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Cislunar CubeSats to Measure Radiation in Support for Human Space Exploration

Paolo **Guardabasso**¹, Stephanie **Lizy-Destrez**¹

¹ISAE-SUPAERO University of Toulouse, France

12th European Cubesat Symposium

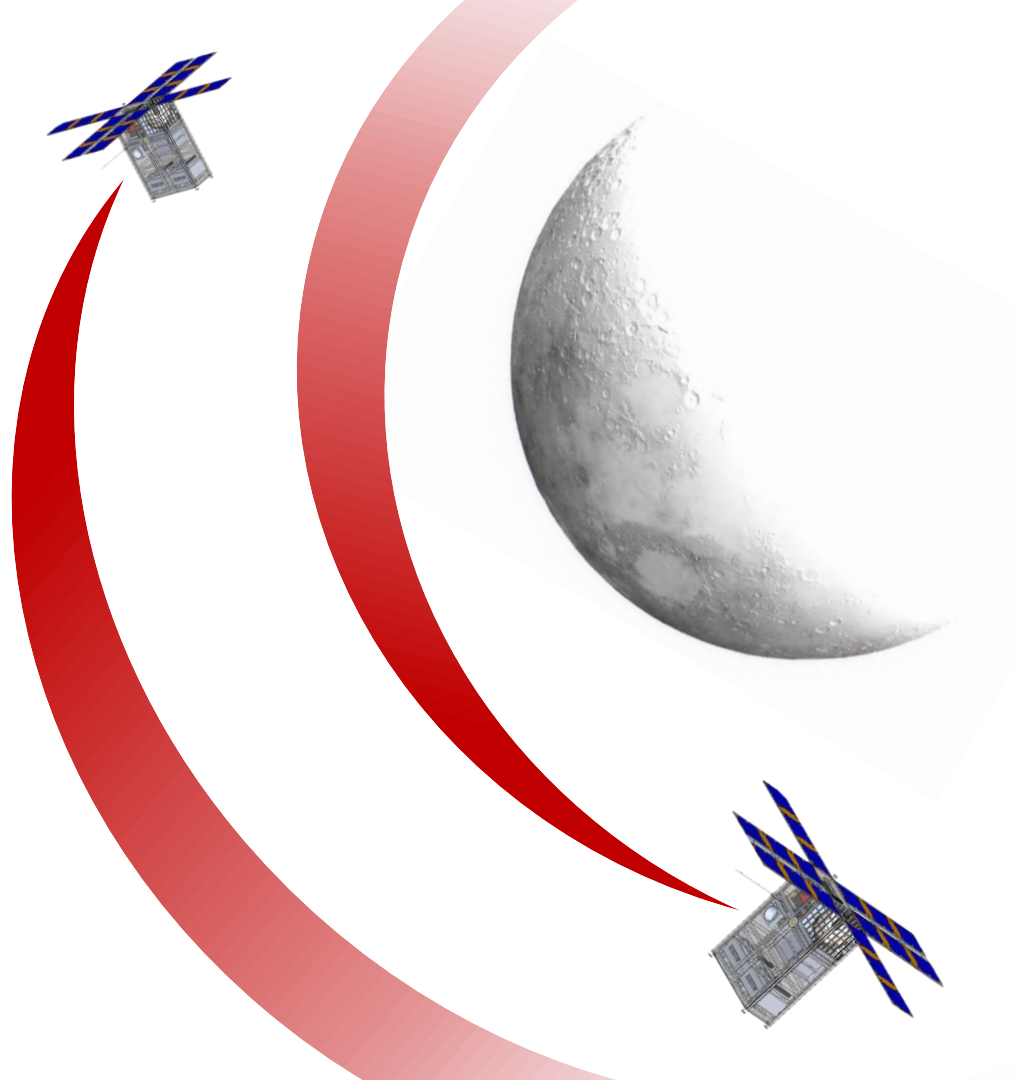
24-26 November 2021

Ecole polytechnique, Palaiseau, FR



Outline

- ▶ **Context**
- ▶ **DRACO Mission Analysis**
- ▶ **DRACO System Design**
- ▶ **Conclusion and perspectives**



Context

Lunar Exploration

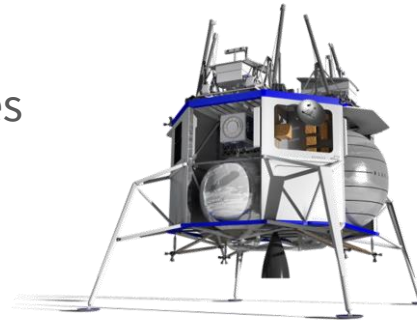
- A **new era** of exploration begins
- Assembly of a **Lunar Gateway** in a L2 southern Near Rectilinear Halo Orbit (**NRHO**).
- Involvement of **public** and **private** entities to provide **transportation** services, **logistics** and **in-situ** resources utilisation.



Lunar Gateway Station.
Credits: ESA



Orion Crew vehicle.
Credits: ESA



Blue Moon Lander.
Credits: Blue Origin



Starship Crew and Cargo.
Credits: Space X

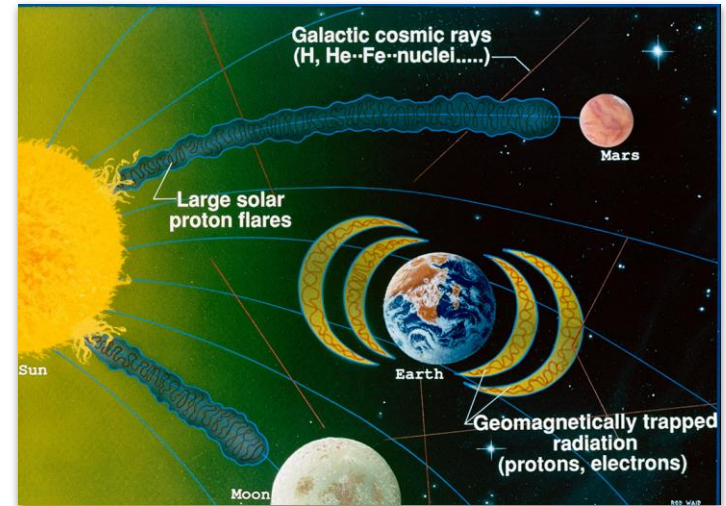
Radiation Environment

Space is filled with radiations, of 2 main types:

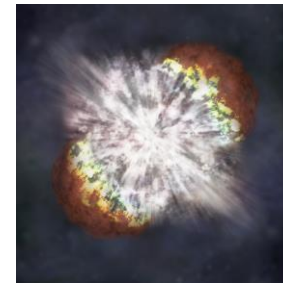
- Solar Particle Events (SPEs)
- Galactic Cosmic Rays (GCRs)

Both types have consequences on:

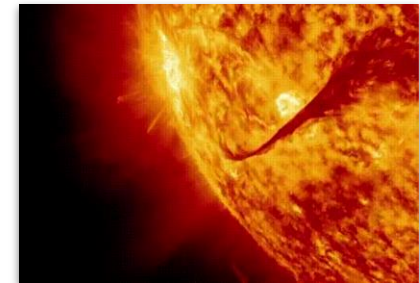
- Electronics
- Materials
- Human body



Recap of space radiation sources.



Supernova explosion (Artist's impression).



Solar flare with Coronal Mass Ejection (Observation).

Beyond Earth

Lunar Orbit

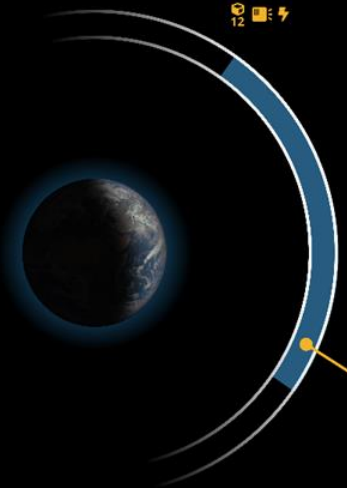
- Lunar IceCube**
2022
- LunaH-Map**
2022
- Lunar Flashlight**
2022?
- Cislunar Explorers**
2022?
- VMMO**
2023?

Lunar Surface

- OMOTENASHI**
2022

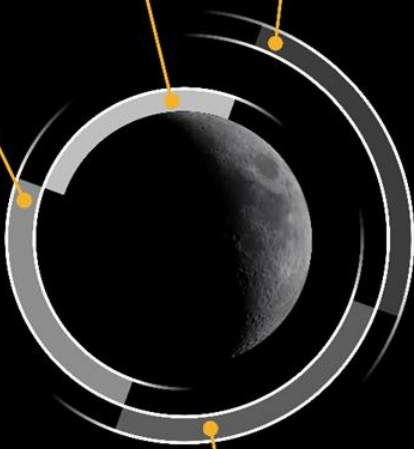
Earth-Moon Lagrangian Point Orbit

- EQUULEUS**
2022
- CAPSTONE**
2022
- LUMIO**
2023?



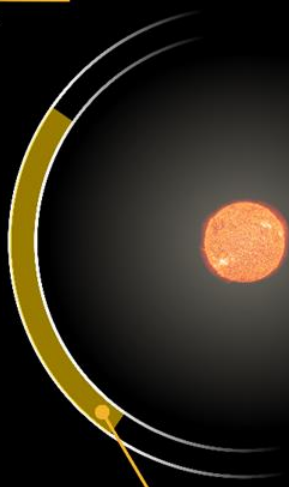
Highly Elliptical Earth Orbit

- ArgoMoon**
2022



Lunar Flyby

- LunIR**
2022



Solar Orbit

- TeamMiles**
2022
- BioSentinel**
2022
- CuSP**
2022
- NEA Scout**
2022
- CU-E³**
2022?

Main Objective

- Measurements
- Imagery
- On-Board Analysis
- Tech. Demonstration

Main Propulsion

- Chemical
- Electric
- Solar Sail

- Number of CubeSat Units
- Piggyback on NASA Artemis I



DRACO Mission Analysis

DRACO = Detection of Radiation in Cislunar Orbits

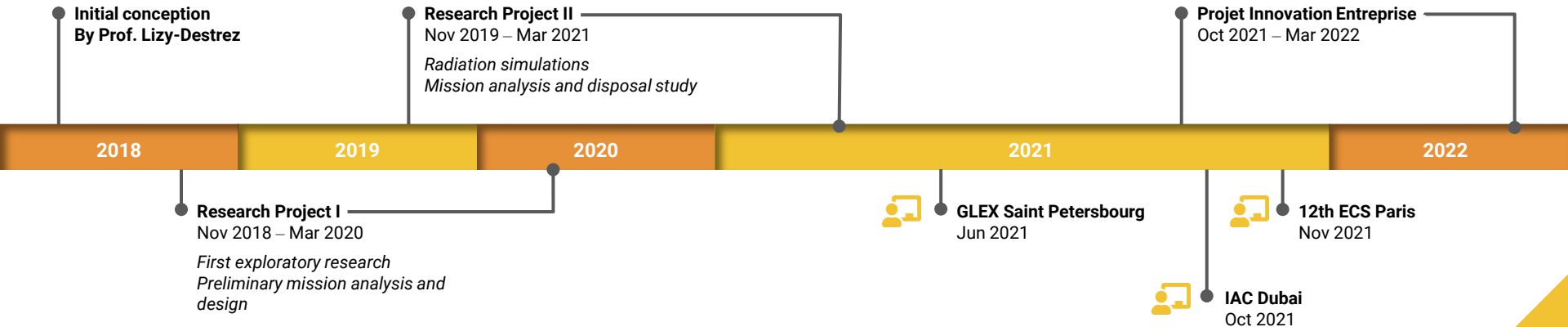
Mission statement

“Characterise the radiation environment and demonstrate the use of CubeSats on Earth-Moon Lagrangian point orbits.”

DRACO = Detection of Radiation in Cislunar Orbits

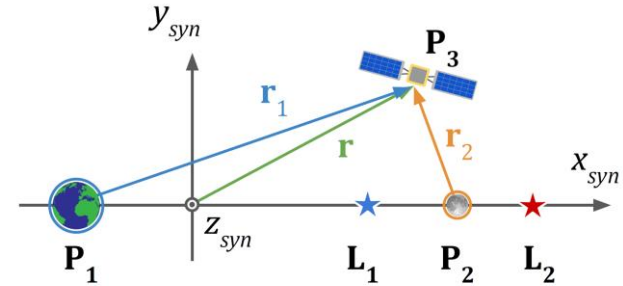
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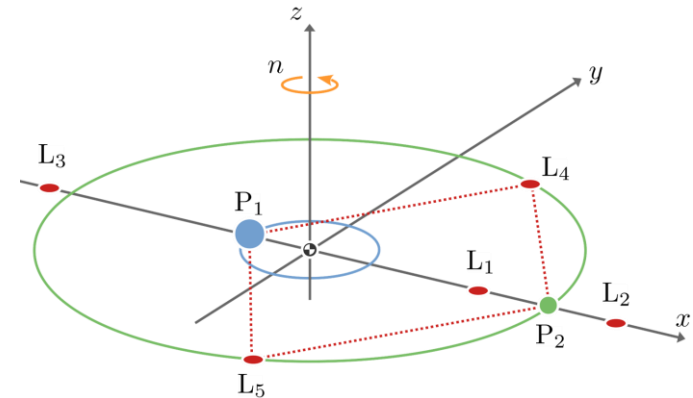


Dynamical Environment

- The Earth and the Moon dominate the “cislunar” space.
- Analysis are run in the **Circular Restricted Three Body Problem (CR3BP)**:
- There are **5 libration points** around which exist periodic solutions → **Orbits!**



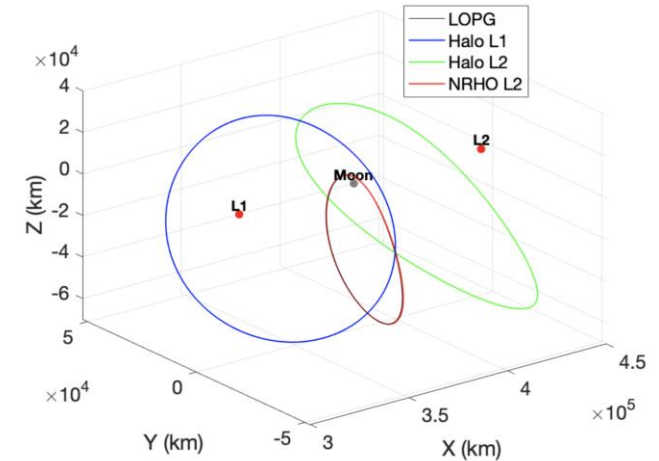
The Earth-Moon system in the rotating “synodic” frame



A rotating frame, used to study the Restricted Three Body Problem. The 5 Lagrange points are highlighted.

DRACO mission Conops

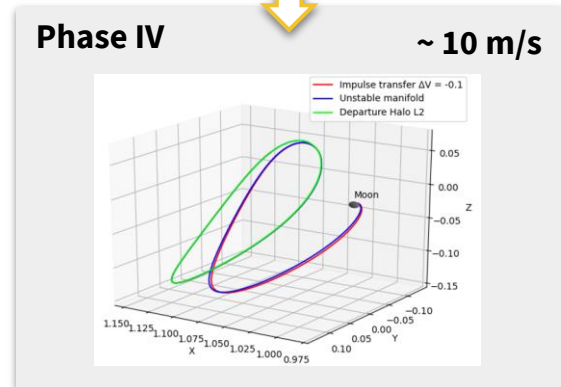
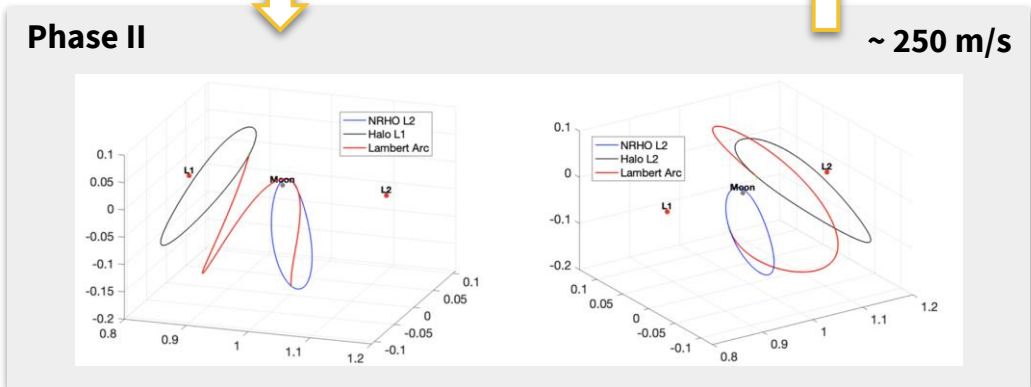
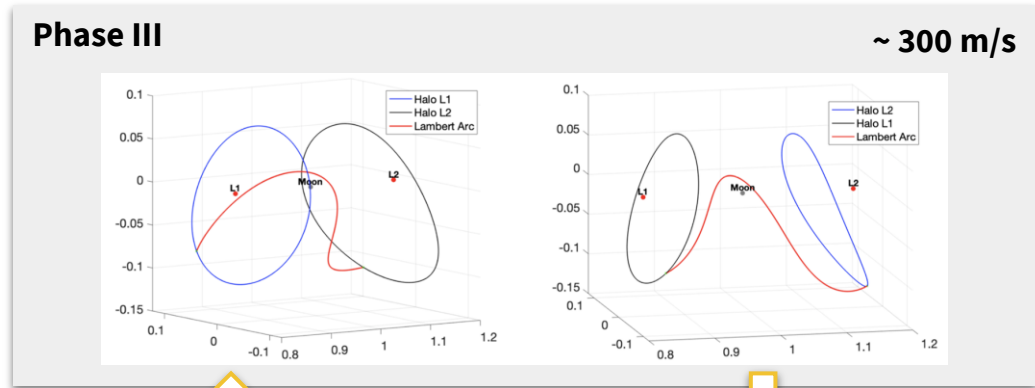
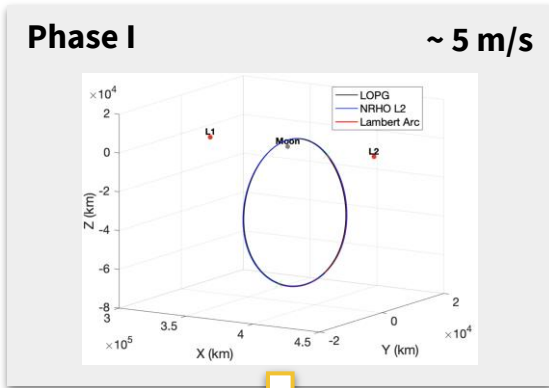
- Phase I.** Release from Gateway of **DRACO-1** and **DRACO-2** to NRHO- L_2 and calibration.
- Phase II.** Transfer **DRACO-1** and **DRACO-2** to science **Halo** orbits around L_1 and L_2 .
- Phase III.** Exchange science Halo orbits.
- Phase IV.** Disposal of both CubeSats with **impact** on the lunar surface.



The orbits involved in the DRACO preliminary study [1]

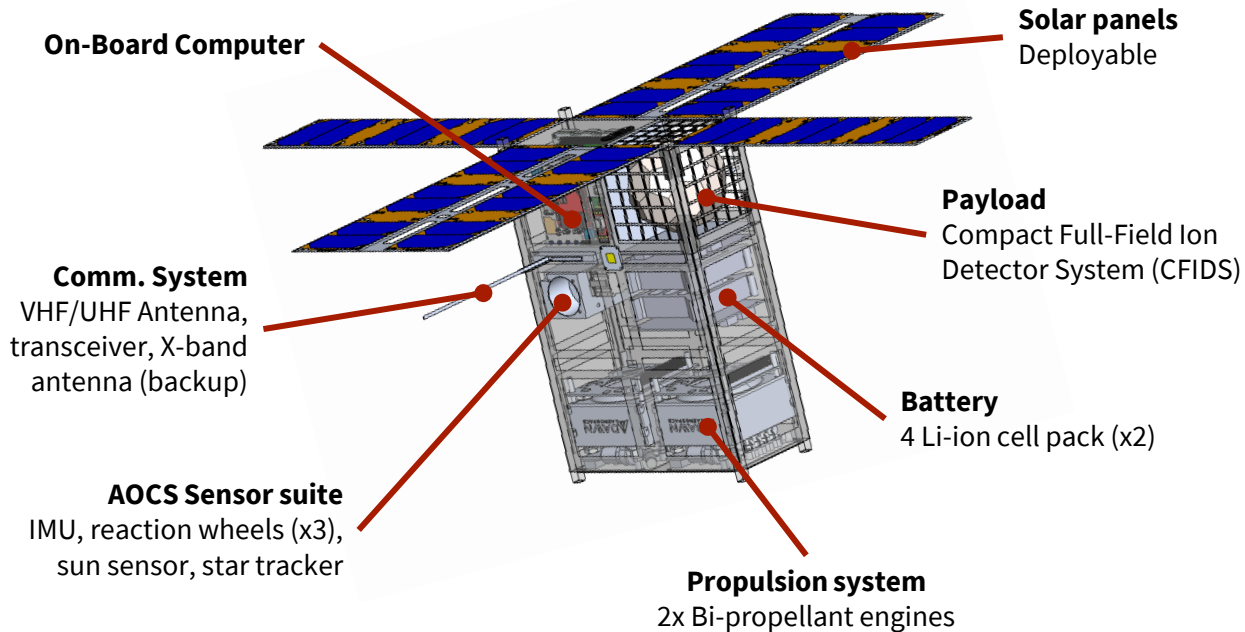
[1] M. Burnichon, E. V. Llamazares, Á. C. Serrano, P. Guardabasso, and S. Lizy-Destrez, “Mission Analysis to Measure Radiation Dose About the Earth-Moon Lagrangian Points” presented at the Global Space Exploration Conference (GLEX), Saint Petersburg, Russia, 2021.

Trajectory Analysis



DRACO System Design

Preliminary System Design

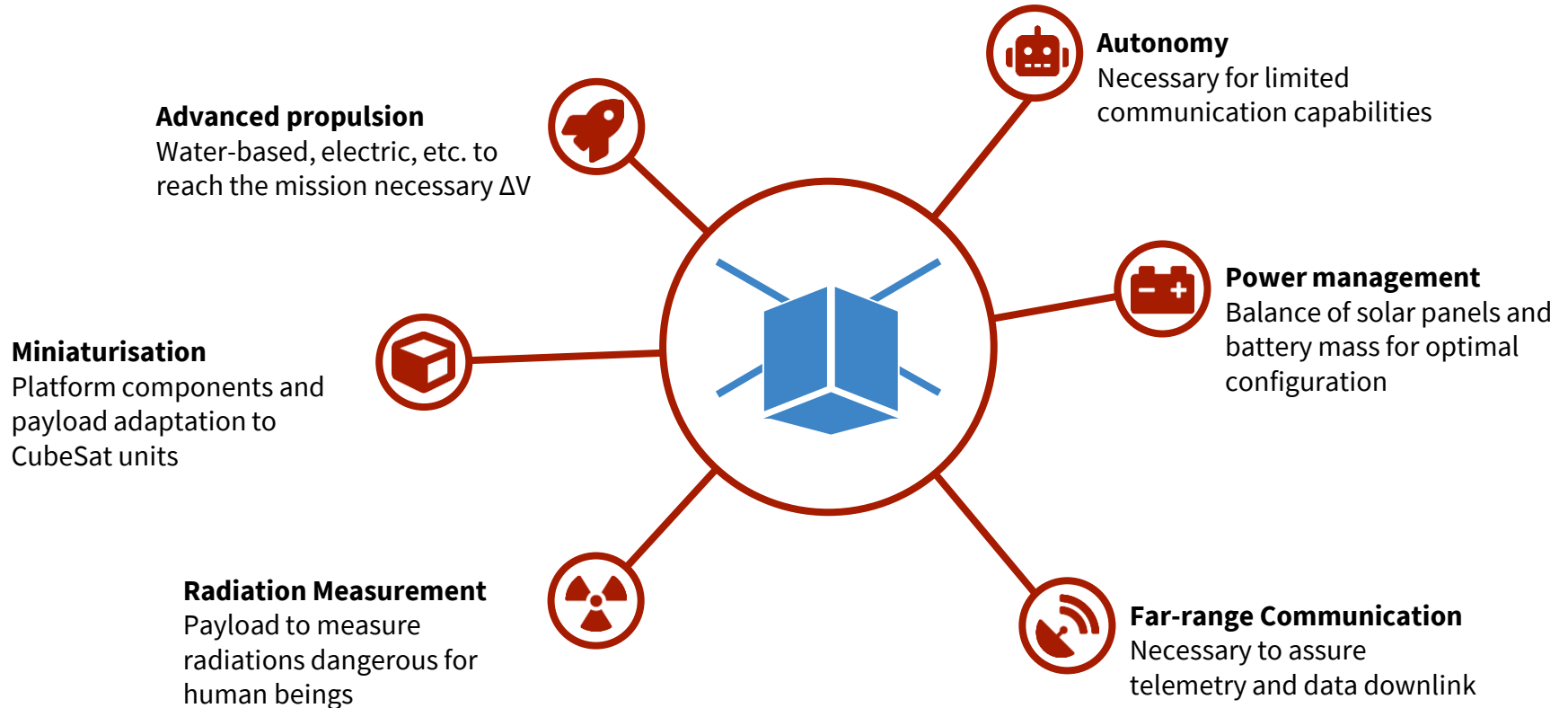


Dry Mass	9.4 kg
Propellant	1.6 kg
Final Mass	11 kg



Nominal	20 W
Peak (transfer)	47 W

Key technologies



Conclusion and future work

Conclusions...



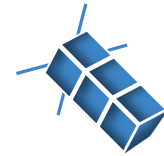
Science and Payload

Review of available models
Preliminary dose simulations



Mission Analysis

Analysis of science orbits
Computation of transfer ΔV



System design

Components technology scouting
Preliminary mass and power budget

Conclusions...and future work



Science and Payload

Review of available models
Preliminary dose simulations



Detailed **review** of existing missions and sensors

Experiment **requirements** preparation



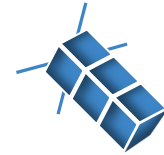
Mission Analysis

Analysis of science orbits
Computation of transfer ΔV



Transfer and **stationkeeping** redesign and optimisation

High-fidelity trajectory refinement



System design

Components technology scouting
Preliminary mass and power budget



Evaluate other **CubeSat configurations** (3U)

Prepare **parametric model** for generalised **system budgets**

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Thank you for your attention!
Any questions?



paolo.guardabasso@isae-superaero.fr

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