ST3LLARsat1 BOIRA:

The first CubeSat program at UC3M

Presentation based on ST3LLARsat1 team presentation at ESA FYS! Design Booster FDR, 7th June 2024

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Master in Space Engineering (MISE)

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ST3LLARsat1 BOIRA – Our Mission

1st student CubeSat program at UC3M

Start Date: September 2022 (expected launch 2026-27)

Required Skills: Multidisciplinary (aero, telecom, signals, SW, HW …)

Director: UC3M / Aero – Dr. Andrés Marcos

First mission: **ST3LLARsat1 "BOIRA"**

"Boira" means fog in two of Spain's official languages: Galician & Catalonian

ST3LLARsat1 BOIRA: Project Goals

EDUCATIONAL

1st UC3M CubeSat student programme

To provide students with **hands-on experience in a real space project**

SCIENTIFIC

Aim is to **design, build, launch and operate a 2U CubeSat**

to monitor climate change by measuring local atmospheric moisture

TECHNOLOGICAL

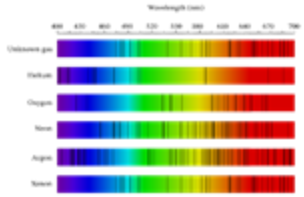
IOD of

1. **All the operating equipment** (except payload) fitting in about **1U**
2. **A weather-observing scientific instrument** fitting in about **1U**
3. An in-house **state-of-art compact communication antenna**
4. An in-house OBC software for **advanced AOCS/ADCS algorithms**

ST3LLARsat1 2U structure & internal config

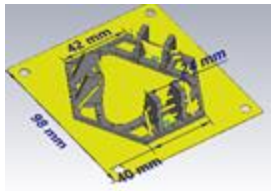
@ BDR (March'23) @ FDR (Feb'24)

ST3LLARsat1 science: measure water vapor (WV)

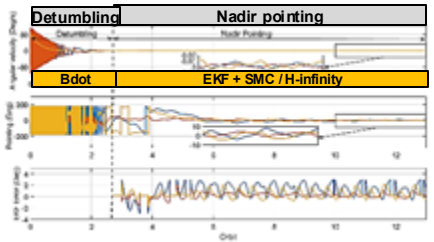


ST3LLARsat1 technology:

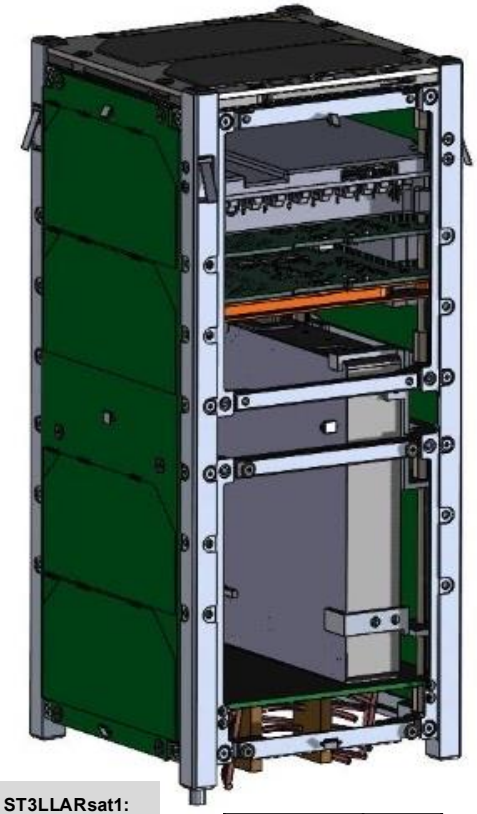
Compact antenna



Advanced ADCS



ST3LLARsat1 BOIRA – 2U CubeSat Configuration



ST3LLARsat1: 2U configuration

Mass** (Kg)	1.366

** := 20% margin

Structure: 2U SpaceMind SM-02

Solar cells: (16) 1x SpaceMind-SP1X, 3x SpaceMind-SP2X, 1x SpaceMind-SP1Z

Deployable UHF antenna: Endurosat 1U

PCDU+Battery: Endurosat EPS-I

OBC-PCB: Microchip SAMV71Q21B-AAB MCU

GNSS Antenna: Molex 206640-0001

GNSS receiver: Skytraq Orion B16C1

RF transceiver: Semtech SX1276

Photodiodes: 13x OSRAM SFH 2401

ADCS-PCB: same MCU as OBC-PCB

3-axis gyro: MEMS ADIS 16500

Magnetometer: PNI RM3100

Magnetorquers: 2x CubeSpace rods CR0002, 1x CubeSpace Coil

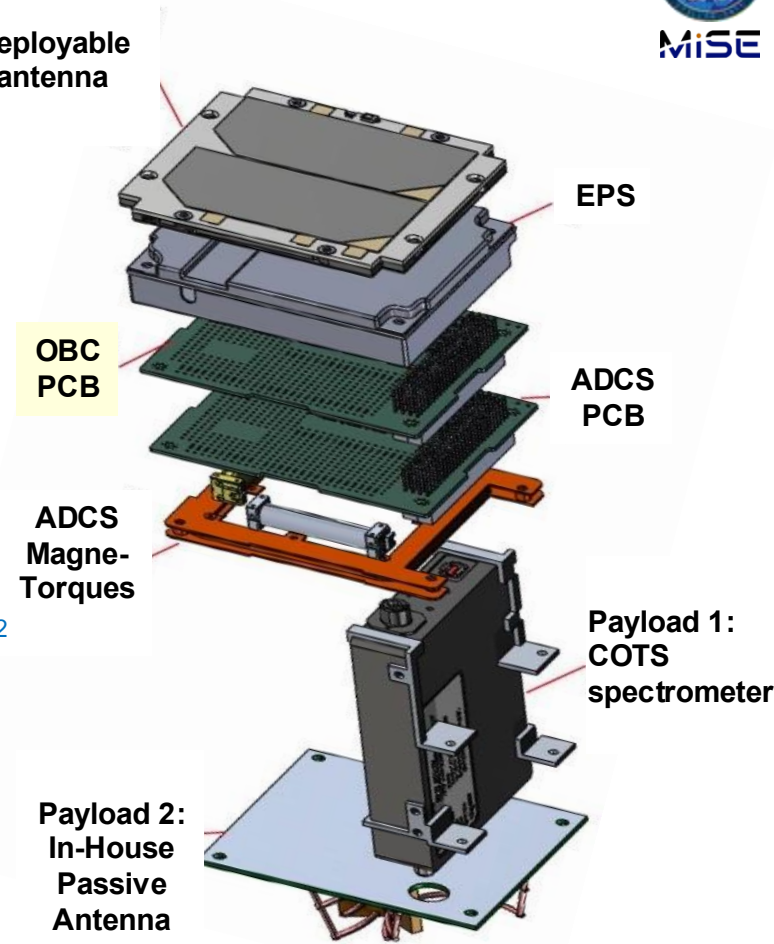
Payload1: Avantes AvaSpec-Nexos Spectrometer

Payload2: In-House UHF antenna

OS: freeRTOS / Fprime

CoM	cm
X	0.26
Y	0.50
Z	0.12

MoI	kg•m²
Ixx	0.00460
Iyy	0.00460
Izz	0.00145



ST3LLARsat1: Internal configuration

ST3LLARsat1 Obj1: Education – Formal program

https://www.uc3m.es/master/space-engineering

UC3M's Student CubeSat programme

is structured around its 1.5-years / 90 ECTS

Master in Space Engineering (MISE)

1 of only 5 (out of 192) masters in CAM accredited with 2 A's
1 of only 2 with an A in "Learning Results"

1st year

* **Core classes in space engineering**
* **[C] Space Pre-Design (SPD) Team Course**
  Feasibility study
  Changed ETCS/bimester on 23/24: 3/1 → 6/2

2nd year

* **Optional classes & industry internships**
* **[C] Master Thesis (TFM):** Advanced developments
* **[O] Integral Project (IP) Team Course:** Consolidation
  New from 22/23 (start of ST3LLARsat1), 12ETCS/2bimesters

Space Pre-Design (SPD) is a **mandatory** 6-ECTS MISE course offered in the 2nd part of the 1st year.

The main goal of the course is to apply all the student's knowledge and skills developed during the 1st year via a team-based space challenge.

In **teams of 4-10 members**, the students must perform a feasibility or consolidation design of a space mission, or its components, covering from project management to system engineering.

The proposed designs are evaluated by a multi-disciplinary panel of academic and industry staff, and each year a winner is chosen.

From 2021/22, it was focused on **CubeSat (New Space).**

From 2023/24, this course was extended from 3 to 6 ECTS credits and from 1 to 2 bimesters to better reflect its complexity.

Integral Project (IP) is an **optional** 12-ECTS (~300hrs' work) MISE course offered at the beginning of the 2nd year.

This course is offered to deepen engineering studies via:

- **Group projects**: to work in an integrated manner in a common project, but each student leading a specialism / topic.
- **Individual projects**: an additional path for deeper study of a selected topic, or to complement and extent the TFM work.

Started in 2022/23 articulated around the development of the 1st UC3M **CubeSat: ST3LLARsat1 "Boira".** Initially, it was running from Sept to March to align it with ESA FYS! "Design Booster" program.

From 2024/25, we are back to a period of Sept to Dec (2 bimesters).

ST3LLARsat1 Obj1: Education – A truly student-centered CubeSat

ST3LLARsat1 "BOIRA"

***Sept'22**: Official start of the 1st UC3M student CubeSat program*

Oct'22: Submitted mission feasibility study proposal to **ESA's FYS Design Booster** program

Nov'22: Pre-selected by ESA for its "Training and Selection" phase in ESA-ESTEC

Dec'22: **Selected by ESA for its FYS-DB program** (only 5 out of 12 EU university teams)

Jan-Jun'23: **Baseline Design Review (BDR)**

Jun'23-Jun'24: **Final Design Review (FDR)**

Phase 1: [Sept'22 – Jun'23] **Feasibility** & ESA-FYS-DB **BDR**

Phase 2: [Sept'23 – Jun'24] ESA-FYS-DB **FDR**

Phase 3: [Sept'24 – Jun'26] Consolidation & **AIV** activities

1st CubeSat from a University in Madrid selected by ESA

ESA Training opportunities:

- Processes & docs & RIDs
- Sites' visits
- On-site training

30+ students / ~900+ hours

STRONG STUDENT INVOLVEMENT

Over 100+ students in 3 years!!!

completed: 2 TFGs + 10 TFMs

ongoing: 2 TFGs + 2 TFMs

Continuous knowledge hand-over due to strong participation of 1st yr MISE volunteers in each phase

Phase 1: **2** professors + **25** grad-students

Phase 2: **4** professors + **35** grad-students + **3** undergrad

Phase 3-A: **5** professors + **24** grad-students

Phase 3-B: **6** professors + **19** grad-students + **2** undergrad

ST3LLARsat1 Obj1: Education – MGT & training

Overview of activities within ESA FYS-DB program

2022 | 2023 | 2024

Sept'22

1 oral presentation — Feb 21-23 SSSIF Forum

1 article — Jul 3-5 EDULEARN conference

1 oral pres. 2 posters — Dec 11-13 European CubeSat Symposium

1 oral pres. 4 posters — Feb 20-22 SSSIF Forum

1 oral pres. 1 poster — May 27-31 4S symposium

BOIRA Phase-I BDR — IPMs every 2 weeks

Concurrent Design Session — Feb 26

BOIRA Phase-II FDR — Summer (no IPMs)

BOIRA Phase-II FDR — IPMs every 2 weeks

ITU/API meeting — Dec 15

BOIRA Phase-III AIV

Training opportunities:
* Conference participation
* Public speaking
* Networking
* Team leadership abilities
* Documentation
* Engineering trade-offs

Nov 7-11 FYS-DB training week — A. Ponche, J.M. Herrera, S. Cuevas, B. Escamilla, A. Rabuñal, B. García, M. Sampietro

Dec 6-7 FYS-DB Selection workshop

Jan 17 FYS-DB Kick-off

Jan 24 ESA PAY expert meeting

Feb 16 ESA PM01

Mar 2 ESA PM02

Apr 4-24 BDR collocation videoconfs

May 8-12 ESA Training — Space-Weather — A. Rabuñal

May 16 ESA PM03

Jun 1 ESA PM04

Jun 5-9 ESA Training — AIV — C. García

Jul 19 ESA PM05

Aug 10 ESA PM06

Sep 4-8 ESA Training — Space Debris — J. Ruiz, D. Tirado

Sep 21 ESA PM07

Oct 19 ESA PM08

Nov 24 ESA PM09

Nov 28-Dec 1 ESA Training — Sat-Comms — V. Cegarra, A. Ruiz

Nov 29 PAY expert meeting

Dec 19 ESA PM10

Jan 11 ESA PM11

Jan 18 ESA SW expert meeting

Jan 23-26 ESA Training — Tech-Trnsfr — L. Lobera

Feb 5-9 ESA Training — Space Law — L. Pérez

Feb 8 ESA PM12

Feb 29 ESA PM13

Apr 8-12 FDR collocation Meeting — F. Solano, D. Jiménez, A. Hernández, E. Flores, M. Sarahi, J. Palacios, A. Infante, F. Ezzahra

Training opportunities:
* ESA processes & documentation & RIDs
* ESA sites' visits
* ESA in-site training (**30 students ~ 900+ hrs**)

Phase-II-2-III handover
* 3 students' formative contracts
* 5 TFG/TFMs

Oct 2 FYS-DB proposal

Nov 23 FYS-DB updated proposal

Mar 12 BDR submission

Jun 7 EMC webinar

Oct 4 ITU webinar

Nov 2 IARU webinar

Dec 6 SDM webinar

Jan 21 FYS14 proposal

Mar 10 FDR submission

May 22 FDR final presentation

May'24

ST3LLARsat1 Obj1/2/3: Develop a first 2U CubeSat

From beginning to FDR: Mission Analysis evolution

Always analyze the desire orbit … and many more ➔ ranges!!

MISE

2022 | 2023 | 2024

- Oct 2 — **FYS-DB proposal**
- Nov 23 — **FYS-DB updated proposal**
- Mar 12 — **BDR submission**
- Oct 10 — **New ESA SDM Requirements**
- Dec 6 — **SDM webinar**
- Jan 21 — **FYS!4 proposal**
- Mar 10 — **FDR submission**
- Apr 8-12 — **FDR collocation meeting**
- Jun 7 — **FDR final presentation**

Sept'22

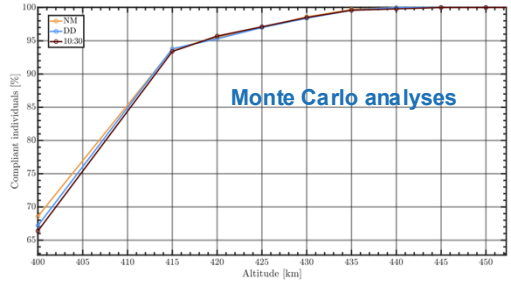
1st MA iteration

- **9 orbits** (300, 500, 600 km)
- **Preliminary analyses:**
  - Lifetime
  - Spain coverage
  - GS contact (3 GSs)
  - Spain daytime contact
  - Eclipses
- **25 years re-entry limitation**

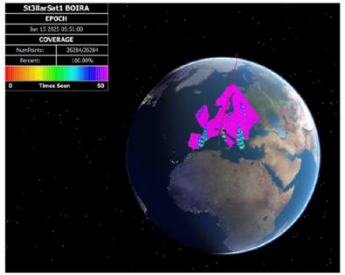
New ESA's Zero Debris Approach
5 years re-entry limitation

2nd MA iteration

- **8 orbits** (415 - 450 km)
- **5 years re-entry limitation**
- **Consolidated analyses:**
  - Lifetime (+Montecarlo)
  - Spain + Europe coverage
  - GS contact (+17 GSs)
  - Spain daytime contant
  - Eclipses
  - Radiation analysis
- **Updated ESA Zero Debris Approach**
- **+3 Space Debris Mitigation analyses:**
  - Collision risk + vulnerability to impacts
  - Safe re-entry & assessment of casualty risk

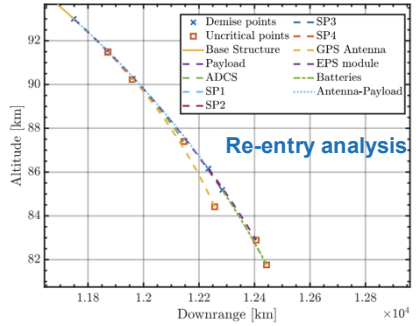


Europe coverage analysis



Parameter	Range
Altitude	350-600 km
Inclination	96-98 degrees
Orbit type	SSO
LTAN	NM, DD & 10:30

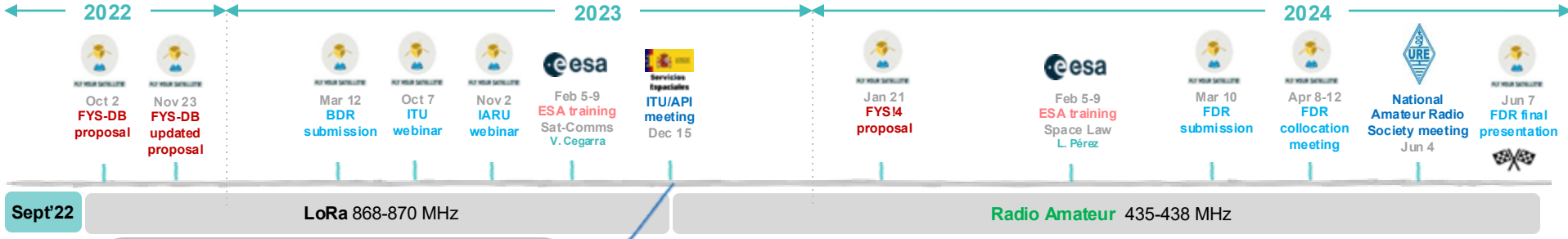
ST3LLARSat1's orbit ranges for analysis



ST3LLARsat1 Obj1/2/3: Develop a first 2U CubeSat

From beginning to FDR: Legal and TT&C evolution

Legal is important, do not forget to tackle it early



First contact with Spanish authorities

868-870 MHz band potential issues:

- 15k€ deposit for ITU-API process
- Landing rights at each country potentially needed

To avoid above issues, on-board antenna was redesigned to **amateur-satellite band**

Legal and regulatory compliance plan status

ITU

- Attended ITU webinar
- Review of applicable ITU Radio Regulations
- Request and Completion of Anticipated Publication Information (In process)
- Evaluated ITU BR software

BrSis SpaceCap GIMS

IARU

- Attended IARU webinar
- Contacted and met with Spanish National Amateur Radio Society
  - They mentioned **our mission might not be** considered as **amateur**.
  - Preliminary contact with IARU to confirm amateur-satellite compliance

TT&C status

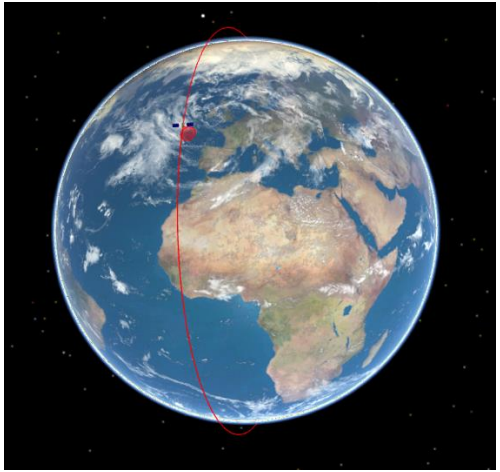
- GMSK modulation
- CCSDS Space Packet Protocol
- Coding techniques (Reed-Solomon and BCH)
- Positive link budget margins

Table 1. TT&C quick facts table

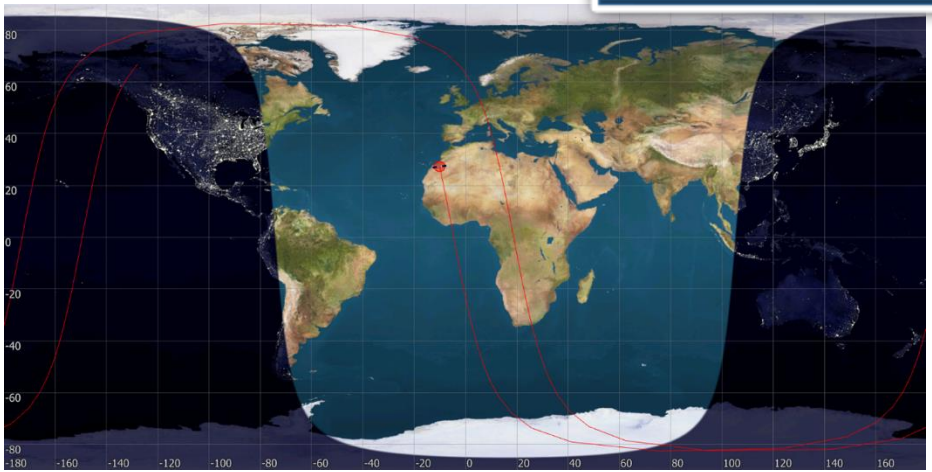
	Downlink	Uplink
Frequencies	435-438 MHz (UHF)	435-438 MHz (UHF)
Modulation	GMSK	GMSK
Coding	Reed-Solomon (255, 223) with I = 5	BCH
Frame format	ASM + CCSDS SPP + RS	CCSDS SPP (inside CLTU with BCH applied)
Bit-rate	2.4 kbps / 4.8 kbps	2.4 kbps / 4.8 kbps
RF bandwidth	25 kHz	25 kHz
BER	10-5	10-5
Signal power at LNA input	17 dBm (0.05W)	30 dBm (1W)
Link margin (nominal)	13.43 dB / 10.42 dB	6.99 dB / 3.08 dB

ST3LLARsat1 Obj2: Science – Measure Water Vapor

Make sure your science goal is feasible



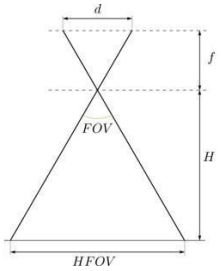
ST3LLARsat1's orbit @ FDR (SSO-450-10:30 case, J2000 frame)

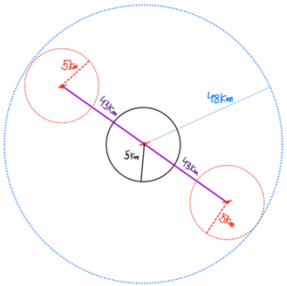


ST3LLARsat1 Ground Track @ FDR (SSO-450-10:30 case)

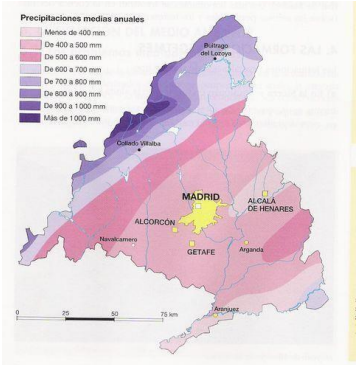
Payload: We considered an **In-House MW radiometer** and subsequently chose a **COTS spectrometer**

- $HFOV$: horizontal field of view (m)
- FOV: field of view (deg)
- GSD: ground sampling distance (m)
- H: altitude (m)
- d: sensor width (m)
- f: sensor focal length (m)
- n_p: resolution, number of pixels

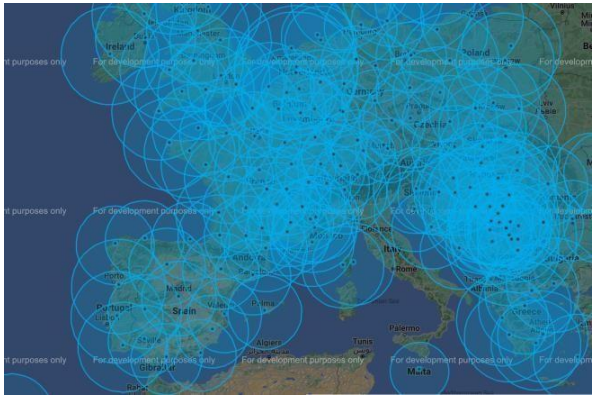




ST3LLARsat1 science footprint analysis @ BDR



Madrid annual rain zones [Lopez-Bueno'21]



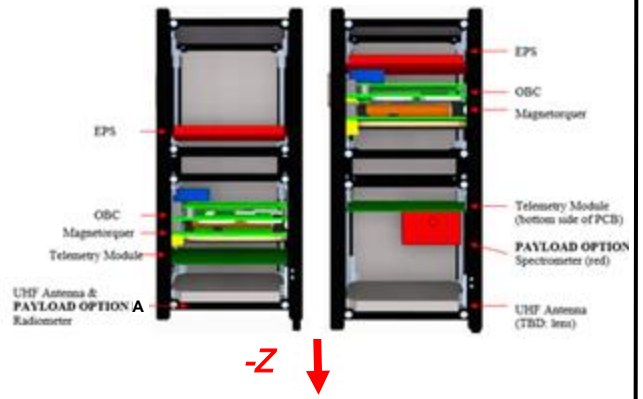
OPERA weather stations' coverage [Overeem'23]

ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

From beginning to FDR: Configuration

Do not be afraid to change.
Be flexible, but justify the changes

@ Proposal (Dec'22)



ADCS: **STM32H7** CPU
3-axis gyro: ADIS 16460
Magnetorquers: 1x iMTQ board
Magnetometer: 1x HMC5883L
Photodiodes: 6x SLCD-61N8
Solar cells: 1x SpaceMind-SP1X
2x SpaceMind-SP2X

PCDU+Battery: ENDUROSAT EPS-I
GNSS receiver: Orion B16C1
RF transceiver: Semtech SX1277

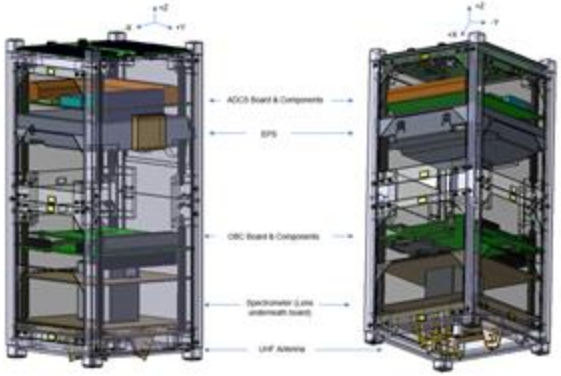
Structure 2U: **In-House**

Payload: **In-House MW radiometer**
or COTS Spectrometer (Ocean Insight ST-NIR-25)

OBDH: **STM32F4** CPU
Watchdog: 2x MAX6320PUK
MRAM: 1x M10162040108X0PWAY
OS: **freeRTOS**

CoM Opt-B	cm
X	-1.41
Y	0.04
Z	1.74
Mass (Kg)	1.948

@ BDR (March'23)



ADCS: STM32H7 CPU
3-axis gyro: ADIS 16500
Magnetorquers: 2xNCTR-M003
Magnetometer: 1x RM3100
Photodiodes: 6x SLCD-61N8
Solar cells: 2x SpaceMind-SP2X
2x SpaceMind-SP2X
1x SpaceMind-SP1Z

PCDU+Battery: ENDUROSAT EPS-I
GNSS receiver: Orion B16C1
RF transceiver: Semtech SX1276

Structure 2U: **In-House**

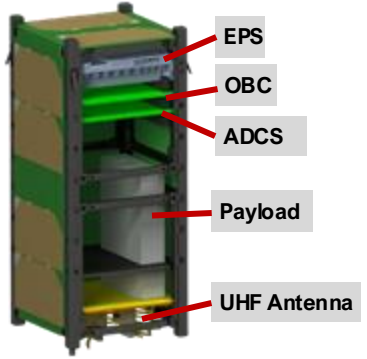
Payload: COTS Spectrometer

OBDH: STM32F4 CPU
Watchdog: 2x MAX6320PUK
MRAM: 2x M100424204
OS: RTEMS

CoM	cm
X	0.4
Y	-0.27
Z	0.42
MoI	**kg·m²**
Ixx	0.005
Iyy	0.005
Izz	0.002
Mass* (Kg)	2.439

Mass*:= includes 5-20% component & 20% total margins

@ FDR (Feb'24)
[as per ST3_DML_2024-03-10_v1.0.xlsx]



ADCS: SAMV71Q21B-AAB CPU
3-axis gyro: ADIS 16500
Magnetorquers: 2xCR0002 + 1xCoil
Magnetometer: 1x RM3100
Photodiodes: 15x SFH 2401
Solar cells: 1x SpaceMind-SP1X
3x SpaceMind-SP2X
1x SpaceMind-SP1Z

PCDU+Battery: ENDUROSAT EPS-I
GNSS Antenna: Molex 206640-0001
GNSS receiver: Orion B16C1
RF transceiver: Semtech SX1276
Structure 2U: SpaceMind SM-02
Payload: COTS Spectrometer

OBDH: SAMV71Q21B-AAB CPU
Watchdog: 2x MAX6320PUK
MRAM: 2x MR5A16ACYS35
OS: freeRTOS

CoM	cm
X	0.26
Y	0.5
Z	0.12
MoI	**kg·m²**
Ixx	0.0046
Iyy	0.0046
Izz	0.00145
Mass (Kg)**	1.366

Mass**:= only 20% total safety margin, lighter structure

ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

From beginning to FDR: Structure evolution

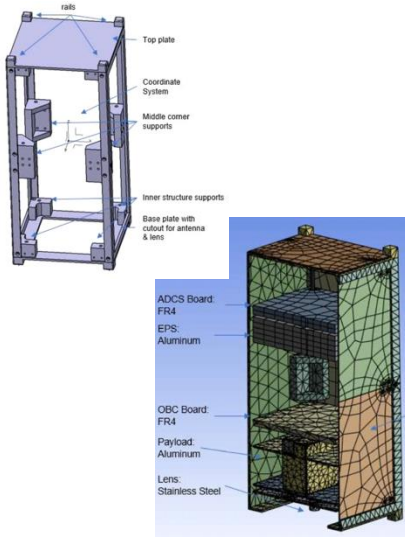
> Do not be afraid to change.
> More than the change itself, the important thing is to analyze & justify it.

2022 | 2023 | 2024

- Oct 2 — FYS-DB proposal
- Nov 23 — FYS-DB updated proposal
- Mar 12 — BDR submission
- Jan 21 — FYS!4 proposal
- Mar 10 — FDR submission
- Apr 8-12 — FDR collocation meeting
- Jun 7 — FDR final presentation

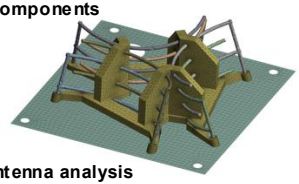
Sept'22 | **BDR preliminary analyses** | **FDR Analyses for design** | **Post RIDs**

BDR: Prelim. analysis for in-house structure

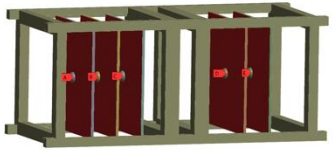


FDR: Towards the use of COTS components

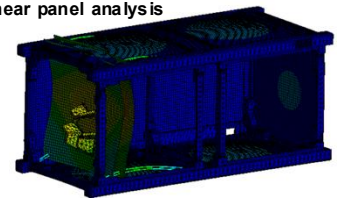
- SPACEMIND SM-02 structure
- Analysis driven design



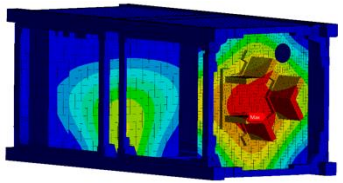
Antenna analysis



Shear panel analysis



Close-off analysis

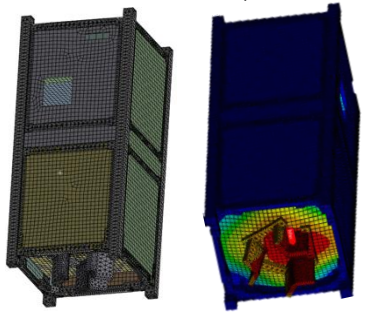


Cubesat Analysis

Final model

Finalising the analysis

- Load profile revision
- Model checks
- Sine vibration analysis
- New material requirement



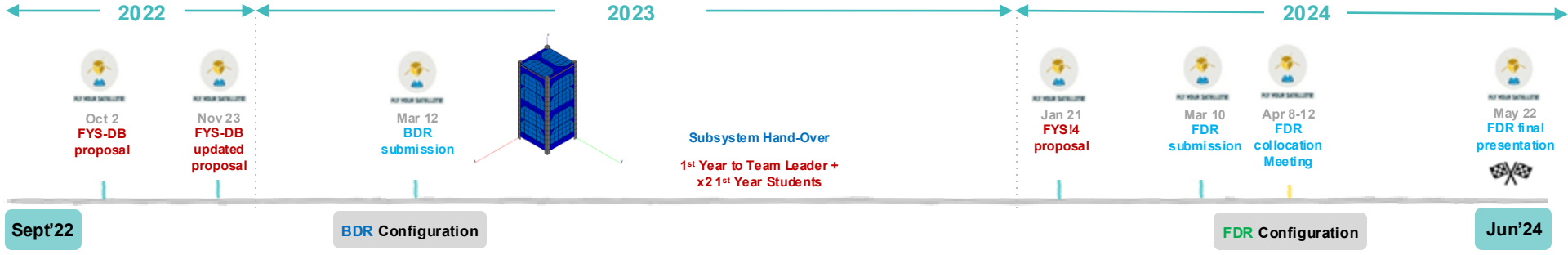
Future Work

- Torque analysis on structure
- Integrate payload into model
- Towards a less discretised model

ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

Recognize when something is wrong and then look to improve it.

From beginning to FDR: EPS evolution



1st Iteration

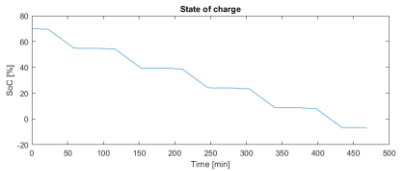
- **Components Trade-Off and Selection**
- **Preliminary Design:**
  - Solar Panels Sizing Analysis
  - Battery Sizing Analysis
  - Power Budget Analysis
  - Energy Budget Analaysis
- **Proposed Configuration:**
  - x3 Faces covered in panels
  - Endurosat EPS I
  - Spacemind Solar Panels

MATLAB

ESATAN-TMS thermal modelling suite

Insufficient Power Generated!!!

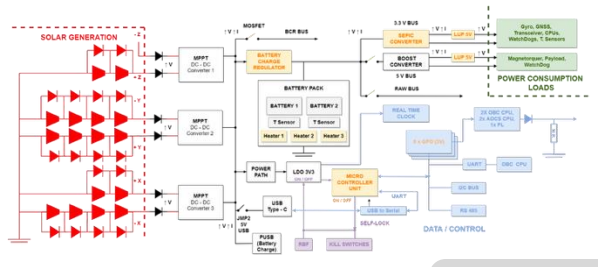
Value of Innefficiencies obtained after further contact with Suppliers



WCS: Detumbling Case for BDR Configuration

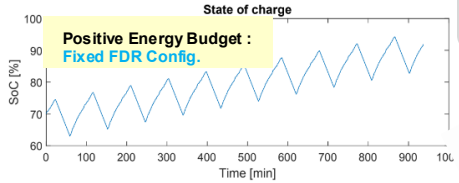
2nd Iteration

- **Trade-Off Re-Iteration + Supplier Contact**
- **Consolidated analyses and Design:**
  - Final Input Orbits from MA
  - Updated Orbital Detumbling Analysis
  - Duty Cycles stablished for the different modes
  - Inhibits Update between SP and EPS Module
  - Analysis Iteration with all above information
- **RIDs Solving**
- **New Proposed Configuration:**
  - x5 Faces Covered in Panels

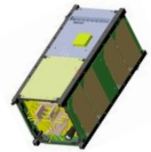


Final EPS Architecture

FDR Configuration:
x4 Lateral Panels (x3 2U + x1 1U)
+ Top Panel



WCS: Detumbling Case for FDR Configuration



ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

In the first design phase, always from top (system-level) to bottom (unit-level)

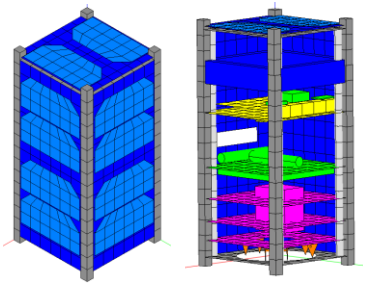
From beginning to FDR: Thermal control subsystem evolution

2022 | 2023 | 2024

- 2nd Oct 22 – FYS-DB proposal
- 23rd Nov 22 – FYS-DB updated proposal
- 2th Mar 23 – BDR ubmission
- 21st Jan 24 – FYS!4 proposal
- 10th Mar 24 – FDR submission
- 7th Jun 24 – FDR final presentation

Sept'22

Implementation of preliminary ESATAN GMM and TMM model:
- Preliminar Heat load dissipation
- Estimated conductances
- SOLCYC algorithm
- Identification of critical components: battery and payload.



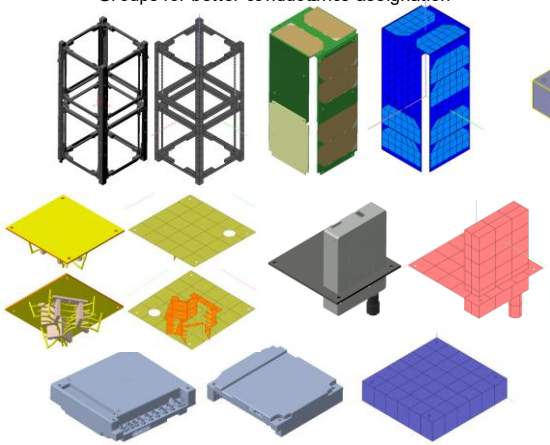
Passive thermal control:
- White paint for solar panels

Active thermal control:
- Heaters in battery module

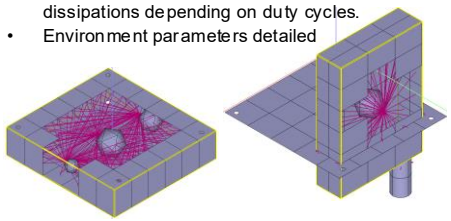
CubeSat Configuration and thermal environment:
- Missing geometry and materials now gathered
- Thermo optical and bulk properties more accurate (references to values collected)
- Orbit parameters, altitude and attiude detailed.
- Temperature limits of design drivers components identified.

Conceptual analysis and design for rapid changes:
- Development of procedures (files and processing results) and methodological steps to asses if a change in other subsystem is critical,
- Steady and transient states analysis with Matlab

Geometrical Mathematical Model:
- Geometry redefinition of solar panels
- Structure geometry detailed
- Payload configuration changed
- PCBs design changed
- Individual GMM modules created to streamline changes
- Node numbering for debugging
- Groups for better conductance assignation



Thermal Mathematical Model:
- Computation of conductances and specific heats based on mass and volume ponderations
- User defined conductors enhanced to connect all missing nodes.
- New nongeometrical nodes created for dissipations depending on duty cycles.
- Environment parameters detailed



Big effort on traceability for information flow

FileName	Inherent Conductor	Type	Connected Source	Connected Destination	Method	Dissipative Value (W/K)
ATTITUDE AND ORBIT CONTROL	AOCS_V01					
	GL_AOCS_MT1_PCB	Conductive	AOCS_MT1:face1	AOCS_PCB:face45	Value	0.01
	GL_AOCS_MT2_PCB	Conductive	AOCS_MT2:face1	AOCS_PCB:face29	Value	0.01
ELECTRICAL POWER SUBSYSTEM	EPS_Module_V01					
	BATT_EPSCASE	Conductive	BATTERY	EPS_Case_Base:surface2	Value	0.05
	BUS_EPSCASE	Conductive	BUS	EPS_Case_Base:surface2	Value	0.05
	EPSINTCOMP_EPSCASE	Conductive	INT_COMP	EPS_Case_Base:surface2	Value	0.05
	EPS_SolarPanels_V01					
ON BOARD DATA	NONE					
	OBDH_V01					
	NONE					
PAYLOAD	PAYLOAD_V02					
	PAY_AVASPECCASE	Conductive	PAY:PAY_IN	PAY:AvaSpecMini:surface2	Value	0.05
	GL_AVASPECMINI_LEN1	Conductive	PAY:LENS_CASE:face15	PAY:AvaSpecMini:face143	Value	0.05
	GL_AVASPECMINI_LEN2	Conductive	PAY:LENS_CASE:face9	PAY:AvaSpecMini:face143	Value	0.05
	GL_AVASPECMINI_LEN3	Conductive	PAY:LENS_CASE:face11	PAY:AvaSpecMini:face141	Value	0.05
	GL_AVASPECMINI_LEN4	Conductive	PAY:LENS_CASE:face13	PAY:AvaSpecMini:face141	Value	0.05
	GL_AVASPECMINI_PAYPCB1	Conductive	PAY:AvaSpecMini:face105	PAY:PAY_BOARD:face21	Value	0.05
	GL_AVASPECMINI_PAYPCB2	Conductive	PAY:AvaSpecMini:face107	PAY:PAY_BOARD:face11	Value	0.05

Selection of possible temperature sensors: .

AIV procedures literature reviewed and subsystem representativeness in models assesed

Now working on SENSITIVITY ANALYSIS:
- Parameter inaccuracies.
- Uncertainty Margins

Current TCS:
- Battery heaters
- Thermo optical properties of external surfaces
- Strategic distribution of elements
- Z-axis rotation for temperature gradients decrease

Jun'24

ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

From beginning to FDR: OBDH evolution

Read the regulations and previous CubeSat programs' references to identify common issues and solutions

2022 | 2023 | 2024

- Oct 2 — **FYS-DB proposal**
- Nov 23 — **FYS-DB updated proposal**
- Mar 12 — **BDR submission**
- Jun 7 — **EMC webinar**
- Jan 21 — **FYS!4 proposal**
- Mar 10 — **FDR submission**
- Apr 8-12 — **FDR collocation meeting**
- Jun 7 — **FDR final presentation**

Sept'22

MCU: **STM32F4** (Cortex M4, 180 MHz, 512 KB flash)
Ext. Memory: **M10162040108X0PWAY** (2 MB)
Supervisory circuit: **MAX6320PUK30DZ+T**

MCU: **SAMV71Q21** (Cortex M7, 300 MHz, 2 MB flash)
Ext. Memory: **MR5A16ACYS** (4 MB)
Supervisory circuit: **MAX6320PUK30DZ+T**

Jun'24

Updated physical architecture

Updated functional architecture

MCU upgrade:

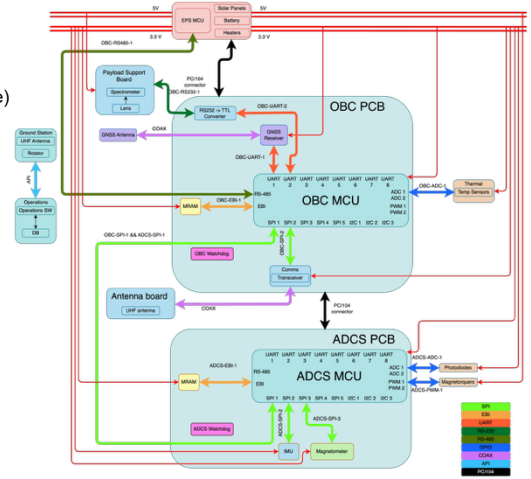
- Switch to SAMV71Q21
- Higher performance Cortex-M7 core (67 % MHz increase)
- 2MB flash memory (4x increase)
- ECC protection
- Good feedback on radiation tolerance properties

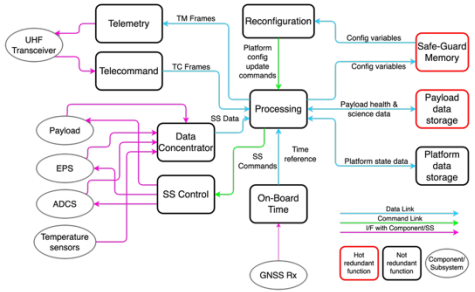
External memory upgrade:

- Switch to higher capacity MRAM (2x increase)
- Positive data on SEL tolerance for similar references

Other progress:

- Radiation effects mitigation assesment
- EMC/EMI initial assesment





Physical architecture update:

- Avoidance of I2C protocol, favoring SPI & Serial
- Centralized architecture

Functional architecture update:

- New functional architecture based on SAVOIR reference

ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

From beginning to FDR: SW evolution

CubeSats are truly multidisciplinary, make every effort to involve SW students and experts

Sept'22

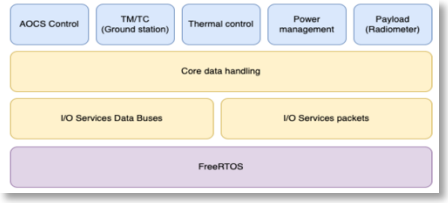
FYS proposal status
- Preliminary SW architecture
- FreeRTOS

BDR status
- Preliminary SW architecture
- RTEMS

FYS!4 proposal status
- In-house SW development
- FreeRTOS
- ECSS services

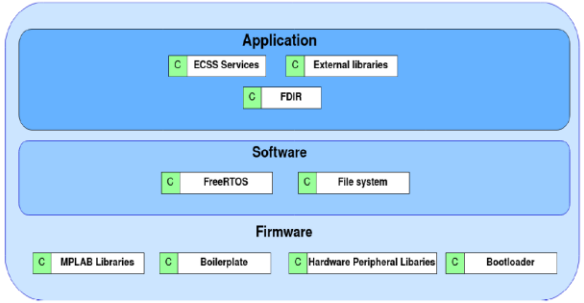
FDR status
- In-house SW development
- FreeRTOS
- Memory management
- Preliminary SW development plan

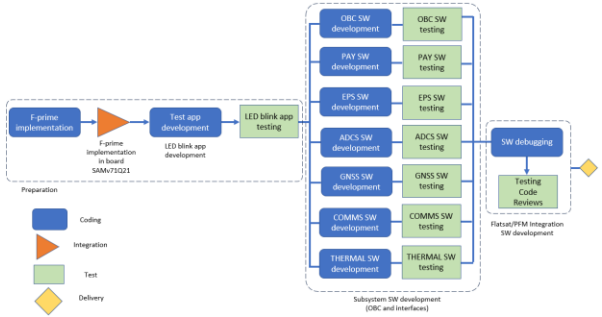
Next steps
- Fprime evaluation
- SW architecture selection
- SW development plan consolidation
- Preliminary SW verification plan



Discussion SW selection
In-house development
Vs
Flight software

Discussion SW selection
ESA expert recommended to evaluate a flight software in parallel, evaluate and decide





ST3LLARsat1 Obj3: IOD2 – A scientific instrument in 1U

From beginning to FDR: Payload evolution

Sometimes, things fail and all-hands onboard are required

2022 | 2023 | 2024

- Sept'22
- 2nd Oct'22 **FYS-DB proposal**
- 23rd Nov'22 **FYS-DB updated proposal**
- 12th Mar'23 **BDR submission**
- 19th Jul'23 **ESA PM05**
- 8th Jan 24 **IPM08**
- 21st Jan 24 **FYS!4 proposal**
- Mar 10 **FDR submission**

UC3M in-house 183GHz MW Silicon-Germanium radiometer

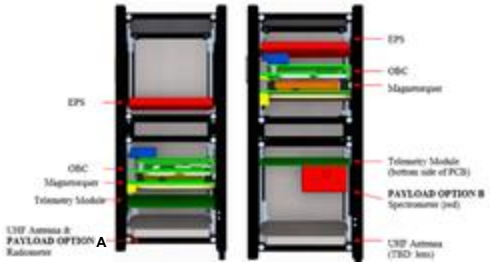
Opt-A. UC3M in-house 183GHz MW Silicon-Germanium radiometer

Opt-B. COTS ST-NIR25 spectrometer

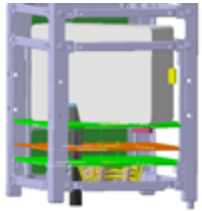
PAY-1A. COTS ST-NIR25 → ST-NIR200 spectrometer

PAY-1C. COTS NEXOS™ spectrometer

PAY-1A. COTS ST-NIR200 spectrometer
PAY-1B. COTS Mini2048CL spectrometer

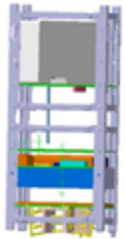


Recommendation by supplier to use a more space-ready version of spectrometer



Fiber optic cable for ST-NIR200
connectors are 6.5 cm long each and cable is 12 cm.

Sketch of possible cable implementation



Test with a new possible configuration

@ FDR (Feb'24)

ST3LLARsat1 Obj3: IOD3 – In-House compact antenna

Iterate, iterate, and iterate

From beginning to FDR: Antenna evolution

2022 | 2023 | 2024

Sept'22 — FYS-DB updated proposal

23rd Nov'22 — FYS-DB updated proposal

12th Mar'23 — BDR submission

19th Oct'23 — Meeting with GREMA

24th Nov'23 — PM09

Dec 11-13 — European CubeSat Symposium

Dec 15 — LoRa meeting

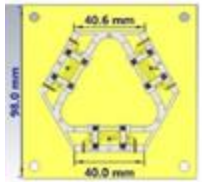
8th Jan 24 — IPM08

21st Jan 24 — FYS!4 proposal

Mar 10 — FDR submission

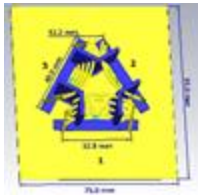
LoRa 860/870 MHz antenna

Standard UHF 435-438 MHz antenna



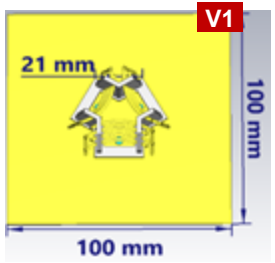
1ST DESIGN & PROTOTYPE:

* Favoured size reduction and lower manufacturing cost
* Polylactic Acid (PLA) support at center of –Z face
* Prototype manufactured / tested



[V1] 2ND DESIGN – 1ST ITERATION:

* Fiberglass support instead of PLA => Space-ready + Large size reduction
* Possible new placements

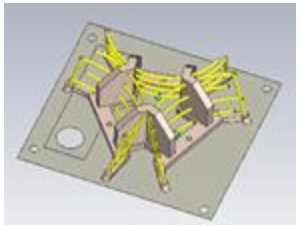


[V2] 2ND ITERATION:

* Improved coupling and element separation
* Increased directivity (3dB)
* Face centre free for lens

3RD DESIGN:

* Proven robust & flexible antenna design process (i.e. quickly produced a UHF 435-438 MHz design)
* Larger than 1st & 2nd designs, but still fits in –Z face
* Position accounts for new spectrometer (Mini2048CL)



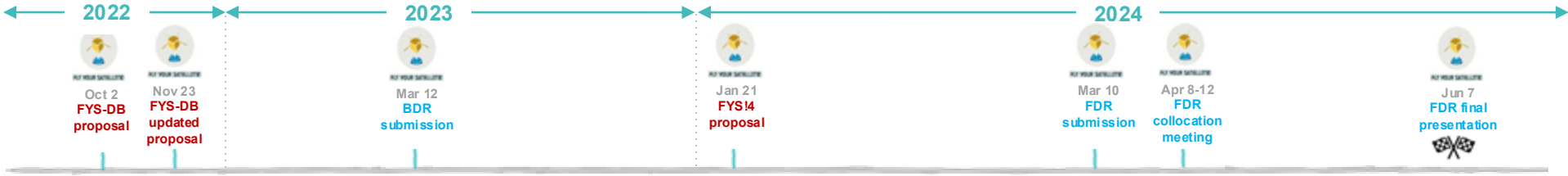
3RD DESIGN – 2ND ITERATION:

* Copper plates' stress levels in shock analysis **exceeded** yield ➔ change them to aluminium

ST3LLARsat1 Obj3: IOD4 – In-House ADCS / OBC

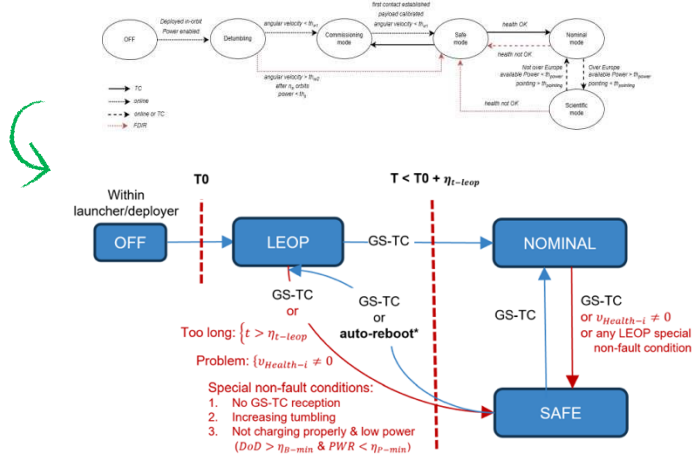
CubeSat simulators and basic Hardware-In-the-Loop are a must

From beginning to FDR: Modes and ADCS evolution



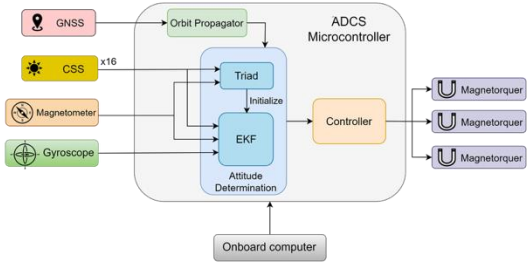
Operational modes evolution

- Simplified operational modes flow:
  3 main operational modes
- Detailed mode transition triggers
- Detailed health tests for mode transition
- Consolidated activation sequence



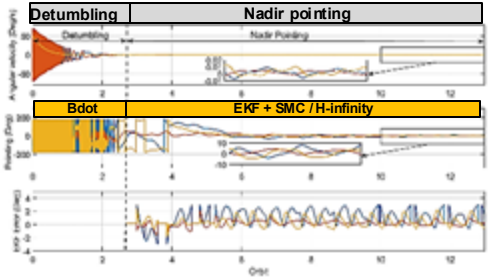
ADCS status

- Sensors (magnetometer, GYR GNSS, CSS)
- Actuators (2 magnetorquer rods and 1 coil)
- Navigation (Triad + EKF)
- ADCS modes:
  - Detumbling (b-dot algorithm)
  - Nadir pointing (sliding mode)



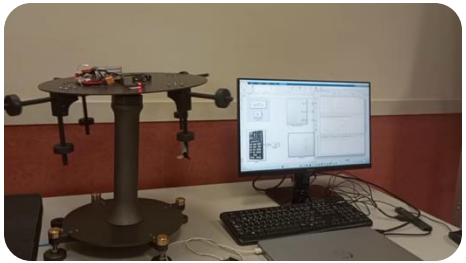
MIL Monte Carlo results

- Succesful detumbling < 6 orbits
- Pointing APE < 10 deg



HIL setup

- 3 DoF balancing system



ST3LLARsat1 – CSAT & Ground Station Status

Set at least the GS at your university (and If economically possible, an R&D / AIVT lab)

UC3M-CSAT

"*Centro de investigación e integración de tecnología espacial y nano/micro SATélites*"

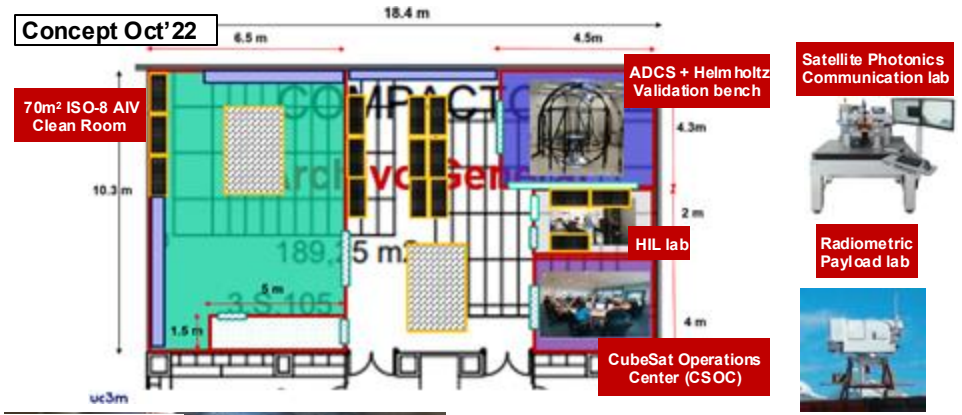
Spanish-Ciencia - Infraestructuras y Equipamiento award to Dr. A. Marcos (1.5 M€, Nov'21)

UC3M-GS

Collaboration between four actors at UC3M

1. UC3M-CSAT
2. St3llar
3. UC3-BASE
4. E.T.-PACK-F

Concept Oct'22



Status Jan'24

Status July'24

Status Nov'25

UC3-BASE is leading a national project to create a Spanish GS federation:

1. UC3M ST3LLARsat1 "BOIRA"
2. UVIGO's SpaceLab
3. ULaguna's TEIDESAT
4. UPM's EIR EA4RCT
5. UPV's PLUTON
6. UVA

ST3LLARsat1 – Next steps and challenges/Risks

Be flexible, but …
Plan and identify the Risks

Phase III objectives Jun'24-Jun'2025
(MISE cohort 2023/24 & 2024/25 volunteers)

- **Smooth handover** (**Done.** Half of team at ESA-FDR collocation was 1st year 23/24 volunteers & they continued to MISE-IP 24/25)
- **Initial assembly and integration** (antenna, 3D printed structure, payload, ADCS HIL-test, design of ADCS & OBC PCBs)
- **Clarify amateur status & consolidate legal**
- **Operative ground station** (ongoing, aim is Dec-2024)
- **Specific SW development** (reach out to other masters and dept.)
- **First Flat-Sat** (main components)
- **Prepare to apply for ESA testing opportunities** (from Jan'25)

Phase IV objectives Jun'25-Jun'2026
(MISE cohorts 24/25 - 25/26)

- **Smooth handover**
- **Operative CSAT** (March'25, but Helmholtz/ADCS by Nov'25)
- **Main subsystems' AIV** (Antenna, Payload, PCBs)
- **Apply to ESA testing opportunities**
- **Final Flat-Sat**
- **First EQM**
- **Apply to FYS5! Proposal**
- **Look for launch opportunities**

Phase V objectives Jun'26→
(MISE cohorts 25/26 - 26/27)

- **Smooth handover**
- **Final EQM**
- **EQM AIV**
- **Apply to ESA testing opportunities**
- **FM**
- **Look for launch opportunities**

Challenges & Risks [criticality / probability]

- **[Major, High]** Maintain students' interest over the end of the 'novelty'
- **[Major, Med]** Regulatory status
- **[Major, Low]** Access to AIV testing facilities or finding launch opportunity
- **[Medium, High]** Need for subsystem redesign (e.g. prelim integration or AIV indicating a shortcoming)
- **[Medium, Med]** Involvement of experts and other professors (especially, SW & electronics)
- **[Low, Low]** Funding

Acknowledgements & THANK YOU FOR ATTENDING

A. Marcos *gladly acknowledges the* ***Senior Distinguished Beatriz Galindo award*** *by the Spanish government & additional funding by the VPRICIT framework of the Comunidad de Madrid and UC3M.*

UC3M-SENER aerospace chair ST3LLAR*, for funding and expert support*

For expert support, training and providing access to their facilities within the ***FYS Booster Design programme***

UC3M's Aeroelastic and Structural Design Lab *for their knowledge and support on the* ***structural machining***

E.T.PACK-F H2020 project *Coord. by prof. G. Sánchez-Arriaga (Aerospace Engineering department) for joint* ***GCS development activity***

UC3-BASE

UC3M radioamateur-certified society *by prof. D. Segovia (Signal Theory dept.) and prof D. Larrabeiti (Telematics dept.) for joint* ***GS development activity***

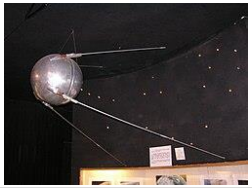
For providing free their ***thermal modeling software***

For providing free their ***Mission Analysis software***

TRIVIA TIME

TRIVIA TIME

Q1. What is the name of the first satellite sent up by humanity?



https://en.wikipedia.org/wiki/Sputnik_1

Sputnik,19: Launched by Soviet Union on the 4th October 1957

It was a metal sphere of 58 cm in diameter and 83Kg

Lasted 22 days and burnt on re-entry on 4th January 1958

Q2. Name at least one company in Spain that makes CubeSats?

Platforms: Alen Space, EMXYS, Hydra Space, SATLANTIS

Subsystems: Aistech, Alter, Anteral, Arquimea, Balamis, BHDynamics, Comet Ingeniería, Compoxi, DHV Technology, FOSSA Systems, IENAI Space, Karten Space, Kreios Space, Prosix Eng., Radian Systems, Sateliot, SLIMOp Space, VALAR, Xiroi

Q3. Name at least one Spanish University that has launched a CubeSat?

Launched: Universidad de Vigo, UPM, UPC

Ongoing: UC3M, Universidad de Cadiz, Universidad de La Laguna

TRIVIA TIME

Q4. How much is the (typical) weight of a CubeSat?

A. < 1 Kg
B. 1-10 Kg
C. 10-50 Kg
D. >100 Kg

Q5. How long can be the side of CubeSat?

A. 5 cms
B. 10 cms
C. 30 cms
D. 80 cms

TRIVIA TIME

Q6. How much is the (typical) orbit altitude for a CubeSat?

A. 10-100 Km

B. 100-300 Km

C. 300-600 Km 

D. 600-900 Km

Q7. How much is the (typical) maximum travelling speed of a CubeSat?

A. 300 km/h

B. 3,0000 km/h

C. 30,000 km/h 

D. 300,000 km/h

TRIVIA TIME

Q8. How many CubeSats have been launched into space?

A. <1,000
B. 1,000-3,000
C. 3,000-6,000 
D. >6,000

Q9. What is the success rate of a first CubeSat program/launch?

A. < 30 %
B. 30-50 % 
C. 50-70 %
D. > 70 %