Title: LeSTAR – Lessius Satellite for Teaching and Autonomous Research

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Need

As long duration manned missions are considered in the near future, a lot of experiments on regenerative life support systems, including biological components will be necessary.
This is important to safeguard astronauts during their space exploration work.

Mission Objectives

- Proof-of-Technology: we will prove that complementary microgravity research can be performed onboard CubeSats, more frequent and cost-effective, than tests onboard the ISS or in large satellites, if tests can be automated, controlled and monitored from earth.
- Development of biological payload:
  - production of a miniature bioreactor
  - environment control (light, temperature, pressure)
  - micro fluidic network for reagent distribution
  - automation, digitalization and communication of the measured results
  - biocompatibility of the biochemical load and the materials used for the bioreactor
- Integration of biological payload: interface with the satellite command and data handling system
- Benchmark biological space research and set up different requirements for future missions: which research can and which cannot be performed, also experiments on bacteria which are potentially hazardous to astronauts or with corrosive properties.

Concept of Operations

For the biological payload, prokaryotic blue-green algae, also known as cyanobacteria, are selected. They are used for CO_2 and nitrate removal and they produce oxygen and biomass due to photosynthesis, and moreover they are resilient to ionizing radiation up to 3200Gy
To grow the bacteria three conditions must be fulfilled, being the presence of a light source, warmth and nutrient supply.
So we need:

- LEDs for light control
- a suitable heating device for temperature regulation
- a peristaltic pump for nutrition distribution

To reproduce the experiment in earth conditions, as reference material, the following process parameters need to be controlled:

- biomass growth (optical density @ 750nm)

- pressure
- PAR-data: Photosynthetic Active Range
- pH
- fluorescence
- temperature

For the 6-week experiment, we need to have a nutrient vessel, which needs room and we need to warm our experiment, this will need power. A 3-unit CubeSat is envisaged.

Preliminary research on thermal conduct have shown that it is well possible to keep the spacecraft, or at least the bioreactor at the wanted temperature between 22°C and 35°C.

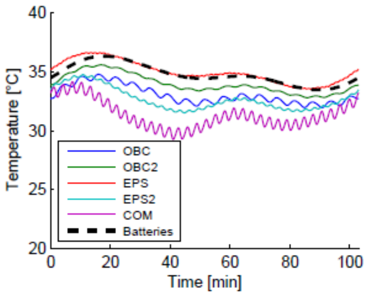

Fig. 1: Thermal Conduct

As microgravity is very important for the experiment, we use small-sized active ADACS, to keep the satellite steady and not tumbling, to prevent gravitational forces on the biological load. Sensors should be onboard, to check if microgravity conditions and steady flight are reached. The detumbling phase must not take more than one week, after launch. Then the biological experiment is started.

A daily data retrieval of 1Mbit is largely enough for telemetry and payload data, including error correction and packaging overhead. Sending and receiving can be done in the amateur band, with a 1200 bits/s uplink and a 4800 bits/s downlink. Lessius made partnerships with other universities, from Belgium to Siberia, for back-up ground stations..

Because algae need to be delivered to the biocontainer as late as possible, late access to the launch vehicle is needed. This is possible at Baikonur, where an ESA laboratory is present, where the necessary sterile conditions for the experiment can be guaranteed.

The temperature transitions at launch conditions must receive close attention, as the heat transfer by convection is not negligible on the outside of the launch vehicle. We don't need temperature control during launch, but we need to log the temperature of the biological load, to be able to reproduce the experiment. So a low-power temperature logging device is necessary.

Key Performance Parameters

To measure the performance of our system we must check if the bacteria grow in our reaction vessel and that the growth dynamics can be measured and modeled with the parameters mentioned before. This growth should have comparable results with other experiments, for instance in the ISS.

An important parameter is the reproducibility of the experiment with earthly conditions. So the temperature and pressure curve of the biological load followed from access to the reaction vessel to the start of the experiment and during the experiment should be known afterwards.

Microgravity is key to the experiment, so steady conduct in orbit must be guaranteed. The dynamics of the spacecraft should be measured with sensors.

A last, important parameter is comparing the economic relevance and benefits which are to be gained when performing the research onboard a CubeSat. We also want to find a possible client base in local SME's who can perform their own space research, due to lowered start-up costs.

Space Segment Description

A standard bus configuration is selected with COTS components. Prices and budgets are available from the CubeSat Shop.

Power Budget	Value
	mW
EPS	820
C&DH	220
Comm	220
ADACS	510
Structure	
Payload	1000
Total	2770
Margin	554,00
Total + Margin	3324,00
Sollar Arrays	3600,00
Available	276

Mass Budget	Value
	g
EPS	665
C&DH	205
Comm	168
ADACS	195
Structure	355
Payload	1000
Total	2588
Margin	517,60
Total + Margin	3105,60
Maximum	4000,00
Available	894

Volume Budget	Value
(in height)	mm
EPS	26
C&DH	40
Comm	25
ADACS	15
Structure	
Payload	140
Total	246
Margin	49,20
Total + Margin	295,20
Total Height	300,00
Available	5

Table 1: Budgets

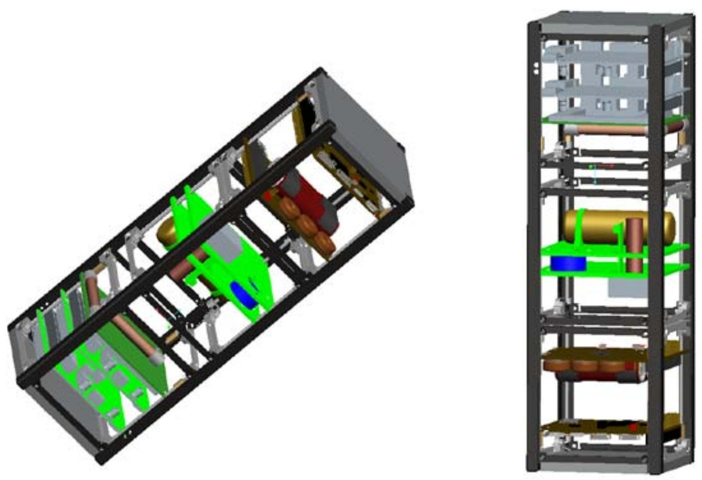

Fig. 2: LeSTAR CAD-model

Orbit/Constellation Description

Orbital demands are quite low, as we only need microgravity for our experiment. This helps a lot to reduce cost, as piggybacking with several missions is possible.

For better communication a near polar orbit is preferred, at a minimum height of around 320km, to have a reasonable long lifetime.

To comply with international law, the orbit mustn't be higher than 600km, to not pass the maximum allowed life span of 25 years.

Implementation Plan

The possible partners in the project are SCK/CEN, the Belgian Nuclear Research Center, with the Microbiology Unit as an experienced biological microgravity research center, Belspo, the Belgian Scientific Policy Organization as a supporter to get PRODEX funding from ESA and the Technical University of Berlin, as reflection board.

The total start-up cost are quite low compared with an experiment onboard the ISS.

Institutional costs, mainly to pay for researchers, laboratory costs, equipment, travel and overheads, is around €500.000 ROM.

Hardware costs are estimated around €300.000 ROM.

No strict clean room is needed for development, but a sterile laboratory to fill the biocontainer is needed at the launch site. Test facilities to do certified testing for launch and orbital conditions are present at Lessius University.

The top 5 risks are in arbitrary order

- Lack of funding
- Launch vehicle malfunction
- Biocontainer malfunction
- Communication malfunction
- EPS malfunction

Project Organization

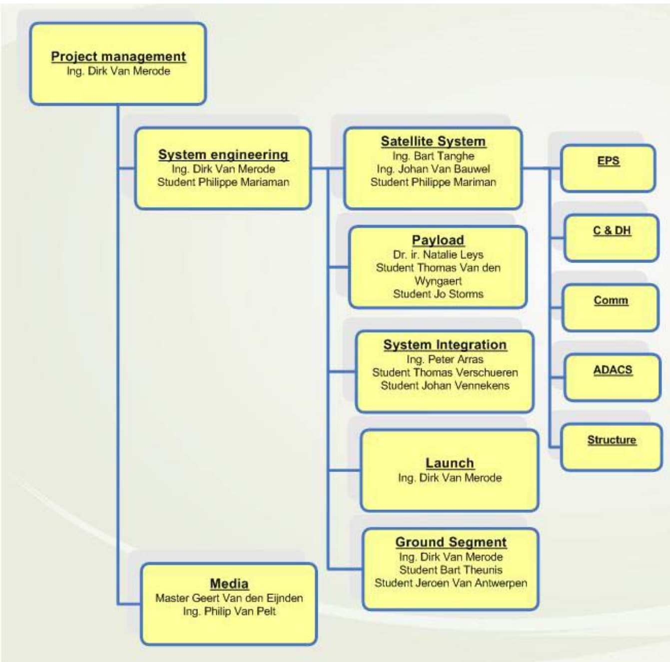

Fig. 3: Project Organisation

Schedule

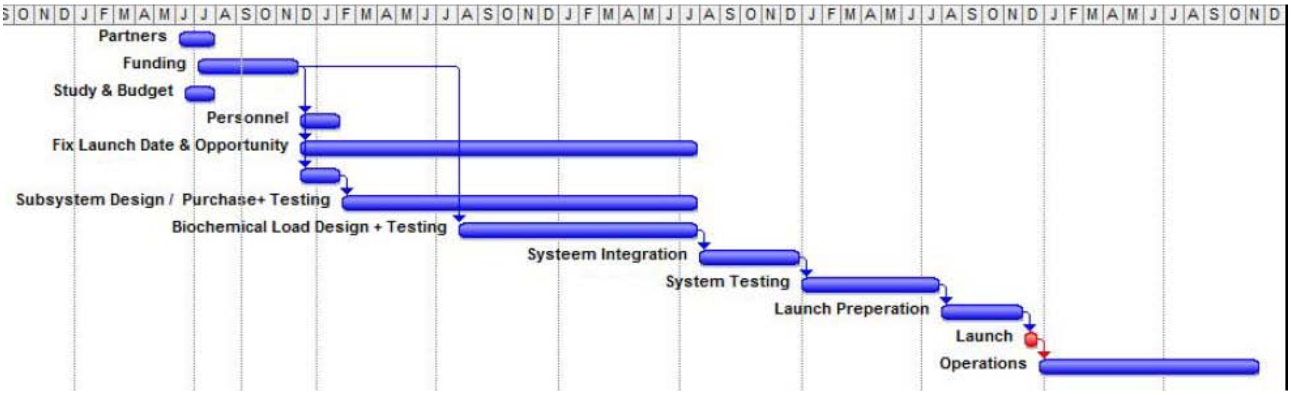

Fig. 4: Schedule

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