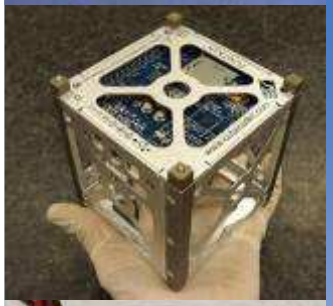
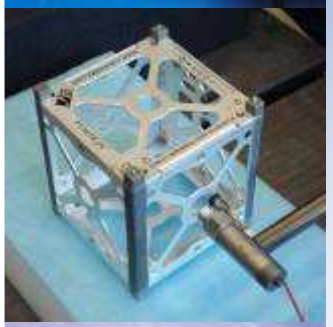




OUFTI - 1

Realizations and prospects

University of Liège,
June 18, 2009

Université de Liège

Agenda

13h45: welcome and registration

14h00: presentation « OUFTI-1 : realizations and prospects »

15h00: visits and demonstrations

15h30: « verre de l'amitié »

Outline

A. OUFTI-1 project

B. Technical overview

C. Concluding remarks

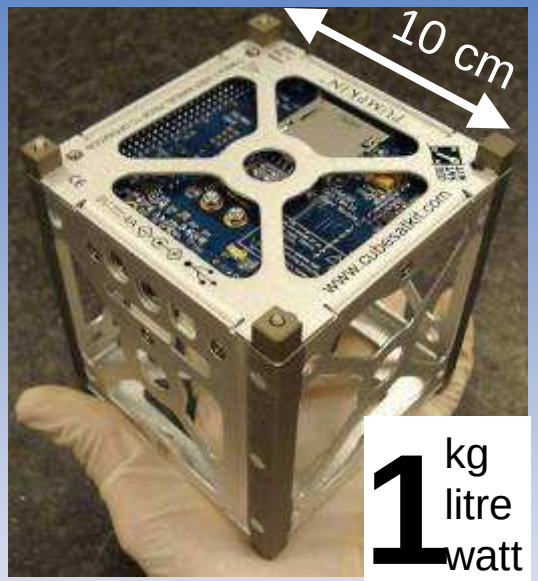
Outline

A. OUFTI-1 project
    1. A brief recall about OUFTI-1
    2. System & team overview
    3. Mission objectives
    4. Project organization chart
    5. Lessons learned

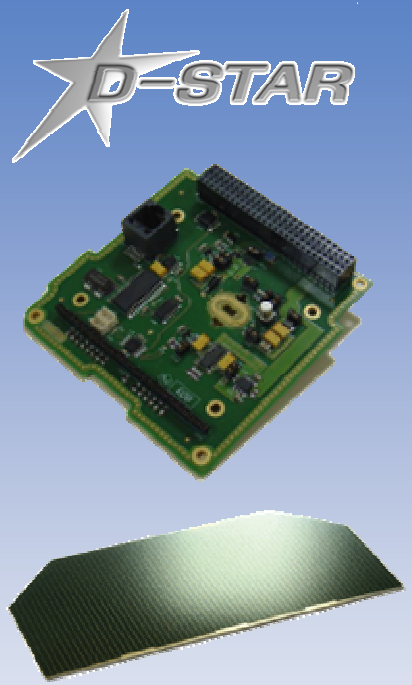
B. Technical overview

C. Concluding remarks

1. A brief recall about OUFTI-1



CubeSat standard



Three payloads

VEGA Maiden Flight

Université de Liège

ULg, Helmo-Gramme, HEPL ISIL

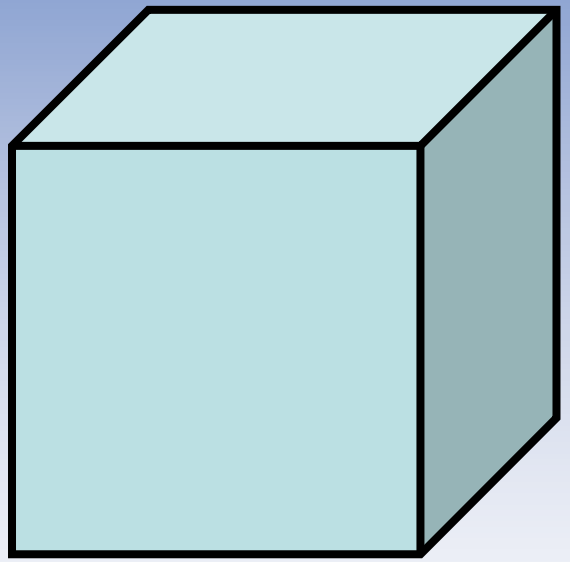
2. System & team overview

STRU:
Gauthier PIERLOT

COM:
Renaud HENRARD
François MAHY

MIAS:
Vincent BEUKELAERS

AX.25:
Johan HARDY



EPS:
Pierre THIRION

MECH:
Jérôme WERTZ

OBC:
Damien TENEY

GND:
Laurent CHIARELLO

THER:
Lionel JACQUES

Exp.EPS:
Philippe LEDENT

ADCS:
Samuel HANNAY

MHP:
Nicolas EVRARD

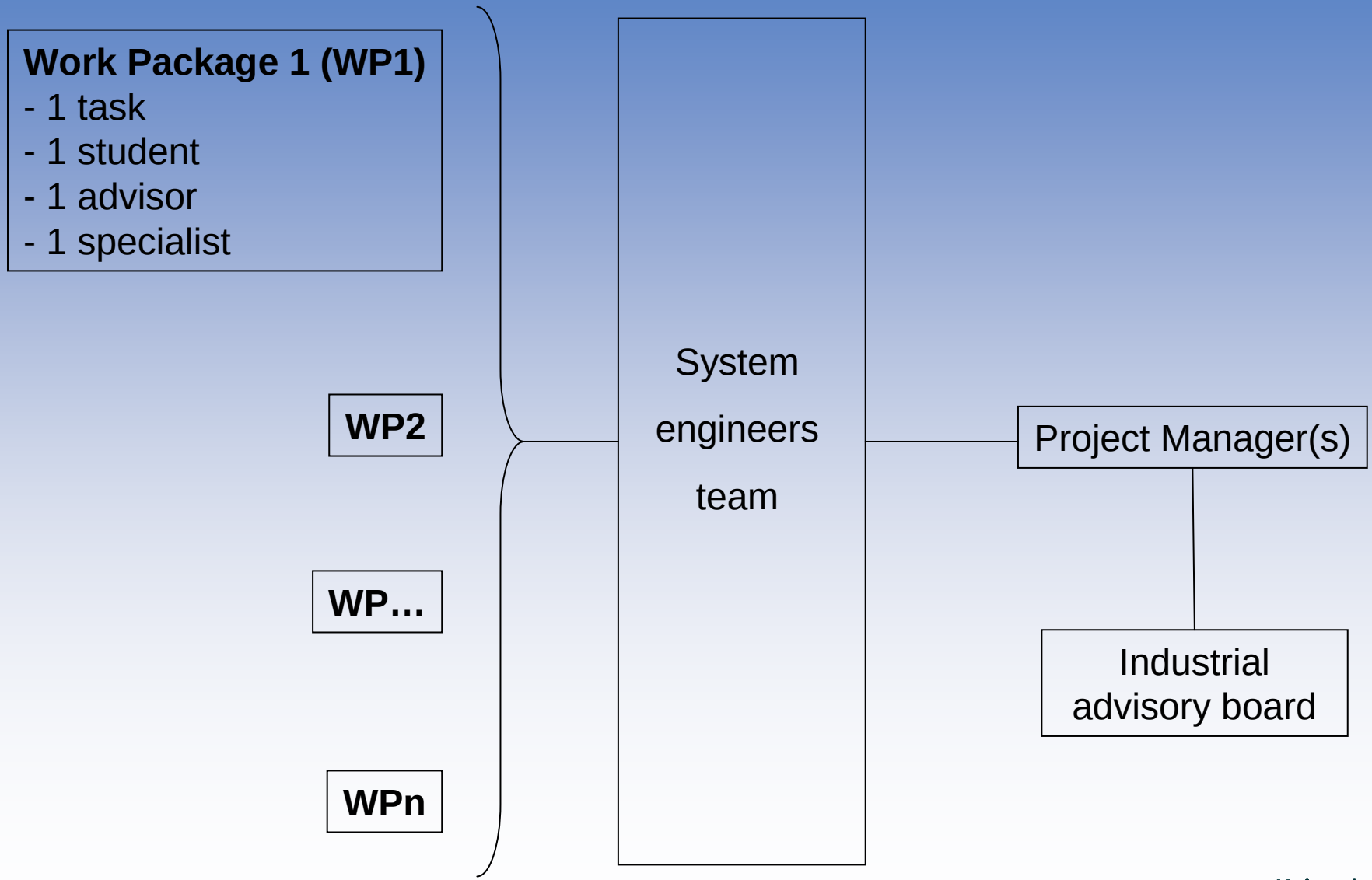
3. Mission objectives

1. Fun and education

3. Mission objectives

1. Fun and education
2. Design of the OUFTI-1 system
3. Launch of OUFTI-1
4. Having the satellite alive in space
5. Operating the satellite
6. Having the D-STAR functional
7. Operating the secondary payloads

4. Project organization chart



5. Lessons learned (1)

- Technical issues are not the most time-consuming
- Crucial need for rigorous documentation
- Need for full-time project manager and well-defined organization chart
- Multidisciplinary team: not easy to manage, but really enriching
- Autonomy and initiative spirit must be learned
- Interfaces can not be managed by students

5. Lessons learned (2)

- Strong interest & support from academics, ham-radio community, industrial, and general public
- Real & great CubeSat community spirit
- Numerous dicoveries and encounters
- Highly motivated team
- Everybody (not only students) learns !

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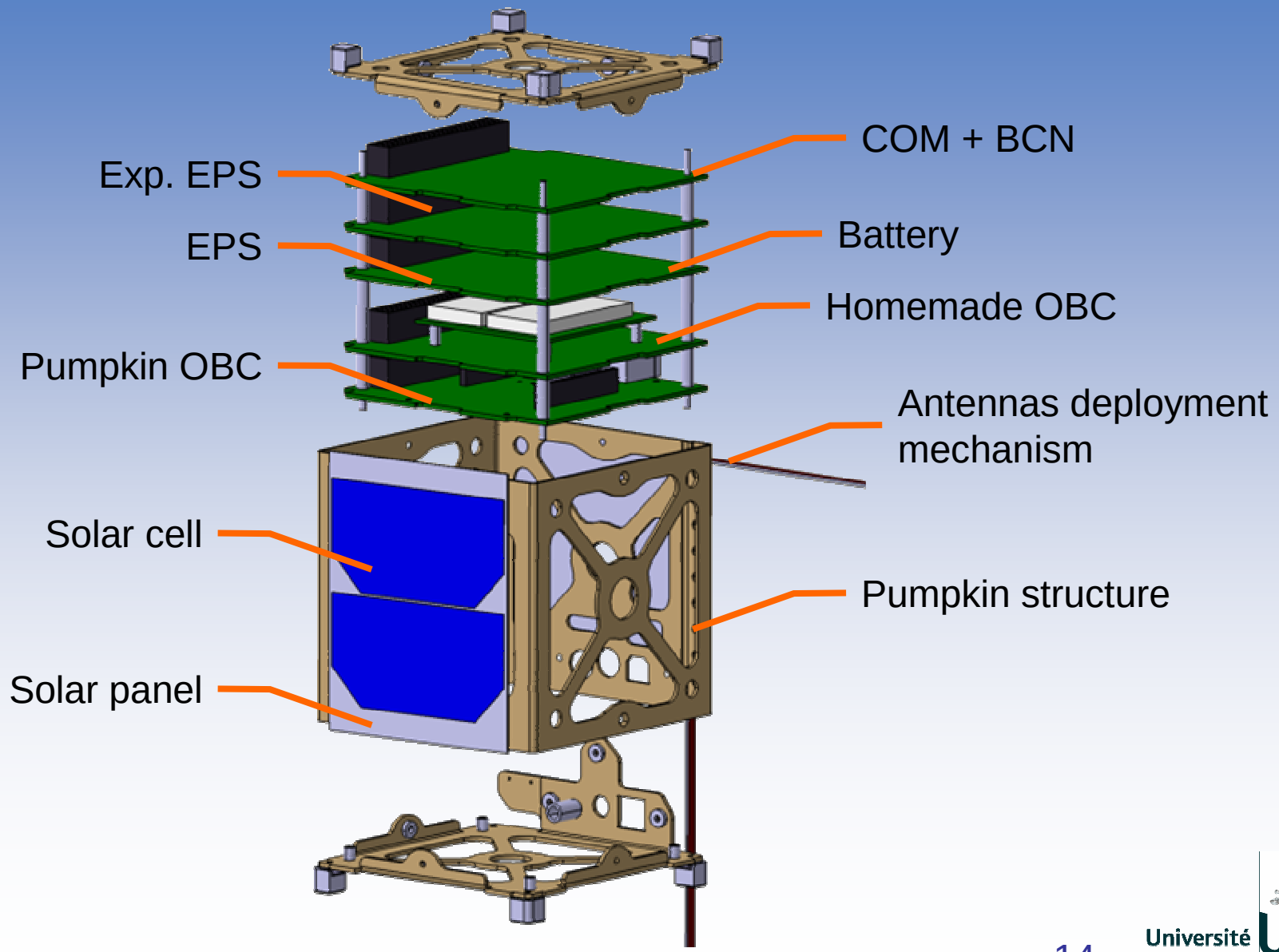
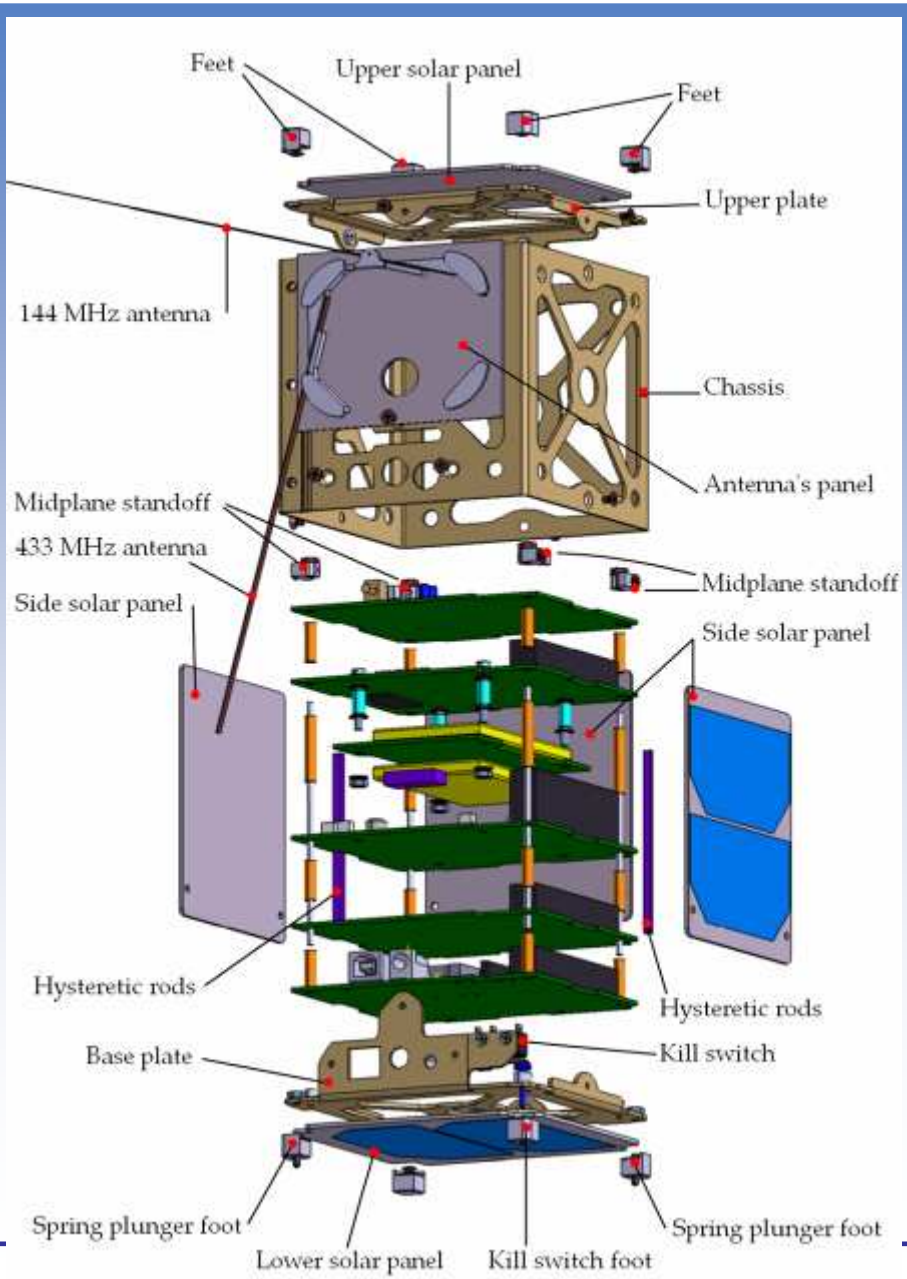
1. Configuration



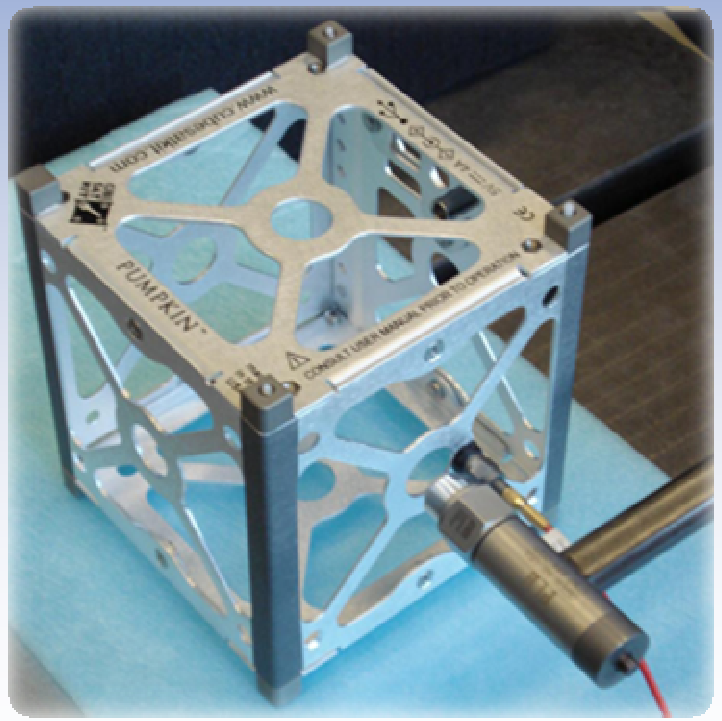
1. Configuration

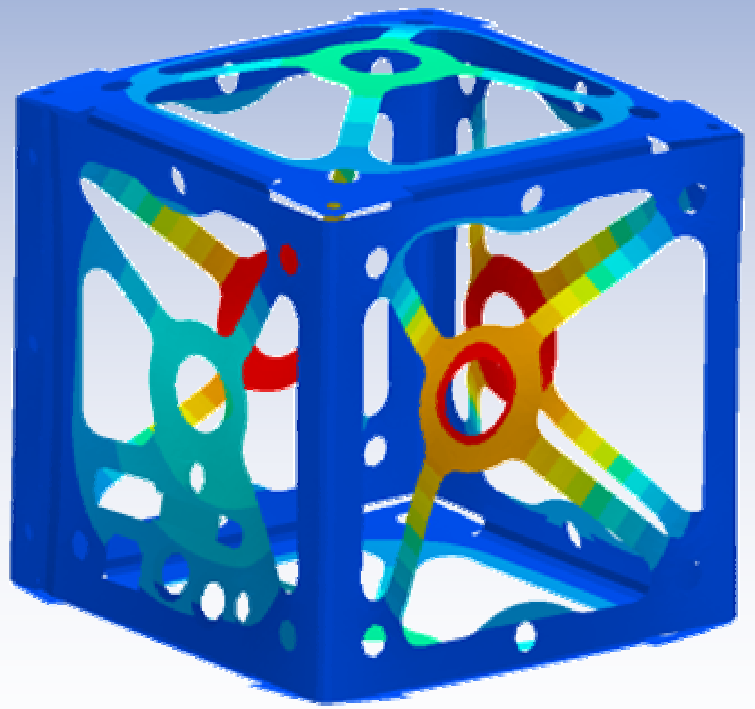


1. Structure

Preliminary vibrations tests:

Good correlation between FEM and experimental results (1st frequency above 500Hz)





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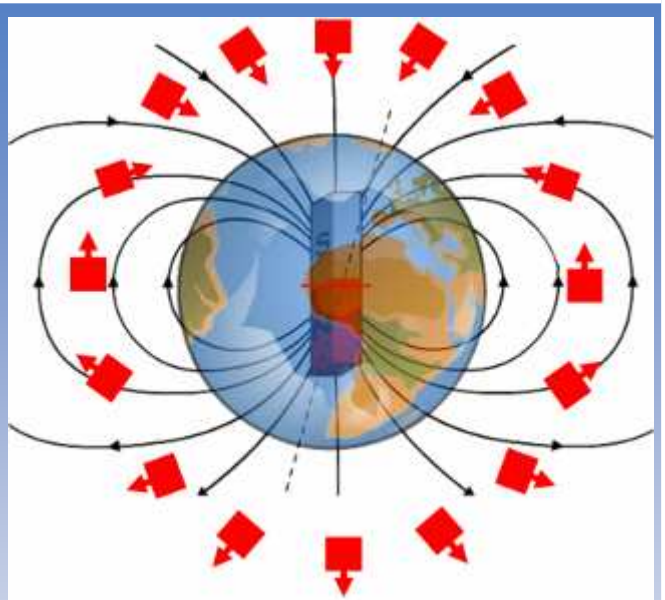
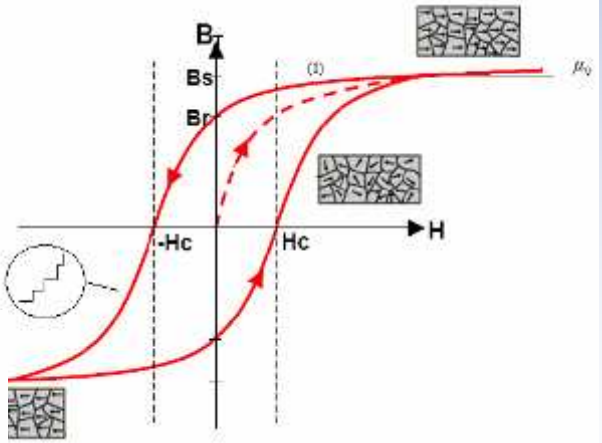
C. Concluding remarks

2. ADCS

- Responsible for the orientation
- Two major kinds:
  - Active ADCS
    - More accurate…but
    - More complex
    - Fuel dependant…
  - Passive ADCS
    - Based on magnetic materials
    - Hy-Mu-80, Permenorm 5000H2





$Quantity$	$Alnico-5$	$Hy-Mu-80$	$Permenorm\ 5000\ H2$
ρ	$7,3[g/cm^3]$	$8,747[g/cm^3]$	$8,25[g/cm^3]$
H_c	$5,09.10^4[A/m]$	$1,59[A/m]$	$5[A/m]$
B_s	–	$0,73[T]$	$1,55[T]$
B_r	$1,28[T]$	$0,35[T]$	$0,755[T]$

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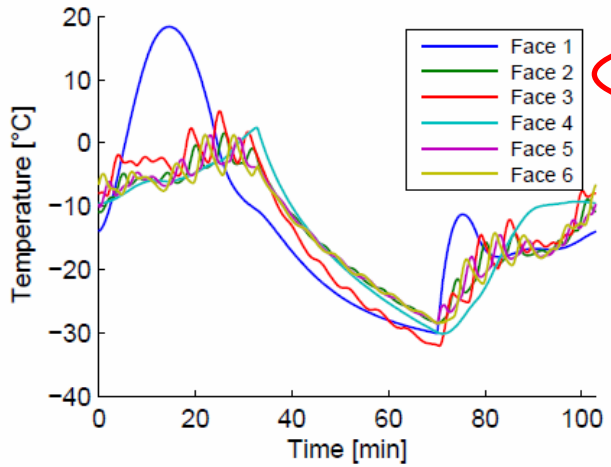
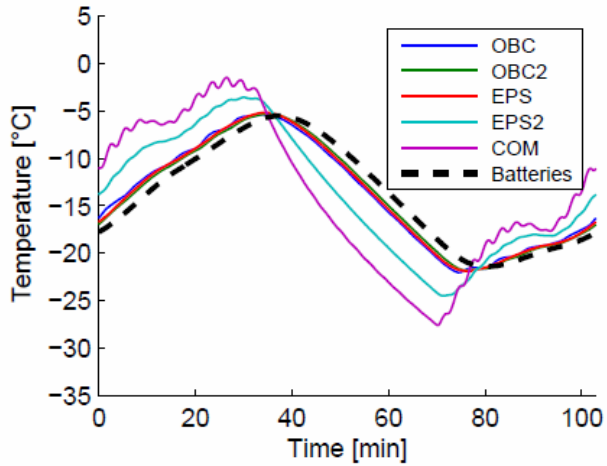
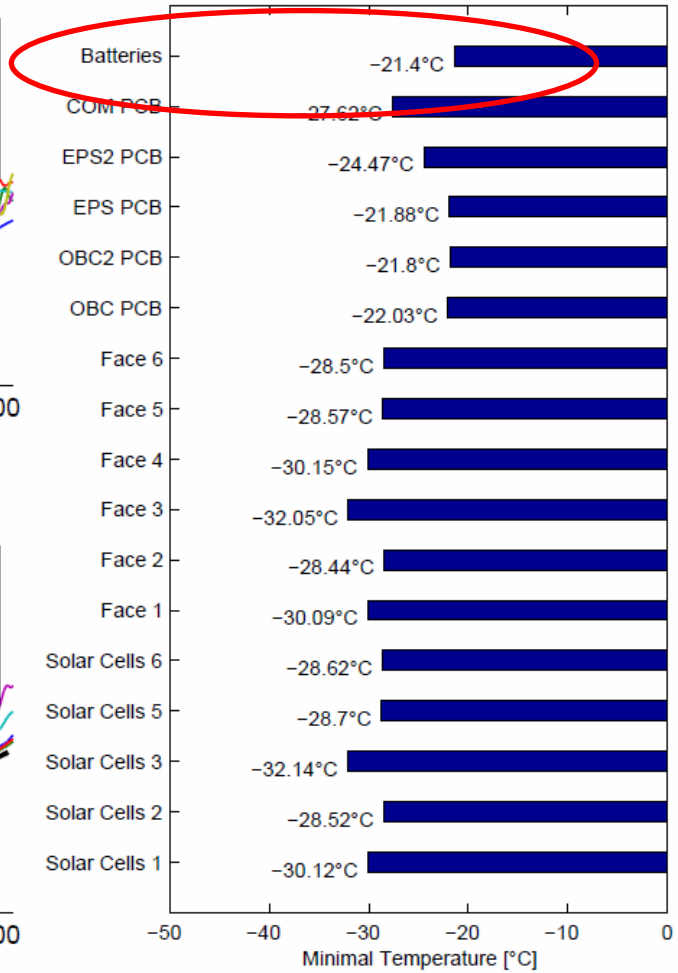
C. Concluding remarks

3. Thermal subsystem

- 2 cases : hot case and cold case
- Active system for batteries in cold case







- Thermal insulation of batteries
- Influence of the orbit definition
- Influence of the ADCS system

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C. Concluding remarks

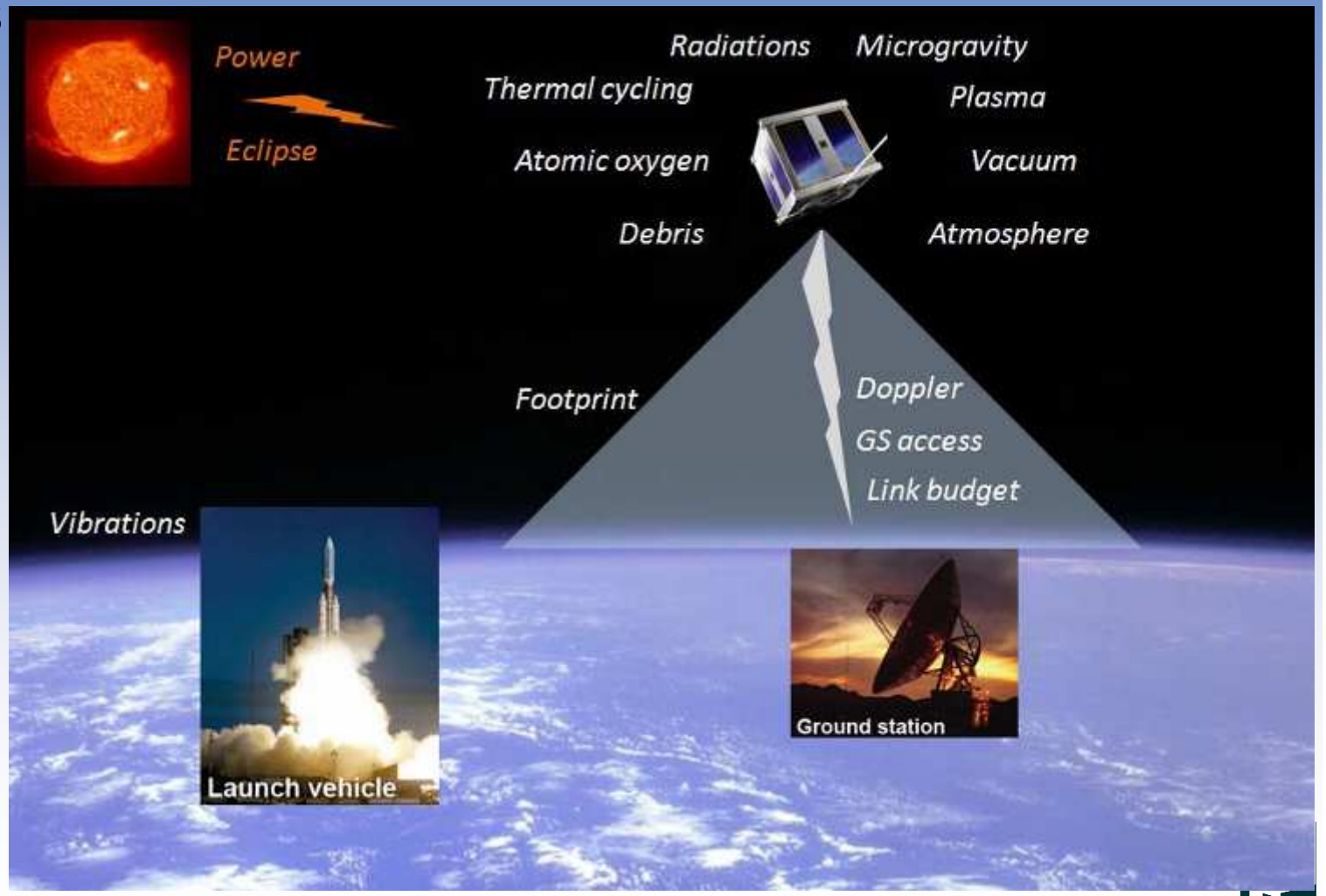
4. Mission analysis

• Objectives : quantify the system parameters and the resulting performances

1.Orbit parameters

2.D-STAR in space

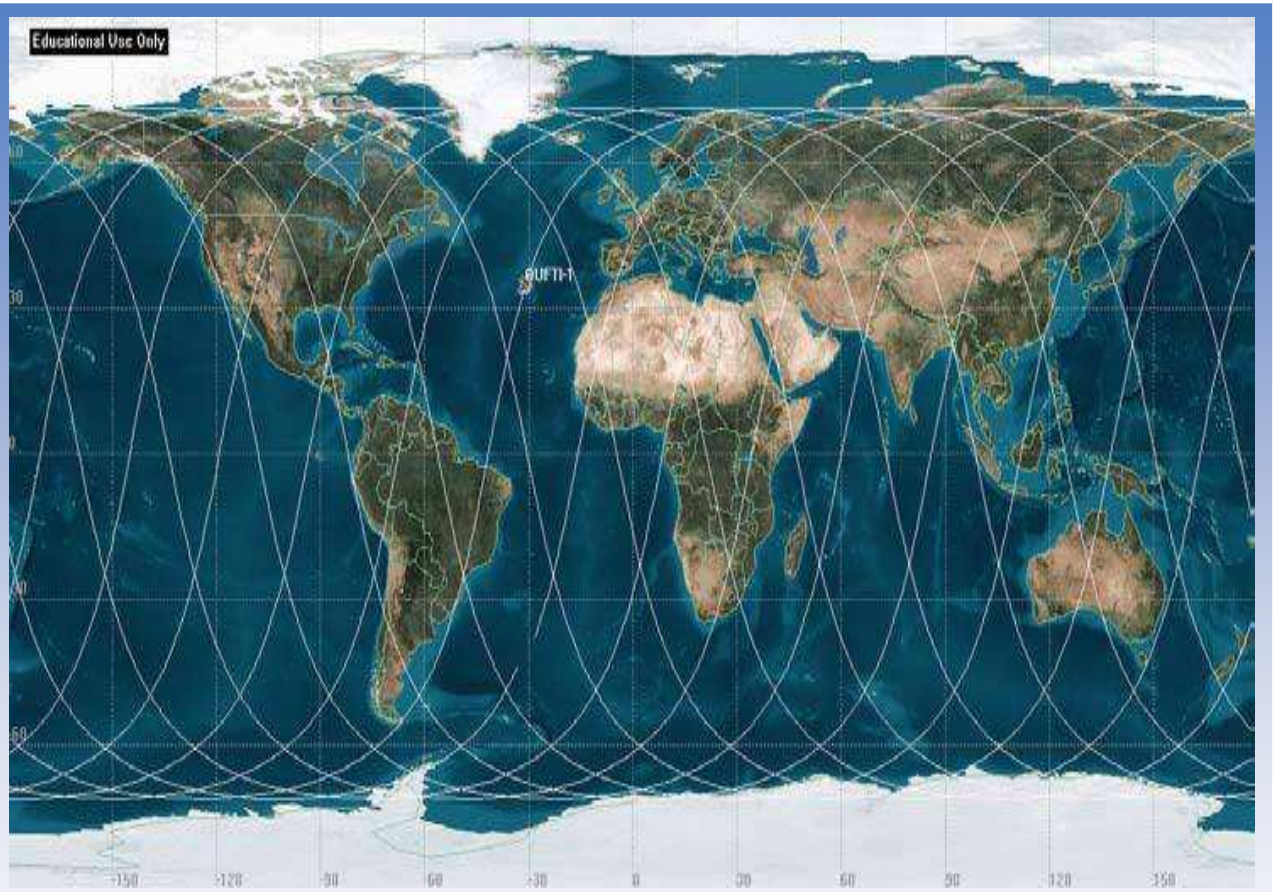
3.Space environment



4. Mission analysis: orbit

Main parameters :

- Orbit LEO
- Perigee/ apogee : 354/1447 km
- Inclination : 71°
- Launch on 1/11/2009

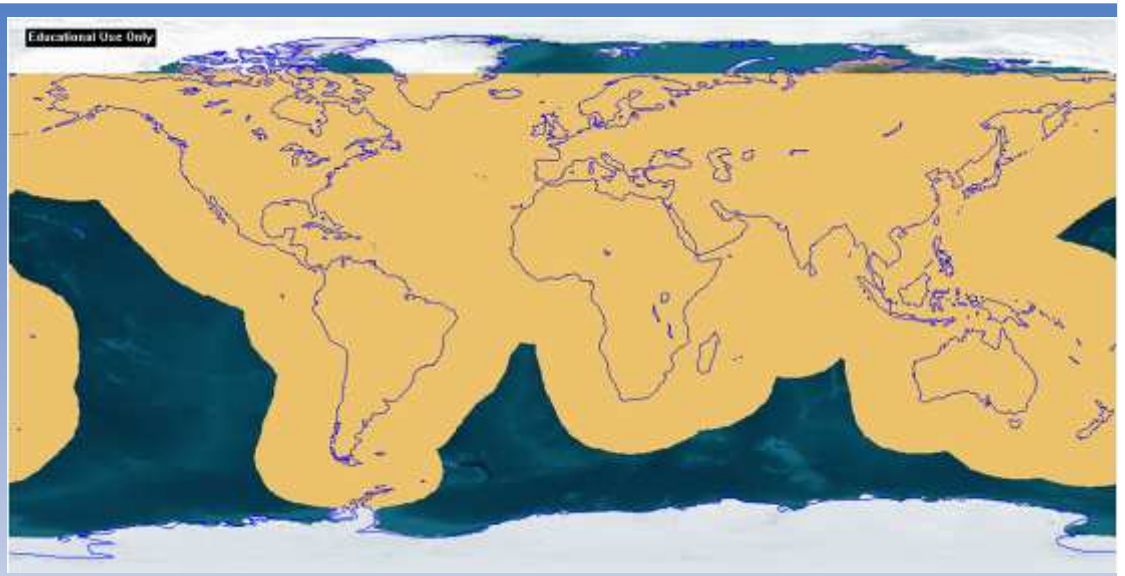


- Orbital period (103 min) , 75.8% in sunlight,
- 14 revolutions per day
- Mean power available : 3,1 W
- Mean integrated power : 2,4 w

4. Mission: D-STAR in Space (1)

	Access (min)	Number/day
Mean	14,33	3,3
Max	20,35	6
Min	7,42	1

Around 30% over oceans !



Footprint length :

Apogee : 6837 km Perigee : 3183 km

Orbit suitable for using D-STAR in space.

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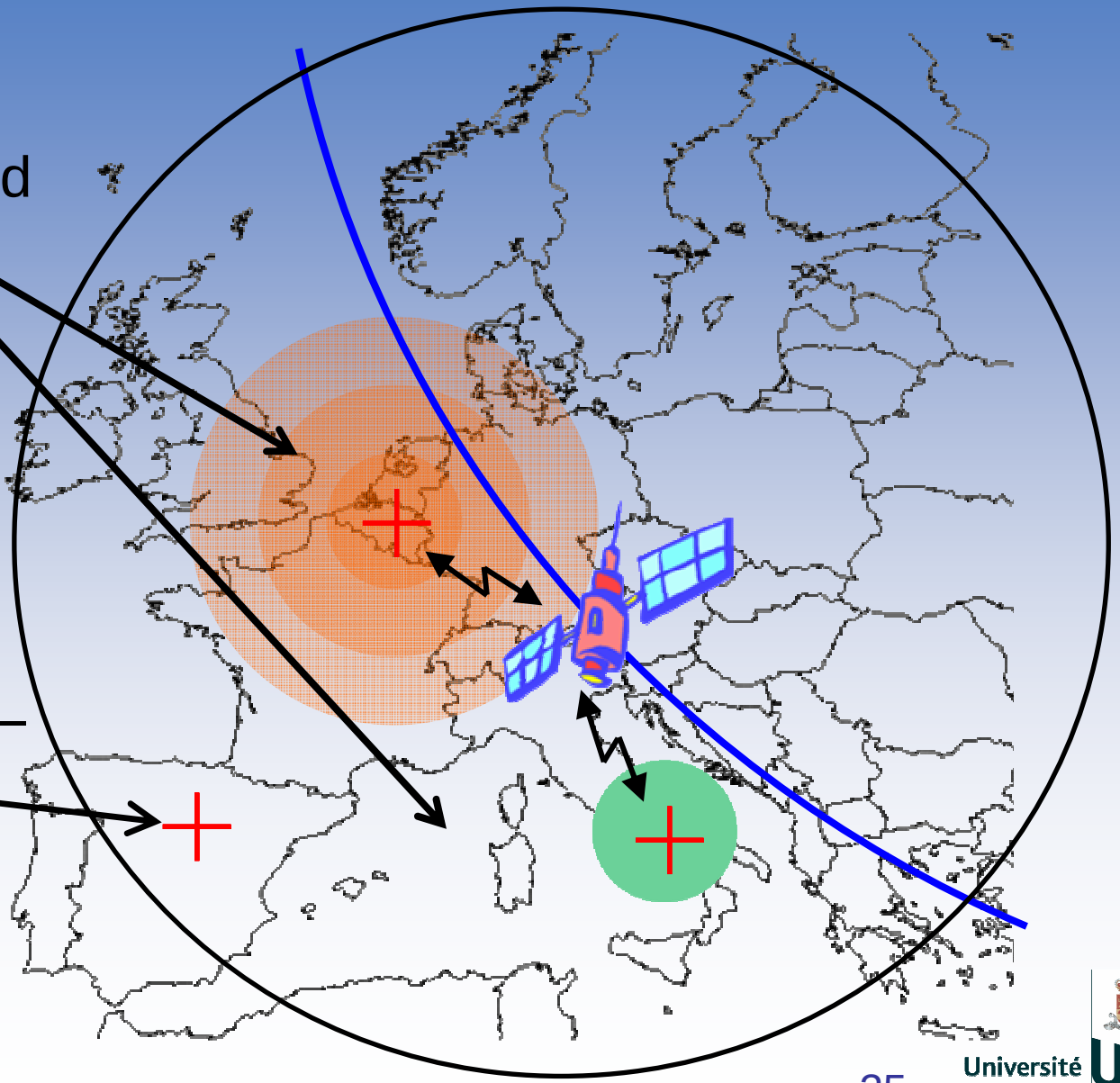
4. Mission: D-STAR in Space (2)

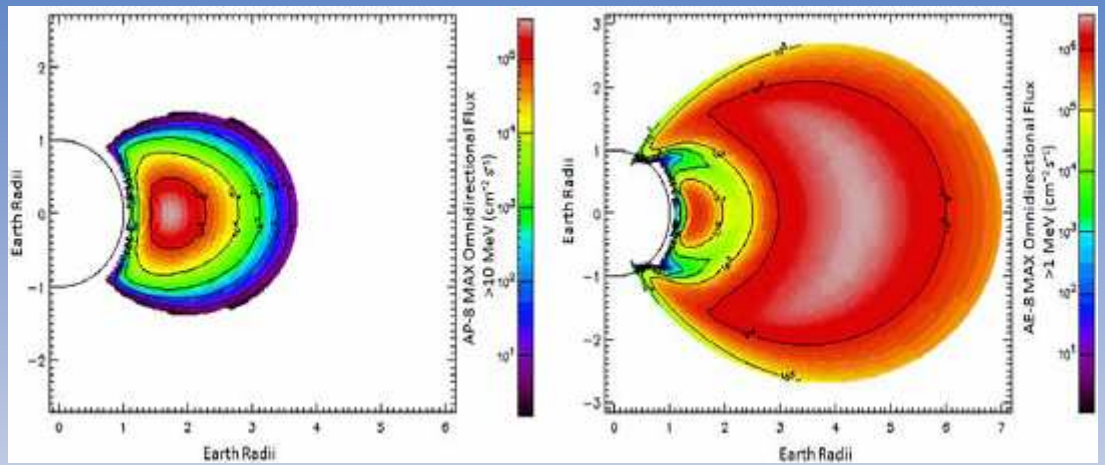
- 2 system-selected Doppler-compensated coverage zones
  - ULg for control
  - Dynamically determined

- Personnal Doppler – compensation possible within OUFTI-1 coverage zone

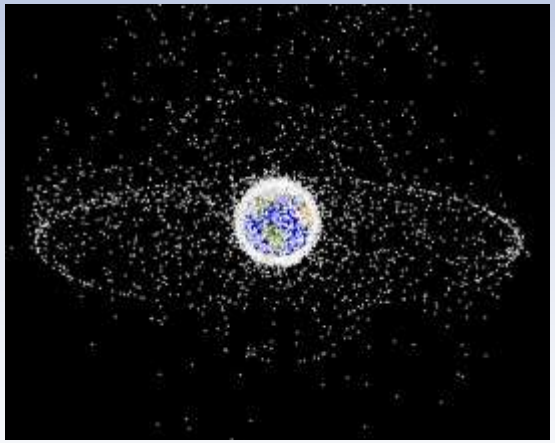


4. Mission: Space environment

- Radiations: restrictive on the mission lifetime



→ Global and local shielding with aluminium



- Space vacuum (10E-11 Pa)

→Blowing up

→15% mass lost

- Destructive impact probability: 7.2E-4 over one year

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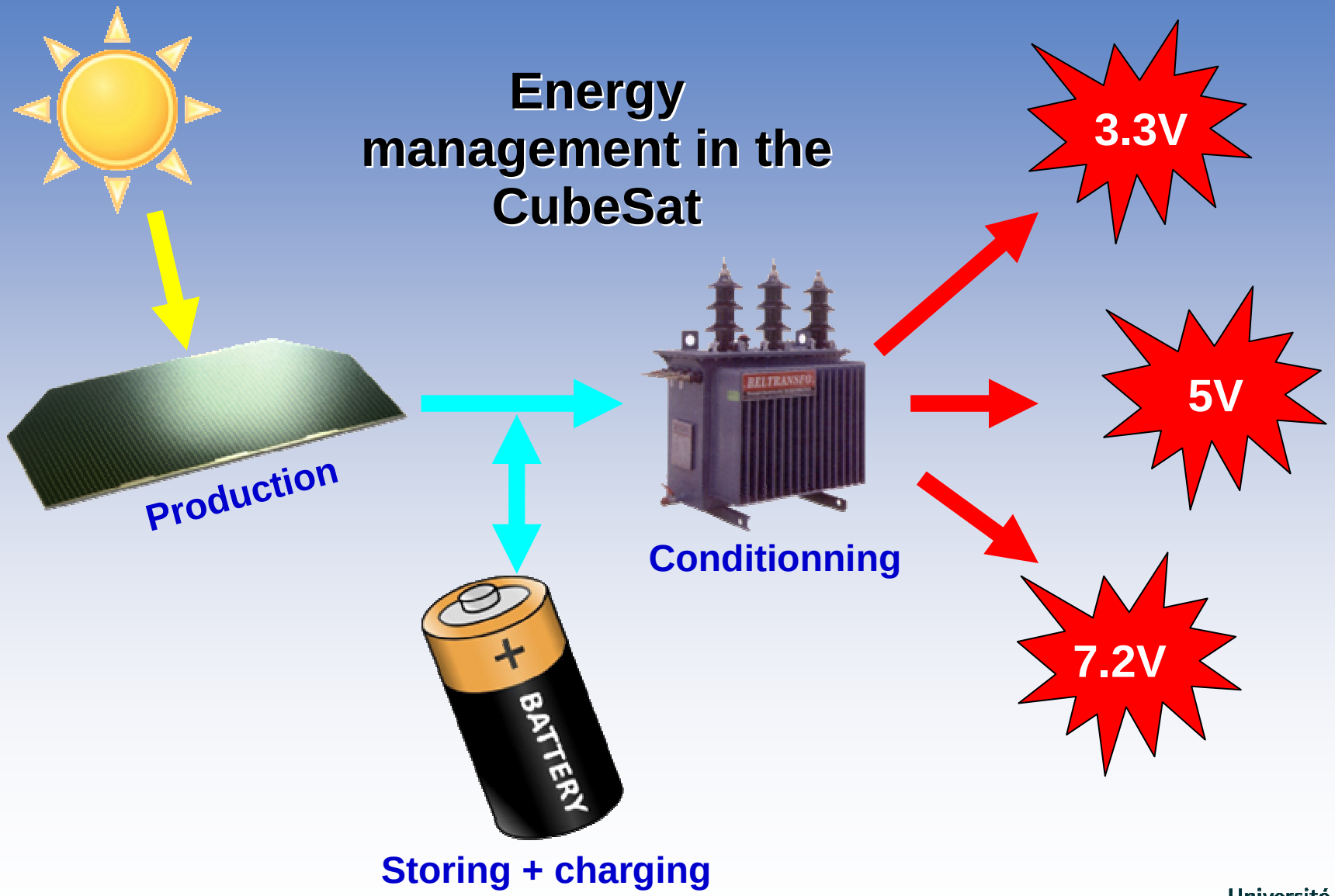
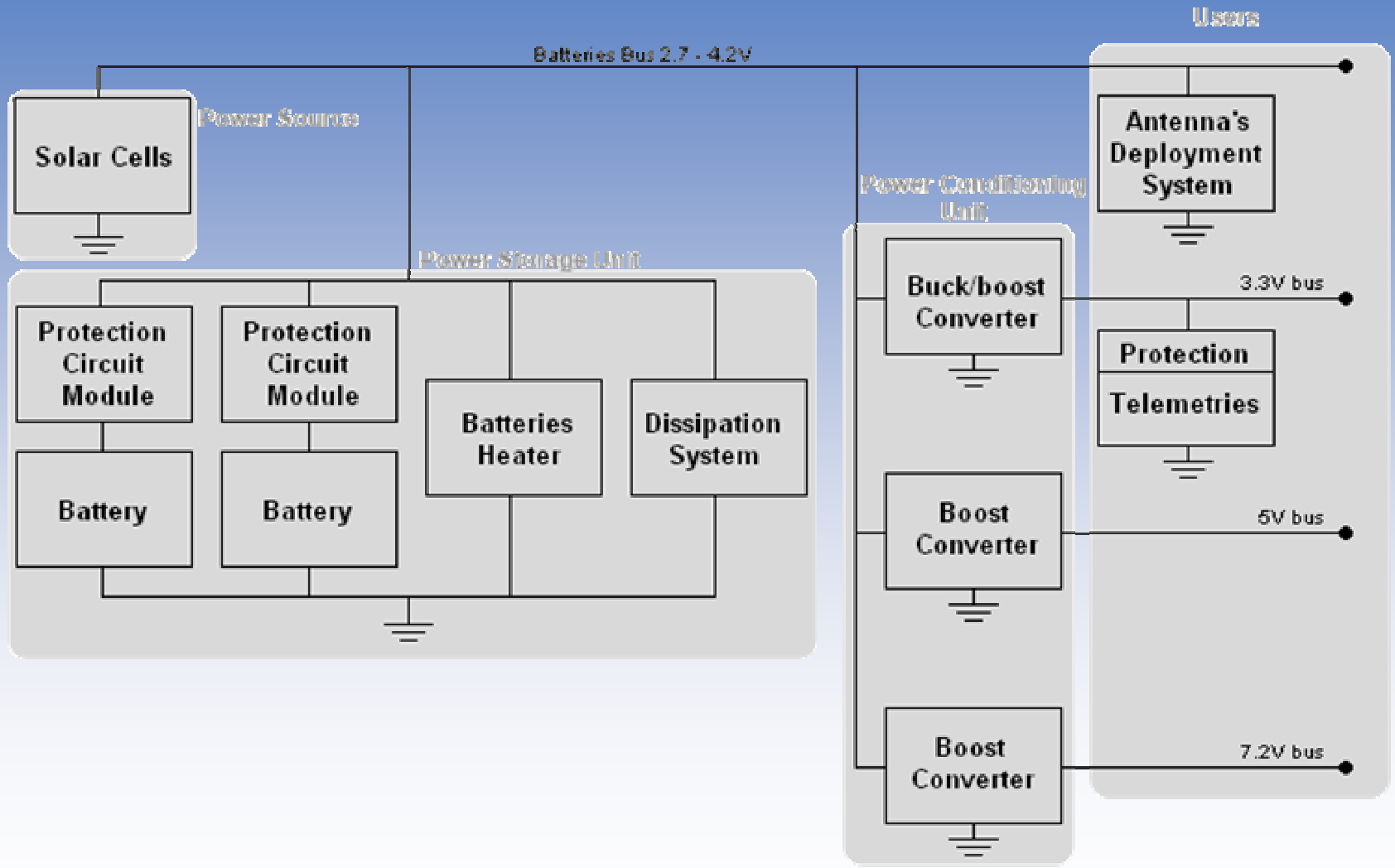
5. Electrical Power System (EPS)

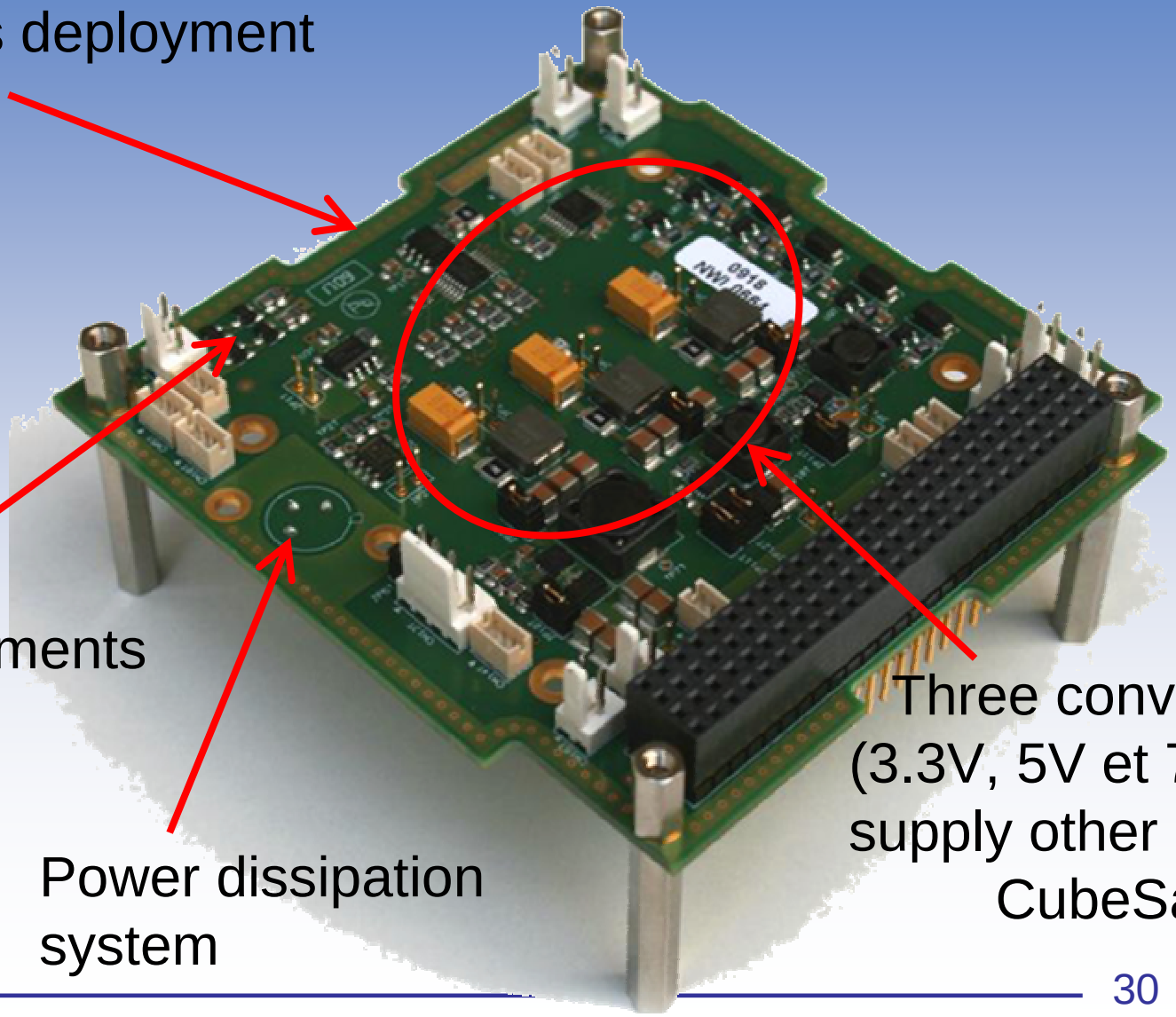


5. Main EPS: architecture



5. Main EPS: engineering model

Command of the antennas deployment system



Measurements circuits

Power dissipation system

Three converters (3.3V, 5V et 7.2V) to supply other parts of CubeSat

5. Future work

- Prototype of the battery-PCB
- Test of Exp.EPS
- Test of the entire EPS
- Interconnect EPS with other subsystems

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6. OBC: overview

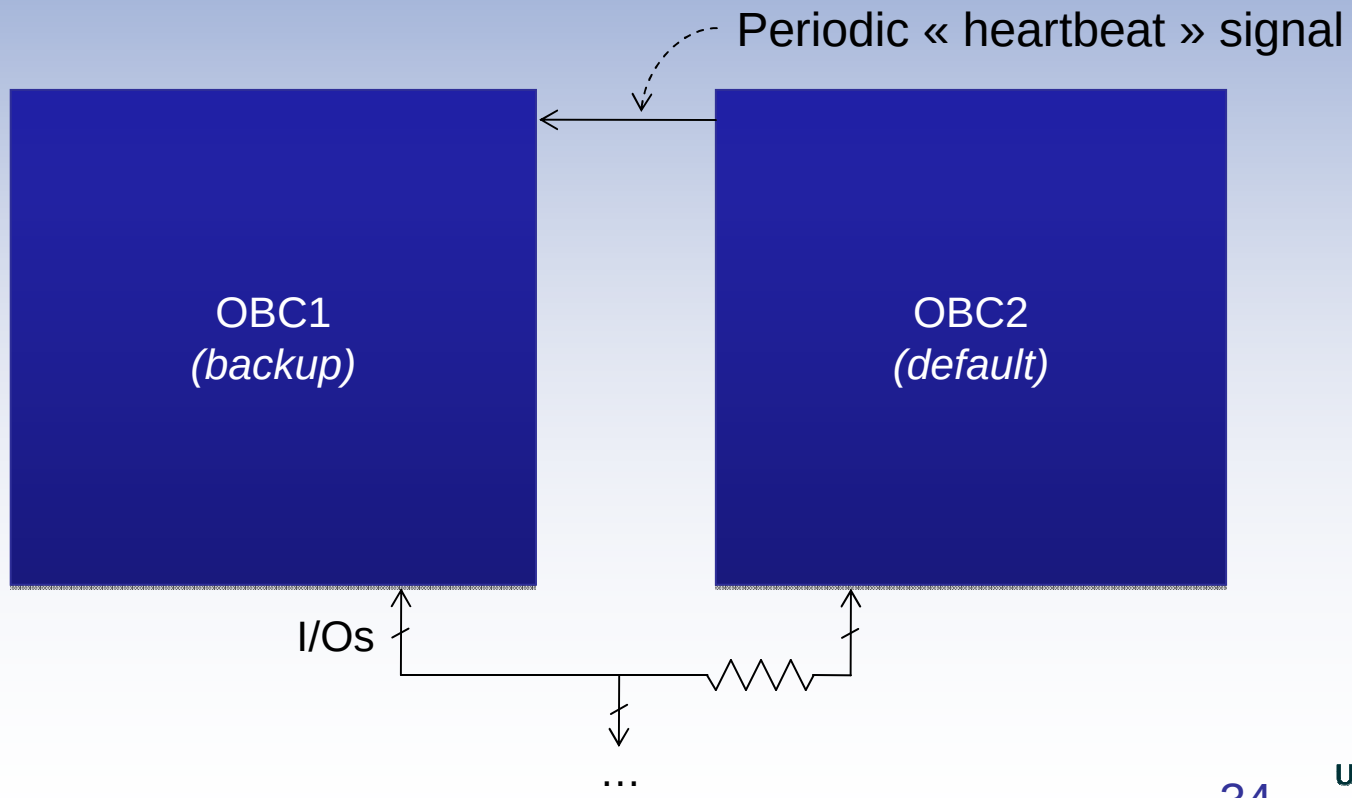
- **Roles of the on-board computer**
  - Perform measurements and handling of housekeeping andscientific parameters
  - Encode telemetry and handle telecommands
  - Perform electrical power supply management
  - Manage the payloads
- **Constraints**
  - Very low power available
  - Desire of very high reliability

6. OBC: hardware solution (1)

- **Reliability through simplicity**

  One central processor, handles all tasks

  Doubled for redundancy: only one active at a time

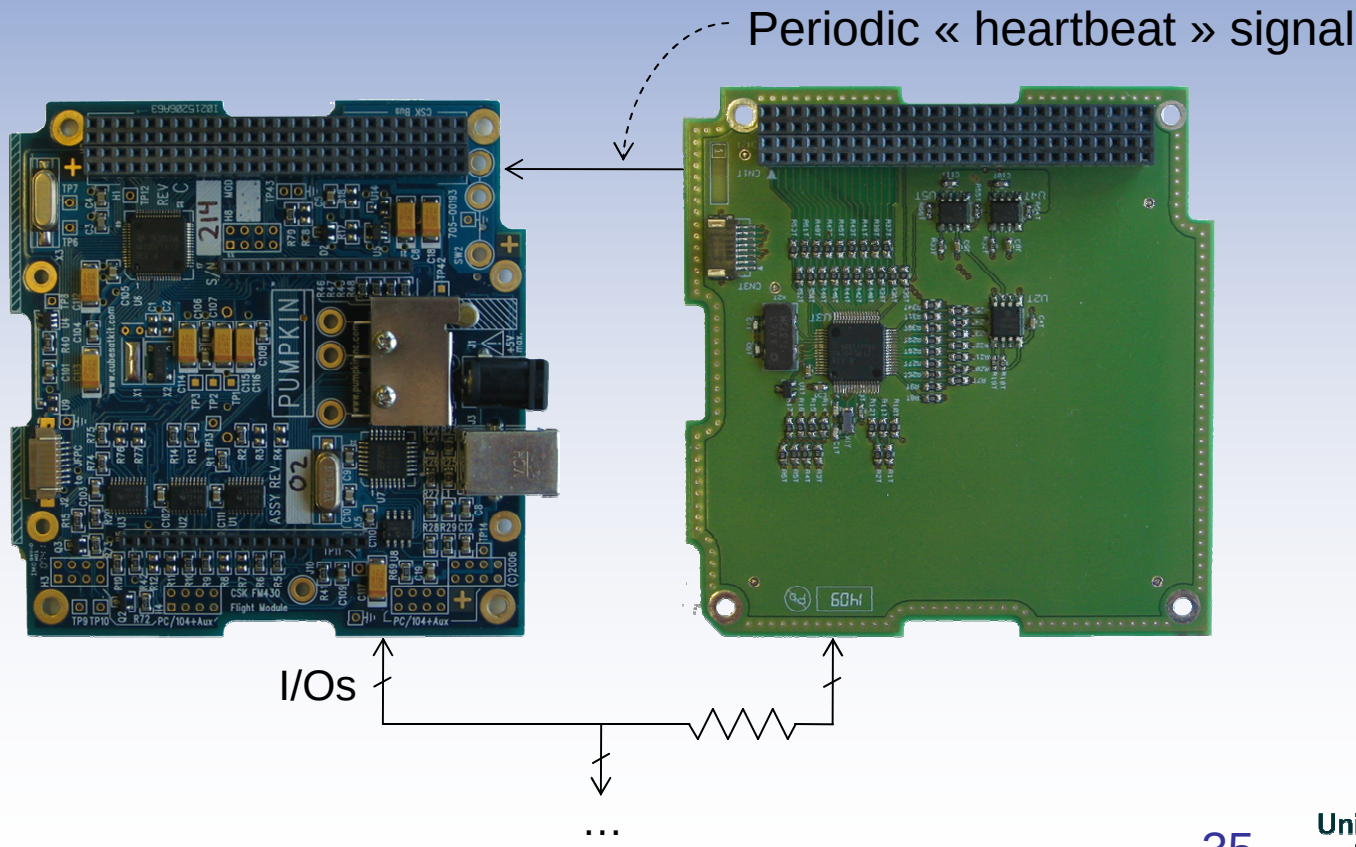


6. OBC: hardware solution (2)

- **Reliability through simplicity**

  One central processor, handles all tasks

  Doubled for redundancy: only one active at a time



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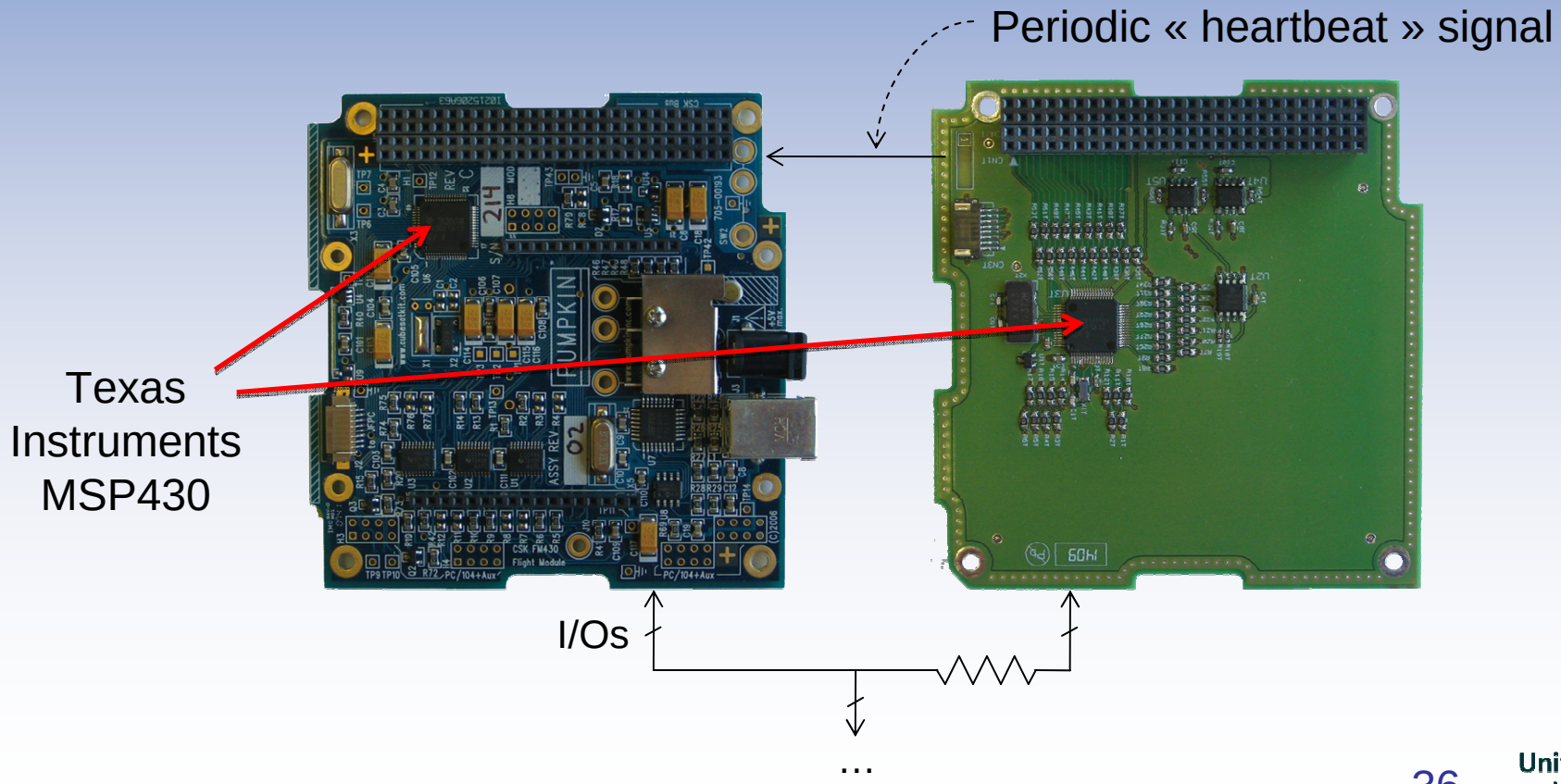
6. OBC: hardware solution (3)

- **Reliability through simplicity**

  One central processor, handles all tasks

  Doubled for redundancy: only one active at a time



6. OBC: software solution

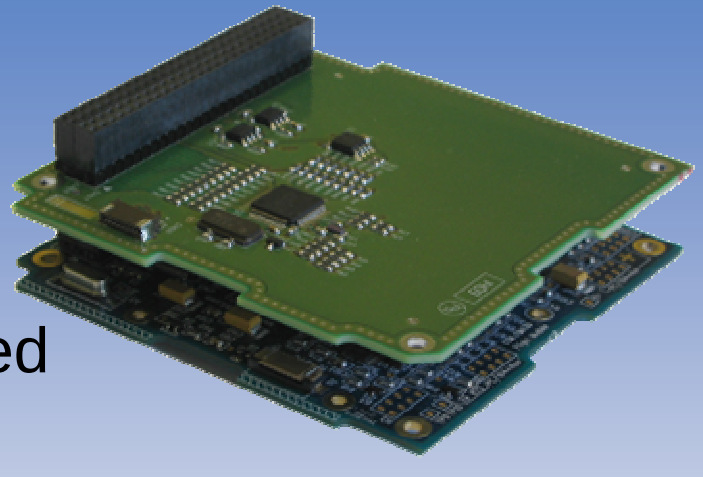
- **Architecture**
  - Modular/flexible software architecture
  - 6 general purpose modules:
    - monitoring (housekeeping, EPS management)
    - measurements
    - communications
    - sequencer (pre-planned sequences of operations)
    - log
    - clock (on-board time reference)
- **Implementation**
  - Use of FreeRTOS, open-source, lightweight, real-time OS
  - Programmed in C-language

6. OBC: future work

- **Hardware**

  OBC hardware 100% functional

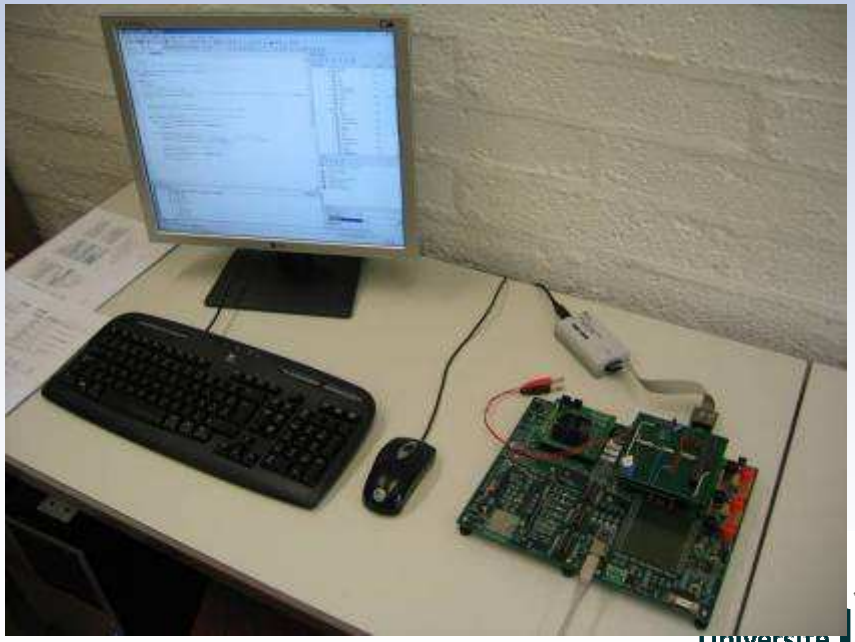
  Flight models to be manufactured



- **Software**

  Generic implementation of software functional

  OUFTI-1 mission-specific details to be integrated



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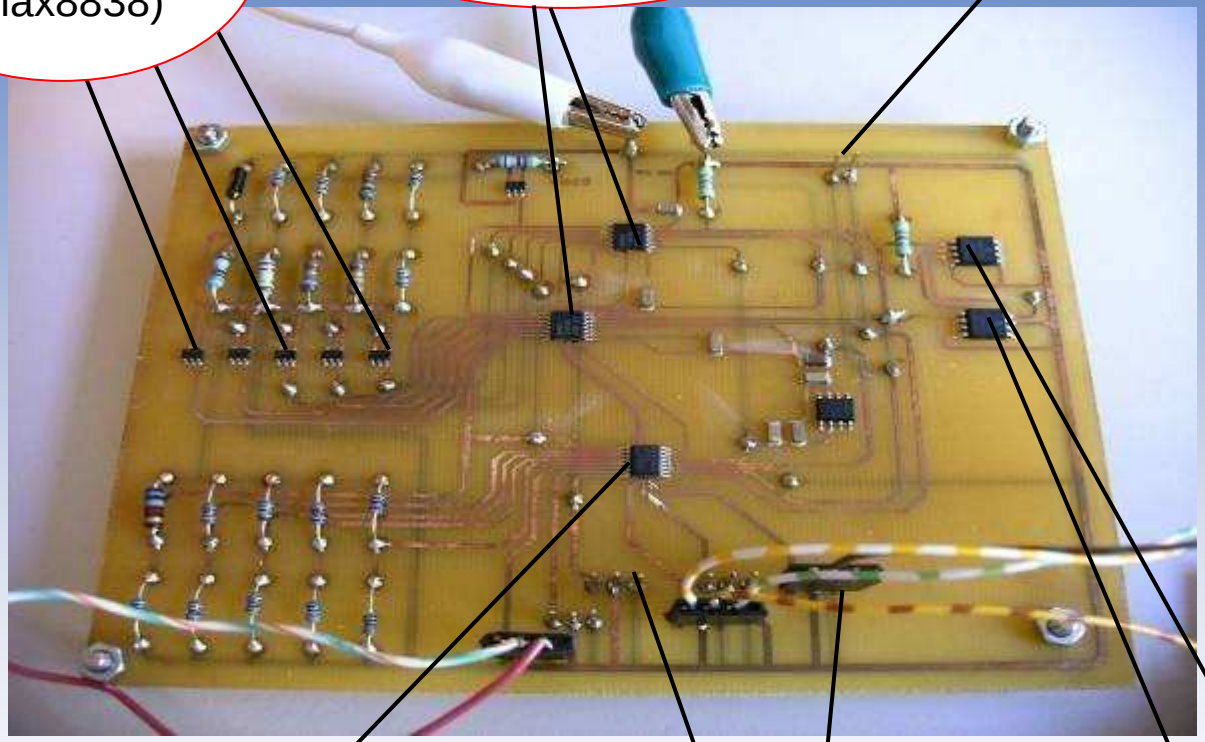
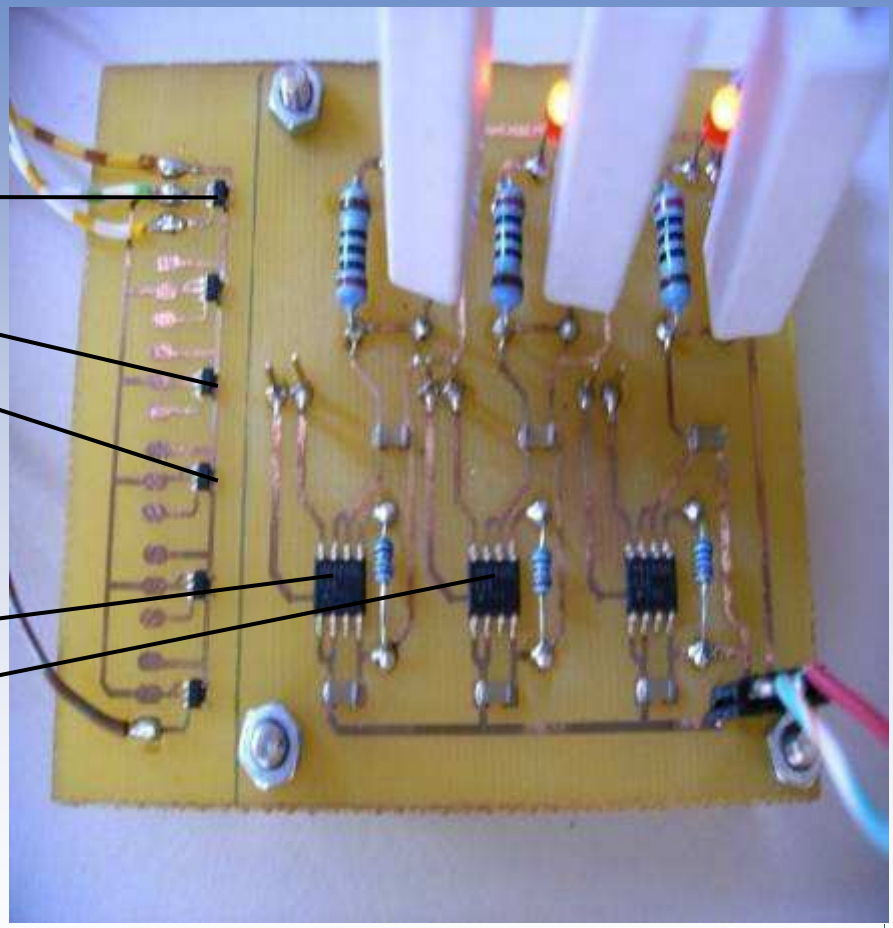
7. How to take those measurements ?



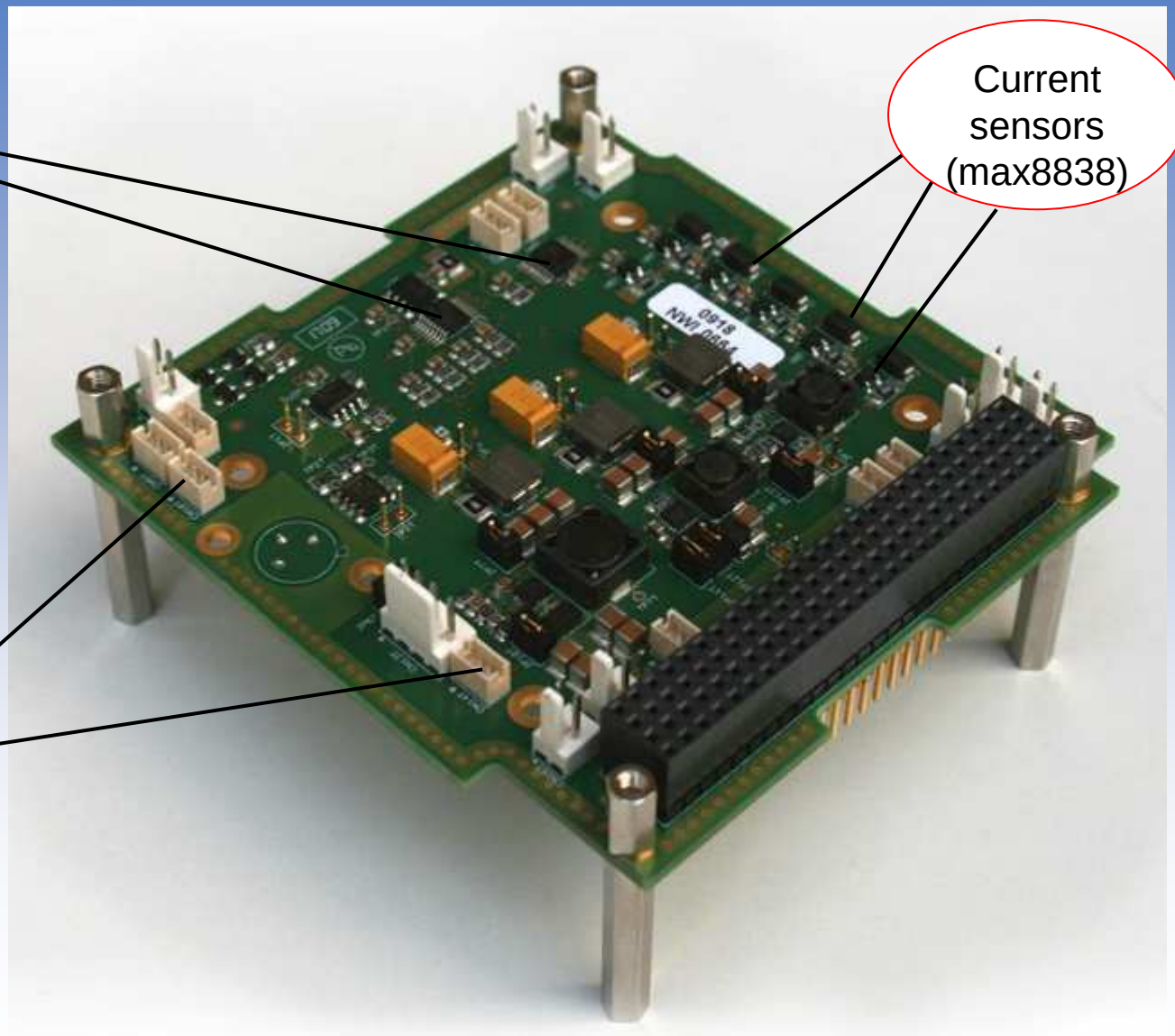
7. How to take those measurements ?

Temperature sensors (lm94022)

Switch (MAX890)



7. Measurements on EPS



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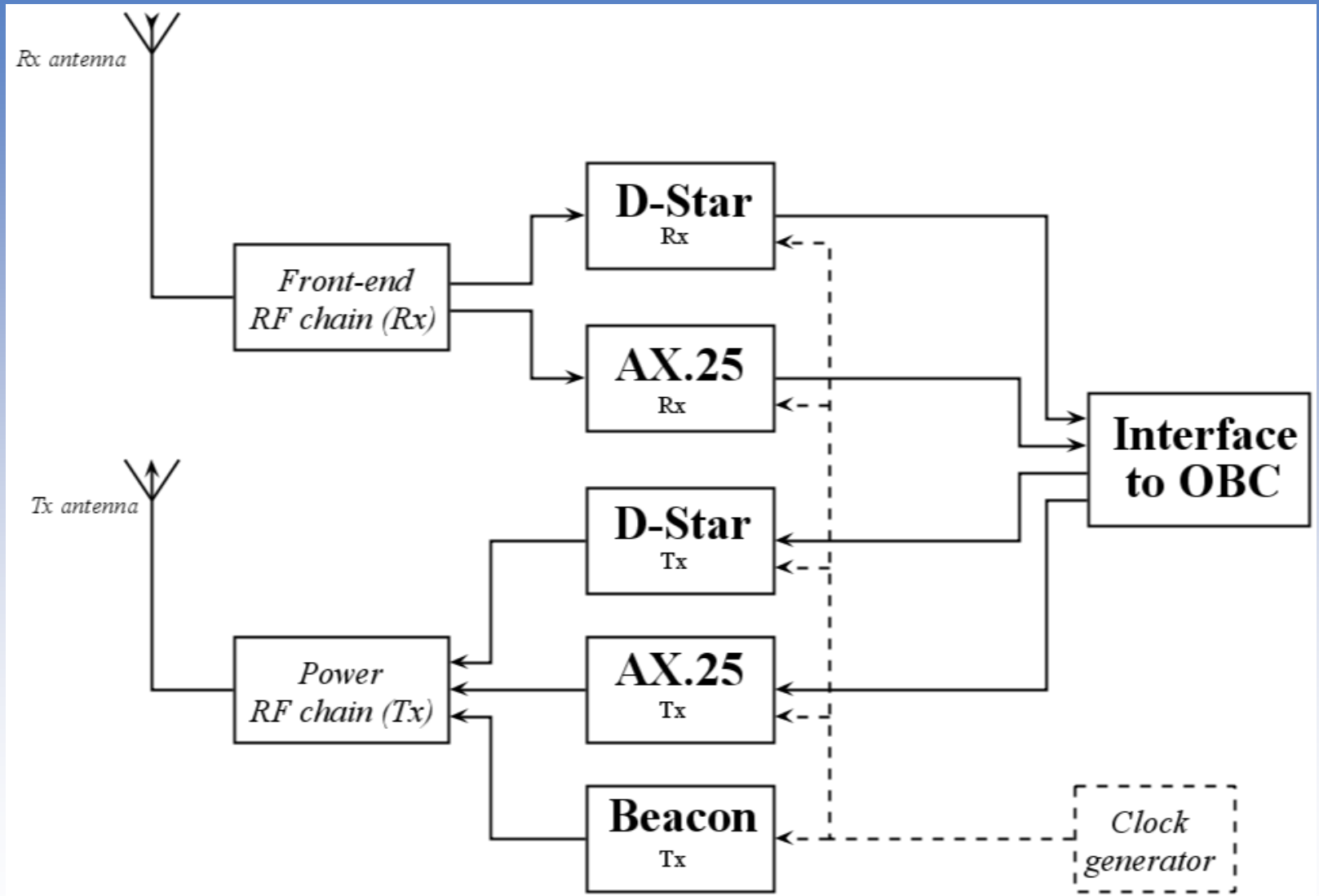
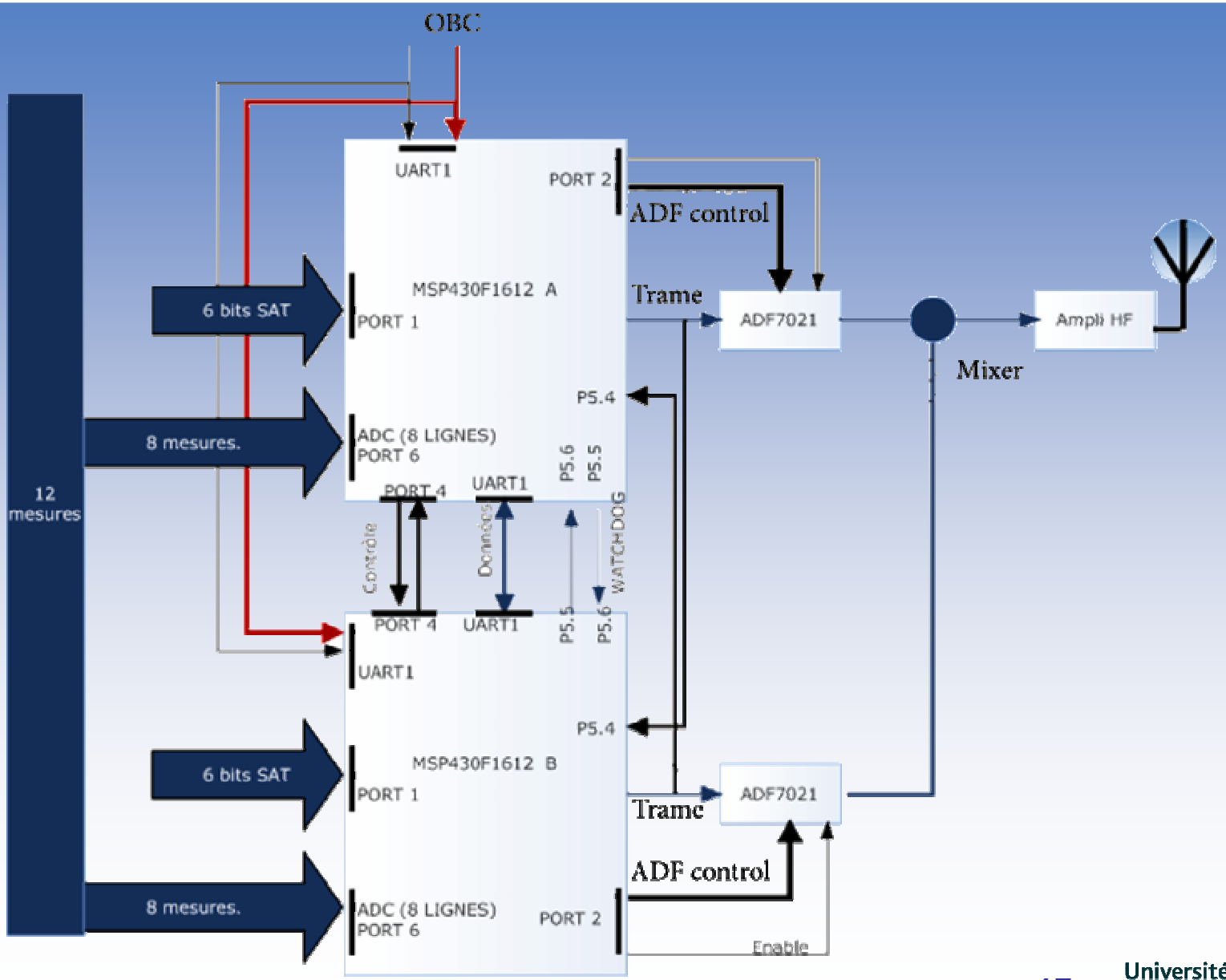
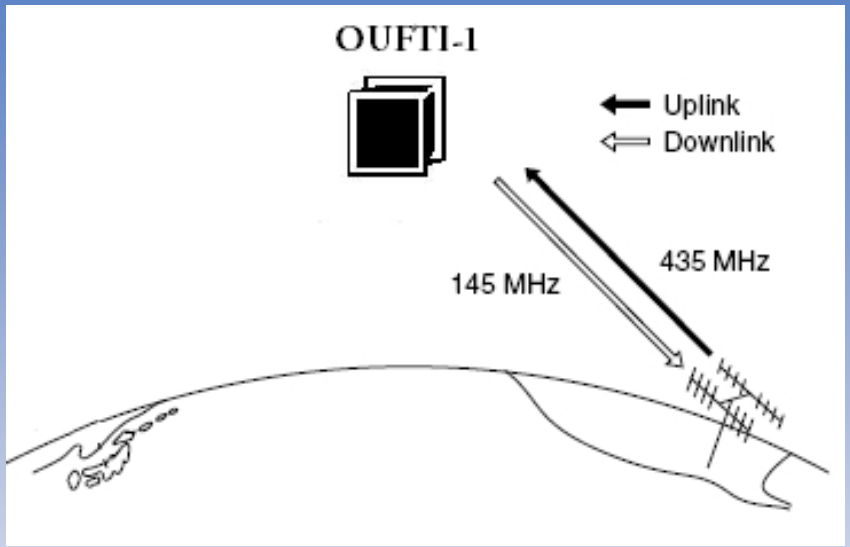
8. COM: 3 means of communication



8. COM: beacon


OBC
UART1
PORT 2
ADF control
MSP430F1612 A
6 bits SAT
PORT 1
Trame
ADF7021
Ampli HF
Mixer
P5.4
8 mesures.
ADC (8 LIGNES)
PORT 6
P5.6
P5.5
PORT 4
UART1
12
mesures
Contrôle
Données
WATCHDOG
PORT 4
UART1
P5.5
P5.6
UART1
P5.4
MSP430F1612 B
6 bits SAT
PORT 1
Trame
ADF7021
ADF control
8 mesures.
ADC (8 LIGNES)
PORT 6
PORT 2
Enable

8. COM: AX.25



AX.25 :
- Ham radio protocol
- Modem G3RUH
- 9600 baud
- 2-FSK

AX.25 is mainly used for telecommands & telemetry (CCSDS format)

- Structure of a AX.25 frame

Flag	Address	Control	PID	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	8 Bits	N*8 Bits	16 Bits	01111110

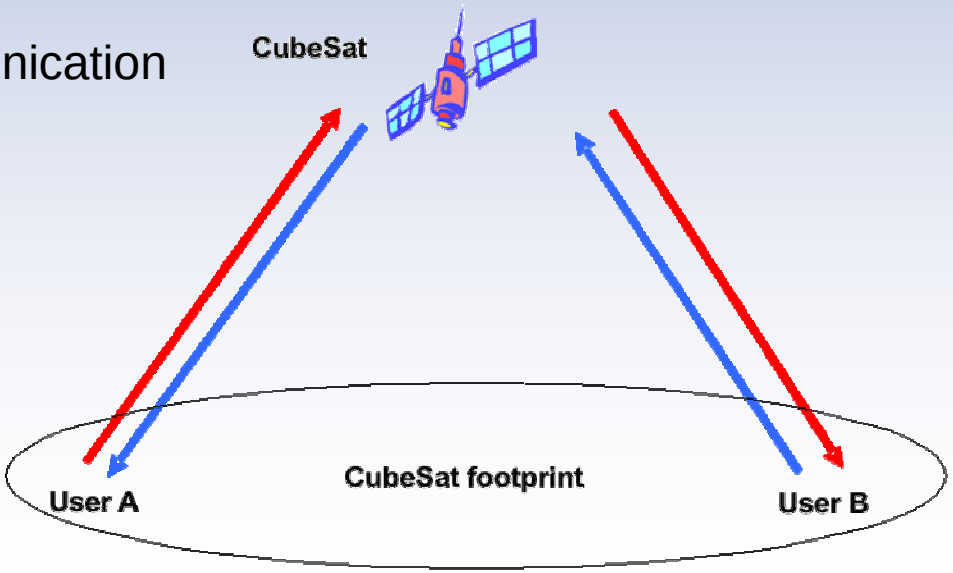
Bit stuffing - NRZ-I encoding - scrambling

8. COM: D-STAR

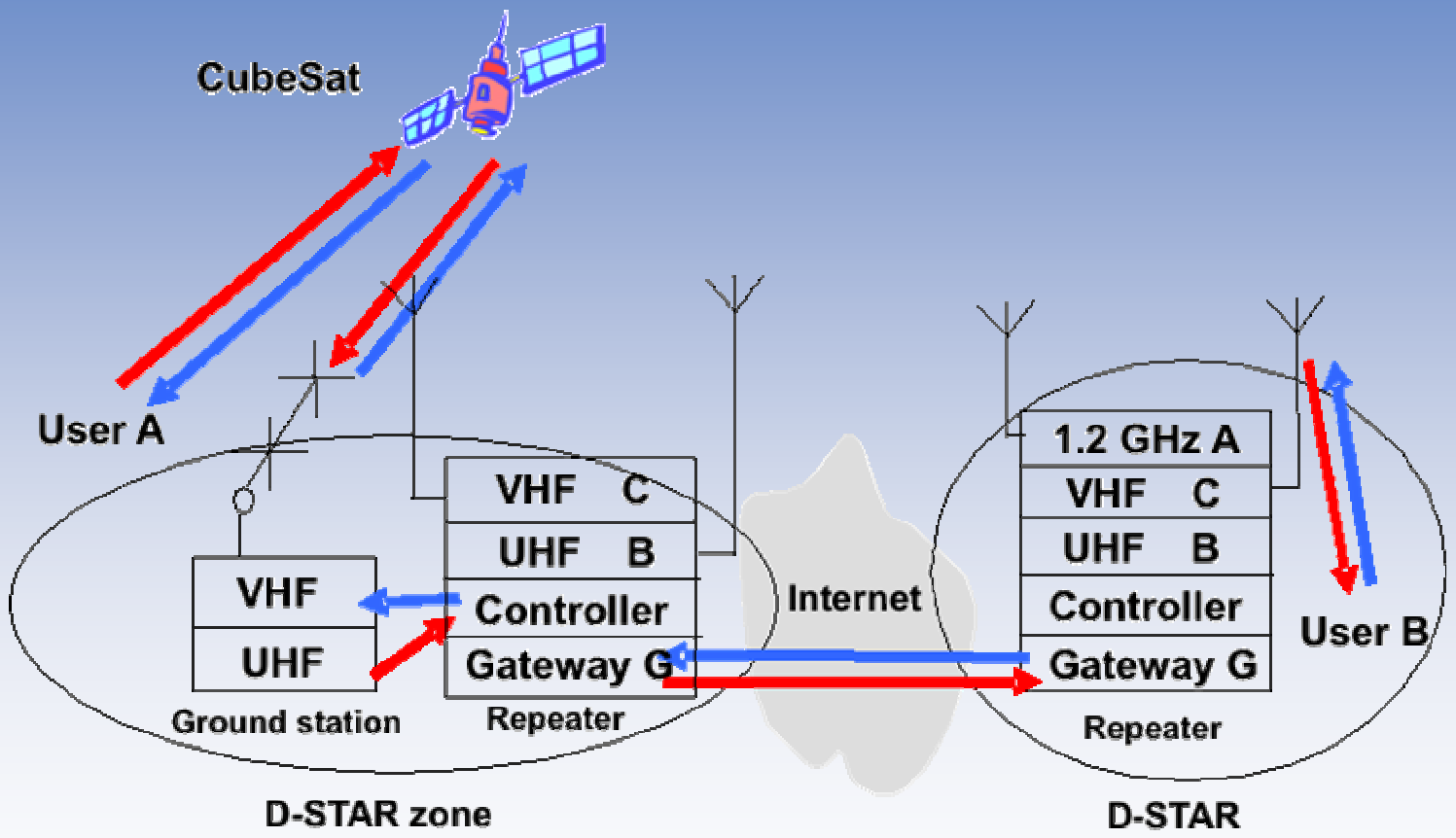
- Simultaneous data and voice digital transmission
- Data : 1200 bps - Voice : 3600 bps (AMBE encoding)
- GMSK modulation
- Structure of a D-STAR frame

Sync	Pattern	Header	Voice	Data	. . .	Voice	Data	End of frame
64bits	15bits	660bits	72bits	24bits		72bits	24bits	48bits

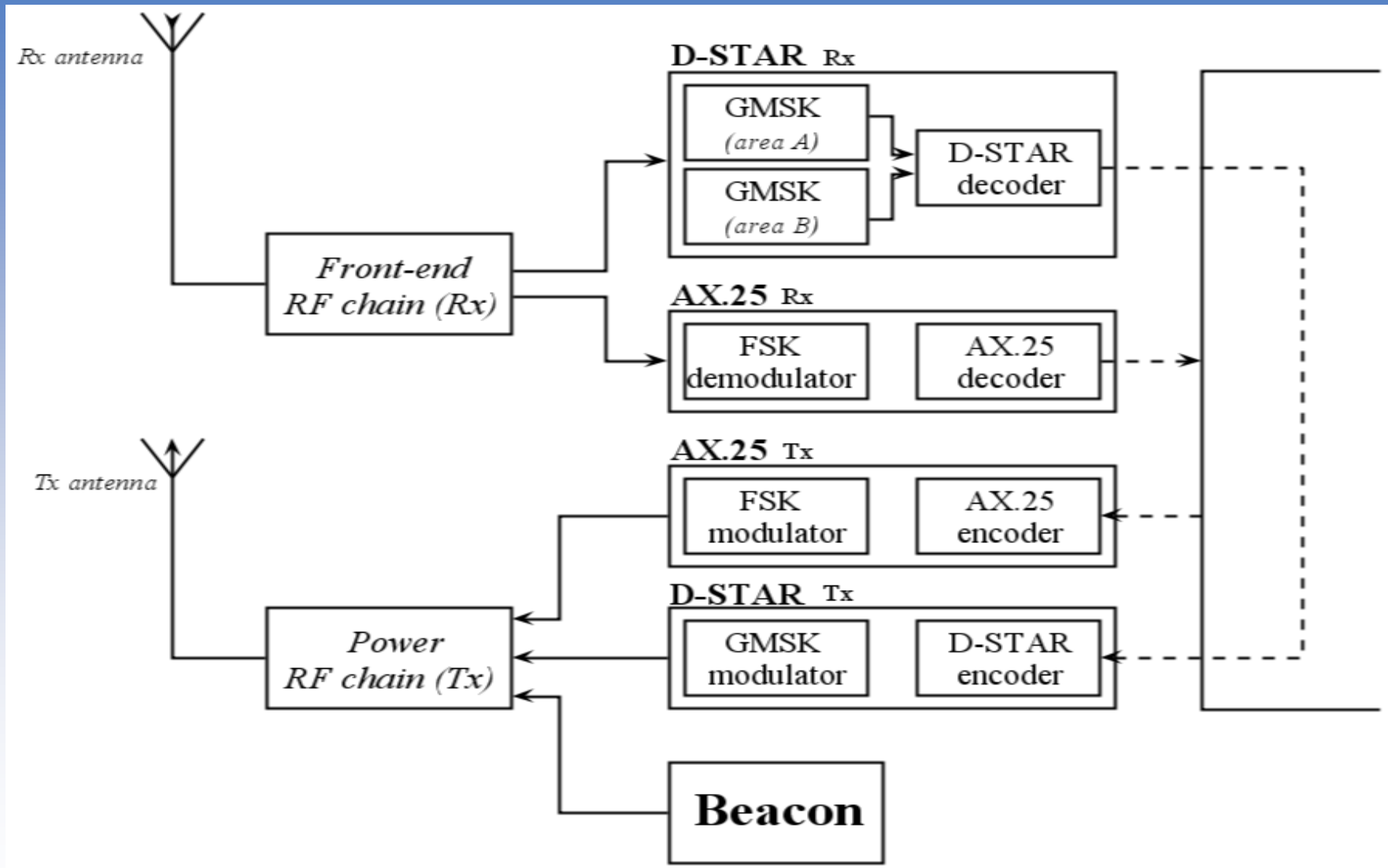
- Basic communication



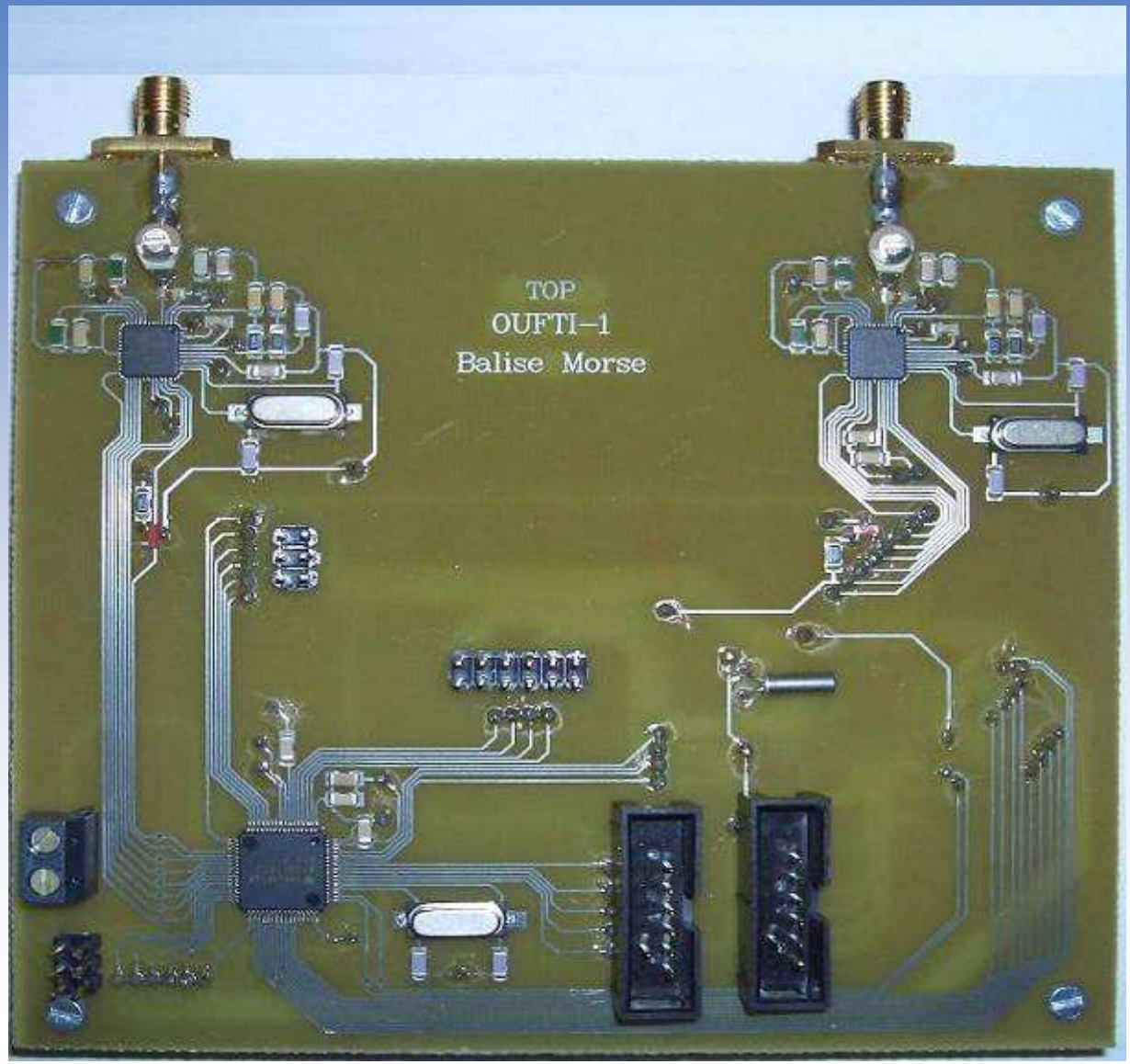
8. COM: link with D-STAR network



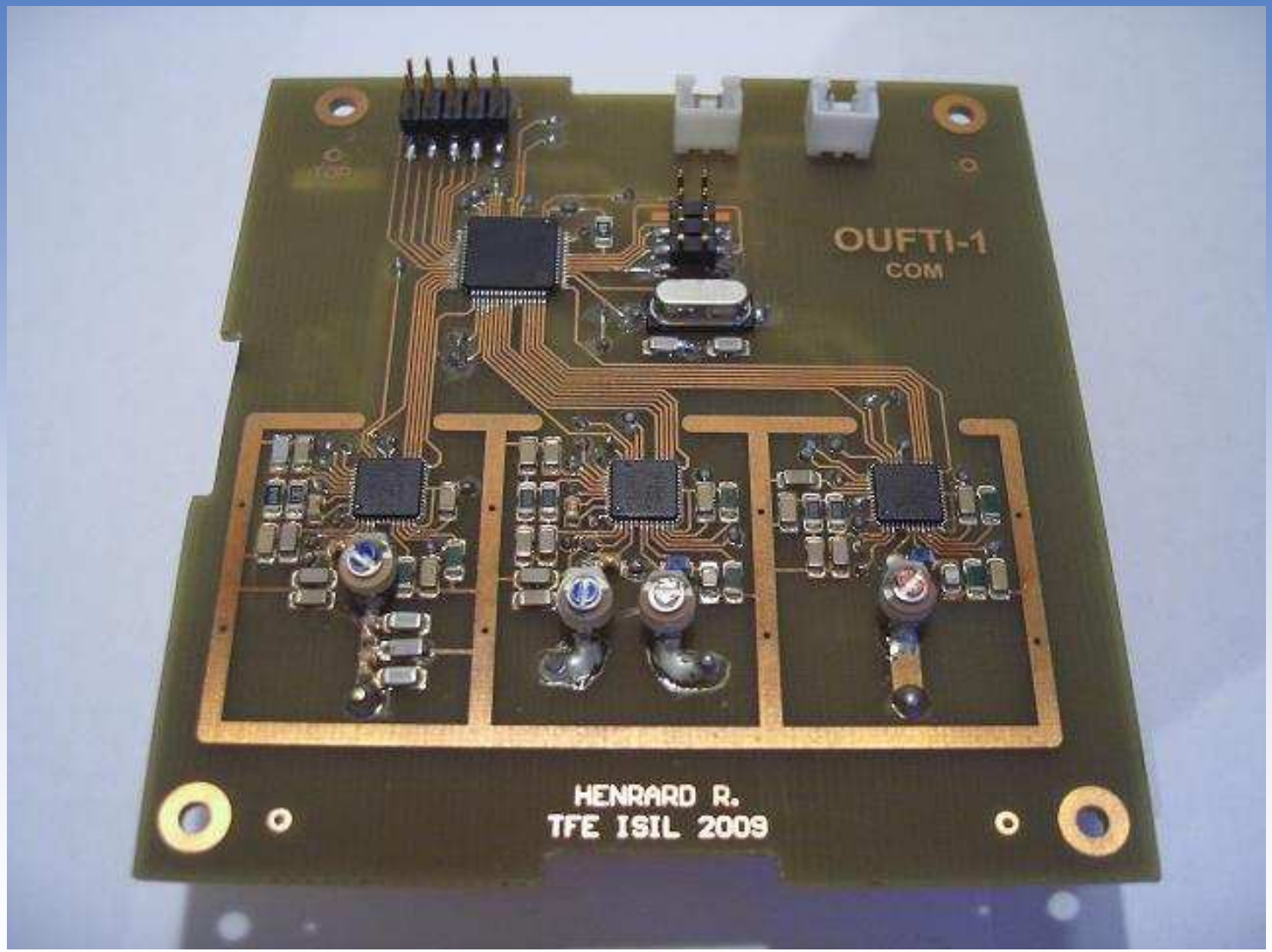
8. COM system overview



8. COM: Beacon



8. COM: Prototype



8. COM: Further works

1. Input RF stage (LNA, splitter)
2. Output RF Stage (RF amplifier, combiner)
3. OBC-COM Interface
4. Master clock system

Outline

A. OUFTI-1 project

B. Technical overview

1. Configuration and structure (STRU)
2. Attitude Determination and Control System (ADCS)
3. Thermal subsystem (THER)
4. Mission analysis (MIAS)
5. Electrical Power System (EPS)
6. On-Board Computer (OBC)
7. Measurements of Housekeeping Parameters (MHP)
8. Communication susbsystem (COM)
9. Antennas deployment mechanism (MECH)
10. Ground segment (GND)

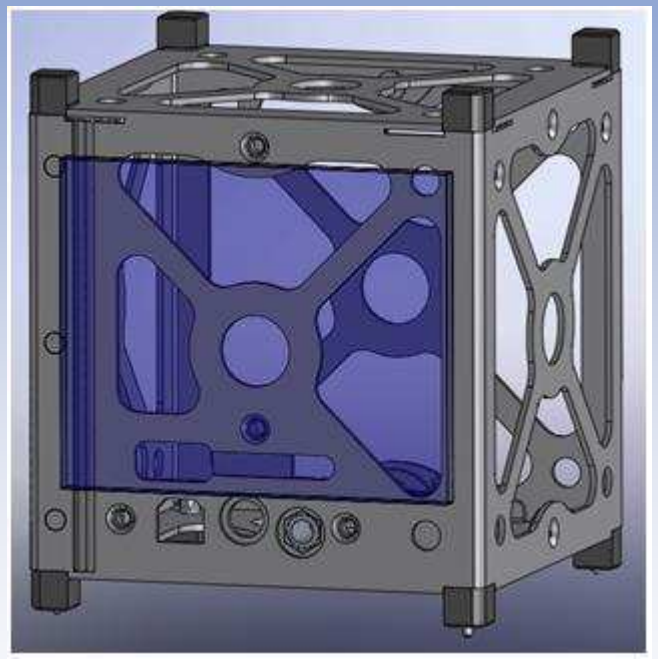
C. Concluding remarks

9. MECH: functions

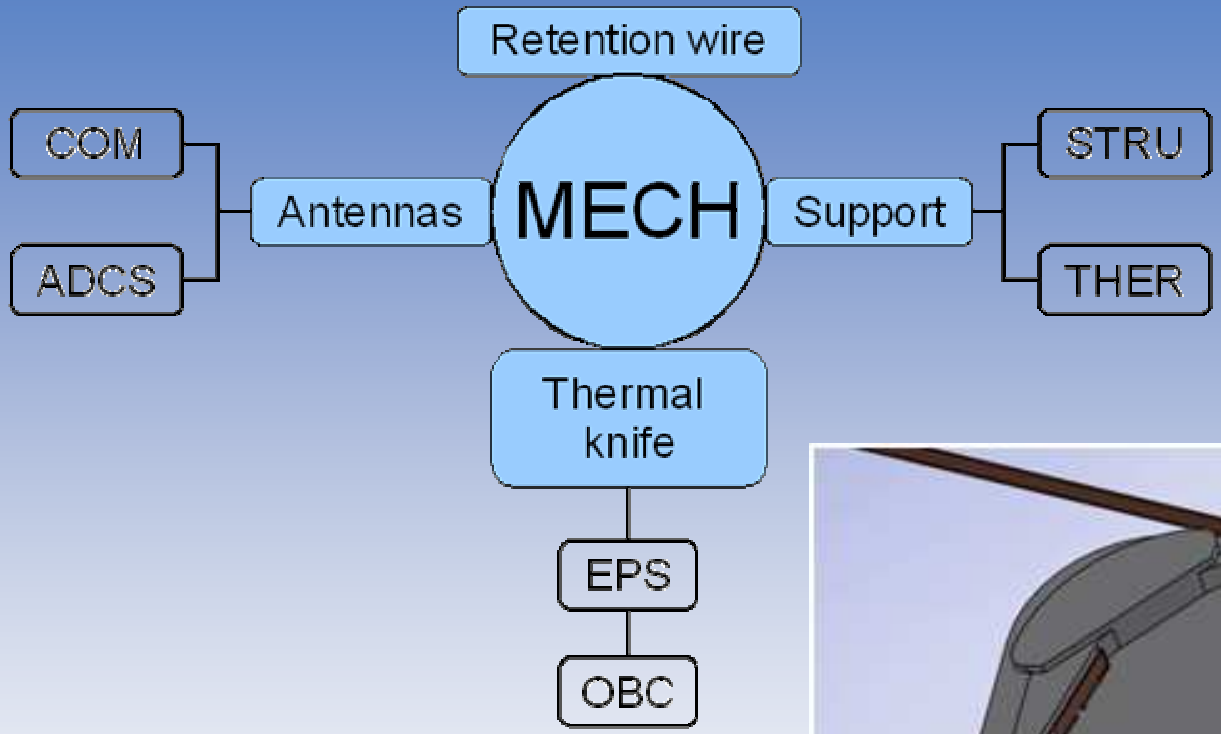
➔ Antennas + deployment system design and realization

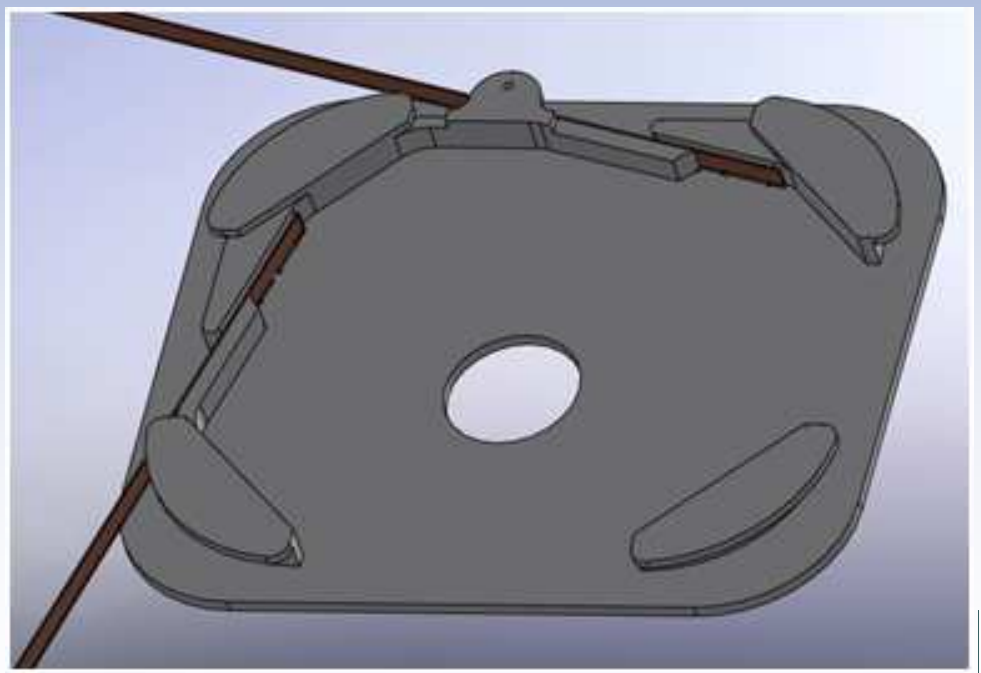
- Main features:

  - 2 antennas : 170 mm and 500 mm
  - Mass budget : 53 g
  - Available volume : about 80 x 70 x 6 mm
  - Deployment 15 minutes after P-POD ejection



9. MECH: system configuration



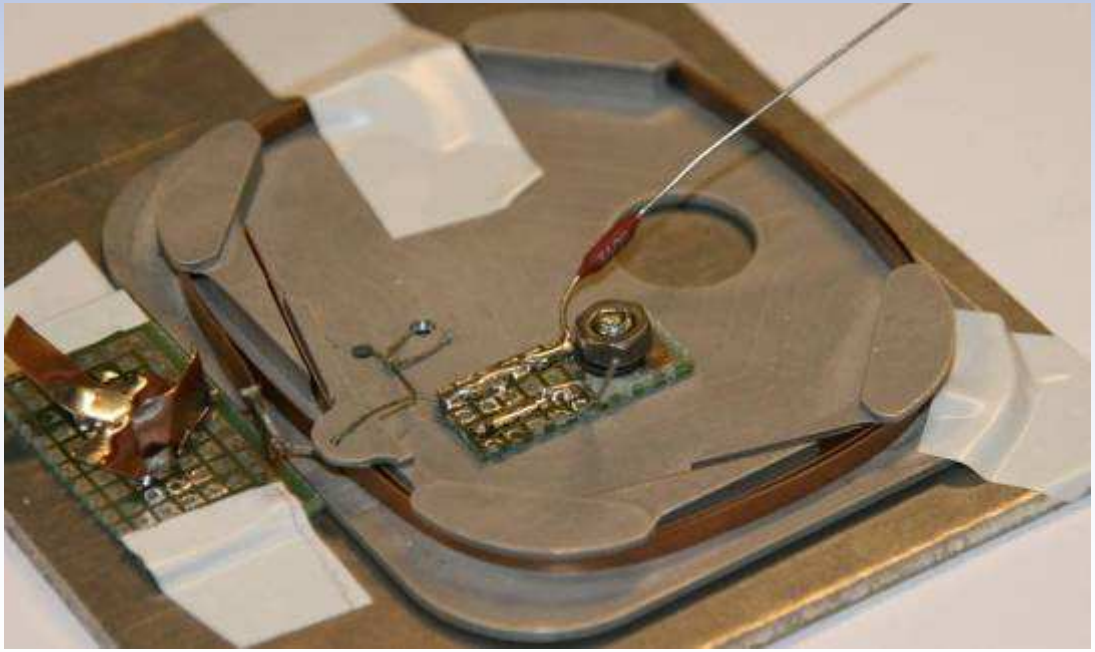


9. MECH: work carried out

- Design of the main parts of the system: support, antennas, thermal knife, retention wire.

- Realizations: 2 prototypes

- Tests: vacuum thermal tests (-20℃ / +60℃)



9. MECH: future work

- Design:
  - Assembly to define precisely
  - Connection of hardware with other subsystems to define precisely
  - Determination of the torque produced by deployment

- Tests:
  - Vibrations
  - Chocs
  - Integration (with COM, EPS, OBC, STRU)

- Realizations:
  - Protoflight model
  - Flight model

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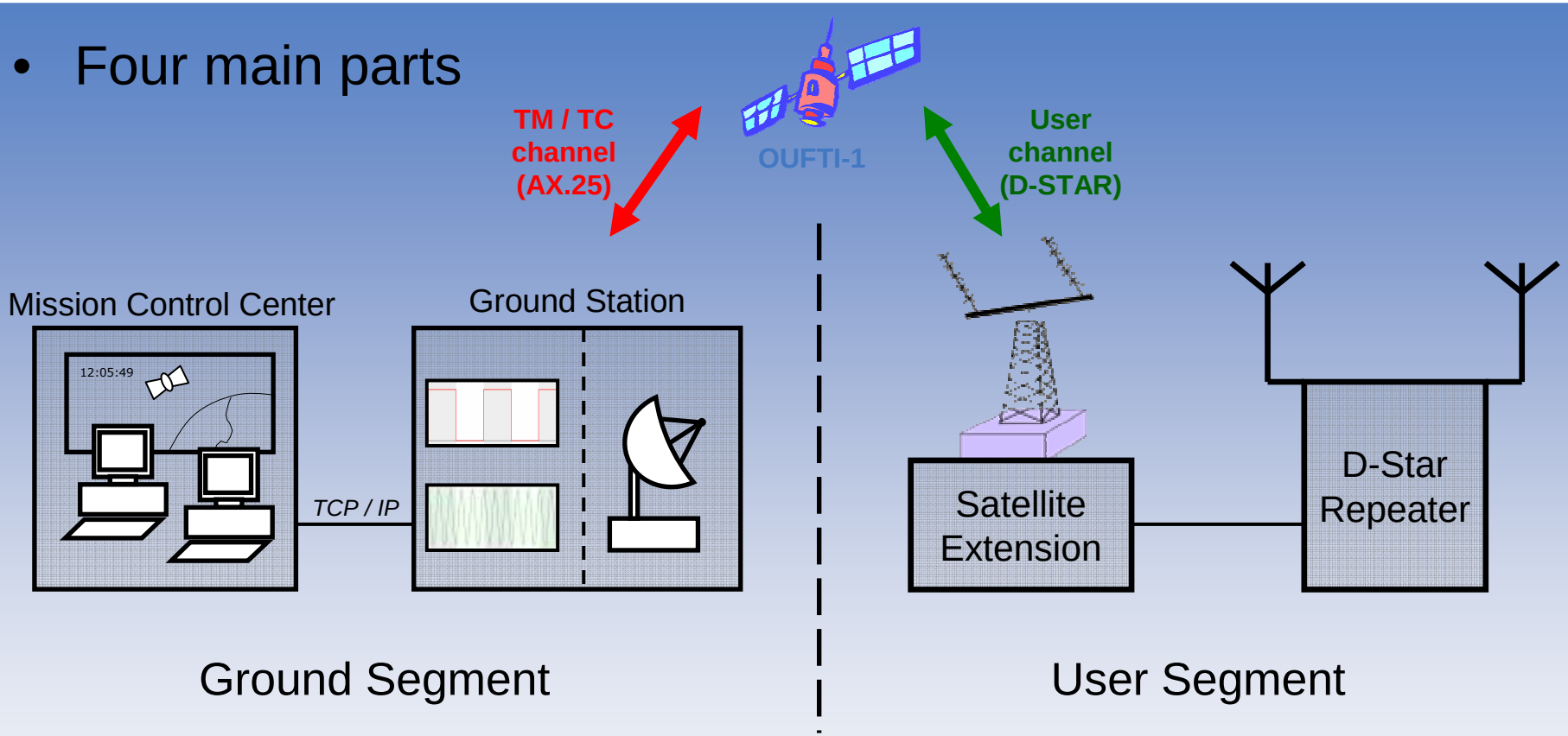
10. Ground segment (GND)

C. Concluding remarks

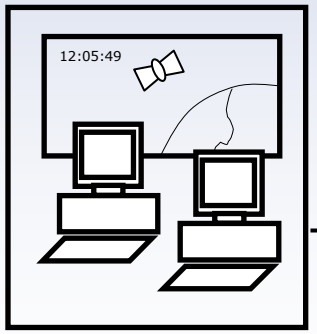
10. GND: ground facilities

- Four main parts



- Ground Segment → control and monitoring of OUFTI-1, by satellite operators
- User Segment → operations with OUFTI-1 main payload (D-Star relay), by ham community

10. GND: ground segment architecture



UHF Antenna

VHF Antenna

el

az

H

V

H

V

Rotators controller

Phasing line

Phasing line

FM UHF

FM VHF

Tracking card

CI-V

UHF/VHF Transceiver

Pointing data

Control

AX.25

TCP / IP

Serial Data

TNC

GS computer

Mission Control Center

Ground Station

Université de Liège

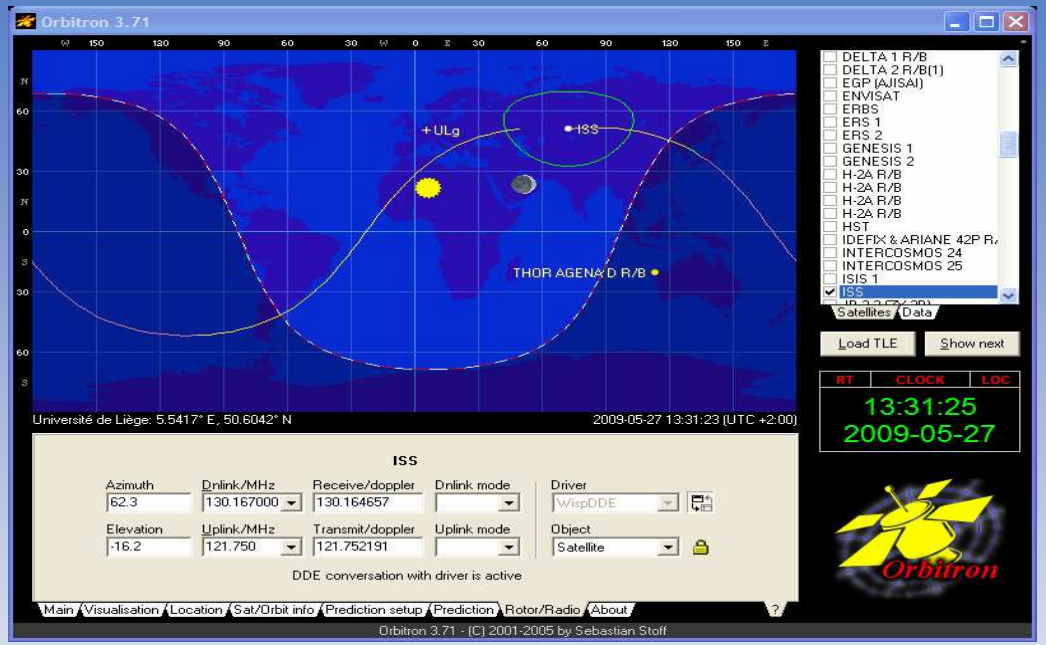
10. GND: ground station (GS)

- Comply with Amateur radio requirements
  - TM / TC exchanged in AX.25 frames (using TNC)
  - Satellite-capable transceiver in amateur bands (VHF / UHF)

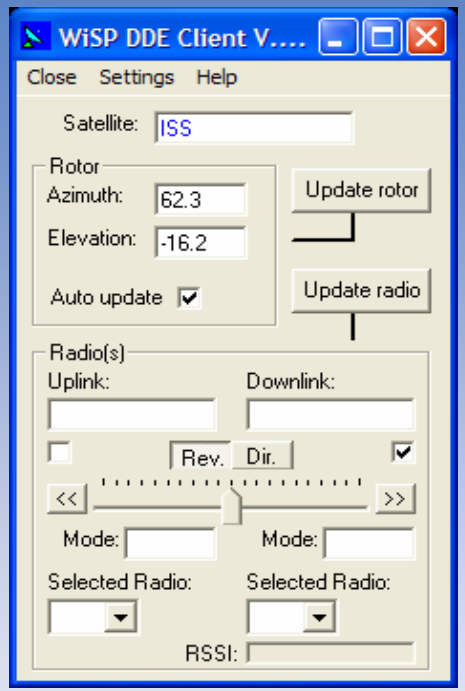
- X-Quad antennas → circular polarization
  - Elevation (180°) and azimuth (360°) rotators
  - Tracking card developed by ham operator (EA4TX)

- GS computers runs software for:
  - Automatic tracking (Orbitron + WispDDE + ARSWIN)
  - Automatic Doppler compensation (Orbitron + WispDDE)
  - TCP server listening to Misson Control Center

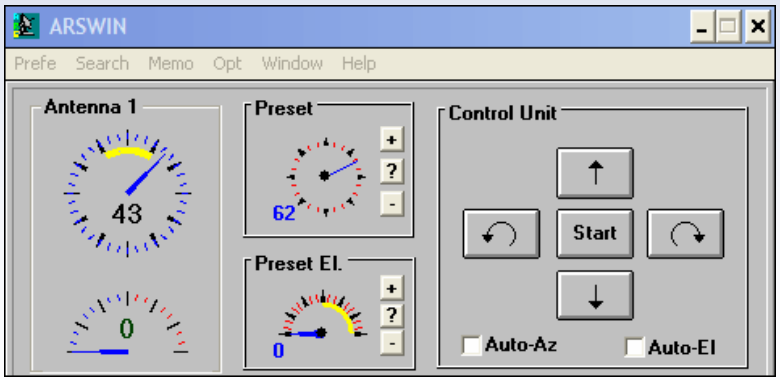
10. GND: GS ham softwares



Orbitron **(developed by S. Stoff)**



WispDDE **(developed by F. Mederos, CX6DD)**



ARSWIN **(developed by J. Pablo Garcia, EA4TX)**

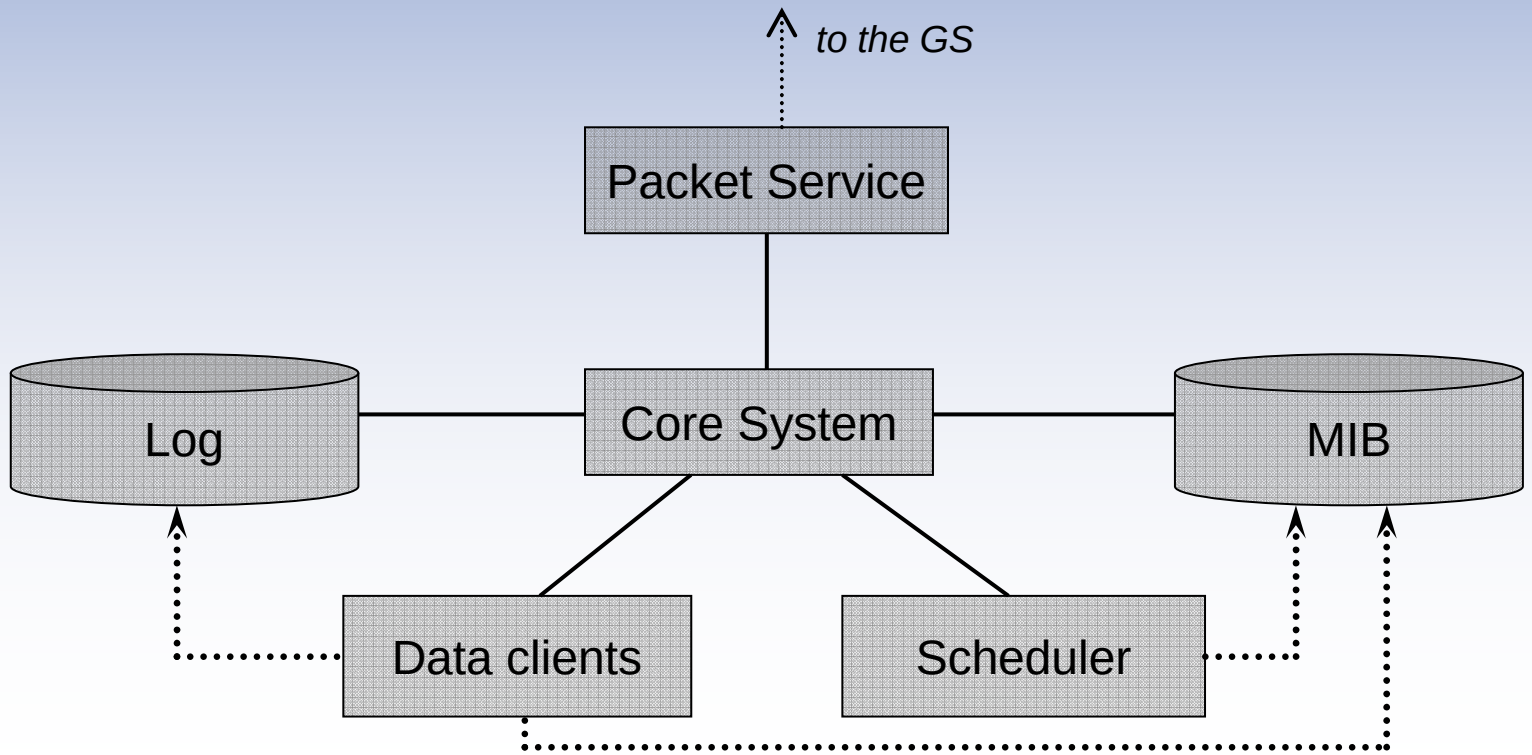
→ Free softwares developed by the ham community !

10. GND: Mission control center (MCC)

- Protocol based on ECSS *Packet Utilization Standard* (PUS), which in turns relies on the CCSDS *Space Packet Protocol*
  - OUFTI-1 mission control software will implement a simplified subset of these standards
  - E.g., base services such as telecommand verification, function performing, housekeeping reporting, On-board storage, …
- OS-independent and largely deployed technologies to allow for maximum portability
  - Java SE programming language
  - MySQL databases

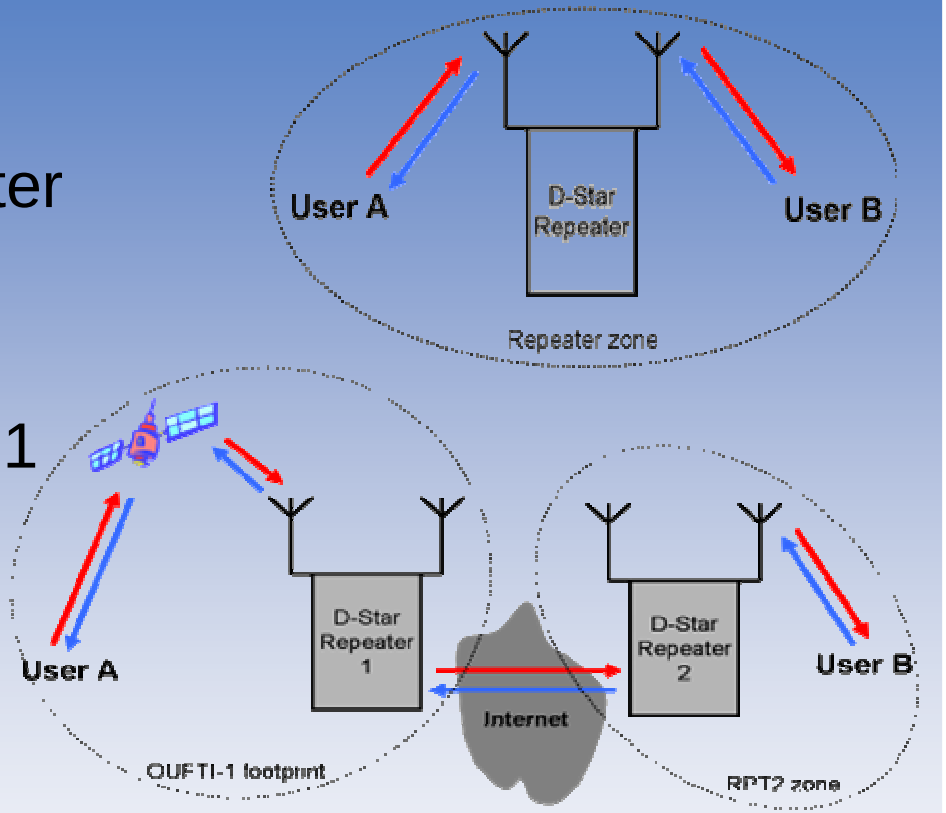
10. Mission control software overview

- Try to be as generic as possible (not tied to OUFTI-1)
  - Mission-specific data defined in MIB (Mission Information Base)
    - TM/TC general configuration
    - Parameters description, format, housekeeping calibration
    - Function IDs
  - Modular code, Object-Oriented programming to ease future extensions and plug-ins for mission-specific services



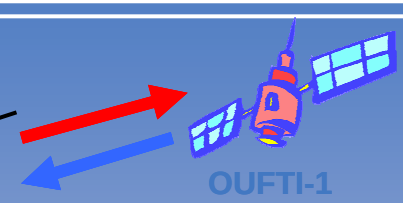
10. GND: user segment

- « Terrestrial » D-Star repeater
  - Callsign ON0ULG
- Extended to allow satellite communication with OUFTI-1



- Any ham operator will be able to use the relay to communicate with OUFTI-1
- Also possible through internet !

10. GND: D-STAR repeater + extension



Duplexer

Duplexer

Tx

Rx

Tx

Rx

VHF module

UHF module

Controller

Gateway

Internet

D-Star Repeater

Tracking System

Frequency Converter

VHF or UHF module

Satellite extension

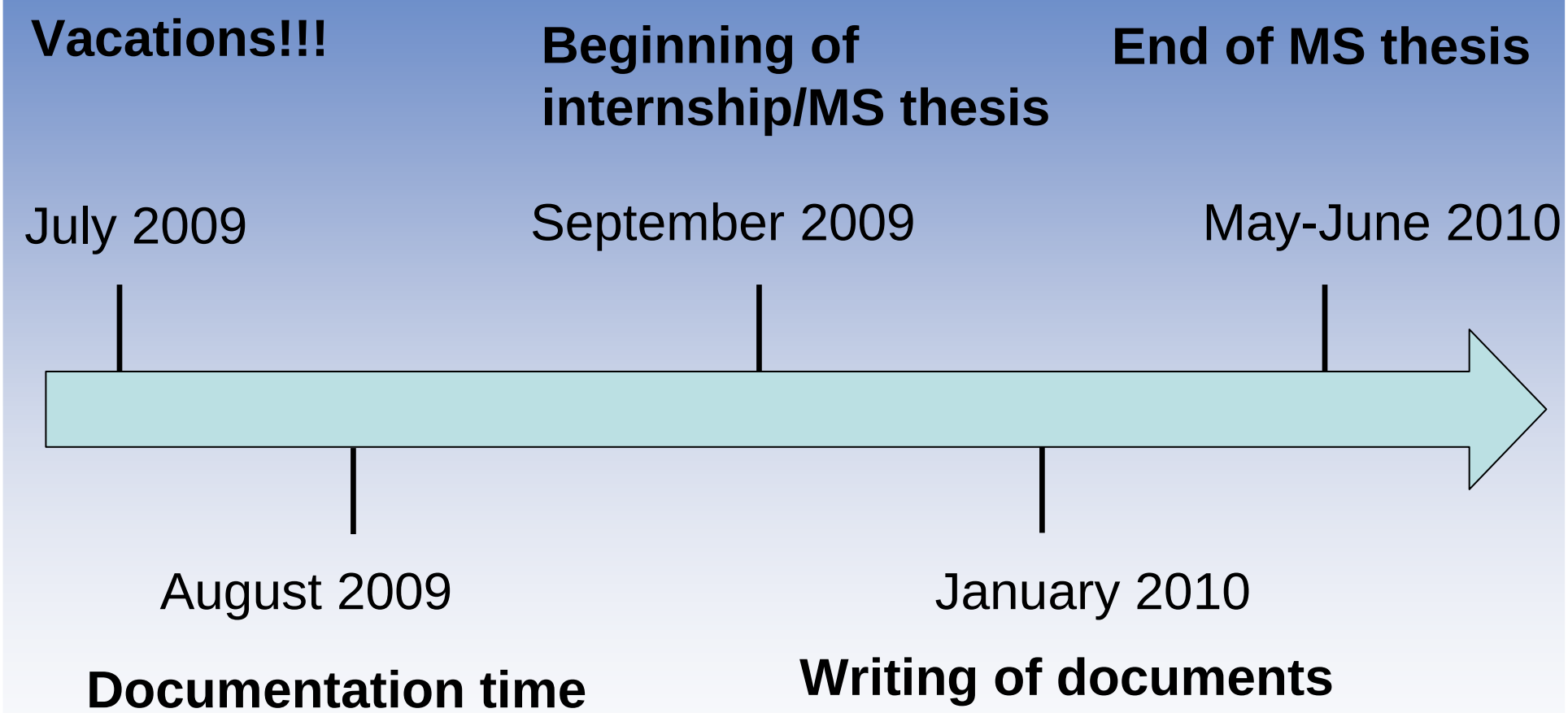
Outline

A. OUFTI-1 project

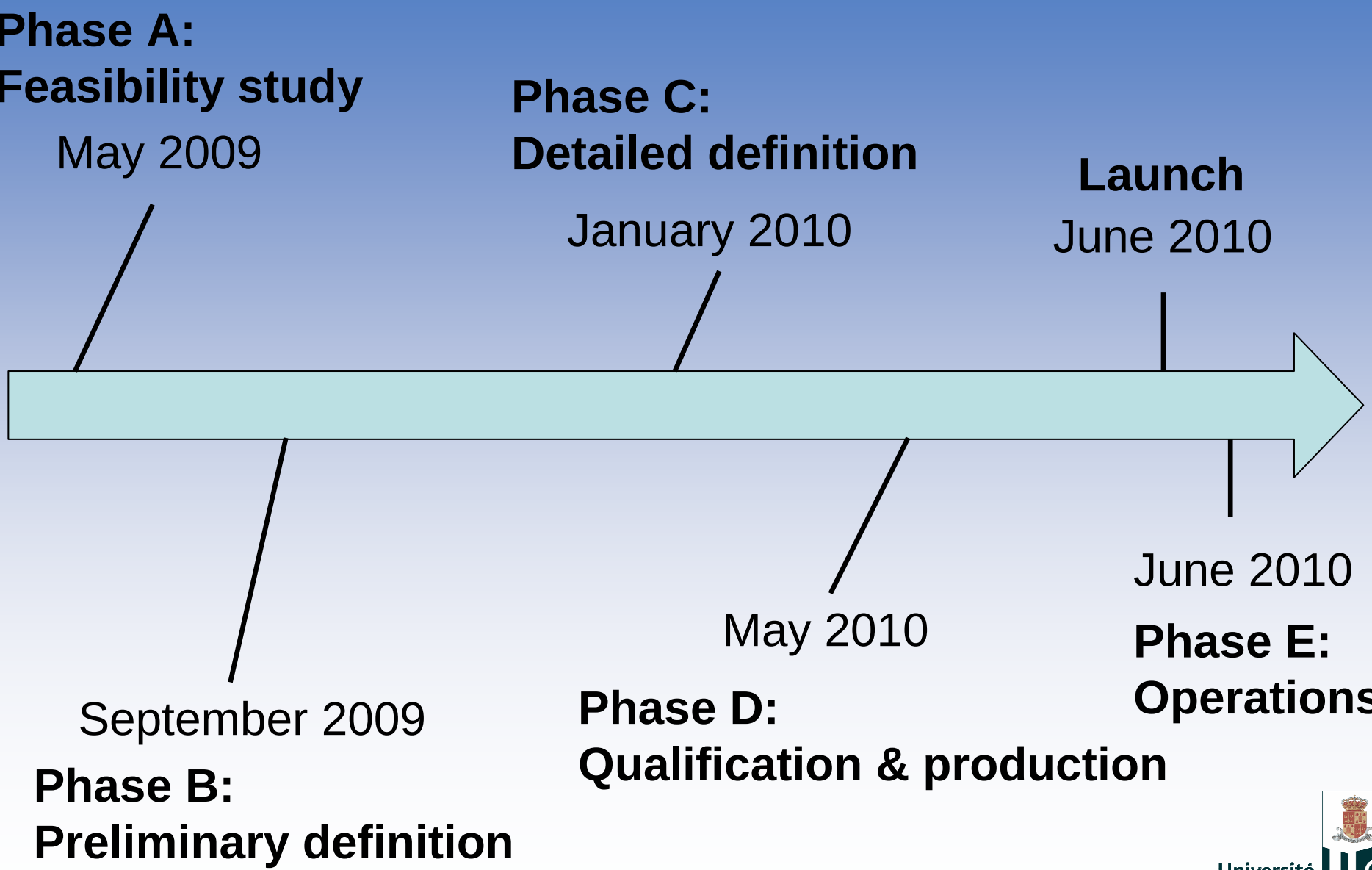
B. Technical overview

C. Concluding remarks
   1. Next year…
   2. Timeline
   3. Demonstrations

1. Next year…


Vacations!!!
Beginning of internship/MS thesis
End of MS thesis
July 2009
September 2009
May-June 2010
August 2009
Documentation time
January 2010
Writing of documents

2. Timeline


Phase A:
Feasibility study
May 2009
Phase C:
Detailed definition
January 2010
Launch
June 2010
September 2009
Phase B:
Preliminary definition
May 2010
Phase D:
Qualification & production
June 2010
Phase E:
Operations

3. Demonstrations

- 2 groups

- 1st group:
  - On-board computer
  - D-STAR
  - AX.25
  - Electrical power system

- 2nd group:
  - CubeSat
  - Simulator
  - Antenna deployment
  - Educational model

Thank you for your attention !