ST3LLARsat1 BOIRA:

The first CubeSat program at UC3M

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Aerospace Engineering Department

Master in Space Engineering (MISE)

Universidad Carlos III de Madrid, Spain

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

ST3LLARsat1 BOIRA – Our Mission

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

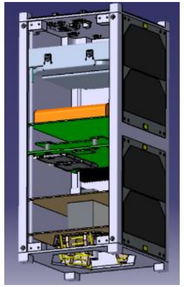
TECHNOLOGICAL

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**

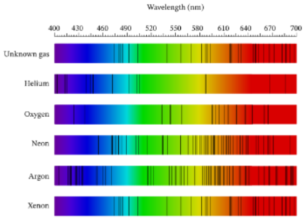
ST3LLARsat1 2U structure & internal config

@ BDR (March’23)



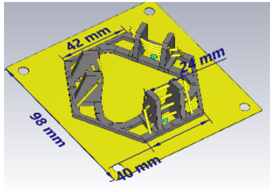
@ FDR (Feb’24)

ST3LLARsat1 science: measure water vapor (WV)

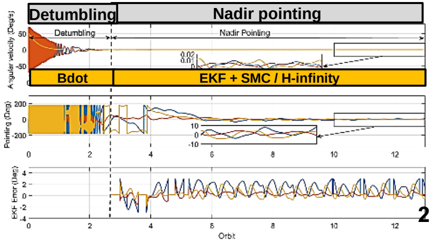


ST3LLARsat1 technology:

Compact antenna



Advanced ADCS



ST3LLARsat1 Obj1: Education – formal program

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

uc3m

MiSE

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 – BDGT

ST3LLARSat1 BOIRA

Supported and funded by:

A.Marcos' Beatriz Galindo award + Aero.Eng.Dept. + ST3LLAR, UC3M-SENER aerospace chair

Phase 1: [Sept'22 – Jun'23] Feasibility* & ESA-BDR *Mar-May'22: idea of mission in MISE/SPD course

Phase 2: [Sept'23 – Jun'24] ESA-FDR

Phase 3: [Sept'24 – Jun'25] AIV activities & application to Launch opportunity

ESA Fly-Your-Satellite (FYS) Design Booster (DB) program:

Oct'22: **Submitted mission feasibility proposal** to **ESA's FYS-DB** program

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

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

Mar'23: Baseline Design Review (**BDR**)

Mar'24: Final Design Review (**FDR**)

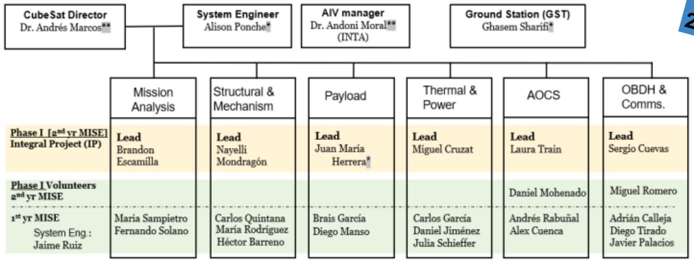
Jun'24: Final Presentation to ESA

1st CubeSat from a University in Madrid selected by ESA

ST3LLARsat1 Obj1: Education – MGT

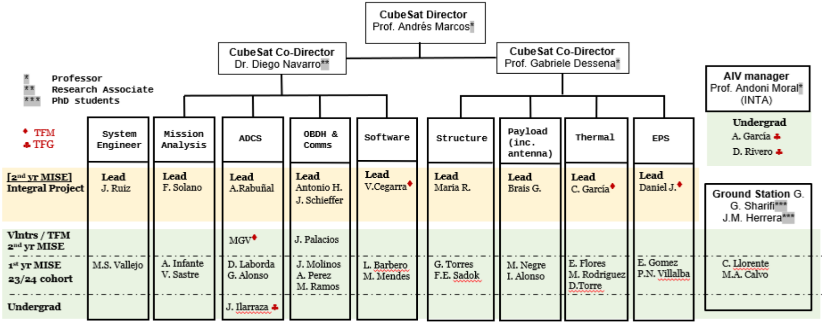
People, people, people ...
the important component

Phase-I Team: 2 professors + **25** grad-students
ESA-BDR (**3** PhDs + **7** 2nd yr-MISE + **15** 1st yr-MISE volunteers)

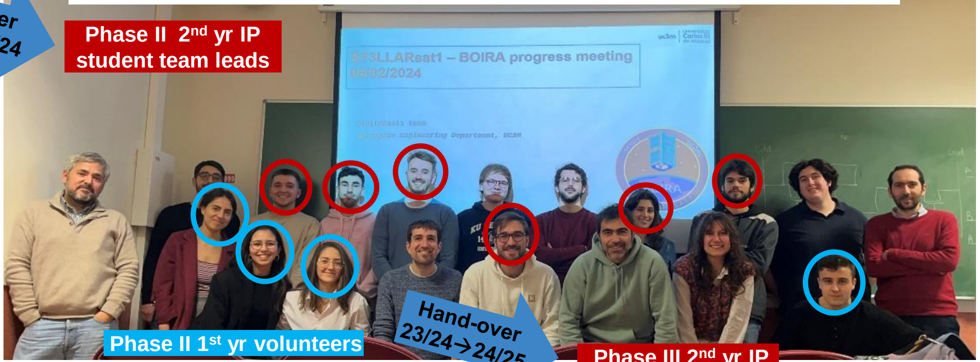


Hand-over 22/23→23/24

Phase-II Team: **3** professors + **1** research associate
ESA-FDR **35** grad-students + **3** undergrad [2 TFG / 5 TFMs]
(**2** PhDs + **12** 2nd yr-MISE + **21** 1st yr-MISE volunteers)



Phase II 2nd yr IP student team leads



Hand-over 23/24→24/25

Phase III 2nd yr IP student team leads

Phase I team leads: 2nd yr students enrolled in **MISE-IP** course
(supported by 1st & 2nd yr MISE volunteers)
Phase II team leads: 1st yr phase-I volunteers
now 2nd yr enrolled in **MISE-IP and/or TFM**
(supported by new cohort of 1st yr volunteer)

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

Phase-III Team: **4** professors + **2** research associate
Phase III-AIV **28** grad-students [6 TFMs]
(**2** PhDs + **16** 2nd yr-MISE + **10** 1st yr-MISE volunteers)

ST3LLARsat1 Obj1: Education – MGT & training

Overview of activities within ESA FYS-DB program

BOIRA

2022 — 2023 — 2024

MiSE

Sept'22

1 oral presentation
Feb 21-23
SSSIF
Forum
St3llar

1 article
Jul 3-5
EDULEARN
conference
St3llar

1 oral pres.
2 posters
esa
Dec 11-13
European
CubeSat
Symposium
St3llar

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

1 oral pres.
4 posters
Feb 20-22
SSSIF
Forum
St3llar

1 oral pres.
1 poster
esa
May 27-31
4S
symposium
St3llar

BOIRA Phase-I BDR
IPMs every 2 weeks
MiSE

Concurrent
Design
Session
Feb 26

BOIRA Phase-II FDR
Summer (no IPMs)
MiSE

BOIRA Phase-II FDR
IPMs every 2 weeks
MiSE

Servicios Espaciales
ITU/API
meeting
Dec 15

BOIRA Phase-III AIV
MiSE

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

Oct 2
FYS-DB
proposal

Nov 23
FYS-DB
updated
proposal

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

Training opportunities:
* ESA processes & documentation & RIDs
* ESA sites' visits
* ESA in-site training (23 students ~ 650+ hrs)

Mar 12
BDR
submission

Apr 4-24
BDR
collocation
videoconfs

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

May 16
ESA
PM03

Jun 1
ESA
PM04

Jun 7
EMC
webinar

esa
Jun 5-9
ESA
Training
AIV
C. García

Jul 19
ESA
PM05

Aug 10
ESA
PM06

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

Sep 21
ESA
PM07

Oct 4
ITU
webinar

Oct 19
ESA
PM08

Nov 2
IARU
webinar

Nov 24
ESA
PM09

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

Nov 29
PAY
expert
meeting

Dec 6
SDM
webinar

Dec 19
ESA
PM10

Jan 11
ESA
PM11

Jan 18
ESA
SW
expert
meeting

Jan 21
FYS!4
proposal

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

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

Feb 8
ESA
PM12

Feb 29
ESA
PM13

Mar 10
FDR
submission

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

May 22
FDR final
presentation

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

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

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

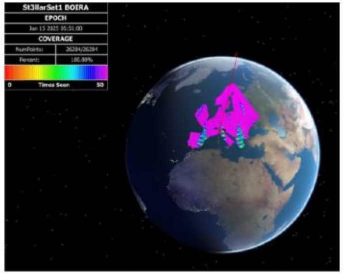
1st MA iteration

- **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

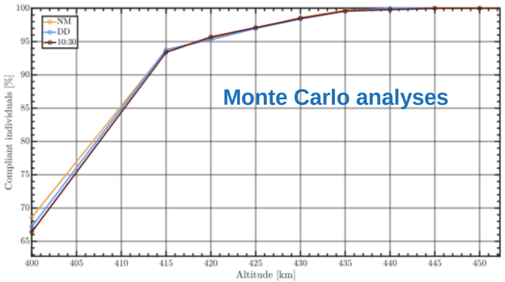
5 years re-entry limitation

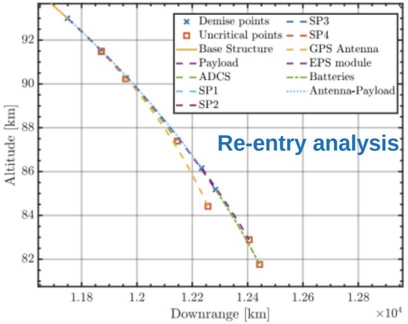
Europe coverage analysis



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





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

From beginning to FDR: Mission Analysis details

Ranges, uncertainties, different analyses & SW tools

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**

2nd MA iteration

- **8 orbits** (415 - 450 km)
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  - Radiation analysis
- **Updated ESA Zero Debris Approach**
- **+3 Space Debris Mitigation analyses:**
  - Collision risk + vulnerability to impacts
  - Safe re-entry & assessment of casualty risk

To characterize performance of ST3LLARsat1's CubeSat while in orbit, 6 critical analyses were made:

- **Lifetime analysis:** assessment of # days until S/C has re-entered Earth's atmosphere.
- **Coverage analysis:** calculation of % of Earth & Spain surface covered by each orbit.
- **Ground Station contact analysis:** computation of # windows with designated ground stations.
- **Spain contact analysis:** assessment of # passes over Madrid & Spain to characterize science windows.
- **Eclipse events analysis:** estimation of # eclipse events and their duration.
- **Radiation analysis:** preliminary estimation of radiation environment during mission.

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's Lifetime analysis: Three-cases approach

Software used for ST3LLARSat1's MA

Name	Type of Analysis	Developer
DRAMA	Lifetime and SDM	ESA
FreeFlyer	Eclipses, Contact time (GS and Spain), Coverage (Europe and Spain)	a.i. solutions
STELA	Monte Carlo analysis on the spacecraft's lifetime	CNES
OMERE	Radiation Analysis	TRAD & CNES

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

BOIRA STELLAR SAT

MiSE

2022
- Oct 2 — FYS-DB proposal
- Nov 23 — FYS-DB updated proposal

2023
- Mar 12 — BDR submission
- Oct 7 — ITU webinar
- Nov 2 — IARU webinar
- esa — Feb 5-9 — ESA training Sat-Comms — V. Cegarra
- Servicios Espaciales — ITU/API meeting — Dec 15

2024
- Jan 21 — FYS!4 proposal
- esa — Feb 5-9 — ESA training Space Law — L. Pérez
- Mar 10 — FDR submission
- Apr 8-12 — FDR collocation meeting
- URE — National Amateur Radio Society meeting — Jun 4
- Jun 7 — FDR final presentation

FLY YOUR SATELLITE!

Sept'22 | **LoRa** 868-870 MHz | **Radio Amateur** 435-438 MHz

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

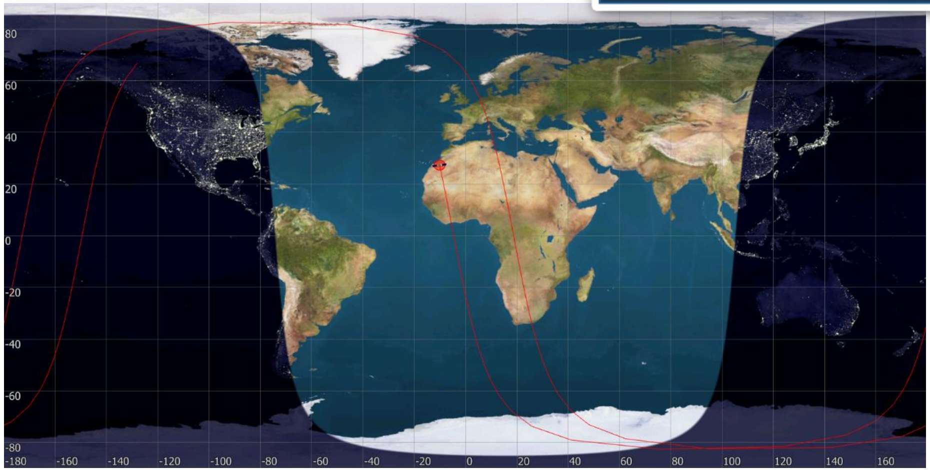
Table 1. TT&C quick facts table

	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

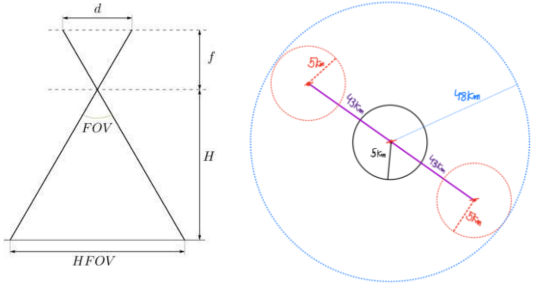
ST3LLARsat1's orbit @ FDR (SSO-450-10:30 case, J2000 frame)



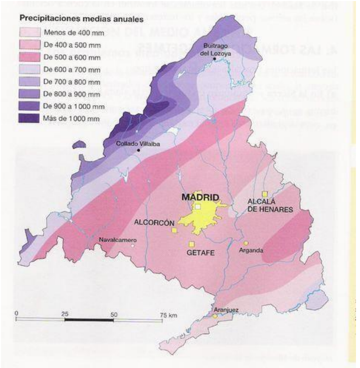
ST3LLARsat1 Ground Track @ FDR (SSO-450-10:30 case)

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

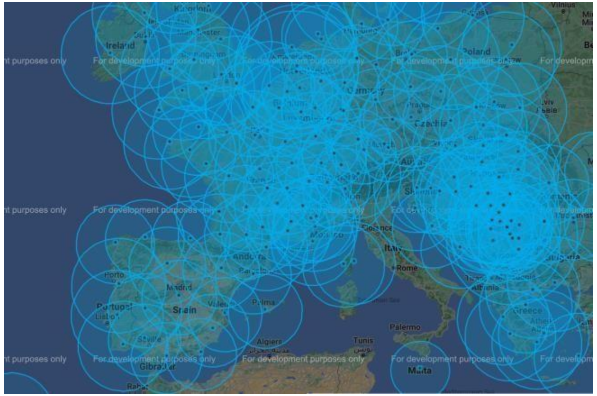
- $HFOV$: horizontal field of view (m)
- FOV: field of view (deg)
- GSD: ground sampling distance (m)
- H: altitude (m)
- d: sensor width (m)
- f: sensor focal length (m)
- n_p: resolution, number of pixels



ST3LLARsat1 science footprint analysis @ BDR



Madrid annual rain zones [Lopez-Bueno'21]



OPERA weather stations' coverage [Overeem'23]

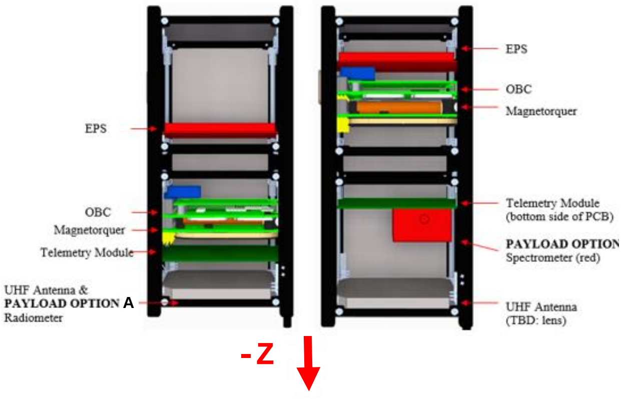
ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

From beginning to FDR: Configuration

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

MiSE

@ 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

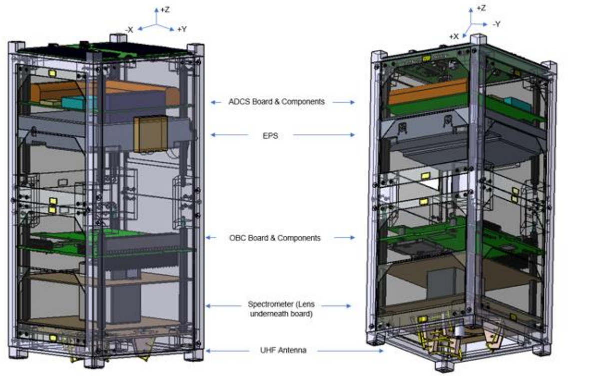
Watchdog: 2x MAX6320PUK

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

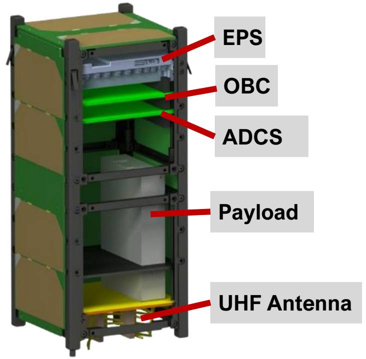
MRAM: 2x M100424204

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

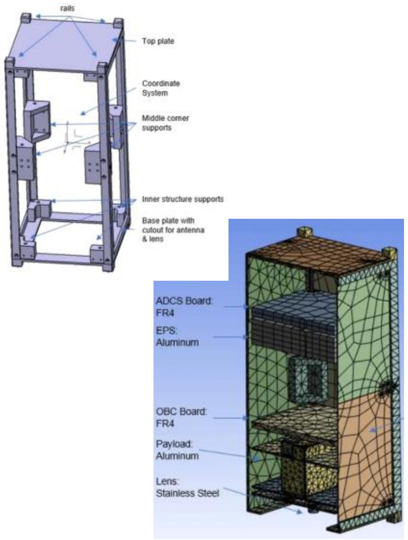
Do not be afraid to change.
More than the change itself, the important thing is to analyze & justify it.

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

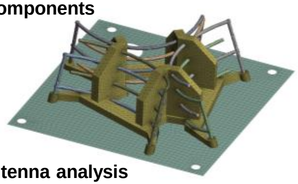
Sept'22 | BDR preliminary analyses | FDR Analyses for design | Post RIDs

BDR: Prelim. analysis for in-house structure

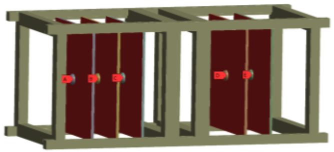


FDR: Towards the use of COTS components

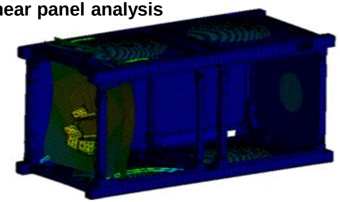
- SPACEMIND SM-02 structure
- Analysis driven design



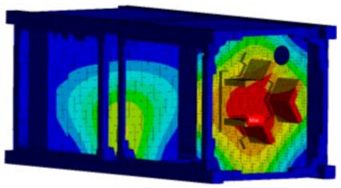
Antenna analysis



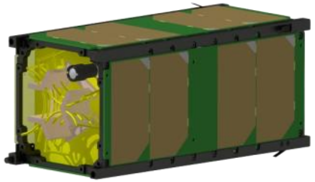
Shear panel analysis



Close-off analysis



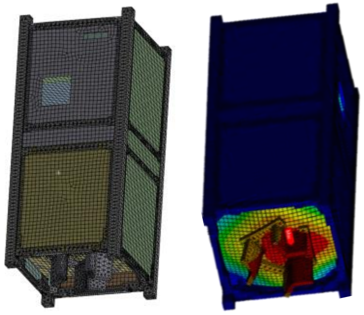
Cubesat Analysis



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

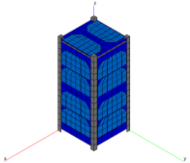
ST3LLARsat1 Obj3: IOD1 – Fit all in a 2U CubeSat

From beginning to FDR: EPS evolution

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

2022 | 2023 | 2024

- Oct 2 – FYS-DB proposal
- Nov 23 – FYS-DB updated proposal
- Mar 12 – BDR submission



- Subsystem Hand-Over
- 1st Year to Team Leader + x2 1st Year Students
- Jan 21 – FYS!4 proposal
- Mar 10 – FDR submission
- Apr 8-12 – FDR collocation Meeting
- May 22 – FDR final presentation

Sept'22 | **BDR Configuration** | **FDR Configuration** | **Jun'24**

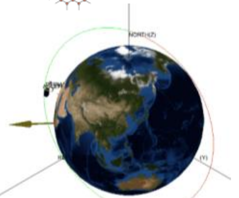
1st Iteration

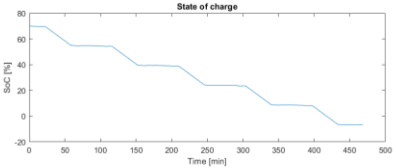
- **Components Trade-Off and Selection**
- **Preliminary Design:**
  - Solar Panels Sizing Analysis
  - Battery Sizing Analysis
  - Power Budget Analysis
  - Energy Budget Analaysis
- **Proposed Configuration:**
  - x3 Faces covered in panels
  - Endurosat EPS I
  - Spacemind Solar Panels

MATLAB | ESATAN-TMS thermal modelling suite

Insufficient Power Generated!!!

Value of Innefficiencies obtained after further contact with Suppliers

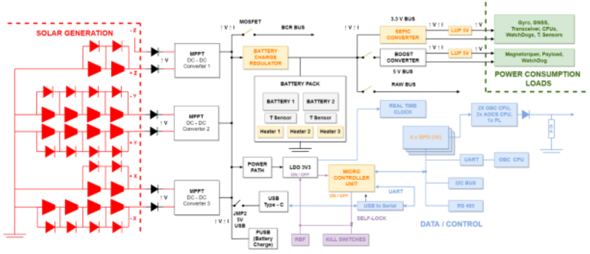




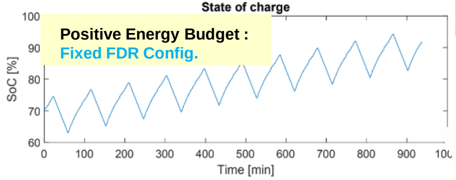
WCS: Detumbling Case for BDR Configuration

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

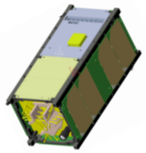


Final EPS Architecture



WCS: Detumbling Case for FDR Configuration

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



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

From beginning to FDR: Thermal control subsystem evolution

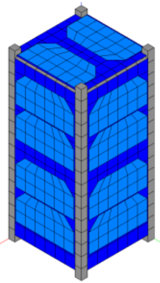
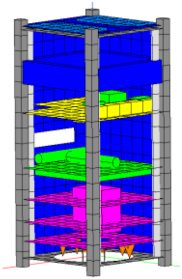
In the first design phase, always from top (system-level) to bottom (unit-level)

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 → **Jun'24**

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

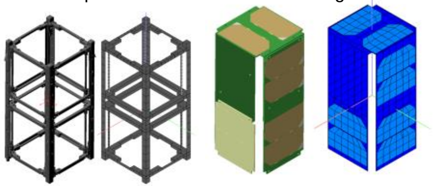
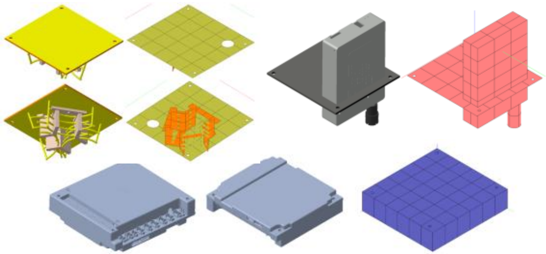
Passive thermal control:
- White paint for solar panels

Active thermal control:
- Heaters in battery module

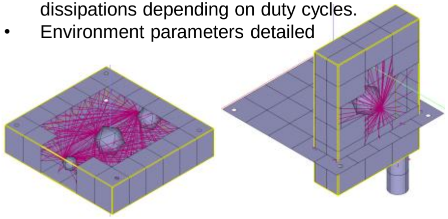
CubeSat Configuration and thermal environment:
- Missing geometry and materials now gathered
- Thermo optical and bulk properties more accurate (references to values collected)
- Orbit parameters, altitude and attiude detailed.
- Temperature limits of design drivers components identified.

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	Source	Destination	Method	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					
	NONE					
ON BOARD DATA	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

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

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

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

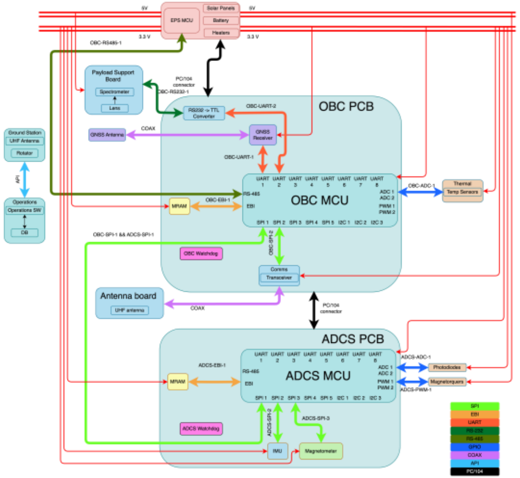
Updated physical architecture

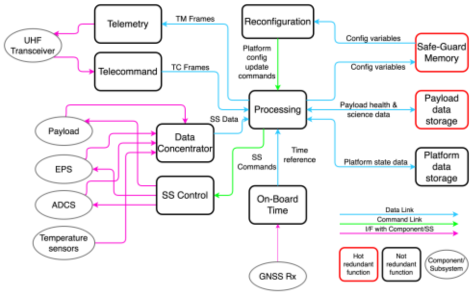
Updated functional architecture

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

2022

- Oct 2 – FYS-DB proposal
- Nov 23 – FYS-DB updated proposal

2023

- Mar 12 – BDR submission

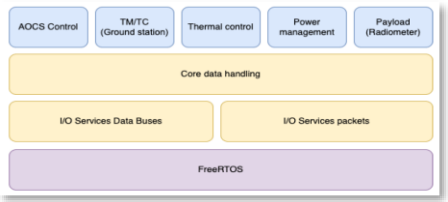
2024

- Jan 18 – ESA SW expert meeting Volkan Salma
- Jan 21 – FYS!4 proposal
- Mar 4 – ESA SW expert meeting Volkan Salma
- Mar 10 – FDR submission
- Apr 8-12 – FDR collocation meeting
- Jun 2 – F prime ported successfully to SAMV71Q21
- Jun 7 – FDR final presentation

F prime integration

Sept'22

FYS proposal status
- Preliminary SW architecture
- FreeRTOS

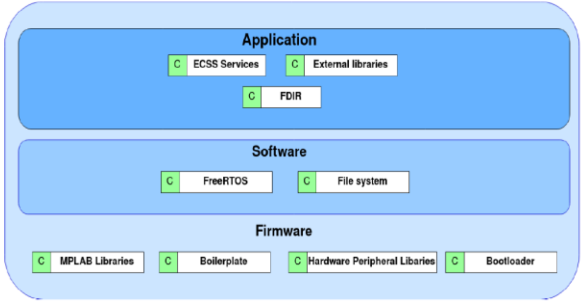


BDR status
- Preliminary SW architecture
- RTEMS

Discussion SW selection
In-house development
Vs
Flight software

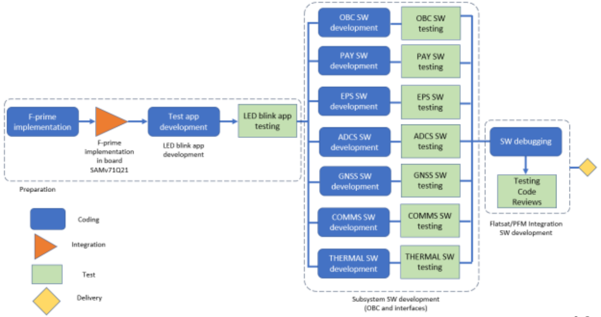
FYS!4 proposal status
- In-house SW development
- FreeRTOS
- ECSS services

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



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



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 (FLY YOUR SATELLITE!)
- 23rd Nov'22 — FYS-DB updated proposal (FLY YOUR SATELLITE!)
- 12th Mar'23 — BDR submission (FLY YOUR SATELLITE!)
- 19th Jul'23 — ESA PM05 (FLY YOUR SATELLITE!)
- 8th Jan 24 — IPM08
- 21st Jan 24 — FYS!4 proposal (FLY YOUR SATELLITE!)
- Mar 10 — FDR submission

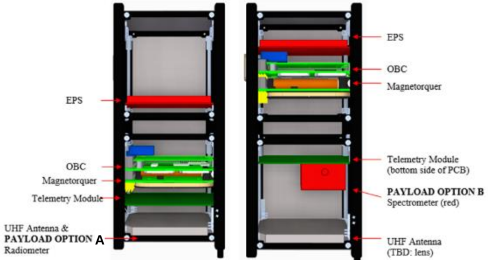
UC3M in-house 183GHz MW Silicon-Germanium radiometer

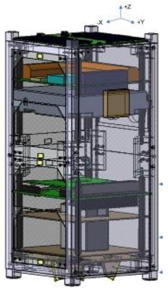
Opt-A. UC3M in-house 183GHz MW Silicon-Germanium radiometer

Opt-B. COTS ST-NIR25 spectrometer

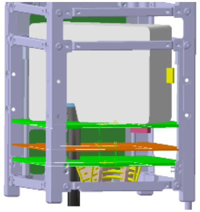
PAY-1A. COTS ST-NIR25 → ST-NIR200 spectrometer

PAY-1C. COTS NEXOS™ spectrometer

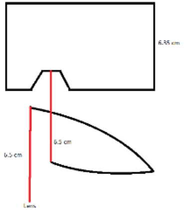




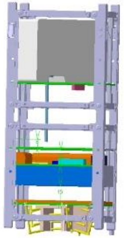
Recommendation by supplier to use a more space-ready version of spectrometer



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



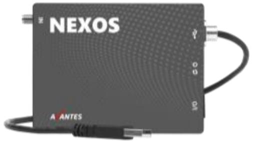
Sketch of possible cable implementation



Test with a new possible configuration

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

@ FDR (Feb'24)



ST3LLARsat1 Obj3: IOD3 – In-House compact antenna

Iterate, iterate, and iterate

MiSE

From beginning to FDR: Antenna evolution

2022

- Sept'22
- FLY YOUR SATELLITE! 23rd Nov'22 — FYS-DB updated proposal

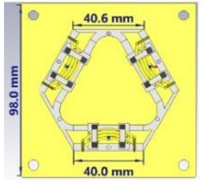
2023

- FLY YOUR SATELLITE! 12th Mar'23 — BDR submission
- 19th Oct'23 — Meeting with GREMA
- 24th Nov'23 — PM09
- esa — Dec 11-13 European CubeSat Symposium — St3llar
- Servicios Espaciales — Dec 15 LoRa meeting

2024

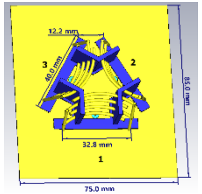
- 8th Jan 24 — IPM08
- FLY YOUR SATELLITE! 21st Jan 24 — FYS!4 proposal
- Mar 10 — FDR submission

LoRa 860/870 MHz antenna | Standard UHF 435-438 MHz antenna



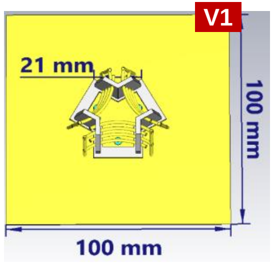
1ST DESIGN & PROTOTYPE:

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



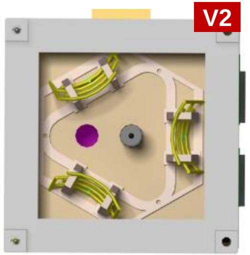
[V1] 2ND DESIGN – 1ST ITERATION:

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



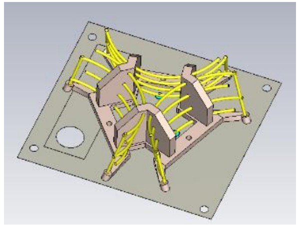
[V2] 2ND ITERATION:

* 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

From beginning to FDR: Modes and ADCS evolution

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

BOIRA

MiSE

2022
- Oct 2 — FYS-DB proposal
- Nov 23 — FYS-DB updated proposal

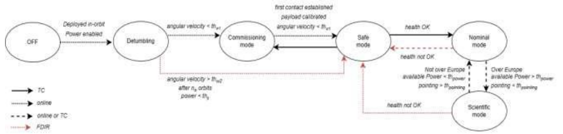
2023
- Mar 12 — BDR submission

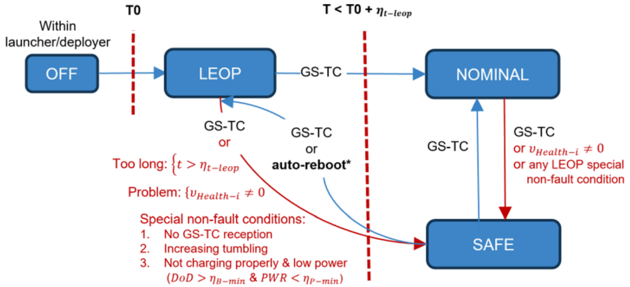
2024
- Jan 21 — FYS!4 proposal
- Mar 10 — FDR submission
- Apr 8-12 — FDR collocation meeting
- Jun 7 — FDR final presentation

(FLY YOUR SATELLITE!)

Operational modes evolution

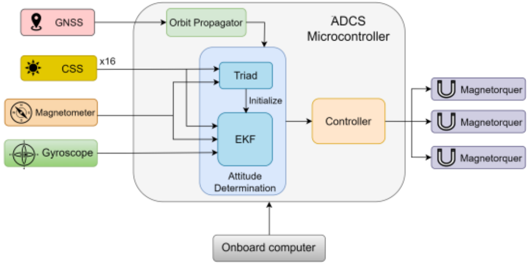
- Simplified operational modes flow:
  3 main operational modes
- Detailed mode transition triggers
- Detailed health tests for mode transition
- Consolidated activation sequence





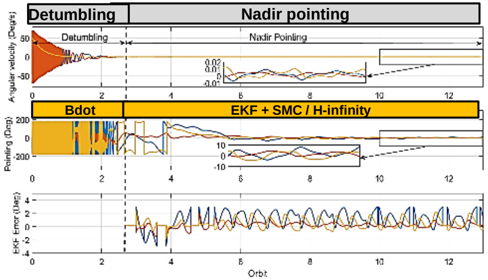
ADCS status

- 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)



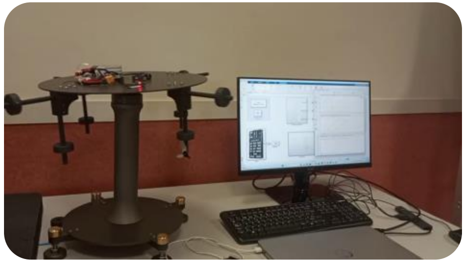
MIL Monte Carlo results

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



HIL setup

- 3 DoF balancing system



ST3LLARsat1 – CSAT & Ground Station Status

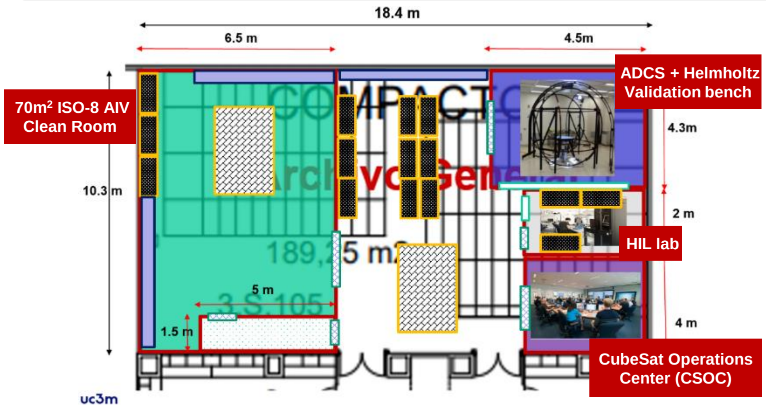
Set at least the GS at your university (and If economically possible, a n R&D / AIVT lab)

MiSE

UC3M-CSAT

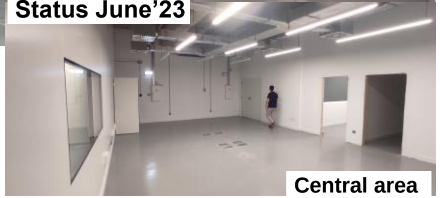
"Centro de investigación e integración de tecnología espacial y nano/micro SATélites"

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



Satellite Photonics Communication lab

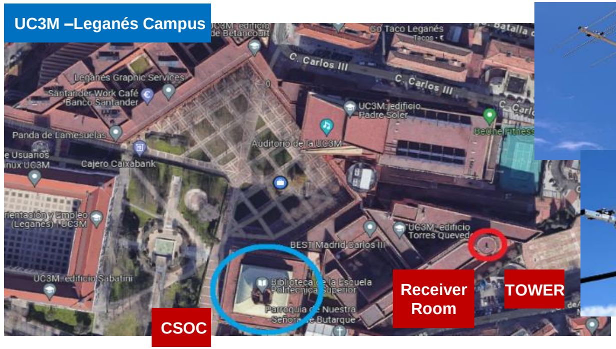
Radiometric Payload lab

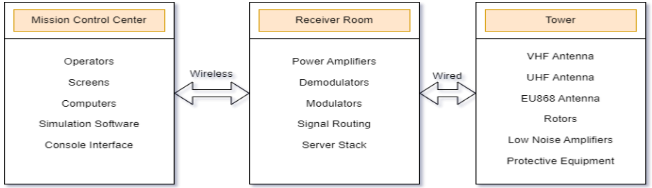


UC3M-GS

Collaboration between four actors at UC3M

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





UC3-BASE is leading a national project to create a Spanish GS federation, with current members:

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 ahead and identify the Risks

MiSE

2024 | 2025 | 2026

Jun'24 — Sept'24 ↔ Jun'25 — Sept'25 ↔ Jun'26 — Sept'26 ↔

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** (Jan'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 <u>or</u> 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

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

UC3-BASE

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

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***

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 **Mission Analysis software***