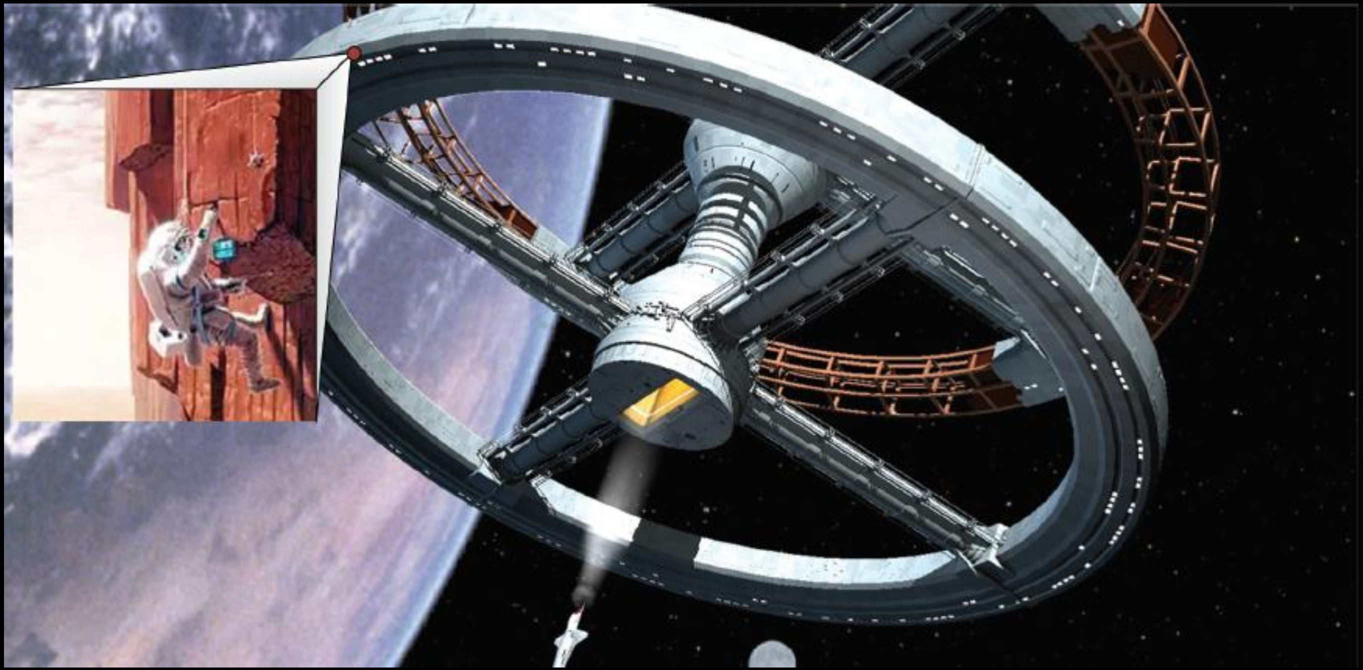


New Avenues for Planetary Science Using On-Orbit CubeSat Centrifuges

Erik Asphaug[1], Jekan Thangavelautham[2] and the AOSAT Team
[1]Lunar and Planetary Laboratory, [2]Space and Terrestrial Robotic Exploration Laboratory
University of Arizona

Motivation

Geo-history

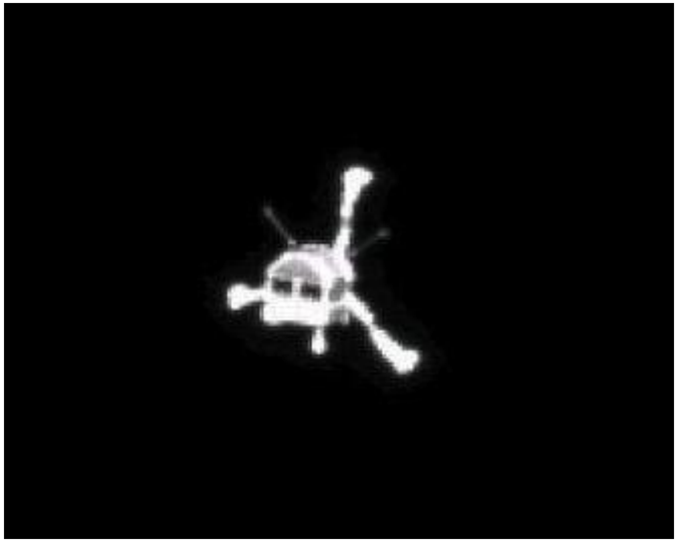
Security/Deflection

ISRU

Asteroid exploration is tied to origin of Earth, origin of solar-system and origin pre-organics.

Surface Exploration

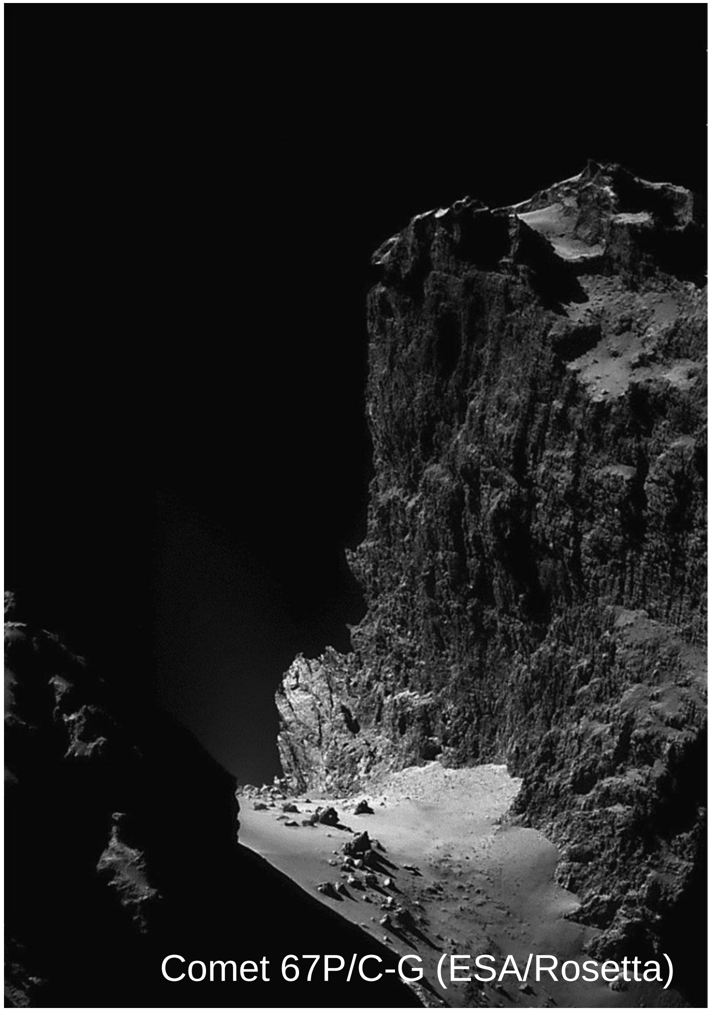
- Extremely challenging due to milligravity environment, unexplored surface physics

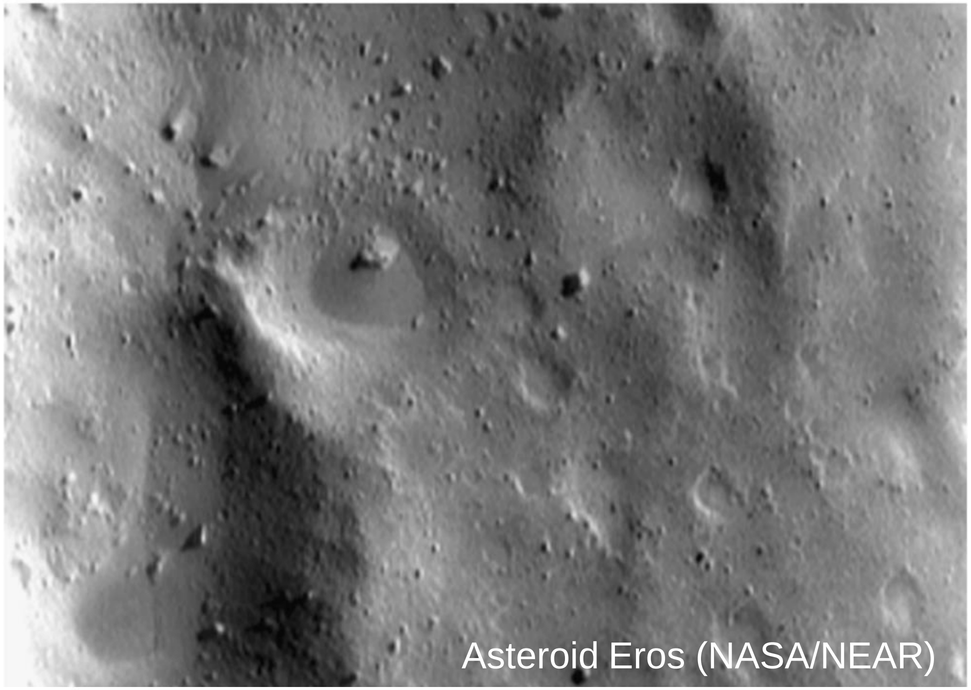


Philae/Rosetta (ESA)

NEO Exploration (NASA)

Science Motivation


Comet 67P/C-G (ESA/Rosetta)


Asteroid Eros (NASA/NEAR)

npj | Microgravity

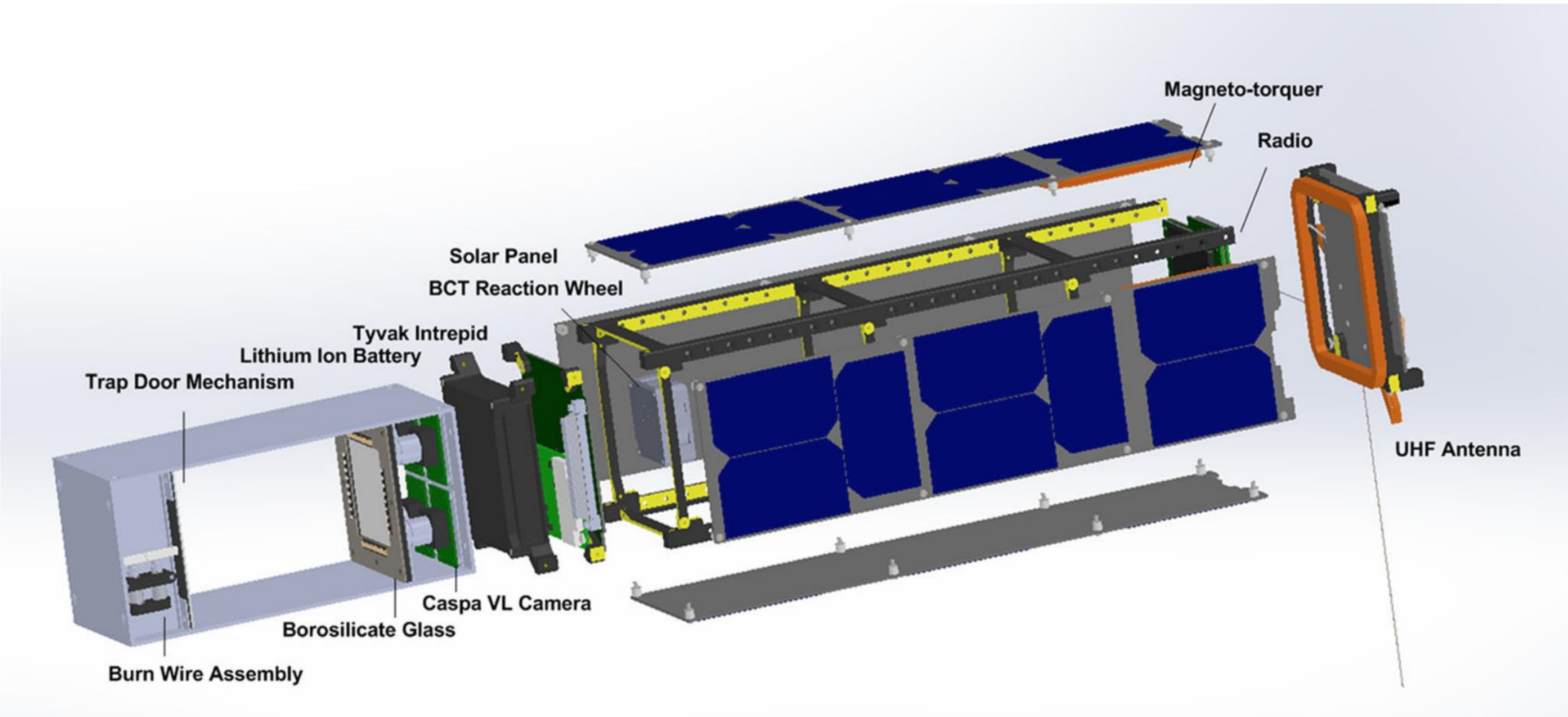
www.nature.com/npjmgrav

PERSPECTIVE OPEN

A cubesat centrifuge for long duration milligravity research

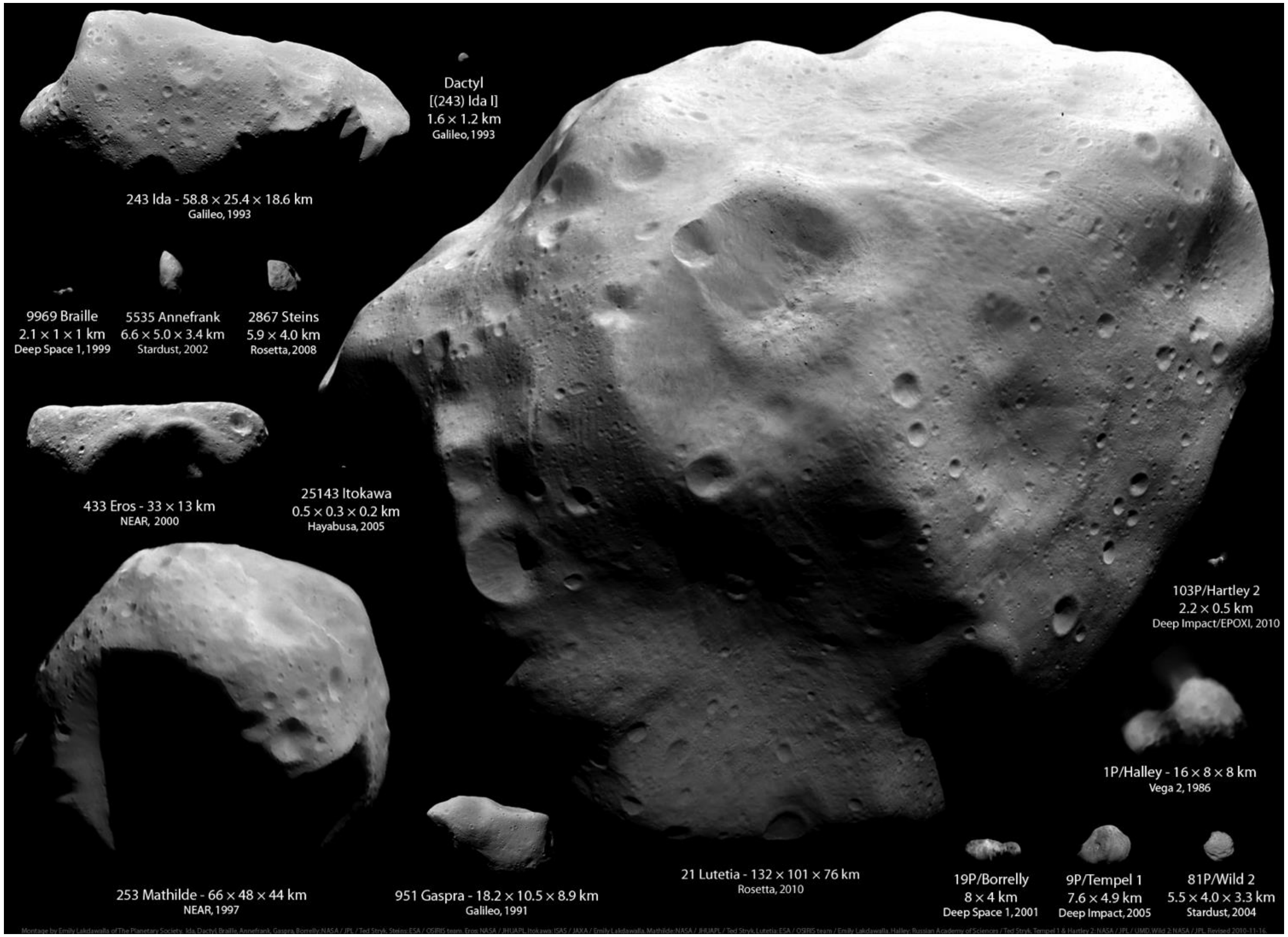
Erik Asphaug[1], Jekan Thangavelautham[1], Andrew Klesh[1,2], Aman Chandra[1], Ravi Nallapu[1], Laksh Raura[1], Mercedes Herreras-Martinez[1] and Stephen Schwartz[1]

AOSAT 1



Launch 2019, NASA CLSI

Milligravity Environments



Practical Questions

- What happens to low gravity regolith during landing, mining or excavation?
- Can a spacecraft be anchored to embedded rocks, or will they pull free?
- Are landforms stable, or will exploration and mining activities disturb them catastrophically?

Need for Controlled Env. / Persistent Link

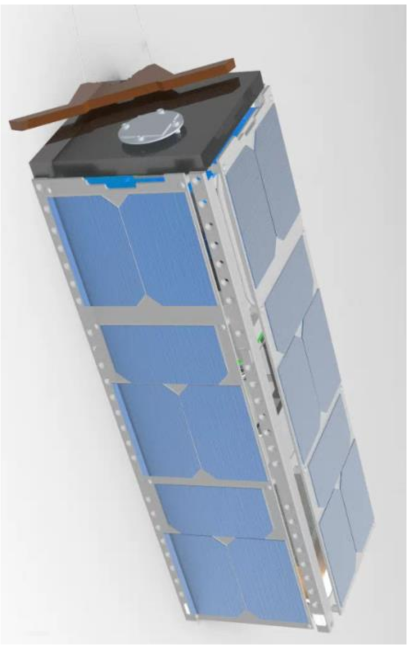
- **Microgravity geophysics investigations are short duration (drop towers, parabolic flights), noisy, or expensive and human-tended platforms.**

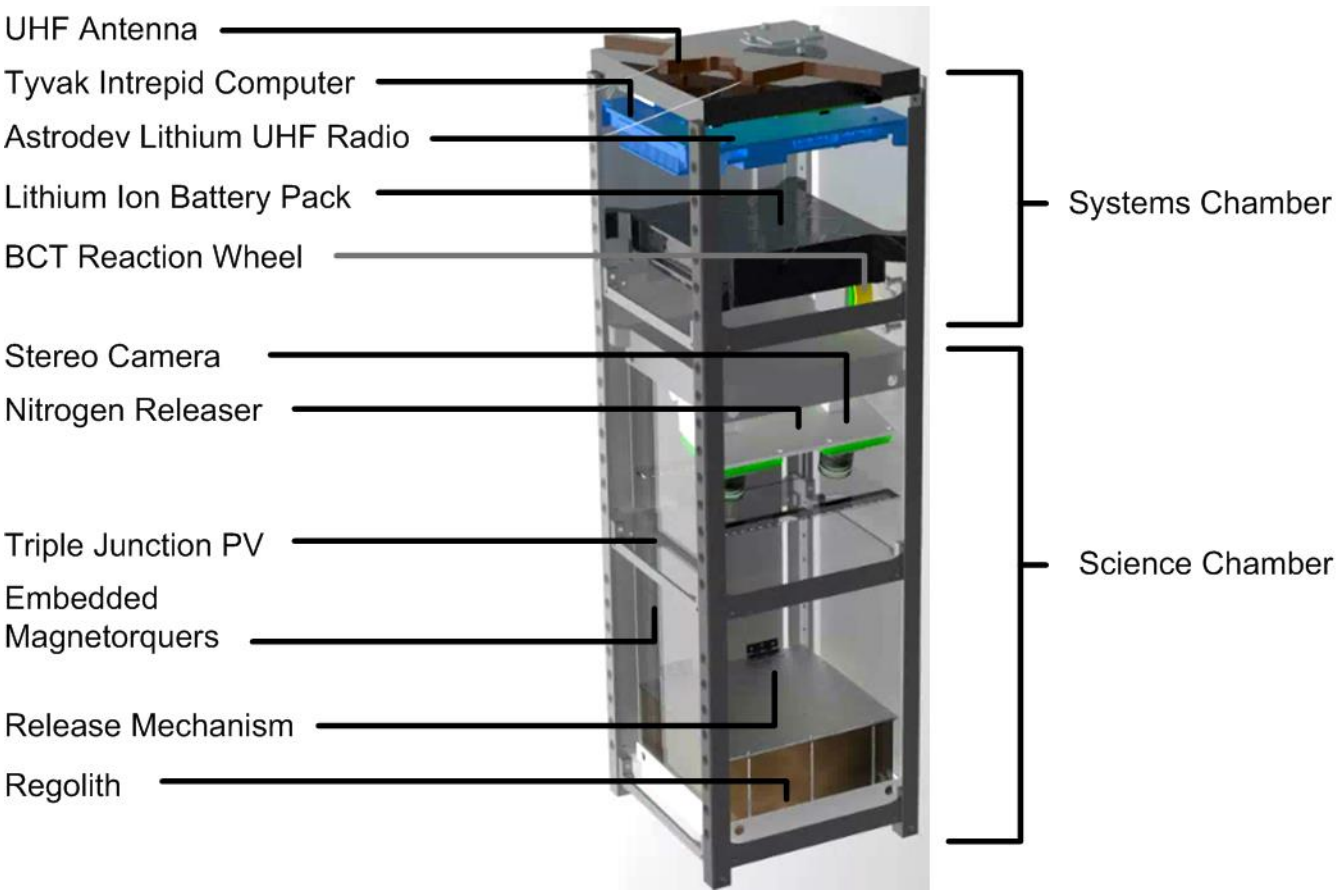
Need for Controlled Env. / Persistent Link

- Need for controlled environments for scaled experiments under milligravity (asteroid, slow centrifuge) conditions
  - Repeatable, incremental experiments
  - Extremely low noise (no vibrtions)
  - Rapid turnaround for hypothesis testing and for reducing risk of flagship/human missions

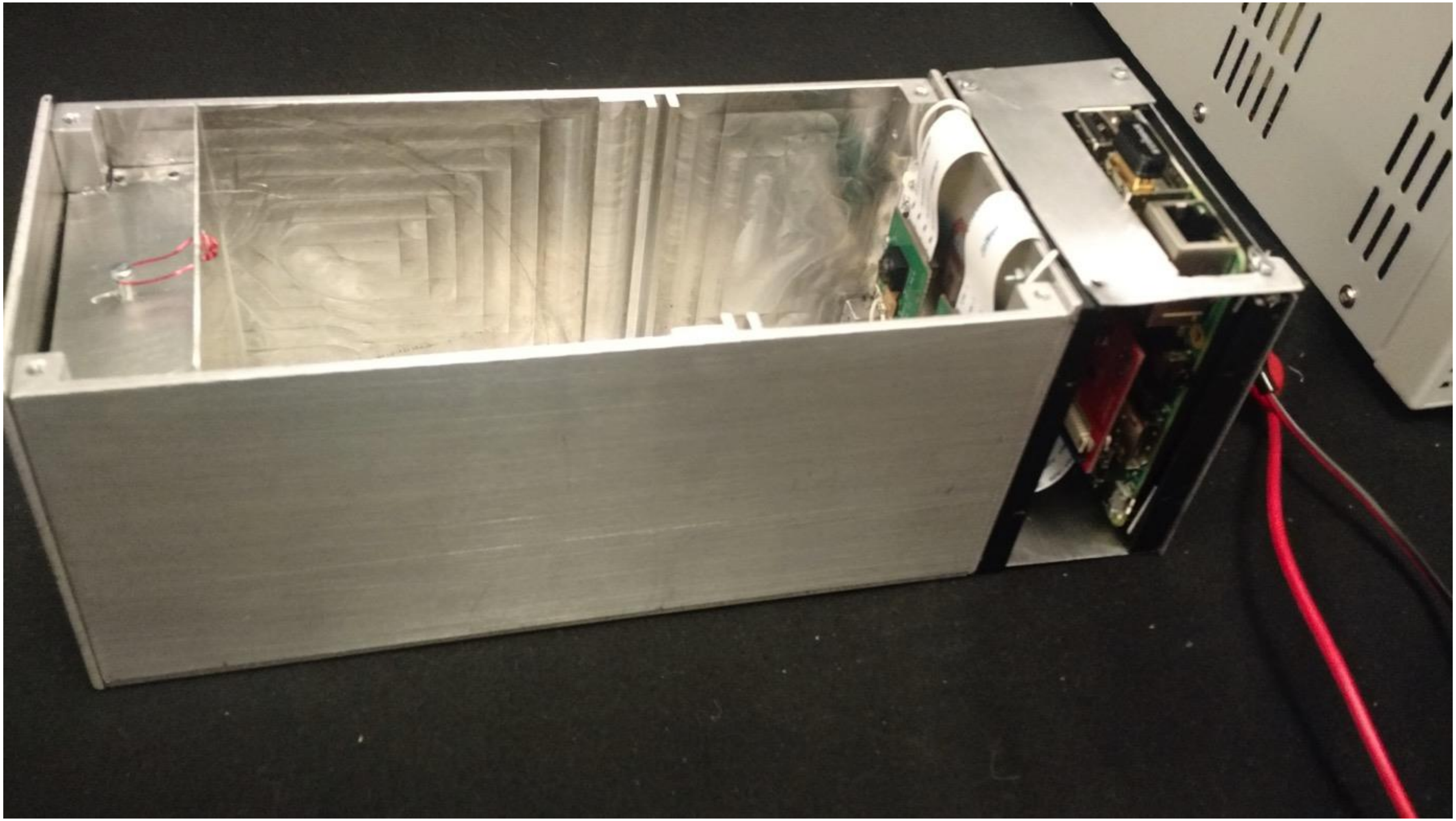

SpaceTREx

AOSAT 1

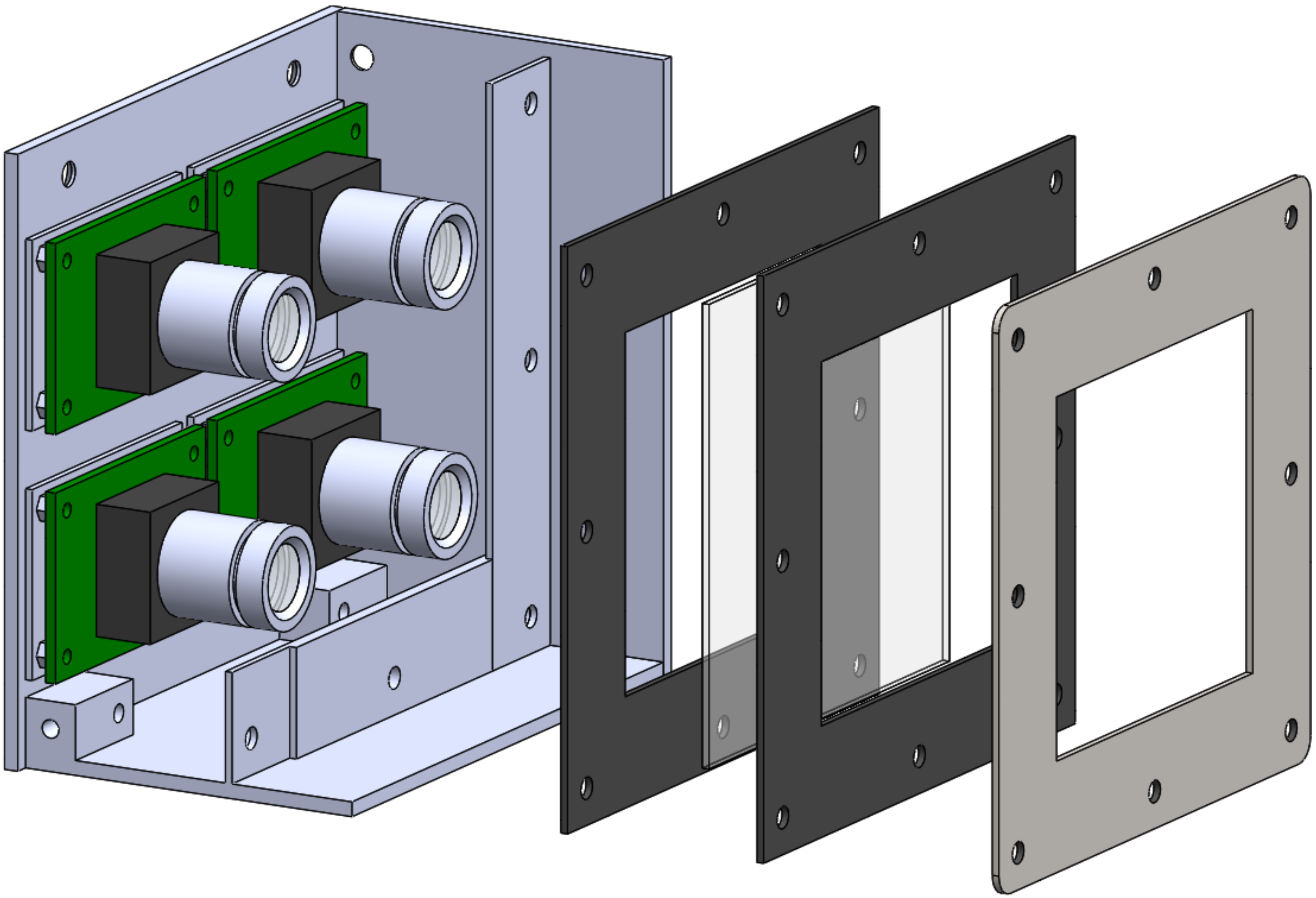



UHF Antenna
Tyvak Intrepid Computer
Astrodev Lithium UHF Radio
Lithium Ion Battery Pack
BCT Reaction Wheel
Stereo Camera
Nitrogen Releaser
Triple Junction PV
Embedded Magnetorquers
Release Mechanism
Regolith
Systems Chamber
Science Chamber

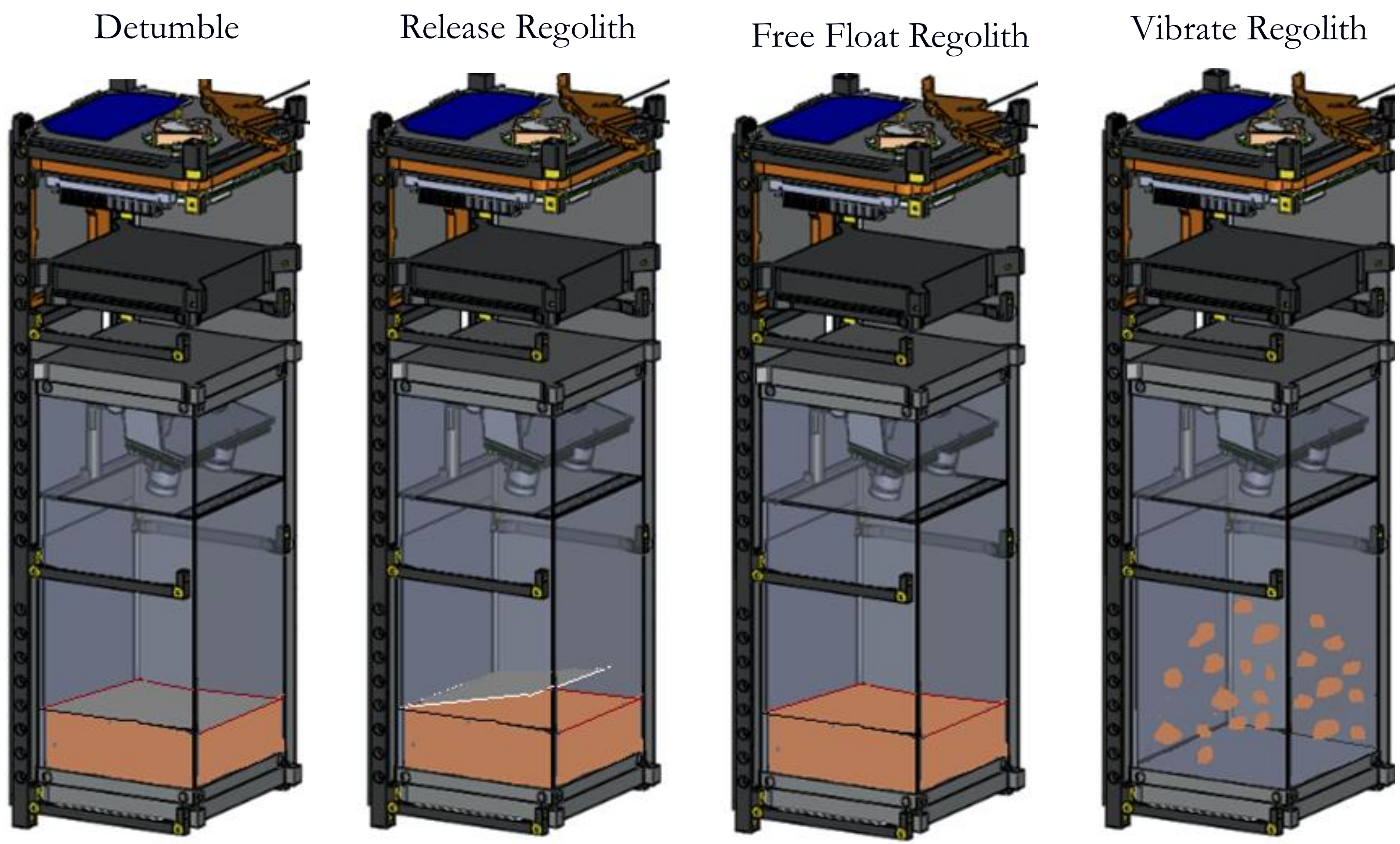
AOSAT 1 Eng Model of Science Payload



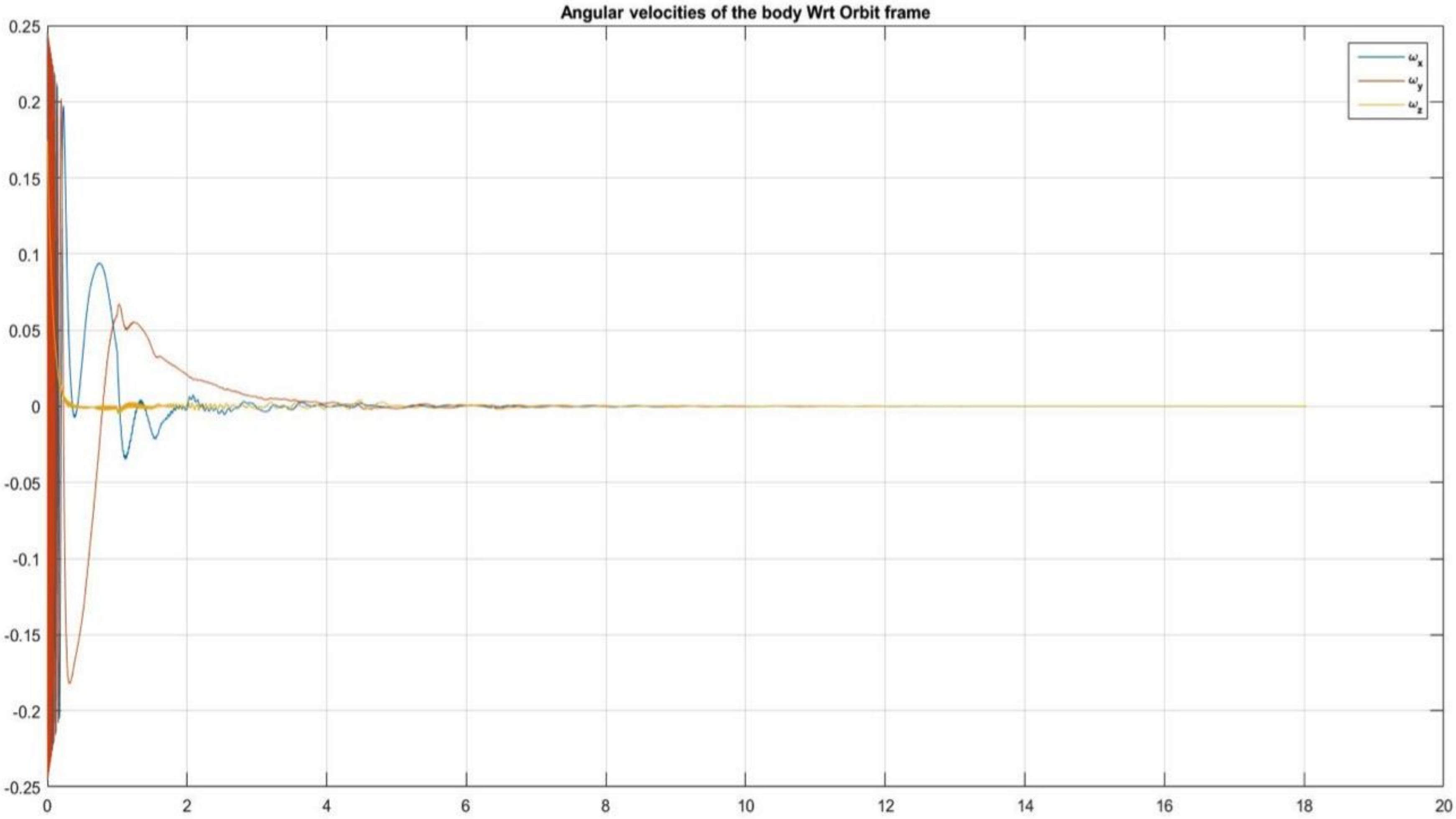
Borosilicate Gasketing



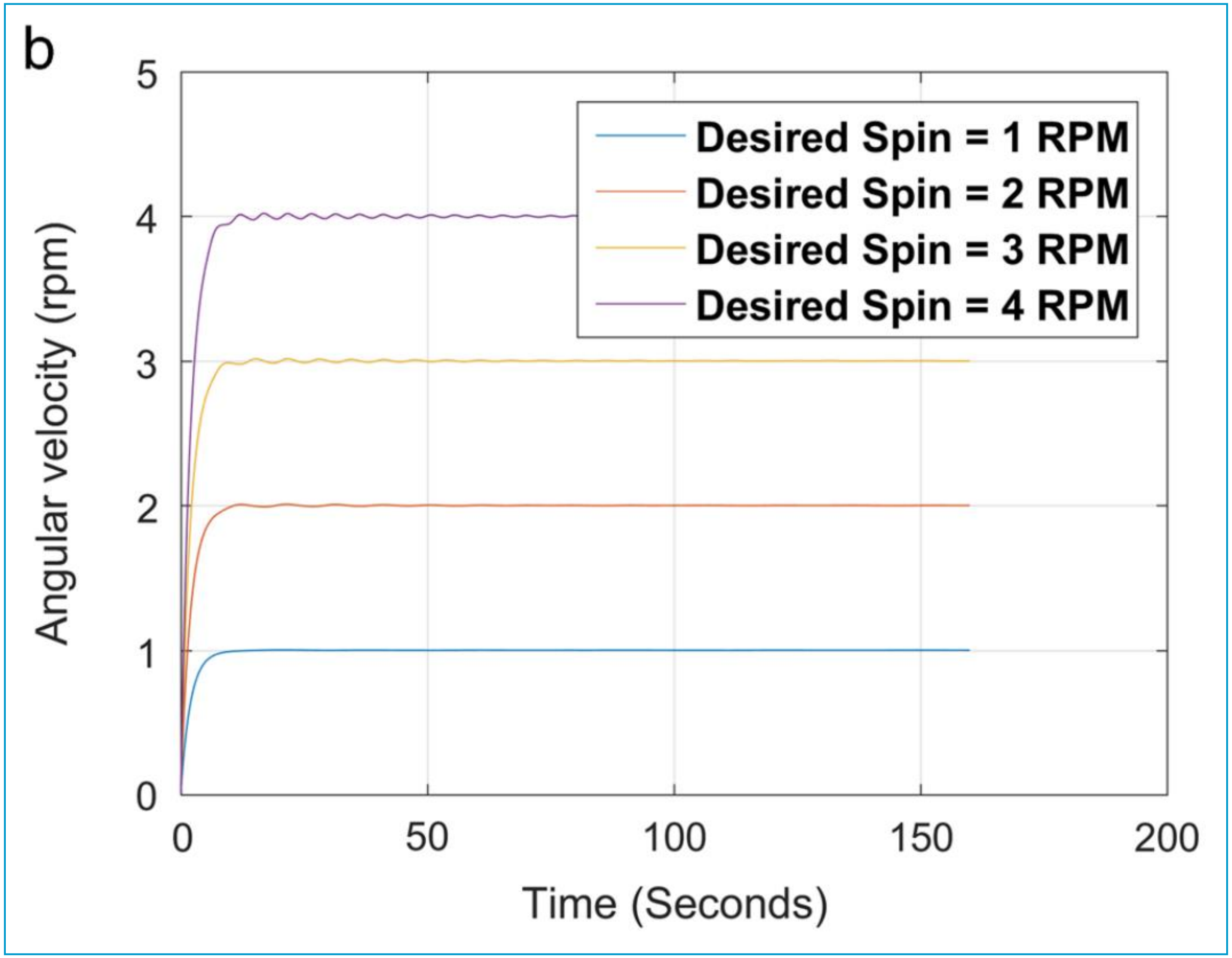
AOSAT 1 Conops



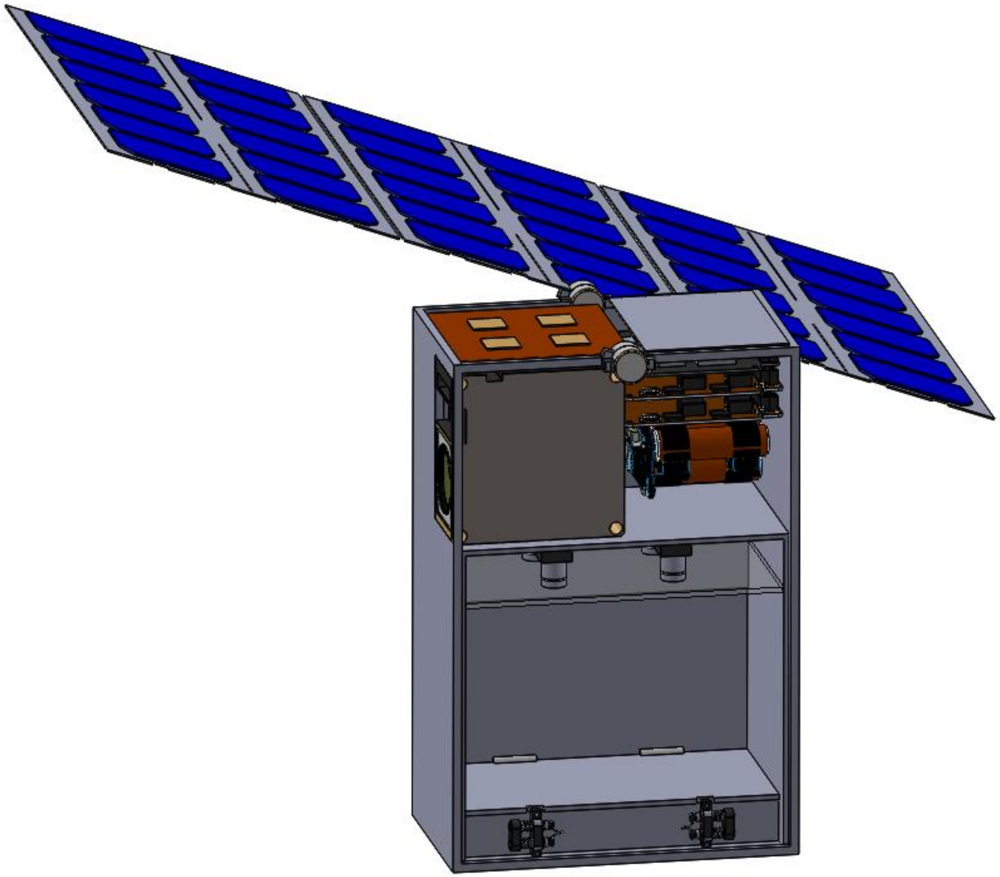
Detumble Simulations

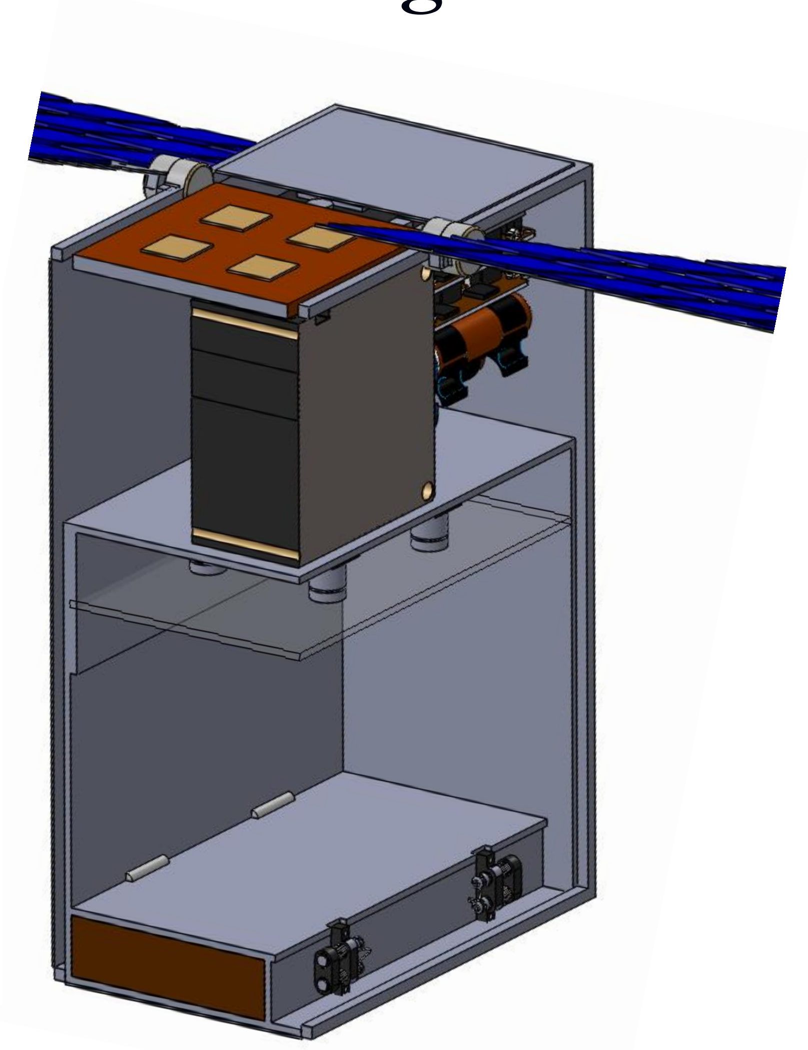


Spin

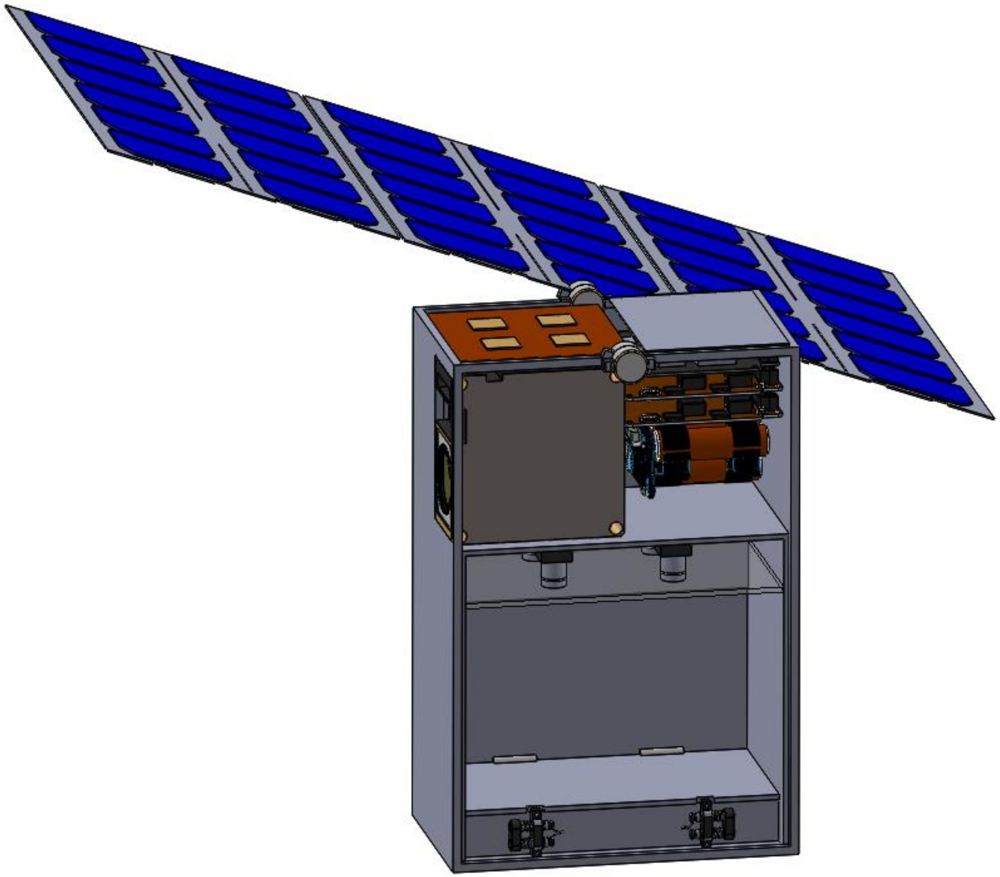

b
Desired Spin = 1 RPM
Desired Spin = 2 RPM
Desired Spin = 3 RPM
Desired Spin = 4 RPM
Angular velocity (rpm)
Time (Seconds)
0
1
2
3
4
5
0
50
100
150
200

AOSAT 2 Prototype: 6U Design





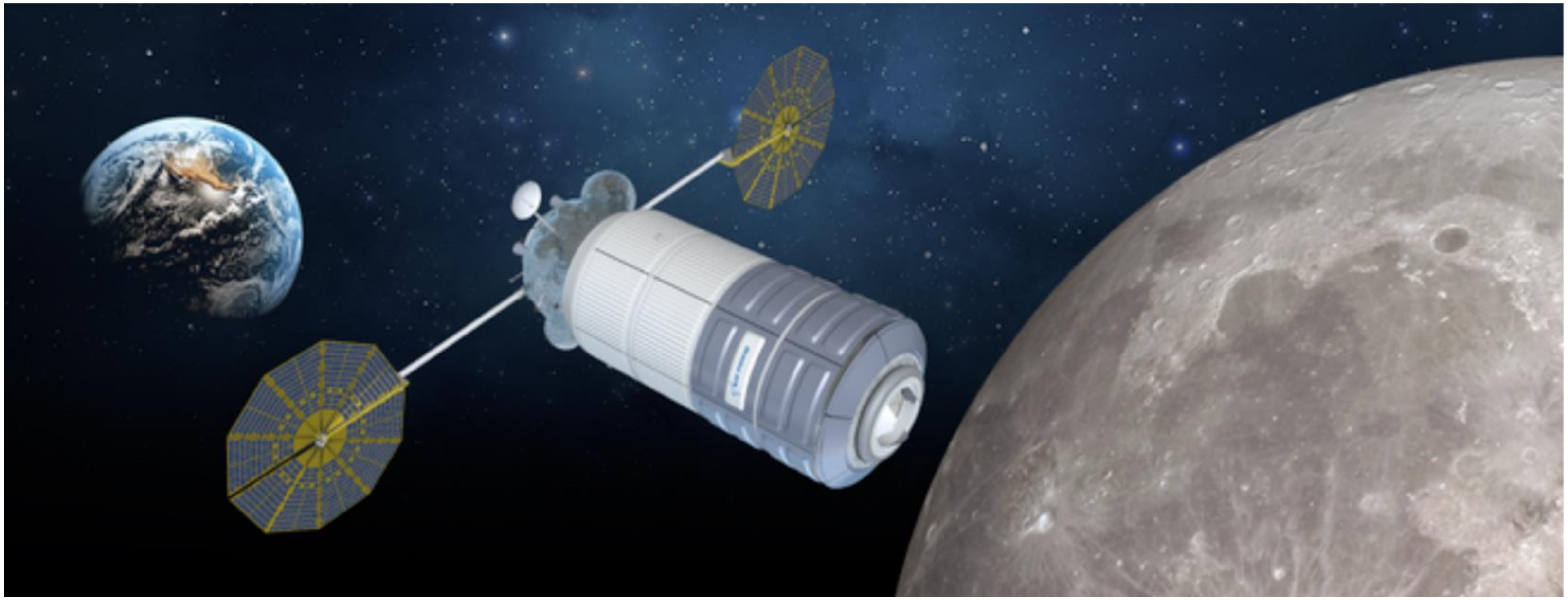
AOSAT 2 Prototype: 6U Design



Upgrades:

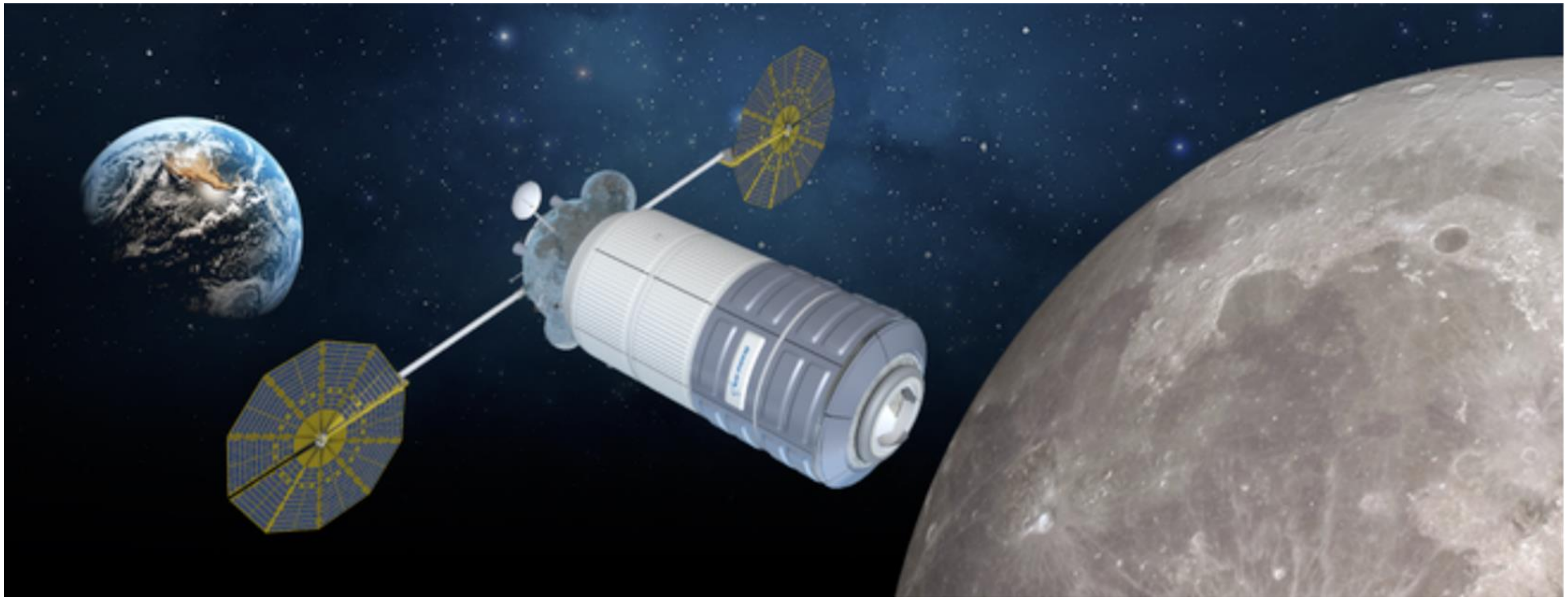
- More power
- S-band communications
- Larger lab/more actuators

Scaling-up for Future Missions



- Can deploy an array of small centrifuges for ongoing low-cost experiments
  - Deploy, retrieve, analyze, re-deploy

Scaling-up for Future Missions



- A large on-orbit centrifuge based on existing service vehicles can be fitted as proving ground to simulate:
  - Asteroids, Comets, Phobos-Deimos: << 1 rpm
  - Moon, Mars: ~10 rpm

Conclusions

BASIC SCIENCE QUESTIONS

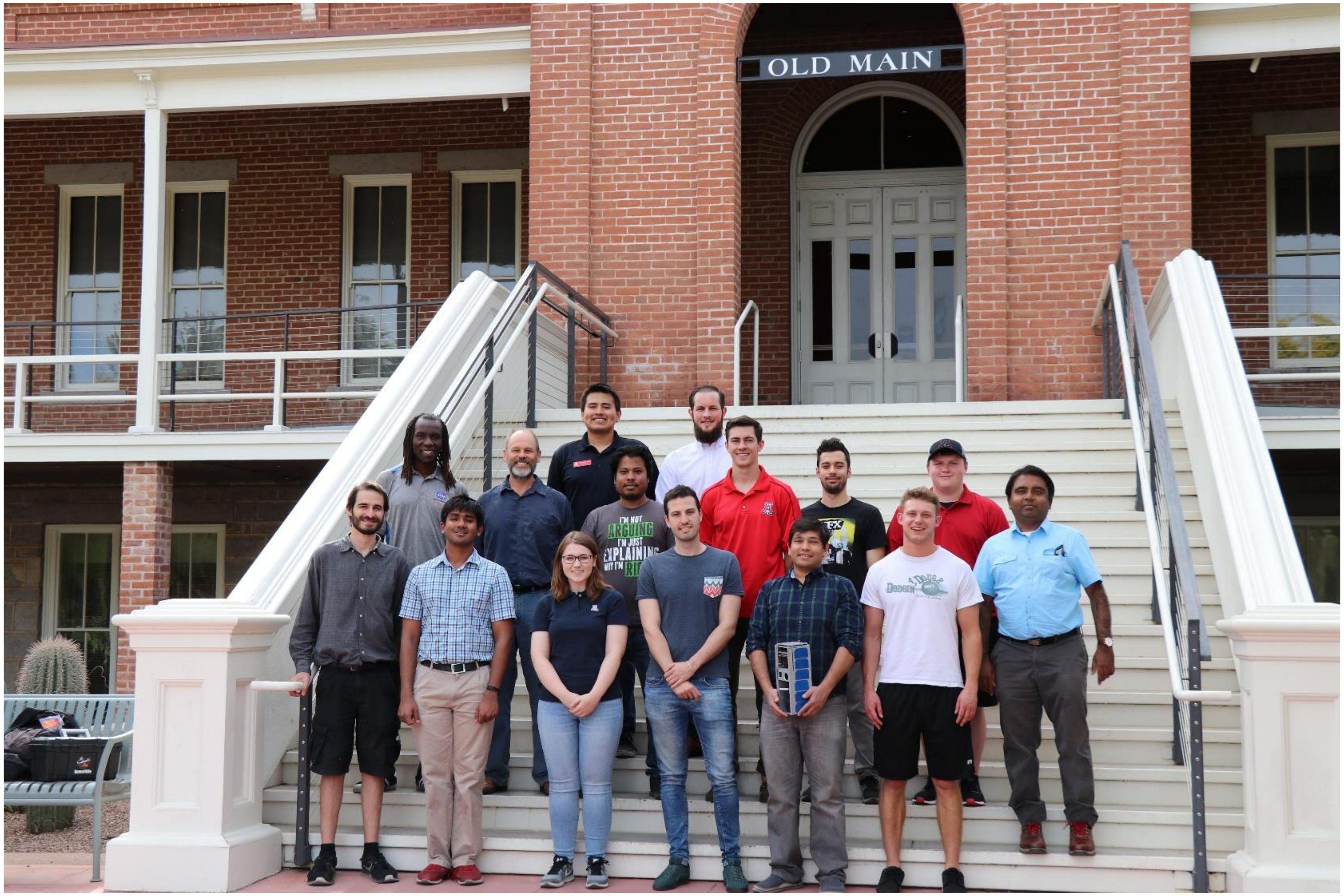
- How much gravity is enough, or just right, for a given artificial or natural process?
- How does a small but constant *g* influence the resting configuration of rocks and airless soils?
- How does presence of small gravity affect the operations of anchors, probes, and excavators?
- Is a small but constant gravity of substantial benefit to humans, crop growth, and medicine?
- In what ways is milligravity an impediment, and in what ways beneficial, to hazardous asteroid mitigation and mining?
- How will we process asteroid regolith in space?

Conclusions

TRL-RAISING FACILITY:

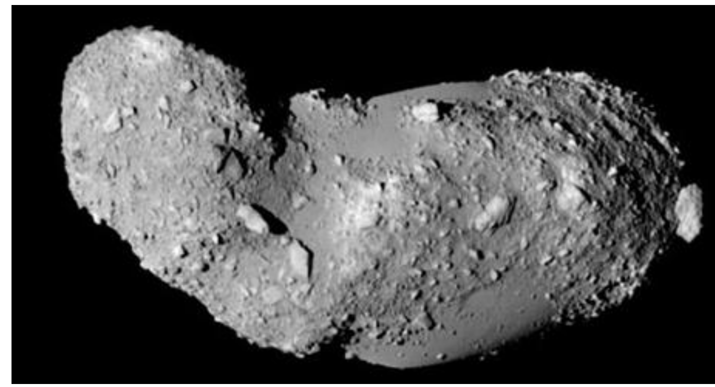
Planetary science *instruments*, scaled or full size *landers*, *spacesuits*, and even *astronauts* can be trained or tested in a milligravity centrifuge laboratory ahead of deep space missions to real asteroids.

The Team



Students and Postdocs Involvement

AOSAT I – (2014-2017)	
Undergraduates	32
Masters Students	15
PhD Students	3
Postdocs	2
Total	**52**



Year	2014	2015	2016	2017
Undergraduates	10	8	8	8
Graduates	6	8	9	9
Postdoc	1	2	2	2
Total	17	17	18	18