IPPW Short Course

# Planetary Object Geophysical Observer

## Overview

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POGO

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# What is POGO?

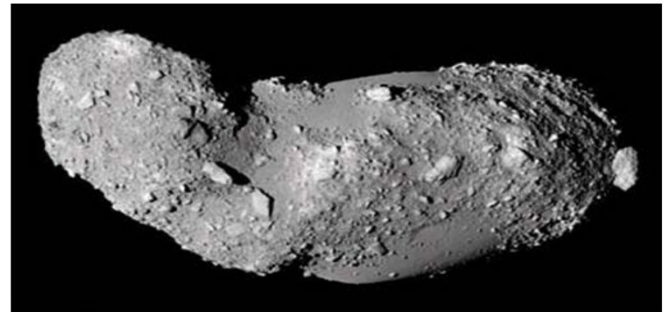
Hopping Lander that measures elemental composition and surface strength of small moons, asteroids and comets

Uses

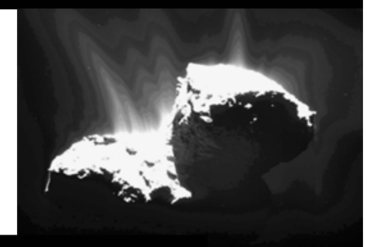
- Gamma Ray Spectrometer (GRS)
- Active X-Ray Spectrometer (AXRS)
- Accelerometers

# Why POGO?

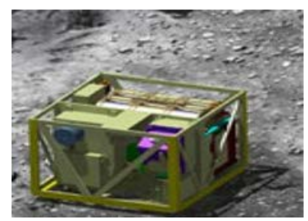
- Understanding small planetary bodies compositions, e.g. comets and asteroids, allows us to learn about the origin and formation of our solar system
  - These observations are best conducted from the surface of the small bodies
- It is important to measure multiple spots on the body to determine heterogeneity of the surface/ subsurface
- Roving on the surface by wheeled vehicles is practically impossible
- Observations can be conducted by landers using propulsion (e.g. cold gas thrusters) to move around or hopping using a mechanical device
  - Platforms must be able to reorient themselves to make sure that they are able to acquire the measurements of their payload
- Philae on Rosetta, Minerva on Hayabusa, MASCOT on Hayabusa-2 are all examples of landers that have attempted or will attempt missions to small planetary bodies



Credit: ISAS, JAXA



Credit: ESA



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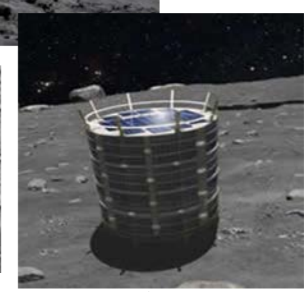
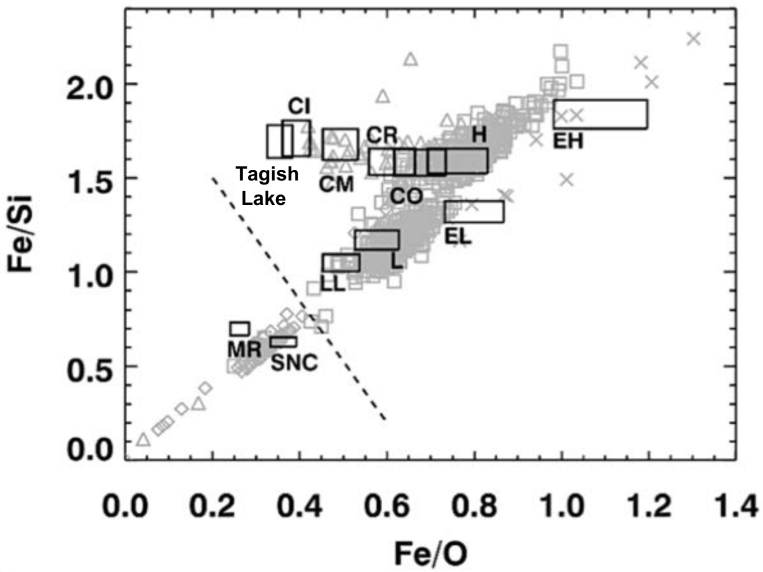
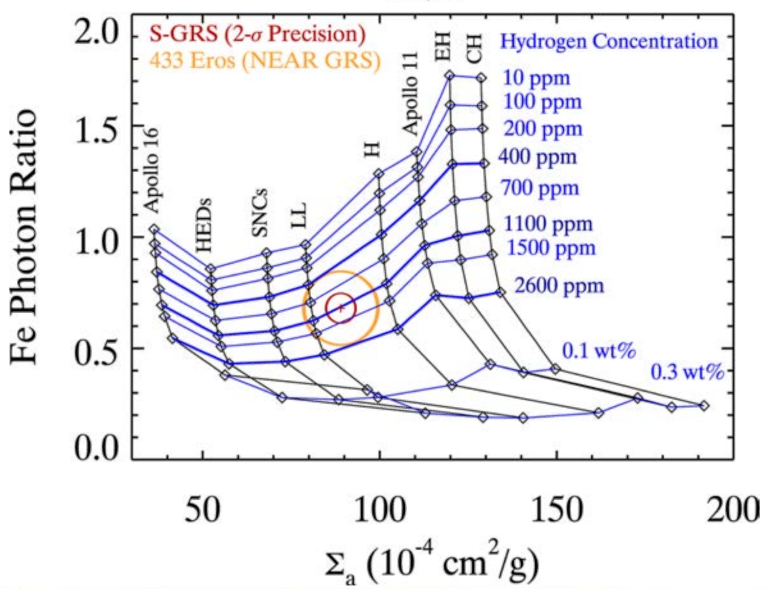


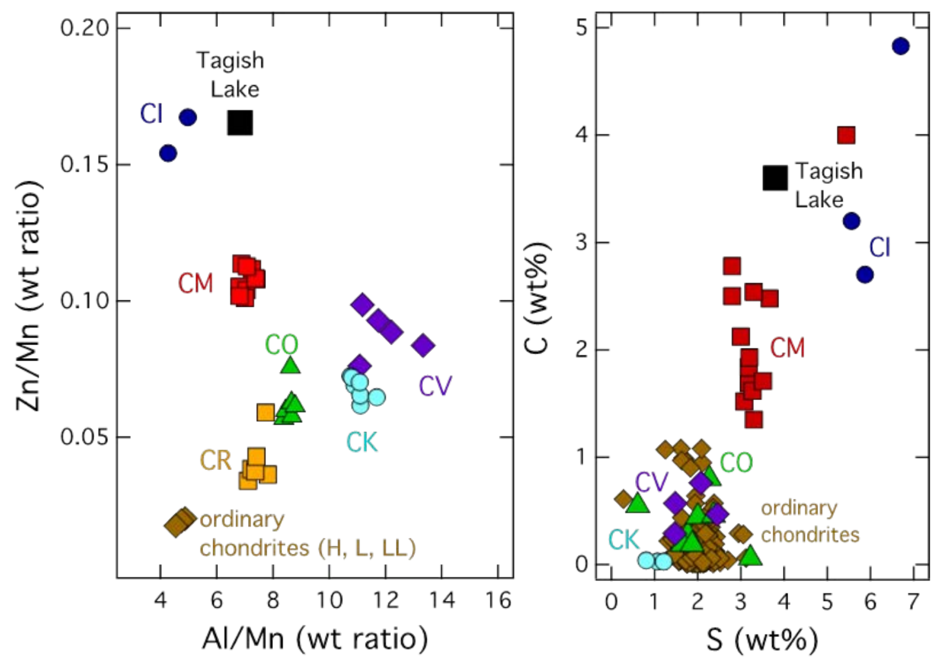
Credit: JAXA

# POGO Provides Comprehensive Chemical Measurements



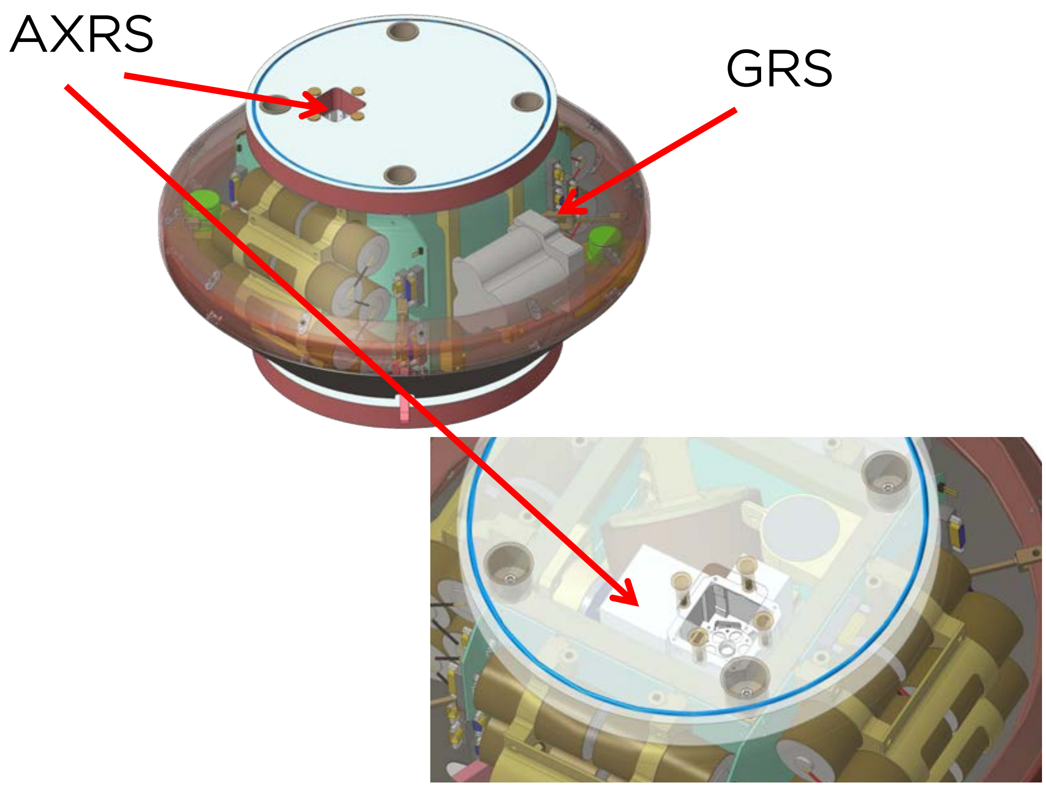

- GRS
  - Major elements distinguish chondrite types and evolved compositions
  - “Indirect neutron spectroscopy” detects H to 100’s ppm [Peplowski et al. 2015]
- AXRS
  - Minor elements distinguish related carbonaceous types
- Both
  - Measuring C, S distinguishes volatile-rich/poor material

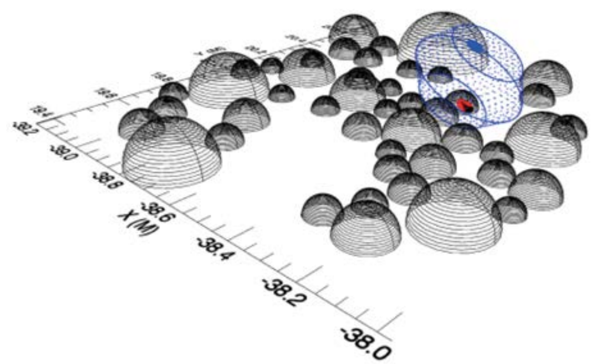


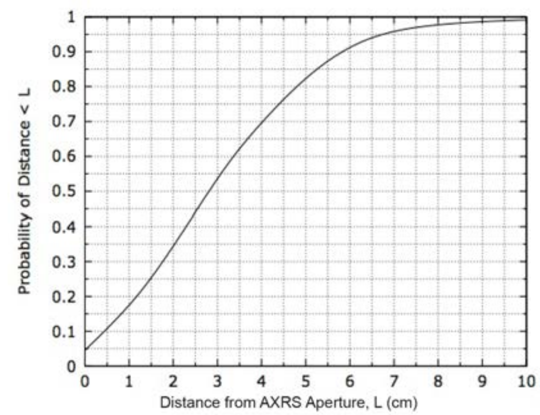
# POGO Science Instrumentation

- AXRS (Active X-ray Spectrometer)
  - Two sensors mounted on POGO oriented 180$^{o}$ to face landed surface.
    - Only sensor facing surface is turned on
  - Able to measure abundances of elements from Na to Zn
  - Each visited location will have an AXRS measurement taken
    - X-ray integration time required: 30 min, compared to 12 hrs for alternative technology (APXS)
- GRS (Gamma Ray Spectrometer)
  - Single instrument consisting of three sensor head assembly mounted in one of four battery bays
  - Measurements reveal presence of O, Mg, Si, Al, K, Fe, H, S, and C
  - GRS will be powered on continuously for duration of POGO mission
    - 24-hr integration time needed for measurements of O, Mg, Si, Al, K and Fe
    - 72-hr integration time needed for measurements of H, S, and C
- 3-axis Accelerometers
  - Provide measurements of regolith strength and porosity of the surface from landing impacts
  - Located on POGO boards

# POGO enables GRS & APXS to perform surface measurements at low risk



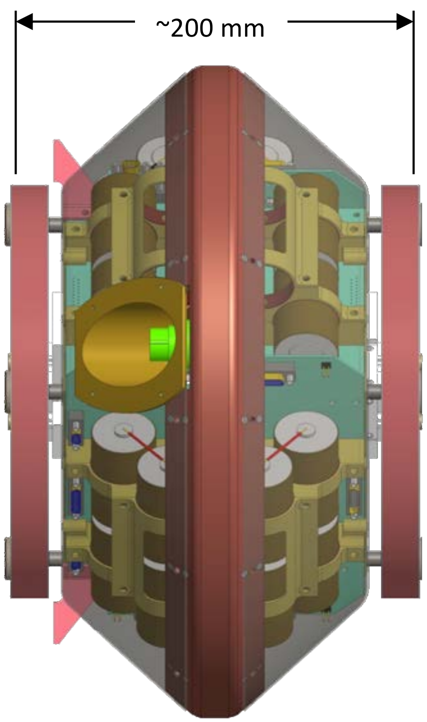



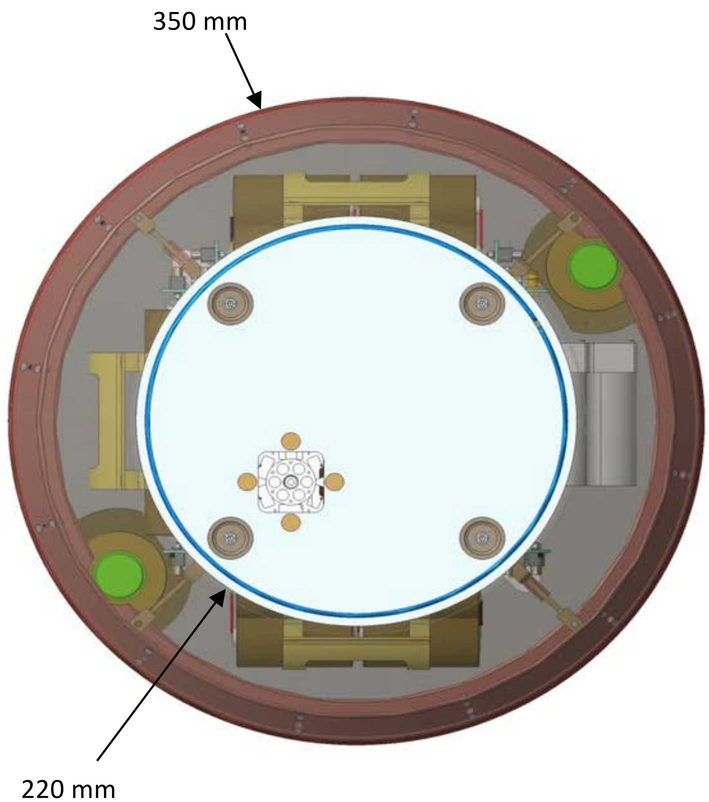



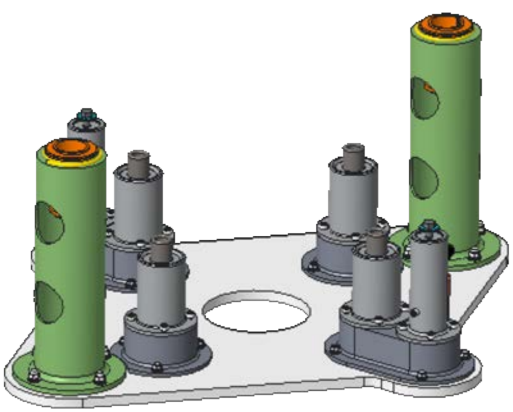

- POGO lands with 1 of 2 flat faces down; both have an AXRS sensor
- Probability of distance of AXRS aperture to surface was modeled by Monte Carlo simulations of POGO coming to rest on an Eros-like blocks surface
  - 99% probability of AXRS within 10-cm design range
- GRS is omni-directional and works in any orientation

# POGO requires few spacecraft resources

- Mass:  13 kg (flyaway) + ~ 3 kg (separation system)
- In cruise: survival heater power: 1 W
- Data Rate to 30 km altitude: ~30 kbps
- Communications: UHF
- Highly autonomous once on surface



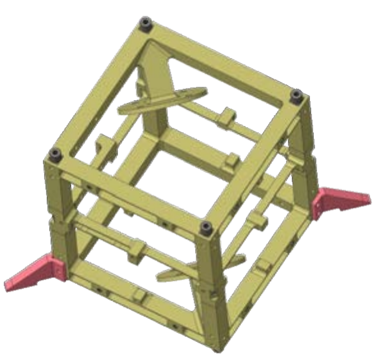



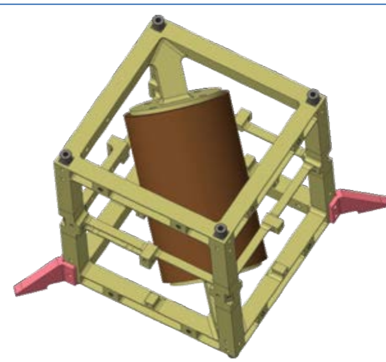



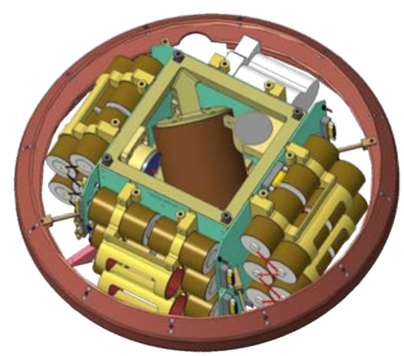
POGO separation system

# POGO subsystems are deliberately kept simple

| POGO Subsystem | Key Characteristics |
|---|---|
| Mobility Mechanism | Voicecoil actuator |
| Structure | Ti; designed to absorb >5 m/s landing shock loads; transfer linear momentum from voice coil into ground for hop |
| Thermal | Thermal vault; keeping constant dissipation |
| Communications | Rugged loop antennas, UHF, 160º beamwidth; transmit-only |
| Power | Primary batteries, allow ~5 days of survival at the surface, depending on # of hops |
| Avionics | Pre-canned sequence of operations; can be updated in flight using S/C umbilical |

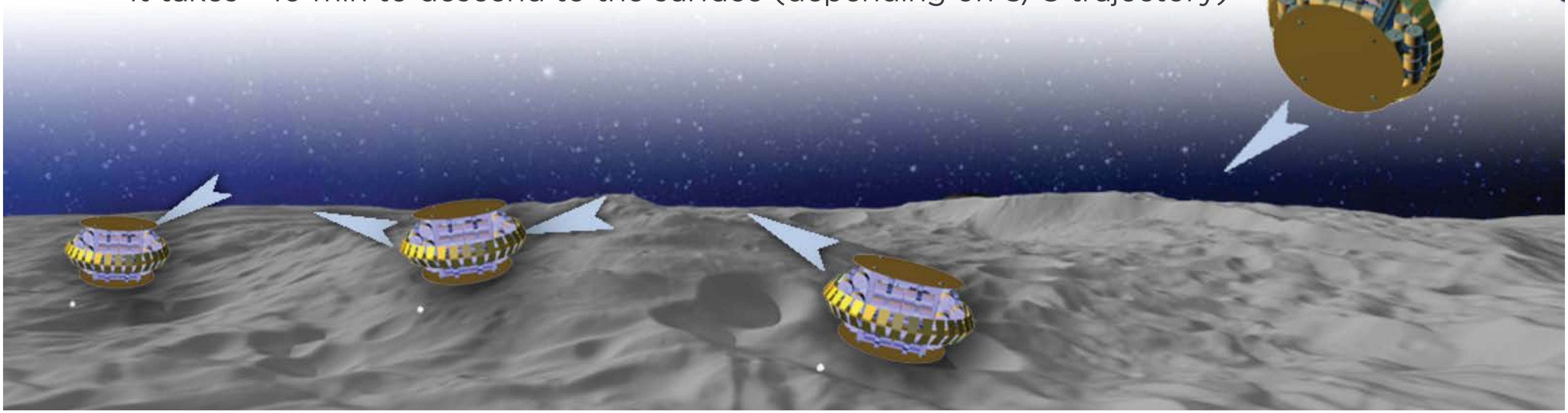






# POGO’s operations are straightforward & low risk

- In cruise, POGO is on the outside of the S/C; S/C provides power, data, and survival heater through umbilical (for software uploads, APXS door actuation, etc.)
- E.g. on Phobos, POGO could be deployed from up to 1.5 km altitude
  - It can land anywhere on the small body surface (sun, shade, any latitude)
- POGO separation system is designed to provide a small push (0.25 cm/s) towards the surface
- Once POGO is released:
  - Power is switched from S/C umbilical to primary batteries
  - POGO starts transmitting its housekeeping data to S/C
  - GRS is on and starting to acquire measurements
- It takes ~ 10 min to descend to the surface (depending on S/C trajectory)



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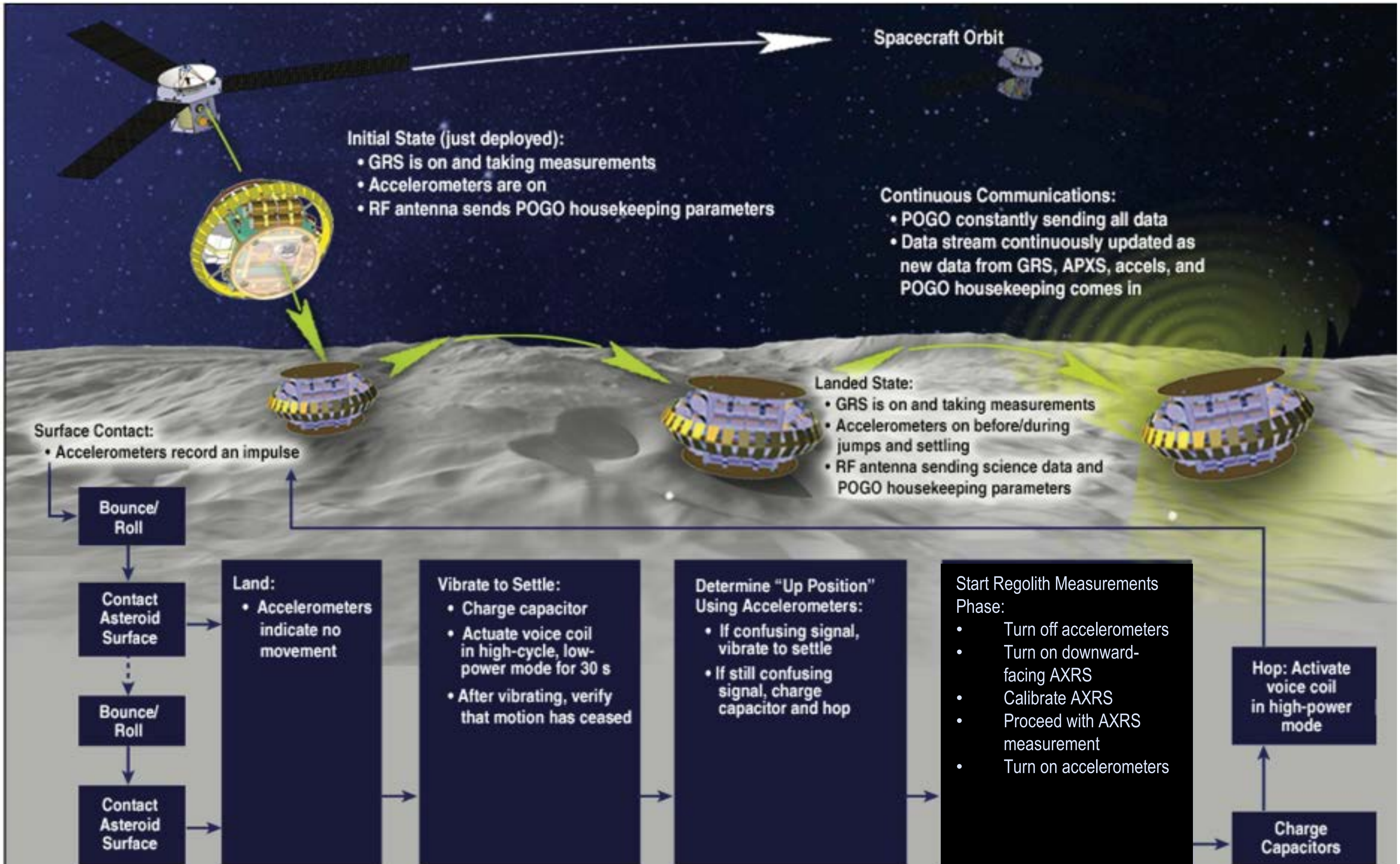
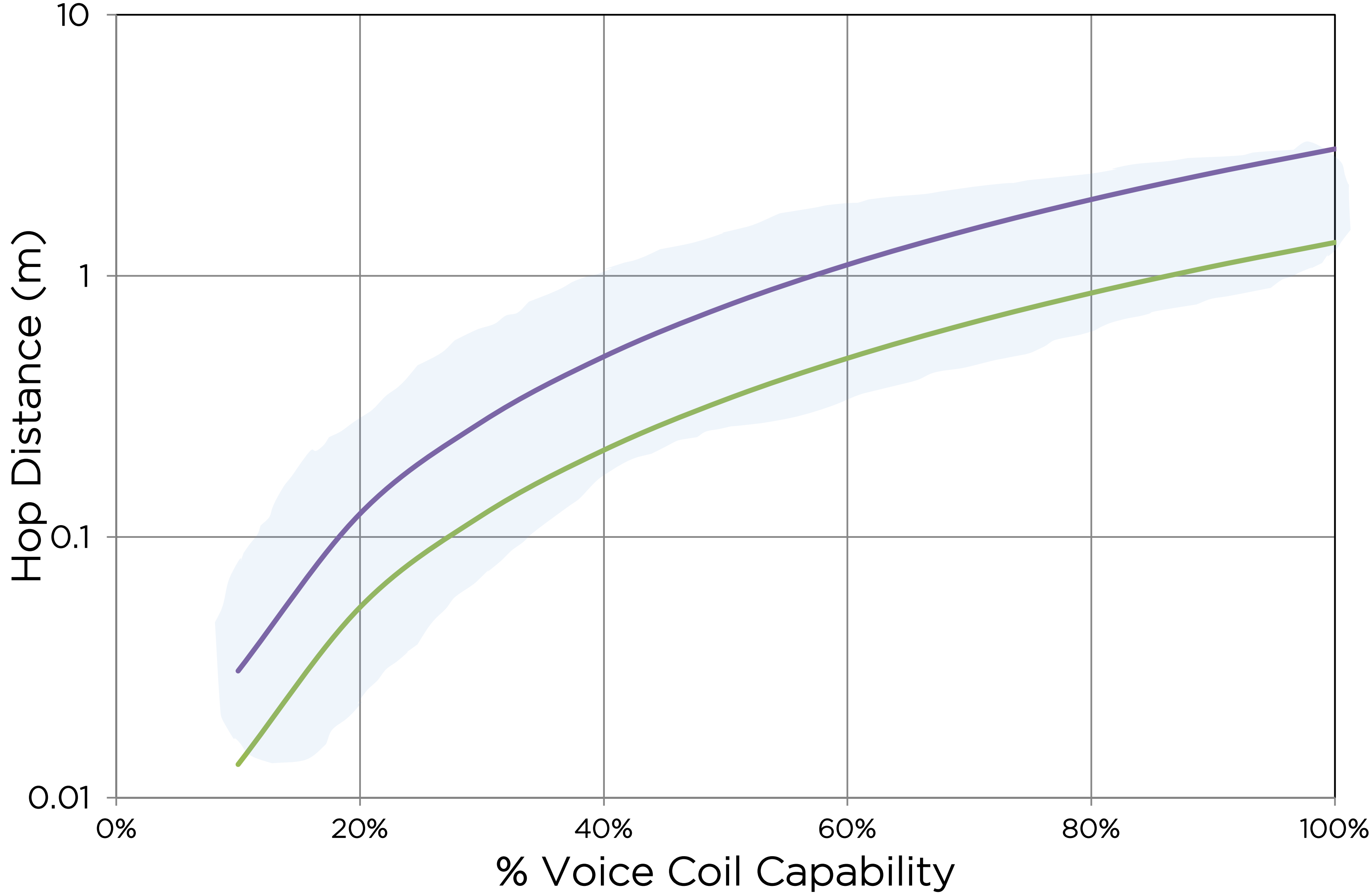
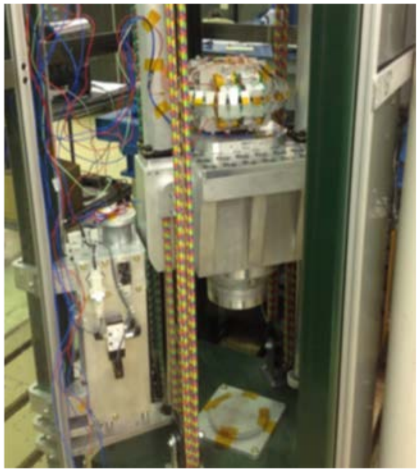


# POGO can hop a few meters on Phobos

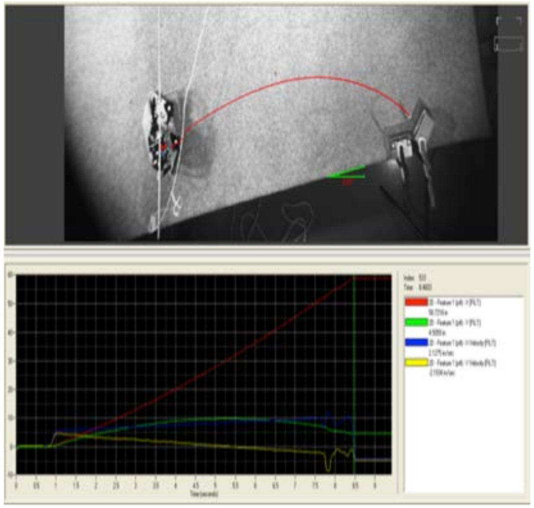


# POGO has been thoroughly tested

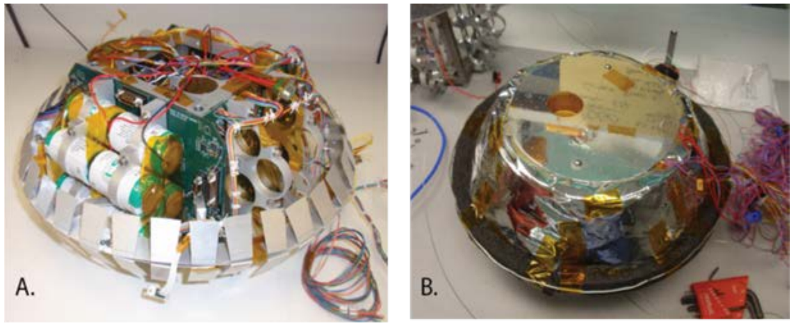
- Voicecoil actuator, batteries, and antenna performance characterized
- Full prototype built up and environmentally tested:
  - Thermal vacuum confirmed that thermal system functions as expected and keeps all of the systems within temperature limits
  - Shock tests confirmed survival to 5 m/s shock in worst case orientation
- Mobility testing performed in 2-D setup
  - POGO was floated on air bearings and actuated on a tilted table, allowing it to travel in a projectile motion
  - Based on angles and velocity, model of impulse vs. current in voice coil was developed



Shock Tests, 2015



Mobility Tests, 2012

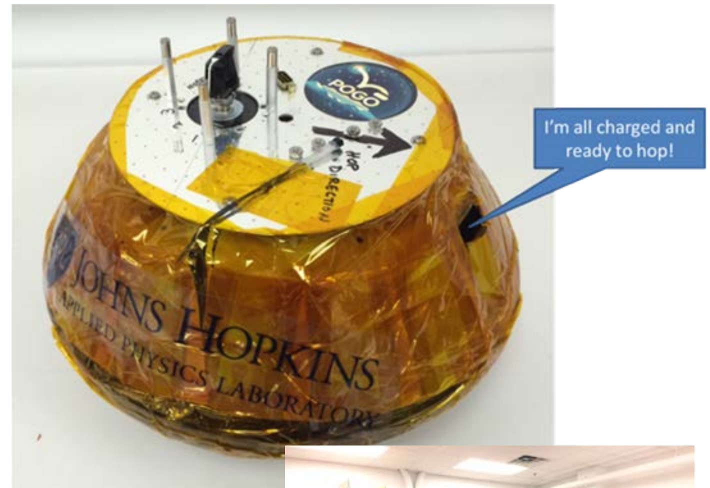


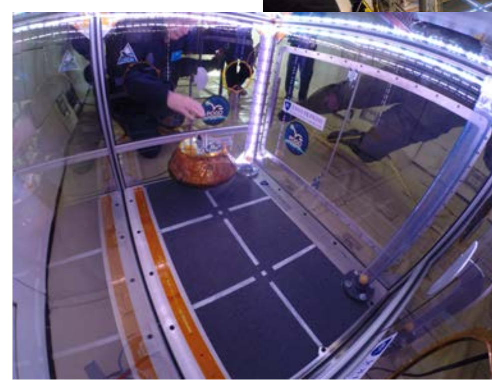

Thermal Tests, 2013

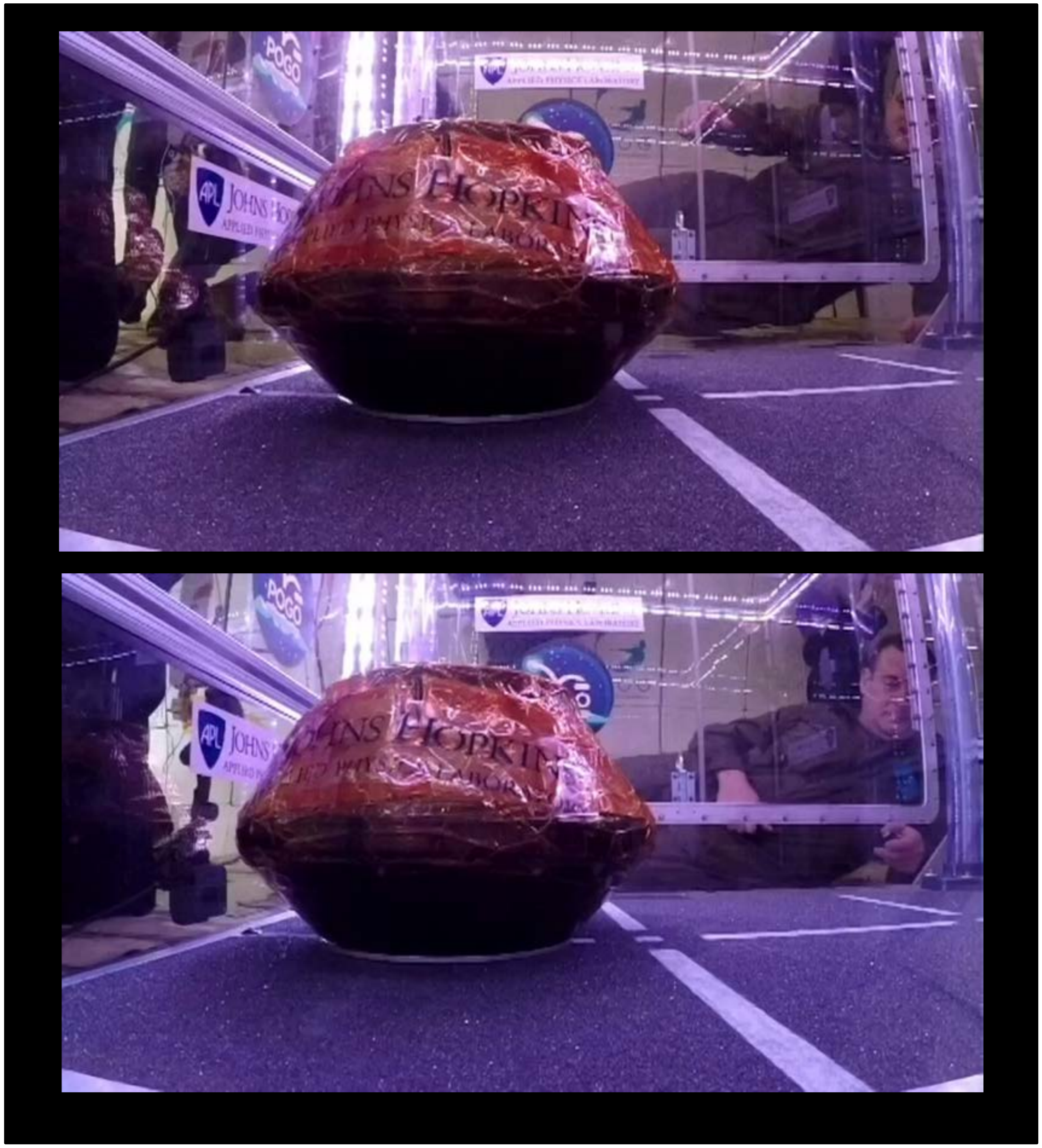
Antenna Tests, 2013

# Testing under Homesteader Grant

- Demonstrated the mobility of the fully assembled prototype in low gravity on the ZeroG flight
- Design, fabrication, and test of the s/c separation system
- Additional system design and test (updates to RF system, qualify POGO to a the range of impact velocities)
- Tested ability to land, hop and communicate in a dusty terrain (e.g. on a comet)
- Battery Lifetime - testing to understand the degradation of the batteries over long cruise





Movies of Hopping

* performed at higher g than expected for Martian moons and other small bodies

# POGO is getting ready to be infused into missions