórico
 - Stanford – Bob Twiggs e CalPoly, El Bispo, CA
 - Padrão surge em 1999 como referência de design
 - Primeiro lançamento 2003
 - Padrão – cubo com 10cm de aresta e ~1kg de massa
 - CubeSat design specification (CDS); rev. 13 (2013)
 - Proposta inicial – formação prática de RH
 - Alunos de Pós passando pelo desenvolvimento completo de um satélite

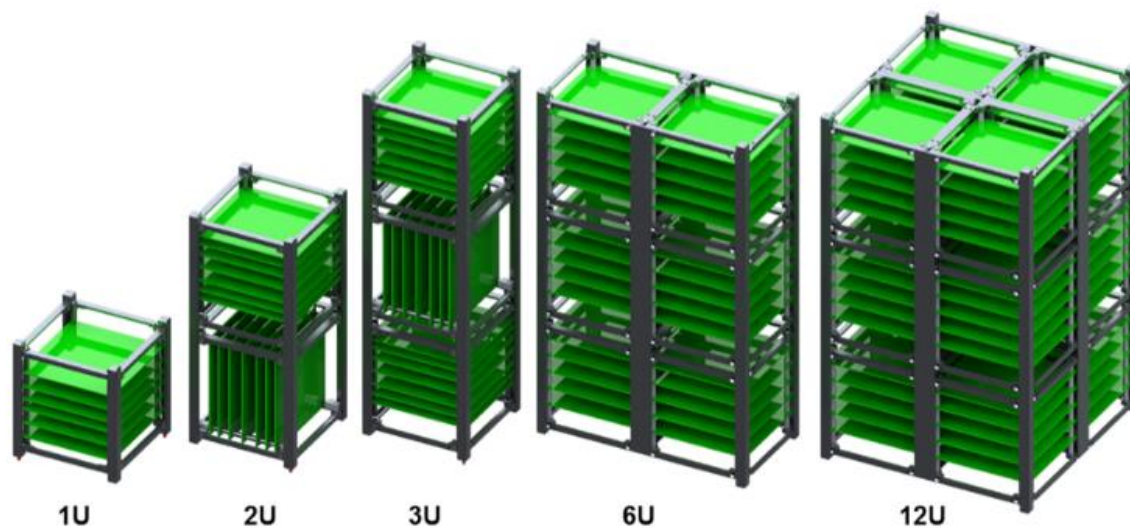


CubeSat – padrão

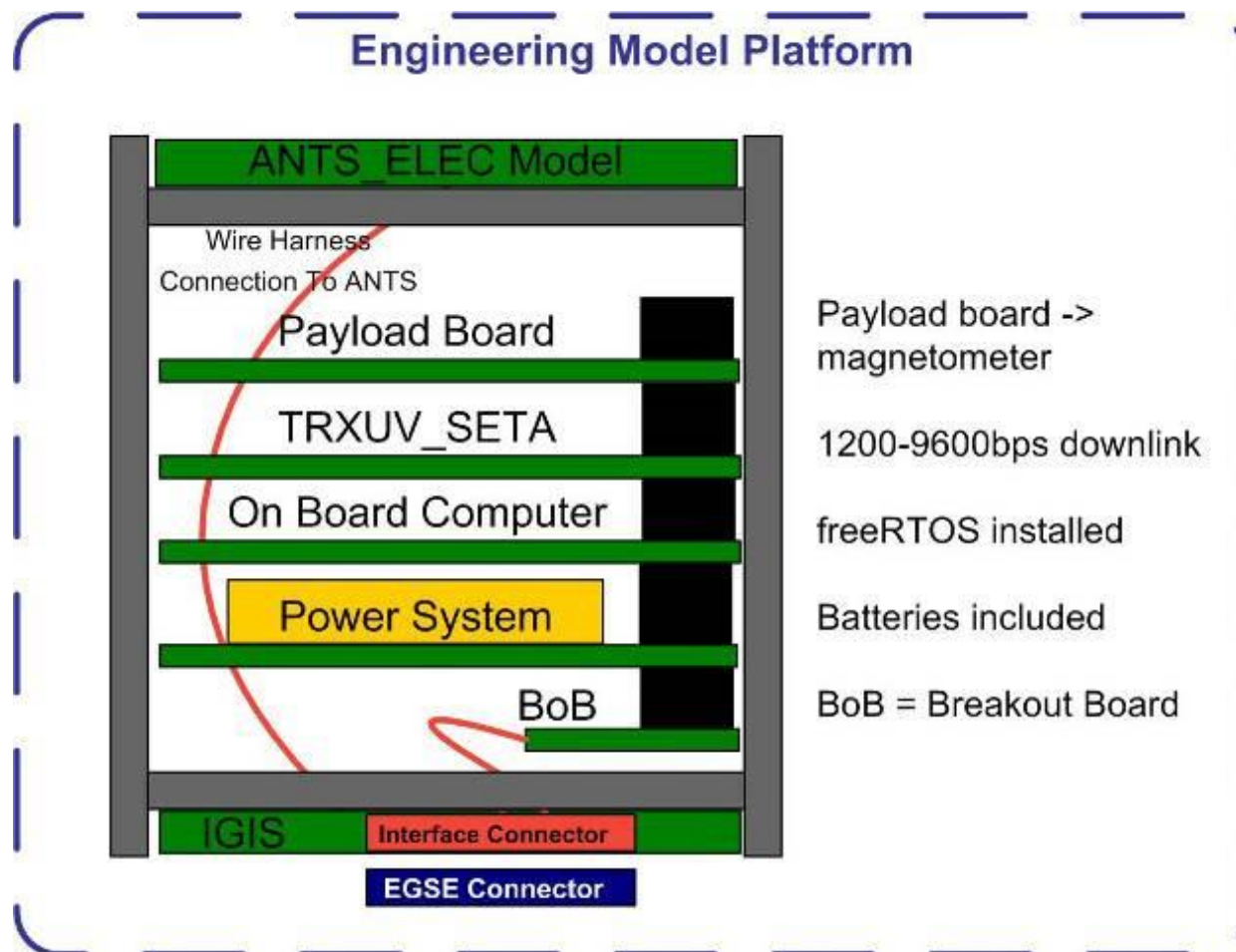
Class	Mass (kg)
Large satellite	>1000
Medium satellite	500 to 1000
Mini satellite	100 to 500
Micro satellite	10 to 100
Nano satellite	1 to 10
Pico satellite	0.1 to 1
Femto satellite	<0.1



Cubesat Size Comparison



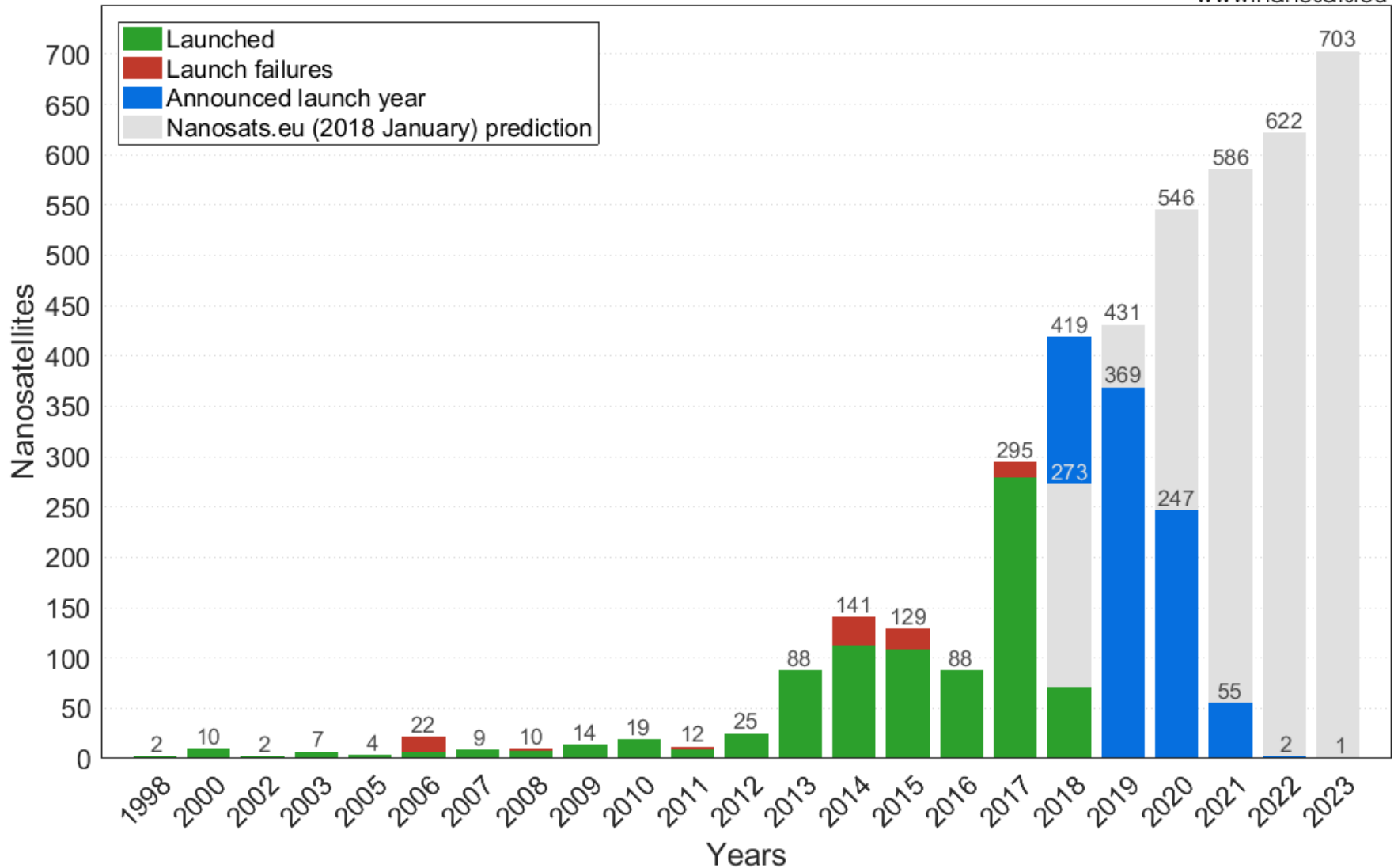
Padrão 1U



Lançamento de Nanosatélites

Nanosatellites by launch years

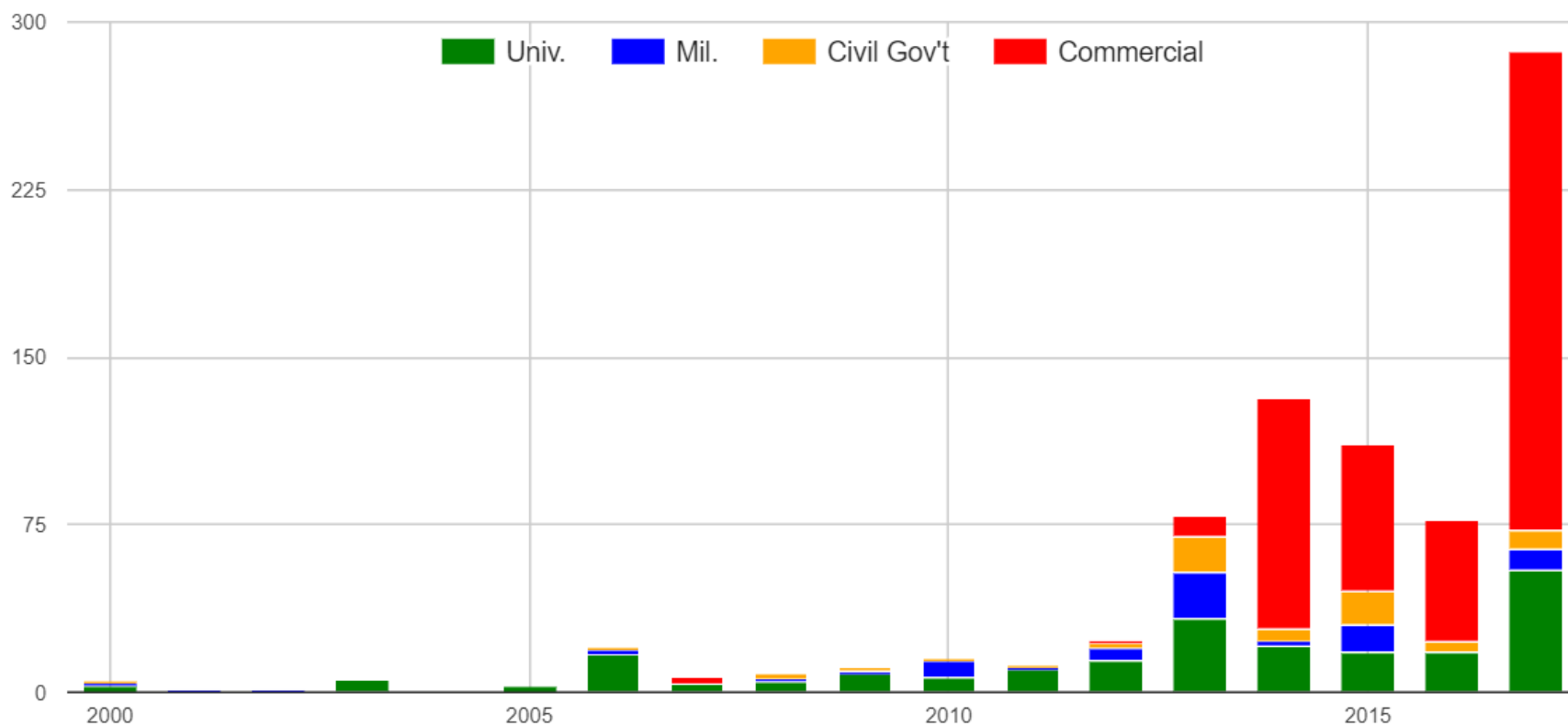
www.nanosats.eu





Usos de CubeSats

CubeSats Each Year by Mission Type

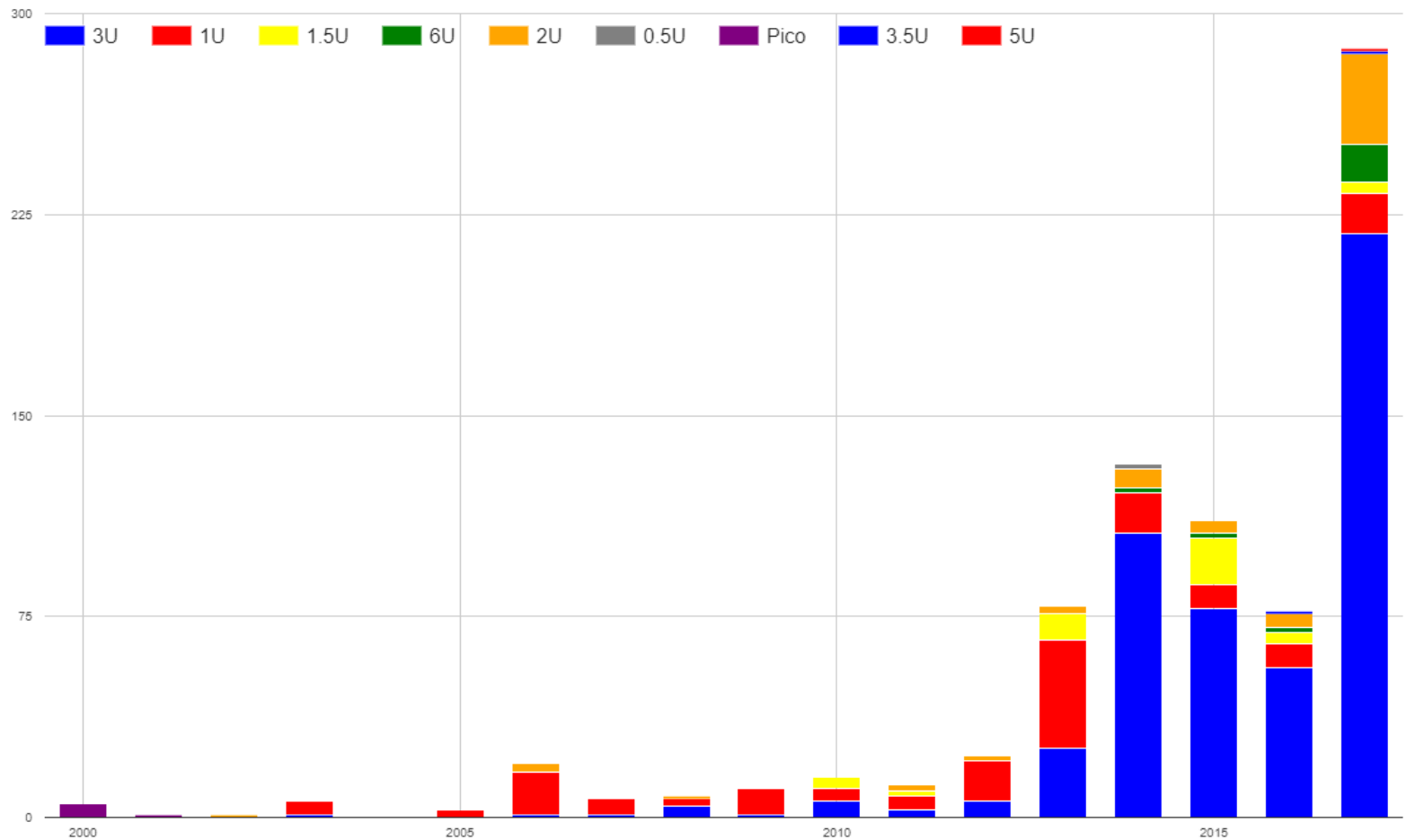


[Chart created on Fri Jun 29 2018 using data from M. Swartwout]



Formatos de CubeSats

CubeSats Each Year by Form Factor



[Chart created on Wed Jul 04 2018 using data from M. Swartwout]

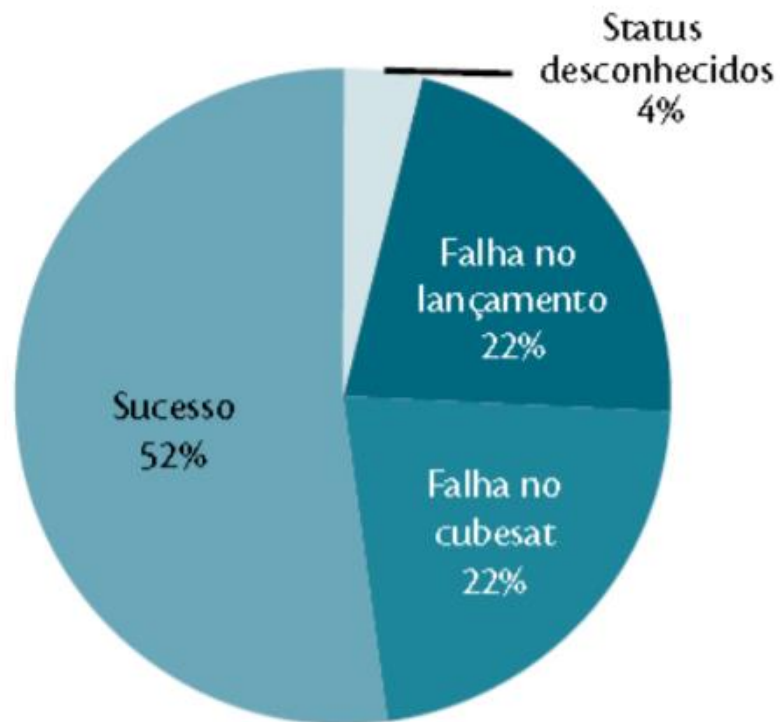


CubeSats X Satélites Tradicionais

- | | |
|----------------------------------|---------------------------------|
| ■ Baixos custos, prazos, equipes | ■ Altos custos, prazos, equipes |
| ■ Uso extensivo de COTS | ■ Componentes Space-Grade |
| ■ Otimização de Testes | ■ Série extensa de testes |
| ■ Requisitos Flexíveis | ■ Requisitos rigorosos |
| ■ Tolerância a riscos | ■ Aversão a riscos |
| | |
| ■ Baixa confiabilidade | ■ Alta confiabilidade |
| | |
| ■ Modelo de Engenharia | ■ Modelo de Engenharia |
| ■ Modelo de Vôo | ■ Modelo Estrutural |
| | ■ Modelo Térmico |
| | ■ Modelo Radioelétrico |
| | ■ Modelo de Qualificação |
| | ■ Modelo de Vôo |

Success Rate

421 cubesats lançados no
período 2005 - 2015





Why fly CubeSats?

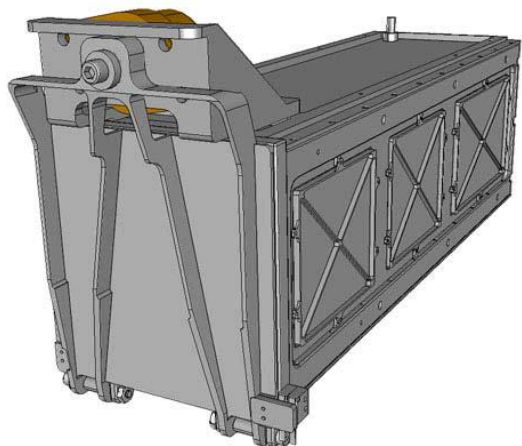
- “Nothing teaches systems engineering like, well, doing systems engineering.”
- Dedicated “simple” science missions
- New tech validation
- Fast development
- High Risk - High Reward

Lançamento

- **Carona**
- Baixo custo; em torno de US\$100.000 por U p/ LEO
- Lançamento terciário em foguetes
- Lançado pela ISS
 - Levadas como carga (SpaceX)



Interface com o lançador



PSLV





Ta, mas e o Brasil?

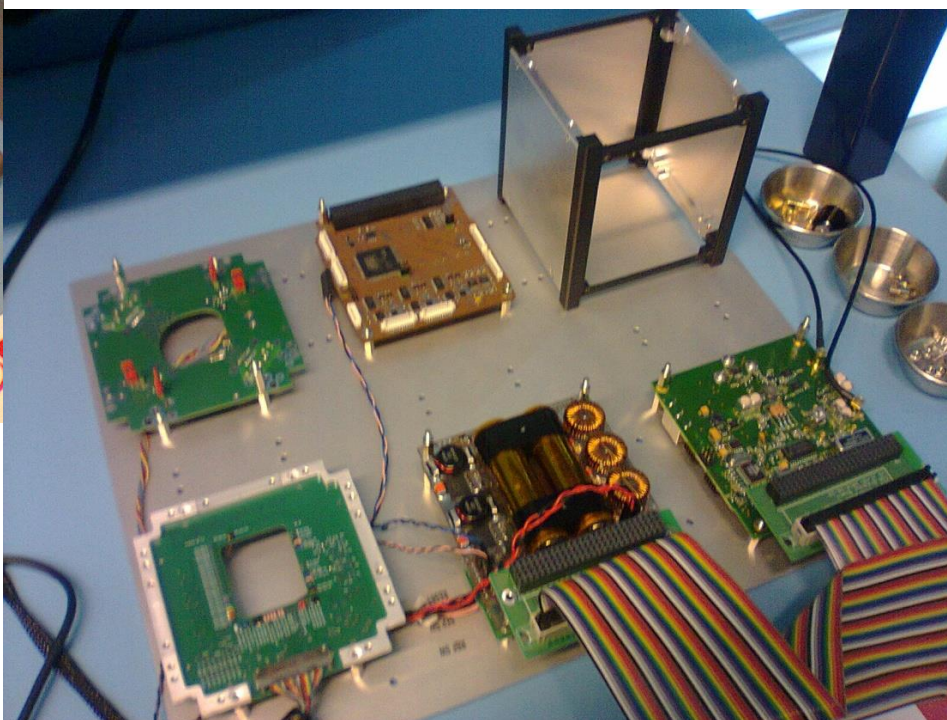
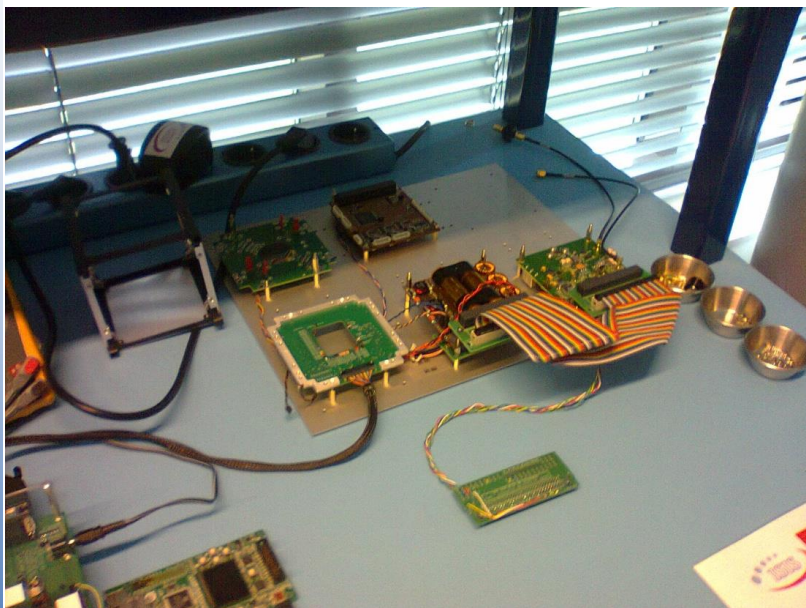
- INPE/UFSM – NanosatC-Br1 (1U, lançamento 19 de Junho de 2014) e NanosatC-Br2 (2U, 2019)
- INPE/UFRN – Conasat (8U, missão SCD)
- ITASAT – 6U (Pronto p/ lançamento)
- AESP-14 – ITA - lançado em 2015
- SERPENS – UnB; 2015
- UbatubaSat - Jan/2017
- Garatéa - Airvantis/USP São Carlos
 - Garatéa-L - Missão Lunar 6U 2022
- INPE/NASA - SPORT 6U
- AKAER - Câmera 3U



NanosatC-Br1

- Cooperação INPE/CRS e UFSM
- Objetivos
 - Missão científica – magnetômetro; medidas do campo magnético na AMAS
 - Missão tecnológica – testes de CI's projetados no Brasil para uso espacial (resistentes à radiação – pioneiros)
 - FPGA com software tolerante a falha e driver on/off
 - Acadêmicos – formação de alunos de graduação e pós
- Compra da plataforma e estação; e desenvolvimento da carga útil, AIT e operação.
- **Imersão do INPE e Brasil em tecnologias cubesat-related**

NanosatC-Br1: plataforma

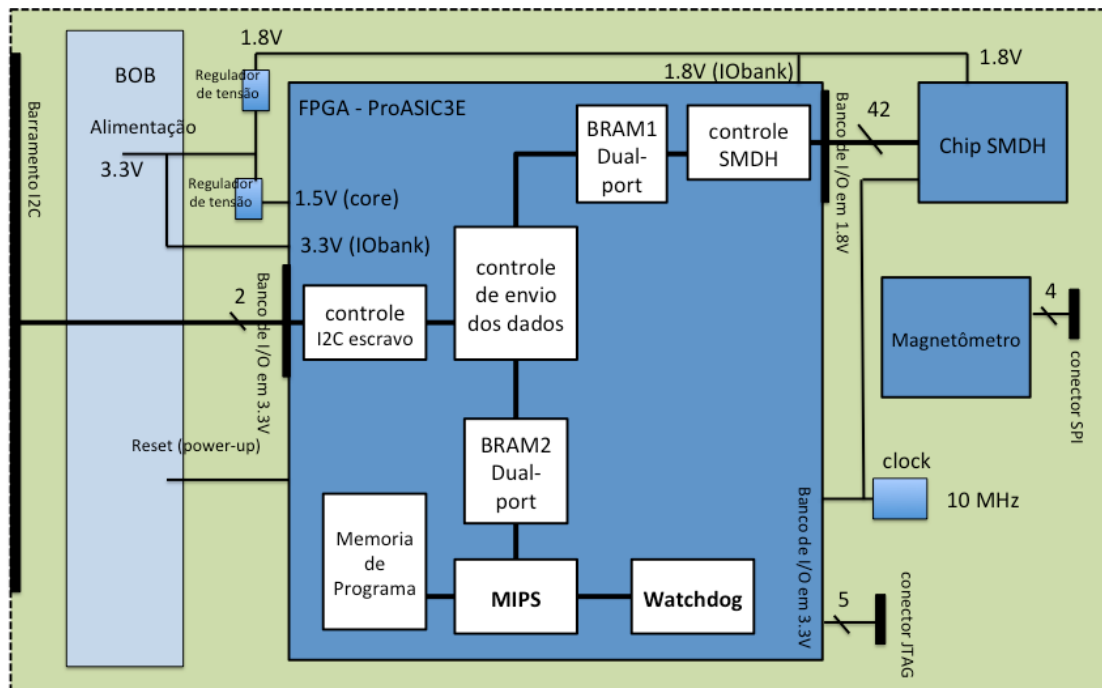




NanosatC-Br1: cargas úteis

- Magnetômetro – XEN1210, 2x2x4 mm., 3 eixos + eletrônica
- Projeto SMDH
 - Projeto com proteção à radiação; pioneiro no país
 - Demanda do INPE/DEA/PMM
- FPGA
 - UFRGS – Lab. Informática
 - Resistência à radiação por software tolerante a falha; pioneiro no país; testado em solo no IEAv. para dose acumulada.
 - Componente industrial

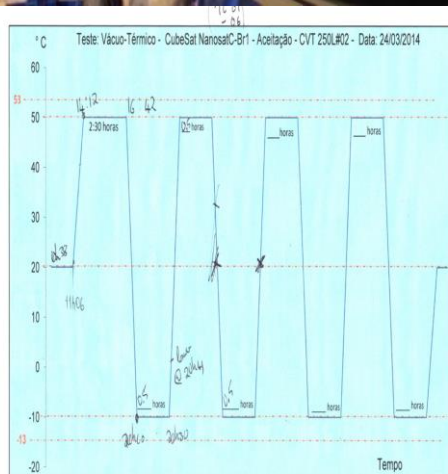
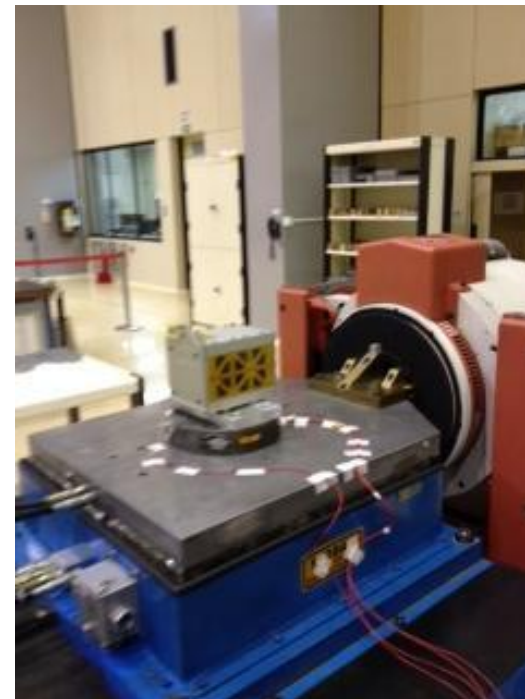
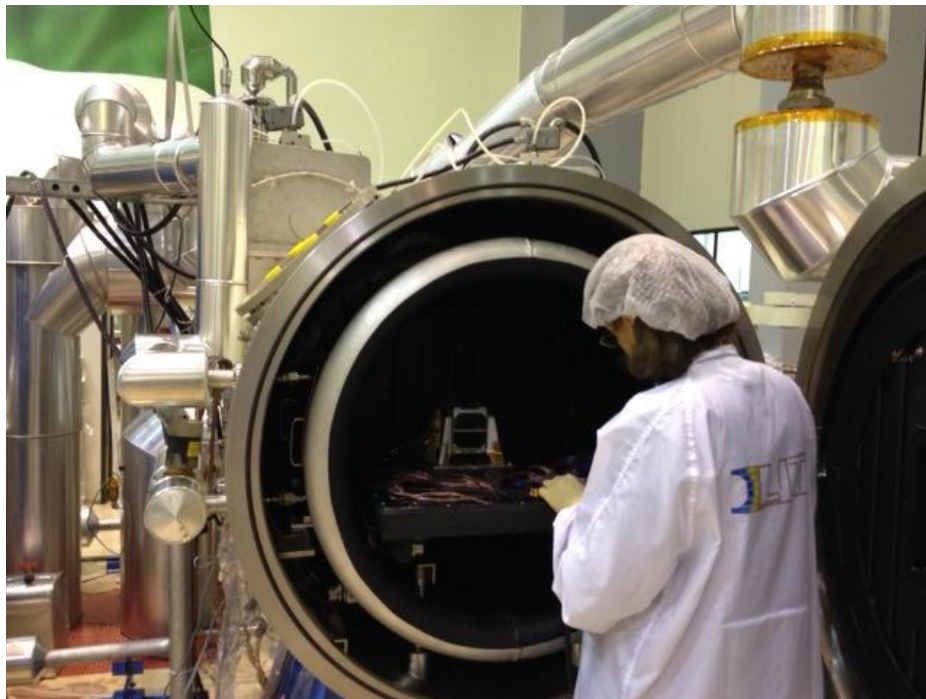
Placa de carga útil do NanosatC-Br1



NanosatC-Br1 - Integração



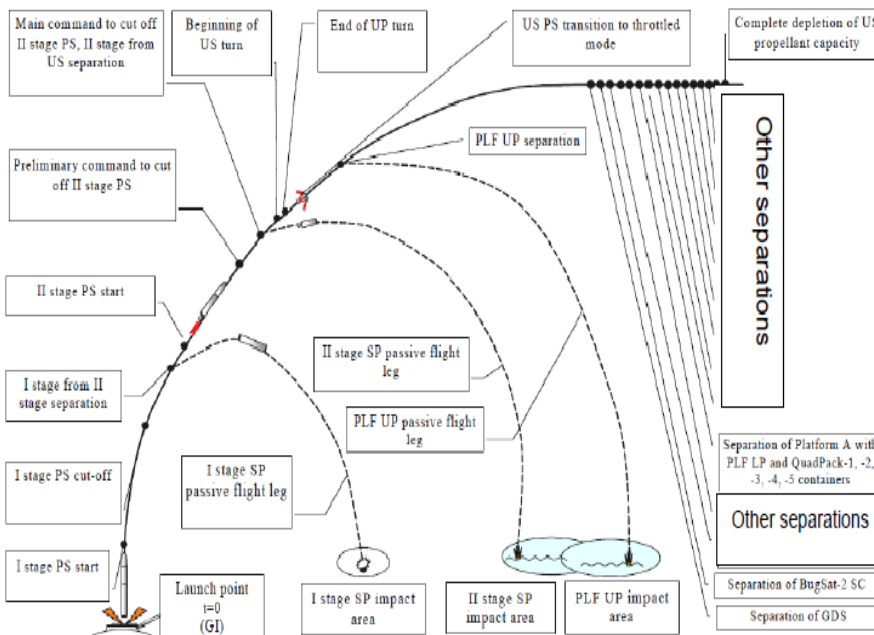
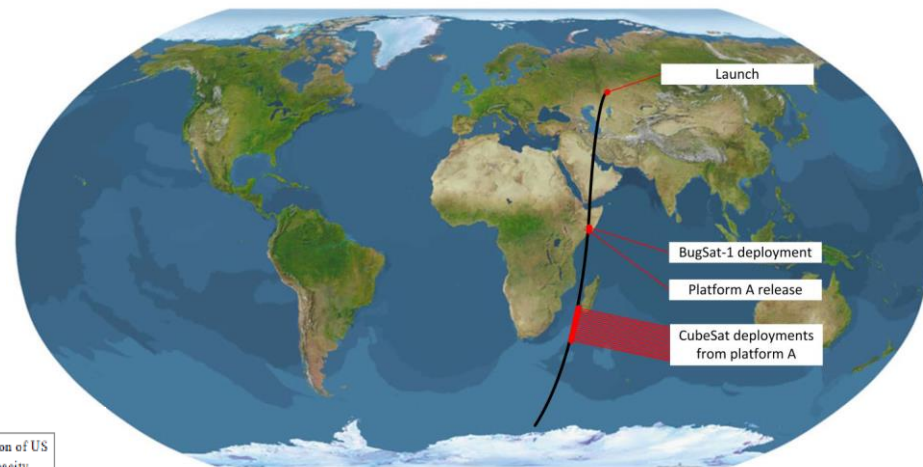
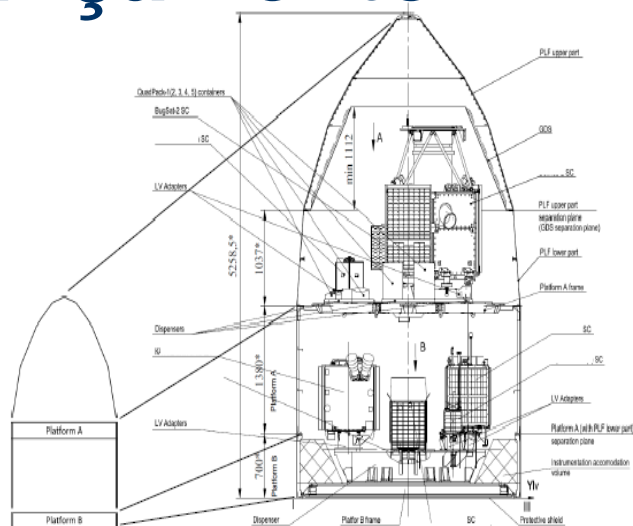
Testes: vibração e vácuo/térmica



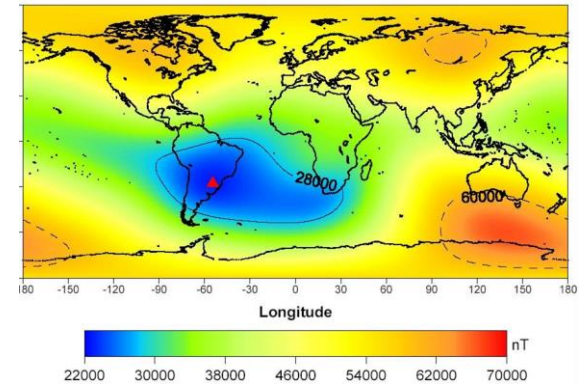
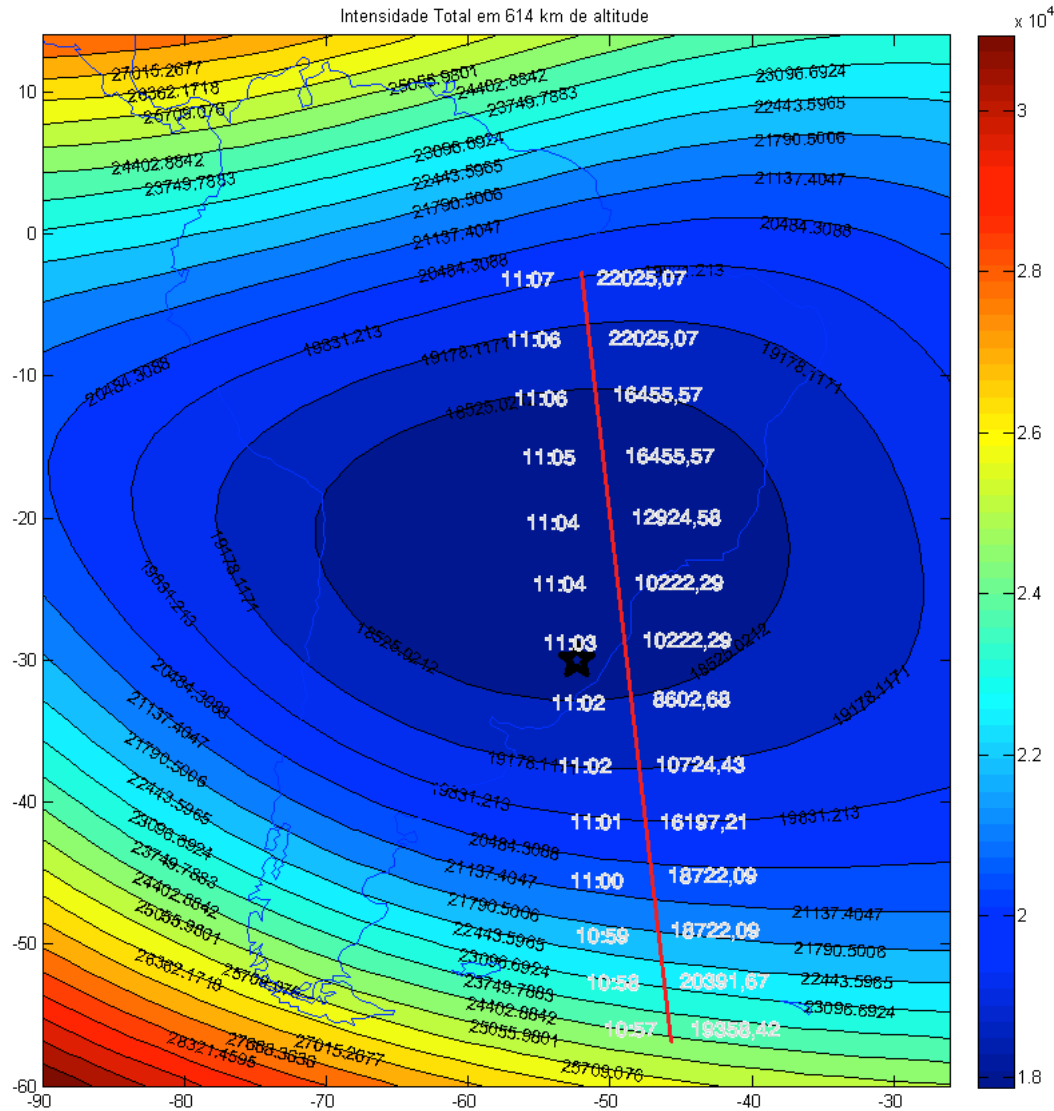
NanosatC-Br1: Lançamento - DNEPR



Lançamento



Resultados Científicos - AMAS

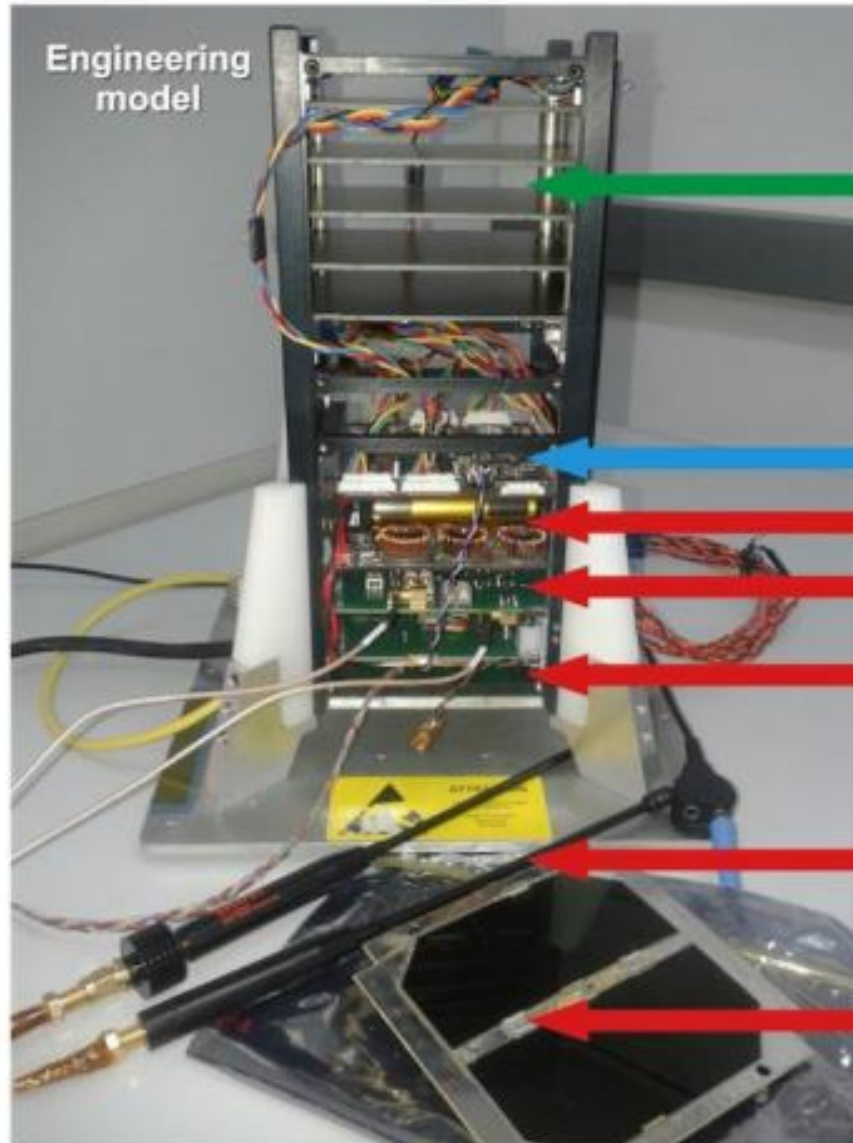


NanosatC-BR2

- Continuação do programa NanosatC-BR
- Desenvolvimento da **Missão e Software** pelo INPE
- 3 Cargas úteis físicas
 - Sistema de Determinação de Atitude Tolerante à Falhas (SDATF) - UFACB/UFMG
 - Sonda de Langmuir - INPE
 - Experimento MIPS - SMDH/UFRGS
- 2 Cargas úteis de software
 - Controle de Atitude (B-dot)
 - Exp. Radioamador



NanosatC-BR2



Engineering
model

Payloads

Magnetometer:	Measures intensity of a magnetic field.
SMDH ASIC:	Application Specific Integrated Circuit.
FPGA:	Field Programmable Gate Array.
Langmuir:	Measuring the numeric density of electrons, kinetic temperature and the spectral distribution of plasma irregularities.
ADS:	Attitude Determination System.

On-Board computer

Power supply

TRXUV VHF/UHF Transceiver

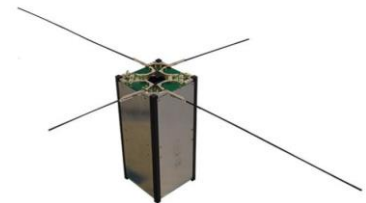
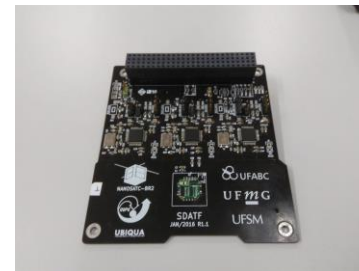
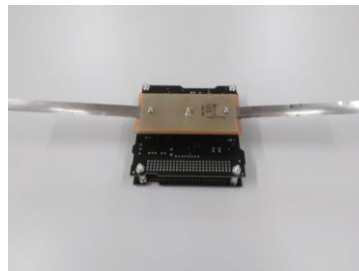
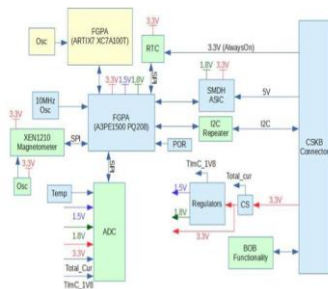
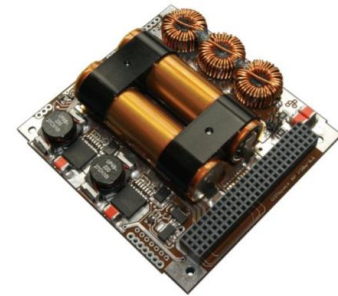
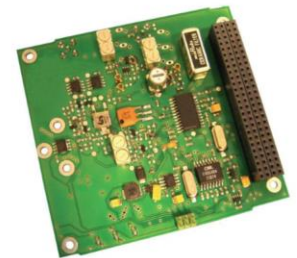
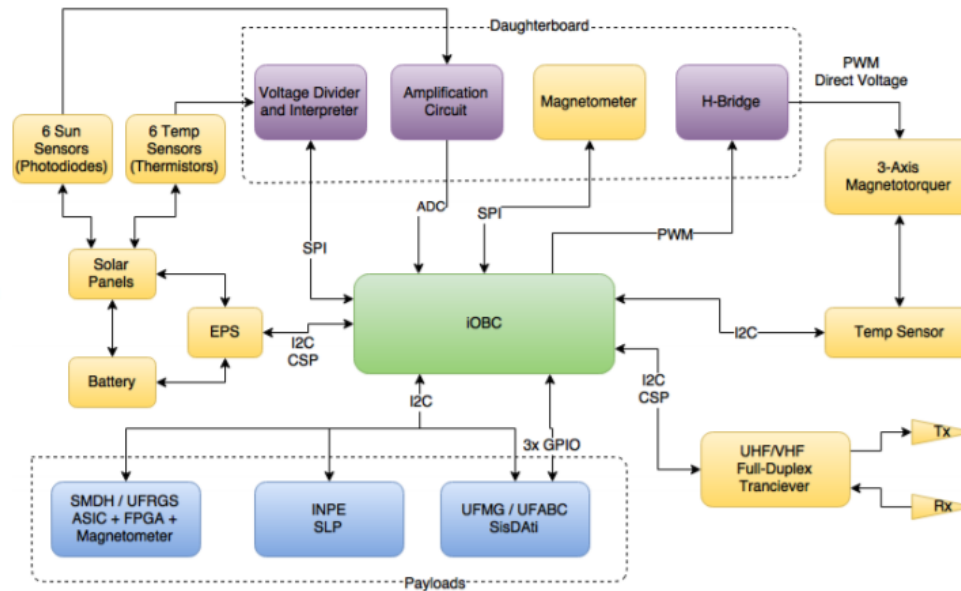
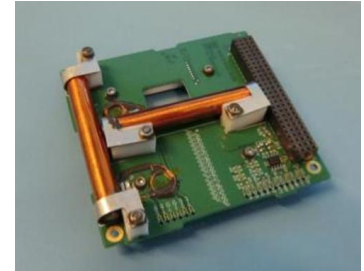
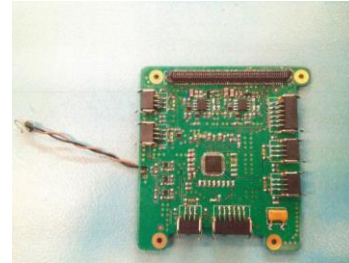
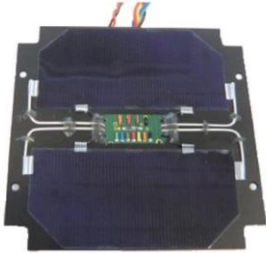
Interface between integrated satellite
and electronic equipment

Antenna

Solar panels

NanosatC-BR2

NCBR2: Bus + Cargas úteis



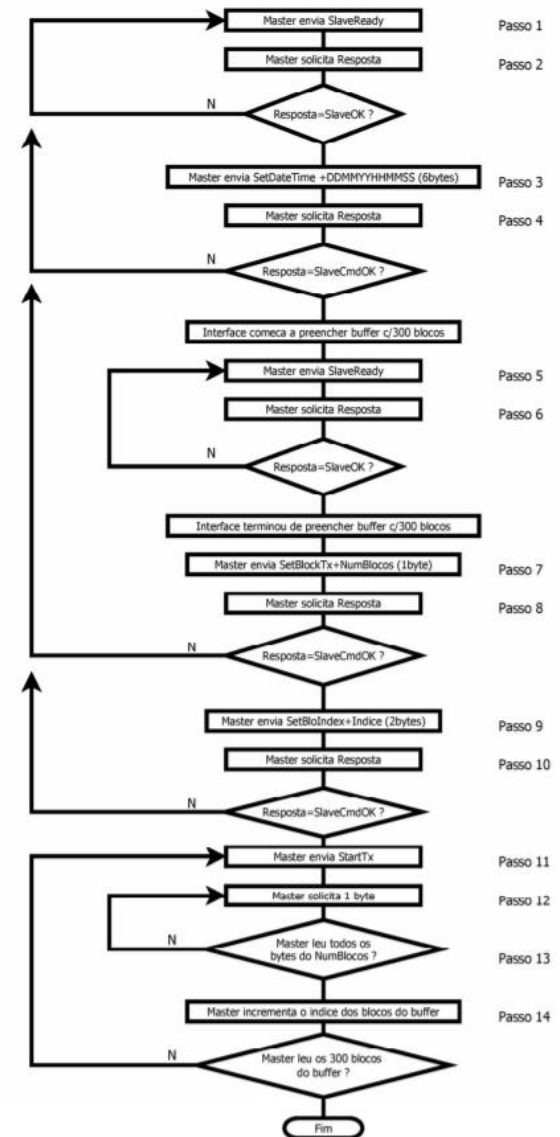
Modelos?



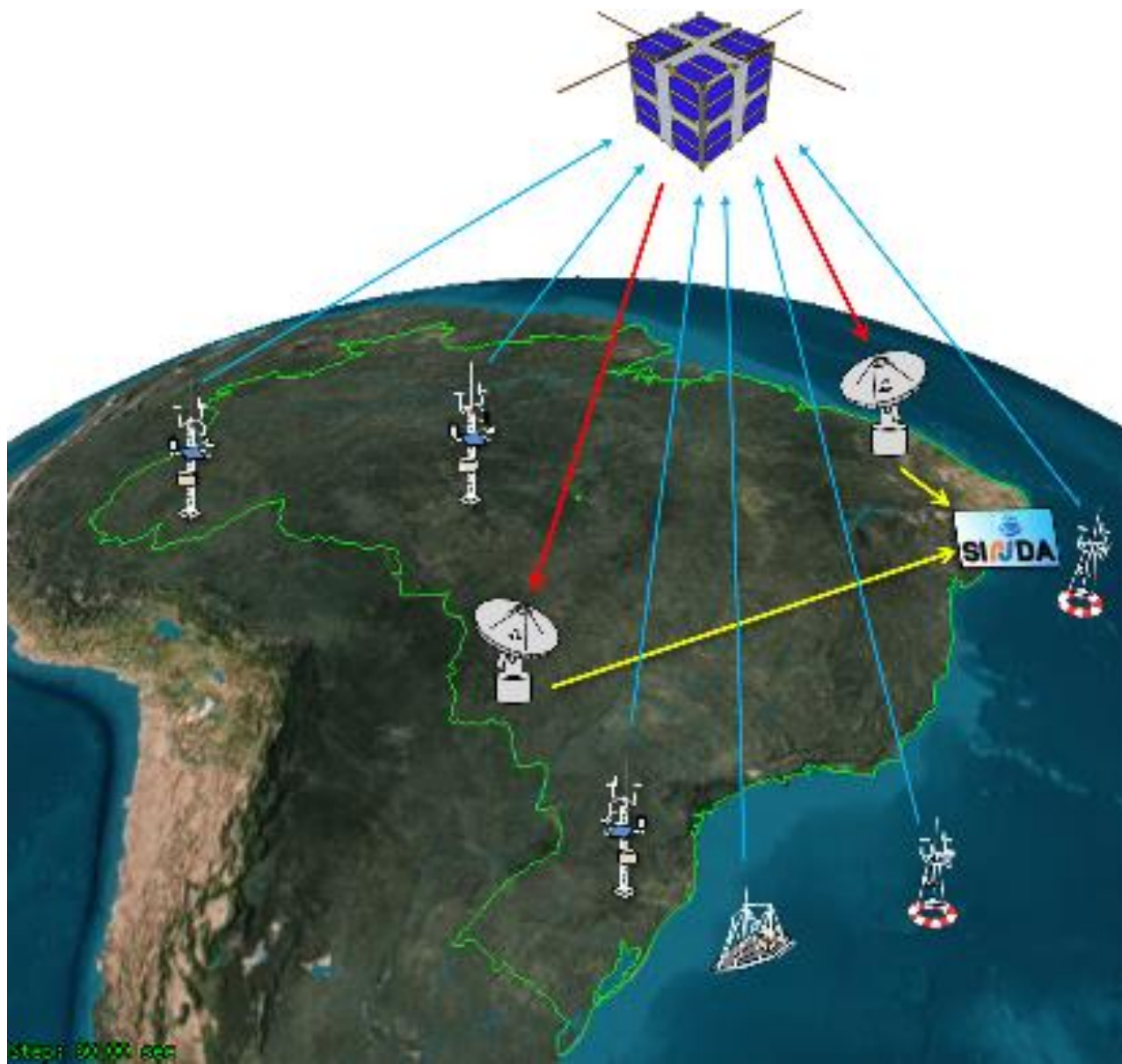
Mini-estágio

Além da minha agradável companhia:

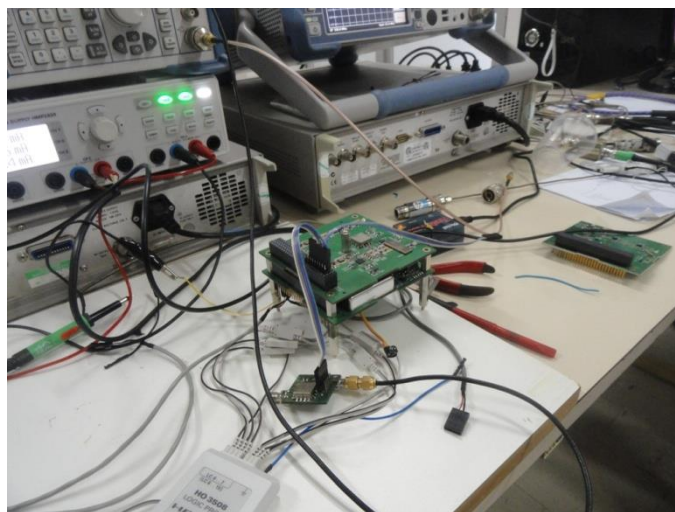
- Simular OBC + SLP com Arduino
 - Validação de Modelos
 - Interface I2C
 - Programação em C
- Coletar dados do magnetômetro
 - Análise e implementação de Datasheet
 - Interface SPI
 - Programação em C



CONASAT



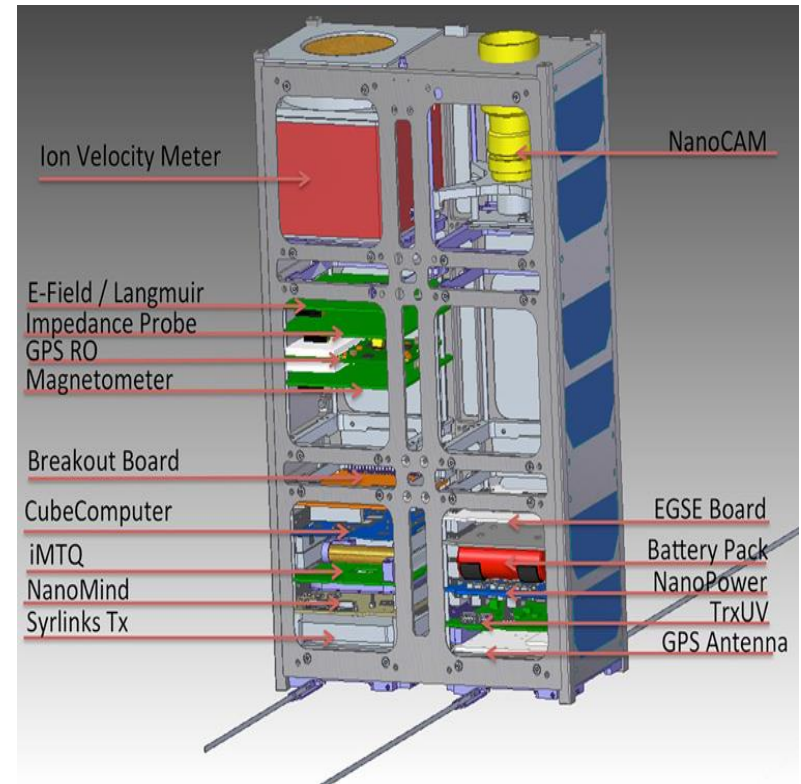
CONASAT: EM + payload



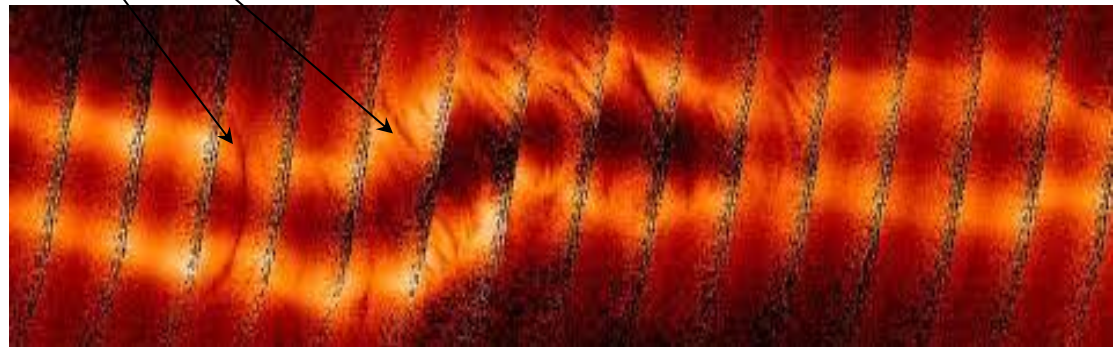
SPORT

Scintillation Prediction Observation Research Task

- Equatorial ionization anomalies
- Plasma Bubbles

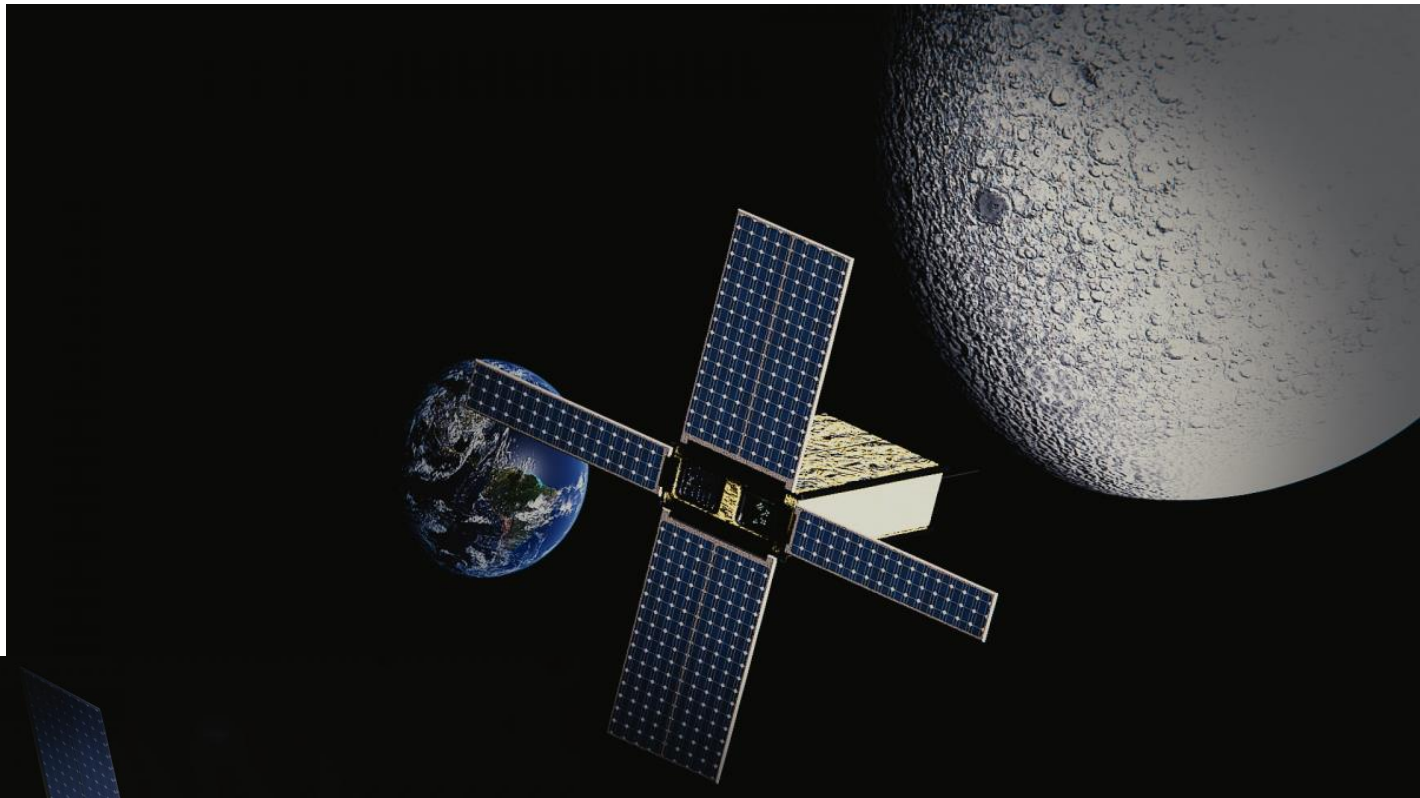


"why bubbles develop and rise to various altitudes at different times in different regions and latitude?"



Kil, Hyosub, et al. "Coincident equatorial bubble detection by TIMED/GUVI and ROCSAT-1." *Geophysical research letters* 31.3 (2004).

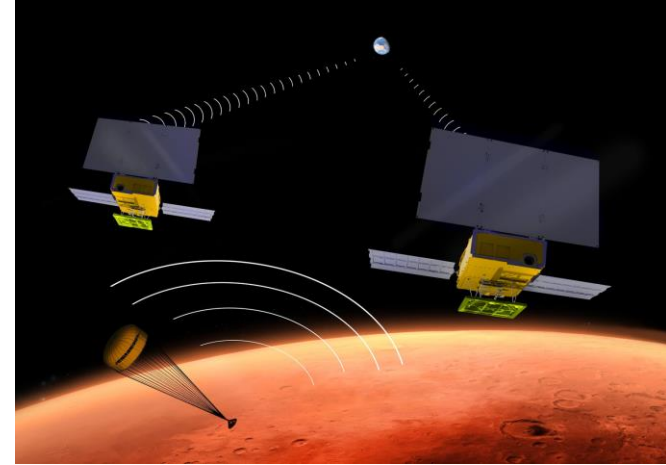
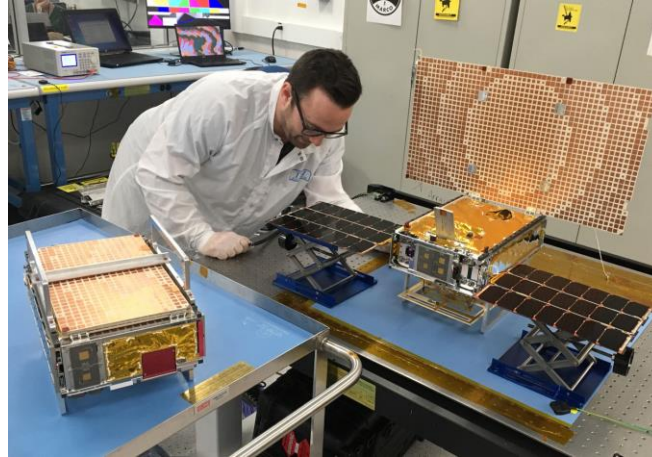
Garatéa-L (Iniciativa privada)



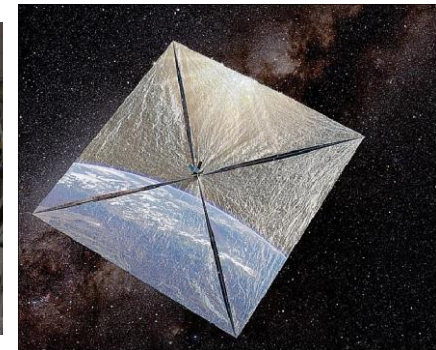
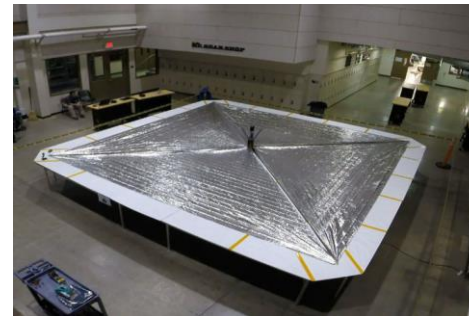
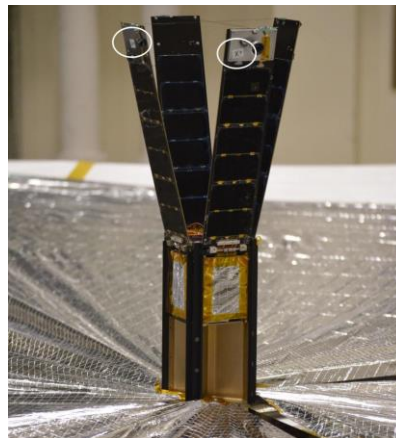


And beyond...

- MarCO (NASA)



- LightSail (Planetary Society)





Muito Obrigado!

- Mais infos acessem:
 - inpe.br/crs/nanosat/
 - garatea.space
 - nanosats.eu
 - www.jpl.nasa.gov/cubesat/missions/
 - www.planetary.org/

- danilo.pallamin@inpe.br