National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Expanding Science with SmallSats/CubeSats

Outer Planets Analysis Group

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2/2/2016

Introduction

- Advances in satellite technology and sensor miniaturization have JPL looking at what could CubeSats/SmallSats do for Planetary science.

- A new class of <u>small</u> and <u>low cost</u> robotic probes to perform focused high priority science investigations and instrument technology demonstrations is now possible.

EXPLORER

INSPIRE

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Potential Science Applications

that we have thought of so far

Fields and particles

– **Distributed/simultaneous magnetic field for dynamic processes**
– **Dust and gas/plume composition**
– **Radiation**
– **Plasma characterization**

Reconnaissance

– **High-risk site study and reconnaissance (eg crevasses, landing sites, caves, etc.)**
– **Object characterization**
– **Water search**

In-Situ (small bodies)

– **Elemental, Isotopic & Mineralogical composition**
– **Regolith mechanical properties**
– **Surface dust dynamics**

Atmospheric Science

– **Distributed atmospheric measurements**
– **Atmospheric composition (noble gases)**

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Decadal Science Mapping and Instrument Availability

THEME	KEY MEASUREMENTS	OBSERVATION STRATEGY	MICROSAT-COMPATIBLE INSTRUMENTS
Origins	Isotopic, elemental, mineralogical composition	In situ (atmospheres, surface)	APXS, TLS, IR spec, Raman, LIBS Submm spec, UV Spec, Gamma ray spec, Dust spec, MassSpec
		Returned sample (small bodies)	Sample Return Capsule *(possibly Acquisition as well)*
Planetary Habitats	Volatile, organics composition, endogenic activity, heat budget, env	In situ, distributed network, subsurface (e.g., penetrators)	MassSpec, micro-XRF, Geophysics Inst., imaging, IR spec, seismometer
Processes	Atmospheric structure, dust, fields, geology	Close proximity, in situ, distributed networks	Cameras, IR spec, Mag, Transponders, Langmuir probes, MassSpec, TLS, dust counter, plasma
Human Exploration (SKGs)	Dust, fields, radiations, Dynamical properties, Mechanical properties, ISRU (composition)	Close proximity, in situ, extreme environments	Dust Counter, imaging, APXS, Geophysics Inst., accelerometers Subsurface probing, neutron spec, IR spec, radar, seismometer

Green = exists Orange = in development Red = does not exist yet

J. Castillo-Rogez

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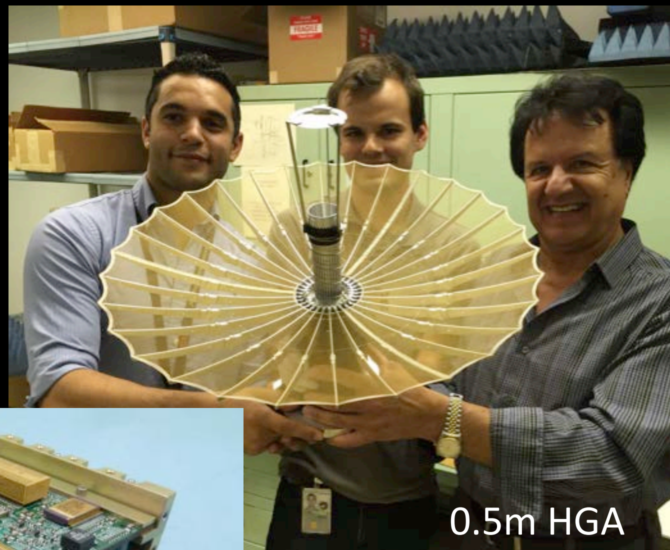
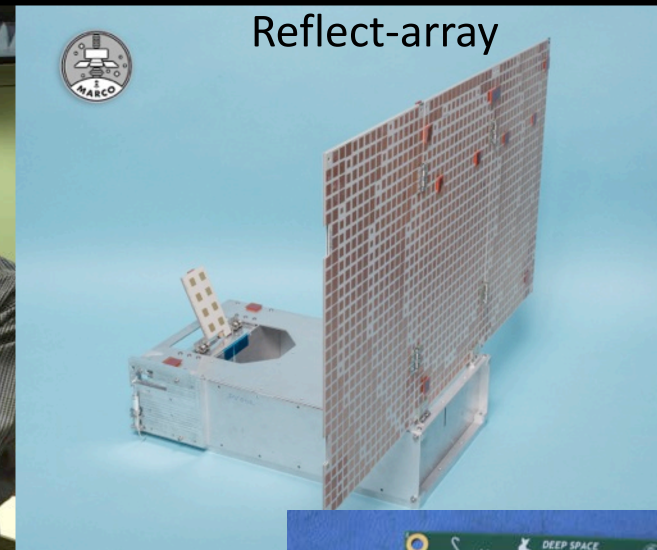
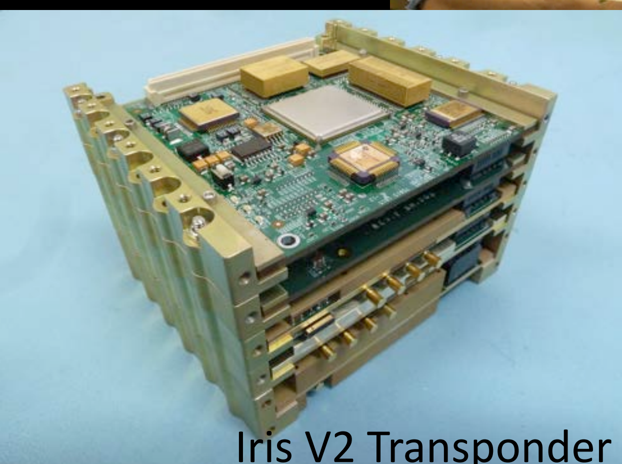
Current Capabilities and Investments



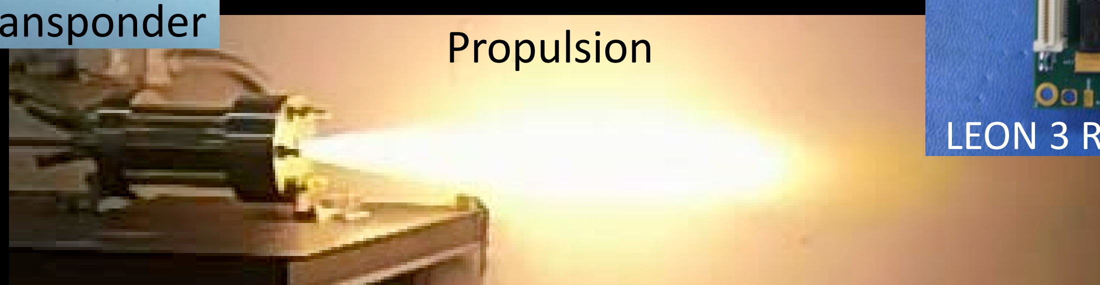
0.5m HGA



Reflect-array



Iris V2 Transponder



Propulsion

LEON 3 Rad-hard Computer

INSPIRE

Interplanetary NanoSpacecraft Pathfinder In a Relevant Environment

PI: Dr. Andrew Klesh, Jet Propulsion Laboratory
PM: Ms. Lauren Halatek, Jet Propulsion Laboratory

University Partners:
- *U. Michigan – Ann Arbor*
- *Cal Poly - San Luis Obispo*
- *U. Texas – Austin*
- *U. California – Los Angeles*

Collaborator:
- *Goldstone-Apple Valley Radio Telescope (GAVRT)*

Technology Demonstration Mission Objectives:

- **Demonstrate and characterize key nano-spacecraft abilities** including DSN-compliant telecommunications, navigation, command & data handling, relay communications, and deep-space reliability / fault tolerance
- **Demonstrate science utility** (Compact Vector Helium Magnetometer & Agile Science Algorithms)
- **Technology demonstration platform** for low-cost COTS / university components

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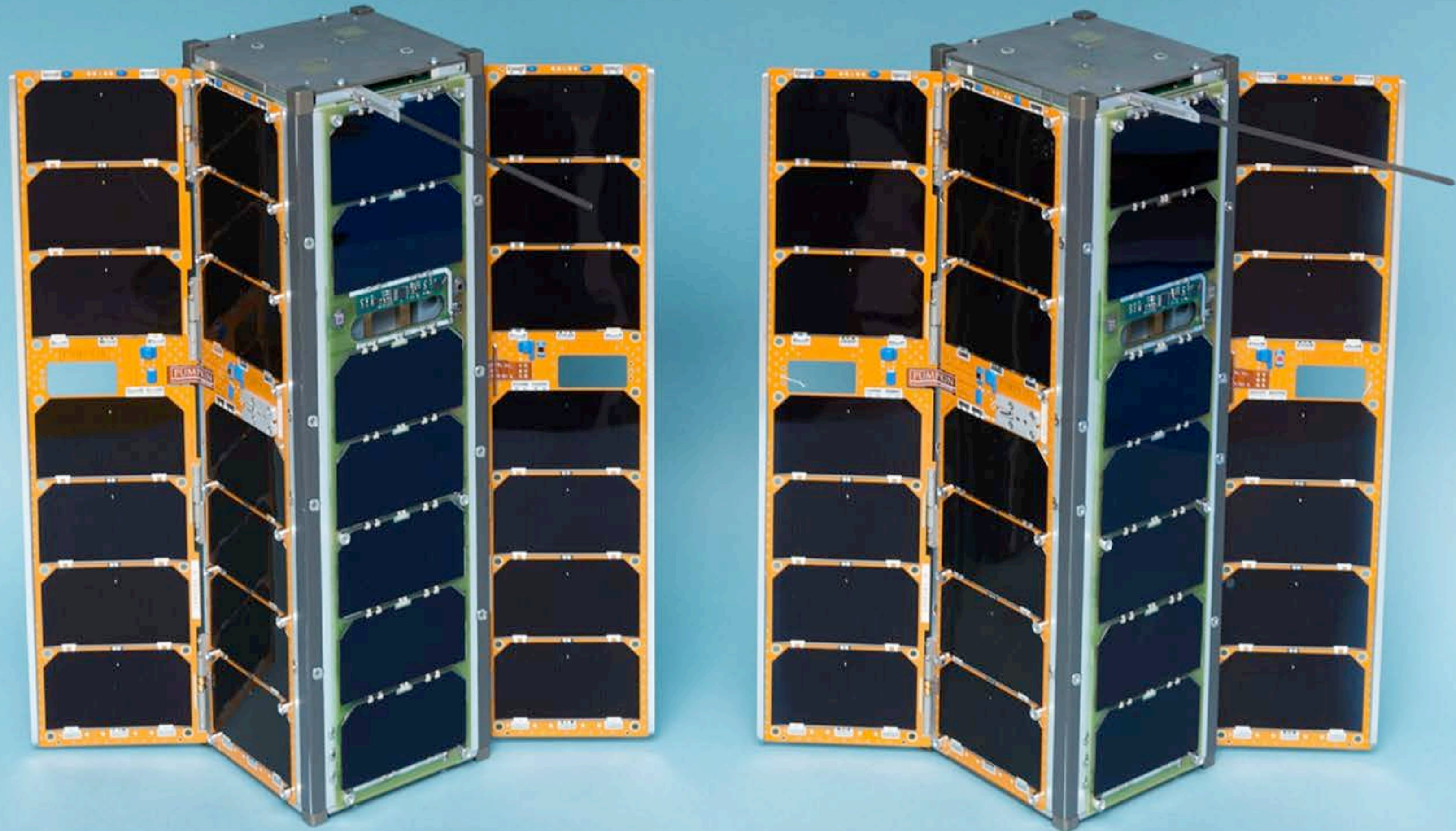
CAL POLY GAVRT MICHIGAN THE UNIVERSITY OF TEXAS AT AUSTIN

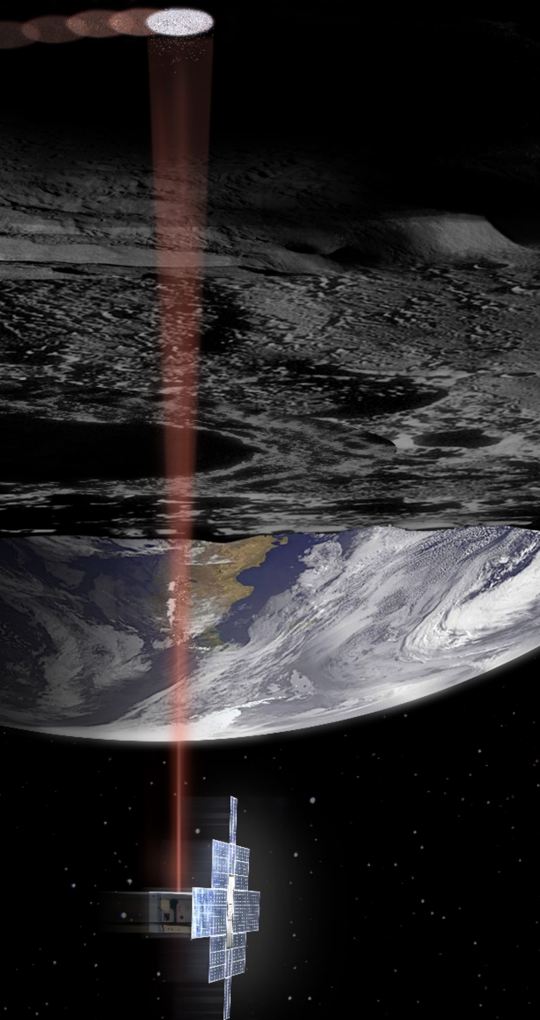
INSPIRE Flight Spacecraft



Completed I&T on Cost and Schedule in June 2014

Lunar FlashLight Overview

To detect surface ice deposits in south pole lunar cold traps



Measurement Approach:

PI: Barbara Cohen

- *Lasers in 4 different bands illuminate the lunar surface with a 3 deg beam (1Km).*
- *Laser light reflected off the lunar surface enters the reflectometer to distinguish water ices from regolith.*

Orbit:

- **Elliptic:** 15-9000Km
- **Period:** 12hrs
- **Perilune:** South Pole
- **Sci Pass:** <6min

Teaming:

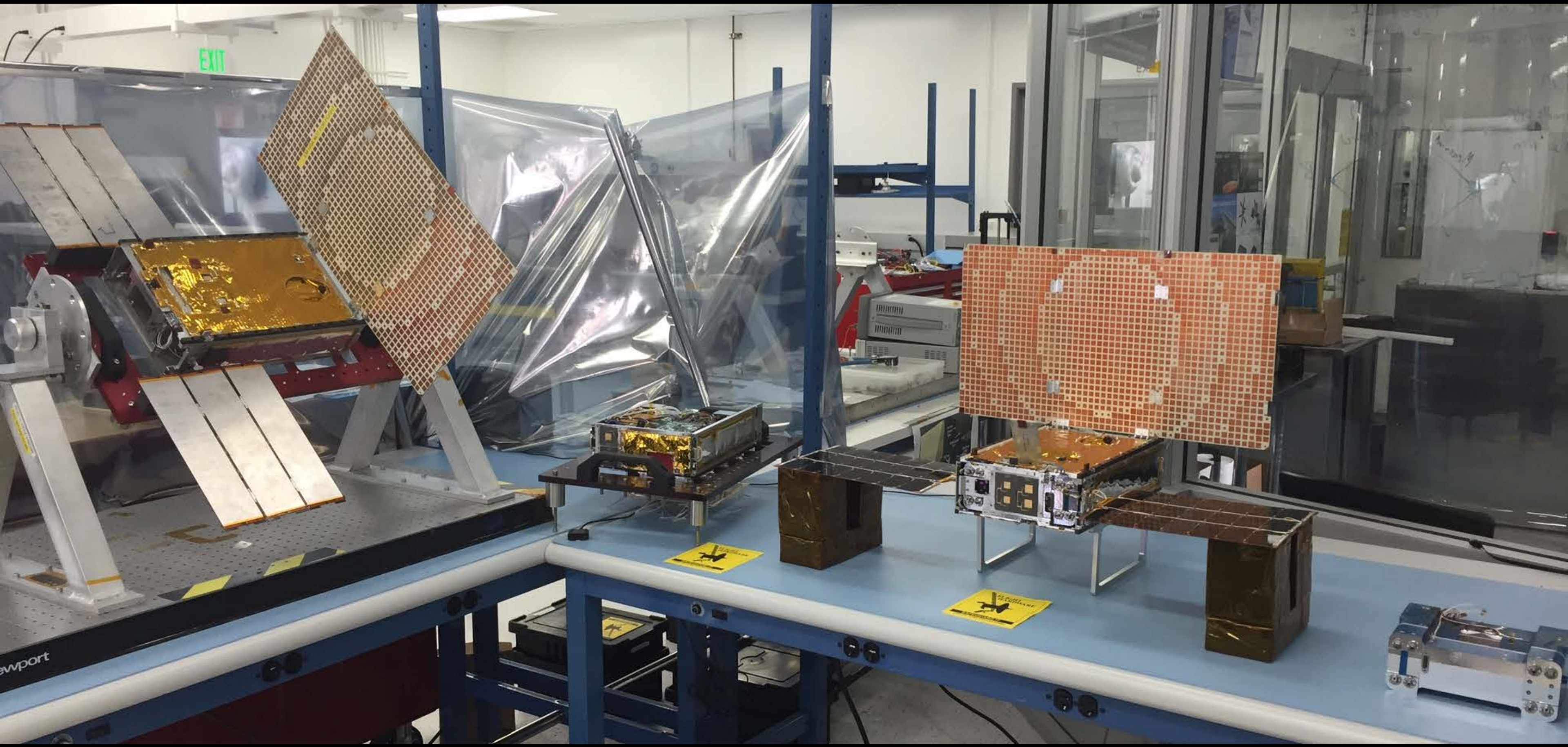
- *JPL-MSFC*
- ***S/C 6U - 11 kg:** JPL*
- ***Mission Design & Nav:** JPL*
- ***Propulsion:** 'Green prop' (MSFC)*
- ***Payload:** 4 laser bands and reflectometer*
- ***I&T:** JPL*

Milestones/Phases

- **Launch:** SLS EM1, 7/2018
- **LOI:** L+6 months
- **Orbit:** 2-4 months

Mars Cube One (MarCO)

8 kbps EDL telecom relay for InSight



Two Spacecraft in 14 months

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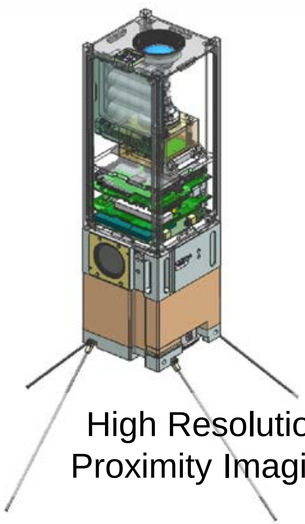
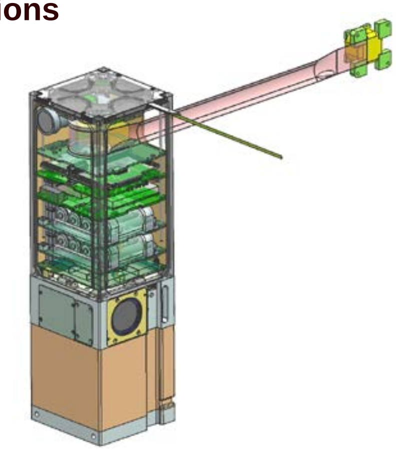
Planetary NanoSat Concepts

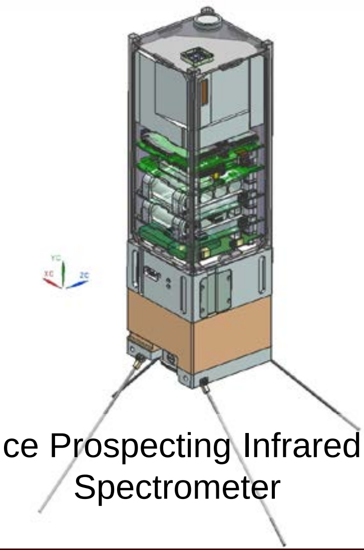
Secondary Orbiters and Flyby Constellations



High Resolution
Proximity Imaging

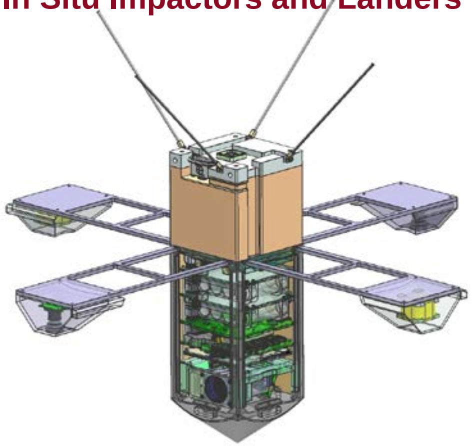


Distributed, Simultaneous Particles
& Fields Measurements



Ice Prospecting Infrared
Spectrometer

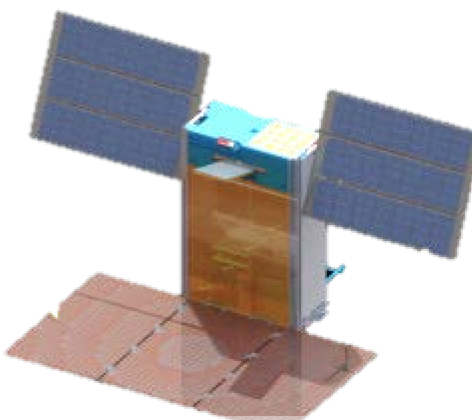
In Situ Impactors and Landers



Asteroid/Comet Instrumented
Surface Penetrator

Surface Landing w/ Gamma
Ray Spectrometer

Deep Space Reconnaissance

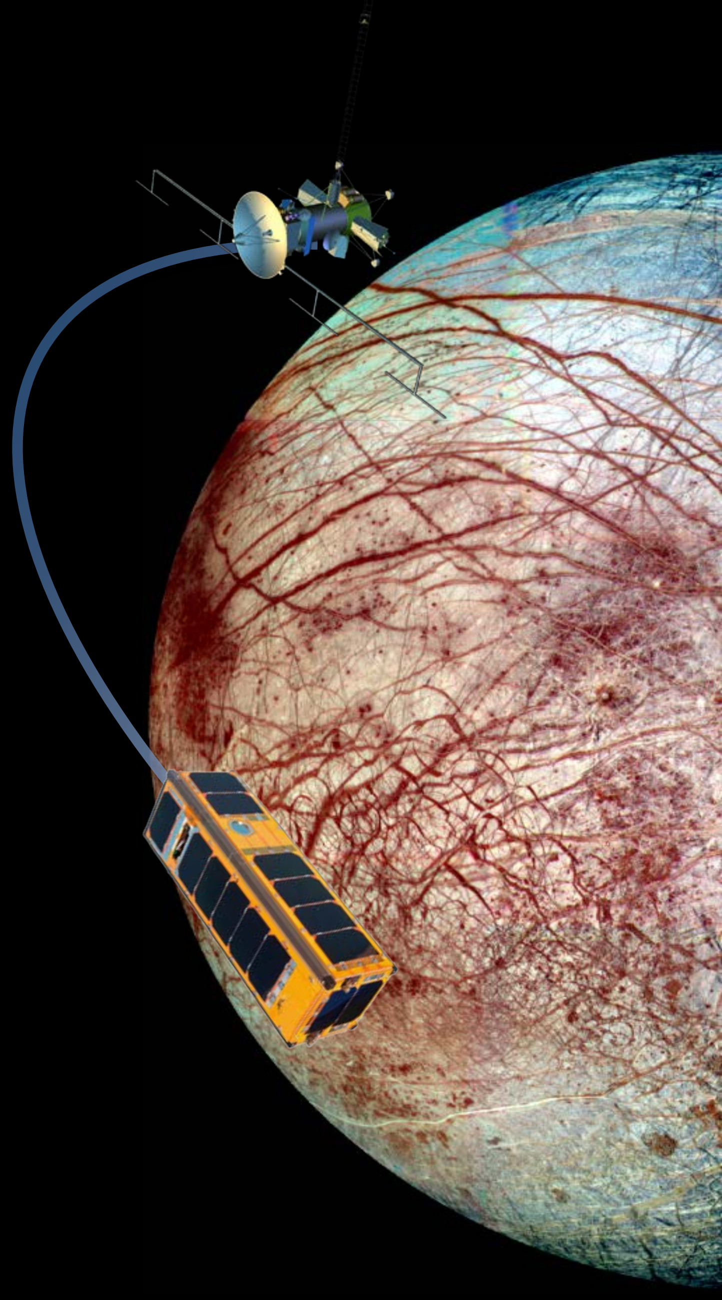


Deep Space Navigation & Radio
Science Demonstrations

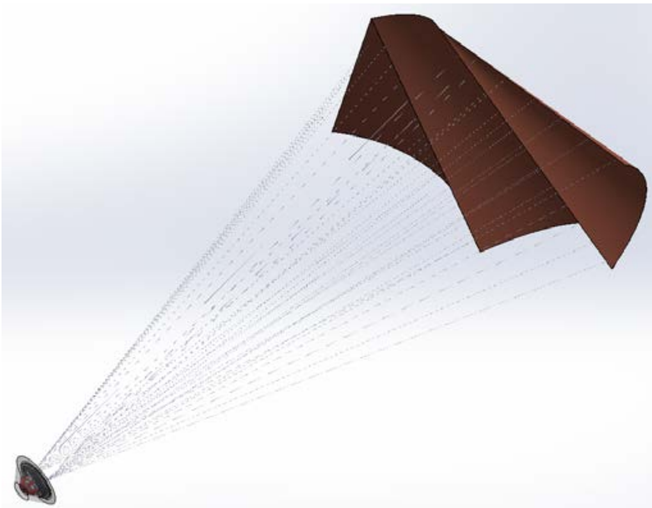
Recent Studies

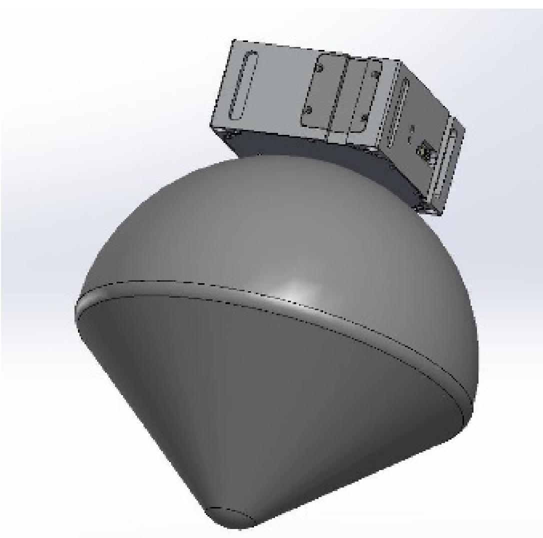
Europa

- 10 Universities were funded to do studies pre-instrument selection.
- Europa science measurements requested/responses:
  - Landing site reconnaissance – 1
  - Gravity Science - 0
  - Magnetic fields – 5
  - Atmospheric and plume Science (dust composition, gas composition, isotopic composition) – 2
  - Radiation Measurements - 2
- Results were innovative!



Tailoring Form Factor to Different Applications





Atmospheric Probe
(MarsDrop, Aerospace, JPL)

Small Body Hoppers
(Hedgehog, Stanford/MIT/JPL; POGO, APL)

Conclusion

- Smallsats/CubeSats have the potential to enable decadal-class science
  - *Innovative capabilities (instruments and engineering) are being created*
- *We have found that these kinds of missions are a great training ground for early career hires*
- *In the future, these kinds of missions will present greater opportunities for Universities and students to develop probes and perform planetary science*