MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

NanosatC-BR e os Modelos das Payloads

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Sumário

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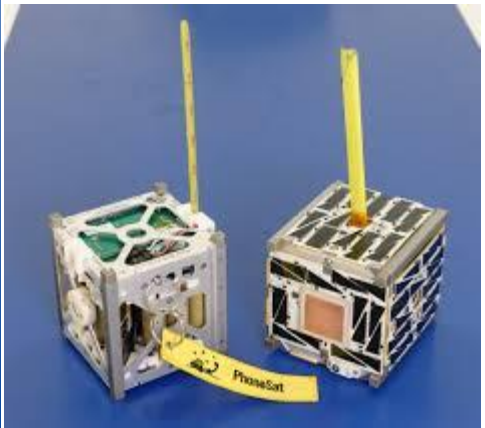
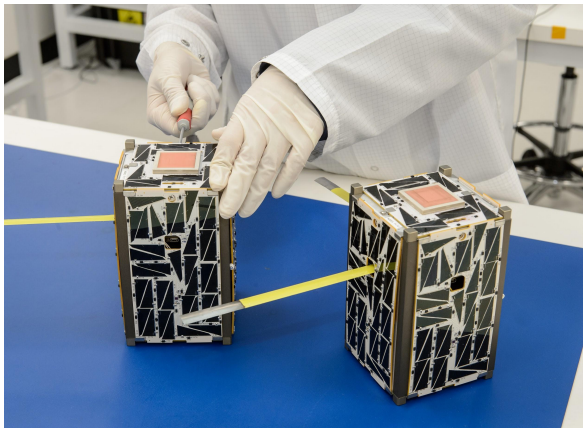
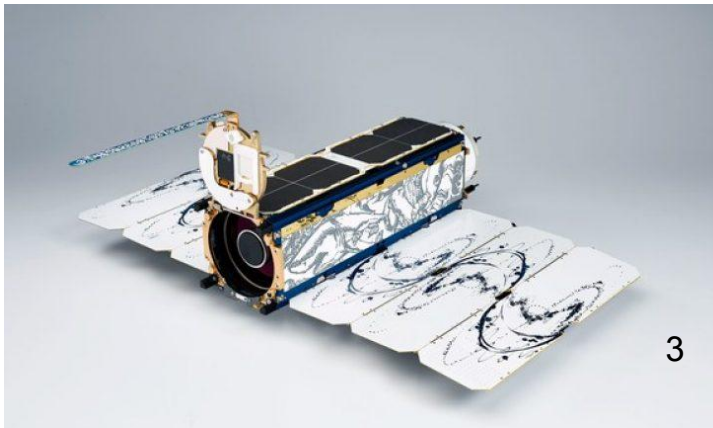
2. NanosatC-Br1
3. NanosatC-Br2
    a. Bus
    b. Payloads
    c. Parâmetros / Operação
4. Modelos UPPAAL
    a. SLP
    b. SDATF
    c. SMDH

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

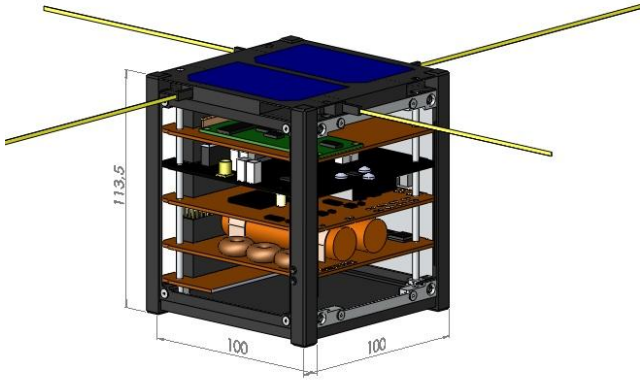


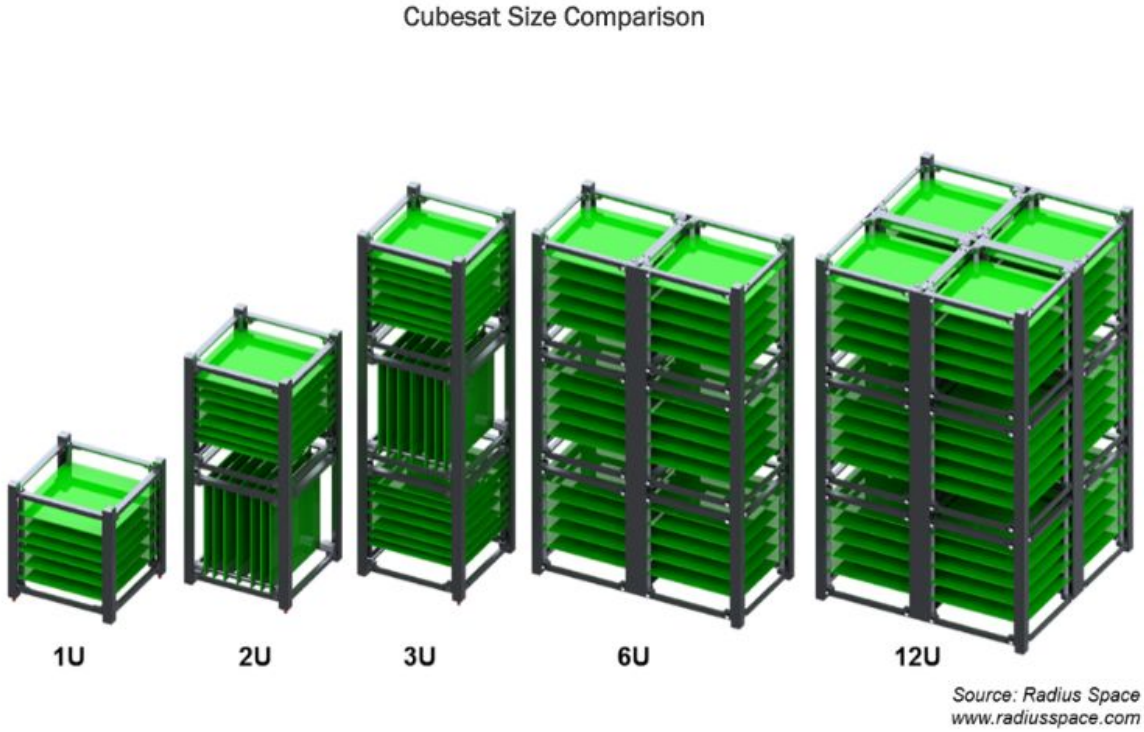




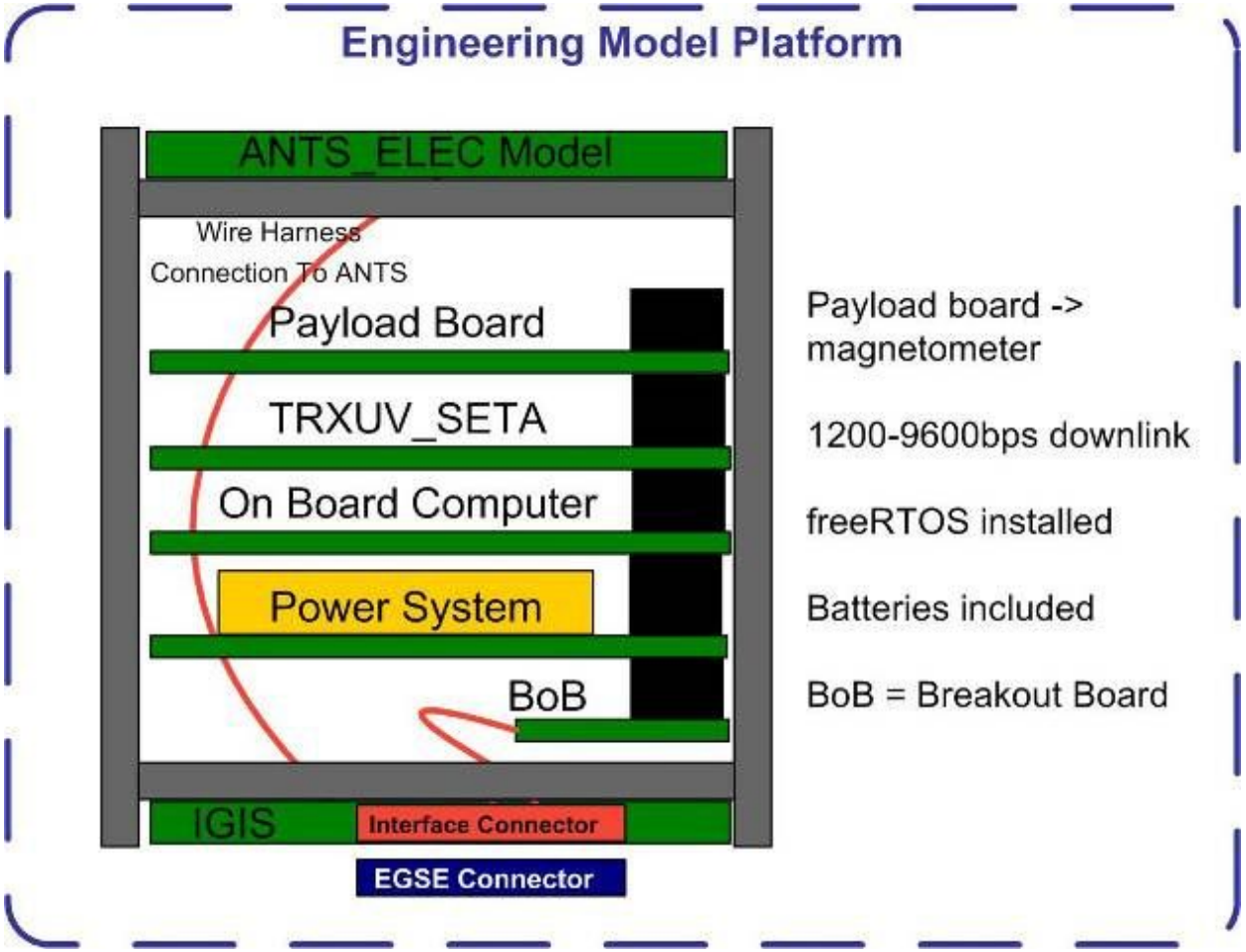
CubeSat – padrão

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

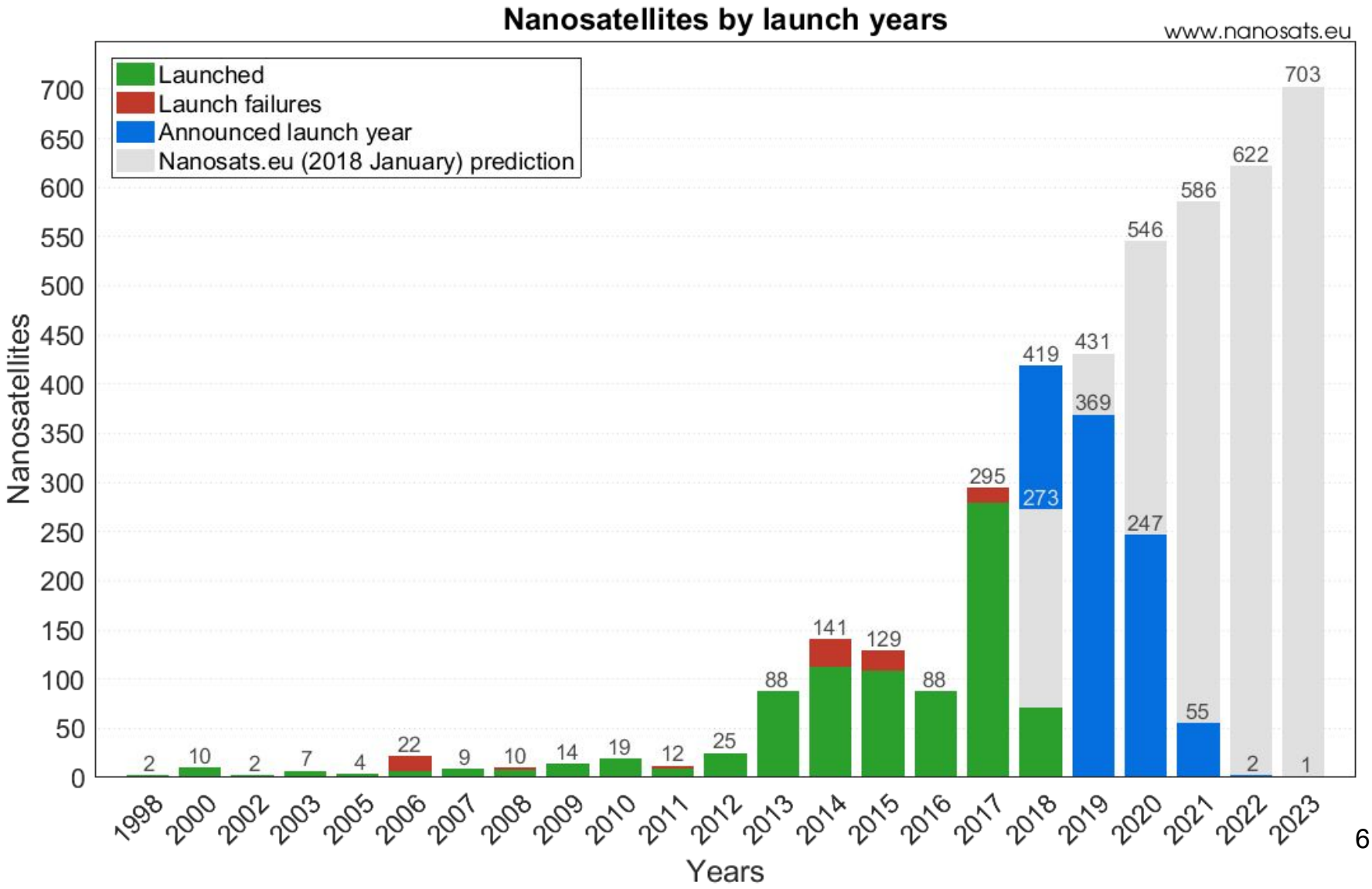




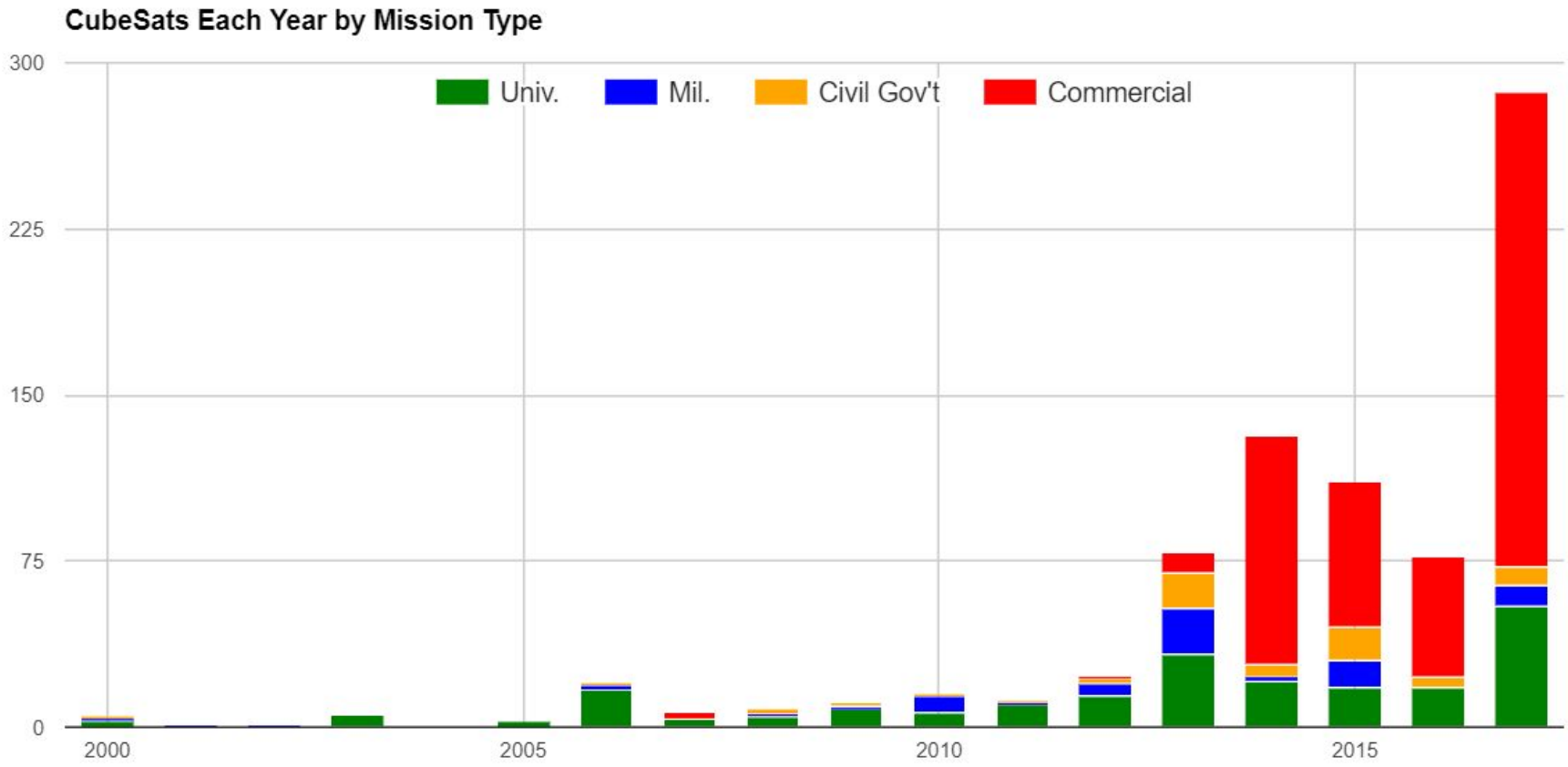
Padrão 1U


Engineering Model Platform
ANTS_ELEC Model
Wire Harness
Connection To ANTS
Payload Board
TRXUV_SETA
On Board Computer
Power System
BoB
IGIS
Interface Connector
EGSE Connector
Payload board -> magnetometer
1200-9600bps downlink
freeRTOS installed
Batteries included
BoB = Breakout Board

Lançamento de Nanosatélites



Usos de CubeSats



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

CubeSats X Satélites Tradicionais

- Baixos custos, prazos, equipes
- Uso extensivo de COTS
- Otimização de testes
- Requisitos flexíveis
- Tolerância a riscos

- Baixa confiabilidade

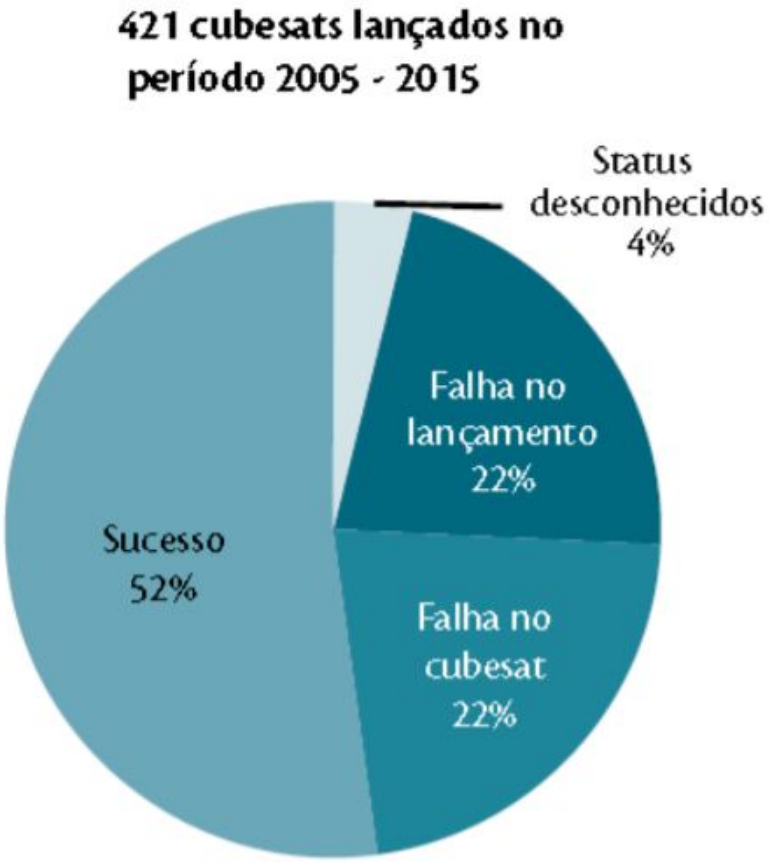
- Modelo de Engenharia
- Modelo de Vôo

- Altos custos, prazos, equipes
- Componentes Space-Grade
- Série extensa de testes
- Requisitos rigorosos
- Aversão a riscos

- Alta confiabilidade

- Modelo de Engenharia
- Modelo Estrutural
- Modelo Térmico
- Modelo Radioelétrico
- Modelo de Qualificação
- Modelo de Vôo

Success Rate



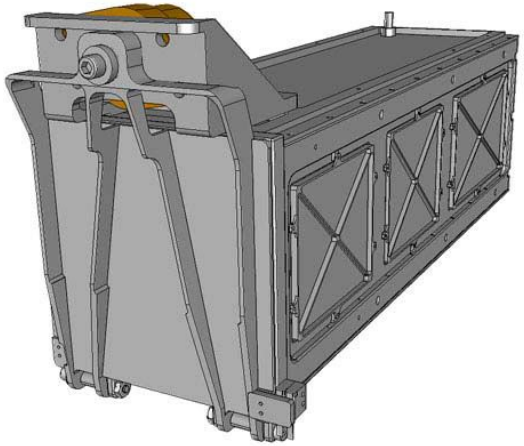
Why fly CubeSats?

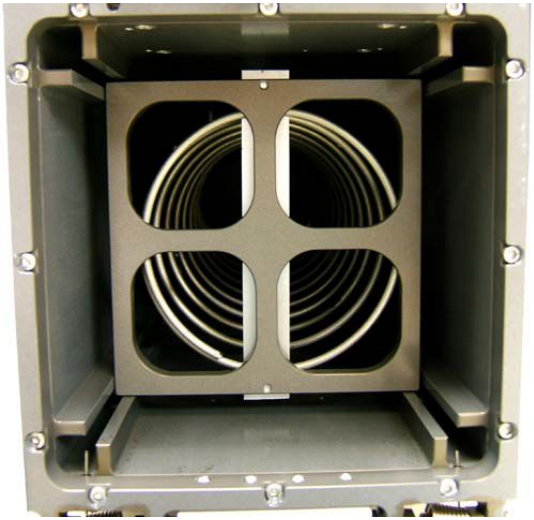
- “Nothing teaches systems engineering like, well, doing systems engineering.”
- Dedicated “simple” science missions
- New tech validation
- Fast development
- High Risk - High Reward

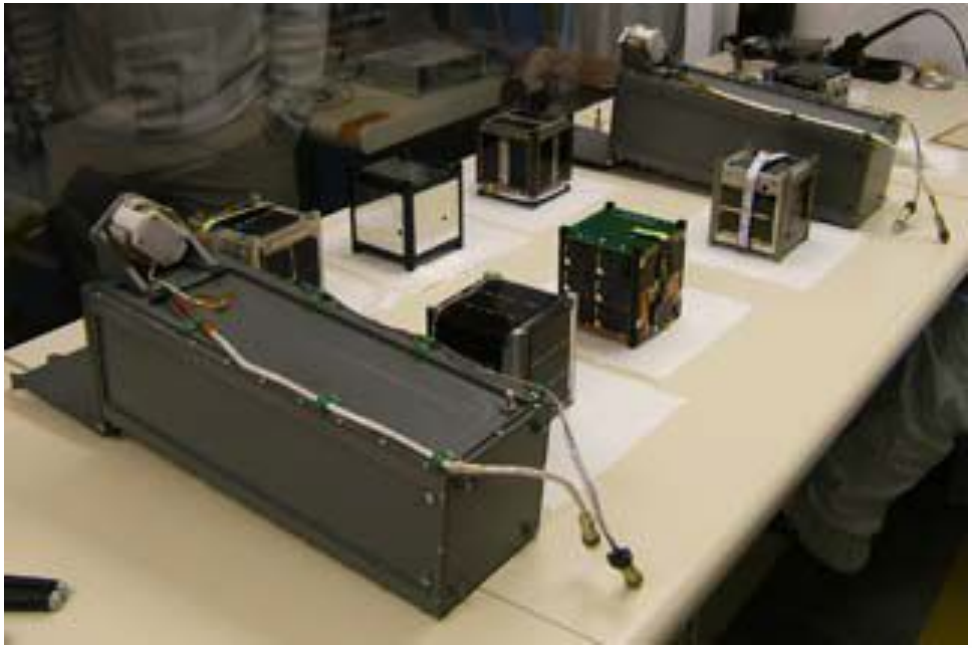
Lançamento

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

Interface com o lançador



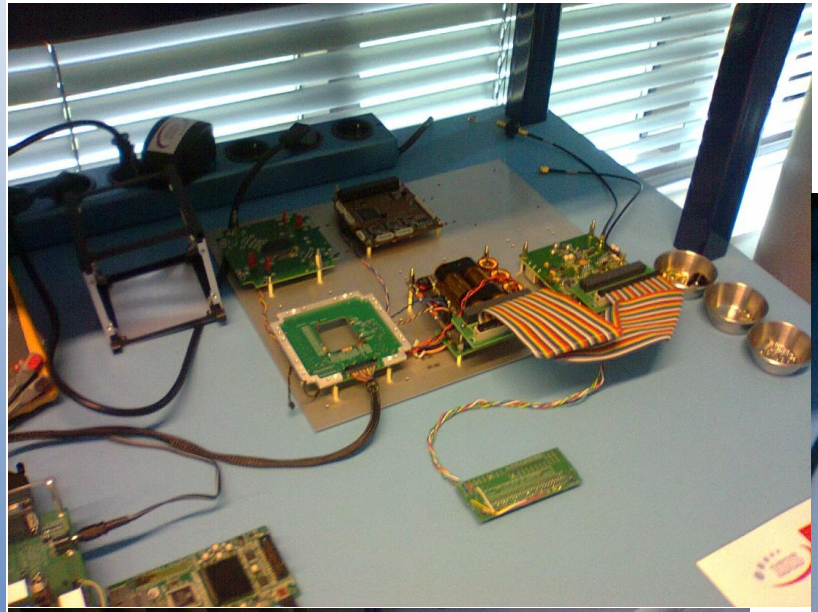


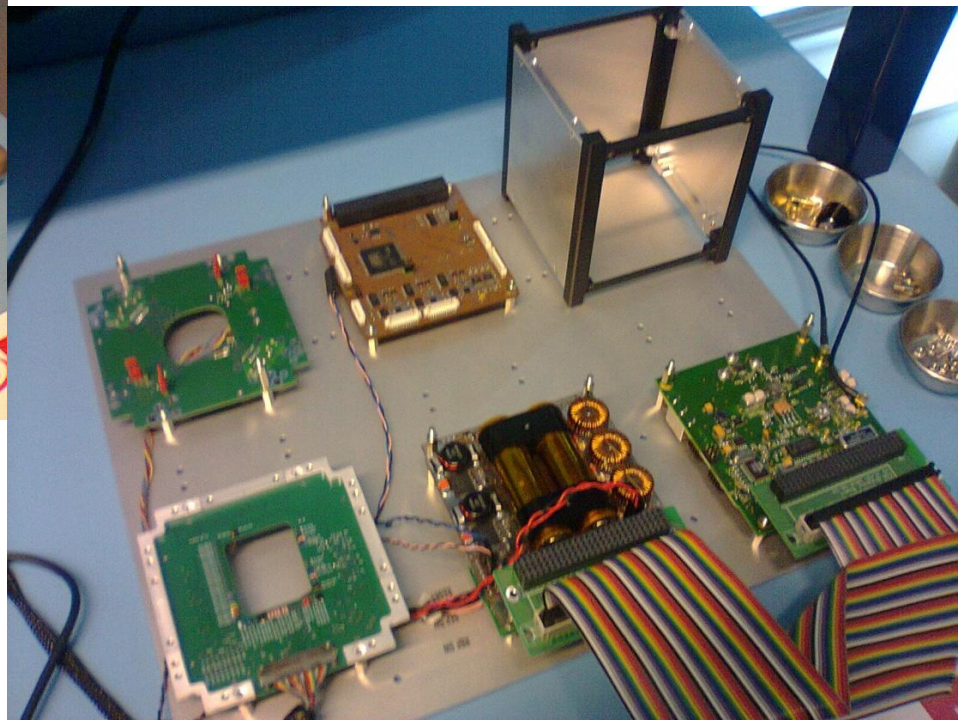


NanosatC-Br1

- Cooperação INPE/CRS e UFSM
- Lançado em 19/07/2014 - DNEPR
- 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



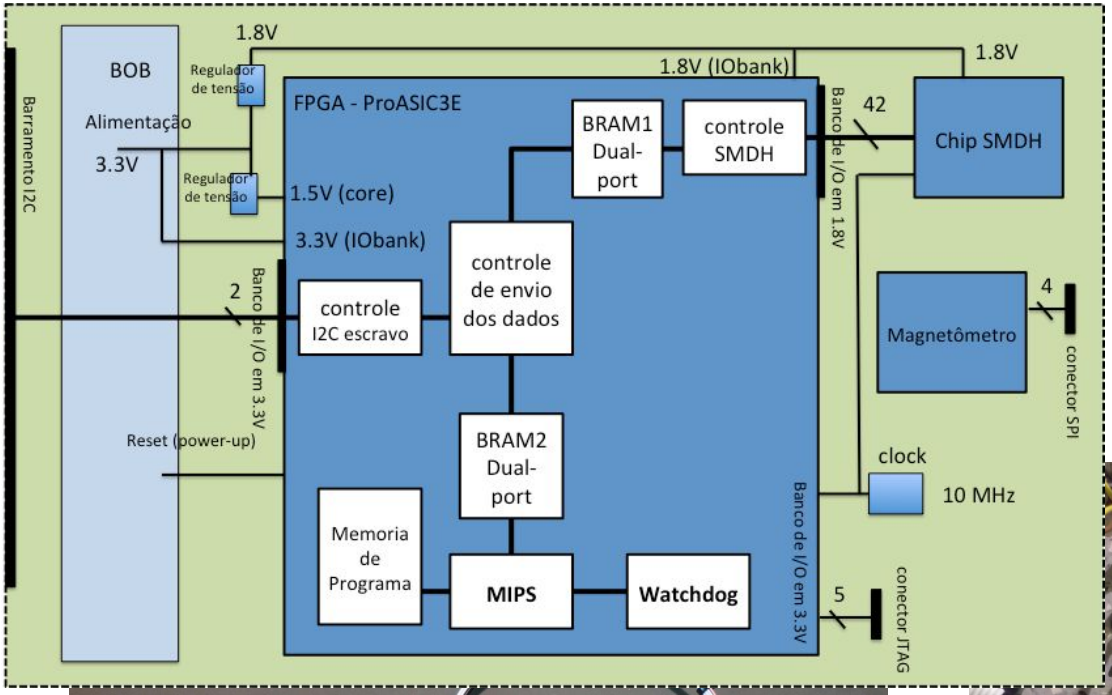


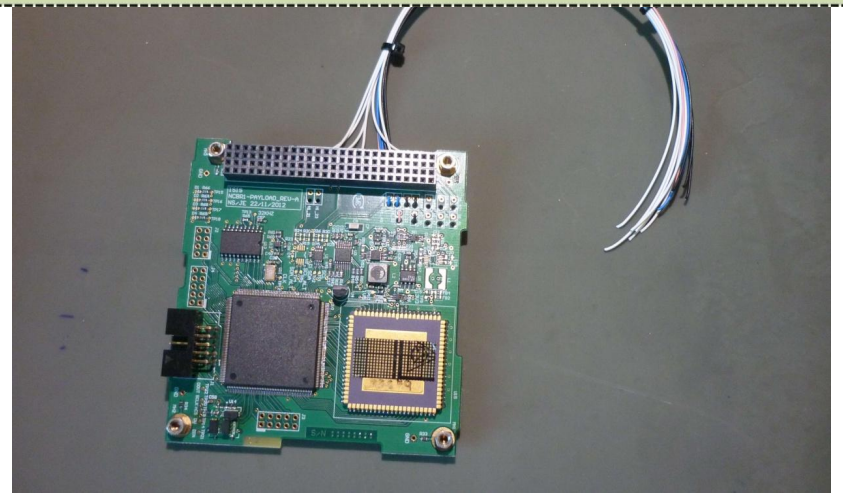
NanosatC-Br1: cargas úteis

- 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

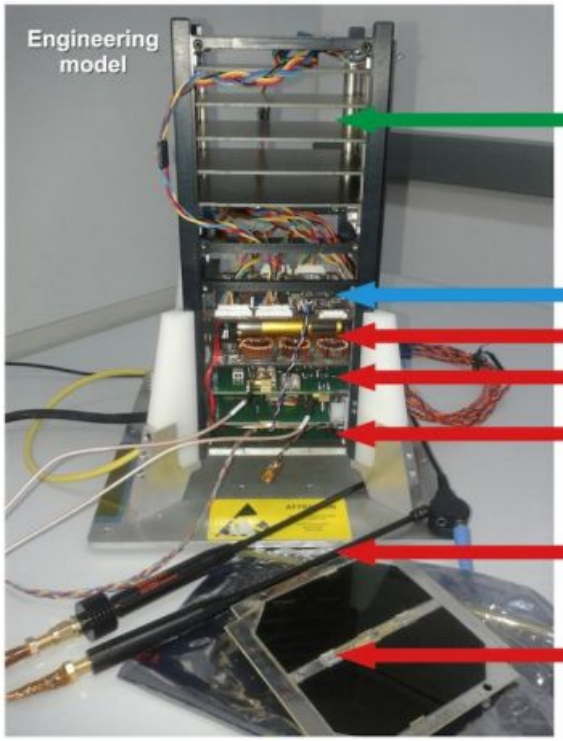




NanosatC-BR2

- 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



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

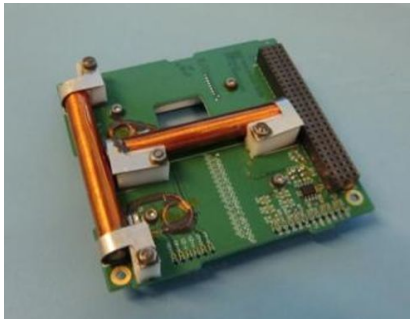
TRXUV VHF/UHF Tranceiver

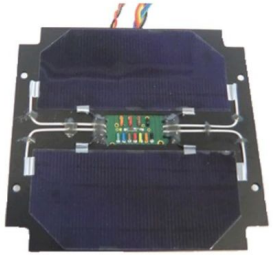
Interface between integrated satellite and electronic equipment

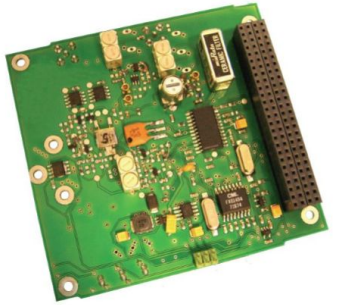
Antenna

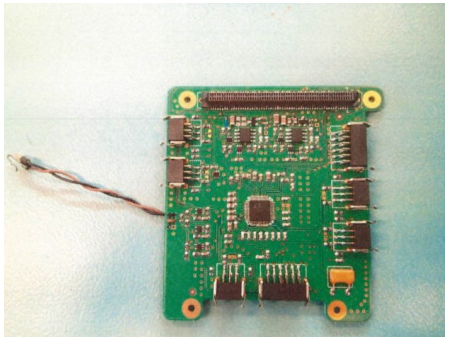
Solar panels

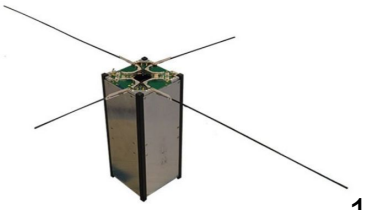
NanosatC-BR2







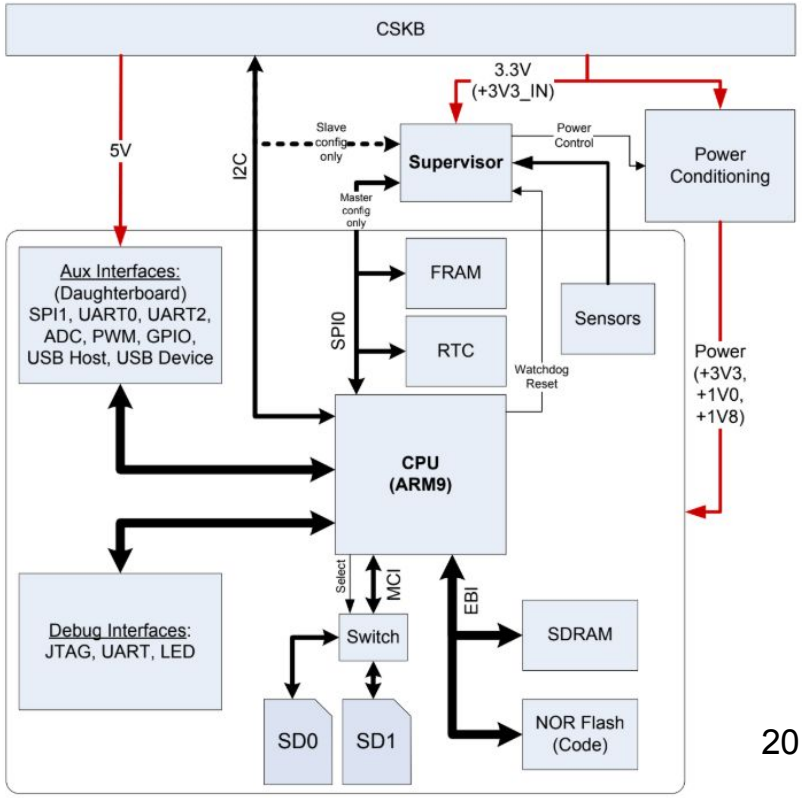




Subsistemas e Interfaces

On-Board Computer

Processor	400MHz, 32-bit ARM9 (AT91SAM9G20)
RAM	32MB SDRAM
Non-volatile data storage	2x2GB SD-Cards with FAT32 file system 256kB FRAM (high endurance and fast read/writes)
Code storage	1MB NOR-Flash
Timing	2 redundant real-time Clocks
Watchdog	External on-board watchdog and power supervisor
On-board sensing	Temperature, current and voltage measurements with over-current protection
Interfaces	1x I²C (master or slave, Fast-mode, ≤400kbit/s) 1x SPI: Up to 8 slaves (≤10Mbit/s) 2x UARTs (≤10Mbit/s, depending configuration): - 1x LVCMOS or RS232 levels (hardware configuration) - 1x RS232 or RS422/485 levels (software configuration) 1x ADC: 8 input channels, 8 or 10-bit modes PWM: 6 output channels GPIO: 27 pins USB: 1x Host and 1x Device (≤12Mbit/s) 1x Image Sensor Interface for directly interfacing with CMOS image sensors (shared with GPIOs)
Programming and debug capabilities	JTAG for programming and debugging, Additional debug UART for console user-interface, 4xLEDs
Average power consumption	380mW, typical usage @ 3.3V supply
Qualified operating temperature range	-25°C to +65°C
Storage temperature range	-40°C to +80°C (RH < 60%)
Dimensions	96 x 90 x 12.4mm (including FM daughterboard)
Mass	106g (including daughterboard)



Transceiver

1.3 Overall Specifications

Supply voltage:	6.5-12.5V DC
Operating temperature range:	-10 to +60°C
Mass:	90 grams

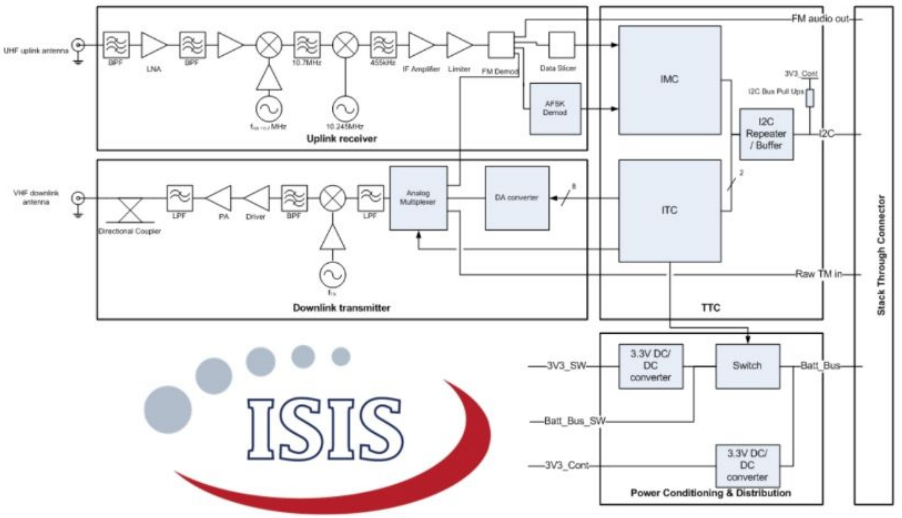
1.4 UHF Receiver Specifications

Frequency range:	400-450MHz
Data rate:	300-1200bit/s
Protocol:	AX.25
IF bandwidth:	15kHz
Modulation scheme:	FM
Receiver type:	Double Conversion Superheterodyne, FM receiver
First Intermediate Frequency:	10.7MHz
Second Intermediate Frequency:	455kHz
Local oscillator frequency:	Receive frequency - 10.7MHz
Receiver sensitivity:	-105dBm, for a Bit Error Rate of 10E-5

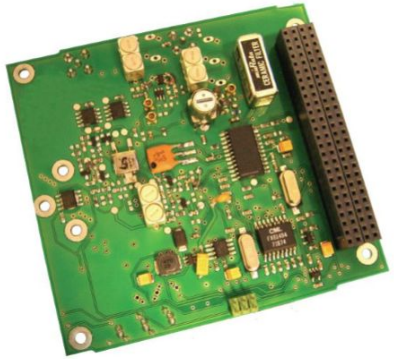
1.5 VHF Transmitter Specifications

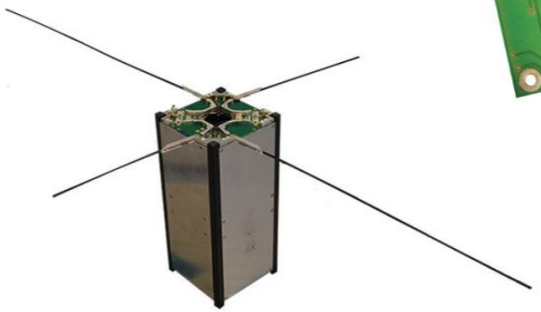
Frequency range:	130-160MHz
Spurious suppression:	> -50dBc
Allowable duty cycle:	100%
Modulation scheme:	Raised-Cosine Binary Phase Shift Keying
Data rate:	1200-9600bit/s
Protocol:	AX.25

3.1 Functional Block Diagram

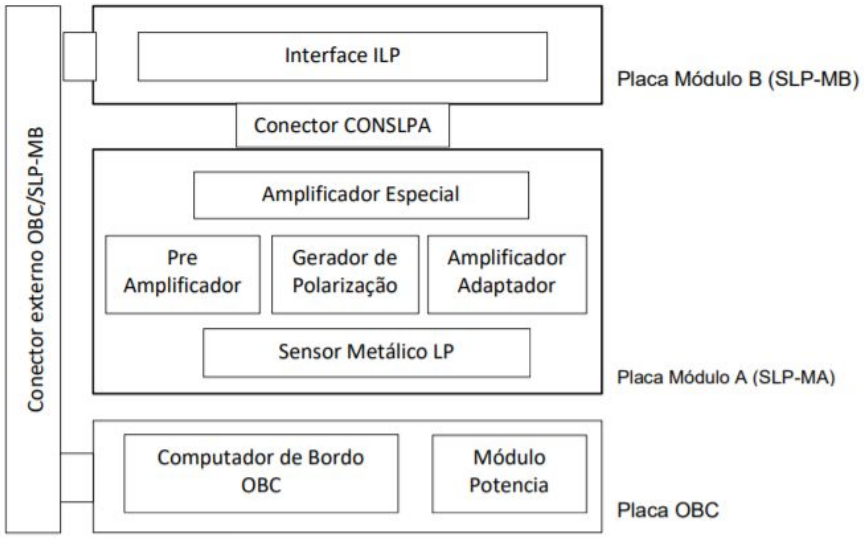


ISIS TRXUV CubeSat VHF/UHF Transceiver Block Diagram

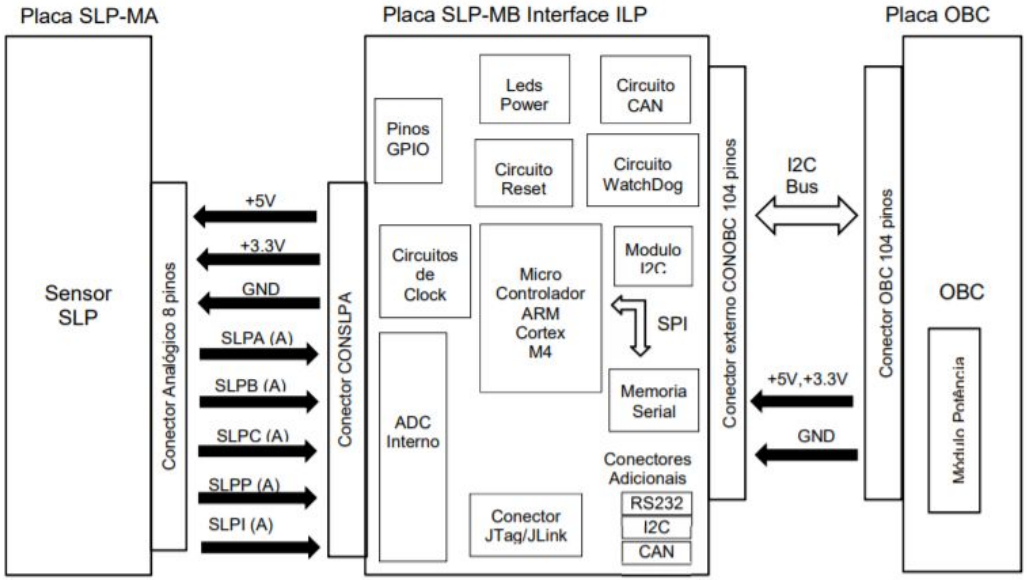


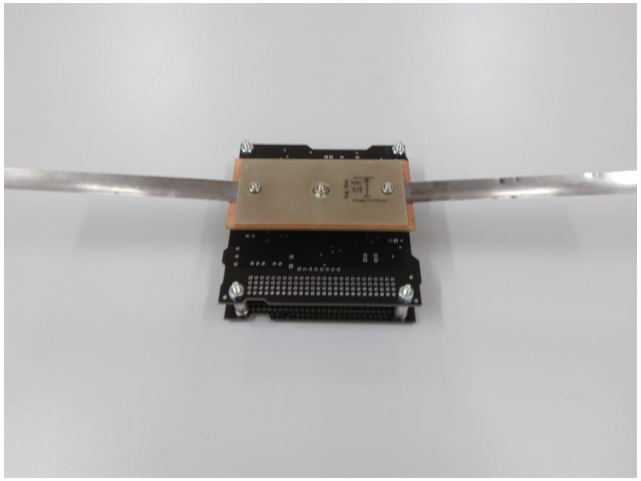


Sonda de Langmuir

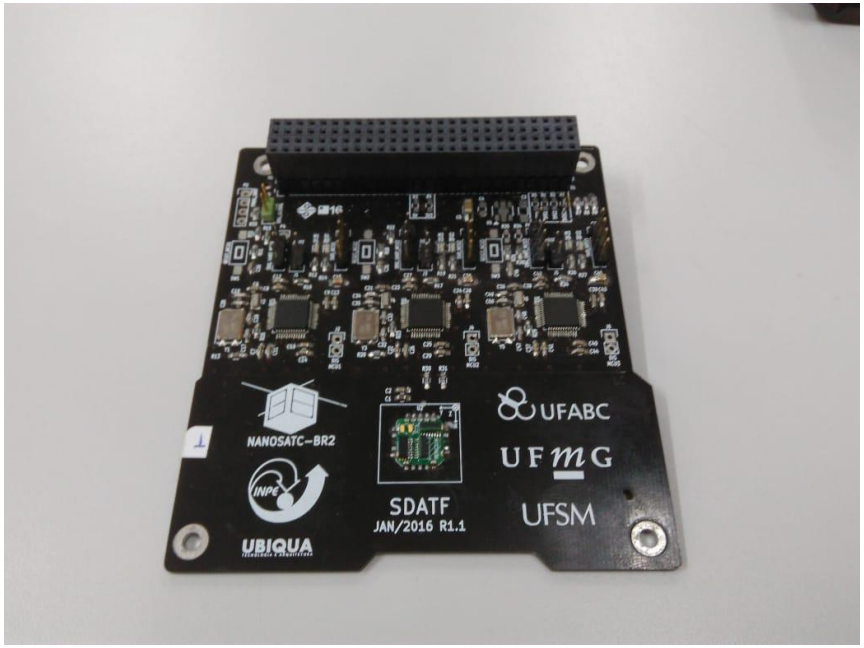


- O objetivo principal é de observar a distribuição global da densidade e temperatura de elétrons, especialmente na parte noturna das órbitas.
- Parte diurna também interessante mas não prioridade
- Interessante obter dados quando passar pelo território brasileiro
- Geração de dados: 100B/s
- Buffer 30KB (5 mins)
- Max (90 mins = 540 KB)

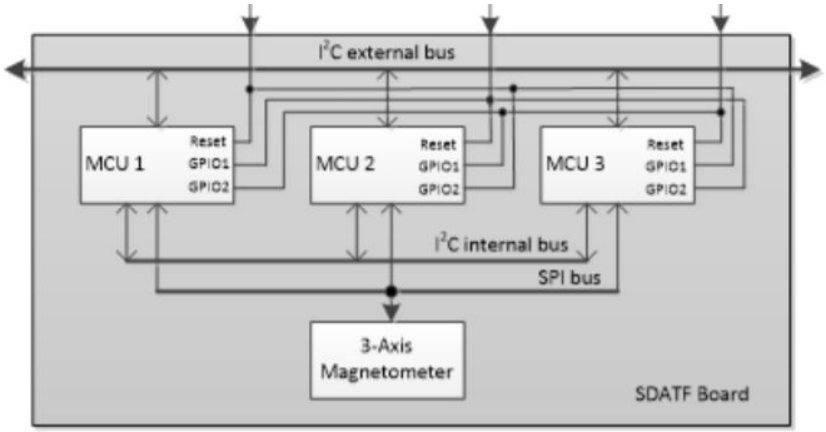




Sistema de Determinação de Atitude Tolerante à Falhas (SDATF)

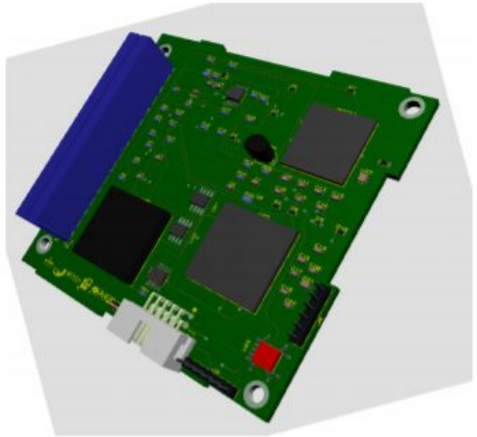


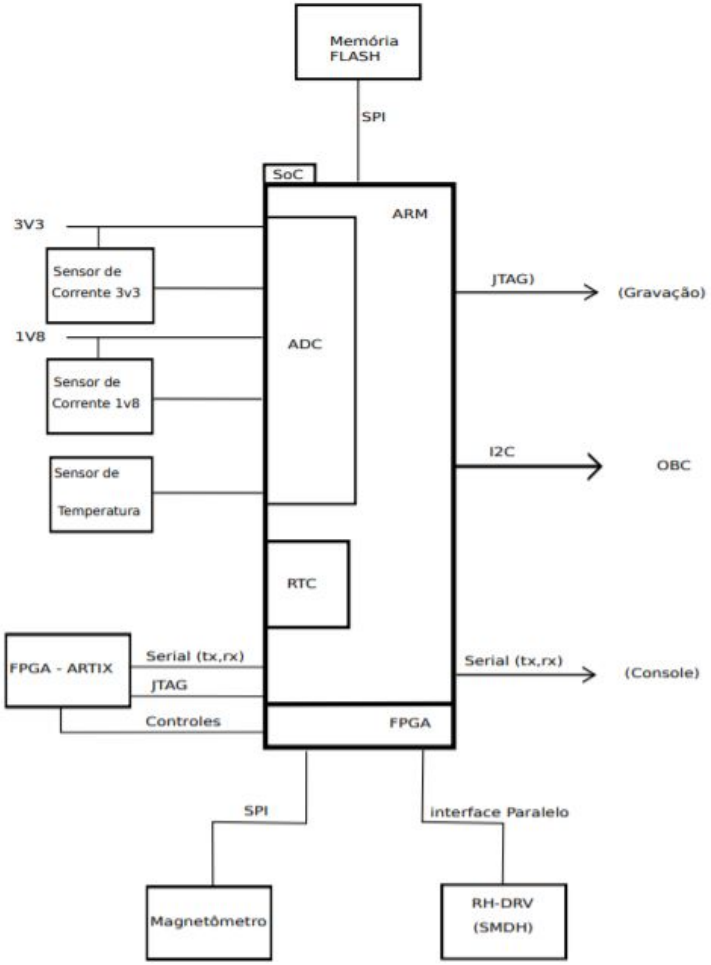
- Recebe versor do Sol e TLE, faz leitura do magnetômetro e determina a atitude.
- Tolerância à falhas por software
- Máximo 230 KB/órbita



Payload UFRGS/UFSM/SMDH

- Continuação do experimento do BR1
- Magnetômetro XEN1210
- SoC com ARM e FPGA
- FPGA - ARTIX
- ASIC da SMDH
- Estimativa 1 KB/órbita





Parâmetros Orbitais

Parameter	Value				Unit	Comments
Orbital Parameters (BASEADO NO BR1)						
Orbital height	700				km	
Orbital inclination angle	98				deg	
Orbital period	5926				s	
Orbital period	98.77				min	
Obits per day	14.58				n	
Orbits without groundstation overpasses	4.00				n	
Grounstation parameters						
Average number of groundstation orbits per day	4				n	
Average groundstation contact time	10.00				min	
Ground Station Contact Time	40.00				*[min/day]*	
Ground Station Contact Time	2400.00				*[s/day]*	Available for simultaneous up and donwlink in full duplex communication system
Uplink Calculation						
Uplink Rate	1.2				*[kbps]*	
Overhead losses	25%				*[%]*	losses due to AX25 etc
Uplink Volume	0.26				*[Mbyte/day]*	incl overhead losses
Downlink Calculation						
Downlink Rate	9.60	4.80	2.40	1.20	*[kbps]*	
Overhead losses	25%				*[%]*	losses due to AX25 etc
Downlink Volume per overpass	0.53	0.26	0.13	0.07	*[Mbyte/overpass]*	
Downlink Volume per day	2.11	1.05	0.53	0.26	*[Mbyte/day]*	
Housekeeping Overhead Estimate	0.53				*[Mbyte/day]*	*Estimate based on T1 values and sampling every 30s*
Expected payload data volume per overpass	0.39	0.13	0.00	-0.07	*Mbyte/overpass*	Red fill indicate no data available for payload
Expected payload data volume per day	1.58	0.52	0.00	-0.27	*Mbyte/day*	Red fill indicate no data available for payload
Note			Nominal Mode	Defualt mode		

Balanço de Potência

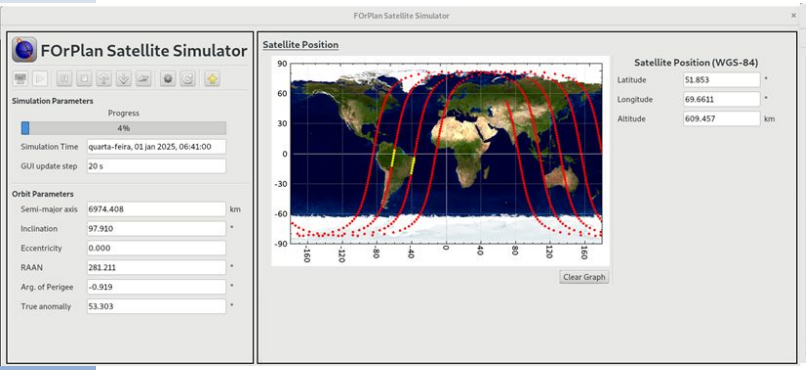
Subsystem	Supply Voltage (V)	Current (mA)	Power (W)
OBC	3.3	116	0.383
Receiver	7	27.5	0.193
Transmiter	7	0	0.000
SDATF	3.3	80	0.264
SLP	5	160	0.800
ILP	3.3	22	0.073
SMDH	3.3	331	1.092
Magnetometer	3.3	4.7	0.016
iMTQ	5	0	0.000
EPS			0.250
Total			3.070

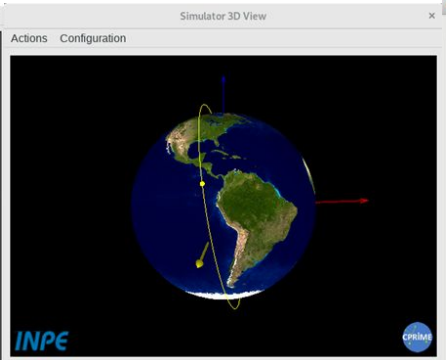
Parameter	Value	
iSPA_Side.REVA.029	**Group A**	**Group B**
Functional Check on sensor interface	OK	
Cell Identifiers	461826	461803
Short Circuit Current [A]	0.522	0.516
Open Circuit Voltage[V]	5.356	5.374
Maximum power [W]	2.423	2.427
Current at Maximum power [A]	0.505	0.501
Voltage at Maximum power [V]	4.799	4.848
Measured efficiency [%]	29.67	29.72

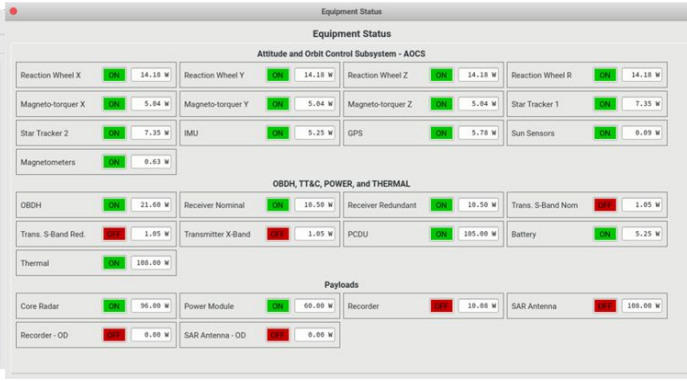
Potência estimada gerada estimada - 2.2 W

⅔ da órbita com Sol - 1.6 W

Simulação: Cenário de Operação

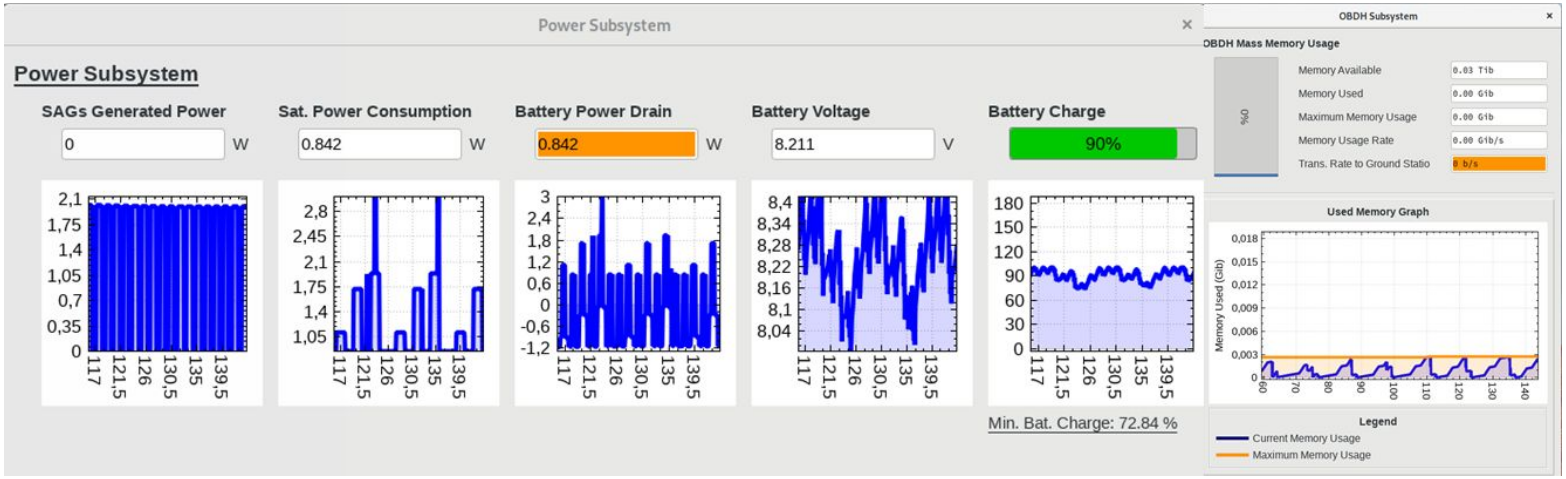




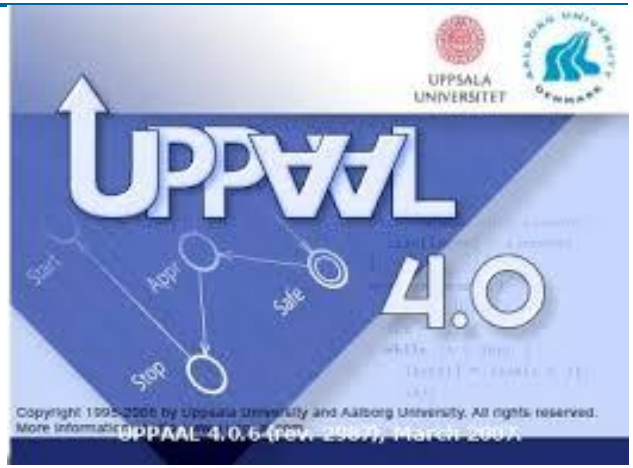


Orbit Number	1	2	3	4	5	6
Payload	A	None	B	None	C	None

Estações: SJC e Santa Maria

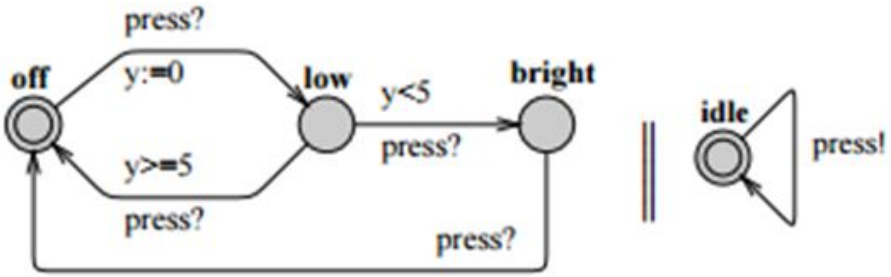


UPPAAL



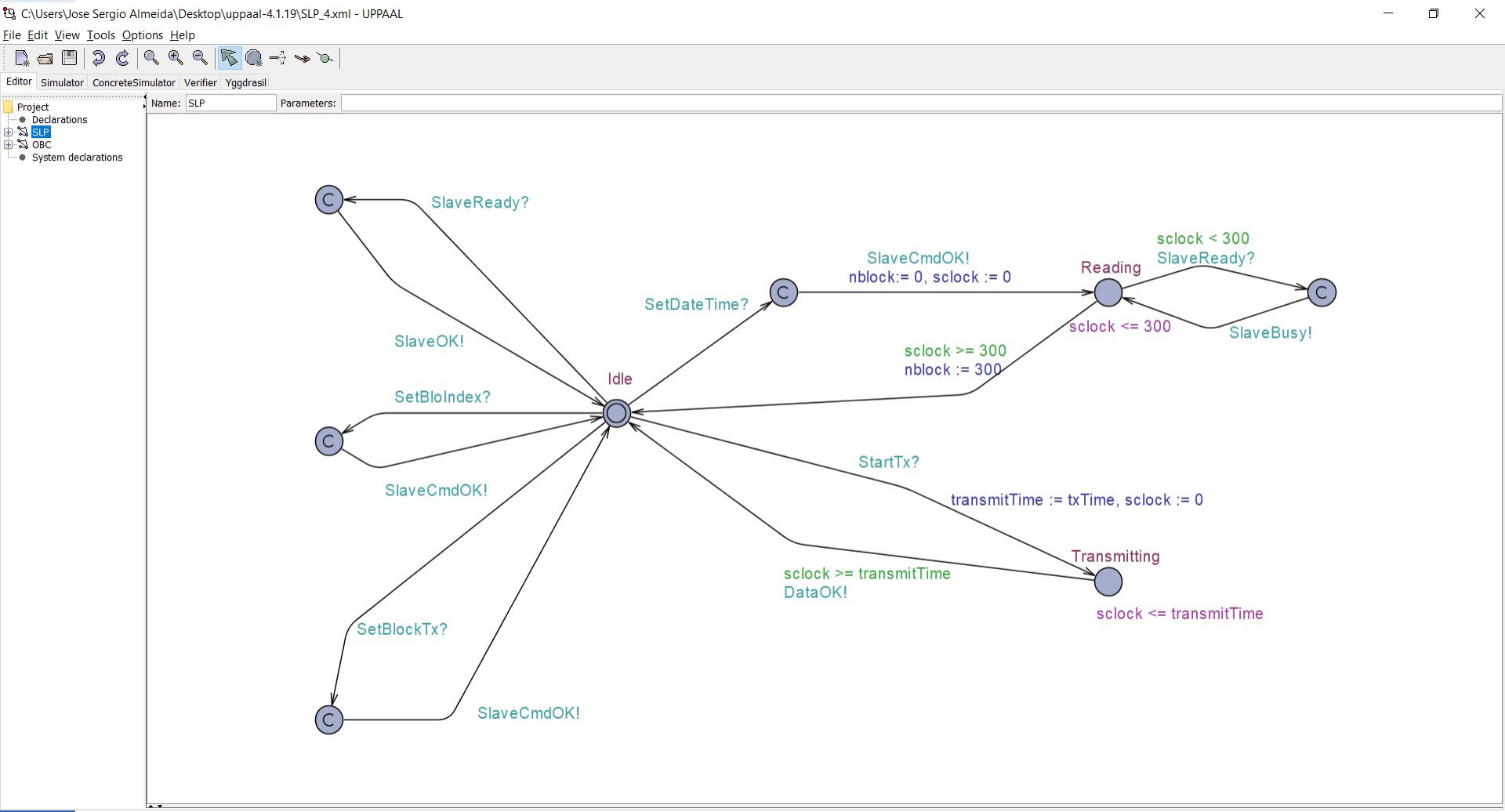
Timed Automata são sistemas de máquinas de estados finitos estendidas com variáveis de relógio (*clock*).

UPPAAL é uma ferramenta para modelagem, verificação e validação de sistemas de tempo-real modelados como redes de *timed automata*.

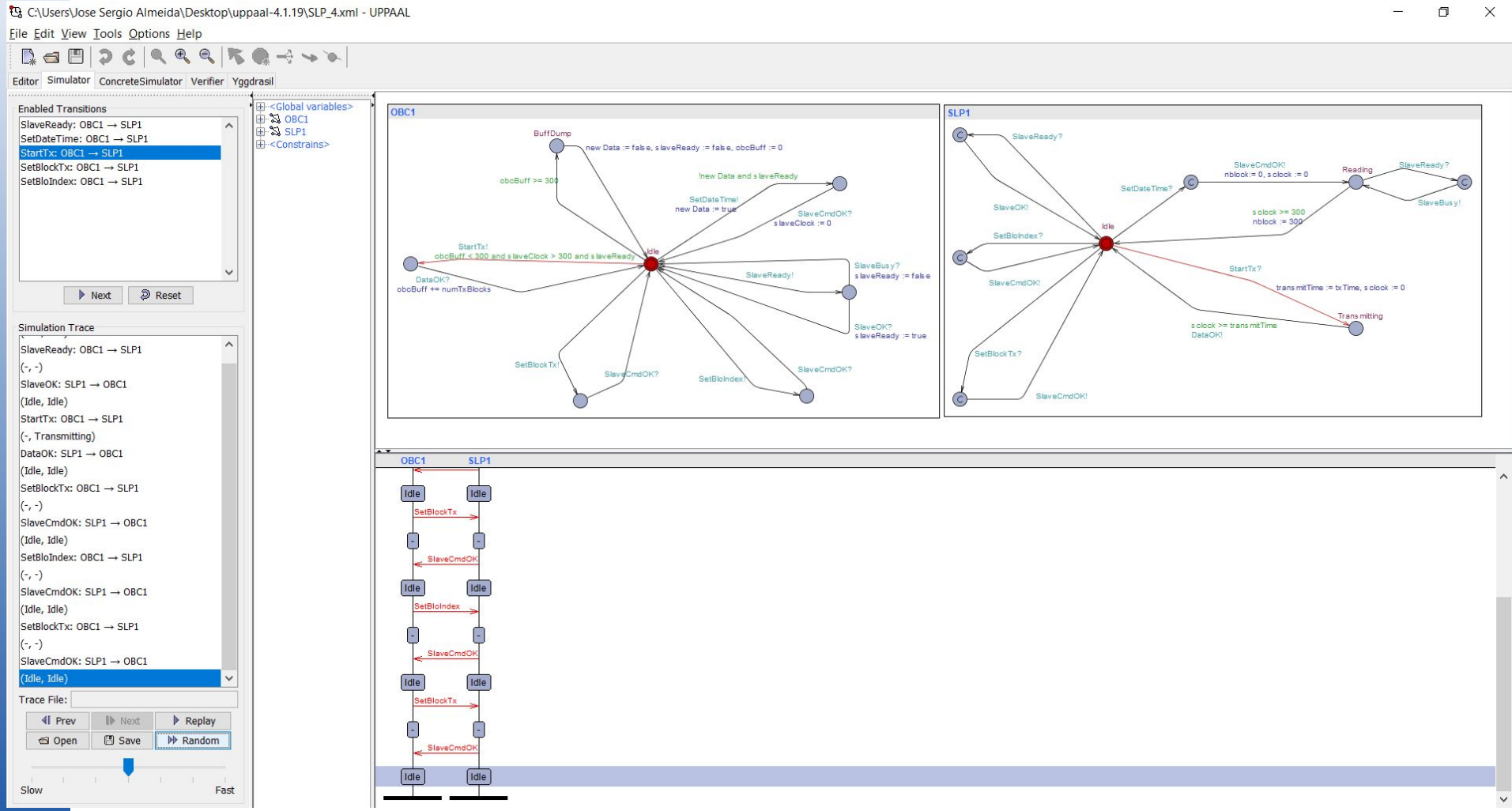


(a) Lamp. (b) User.

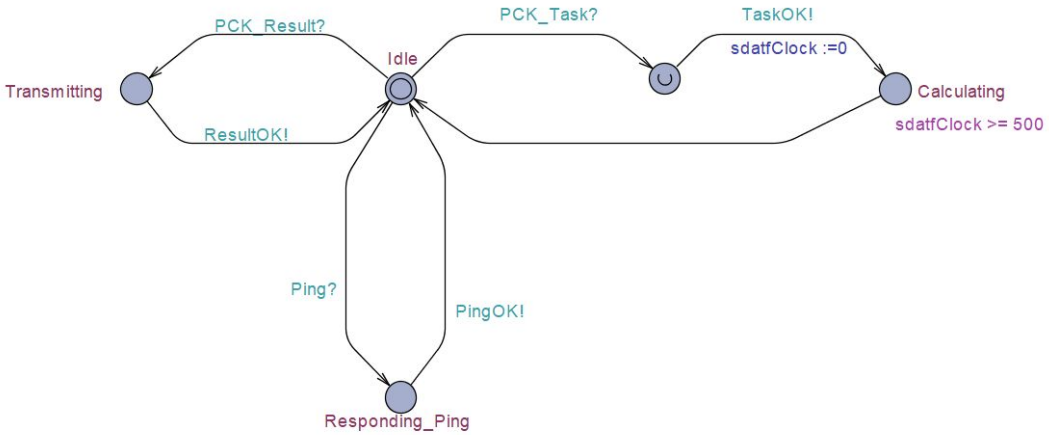
UPPAAL

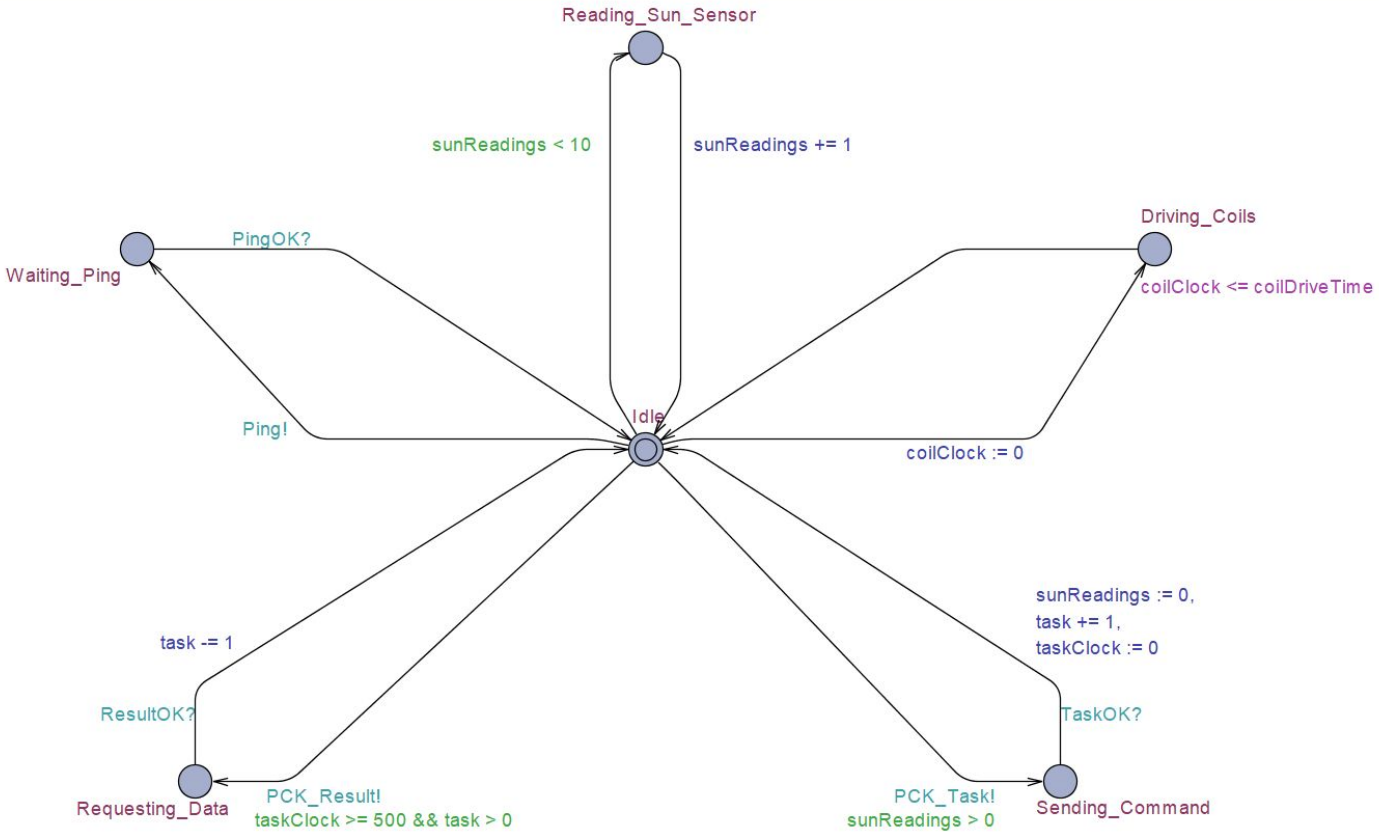

C:\Users\Jose Sergio Almeida\Desktop\uppaal-4.1.19\SLP_4.xml - UPPAAL
File Edit View Tools Options Help
Editor Simulator ConcreteSimulator Verifier Yggdrasil
Project
Declarations
SLP
OBC
System declarations
Name: SLP
Parameters:
SlaveReady?
SlaveOK!
SetBloIndex?
SlaveCmdOK!
SetBlockTx?
SlaveCmdOK!
SetDateTime?
SlaveCmdOK!
nblock:= 0, sclock := 0
Reading
sclock < 300
SlaveReady?
SlaveBusy!
sclock <= 300
sclock >= 300
nblock := 300
Idle
StartTx?
transmitTime := txTime, sclock := 0
Transmitting
sclock >= transmitTime
DataOK!
sclock <= transmitTime

UPPAAL - Simulador



Modelo SDATF





Simulação SDATF