JPL Innovation Foundry

JPL Does Cubesats

Tony Freeman*
Manager, Innovation Foundry

April 2013

- With a lot of help from the Cubesat Kitchen Cabinet:
  C. Norton (3X/8X), J. Baker (4X/6X), A. Gray (7X), L. Deutsch (9X)

Explorer 1 - JPL's Origins in Small Spacecraft

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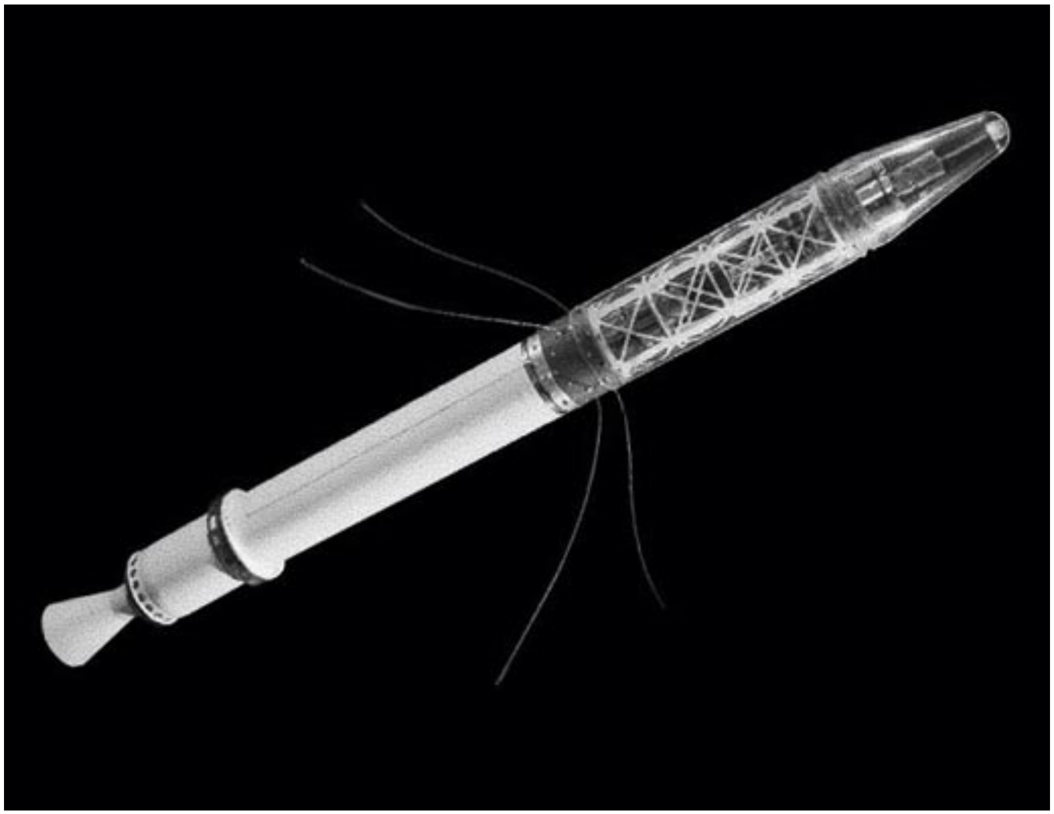

Explorer 1 – First US Satellite - Launched on January 31, 1958 – Cape Canaveral, FL

Courtesy: JPL Photo Archives

Explorer 1 - JPL's Origins in Small Spacecraft

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Explorer 1 – First US Satellite - Launched on January 31, 1958 – Cape Canaveral, FL

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Explorer 1 - JPL’s Origins in Small Spacecraft

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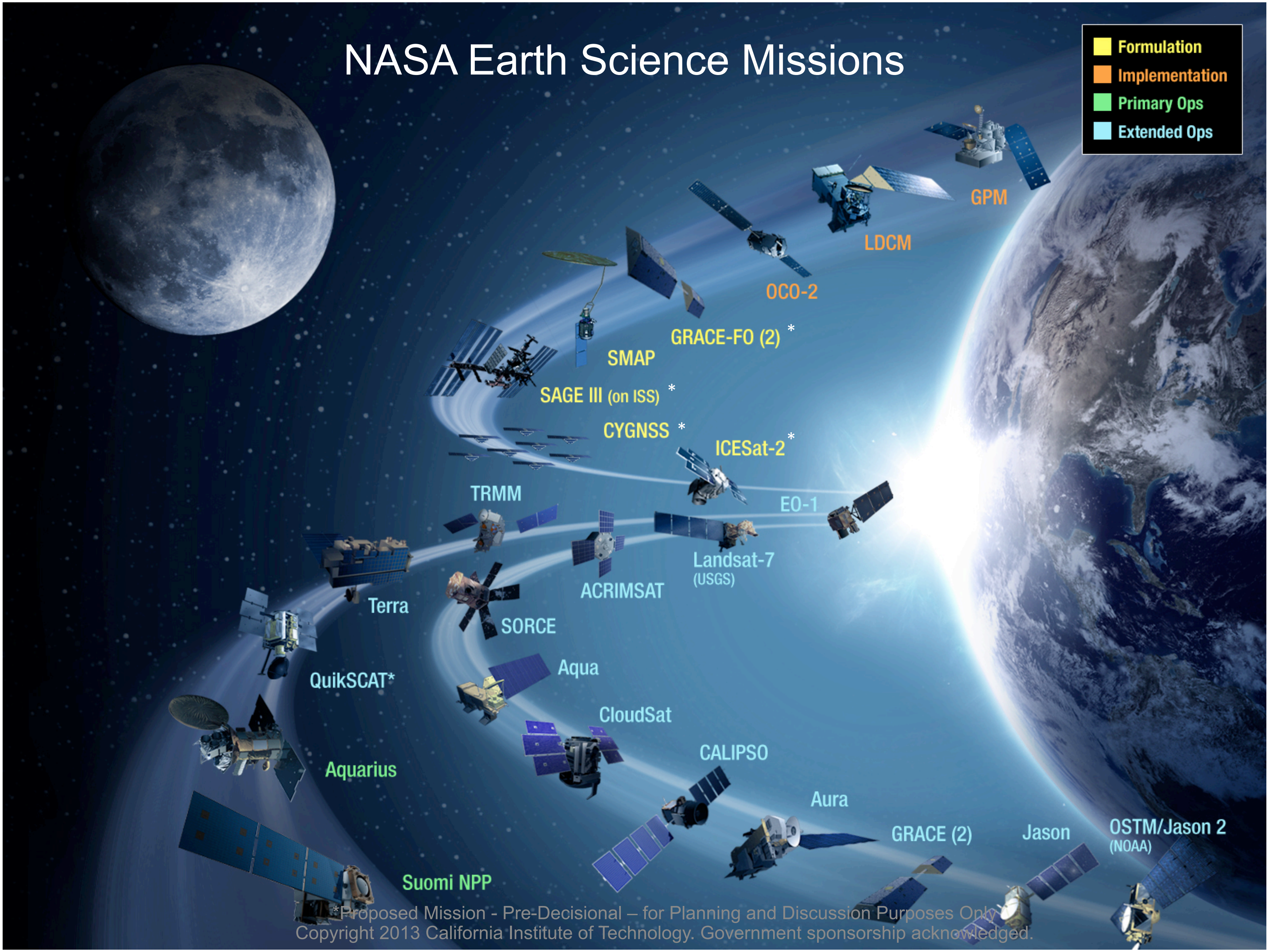
Explorer 1 – JPL/Army Joint Launch – Nervous wait for ground station acquisition

Courtesy: JPL Photo Archives

Explorer 1 - JPL's Origins in Small Spacecraft

Courtesy: JPL



NASA Earth Science Missions
Formulation
Implementation
Primary Ops
Extended Ops
GPM
LDCM
OCO-2
GRACE-FO (2) *
SMAP
SAGE III (on ISS) *
CYGNSS *
ICESat-2 *
EO-1
TRMM
Landsat-7 (USGS)
ACRIMSAT
Terra
SORCE
QuikSCAT*
Aqua
CloudSat
Aquarius
CALIPSO
Aura
GRACE (2)
Jason
OSTM/Jason 2 (NOAA)
Suomi NPP
*Proposed Mission - Pre-Decisional – for Planning and Discussion Purposes Only
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Dawn – Understanding the Processes of Solar System Evolution

Courtesy: McRel

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Why Cubesats? Why Now?

- Cubesats have been around since 1999
- They have been through a lengthy 'Sputnik' period
- Cubesat spacecraft capabilities have advanced…
- And they are now at their 'Explorer-1' moment:
  – 2009 JPL begins technology validation payloads (Earth Science)
  – 2010 U. Mich Radio Aurora Explorer (Heliophysics)
  – 2011 Rob Staehle (JPL) Interplanetary cubesat NIAC study funded
  – 2014 MIT/Draper Labs Exoplanetsat cubesat (Astrophysics)
  – 2014 MIT/LL MicroMAS cubesat radiometer (Earth Science)
  – 2014 JPL RACE/CHARM μwave radiometer (Earth Science)
  – 2 interplanetary cubesat conferences
  – Cubesat ideas proposed to Mars program at recent LPI event
  – CubeSat ideas explored for Outer Planet missions (Europa)
  – 2014 JPL's proposed INSPIRE could be the first cubesat to fly beyond Earth orbit (we think)
- Cubesats beyond Earth orbit would be an obvious next step for JPL

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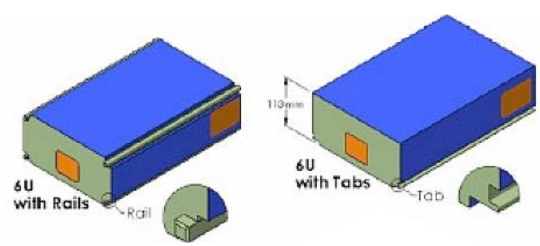
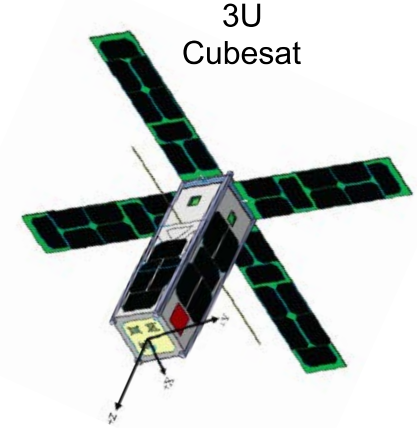
Cubesat Capabilities have advanced

- Position and Attitude Determination and Control
  - Active systems using reaction wheels, torquers, and sun sensors have provided <0.2 deg RMS
  - 3-sigma 2.3 arcsecond pointing has been demonstrated in lab
  - Position knowledge typically obtained by NORAD TLEs, or occasionally GPS
- Propulsion
  - 20 m/s cold gas systems have flown
  - JPL is developing a small (0.5-1U) propulsive stage (MEP) that could provide ~1 km/sec
- Command, Communications and Control
  - Microcontrollers (especially the MSP430, PIC and Atmel chips) have primarily been flown, Linux-based computers, ARM chips, and now FPGAs have all been demonstrated.
  - UHF L3 transceiver or Software Defined Radio >1.5 Mbps
- Power
  - Several deployable solar array configurations, capable of providing up to 50 W average
- Structure
  - CubeSat structure is driven by the dispenser design
  - Currently only 3U dispensers exist; expect 6U flight demo in 2013 or later

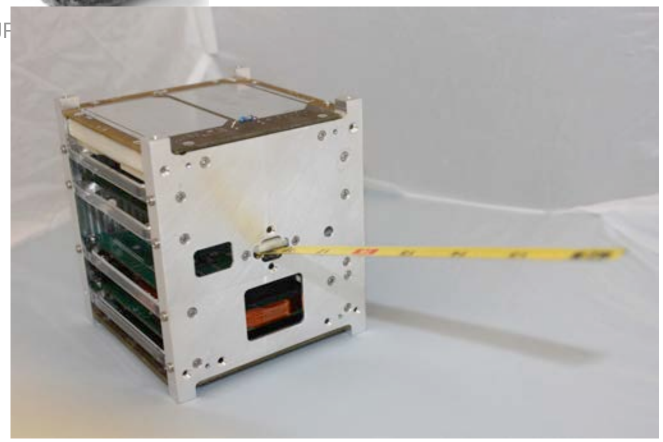


6U
Cubesat

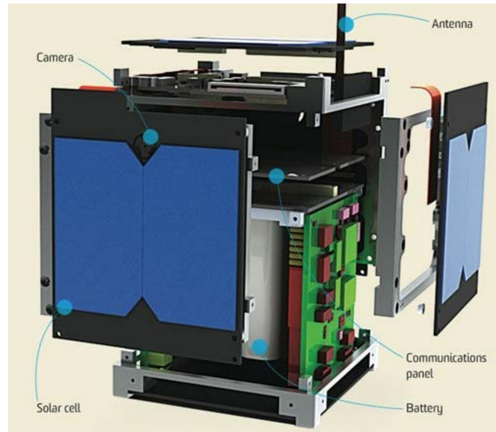
3U
Cubesat



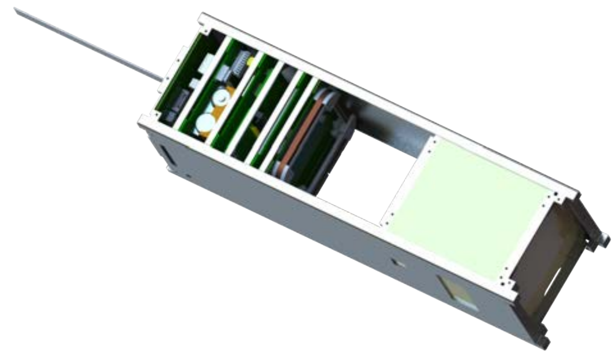
JPL is Already in the CubeSat Business



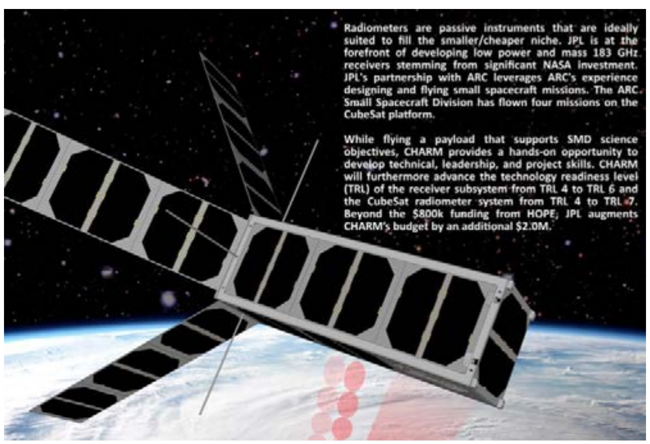
M-Cubed/COVE
High data-rate on-board processing
P. Pingree: JPL, U. Michigan



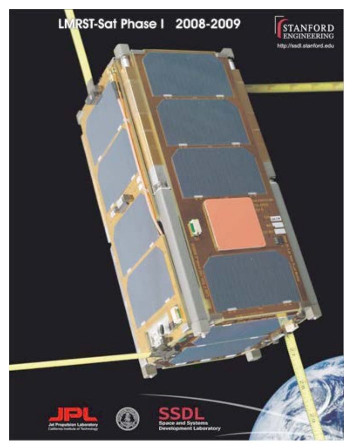
IPEX
Autonomous low-latency product generation
S. Chien: JPL, GSFC, Cal Poly SLO



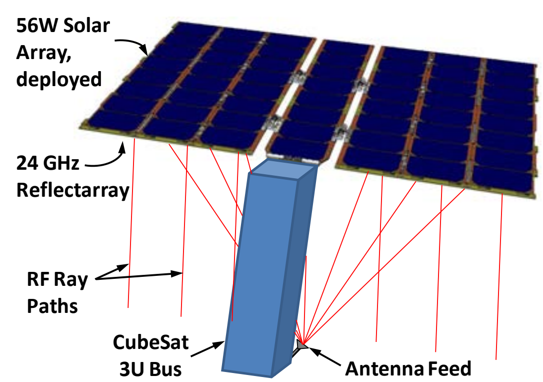
GRIFEX
Unprecedented frame-rate ROIC/FPA
D: Rider JPL, U. Michigan



RACE
183 GHz radiometer for precipitation science
B. Lim: JPL, UT Austin



LMRST*
Deep Space Radio Transponder
C. Duncan: JPL, Stanford



ISARA*
Integrated Solar Array & Reflectarray Antenna
R. Hodges: JPL, Pumpkin Inc.

*Proposed Mission - Pre-Decisional – for Planning and Discussion Purposes Only

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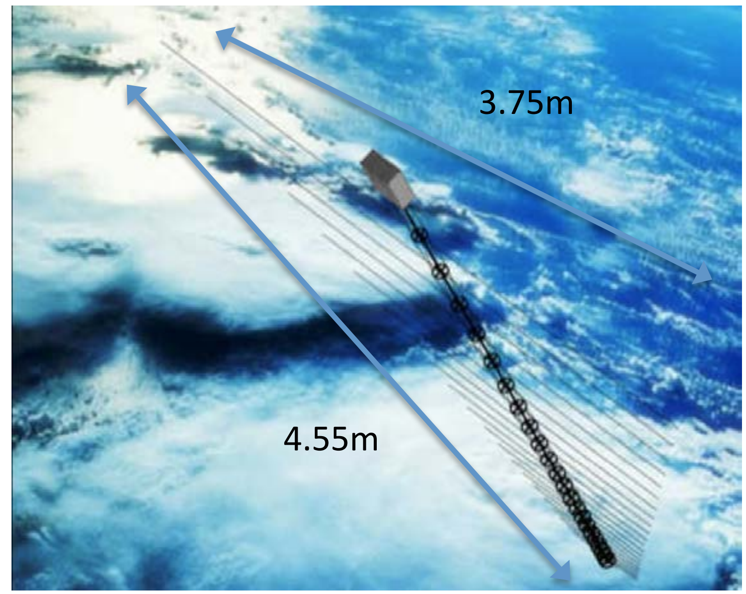
INSPIRE*
Interplanetary Nano-Spacecraft Pathfinder in Relevant Environment
A. Klesh: JPL, U. Michigan, UT Austin, Cal Poly SLO



CHIRP*
CubeSat very high frequency transmitter to study Ionospheric transmission of Radio Pulses
A. Romero-Wolf: JPL

AAReST*
Autonomous Assembly and Reconfiguration Experiment for a Space Telescope (Tech Demo)
S. Pellegrino: Caltech

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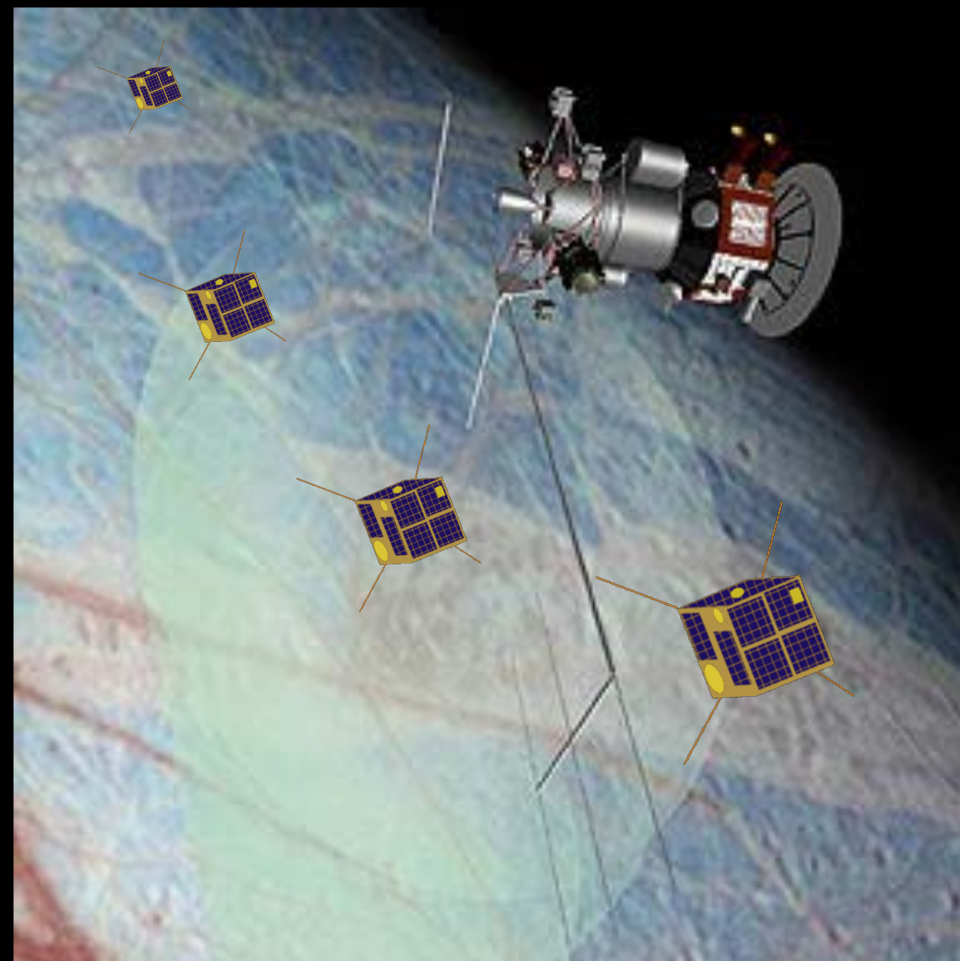
The Future – CubeSat Secondaries?



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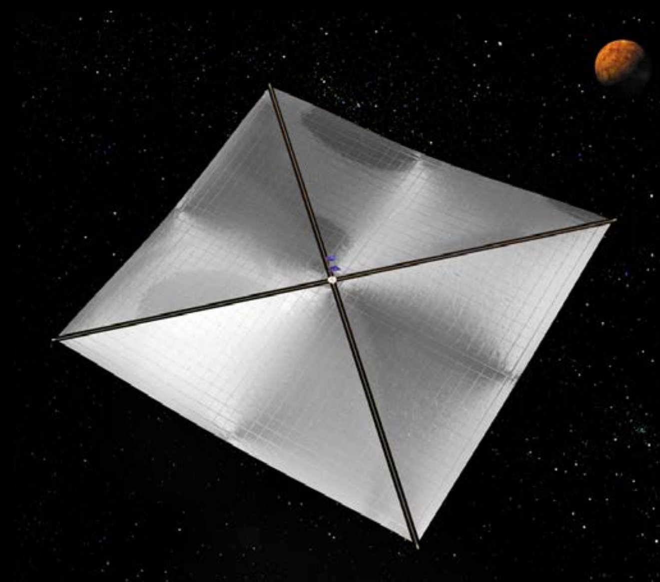
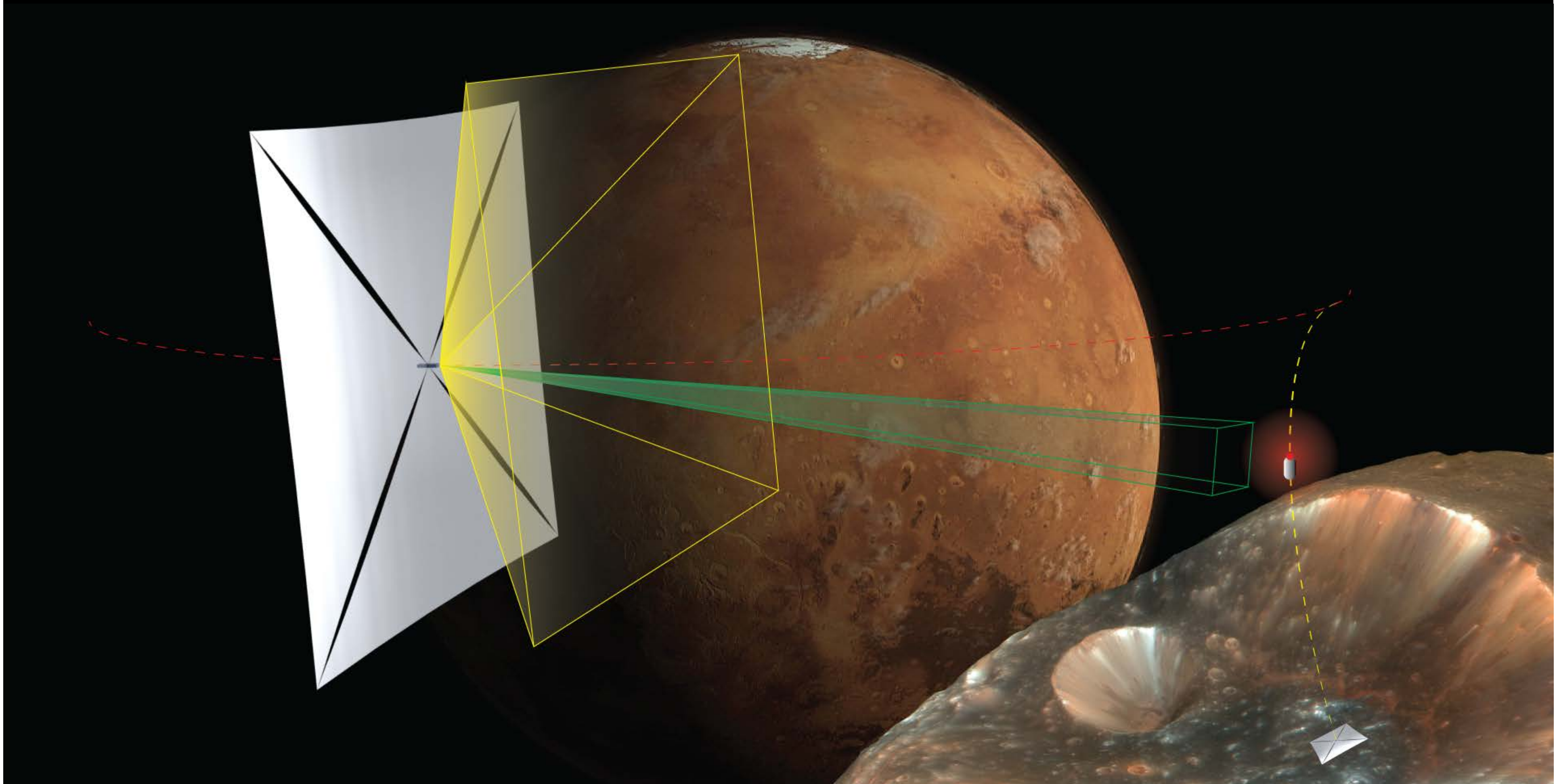
The Future – Lunar Science Concepts



Cosmology, radio science, and other topics

Exploring Multiple, Collaborative, and Mixed-Scale Missions

Can two Interplanetary CubeSats retrieve a sample from Phobos or Deimos?



Courtesy: Robert Staehle (JPL), Louis Friedman (The Planetary Society) 2012 May
Art: Ryan Sellers/CalPoly SLO

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On-going Initiatives

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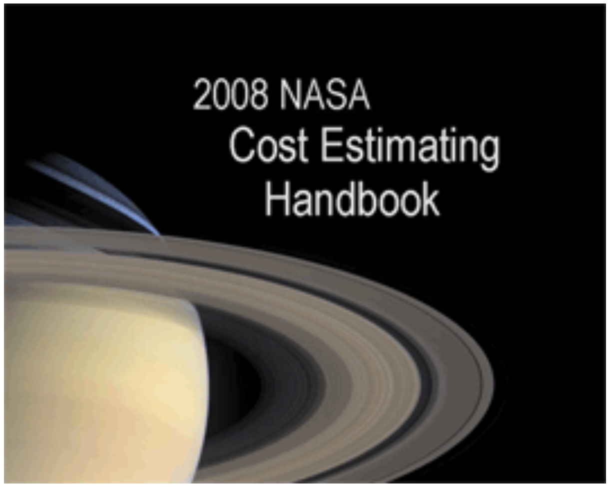
Dedicated Facilities
Community Labs and Environmental Test Capabilities

CubeSat Tracking Station
UHF/VHF (receive-only) and other capabilities

Deep Space Network (DSN)
Standard Interfaces, Services, Ops & Nav Support beyond LEO



Cost Model Development
New models relevant to small missions

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What is Next?

- *Work with the community to support formulation and implementation of cubesat missions that return Science*
- Grow personnel who are familiar with the cubesat paradigm (mission architects, SEs, payload developers, navigators, scientists)
- Develop instruments/payloads that fit the cubesat form/ function
- Develop critical subsystems – e.g. Microfluidic Electric Propulsion (MEP) thrusters, Comm, etc
- Provide community with a deep space radio that is DSN compatible
- Support leadership of standards/protocols for Cubesat Comm/ Nav and frequency allocation beyond Earth orbit
- Contribute to increased reliability of long-duration spacecraft systems and electronics

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