MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

SeCiAer
Seminário de Serviços Científicos e Aeronáuticos
De 01 a 04 de outubro 2018
São José dos Campos - SP

O Desenvolvimento de CubeSats no Brasil

Walter Abrahão dos Santos – DEA-ETE
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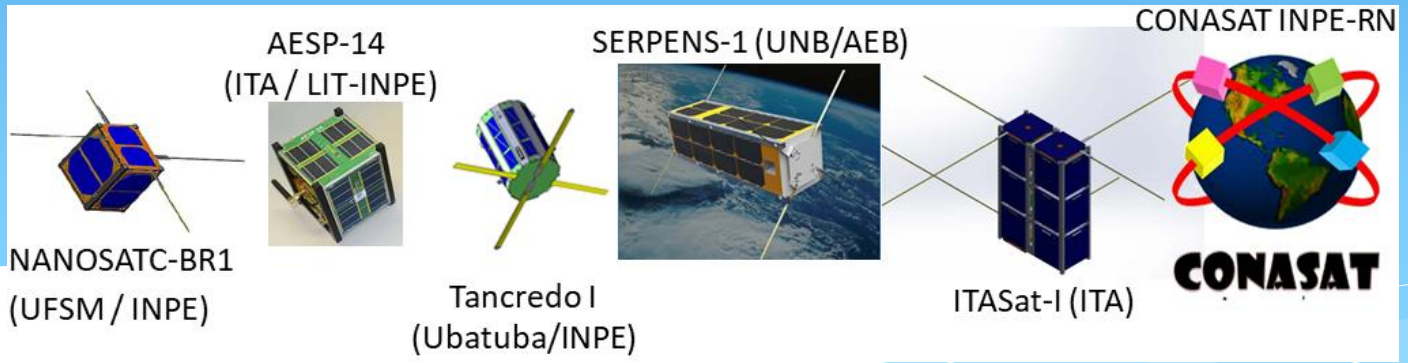
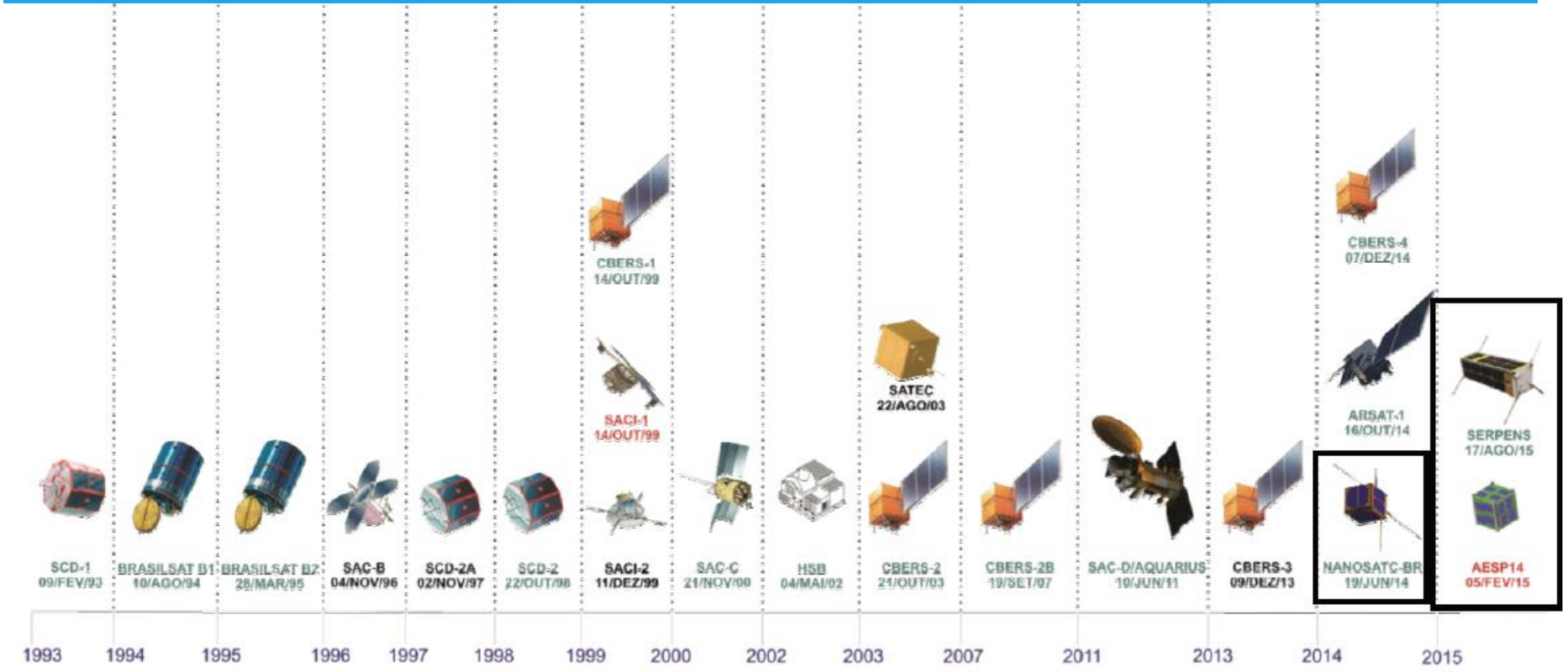
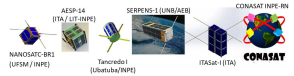


Agenda

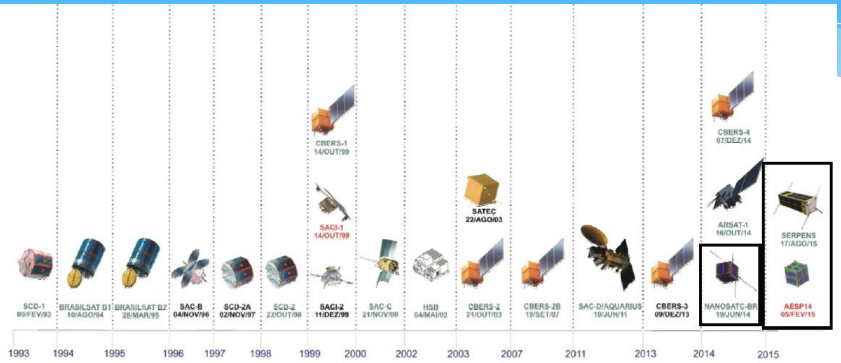
- INPE, seus satélites e Introdução a cubesats e seus padrões
- SmallSats no Brasil
- Algumas Projetos: AESP14, Tancredo I, NanoSatBR, CubeDesign, UNOOSA-BSTI
- Futuras Missões: CONASAT, FloripaSat, CCST-Sats, SPORT, Visiona VCUB1, SENAC, etc
- Picosatélites - Projeto UbatubaSat e Sonda de Langmuir
  - Integração, Lançamento, Estações Terrenas
- CubeDesign – Competição
- Encerramento / Perguntas

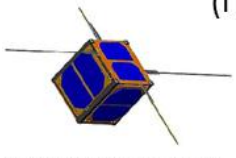
INPE, seus satélites e introdução a cubesats





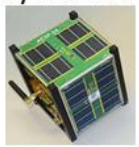
INPE, seus satélites e introdução a cubesats

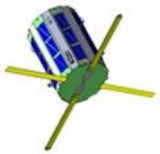




NANOSATC-BR1
(UFSM / INPE)

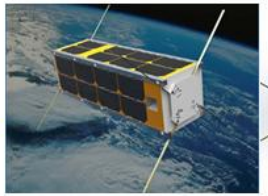
AESP-14
(ITA / LIT-INPE)

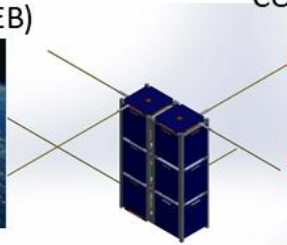




Tancredo I
(Ubatuba/INPE)

SERPENS-1 (UNB/AEB)





ITASat-I (ITA)

CONASAT INPE-RN

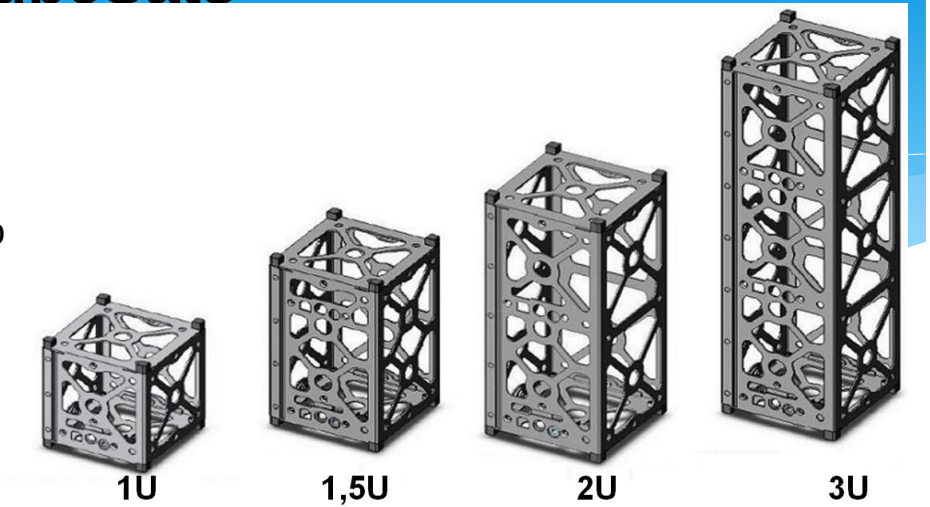
Classificação de satélite por massa

Classe	Massa (kg)
Satélite grande convencional	> 1000
Satélite pequeno convencional	500 a 1000
Minissatélite	100 a 500
Microssatélite	10 a 100
Nanossatélite	**1 a 10**
Picossatélite	**0,1 a 1**

Fonte: Fortescue (2003)

Padrões de CubeSats

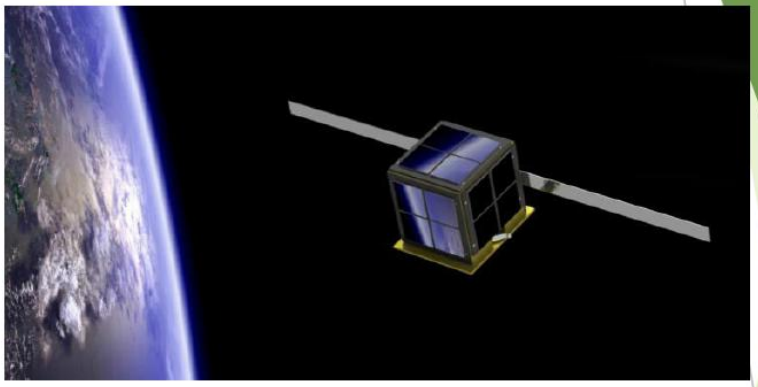
Cubesat
O cubesat — abreviação das palavras em inglês “cube” (cubo) e “sat” (satélite) — caracteriza-se por sua estrutura simplificada e custo reduzido: enquanto para o seu lançamento são gastos aproximadamente 100 mil dólares, para o de um satélite convencional os custos chegam a 250 milhões. Os satélites de pequeno porte, conhecidos como nanossatélites, também se distinguem pelo alto valor agregado.



O padrão cubesat foi desenvolvido em 1999, no contexto da tendência dos nanossatélites, com o intuito de fomentar a pesquisa universitária na área de Engenharia Aeroespacial. Seus idealizadores, Jordi Puig-Suari e Bob Twiggs, professores das universidades norte-americanas California Polytechnic State University e Stanford University, tinham o propósito de proporcionar aos estudantes de graduação e pós-graduação a possibilidade de projetar, construir, testar e operar um satélite semelhante ao Sputnik.

Cubesats in a Nutshell ...

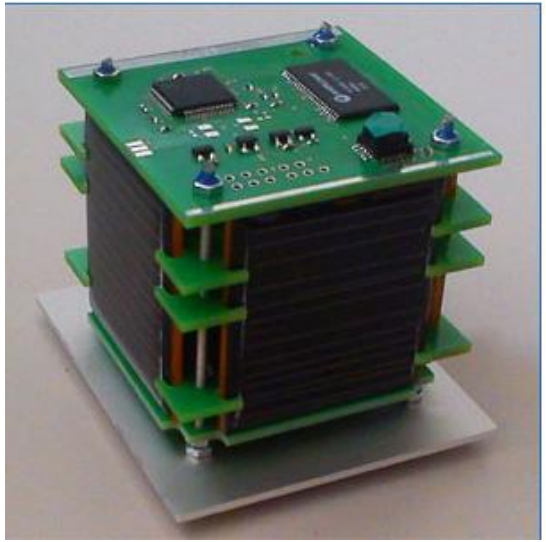
- A type of miniaturized satellite (U-class spacecraft) that is made up of **multiples of 10×10×10 cm cubic units**;
- Have a **mass of no more than 1.33 kg** per unit and often use **commercial off-the-shelf (COTS) components**;
- Can be put in orbit by **deployers on the ISS, or launched as secondary payloads on a launch vehicle**.
- In **1999, Cal Poly Univ. and Stanford Univ. developed the CubeSat specifications** to promote and develop the skills necessary for the design, manufacture, and testing of small satellites intended for low Earth orbit (LEO).
- **Academia accounted for the majority of CubeSat launches until 2013**. By 2014 most newly deployed CubeSats were for commercial or amateur projects that **perform a number of scientific research functions and explore new space technologies**.



Outros padrões de satélites miniaturizados

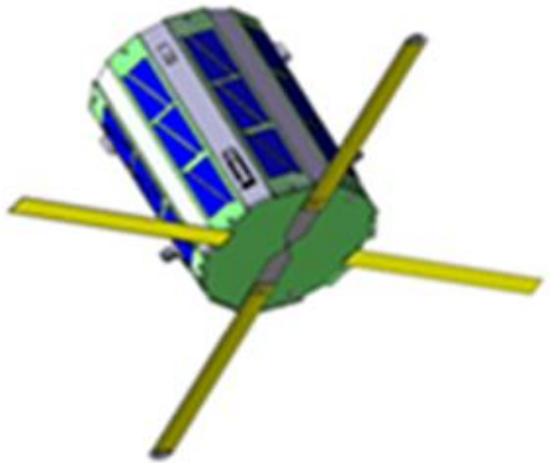
PocketQube

Padrão: 1P (5 cm x 5 cm x 5 cm)



WREN (Alemanha)

TubeSat (~10 x 13 cm)



Tancredo-I

SmallSats no Brasil

Inside the satellites

Structure, function and other features of Brazilian space devices

NANOSATC-BR1

Development INPE and UFSM
Type *Cubesat*
Dimensions 10 × 10 × 11.33 cm
Purpose Scientific-technological satellite
Onboard equipment Computing, power, radio, control and payload subsystems
Launcher Russian DNEPR rocket
Orbit altitude 600 km
Positioning Low polar orbit (complete revolution around the Earth every 90 minutes)
Time in space One year
Cost R$800,000

SERPENS

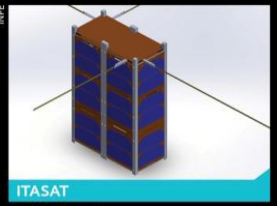
Development Consortium of universities, with support from AEB
Type Nanosatellite - 3U *Cubesat*
Dimensions 10 × 10 × 30 cm
Purpose Proof of concept for the Brazilian data collection system
Onboard equipment Digital transponder for data collection, onboard computer, power and communication system (duplicated)
Launcher International Space Station (ISS)
Orbit altitude 400 km
Positioning Low polar orbit
Time in space Less than 2 years
Cost R$800,000

AESP-14

Development ITA and Inpe
Type *Cubesat*
Dimensions 10 × 10 × 11.33 cm
Purpose Educational tool that will carry a message destined for Brazilian scientists as an experiment
Onboard equipment UHF-band modem to send messages
Launcher ISS
Orbit altitude 350–400 km
Positioning Low polar orbit
Time in space 90 days
Cost R$150,000

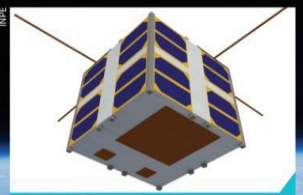
TANCREDO-1

Development Tancredo Neves Municipal School and INPE
Type *Tubesat*
Dimensions 9.7 cm diameter and 12 cm height
Purpose Educational
Onboard equipment Onboard computer, radio transmitter/receiver, antenna, power control subsystem and recorder on a chip
Launcher ISS
Orbit altitude 350 km
Positioning Equatorial orbit, the same as the station
Time in space Four months
Cost R$30,000 (without launch)



ITASAT

Development ITA and Inpe
Type Nanosatellite – 6U *Cubesat*
Dimensions 10 × 22.6 × 34 cm
Purpose Measurement of radiation and image collection
Onboard equipment Communication experiments, radiation and magnetic field sensors and camera
Launcher In the selection phase
Orbit altitude 600–700 km
Positioning Low polar orbit
Time in space One year of operation
Cost R$1.8 million (without launch)



CONASAT

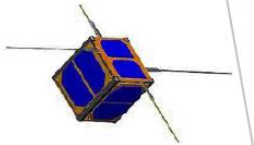
Development Inpe
Type Nanosatellite - 8U *Cubesat*
Dimensions 20 × 20 × 20 cm
Purpose Satellite for environmental data collection
Onboard equipment Computing, attitude control, telemetry and remote command subsystems and antennas
Launcher Not yet chosen
Orbit altitude 650 km
Positioning Low polar orbit
Time in space One year
Cost Forecast of R$5 million

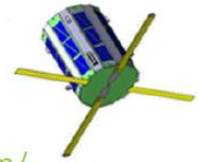
NASA

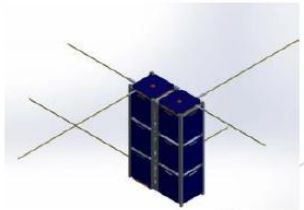
http://revistapesquisa.fapesp.br/en/2014/05/20/small-satellites-make-mark/

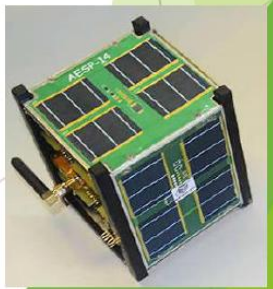
BRAZILIAN'S CUBESATS' INITIATIVES

- NANOSATC-BR1 (UFSM / INPE)
  - 2014, 1U Architecture, 600km Altitude, http://www.inpe.br/crs/nanosat/
  - **Assess data from South America Magnetic Anomaly & Brazilian's Ionospheric Electrojet**
- SERPENS-1 (AEB)
  - 2015, 3U Architecture, International Colaboration
  - UnB, Univ. Vigo, Sapienza, Cal Poly, Morehead, UFSC, UFMG, UFABC, IFF
- CONASAT
  - First CubeSat constellation (in development)
- Tancredo I (UbatubaSat Project)
  - 2017, TubeSat (~10x13cm), http://www.ubatubasat.com/
- ITASat-I (ITA)
  - 6U Architeture (in development), http://www.itasat.ita.br/
- AESP-14 (ITA / LIT-INPE)
  - 2015, 1U Architecture, 400km Latitude, http://www.aer.ita.br/~aesp14/





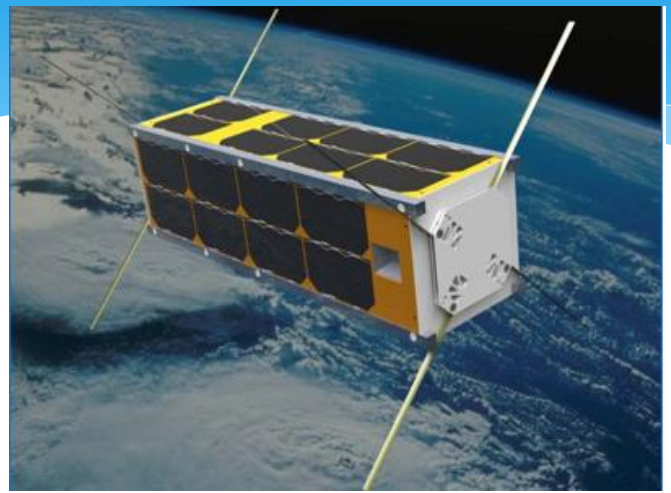




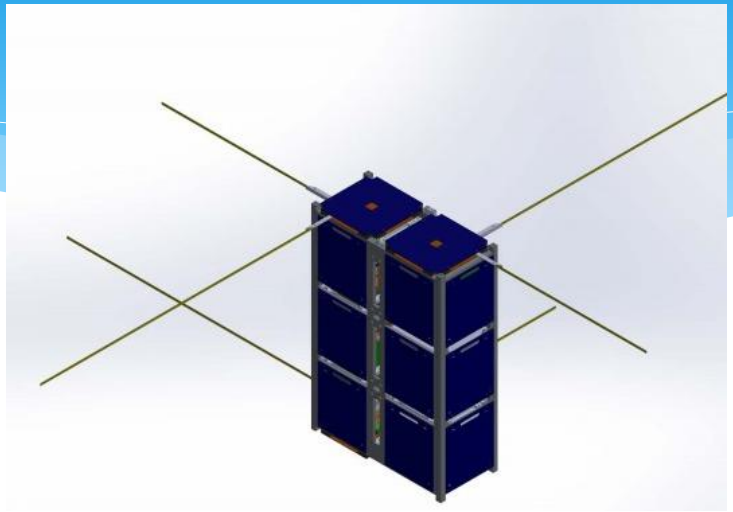
BRAZILIAN'S CUBESATS' INITIATIVES

- NANOSATC-BR2 (2U)
  - Langmuir Probe (CEA / INPE)
  - Magnetometer (UFSM/UFRGS)
  - Altitude Control System (INPE / UFMG / UFABC)
- SPORT - Scintillation Prediction Observations Research Task
  - International cooperation: NASA / AEB / CEA-INPE / ITA
  - To study ionosphere plasm 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)
- Tancredo-2 (UbatubaSAT Project)

SATÉLITES UNIVERSITÁRIOS



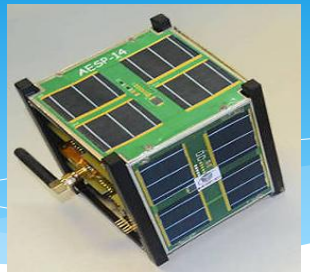
SERPENS: 3U (2015)
UnB / Universidade de Vigo
Outras Universidades: Sapienza (Roma)
CalPoly, Morehead, UFSC, UFMG,
UFABC, IFF



ITASAT: 6U

SATÉLITES MINIATURIZADOS

ISS



AESP-14

(ITA/INPE)

(2015)

400 km

SpaceX

Dragon

Falcon-9

P-POD

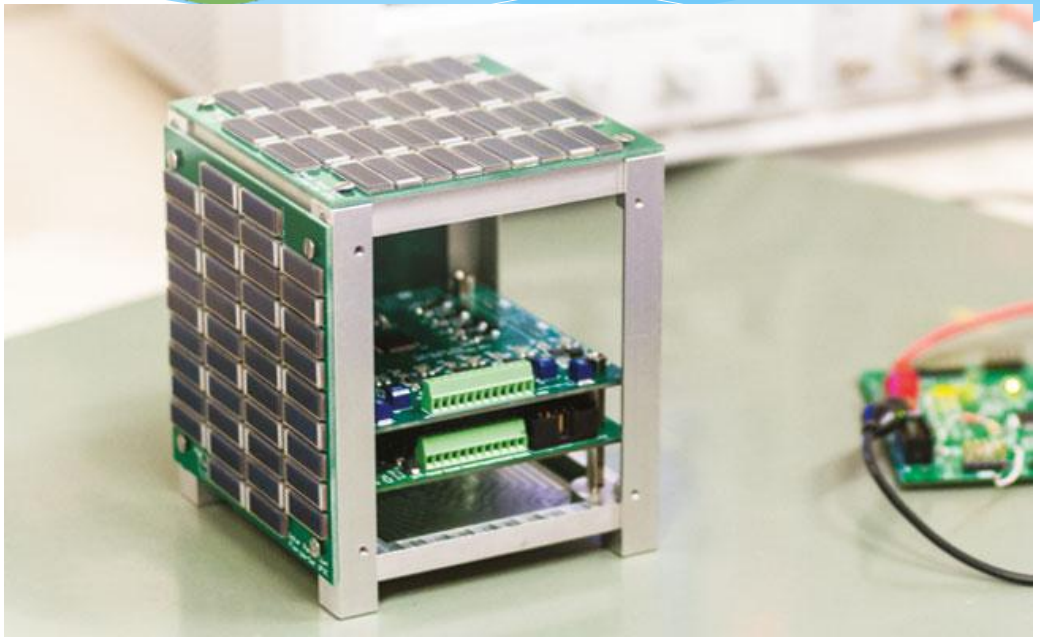
Floripa Sat

• O Floripa Sat surgiu de forma independente, inspirado em outros projetos experimentais do Centro Tecnológico (CTC) — como o BAJA SAE, do curso de Engenharia Mecânica, que se destina a produzir protótipos de veículos automotivos off-road.

• “Existe aqui na UFSC o BAJA; o barco elétrico; o carro elétrico. São vários projetos. Pensamos então em propor o desenvolvimento de um satélite para que os alunos se interessassem e se motivassem também pela área aeroespacial”, explica o professor Eduardo Bezerra, do Departamento de Engenharia Elétrica e um dos coordenadores do projeto.

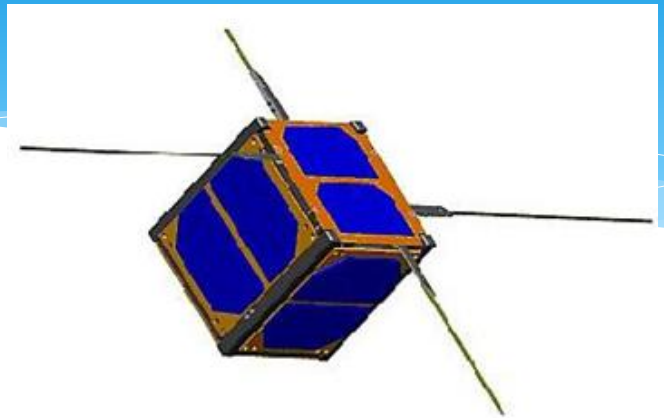
• O curso da UFSC foi criado em 2009 e é uma das únicas seis graduações em Engenharia Aeroespacial em todo o país.

https://github.com/floripasat



http://ciencia.ufsc.br/2015/12/11/missao-espacial/

NanoSatC-BR1



NanoSatC-BR1

(2014)
600 km
INPE - UFSM

Padrão CubeSat 1U

Dnepr

Missão Científica

Coletar dados do campo magnético terrestre:

- AMAS (Anomalia Magnética da América do Sul)

- Setor brasileiro do Eletrojato Equatorial Ionosférico

NanoSatC-BR2

Padrão CubeSat 2U: INPE-UFSM-UFRGS

Missão científica:

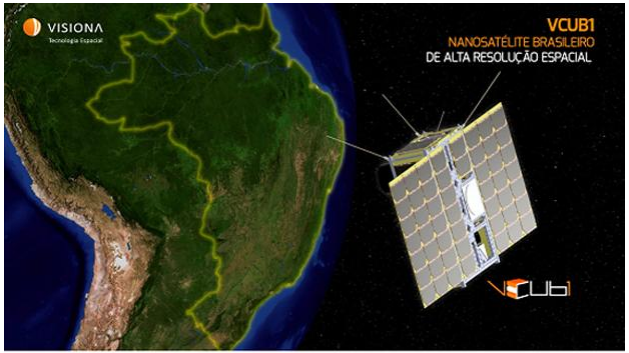
- Sonda de Langmuir (CEA)
- Sistemas de determinação de atitude (INPE/UFMG/UFABC)
- Magnetômetro (UFSM/UFRGS)

https://www.researchgate.net/publication/322746790_NANOSATC-BR_STATUS_-_A_JOINT_CUBESAT-BASED_PROGRAM_DEVELOPED_BY_INPE_AND_UFSM/figures?lo=1&utm_source=google&utm_medium=organic

Nanossatélite VCUB1 - Visiona

O nanossatélite VCUB baseia-se numa plataforma cubesat 6U de 10 kg com dimensões de 30 x 20 x 10 cm. Segundo a Visiona, a missão permitirá o desenvolvimento e validação de tecnologias espaciais e incorpora uma arquitetura de sistemas modular e escalável, que poderá ser utilizada no futuro em satélites de maior porte.

http://www.inpe.br/noticias/noticia.php?Cod_Noticia=4839



Concepção artística do nanosatélite VCUB1

Constelação virtual de 30 sensores de observação da terra

https://www.infodefensa.com/latam/2018/08/02/noticia-agencia-espacial-brasileira-projeto.html

Rumo à Agenda de Desenvolvimento Sustentável

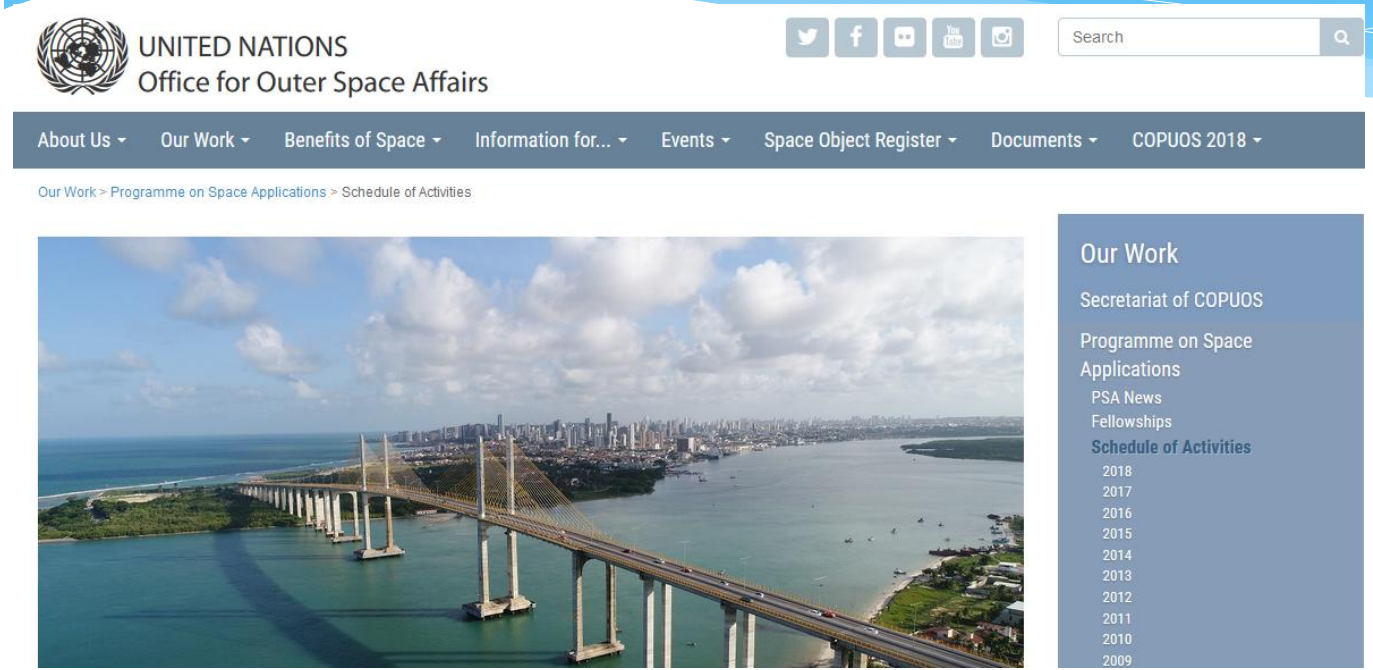
OBJETIVOS DE DESENVOLVIMENTO SUSTENTÁVEL
17 OBJETIVOS PARA TRANSFORMAR NOSSO MUNDO

Essas decisões determinarão o curso global de ação para acabar com a **pobreza**, promover a **prosperidade** e o **bem-estar** para todos, proteger o **meio ambiente** e enfrentar as **mudanças climáticas**.

https://nacoesunidas.org/pos2015/

Rumo à Agenda de Desenvolvimento Sustentável

OBJETIVOS DE DESENVOLVIMENTO SUSTENTÁVEL
17 OBJETIVOS PARA TRANSFORMAR NOSSO MUNDO



United Nations/Brazil Symposium on Basic Space Technology "Creating Novel Opportunities with Small Satellite Space Missions"
Natal, Brazil, 11 - 14 September 2018

Co-organized by the United Nations Office for Outer Space Affairs and the Government of Brazil

http://www.unoosa.org/oosa/en/ourwork/psa/schedule/2018/symposium_brazil_bsti.html

CCST - RaioSat & BiomeSat

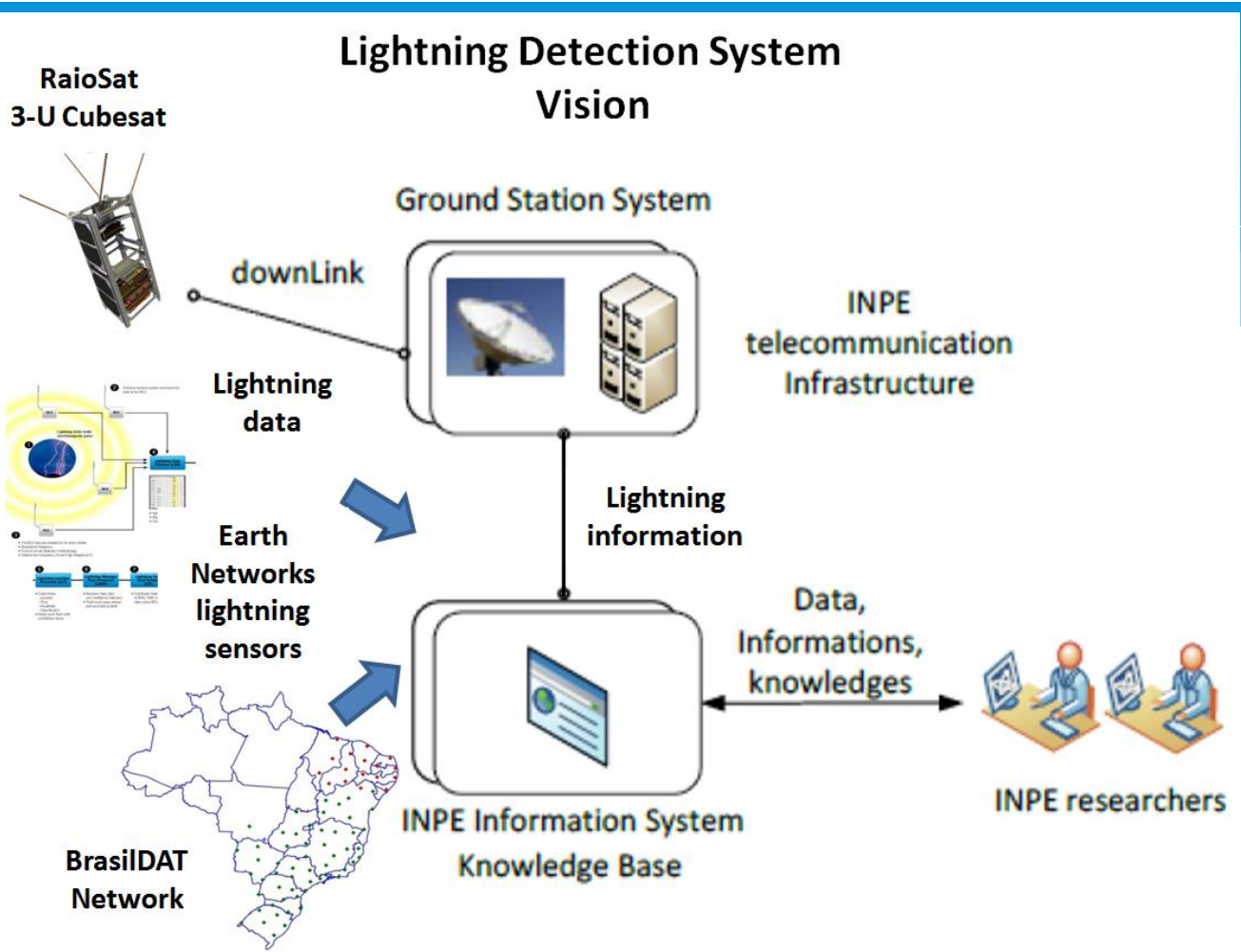
Rumo à agenda de desenvolvimento sustentável

Science for Sustainability

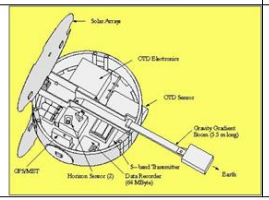
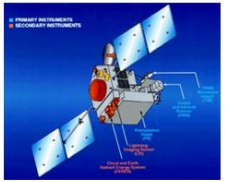
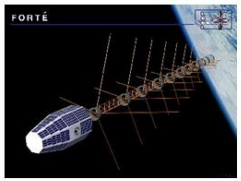
Metas de Desenvolvimento Sustentável (SDGs) da ONU e **Espaço**.

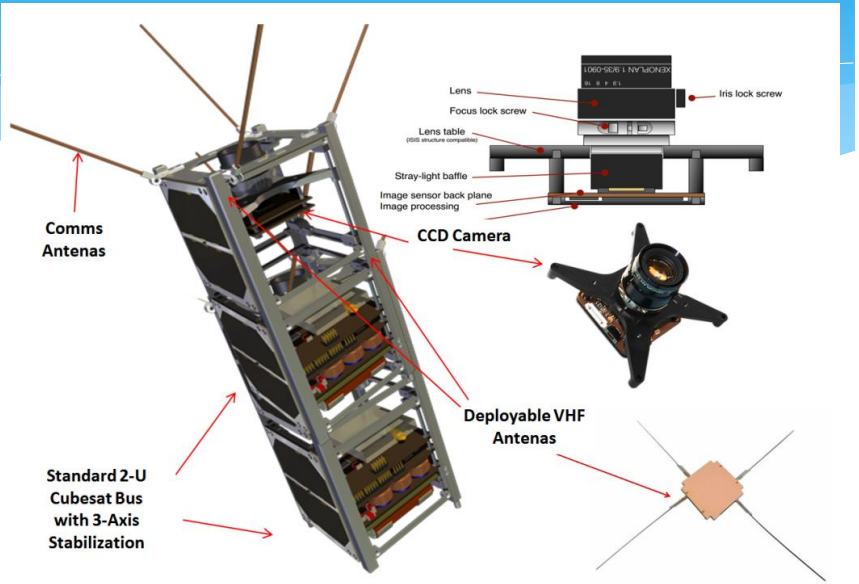
https://nacoesunidas.org/pos2015/

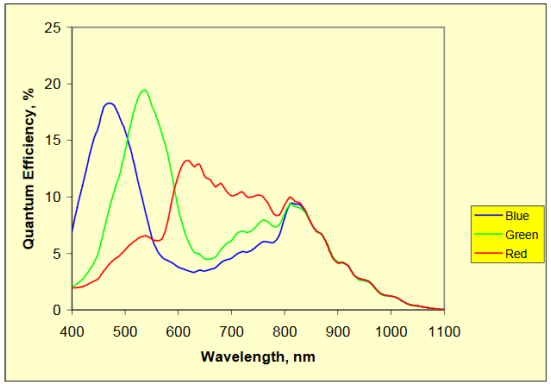
RaioSat

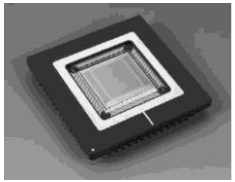

Lightning Detection System
Vision
RaioSat
3-U Cubesat
Ground Station System
downLink
INPE
telecommunication
Infrastructure
Lightning
data
Lightning
information
Earth
Networks
lightning
sensors
Data,
Informations,
knowledges
INPE researchers
INPE Information System
Knowledge Base
BrasilDAT
Network

RaioSat

Satellite	OrbView-1/ MicroLab	TRMM- Tropical Rainfall Measuring Mission	FORTE - Fast On-orbit Recording of Transient
Lightning Detecting Payload	OTD - Optical Transient Detector	LIS - Lightning Imaging Sensor	RF antenna OLS – Optical Lightning Sensor
Mass	74 kg	3620 kg	210 kg
Altitude	785 km	350 e 402 Km	800 Km
Inclination	70°	35°	70°
Launch Date	01/04/1995	27/11/1997	29/08/1997
End of Life	24/08/2015	08/04/2015	
Ilustration			

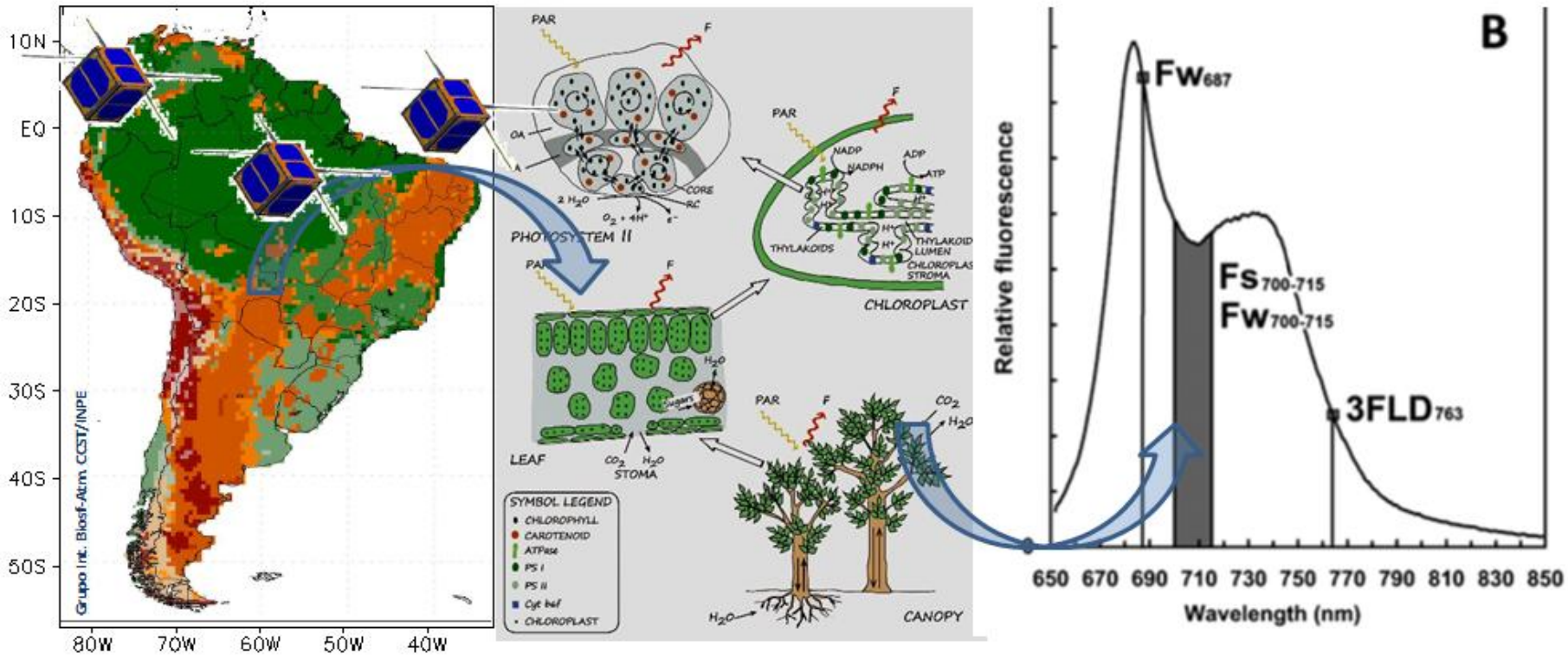






Resolution	Frame Rate	Column_Size	Row_Size	Shutter Width
2048 x 1536 QXGA	12 fps	2047	1535	<1552
1600 x 1200 UXGA	20 fps	1599	1199	<1216
1280 x 1024 SXGA	27 fps	1279	1023	<1040
1024 x 768 XGA	43 fps	1023	767	<784
800 x 600 SVGA	65 fps	799	599	<616
640 x 480 VGA	93 fps	639	479	<496

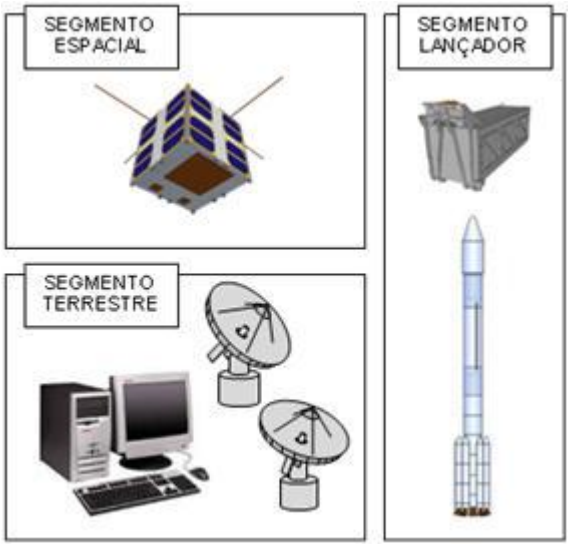
BiomeSat – Monitoração da Saúde de Florestas

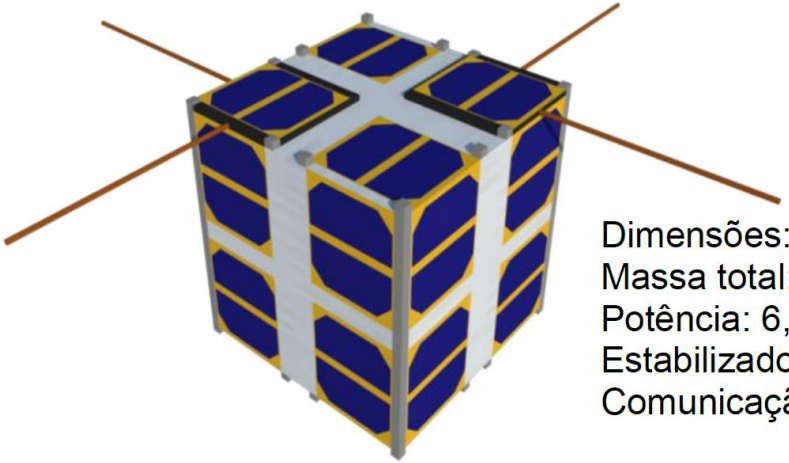


CONASAT - CONSTELAÇÃO DE NANO SATÉLITES PARA COLETA DE DADOS AMBIENTAIS

CONASAT
CONSTELAÇÃO DE NANO SATÉLITES AMBIENTAIS

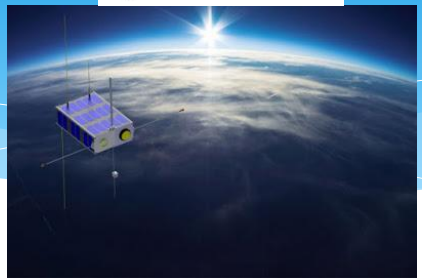
Arquitetura da Missão



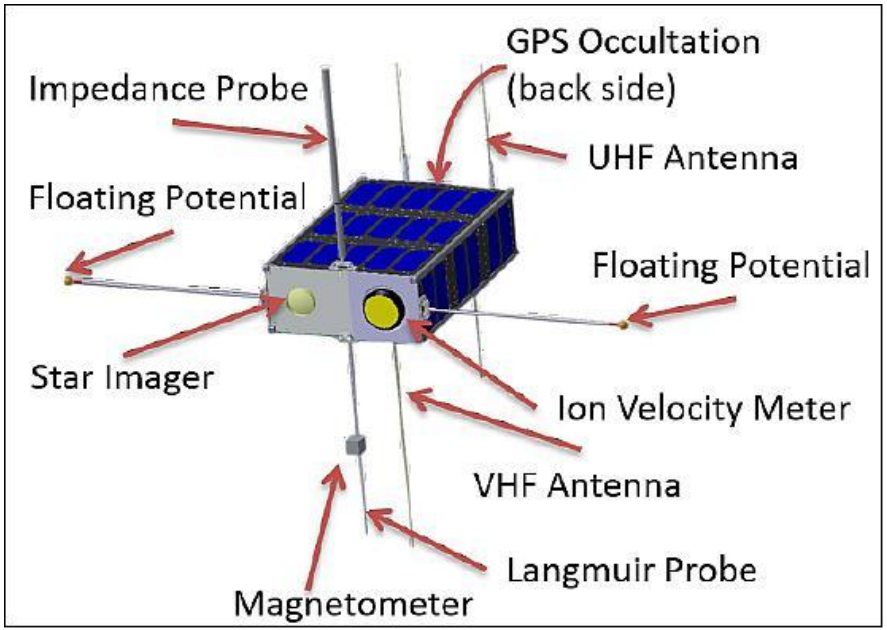


Dimensões: 22,6 x 22,6 x 22,7cm
Massa total: 8,3 kilogramas
Potência: 6,44 watt
Estabilizado em 2 eixos (x,y)
Comunicação: UHF e Banda S

SPORT (Scintillation Prediction Observations Research Task)

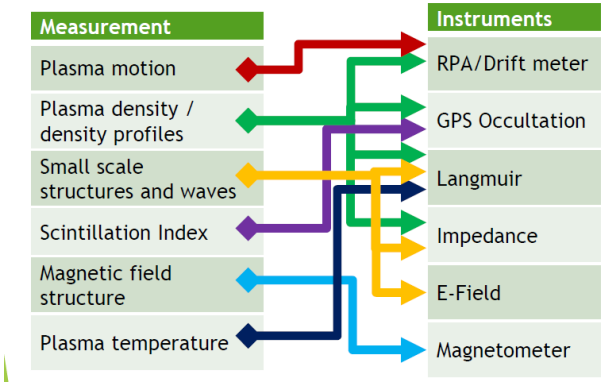


http://panoramaespacial.blogspot.com/2016/12/cubesat-sport-parceria-inpe-ita-e-nasa.html



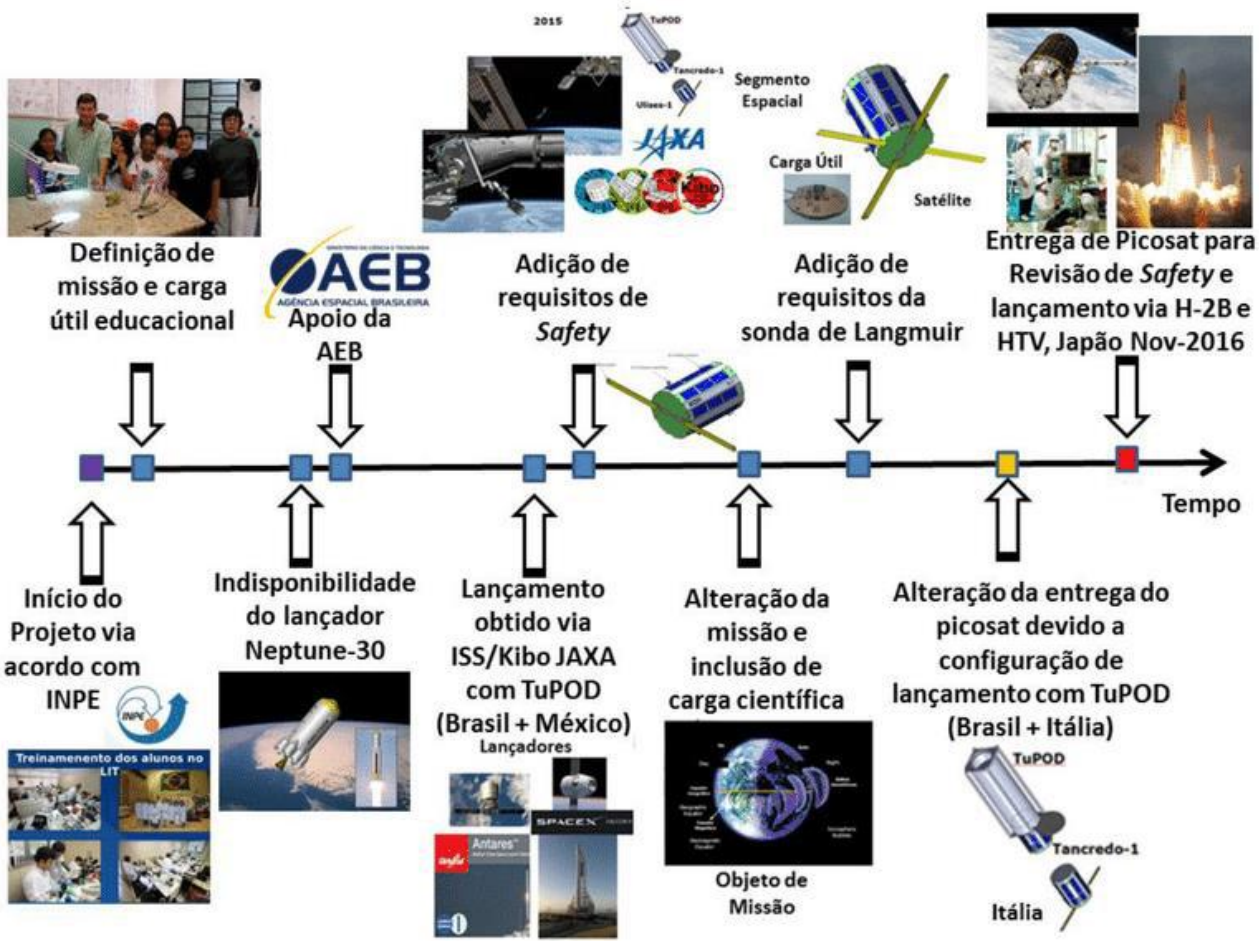
https://directory.eoportal.org/web/eoportal/satellite-missions/s/sport

Space Weather Studies



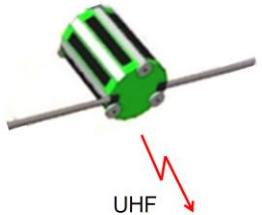
HLF2017_UNOOSA_Naccarato_Brazil_Presentation

A experiência no picosatélite Tancredo-I https://www.researchgate.net/project/UbatubaSat



PicoSat – Tancredo I (UbatubaSat)
Arquitetura da Missão Espacial

Ter frequência de operação coordenada



IARU International Amateur Radio Union

ITU International Telecommunication Union

Anatel AGÊNCIA NACIONAL DE TELECOMUNICAÇÕES

NASA Johnson Space Center

Uplink Command Budget:

Parameter:	Value:	Units:
Ground Station:		
Ground Station Transmitter Power Output:	100.0	watts
In dBW:	20.0	dBW
In dBm:	50.0	dBm
Ground Stn. Total Transmission Line Losses:	3.6	dB
Antenna Gain:	17.5	dB
Ground Station EIRP:	33.9	dBW
Uplink Path:		
Ground Station Antenna Pointing Loss:	0.4	dB
Gnd-to-S/C Antenna Polarization Losses:	0.2	dB
Path Loss:	150.1	dB
Atmospheric Losses:	2.1	dB
Ionospheric Losses:	0.4	dB
Rain Losses:	0.0	dB
Isotropic Signal Level at Spacecraft:	-119.3	dBW
Spacecraft (Eb/No Method):		
Spacecraft Antenna Pointing Loss:	0.3	dB
Spacecraft Antenna Gain:	2.2	dB
Spacecraft Total Transmission Line Losses:	1.8	dB
Spacecraft Effective Noise Temperature:	258	K
Spacecraft Figure of Merit (G/T):	-23.8	dB/K
S/C Signal-to-Noise Power Density (S/No):	85.2	dBHz
System Desired Data Rate:	1200	bps
In dBHz:	30.8	dBHz
Command System Eb/No:	54.4	dB
Demodulation Method Seleted:	AFSK/FM	
Forward Error Correction Coding Used:	None	
System Allowed or Specified Bit-Error-Rate:	1.0E-04	
Demodulator Implementation Loss:	1.0	dB

Potência TX Sat= 100 W

Margem Enlace (Método Eb/No)	Margem Enlace (Método SNR)
32,4 dB	29 dB

Spacecraft Alternative Signal Analysis Method (SNR Computation):

Spacecraft Antenna Pointing Loss:	0.3 dB
Spacecraft Antenna Gain:	2.2 dB
Spacecraft Total Transmission Line Losses:	1.8 dB
Spacecraft Effective Noise Temperature:	258 K
Spacecraft Figure of Merit (G/T):	-23.8 dB/K
Signal Power at Spacecraft LNA Input:	-119.3 dBW
Spacecraft Receiver Bandwidth:	15.000 Hz
Spacecraft Receiver Noise Power (Pn = kTB):	-162.7 dBW
Signal-to-Noise Power Ratio at G.S. Rcvr:	43.4 dB
Analog or Digital System Required S/N:	14.4 dB
System Link Margin	29.0 dB

Downlink Telemetry Budget:

Parameter:	Value:	Units:
Spacecraft:		
Spacecraft Transmitter Power Output:	0.5	watts
In dBW:	-3.0	dBW
In dBm:	27.0	dBm
Spacecraft Total Transmission Line Losses:	2.0	dB
Spacecraft Antenna Gain:	2.2	dB
Spacecraft EIRP:	-2.8	dBW
Downlink Path:		
Spacecraft Antenna Pointing Loss:	0.3	dB
S/C-to-Ground Antenna Polarization Loss:	0.2	dB
Path Loss:	150.1	dB
Atmospheric Loss:	2.1	dB
Ionospheric Loss:	0.4	dB
Rain Loss:	0.0	dB
Isotropic Signal Level at Ground Station:	-155.9	dBW
Ground Station (Eb/No Method):		
Ground Station Antenna Pointing Loss:	0.4	dB
Ground Station Antenna Gain:	17.5	dB
Ground Station Total Transmission Line Losses:	0.5	dB
Ground Station Effective Noise Temperature:	565	K
Ground Station Figure of Merit (G/T):	-10.6	dB/K
G.S. Signal-to-Noise Power Density (S/No):	61.8	dBHz
System Desired Data Rate:	2400	bps
In dBHz:	33.8	dBHz
Telemetry System Eb/No for the Downlink:	28.0	dB
Demodulation Method Seleted:	AFSK/FM	
Forward Error Correction Coding Used:	None	
System Allowed or Specified Bit-Error-Rate:	1.0E-04	
Demodulator Implementation Loss:	1	dB
Telemetry System Required Eb/No:	21	dB
Eb/No Threshold:	7	dB
System Link Margin:	6.0	dB

Potência TX Sat= 500 mW

Elevação	Distância	Eb/No	SNR
5 graus	1709 Km	6 dB	3,4 dB
0 grau	2196 Km	-3,1 dB	-5,6 dB

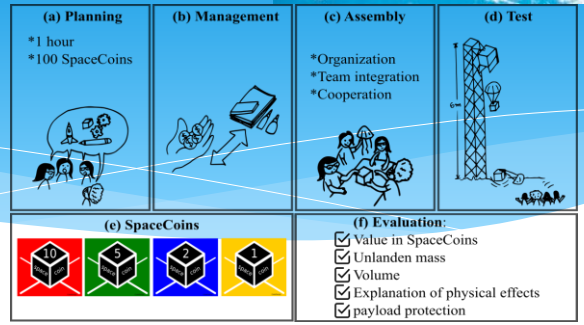
Ground Station Alternative Signal Analysis Method (SNR Computation):

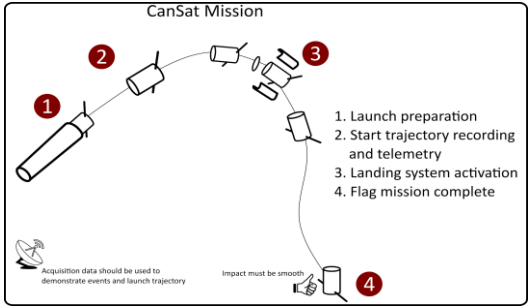
Ground Station Antenna Pointing Loss:	0.4 dB
Ground Station Antenna Gain:	17.5 dB
Ground Station Total Transmission Line Losses:	0.5 dB
Ground Station Effective Noise Temperature:	565 K
Ground Station Figure of Merit (G/T):	-10.6 dB/K
Signal Power at Ground Station LNA Input:	-139.3 dBW
Ground Station Receiver Bandwidth (B):	15.000 Hz
G.S. Receiver Noise Power (Pn = kTB):	-155.3 dBW
Signal-to-Noise Power Ratio at G.S. Rcvr:	27.4 dB
Analog or Digital System Required S/N:	14.4 dB
System Link Margin	3.4 dB

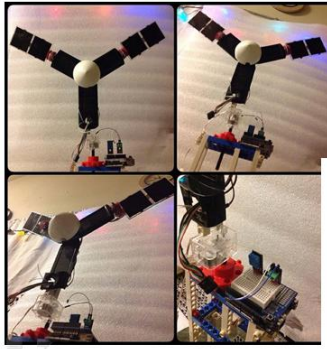
Subsistema de Comunicações

1º CubeDesign – S. J.Campos, 25 a 28 de Julho, 2018

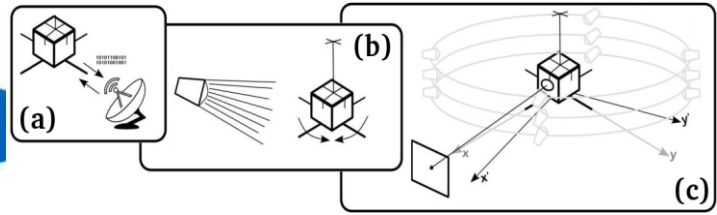
www.inpe.br/cubedesign







KIDS

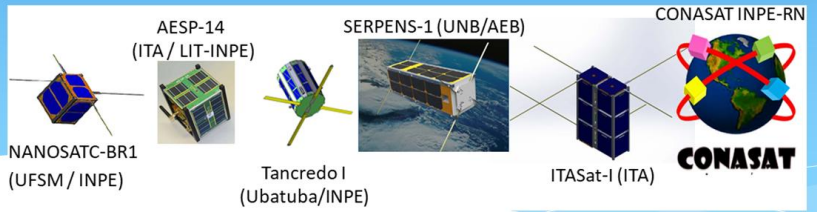


MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

SeCiAer
Seminário de Serviços Científicos e Aeronáuticos
De 01 a 04 de outubro 2018
São José dos Campos - SP

O Desenvolvimento de CubeSats no Brasil

Walter Abrahão dos Santos – DEA-ETE
walter.abrahao@inpe.br



OBRIGADO! Perguntas?