Using Low-cost Off-the-Shelf Components for the Development of an On-orbit CubeSat Centrifuge Laboratory

Jack Lightholder*[1], Adam Polak*[1], Fabian Gadau*[1], Andrew Thoesen[1], Jekanthan Thangavelautham[2], Erik Asphaug[2]
School for Engineering of Matter, Transport and Energy[1] School of Earth and Space Exploration[2]

SpaceTREx

Introduction

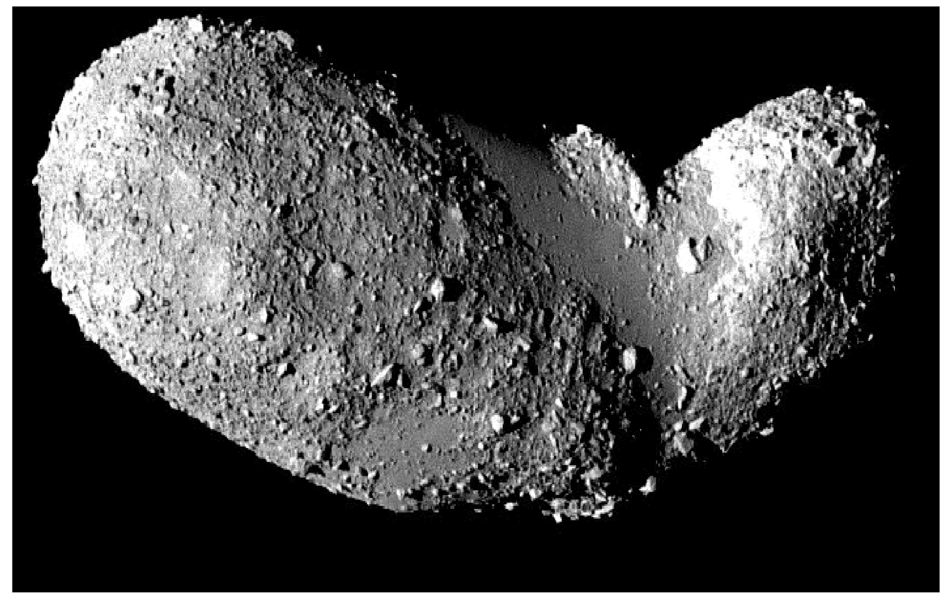

Figure 1. Asteroid 25143 Itokawa

The effect of low gravity and material surface properties on small bodies such as asteroids and comets is not well understood. Missions such as Hayabusa I, Rosetta and Phobos mission show there are significant engineering challenges in landing on asteroids and comets. Accurate physical models of these bodies are critical for future landing, surface exploration and for Insitu-Resource Utilization systems.

Challenges

How to simulate low gravity in space ? Space centrifuge concepts have been proposed and are not new. Current large centrifuge concepts face several technical challenges particularly because you have a spinning spacecraft attached to a rotating one that require large spin stabilizing gyros on both the spinning and non-spinning systems. The momentum from these gyros will need to be periodically dumped using attitude control thrusters.

Solution

Our proof-of-concept utilizes a single 3U (10 cm x 10 cm x 34 cm) CubeSat that is spinning along its major axis and is a simpler design. This produces artificial gravity in the two side chambers. The system is small, low-cost and simple. System specifications are given below and the system layout is shown in Figure 2:

System Specifications	
System:	3U CubeSat Centrifuge spins at 1 rev/min
Instrumentation:	Nitrogen blower, projectile deployer, regolith chambers, vibrator, IMU, Stereo Camera
Mass (Total):	3.9 kg
Payload Chambers:	2
Communications:	UHF (128 Kbps) S-Band (2 MBps)
Life:	1-1.5 Years
Orbit:	Sun-synchronous or LEO

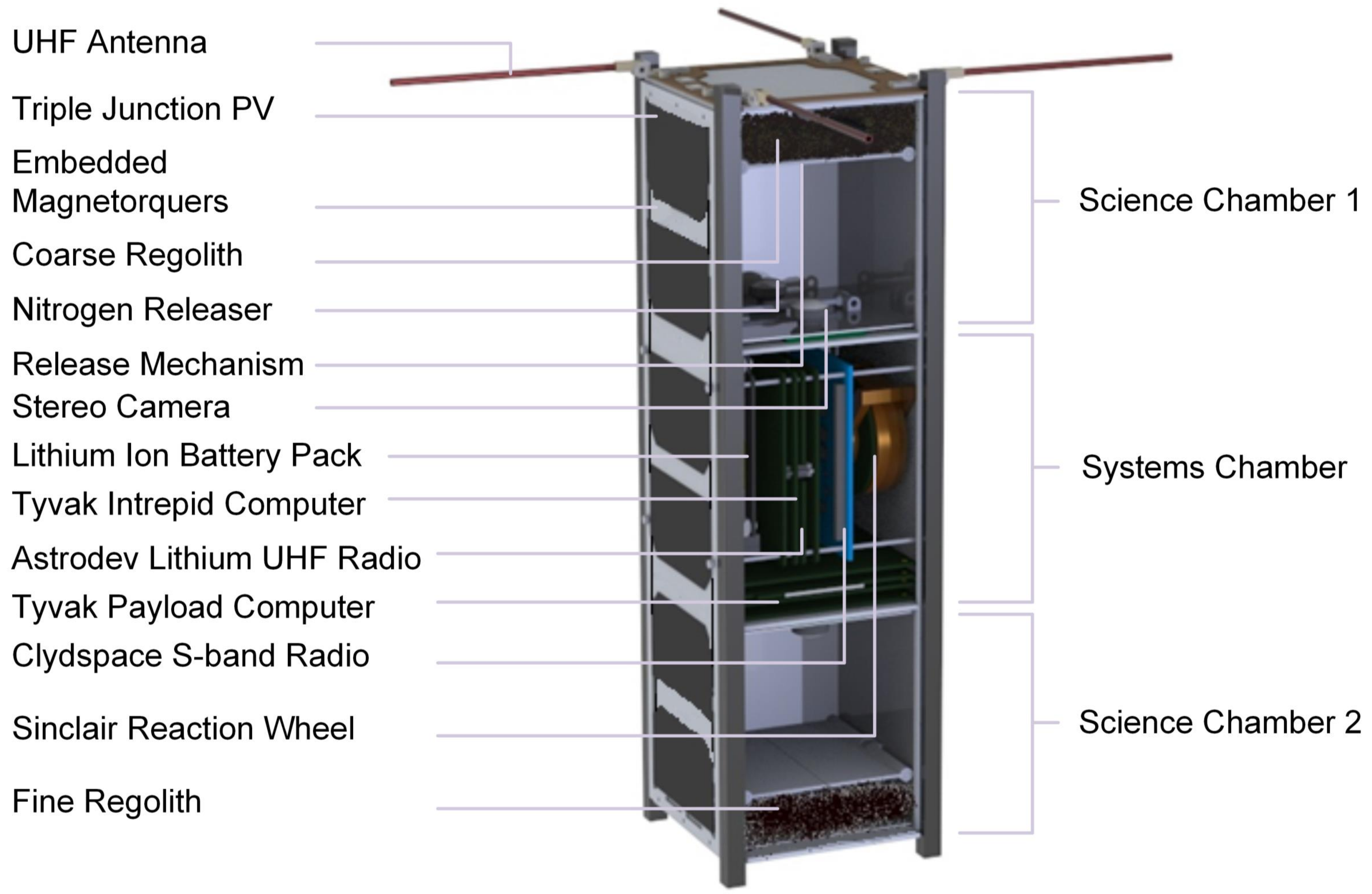

Figure 2. System Design – CubeSat Centrifuge Science Laboratory

Capabilities

- This CubeSat science laboratory can simulate artificial gravity up to 0.1 m/s^2. This is sufficient for simulating asteroid surface with diameter of 200-300 m.
- The CubeSat provides a miniature, low-cost, rapid development platform to perform science and technology experiments on a simulated asteroid surface.
- The CubeSat can be located in low Earth orbit or sun-synchronous orbit with plenty of launch opportunities available as opposed to travelling to a NEO or main belt asteroid requiring significant resources in terms of cost, schedule, engineering expertise (Table 1).

Table 1. Mission Cost Comparison

Mission	Total Cost
Rosetta	1.8 billion
Philae Lander	$260 million
OSIRIS-Rex*	$1 billion*
Hayabusa 2	$275 million
AOSat	$150,000

Discussion

- The selected components except for the science or technology experiments are high TRL, technologically mature off-the-shelf CubeSat components and products (Table 2).
- However it is this combination of off-the-shelf components that is innovative.
- Work is progressing on development of the attitude determination and control system (ADCS), composed of a 3-axis magneto-torquers and reaction wheel for major axis spin.
- The principal development challenges will be focused on verifying the controlled spinning capabilities of the spacecraft, methods to avoid tumbling under worst case scenarios and efficient methods to communicate data to the ground station.

Table 2. System Components

Component	Manufacturer	Model	TRL
Onboard Computer + Power Board	Tyvak	Intrepid ARM9	9
Battery	Tyvak	37Wh Lithium Ion	9
Solar Panels	ClydeSpace	Emcore Triple Junction	9
Primary Communications	Tyvak/Lithium	UHF (AX5042)	9
Secondary Communications	ClydeSpace	S-Band Quasonix NanoTX	9
Magneto-torquers	ClydeSpace	Embedded into PV	9
Reaction Wheel	Sinclair Interplanetary	RE-0.007-4	9
Cameras	IDS	UI-1646LE	9

Future Work

System design progressing towards PDR in spring 2015, CDR Fall 2015 and launch early to mid 2016.

Larger, 6U centrifuge CubeSats being designed to simulate about 9.8 m/s^2 for applications in life-sciences. New deployment technologies being developed to enable higher-g's for lower angular velocities and deployment of bigger solar photovoltaics.