IAA-AAS-CU-20-04-03

NANOSTAR, a Collaborative Approach to Nanosatellite Education

J. B. Monteiro [1,2], A. Guerman [1,2]

1. Department of Aerospace Sciences, University of Beira Interior
2. Centre for Mechanical and Aerospace Science and Technology

5th IAA Conference on University Satellite Missions and CubeSat Workshop
(Rome, 2020)

IAA-AAS-CU-20-04-03

Acknowledgements

- NANOSTAR CONSORTIUM

- NANOSTAR TEAM MANAGEMENT @UBI

- STUDENT TEAMS @UBI

IAA-AAS-CU-20-04-03

OUTLINE

1. NANOSTAR
(who, why, what, how)
2. Student Challenges
    - Mission to the Moon
    - Roscoff Worms Payload
    - Detailed Design and Test Challenges
3. Lessons Learned & the Future of NANOSTAR

The NANOSTAR Consortium

who are we?

The consortium is composed of:

2 Aerospace Clusters

7 Universities

3 ESA Business Incubation Centres (as associates)

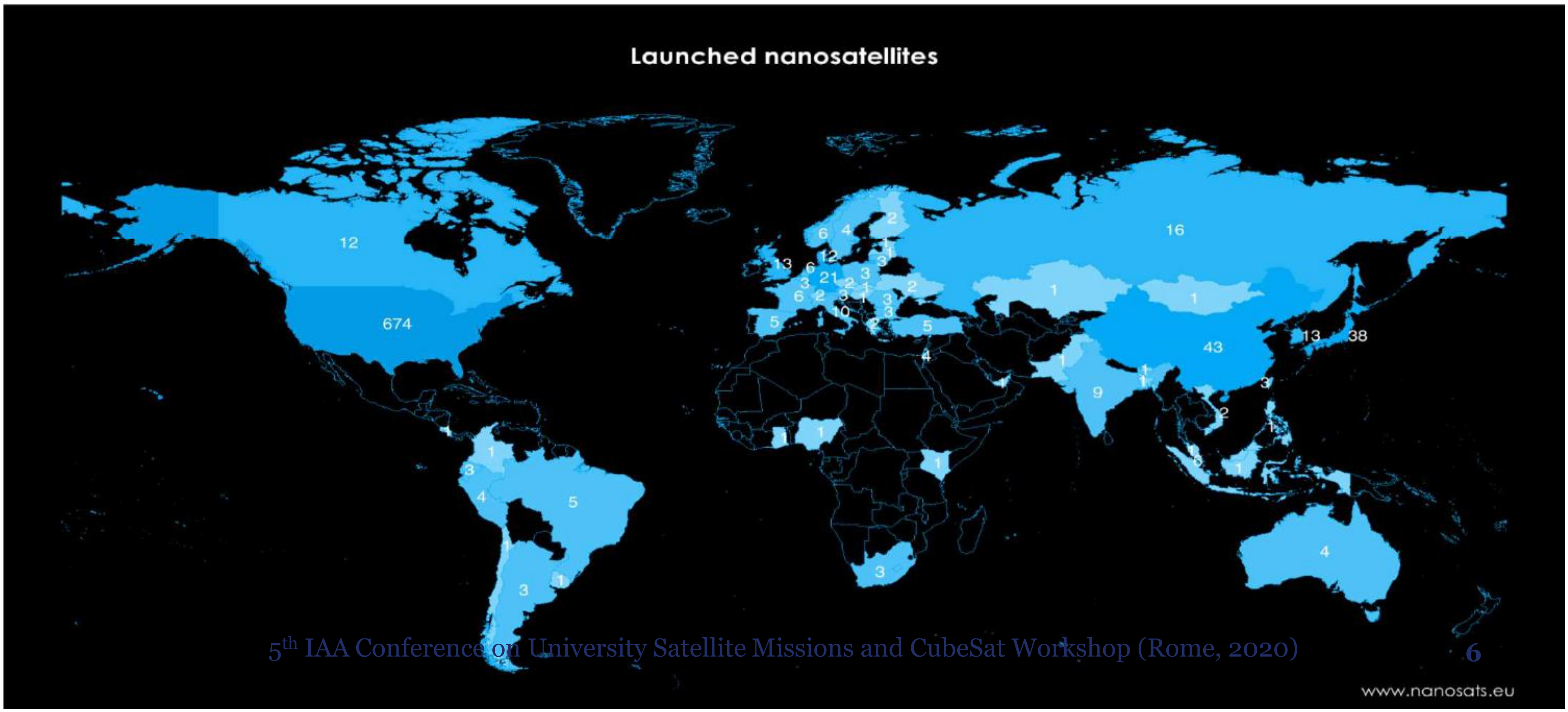
France
Spain
Portugal

NANOSTAR

why, what, and how are we doing it?

Why?

1. The **Southern Europe**, despite its strong influence in the Space sector, **has only 14% of the projects in the European nanosatellite sector**.
2. The development of a nanosatellite mission requires numerous tools and competences, which makes it an excellent training vector, **but it is necessary to have the appropriate experience and resources, hence the need to work in a network and exchange experiences**.



NANOSTAR

Hands-on higher Aerospace Education through Nanosatellite Student Challenges

ERDF budget: 2 million €

Project funded by the Interreg Sudoe Programme through the European Regional Development Fund (ERDF)

What?

- A **collaborative online platform** to provide relevant training on nanosat technology through **student challenges.**
- www.nanostarproject.eu

How?

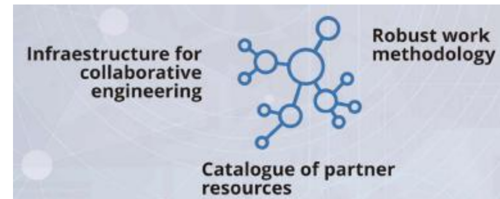
Collaborative online platform:

- Open-source tools (CDF software modules)
- Methodologies and educational content

Student Challenges:

1. Space Mission Predesign Challenges
2. Detailed Design and Test Challenges

Structure



WP1

Catalog of the resources and expertise.

WP2

Development of collaborative work tools (CDF software modules)

WP3

Development of methodology for design, development, integration and testing of nanosatellites based on ECSS standard

WP4

Development and management of competitions between inter-university teams - student challenges

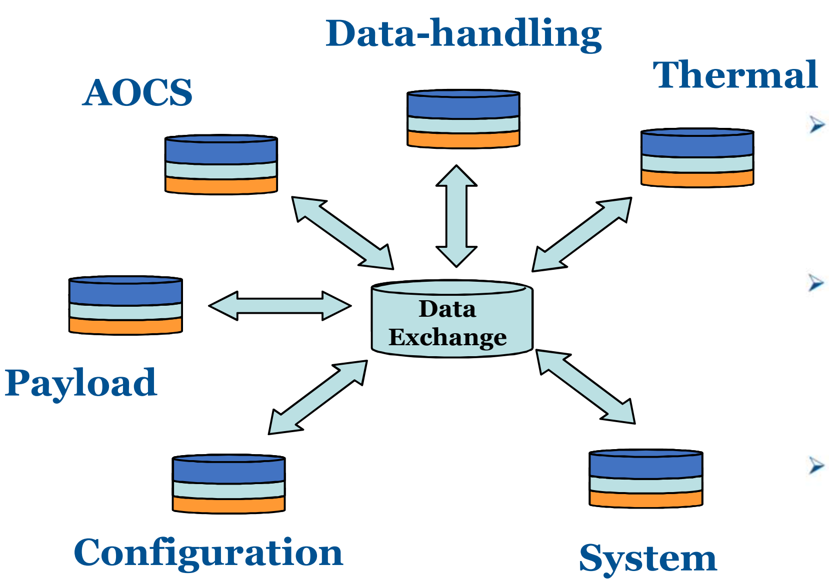
WP5

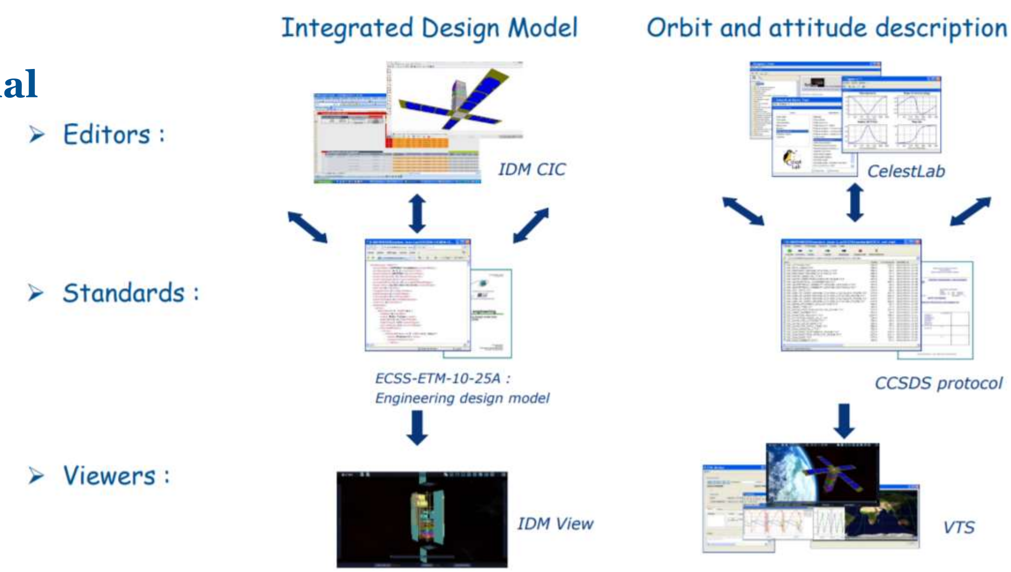
Ensure the continuity of NANOSTAR project and evaluate results.

Collaborative Tools – CDF Software

https://nanostarproject.eu/student-challenges/registration-phase-i/software/

- A Concurrent Design Facility (CDF) was built in all institutions.
- The **Integrated Design Model (IDM)** suite of tools, from CNES, was installed in all CDFs
- It includes an editor (IDM-CIC) and a viewer (IDM View) which offer students a powerful way to design and validate space mission concepts during preliminary studies.
- Collaborative creation of a technical reference allowing establishment of satellite budgets

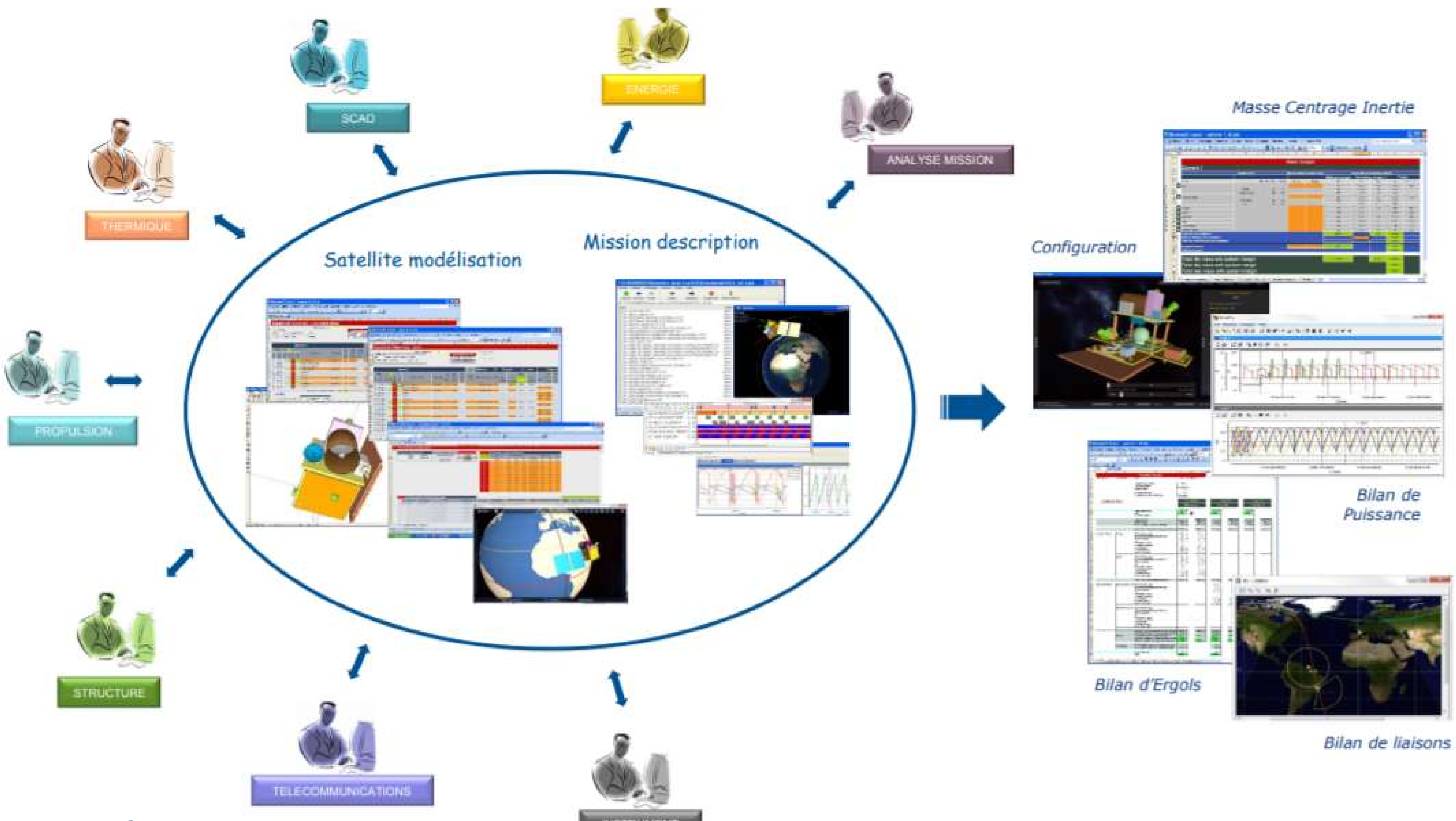




Collaborative Tools – CDF Software

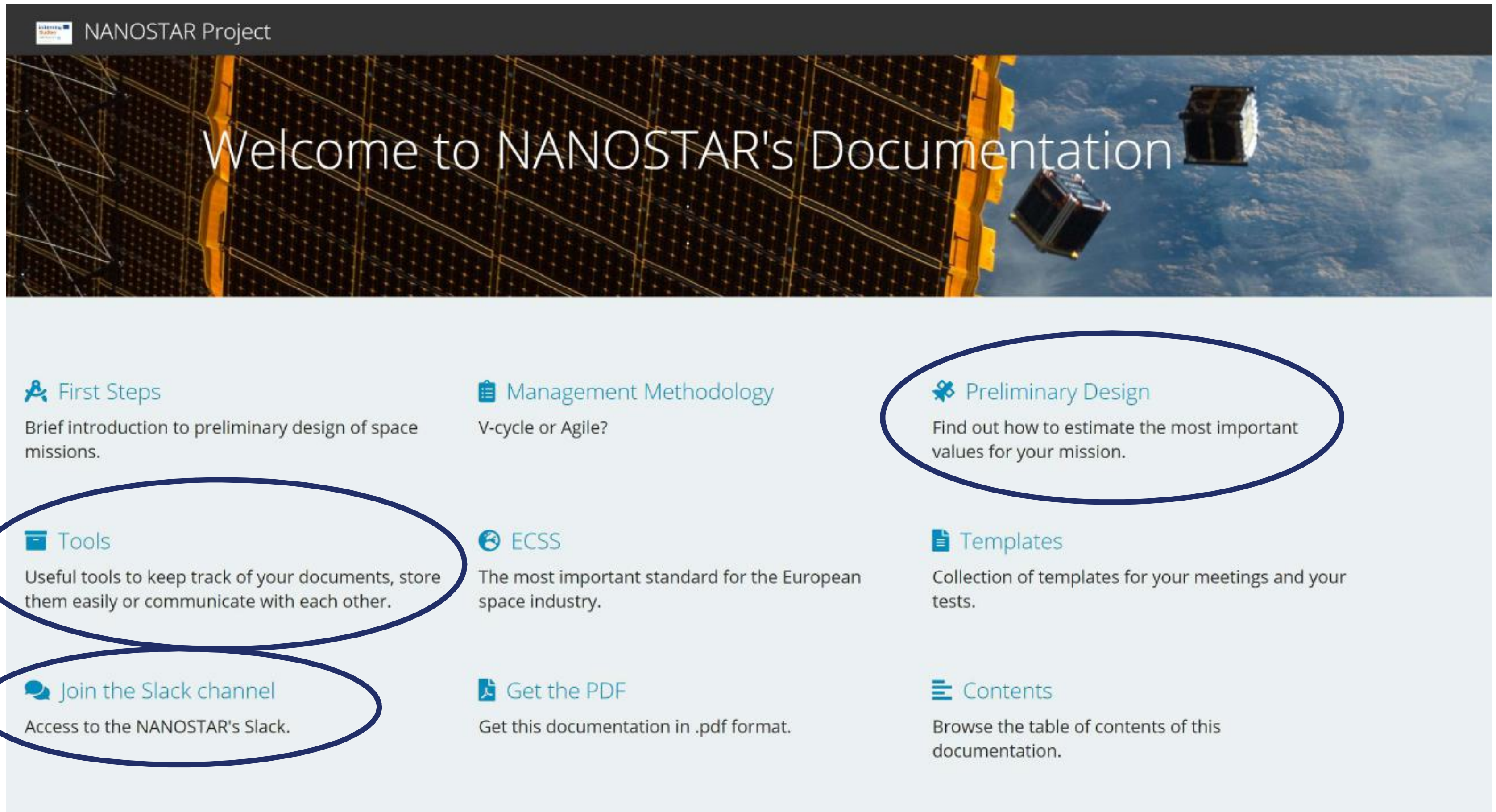
https://nanostarproject.eu/student-challenges/registration-phase-i/software/

New models and interfaces are in development and can be added progressively complying with the needs of the user



Methodologies and Education

https://nanostar-project.gitlab.io/main/



1. Space Mission Predesign Challenges

The Evaluation Committee, composed of members from all NANOSTAR institutions, evaluates based on:

- Compliancy with the top-level requirements
- Project consistency, risk analysis, and physical soundness
- Maximization of the mission figures of merit
- Solution innovativeness
- Document and presentation quality
- Team management and organization
- Team size, multidisciplinarity, gender balance, and inter-institution
- Correct usage of NANOSTAR resources, tools, and methodology

Prizes:

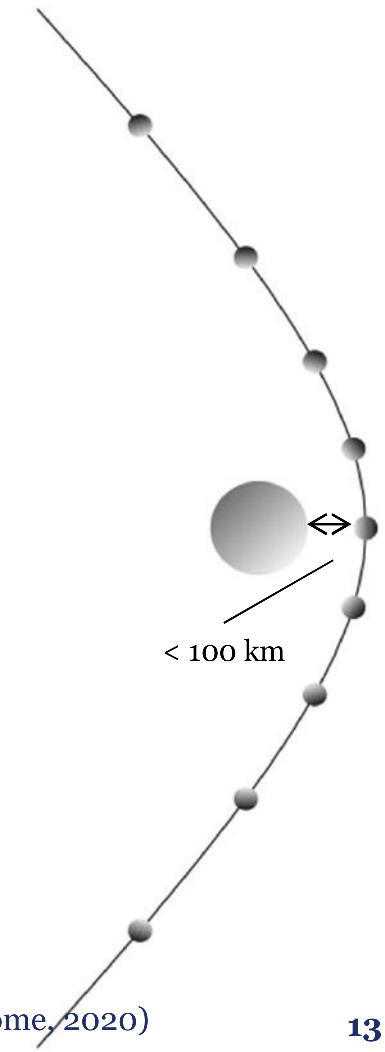
- First Prize - Winner
- Best predesign document
- Most innovative mission
- Best management practices
- Best oral presentation

Space Mission Predesign Challenge – First Edition (1.1)

1.1. SMALL SATELLITE FLY-BY MISSION TO THE MOON

The satellite, equipped with a scientific payload, will perform observations and measurements of the Lunar soil, while executing a close-distance fly-by.

https://nanostarproject.eu/student-challenges/registration-phase-i/



High-Level Requirements:

- Minimum Payload – Optical Camera

(1kg, 1U, 5W, 10Mb/flyby, 0.5 pointing accuracy, 20 deg half cone angle)

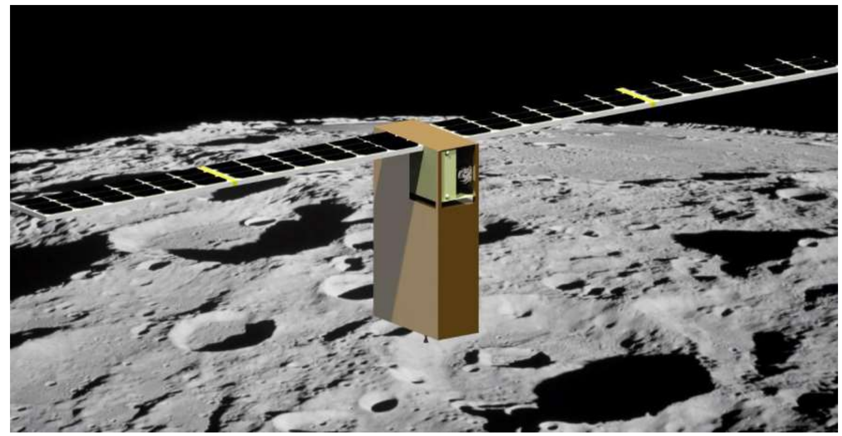
- At least one flyby with altitude of periselenium less than 100km
- 27U max
- Maximum lifetime 5 years
- Transmit data to ESA network
- The satellite is already in a GTO with free inclination

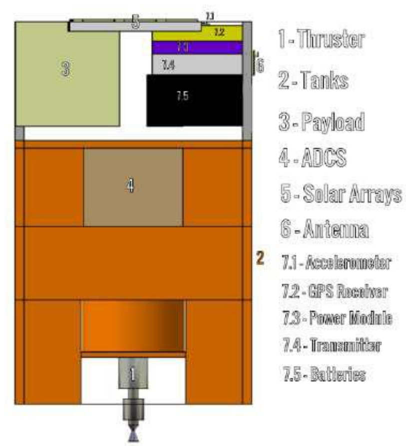
Space Mission Predesign Challenge – First Edition (1.1)

- **103 registered students** (15 teams)
- Different mission objectives, designs and innovations
- **FIRST PRIZE:** MOON INVADERS from Universidade da Beira Interior, UBI (Portugal) and Universidad Politécnica de Madrid, UPM (Spain)
- Present at Symposium on Space Educational Activities (SSEA) at the University of Leicester (United Kingdom), on September 2019.

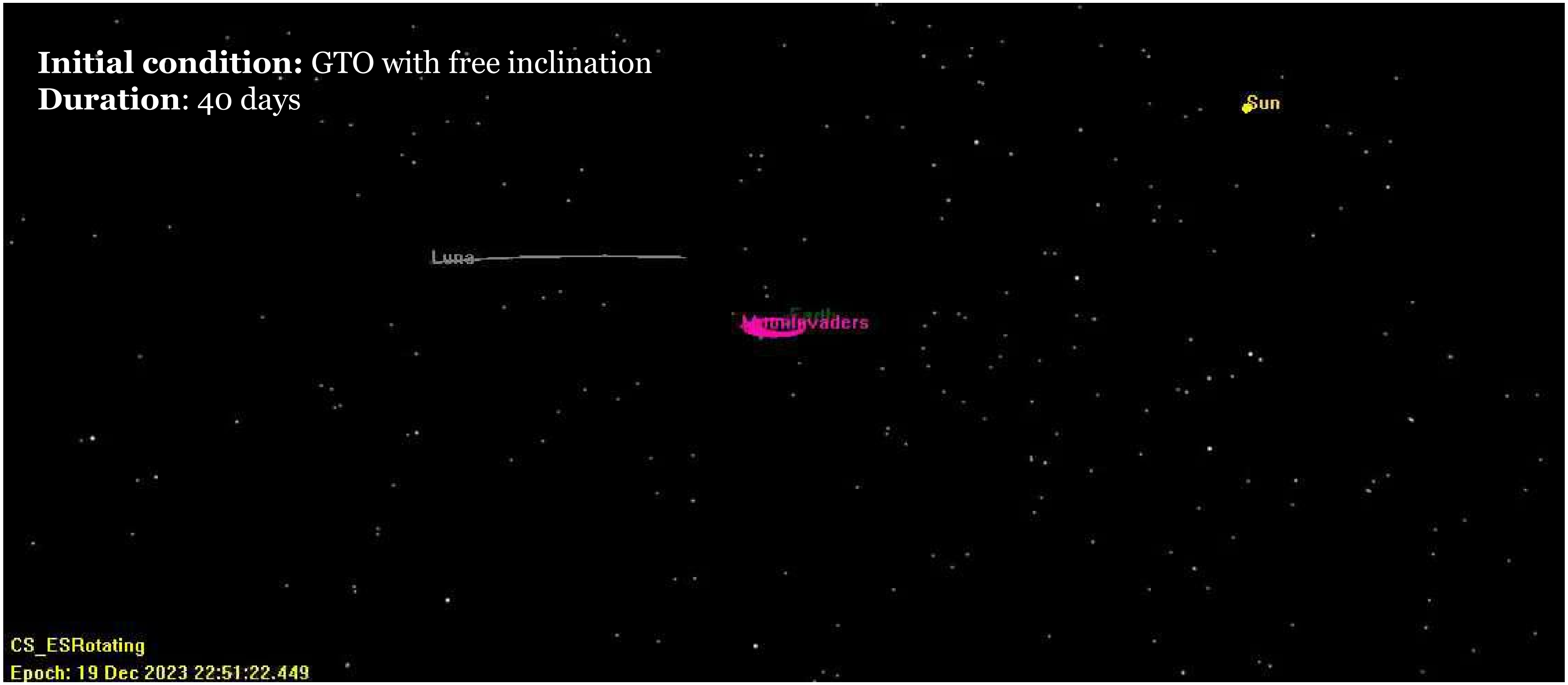
Microsatellite Flyby to the Moon's South Pole

- **GOAL**: Identify different forms of water on the Moon's south pole.
- **Payloads:**
  - Optical camera (minimum required)
  - Neutron Spectrometer System (NSS);
  - Near-Infrared Volatiles Spectrometer System (NIRVSS).
- **NSS** can measure the total volume present up to one meter below the surface.
- **NIRVSS** can check whether the hydrogen found on a specific crater on the Moon is in the form of water (H2O) or Hydroxyl (OH).
- 6U CubeSat with 14 kg
- Average power of 36W and a peak power of 51W
- 18-cell solar panel connected
- X-band communications

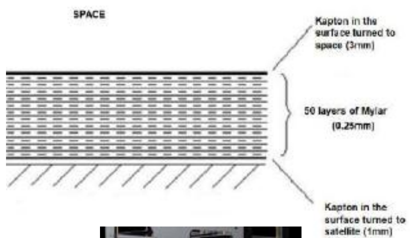


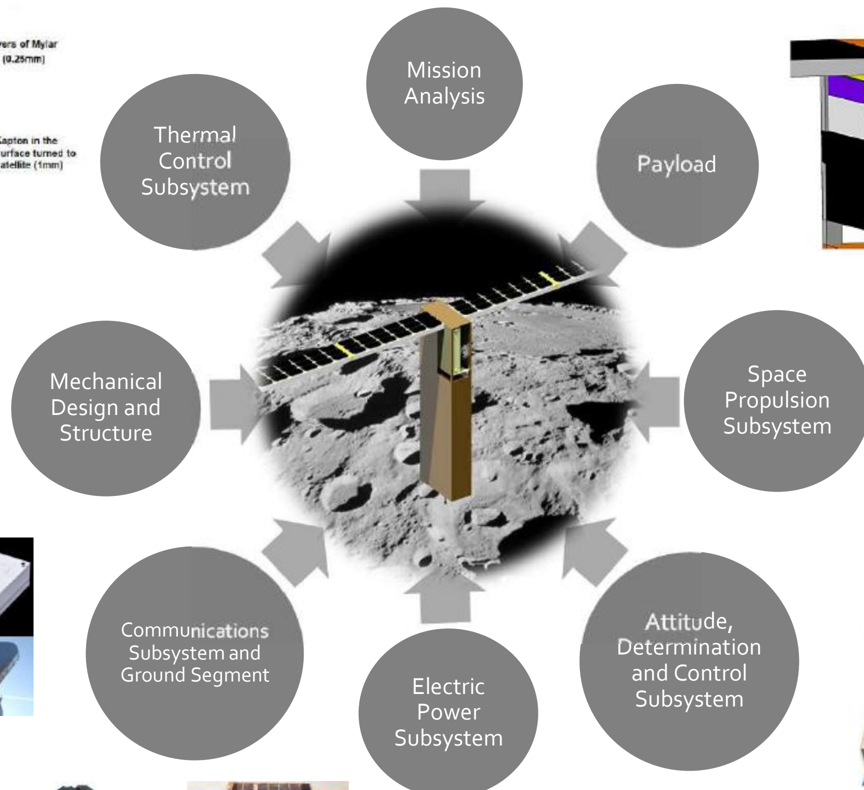


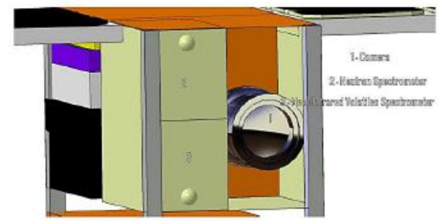
Microsatellite Flyby to the Moon’s South Pole



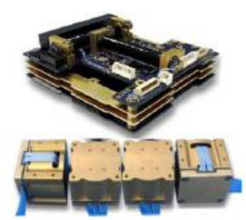
Microsatellite Flyby to the Moon’s South Pole

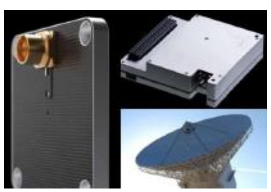


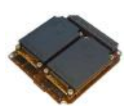




BGT-X5 is a green monopropellant thruster







Space Mission Predesign Challenge – Second Edition (1.2)

1.2 NANOSATELLITE ROSCOFF WORMS MISSION

A science mission to verify the survivability in space of a marine photosymbiotic species of worms (Roscoff worms). The scientific payload will monitor the metabolism of the worms and their efficiency for urea and air recycling via video observations and measurements.
https://nanostarproject.eu/student-challenges/registration-predesign-challenge-second-edition/

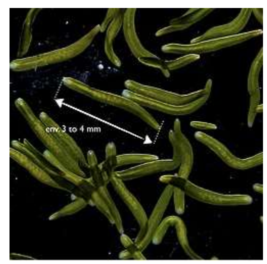
High-Level Requirements:

- Payload - Living organisms*

(7kg, 3U, L-shape, 1 pic/min, 10s HD video per hour , 0.5 pointing accuracy…)

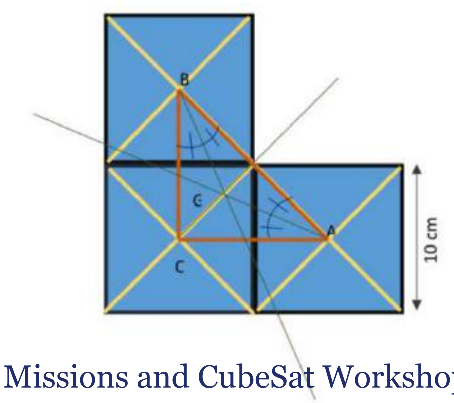
- 8U max
- Lifetime: 2 weeks - 3 months
- Kill button for the worms
- Transmit data to ESA network

*More information about Roscoff Worms on Xavier Bailly's TED talk



PAYLOAD:

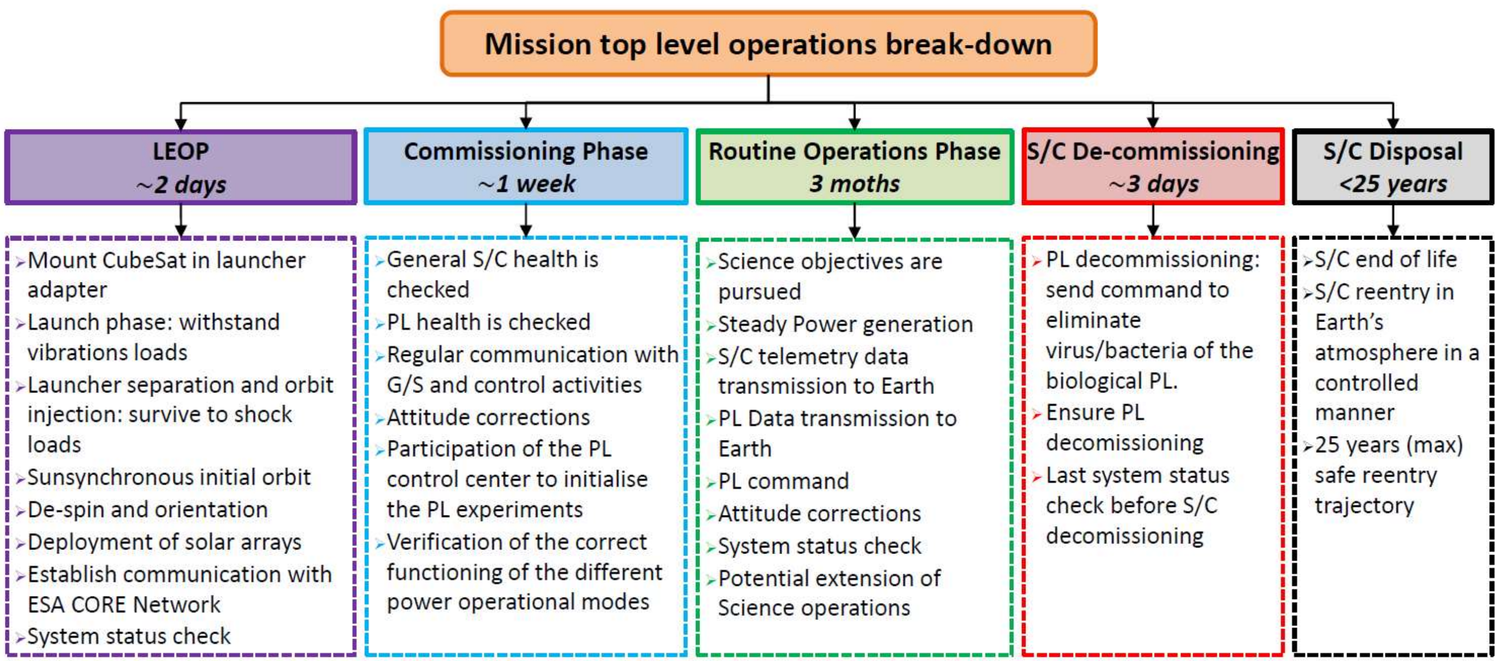
closed environment artificial ecosystem able to maintain alive and retrieve data from a self-sustaining functional colony of Roscoff worms.



- LED light
- High-resolution camera
- Pumping system
- Probes
- Heating control system

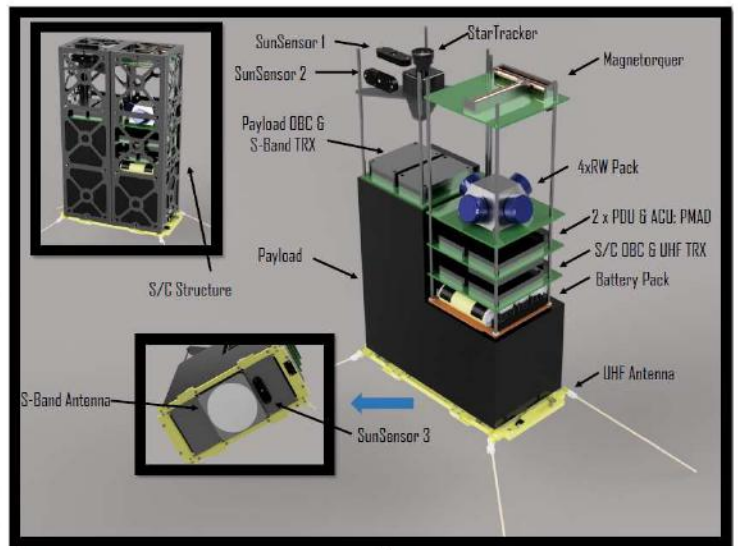
Space Mission Predesign Challenge – Second Edition (1.2)

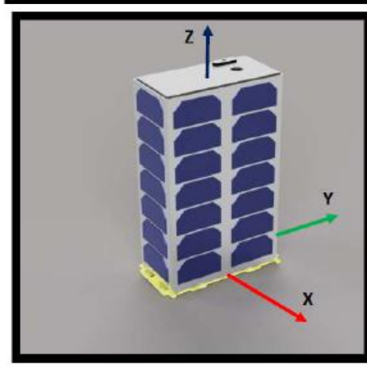
- **82 registered students** (12 teams)
- Multidisciplinar teams – very different fields
- It will be presented soon at 4S Symposium 2020 in Portugal

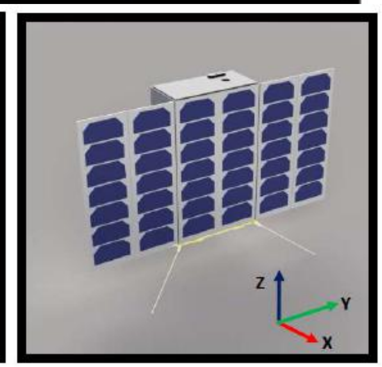


Space Mission Predesign Challenge – Second Edition (1.2)

Key Science Question	- Are Roscoff worms a suitable biological resource to support astronauts' life in space shuttle or space habitat in hostile environments?
Sciene Objective	- Demonstrate the the capability of Roskoff worms to survive in the space environment.
Orbit Geometry	- Science Operations ~3 months - Sunsynchronous Low Earth Orbit - Altitude ~500 km - Inclination ~97,5 deg - Eccentricity ~0 deg - Launch Window ~from FEB to JUL (for no eclipse along the Science Ops.) - Ground Station Coverage per day ~75 mins
Payload	- Biological Payload - 7 kg-3U-L shaped PL - 9.5 W maximum power consumption - 1 W-LED for worms' artificial light - Probes, pumping system and temperature control system to simulate and monitorise worms' environment - HD resolution camera
Science Prod.	- 550 MB data generation per day: HD photos and videos
Spacecraft Design	- CubeSat size 6U with <16 kg mass - Communications: UHF deployable antenna and UHF transceiver for telemmetry, tracking and commands; S-Band patch antenna and S-Band transceiver for PL data transmission (2 Mbps). - Ground Segment: ESA CORE Network. - OBC: dedicated high-speed-high-storage payload OBC; S/C OBC for satellite houskeeping and GNC. - EPS: steady power generation using solar array (~44 W) and eclipse-free orbits. Battery to cover power peaks during communication periods. - ADCS: 3-axis stabilised S/C by means of 4 reaction wheels and magnetorquers for desaturation; star tracker for high pointing accuracy to maximize power generation and fine sun sensors for system redundancy and safe mode. - TCS: semiactive thermal control strategy by means of heaters and advanced coatings. - Structure: lightweight structure with radiation shielding.







2. Detailed Design and Test Challenges

Each institution will be offering specific challenges on the detailed design, development and testing of nanosatellite components.

- Hands-on education for students;
- Increase R&D for the universities;
- Instill collaboration and mobility;
- Provide resources to students and researchers.

Specific challenge name (provide one of the following, if you already have one):

- [ ] B-INP · Ground Base Station
- [ ] B-INP · Nanosatellite antenna
- [ ] B-INP · Building and operating an educational nanosatellite
- [ ] B-INP · Telecom system qualification (sounding balloon)
- [ ] B-INP · Satellite images processing
- [ ] B-INP · Band S board
- [ ] ISAE · Greenhouse on Mars
- [ ] UM · Radiation analysis for a nanosat mission with FASTRAD software
- [ ] UM · Battery testing
- [ ] UM · Center of mass and inertia
- [ ] UM - Attituda, Determination and Control System (ADCS) elements
- [ ] UM - Nanosatellite grounding architecture design
- [ ] UM - Attitude and Orbit Control System (AOCS) software for nanosatellites
- [ ] UPM · Vibration tests
- [ ] UPM · Integration and vibration tests of an ebox
- [ ] UPM · Integration and thermal tests of an ebox
- [ ] UC3M · Vacuum chamber refurbishment for vacuum testing
- [ ] UC3M · Pulsed Plasma Thruster (PPT) components design
- [ ] UC3M · Pulsed Plasma Thruster (PPT) testing
- [ ] UC3M - Design and testing of a thrust balance for a pulsed plasma thruster
- [ ] UC3M · Attitude and Orbit Control System (AOCS) software for nanosatellites
- [ ] UC3M · Space environment simulator
- [ ] UC3M · Ground base station
- [ ] UC3M · Photonics Link
- [ ] UC3M · Laser interrogation of Fiber Bragg Grating (FBG) optical sensors
- [ ] UC3M · Qualification of Vertical-Cavity Surface-Emitting Laser (VCSEL)
- [ ] UC3M · Optical spectrometer design
- [ ] UC3M · 3D printing of a nanosatellite model
- [ ] UC3M - Development of a rocket test platform for nanosatellite components
- [ ] UC3M - Definition of an orbital platform to transport nanosatellites without propellant
- [ ] UBI - Nanosatellite Structure
- [ ] UBI · Propulsion
- [ ] UBI · System integration
- [ ] IST · Attitude, Determination and Control System (ADCS) for abnormal conditions
- [ ] IST - Advanced dynamic sensor calibration
- [ ] IST · Antennas
- [ ] IST - Telemetry and Telecommand unit (T&TC) design and testing
- [ ] IST · Electric Power Subsystem
- [ ] All institutions · Roscoff worms payload design
- [ ] Other:

2. Detailed Design and Test Challenges Specific Examples

Astre'nogs project @ISAE

Developing antennas for an open source global network of satellite ground-stations named Satnogs. They will be made available to the scientific community and will enable to receive UHF and VHF frequencies.

Roscoff Worms @B'INP

Design and develop an artificial environment for a marine photosymbiotic species of worms (Roscoff worms) that guarantees its survival in space.

1U CubeSat Project @UBI

Technology demonstration mission for testing the magnetic attitude determination and control systems. Development of the BUS.

Electric Propulsion @UC3M

Design and testing of a Pulsed Plasma Thruster (PPT)

Etc...

Lessons Learned

- NANOSTAR is developing an **online database of knowledge, a network of expertise and resources, and collaborative open-source tools** that are pushing forward space education.

- Regarding the student challenges, students are extra motivated
  - when the project happens at an international level;
  - when they are challenged to compete;
  - when they can win prizes.

- There is a thin line between cooperation and competition.

- The development of a nanosatellite requires numerous tools and competences. **More opportunities and projects are created when we work in network and cooperation.**

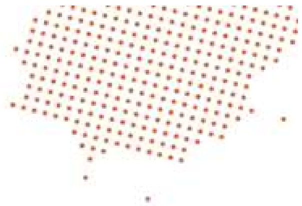
Looking into the Future

- Governance of the open-source tools (maintain and upgrade)
- Expand the network – universities, research centers and industry
- Cooperation in space R&D projects – share of resources and expertise
- Student organizations (SGAC, EUROAVIA, …)
- Mobility of students, researchers and professors
- Joint proposals for space outreach activities
- Joint CubeSat conferences and exchange of experiences

GOAL: Multi-level Interconnected Network

- Network of Resources: To gather all the tools and equipment necessary to design, build, test and operate a nanosatellite in a collaborative approach
- Network of Knowledge: To gather all the experts and skills from different entities.
- Network of Research: To gather companies and research centers that want to develop nanosatellite projects. They can provide funding for specific research projects and provide a work environment for students.
- Network of Students: To gather students that work on the small satellite projects

2 Aerospace Clusters



7 Universities

3 ESA Business Incubation Centres (as associates)

Thank You!

"It's human nature to stretch, to go, to see, to understand.

Exploration is not a choice, really; it's an imperative."

Michael Collins – Apollo 11