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Sudoe

EUROPEAN UNION

NANOSTAR

European Regional Development Fund

Research and innovation

Preliminary design challenge

Mission requirements

NANOSTAR consortium

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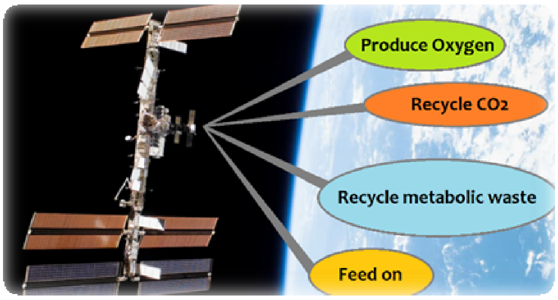
NANOSATELLITE ROSCOFF WORMS MISSION

CONTEXT

Homo sapiens cannot explore space alone and only with technology. Sub-samples of appropriate terrestrial or marine biodiversity must be part of the human environment out of Earth.

The basic biological challenges rely on the capacities to produce oxygen, recycle CO_2 and human metabolic wastes and produce food. For these purposes specific tools called bioregenerative life support systems are key processes in charge of filling out these functions using living organisms supplying the basic resources mentioned above.



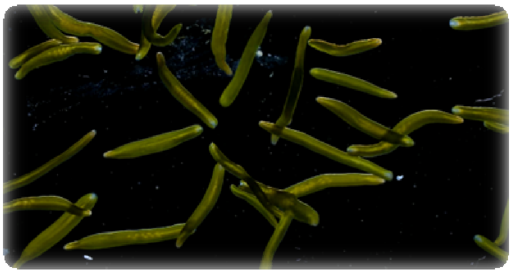
The conception of these systems implies intimate assemblages combining technology and sustainable biological resources.

In other words, to maintain remote alive biological resources from native environment, high technology is needed to properly supplement and mimic natural life conditions.

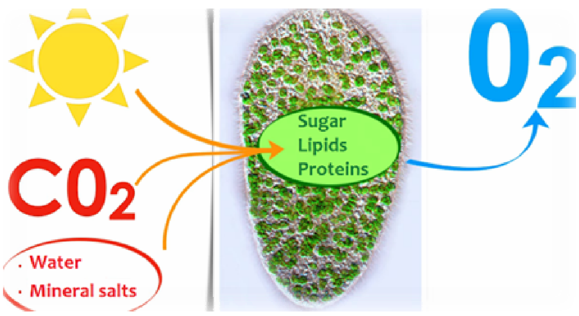
The priority is the identification of the biological resources aiming at supporting astronauts' life in space shuttle or space habitat in hostile environments.

Biological candidates have been already identified such as the cyanobacteria called « spirulina » cultivated in photobioreactors (e.g the Melissa project).

However other species could be potentially used, not necessarily as a unique and definitive solution but as a strong source of inspiration: this is the case of a marine flatworm called the Roscoff worm (Symsagittifera roscoffensis) which harbors and cultivate thousands of micro-algae beneath the skin at a very high density.



The common denominator between these organisms suitable for space exploration is the capacity to use solar energy for converting photons into organic molecules through biological processes exhibited by the biological candidates.



Thus, the prerequisite is the life cycle control in captivity (in laboratory, on Earth) of these species, including a deep knowledge of their biology, their reproduction and their ontogenesis. This is the case for the Roscoff worm, this functional association between an animal and micro-alga leading to the production of oxygen and recycling of CO_2 (among other things) based on solar energy exploitation.

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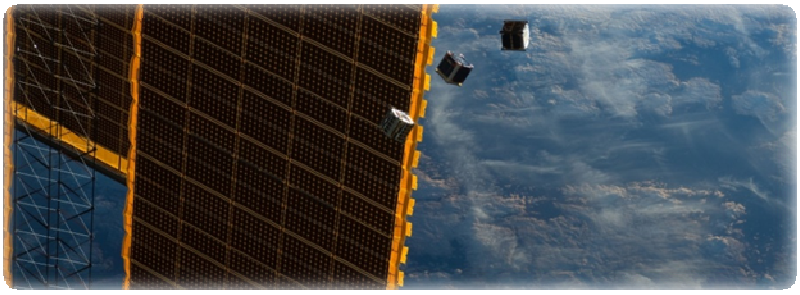
The captivity requires then energy and a set of tools for setting, measuring and following the evolution of variable parameters linked to the maintenance of the right biotic conditions of the biological resource.



Basically, the payload (in addition to the animals, artificial sea-water and "aquarium facilities ») will ideally have to cope with the quality and flow of artificial-sea water, the levels of both oxygen and carbon dioxide, the quality of light spectrum and quantity of photons released for the photosynthesis of the « animalgae », the regulation of temperature, and the regulation of the associated microbiome (population of bacteria naturally associated to the worms).

MISSION

The goal of this space mission design competition is then to predesign **a nanosatellite around a scientific mission with some living science data acquisition** during the experiment. This **demonstrator** mission shall feature a minimal onboard payload consisting of a closed environment artificial ecosystem able to **maintain alive and retrieve data from a self-sustaining functional colony of Roscoff worms** as long as possible.

Your team's objective is to propose a feasible solution to this challenge, which includes performing the **requirement flow-down** of the mission by the mean of Requirement Engineering or Agile techniques, **defining and sizing all the relevant subsystems** using the appropriate tools, carrying out the **mission analysis**, estimating the **performance of your system**, justifying that your solution **satisfies all top-level mission requirements and deals with the constraints** as well as **proposing acceptance test** that allows the nanosatellite's customer to validate that what will be delivered complies with his requirements . Refer to ECSS-E-ST-10C for more information on the requested level of detail of the above-defined activities; notwithstanding this, further detail level will be considered positively in the evaluation.

The expected output of your work includes a report, a presentation explaining your solution and an IDM-CIC file containing the 3D model of the spacecraft with a characterization (in terms of mass and position) of all its subsystems and individual components. See the NANOSTAR Student booklet for more information on the expected deliverables, and the rules of the Preliminary design challenge.

TOP-LEVEL MISSION AND SPACECRAFT REQUIREMENTS

The following list includes the top-level mission requirements and constraints that must be verified by all proposed designs. In order to cope with legacy space project management as well as ECSS standards, requirements will be used here below to define the project main objectives. Feel free to change them into Users Stories when using an Agile project management framework:

RW1. The system shall **carry, activate and operate safely the main scientific payload** described below, during the maximum time in orbit, thus maximizing the total amount of

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scientific data received on Earth. *Additional experiments on the worms possibly requiring new scientific appliances within the payload can be included if they do not have a detrimental effect on the operation of the main one and the system can correctly support their operation. This will be considered positively in the evaluation of the project.*

RW2. The **scientific data** obtained by the main science payload shall be **transmitted to Earth within the mission time-frame.**

RW3. The satellite shall be capable of **performing the mission objectives**, considering the **space environment** constraints.

RW4. The satellite shall **guarantee the correct attitude** of the main science payload (depending on the chosen payload design) or the communication system during the orbits whenever needed.

RW5. The **satellite volume shall not exceed 8U**. *A smaller volume will be considered positively in the evaluation of the project.*

RW6. The **mission duration** from launch to end-of-life **shall not be lower than 2 weeks and ideally up to 3 months**.

RW7. The **maximum mission duration** from launch to end-of-life **shall** comply with space regulation

RW8. Ground segment(s) shall rely only on the tracking stations of the **ESA network**

RW9. During all its lifecycle, the nanosatellite **shall not introduce** any of its embedded photosymbiotic flat worms or its associated viruses or **bacteria** population **into any area on Earth**

RW10. The conception of the nanosatellite shall ensure that all its lifecycle tooling and environment is **ROHS** (Restriction Of Hazardous Substances in electrical and electronic equipments)[1], **REACH** (Registration, Evaluation, Authorization and Restriction of Chemicals)[2] and **CSR** (Corporate Social Responsibility)[3] compliant

MAIN SCIENTIFIC PAYLOAD CHARACTERISTICS

The main scientific payload of the nanosatellite carries a living payload made of a Roscoff Worms and micro algae, experimental probes, worms hydraulic survival apparatus made of pumps, tanks and filters, a fluorescent / optical density device and a high resolution photo/video camera. Its characteristics as well as the mission requirements are described below:

- The payload is a 3**U** box of 7 **kg**.
- The payload geometry is a L-shape.
- **The payload shall be using artificial light only**. Power needed to activate the LEDs is 1 W.
- The payload embeds an **imaging system pointing at the worms**, whose power consumption is **5 W** when ON and **0.1 W** when in SUSPEND mode. It is a full HD resolution. It shall take a picture every min and a 10s video every hour. The data flow sent to the platform for transmission is 550MB per day and cannot be compressed more.
- **Pumping system** within the payload is built upon two redundant micro-pumps, needs a **total power of 0.5 W** turned ON and shall be always ON. The consumed power is dissipated as heat inside the payload.
- Numerous **probes** to be used by the payload (T°, water flow, humidity, O_2, Ph, CO_2, PAR, etc.) need 1W to operate and will be ON all mission long.

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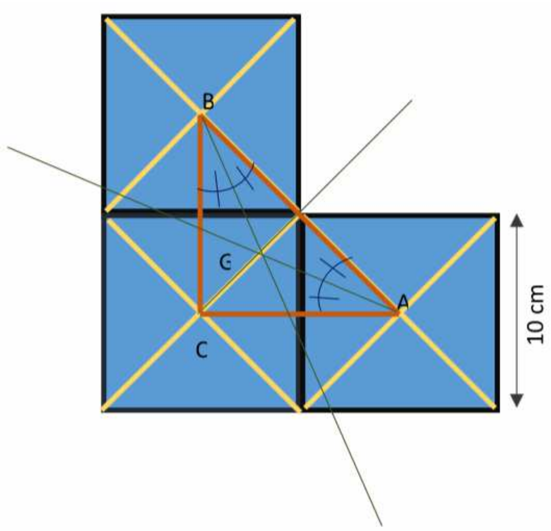
- A **pointing accuracy of 0.5 deg** must be ensured during the payload operation, should it be needed for payload or directive communication system.
- The payload has good internal thermal conductivity and can be treated as an isothermal box. The temperature range outside this box shall be those allowing standard electronic devices use. The **temperature** operating range within the box is **+13 °C ± 2 °C** when in operation to ensure worms viability.
- The main science payload is considered as a box having **Al equivalent shielding of 0.8 mm** in the six directions. Overall mass of the payload already includes the Aluminum mass.
- Payload shall **never** exceed a maximum rotation speed of 3 RPM for **more than** 10s.
- Payload internal **heating** and its control system needs **2W at peak** and will be switched ON only during eclipses.
- The payload **mass center** G would be defined as follows:



ADDITIONAL INFORMATION

- Student teams **do not need to consider launcher availability**.
- The **launcher injects the nanosatellite** at a free inclination.
- System **simplicity** and risk will be part of the items considered in the evaluation of the project.
- Worms need **white light** spectrum: 400-700 nanometers
- The **optimal daylight frequency** for the worms is as follow: 2.5h ramp-up until a 1h flatbed (180-200 PAR) then a 2.5h ramp-down.
- **Temperature** within the payload will be adjusted by a thermal device at the right water temperature as long as the temperature range defined in the payload requirements will be kept.
- All payload subsystems, including dedicated LEDs, heating, **pr**obes**, pumps and imaging system** are self-contained within the payload volume. Their mass is part of the payload overall mass. They shall work under payload temperature.
- The maximum linear acceleration that the worms can handle are compatible with most of the launchers.

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- An inertial moment that might need a correction is created due to the acceleration of the fluids within the tubes in the payload apparatus.
- You can find more information about Roscoff Worms on Xavier Bailly's TED talk[4].
- **Please note that** Nanostar **student**s **team**(s) **designing the Roscoff worms payload** within the **detailed** design and test **challenge might update the payload requirements/characteristics for the** present **S/C preliminary design challenge** based on their own study. If so, present High level Space Mission Requirements will be updated and specific announcements to the S/C teams will be given through Slack channel, advisors, web site or mail.

REFERENCES

[1] The RoHS Directive

[2] Understanding REACH

[3] Corporate Social Responsibility & Responsible Business Conduct

[4] Xavier Bailly: Les leçons de vivre ensemble d'un animal plante | TED Talk (activate subtitles and automatic translation)p

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