Students 2U Nanosatellite project @ Marseille

CASAA-SAT

Aix-Marseille University & LAM

Bernard REPETTI
CASAA-Sat Project Manager
&
Hector SILVA
Electronics development engineer

https://www.lam.fr/formation/nanosats/

LAM Seminar – Thursday 25th October

Aix*Marseille université | cnrs | LAM Laboratoire d'Astrophysique de Marseille

Outline

Bernard REPETTI

- CASAA-Sat objectives, history, planning and organization
- Main presentation of the project and Vibrations test

Hector SILVA

- The Engineering Model

CASAA-Sat objectives ?

- Educational project. The goals are :

  - Increase the scientific and technical interest of our students
  - Teach the students, from different degrees and specialities, to work together, on the same project

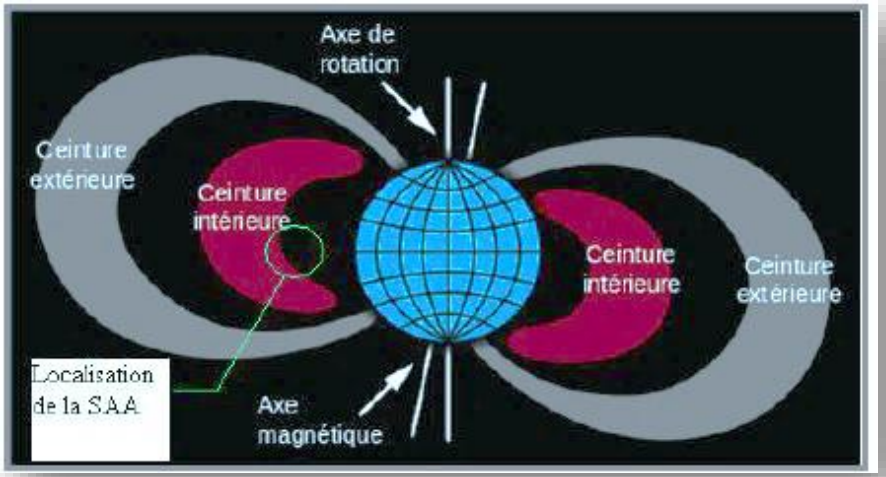
  Proposal for an interesting (but feasible) space mission to develop

➔ **CASAA-Sat was born in 2013, for 6 scholar years :**

- To scan (CArtography) the SAA (South Atlantic Anomaly, above Brasil) :

  - Flow charged particles measurement
  - Magnetic field measurement
  - To capture light phenomena (polar lights)

  ➔ **Correlate the 3 phenomena**

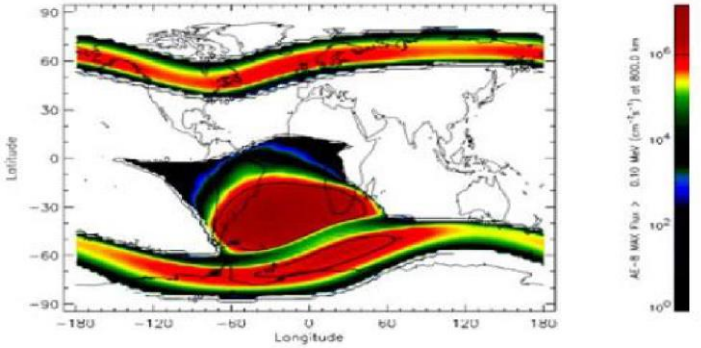


- To test an integrated circuit (Lab development) in space

Scientific objectives

Payload description

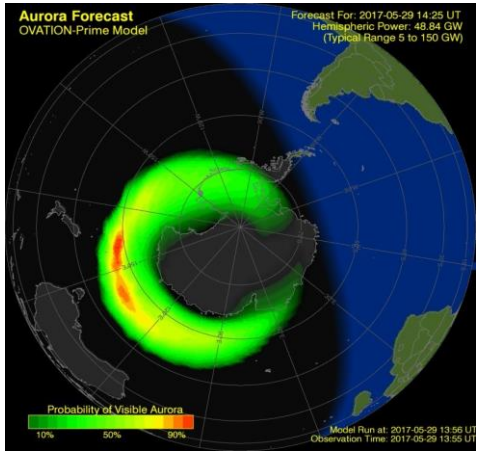
- Flow charge particles measurement :
  Small Integrated Circuit, MOS-FET,
  from TRAD-Space



600 km

- Magnetic field measurement :
  3-axes magnetometer, from HONEYWELL

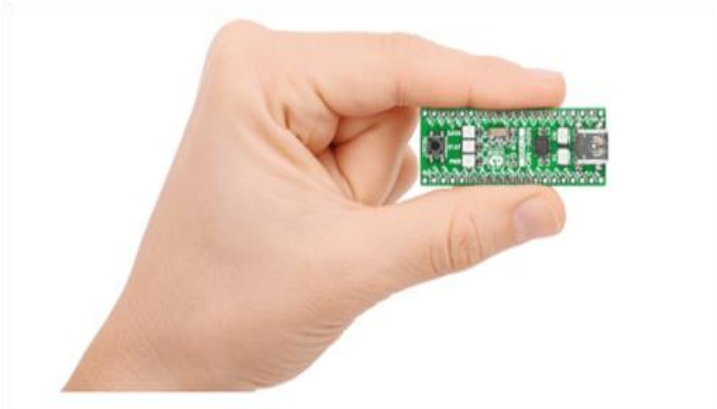
- Polar light phenomena :
  20B44M Videology, delivered by CNES,
  already mounted on TARANIS



➔ **The 3 phenomena will be correlated**

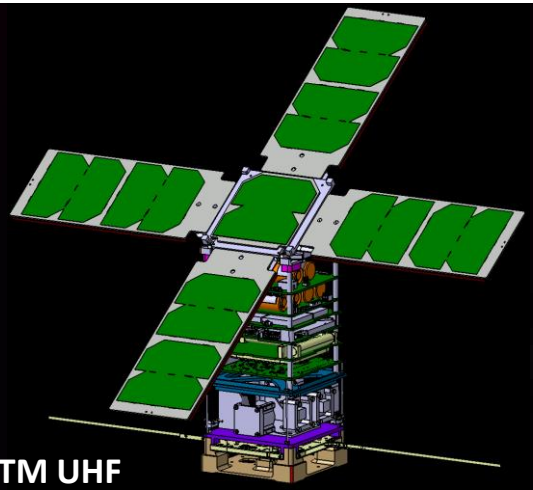
Other objectives

- Technological demonstrator :
  This board (STM-32) includes a memory developed by several laboratories « REER »



➔ **Check the error rate of this circuit in orbit, using a fully known pattern, and highlights the radiation effects on the memory.**

Spatial system



Orbital parameters
Elevation 615 km
Inclination 97°85
Excentricity < 10^{-3}
LTAN 10:30 PM

TM UHF
9600 bits/s

TC VHF
1200 bits/s

Piggy-back launch from KOUROU in a VEGA launcher, orbit of PRISMA

Le Laboratoire d'Astrophysique de...

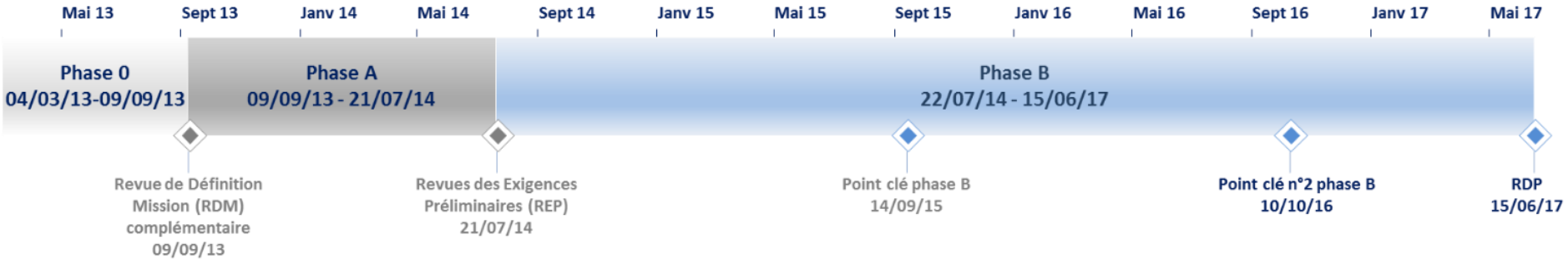
Control and Mission Center at LAM

History and planning of CASAA-Sat

➢ About **180 students** have been involved since 2013

- Mini-projects (1st-half year) & Full time project internships (2nd-half year) :
  19 students have already completed their training course at AMU Spatial Center, inside the LAM

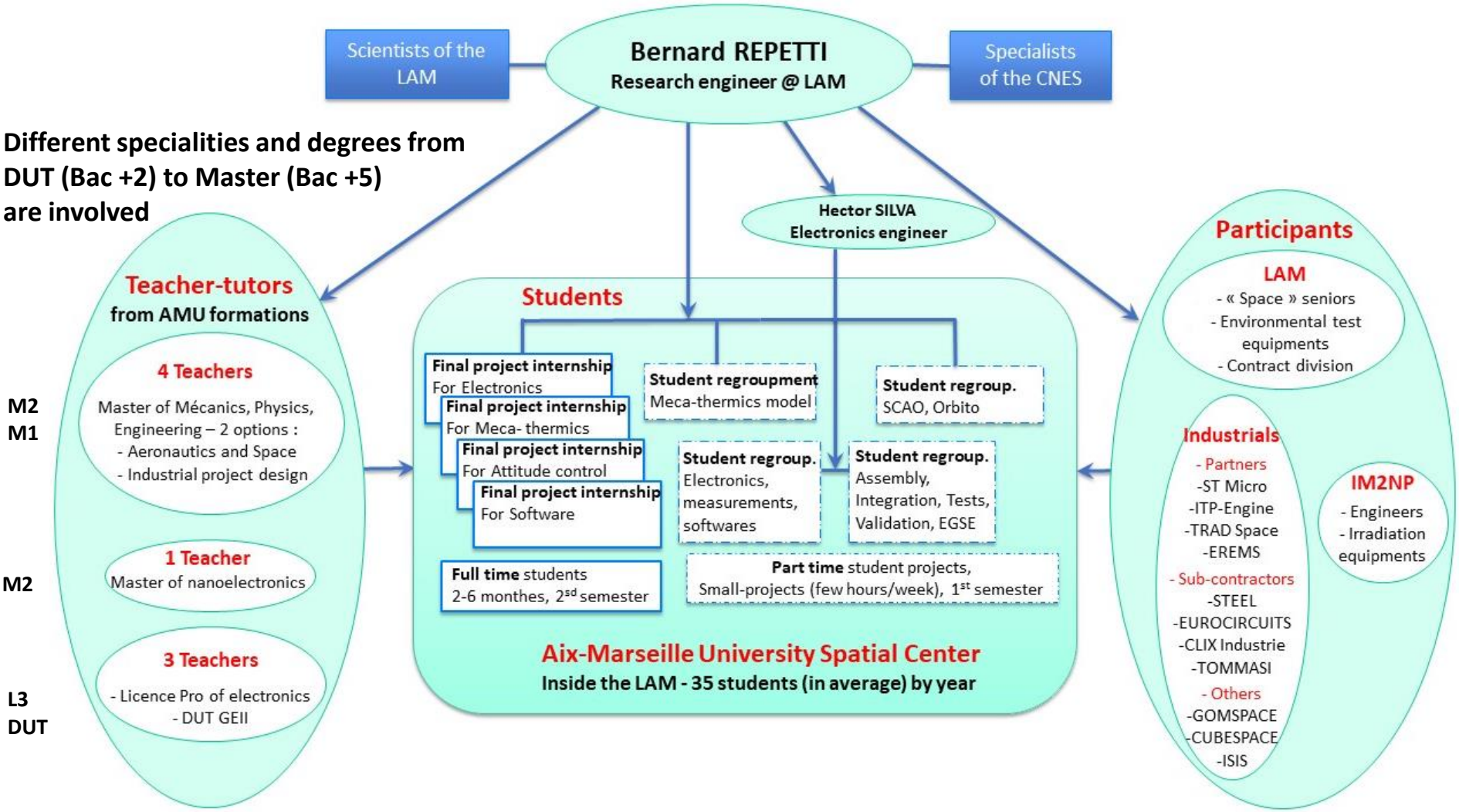
➢ Reviews and Keypoints with the CNES Agency :



➢ A contractual engagement between CNES and AMU through the LAM was signed in 2016 (total budget of ~ 500 k€) and we are working on Phase C

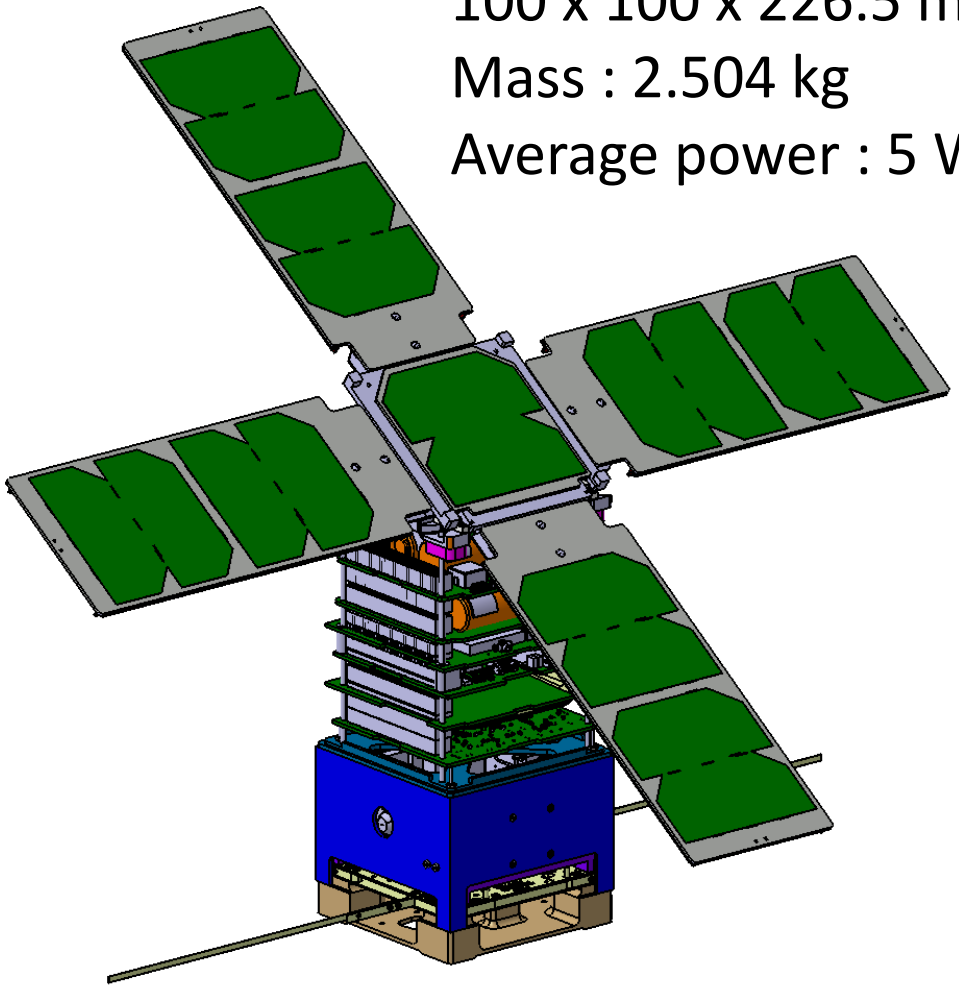
➢ Launch is scheduled at the end of 2019

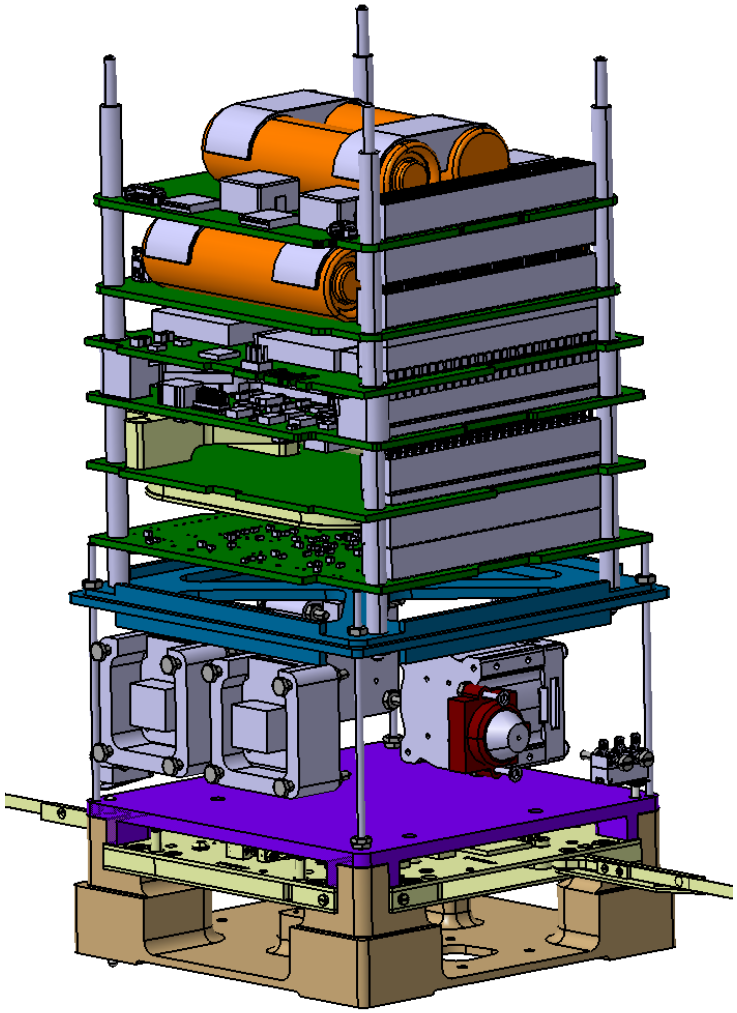
Working organization

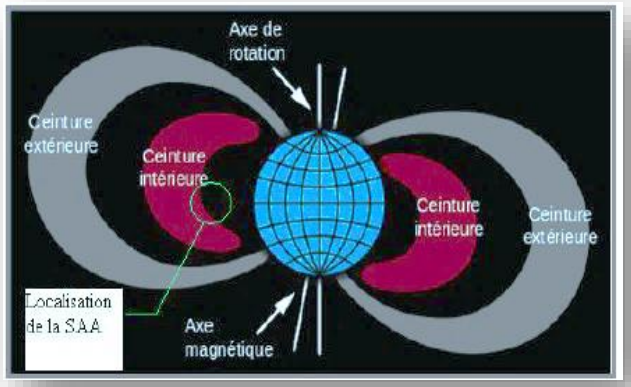


The satellite

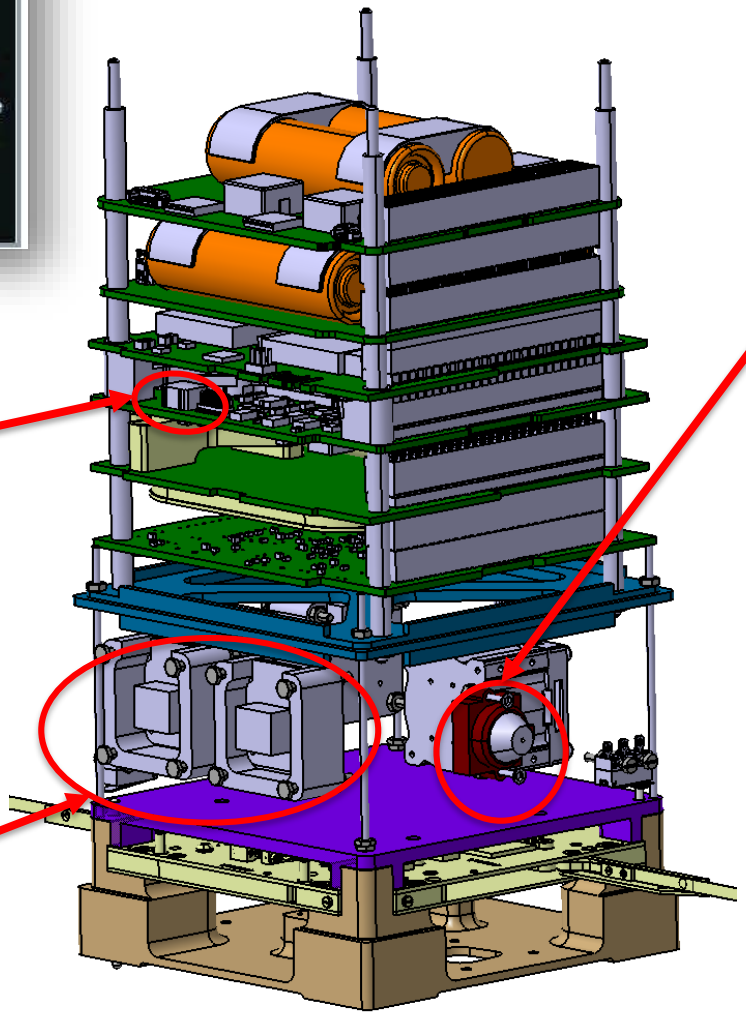
Standard 2U
100 x 100 x 226.5 mm
Mass : 2.504 kg
Average power : 5 W







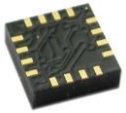
CASAA-Sat Payload



Camera

videology

Magnetometer



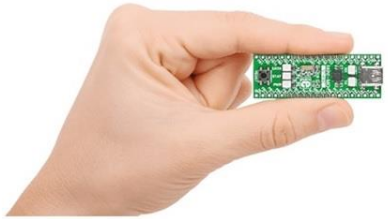
Honeywell

Dosimeter

TRAD tests & radiations

Integrated Circuit

REER – STmicro



To be tested under space environment

The orbit and the AOCS

Ejection

Delay → panel opening → Detumbling → Survival → **Acquisition and survival mode (MAS)**

Prisma's orbit
Z= **615 km**
i= **97,85°**
local time at the ascending node : **10h30 pm**

TC or auto

TC

auto

Order 1 or **Order 2**

Mission

Solar recharge

Nominal Mode (MNO)

End of life

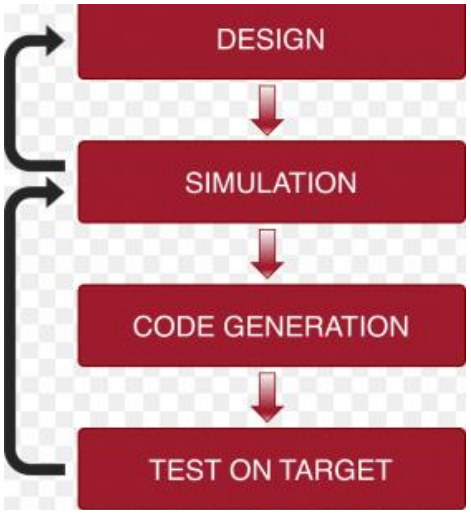
Attitude and Orbit Control System (AOCS)

Requirements :

Pointing	Scroll direction X +
Pointing accuracy	Better or equal to 5 °
Stability	Between 5 ° and 10 ° for 1s
Agility	No agility required

Attitude and Orbit Control System

MATLAB SIMULINK



Input :
- Magnetic field B
- Orbital parameters (i, ΩN, ω, M, e, …)

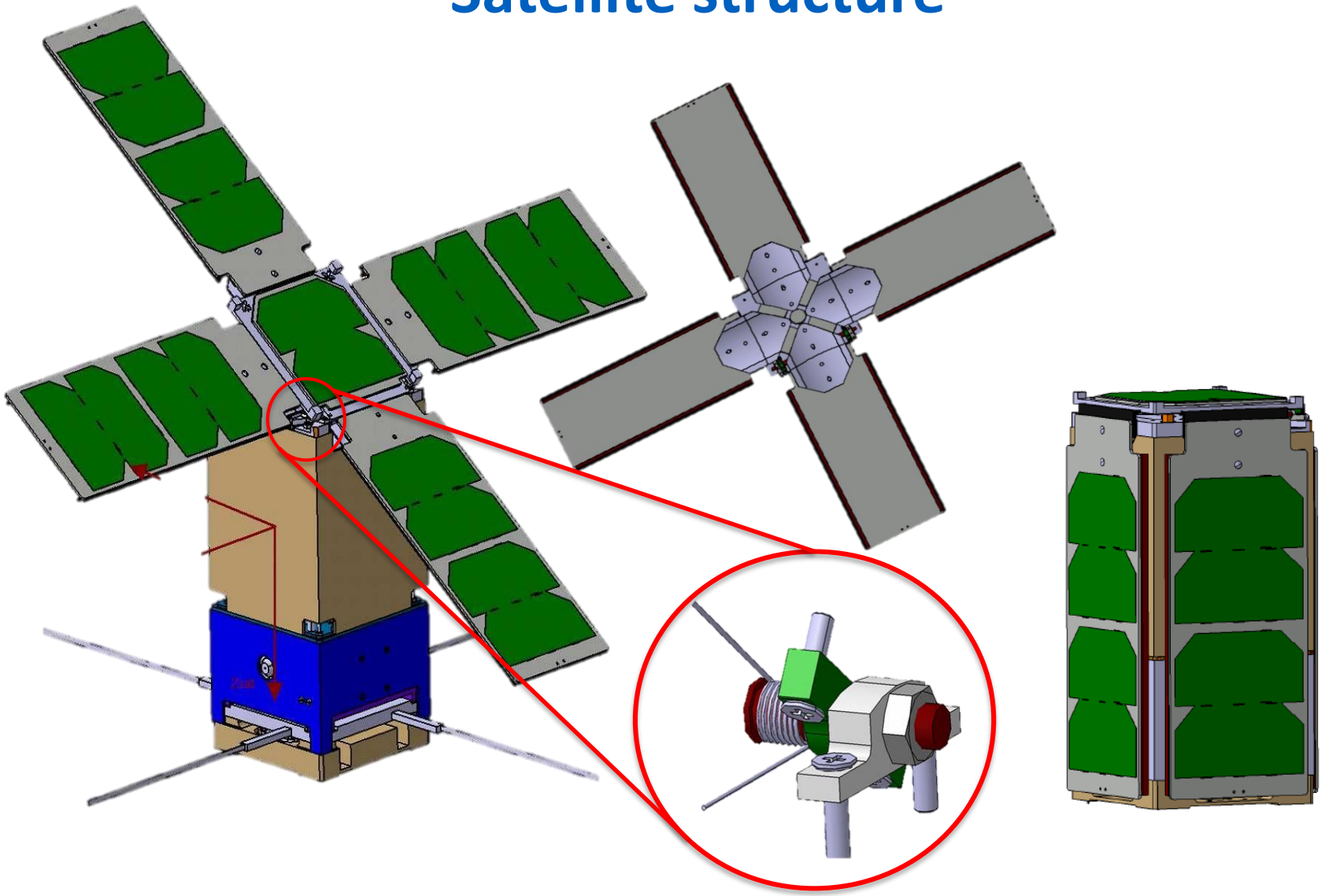
Output :
- Actuators : a Flywheel and 3 Magnetotorquers
- Command laws:

Bpoint law ***Compass type law***

$$\vec{M} = -K\frac{\dot{\vec{b}}}{\|\vec{B}\|} \qquad \vec{M} = \frac{K\vec{b_c} + D(\dot{\vec{b_c}} - \dot{\vec{b}})}{\|\vec{B}\|}$$

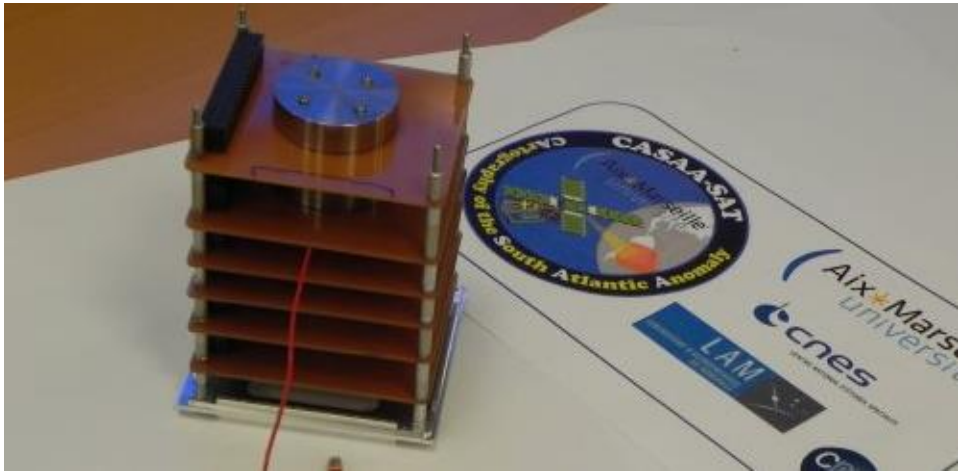
MAS ***MNO***

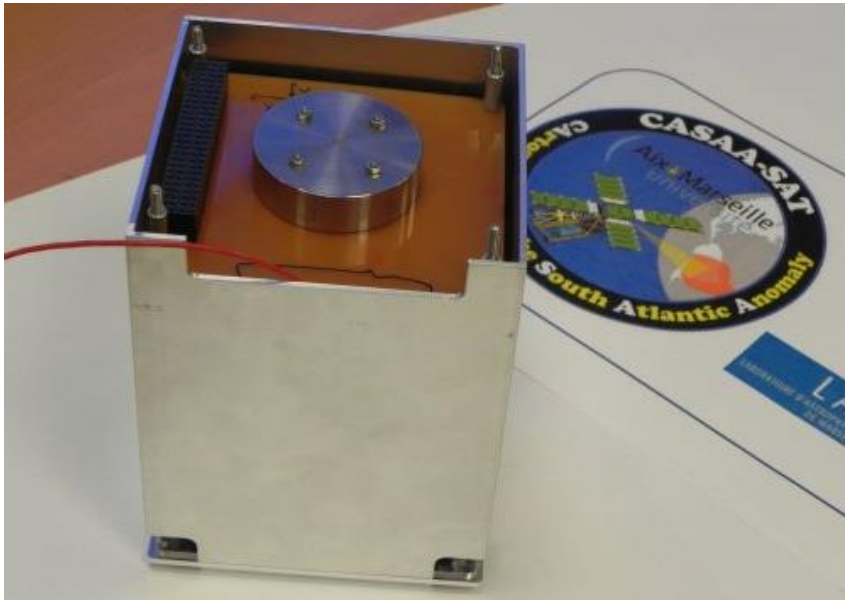
Satellite structure

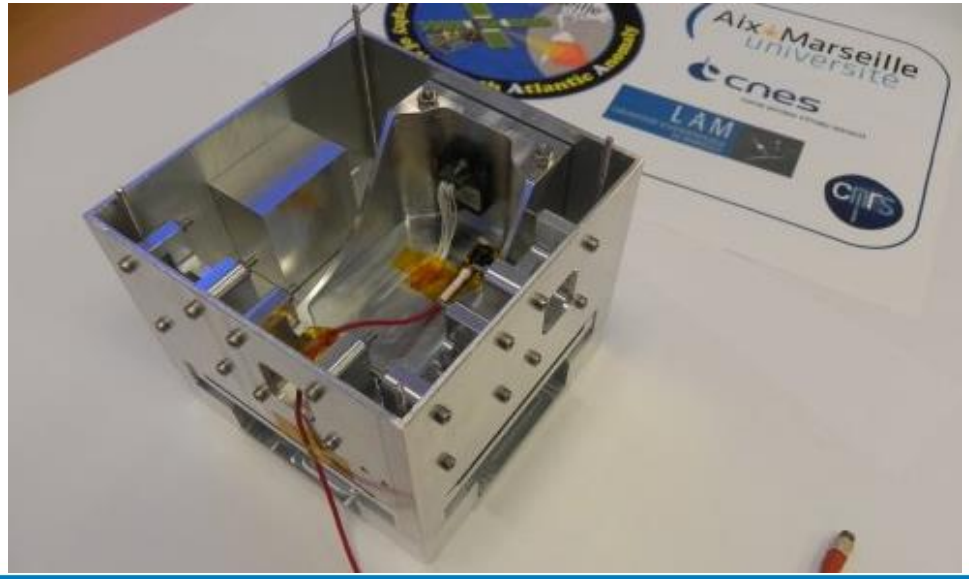


Satellite structure

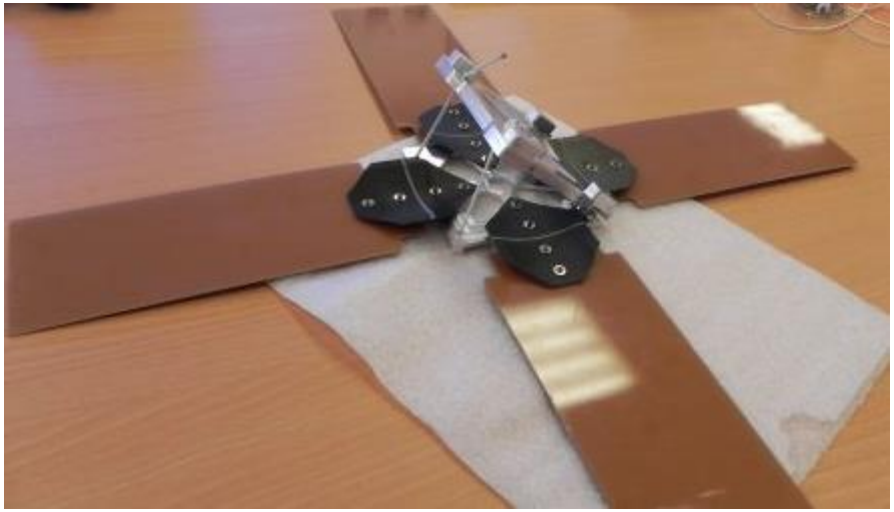
The Structural and Thermal Model

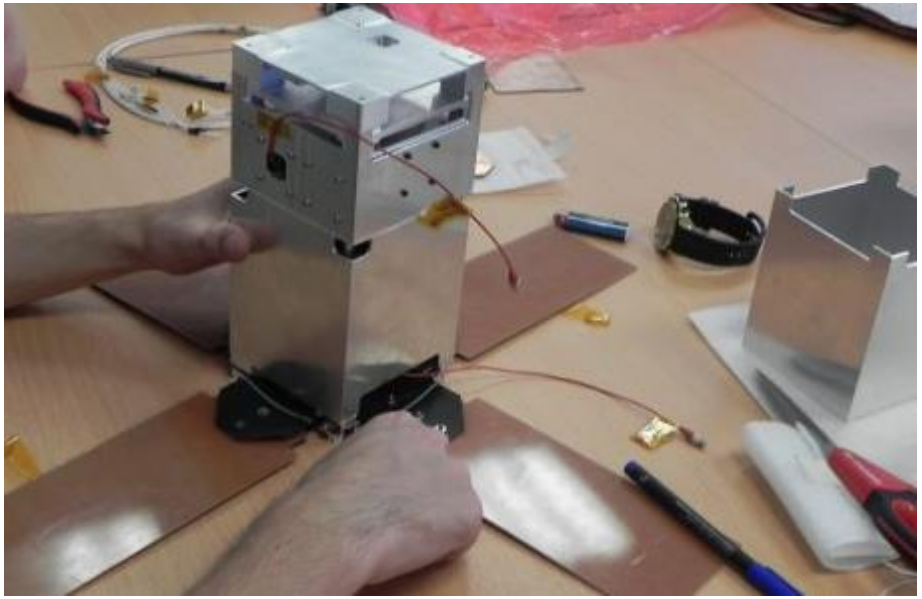


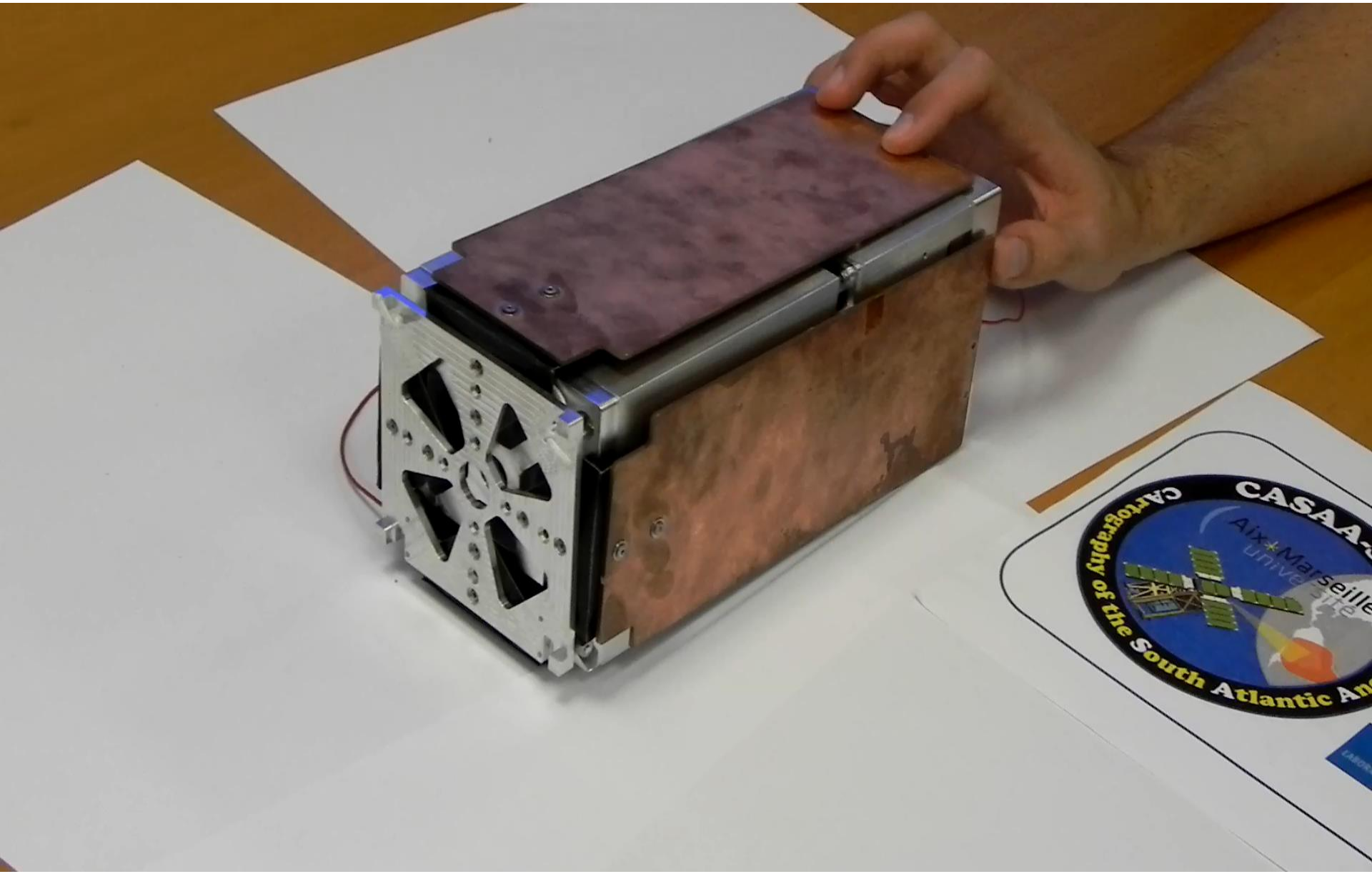




The STM

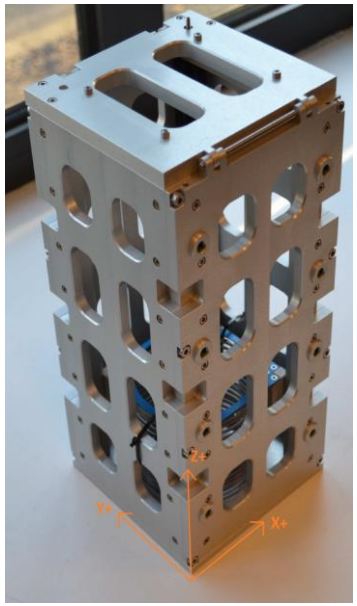





CASAA-Sat
Aix Marseille université
Cartography of the South Atlantic Anomaly

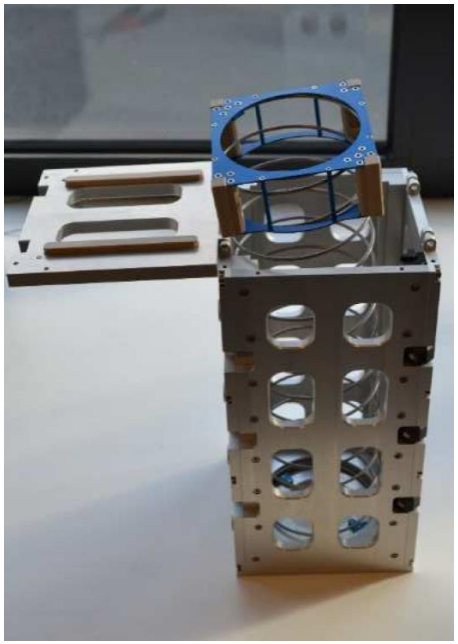
The STM

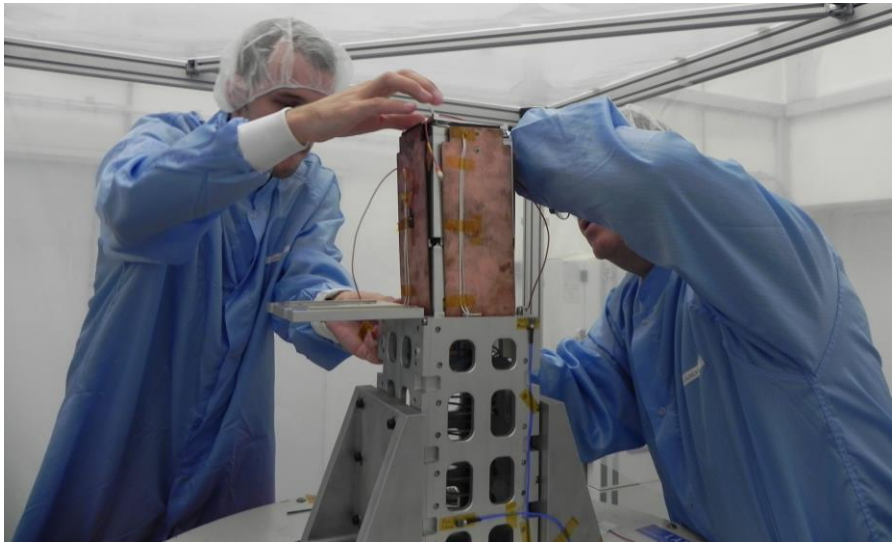
Launcher environment

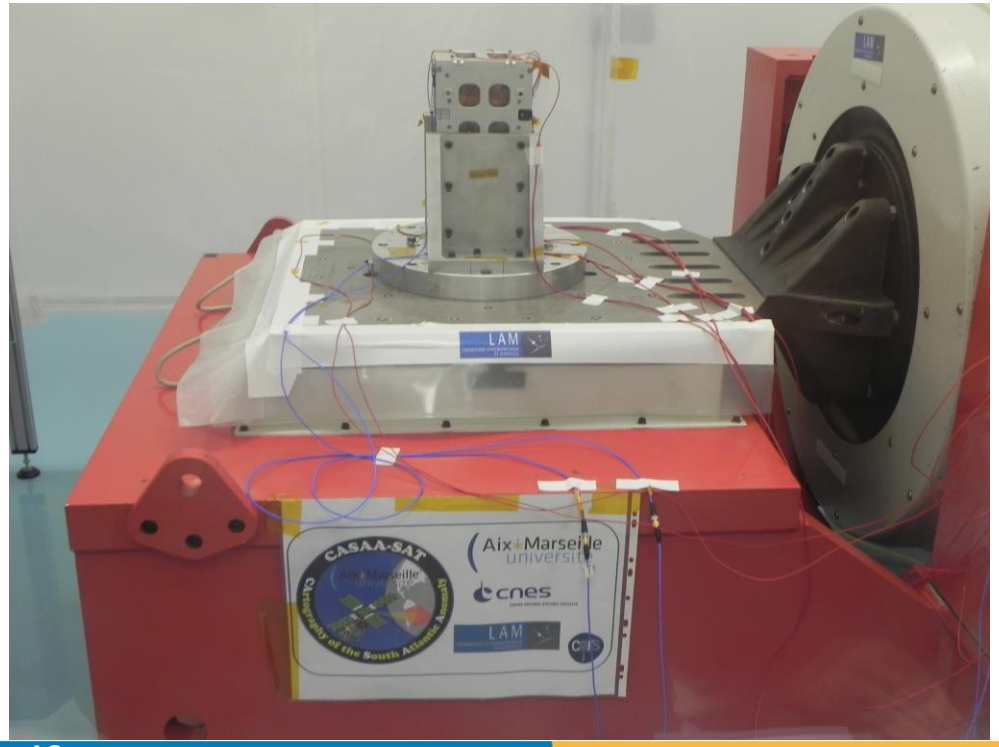


Test ISI-Pod

100% relevant of the Flight Model ISI-Pod.

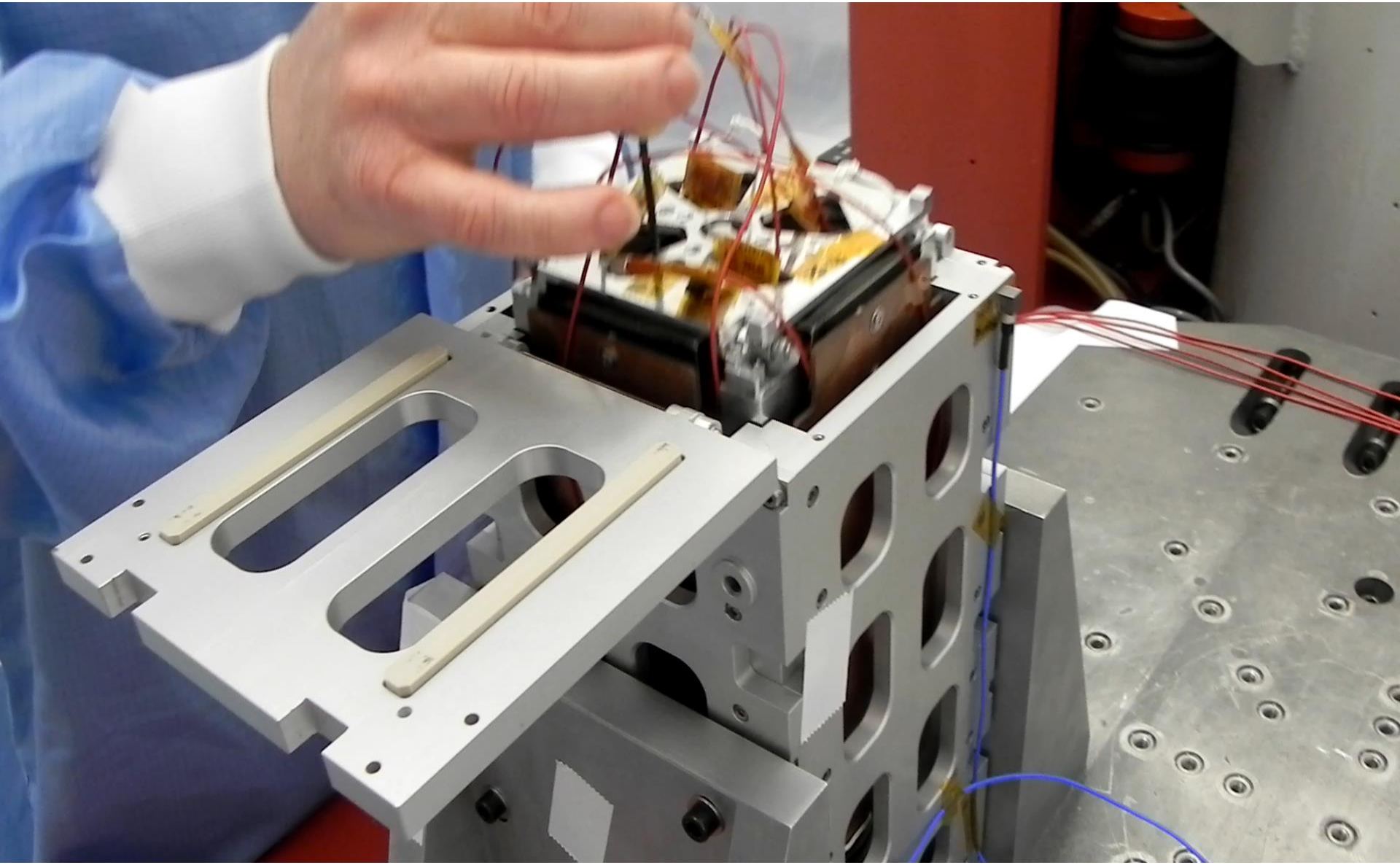


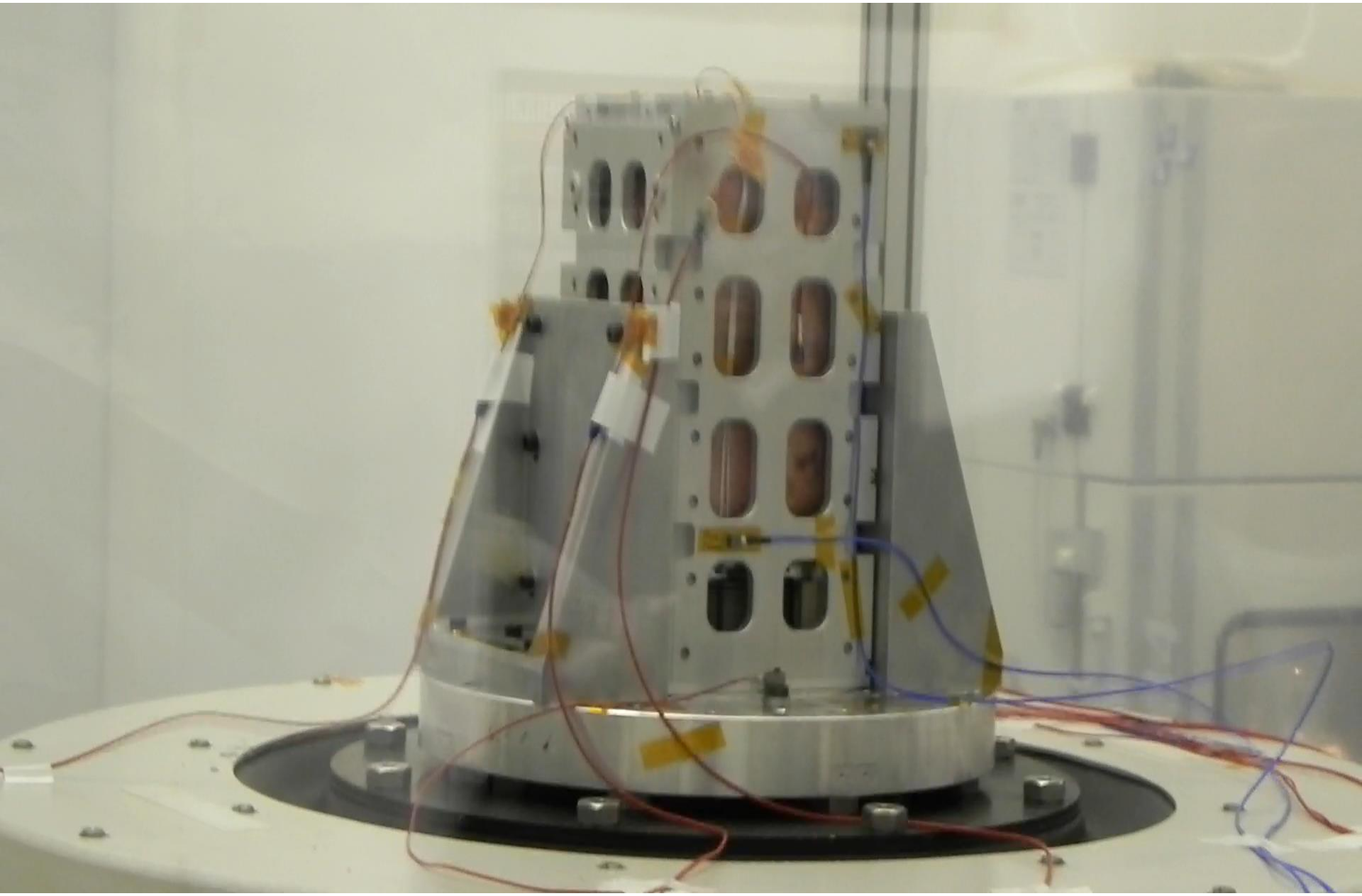




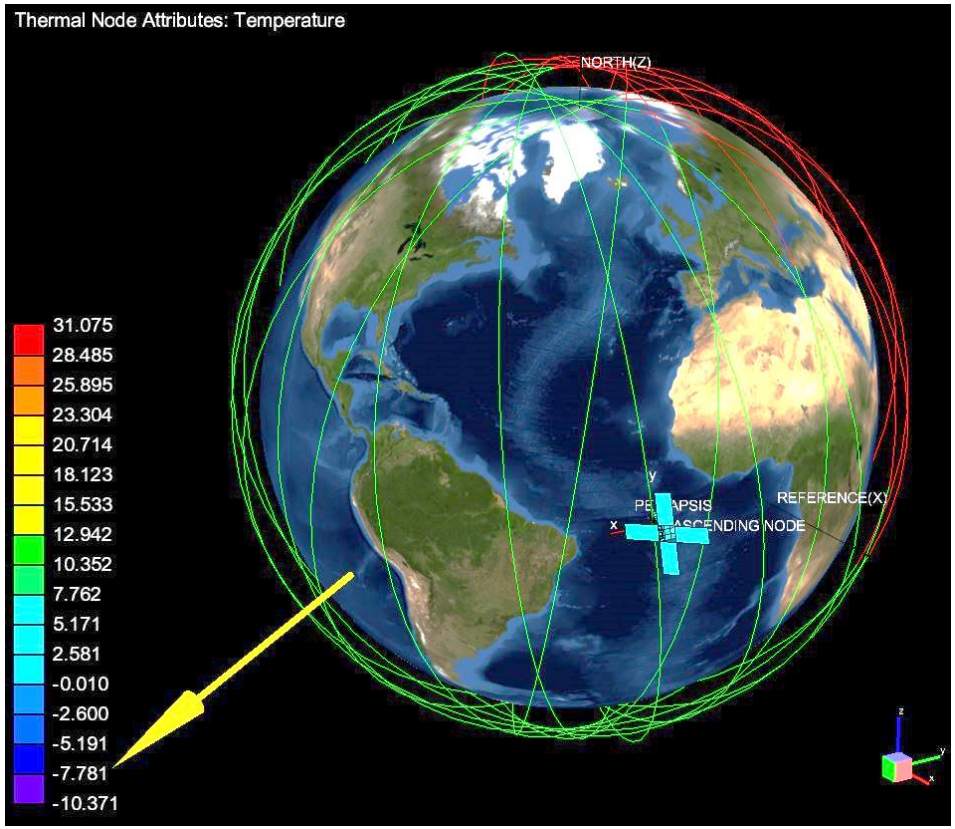
The STM has been fully checked !

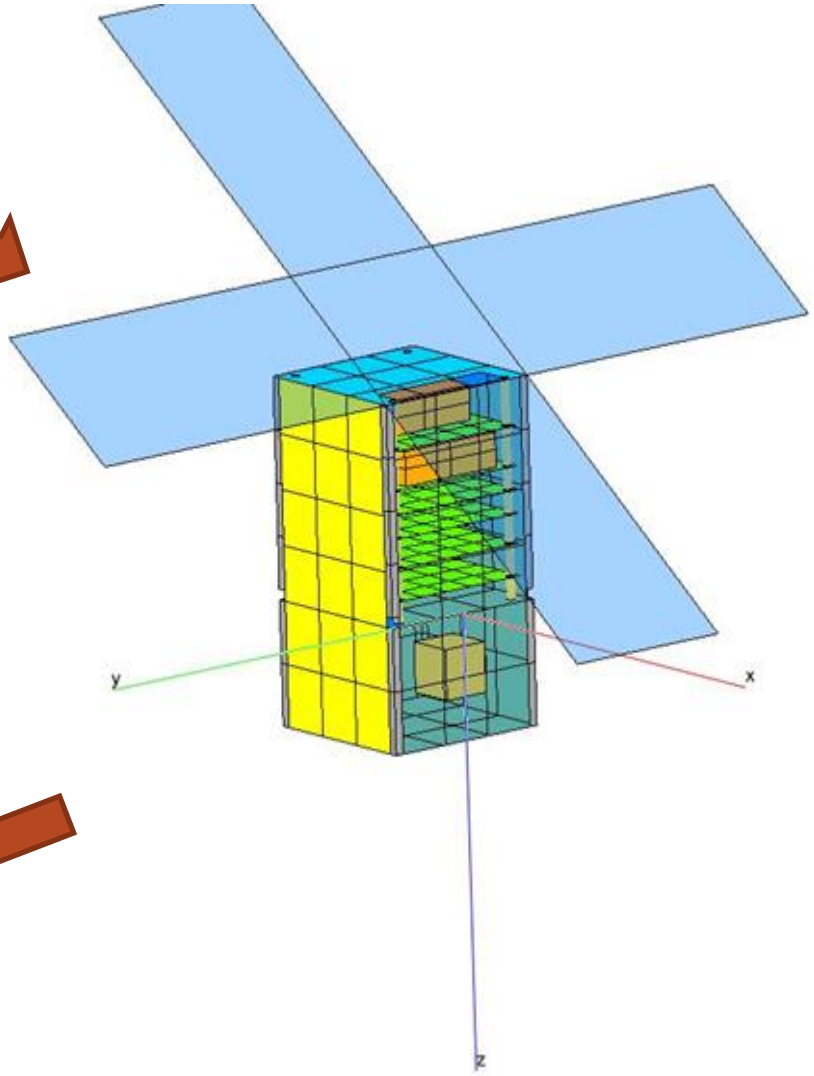
Vega specs (28G peak)





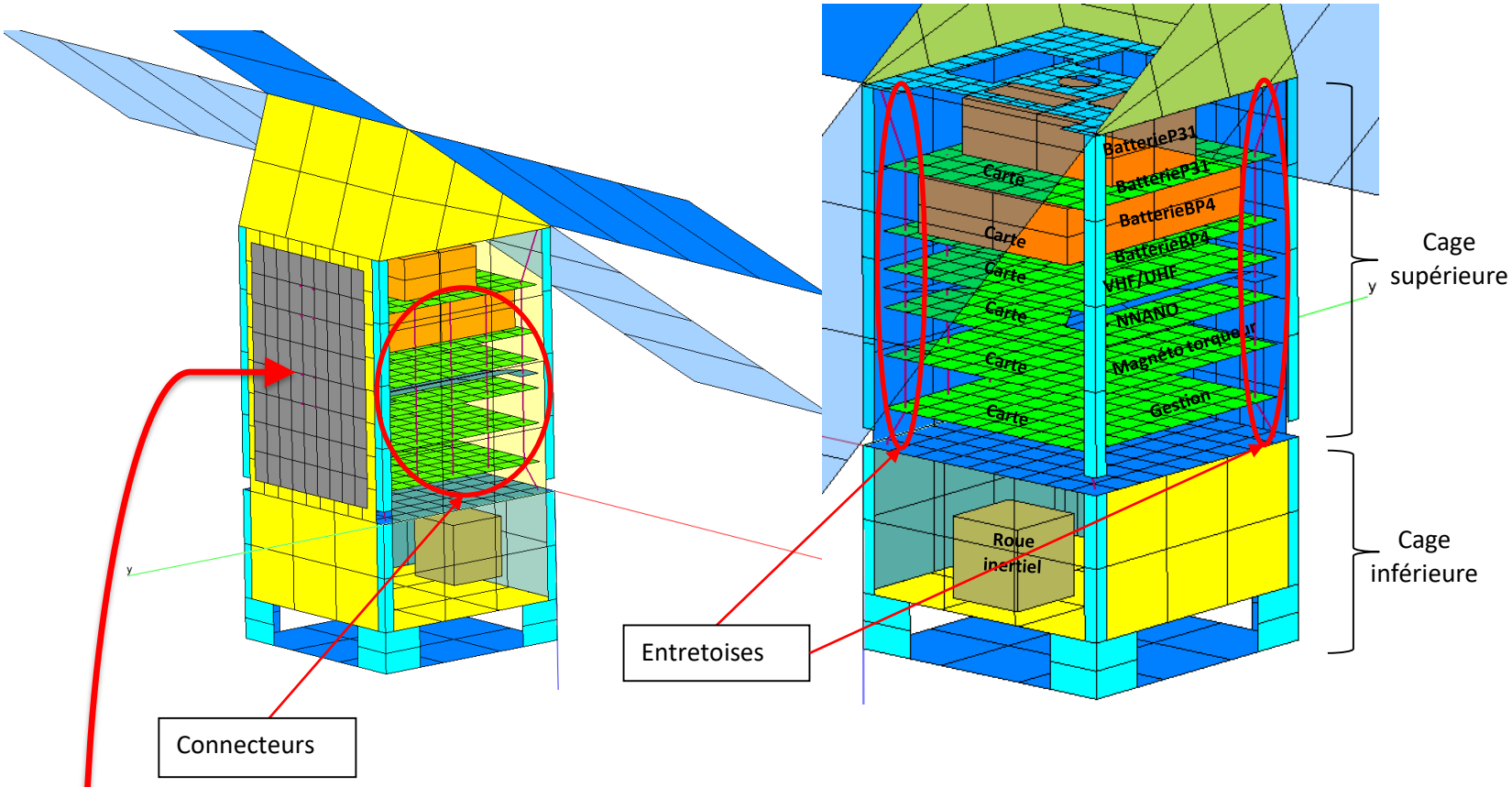
Thermal modeling





Thermal modeling

ESATAN-TMS
thermal modelling suite



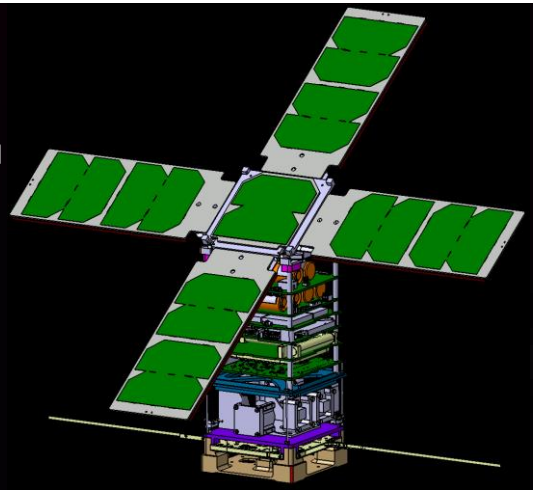
We don't need to heat, but
it will be necessary to drain component calories through a cold satellite face

Spacecraft Ground link

Uplink & Downlink margins > 0

Orbital parameters :
SSO, polar, altitude : 615 km
Inclination : 98,7 °
Local Time on Ascending Node : 10h30 PM

Piggyback launch from KOUROU in a VEGA launcher, orbit of PRISMA.
Engagment scheduled end 2019.



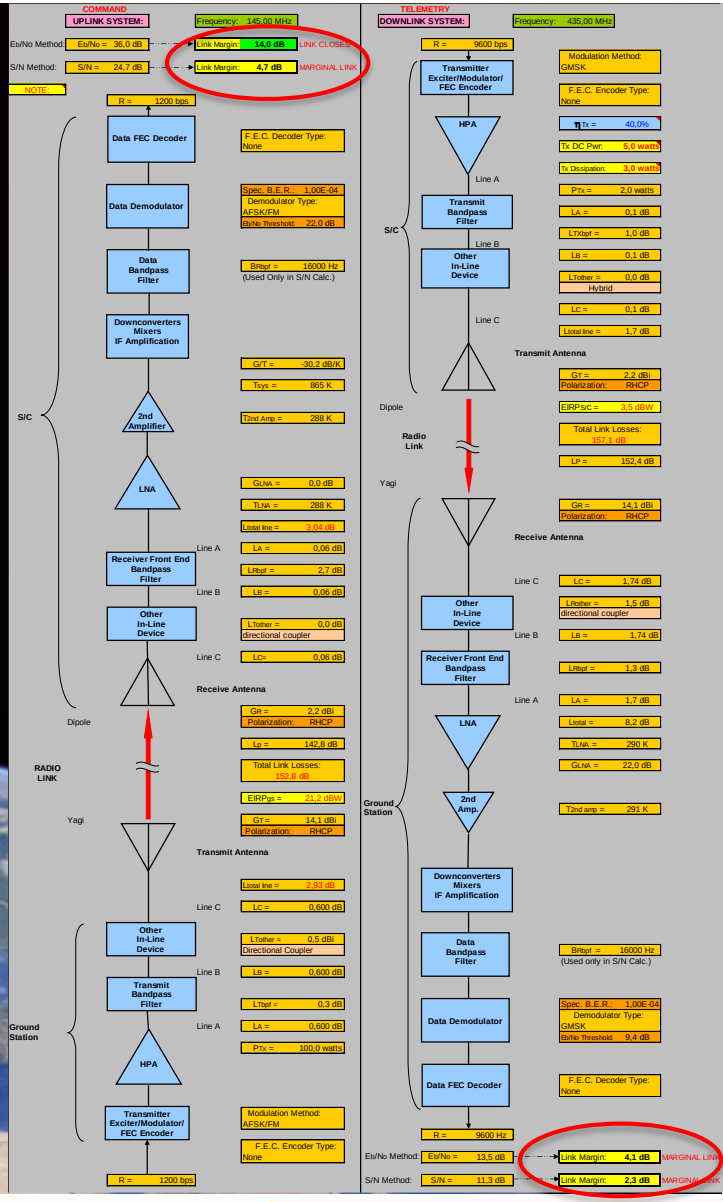
Uplink :
Reception VHF 1200 bps
Orbital parameters, strategy…

Downlink :
Emission UHF 9600 bps
Photos/Magnetic field values /Dosimeter measurements/HK

LAM
Altitude : 120 m
Latitude : 43 °
Longitude : 5 °
Minimum elevation : 7 °

Le Laboratoire d'Astrophysique de…

Mission and control center

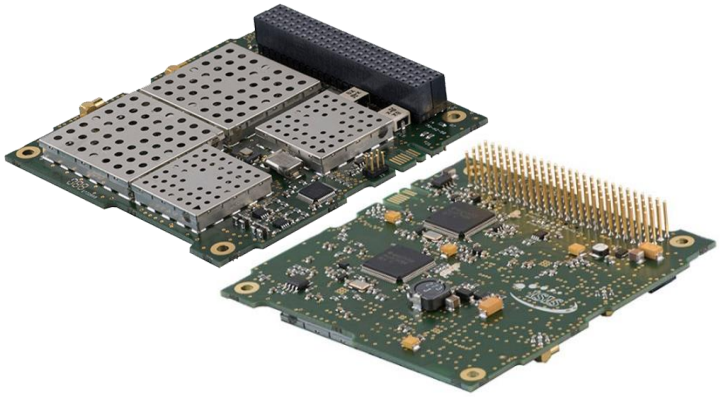


We would like to implement this exemple of Center…

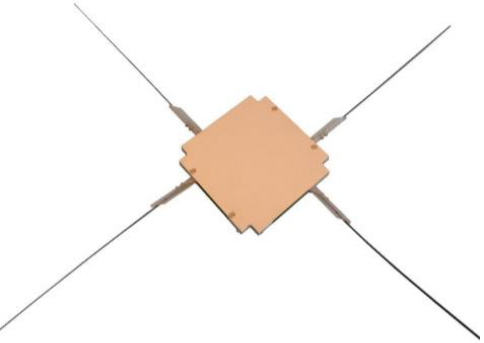
...Let's stay modest, realistic !

SpaceCraft side

➔ UHF/VHF board choosen

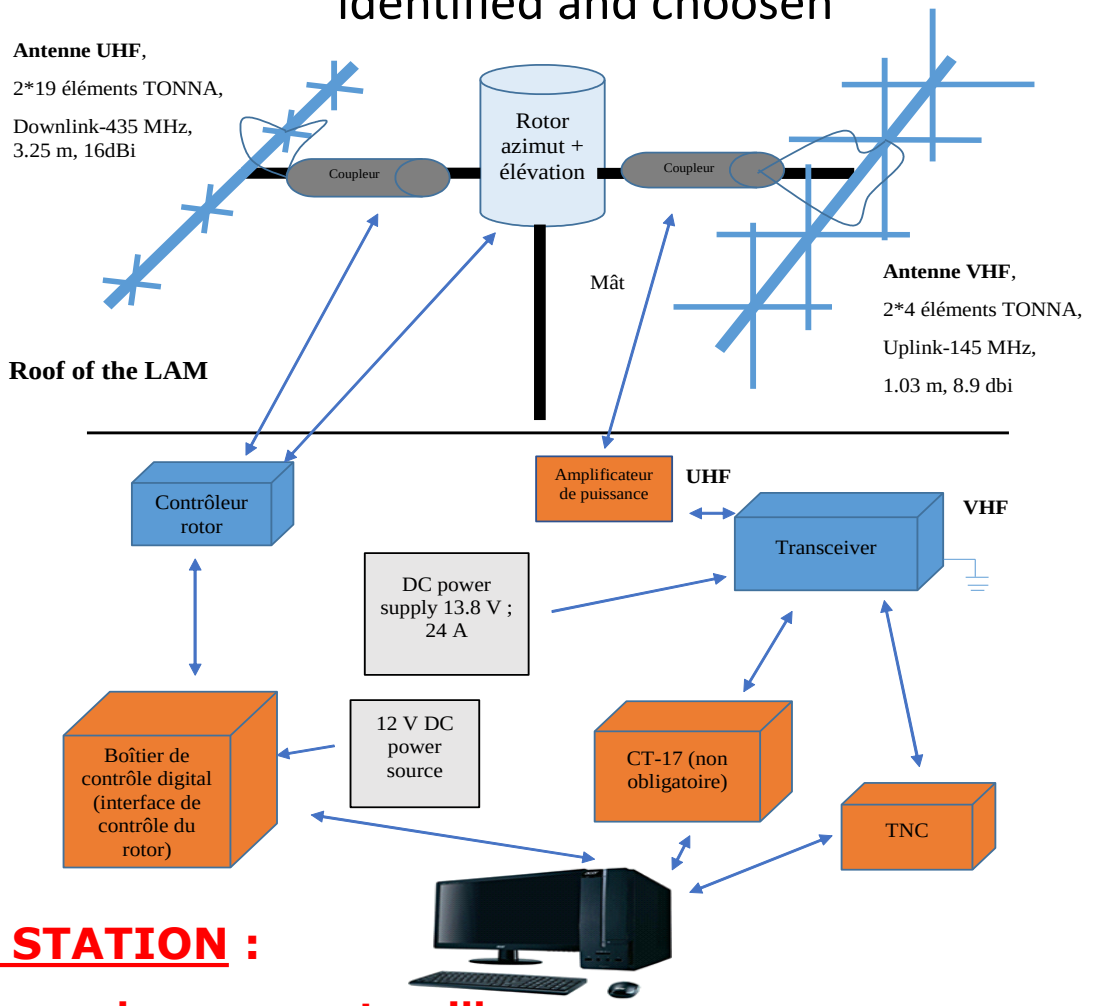


➔ Antenna choosen



Ground side

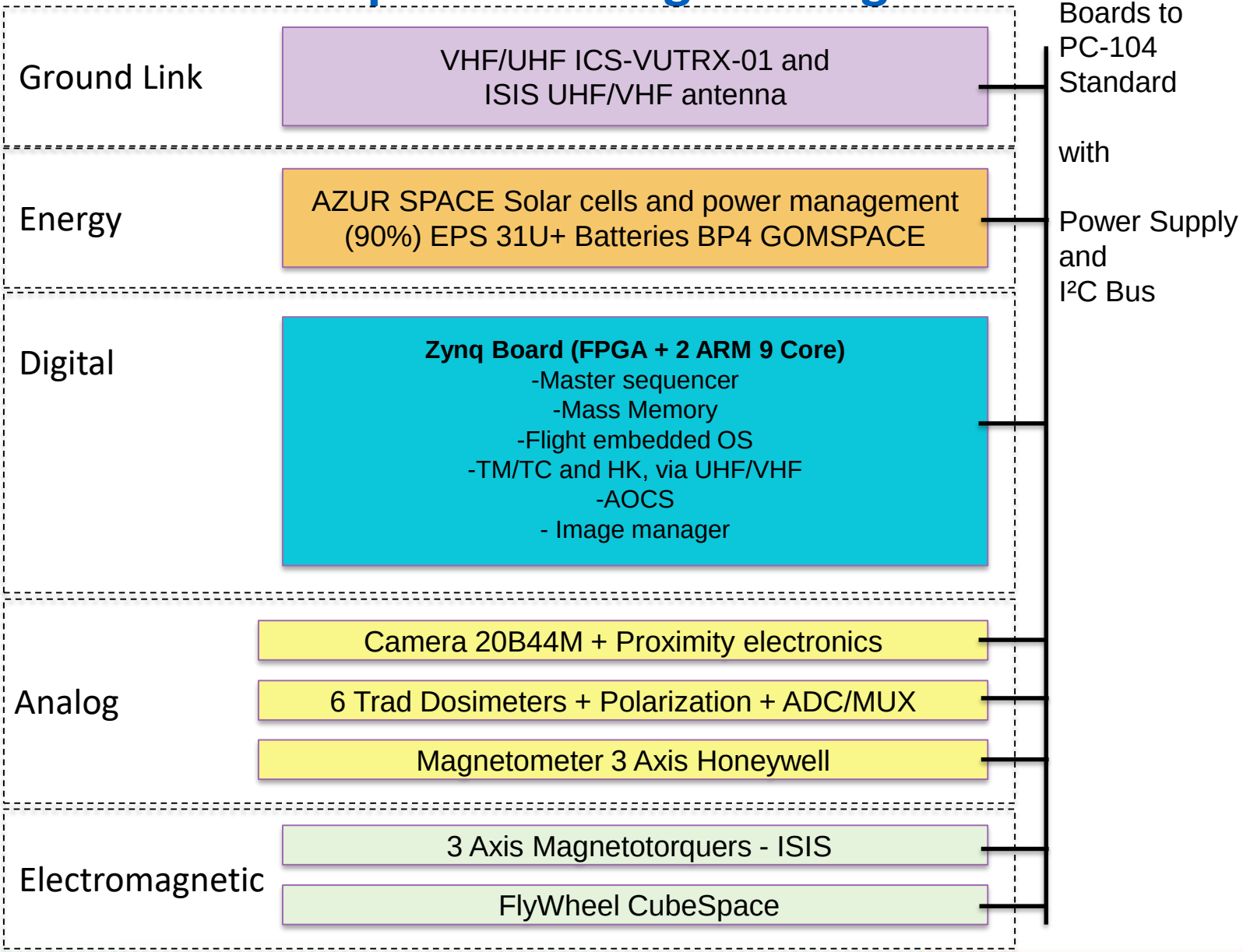
➔ Antenna and components, already identified and choosen



GROUND STATION :

PC, antenna and components will be bought and installed @ LAM

The Electronic part : the Engineering Model



Outline

Bernard REPETTI

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- Main presentation of the project and Vibrations test

Hector SILVA

- The Engineering Model

The Engineering Model

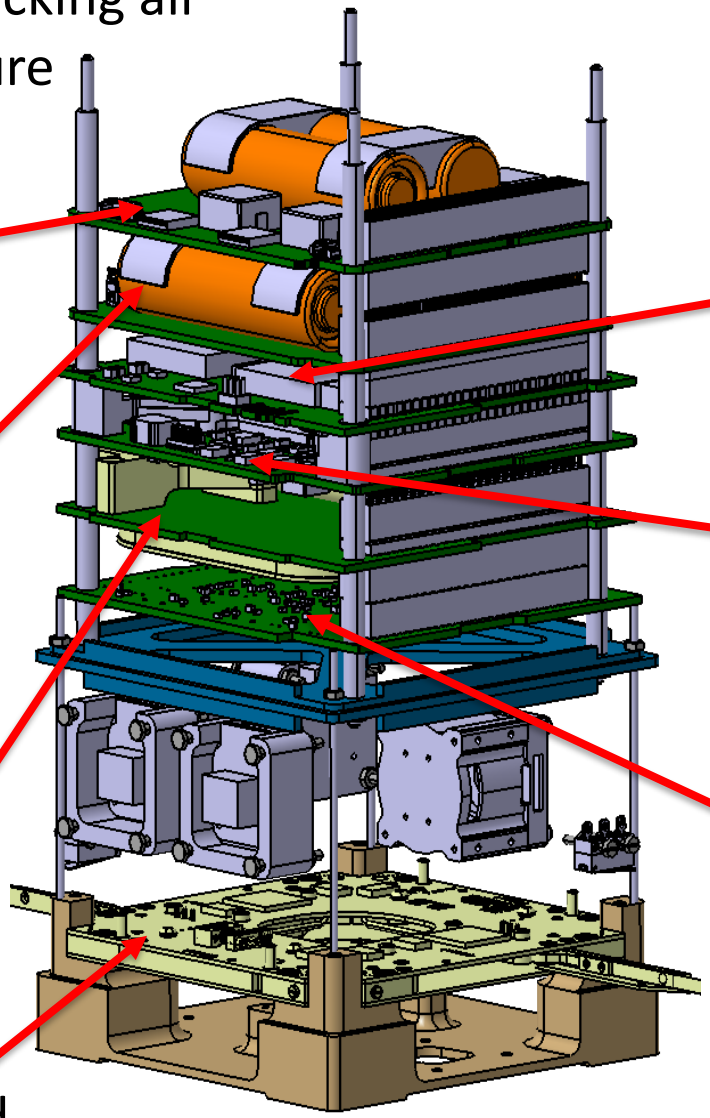
Preview of the board stacking all over the nanosat structure

EPS

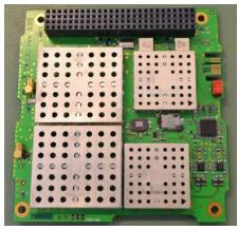
Batteries

Magnetotorquers

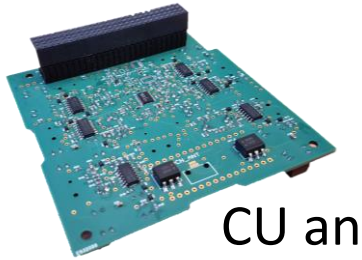
UHF/VHF Antenna board



UHF / VHF



Processor Ninano

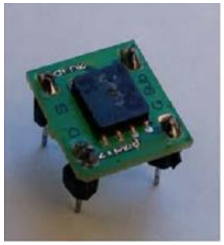


CU and PF board

The Engineering Model

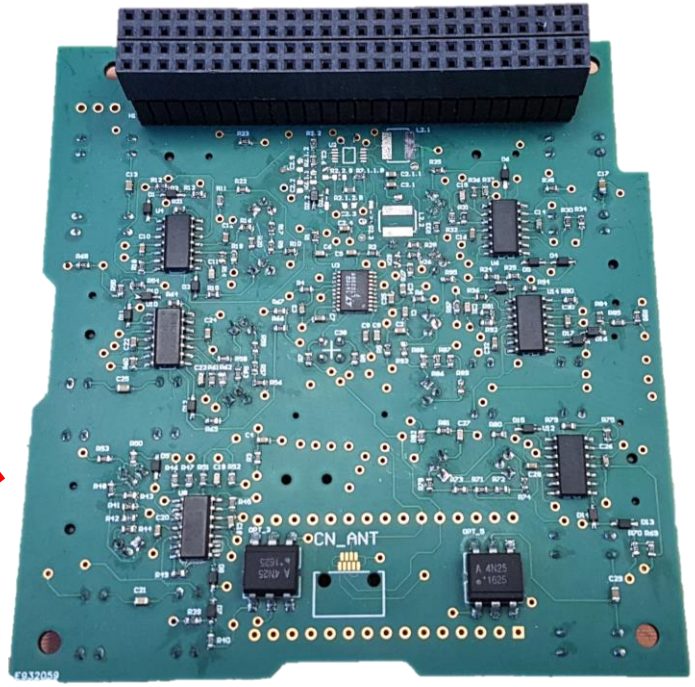
Completely developed by the CASAA-SAT team!

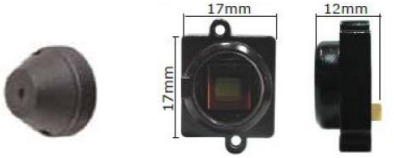
x6



Dosimeter

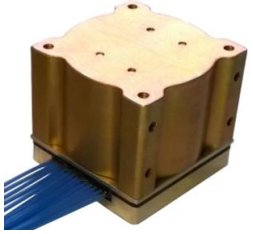
Payload Board

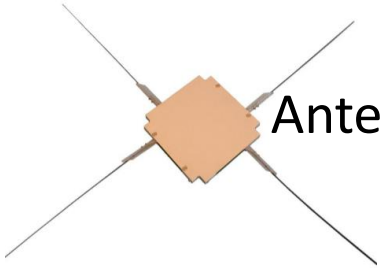




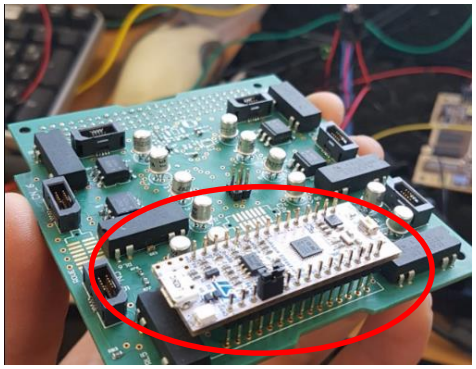
Proximity electronic camera

Small-wheel





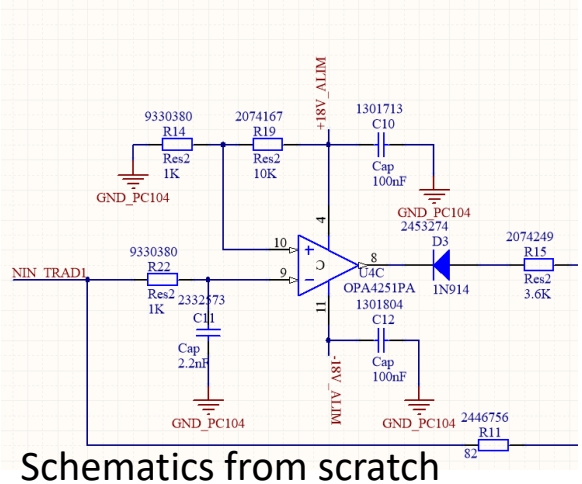
Antenna



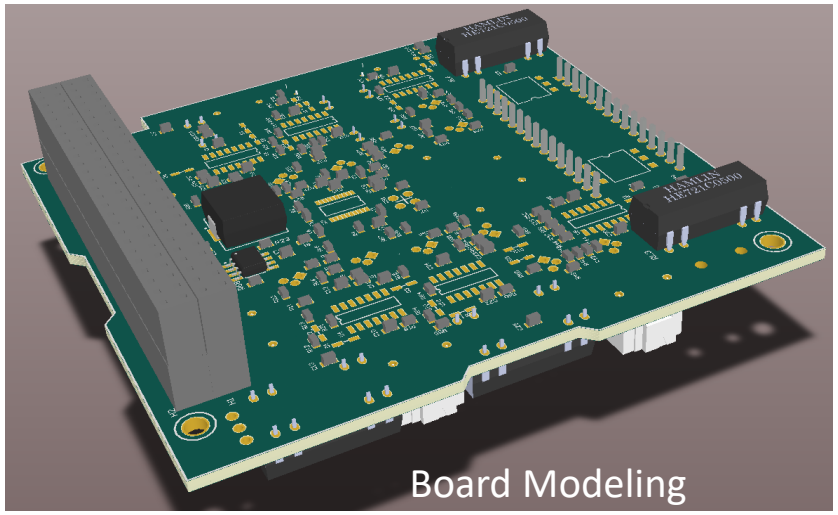
REER circuit

The Engineering Model

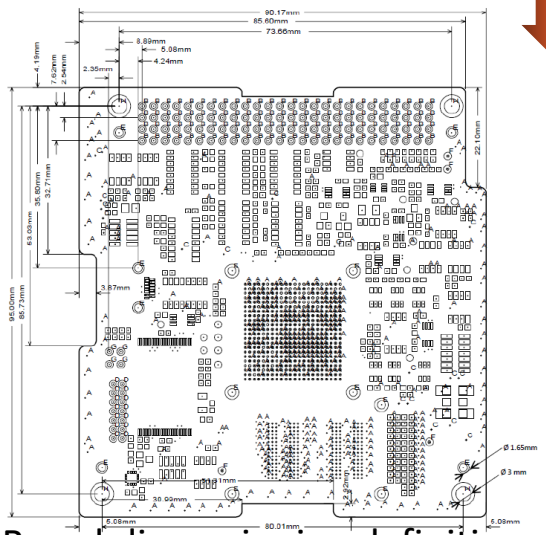
Payload Board development



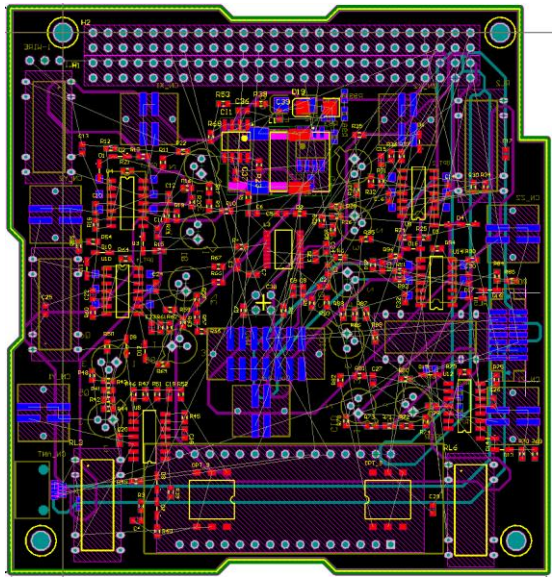
Schematics from scratch



Board Modeling



Board dimensioning definition



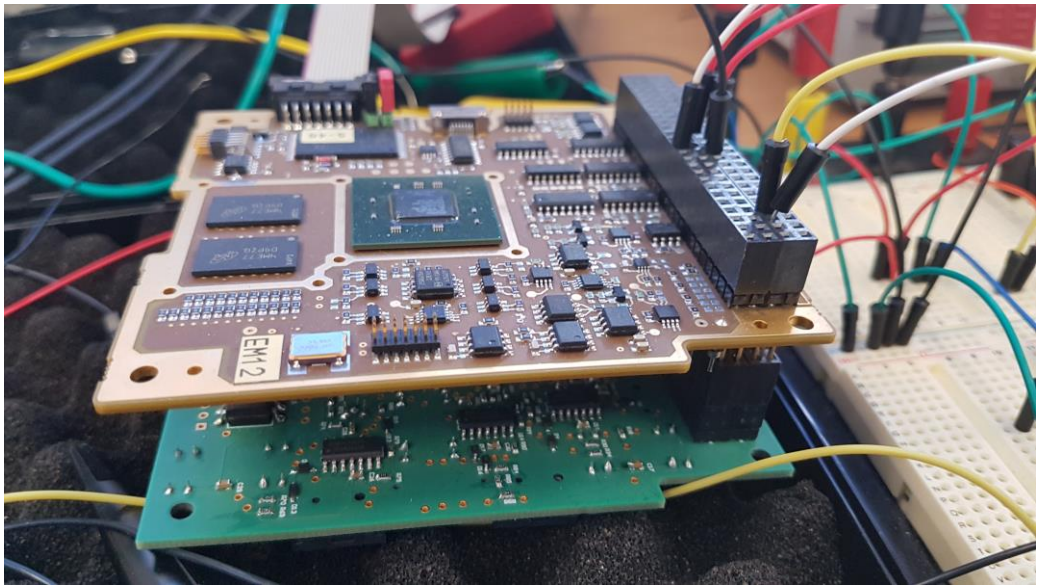
Component placement and routing

The Engineering Model

NINANO (Processor) Board

- Real Time Operating System (FreeRTOS)
- Currently developping **hardware drivers** to be implemented (based on tasks and interruptions)
- AOCS algorythm on board (translated from Simulink to C)

➔ System and hardware priorities to define



Payload Board + NINANO Board

Flight OS development ongoing…

The Engineering Model

FlightOS output example

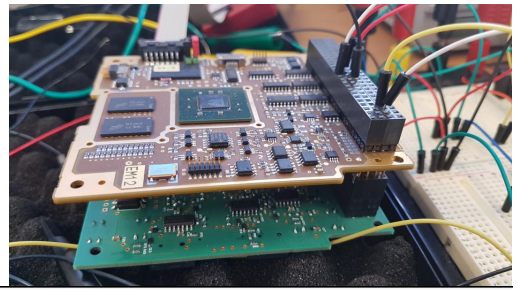
```
454     for( ;; )
455     {
456         printf("Taking semaphore\r\n");
457         /*do{}
458         while(TimerExpired == 0);*/
459         xSemaphoreTake(xBinarySemaphore,portMAX_DELAY);
460
461         TimerExpired=0;
462
463         magnetometer_measurement(&Bpx_in,&Bpy_in,&Bpz_in,&Bx_in,&By_in,&Bz_in);
464
465         XGpioPs_WritePin(&Gpio, USER_GPIO_8, 0x1);
466           rt_OneStep();
467             XGpioPs_WritePin(&Gpio, USER_GPIO_8, 0x0);
468             //rtu.Bpy_in;
469
470             rtU.Bx_in=Bx_in;
471             rtU.By_in=By_in;
472             rtU.Bz_in=Bz_in;
473
474             rtU.Bpx_in=Bpx_in;
475             rtU.Bpy_in=Bpy_in;
476             rtU.Bpz_in=Bpz_in;
477
478             printf("The value of Bx is : %lg \r\n",rtU.Bx_in);
479             printf("The value of By is : %lg \r\n",rtU.By_in);
480             printf("The value of Bz is : %lg \r\n",rtU.Bz_in);
481
482             printf("The value of Bpx is : %lg \r\n",rtU.Bpx_in);
```

C code development with FreeRTOS

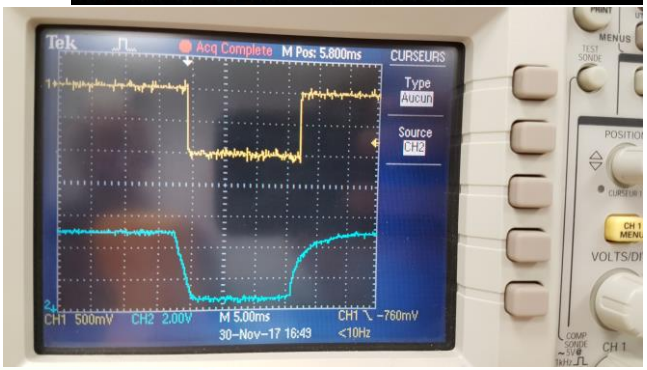
Task execution on NINANO Processor Board

```
Rx task received string from Tx task: Hello World
Warning: The simulation will run forever. Generated ERT main won't simulate mode
l step behavior. To change this behavior select the 'MAT-file logging' option.
Value is 1000.000000
Starting OneStep
Finished OneStep
Value is -0.000000
Value is 0.000000
Value is 0.000000
NINANO says : This is a test and the counter is 0
Starting OneStep
Finished OneStep
Value is 0.000058
Value is -0.000050
Value is -0.000009
NINANO says : This is a test and the counter is 1
```

Acquired results (AOCS, dosimeter and magnetometer tests)



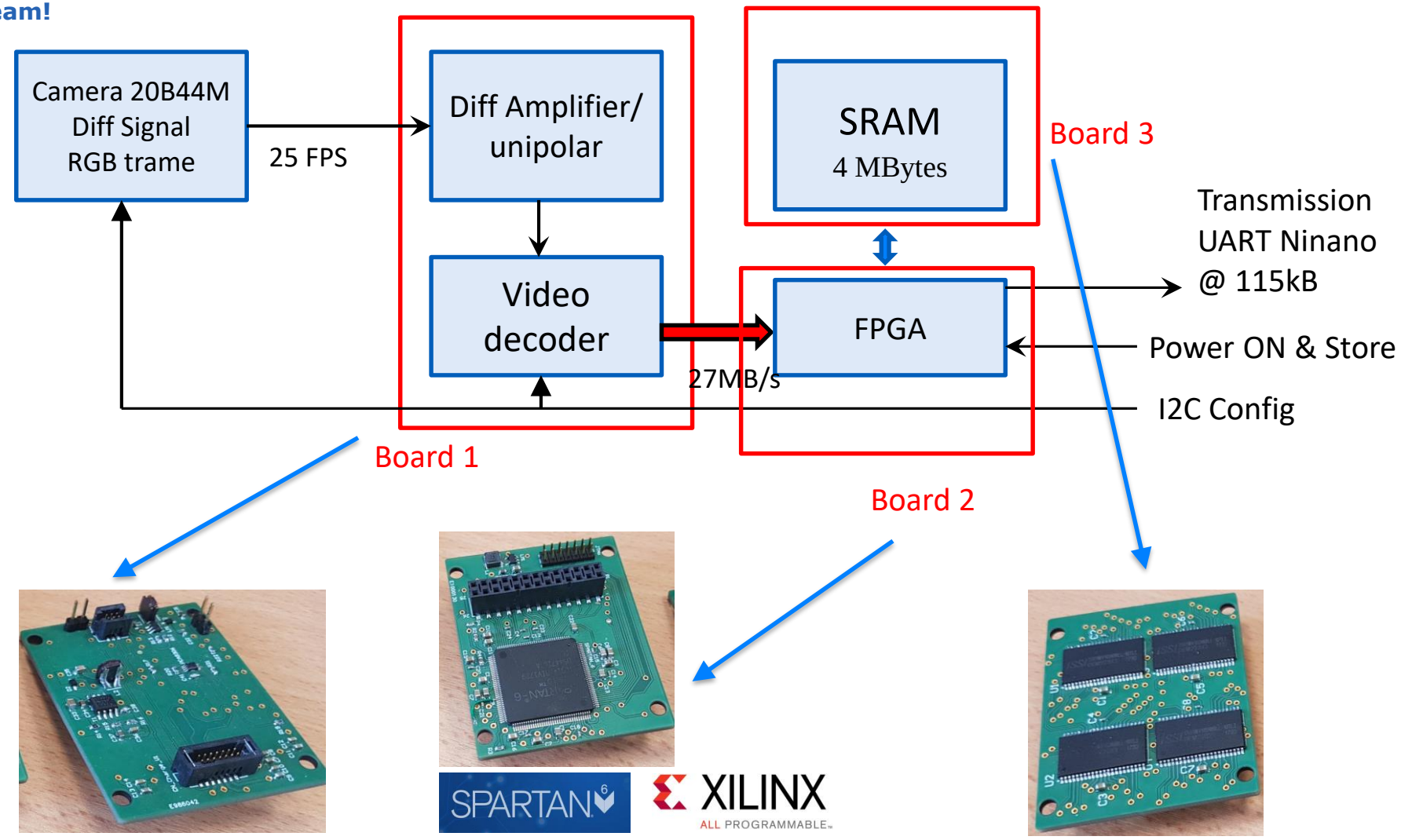
```
COM6 - PuTTY
The result of years is = 2020.000000
The result of minutes is = 1.000000
The value of seconds is = 33.000000
The result of multiplying is: 6.000000
The value of sinus is: 0.866025
The value of Inl = 94.000000
The result of years is = 2020.000000
The result of minutes is = 1.000000
The value of seconds is = 34.000000
The result of multiplying is: 6.000000
The value of sinus is: 0.866025
The value of Inl = 95.000000
```



The Engineering Model

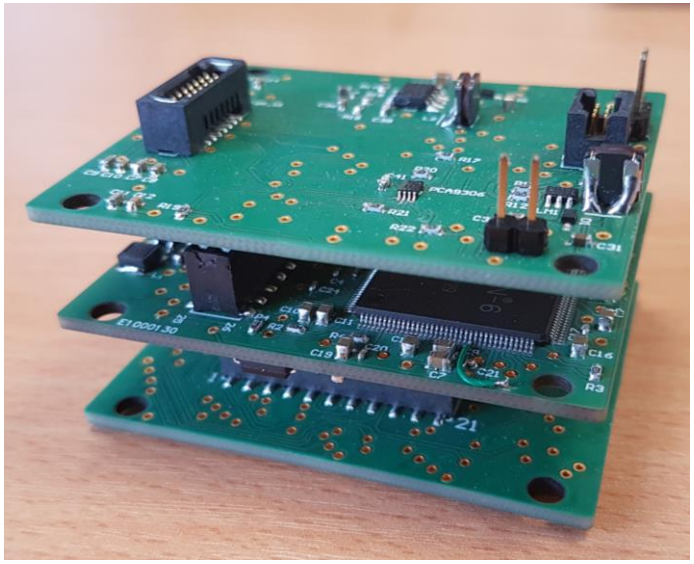
Boards for camera interface

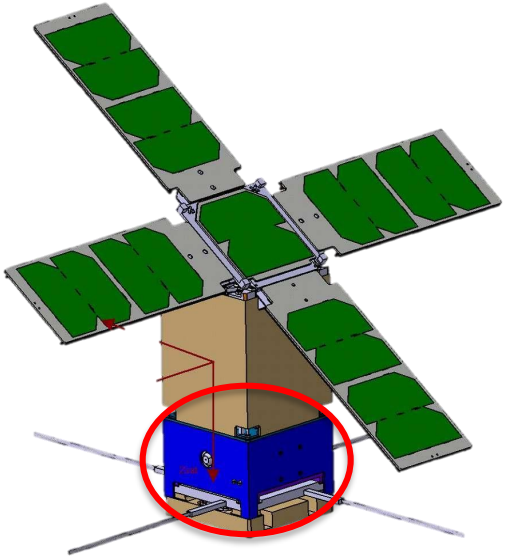
Completely developed by the CASAA-SAT team!

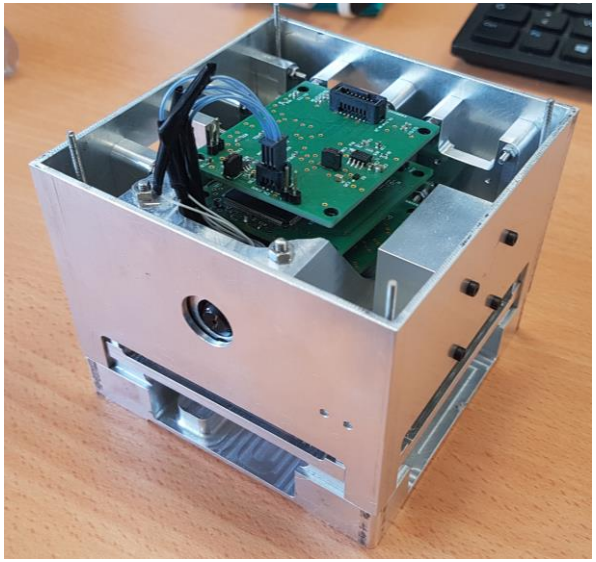


The Engineering Model

Boards and camera placement in the satellite







The Engineering Model

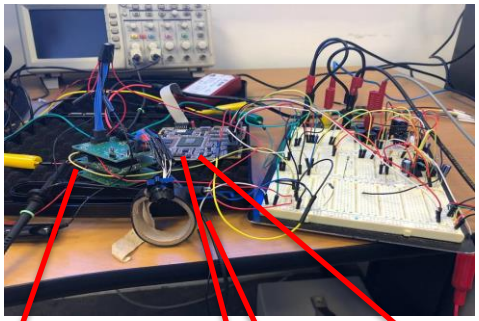
Camera System Test

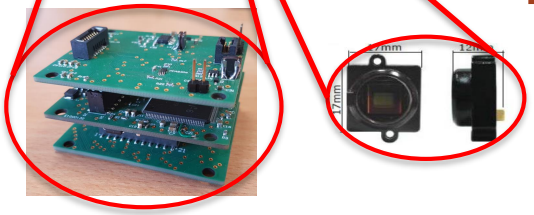
```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

entity Comp_XY is
    Port ( ImByte : in  STD_LOGIC_VECTOR (7 downto 0);
           CLK : in  STD_LOGIC;
           rst : in  STD_LOGIC;
           TS : in  STD_LOGIC;
           EN : out  STD_LOGIC;
           TM : out  STD_LOGIC);
end Comp_XY;

architecture Behavioral of Comp_XY is

    component ff_sr is
        Port ( S : in  STD_LOGIC;
               R : in  STD_LOGIC;
               Q : out  STD_LOGIC);
    end component ff_sr;

    signal Ti, TM_buffer: std_logic;
    signal Ti_set, Ti_reset, Tm_set, Tm_reset, E_set, E_reset: std_logic;
begin

--  ff_Ti: ff_sr
--  Port map (
--       S => Ti_set,
--       R => Ti_reset,
--       Q => Ti);
--
--  ff_Tm: ff_sr
--  Port map (
--       S => Tm_set,
--       R => Tm_reset,
--       Q => TM_buffer);
--
--  ff_EN: ff_sr
--  Port map (
--       S => E_set,
--       R => E_reset,
--       Q => EN);
```

VHDL algorithm for image capture

```
/*
 * Image Processing for the CASAA-Sat Project
 * Author: Josue Ramirez
 */
#include "image.h"
#include "jpeglib.h"

void getName(char * path, char name[]){ //returns the name of the file in the given path without filename extension
    int i=0;
    char pathCopy[200], naming[20];
    strcpy(naming, strrchr(path, '\\'));
    while (naming[i+1] != '.'){
        naming[i] = naming[i+1];
        i++;
    }
    naming[i] = '\0';
    strcpy(name,naming);
}


int HtoI(char * st){ //returns the value of the string argument representing an hexadecimal byte
    int a0, a1;
    if(st[0]>'A'&&st[0]<='F')
        a0 = st[0] - 'A' + 10;
    else
        a0 = st[0] - '0';
    if(st[1]>'A'&&st[1]<'F')
        a1 = st[1] - 'A' + 10;
    else
        a1 = st[1] - '0';

    return (a0<<4) + a1;
}

uchar red(int Y, int Cr){
    int val = (Y) + 1.402*(Cr-128) + offset;
    return val<1? 0 : (val>254? 255 : val);
}
uchar green(int Y, int Cb, int Cr){
    int val = (Y) - 0.71414*(Cr-128) - 0.34414*(Cb-128) + offset;
    return val<1? 0 : (val>254? 255 : val);
}
uchar blue(int Y, int Cb){
    int val = (Y) + 1.772*(Cb-128) + offset;
    return val<1? 0 : (val>254? 255 : val);
}

int fnextXY(FILE * fp){ //Reaches the next XY description byte in the file and returns its value as integer
    char XYs[8]; //size thought to be enough for a line
    char sync[3][8] = {"00","00","00"}, line[4];
```

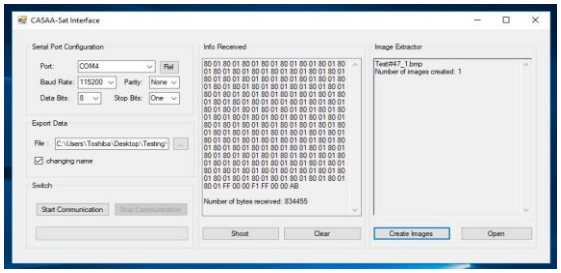
C code for Image processing



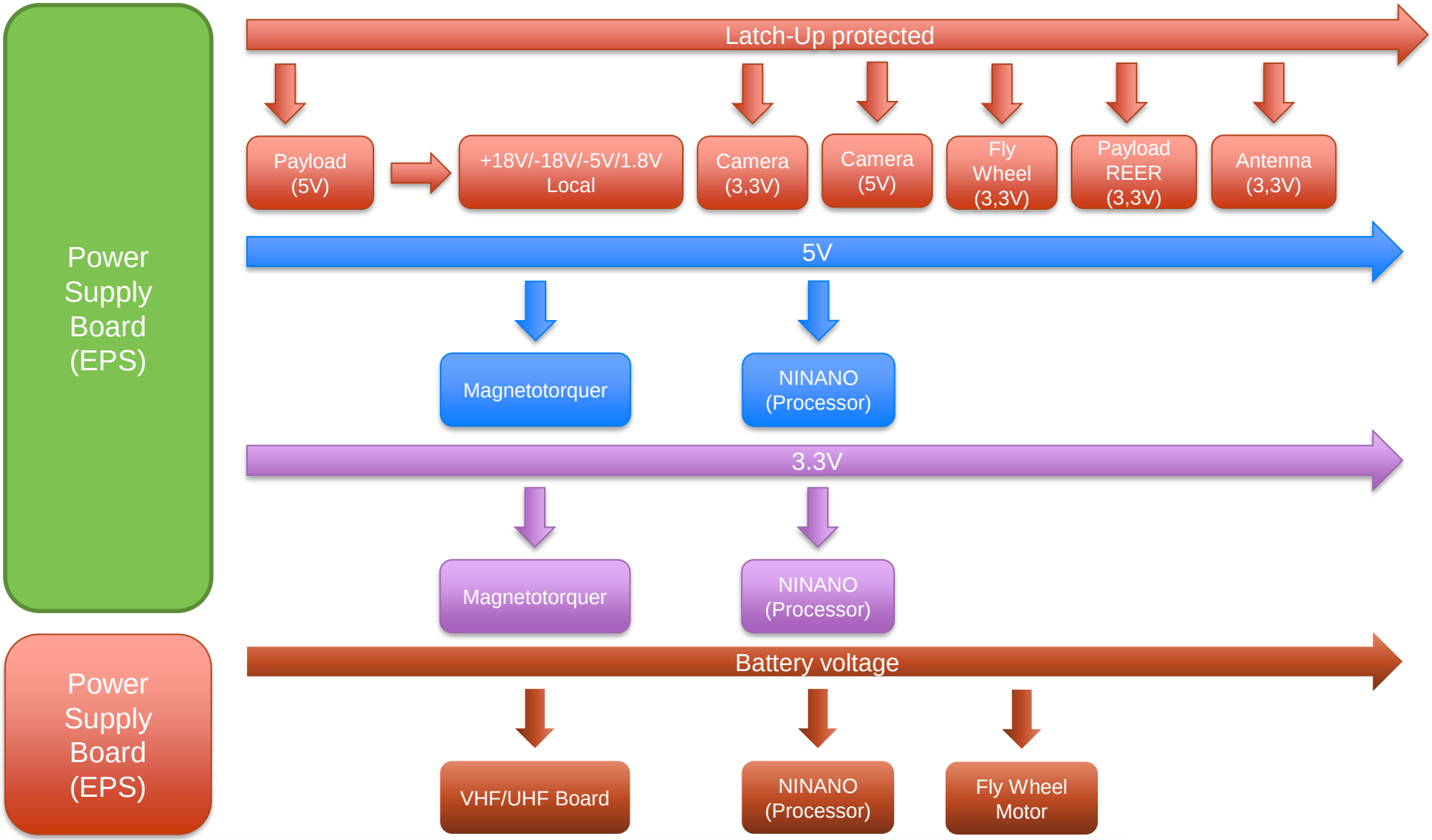


Hardware mounting

Image capture and JPEG compression



Satellite power supply architecture



Thank you for your attention !