Expanding Science with SmallSats/CubeSats

Outer Planets Analysis Group

John D. Baker

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 small and low cost robotic probes to perform focused high priority science investigations and instrument technology demonstrations is now possible.
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 (e.g., crevasses, landing sites, caves, etc.)
- Object characterization
- Water search

**Atmospheric Science**
- Distributed atmospheric measurements
- Atmospheric composition (noble gases)

**In-Situ (small bodies)**
- Elemental, Isotopic & Mineralogical composition
- Regolith mechanical properties
- Surface dust dynamics

Copyright 2016 California Institute of Technology. Government sponsorship acknowledged.
<table>
<thead>
<tr>
<th>THEME</th>
<th>KEY MEASUREMENTS</th>
<th>OBSERVATION STRATEGY</th>
<th>MICROSAT-COMPATIBLE INSTRUMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origins</td>
<td>Isotopic, elemental, mineralogical</td>
<td>In situ (atmospheres, surface)</td>
<td>APXS, TLS, IR spec, Raman, LIBS Submm spec, UV Spec, Gamma ray spec, Dust spec, MassSpec</td>
</tr>
<tr>
<td></td>
<td>composition</td>
<td>Returned sample (small bodies)</td>
<td>Sample Return Capsule (possibly Acquisition as well)</td>
</tr>
<tr>
<td>Planetary Habitats</td>
<td>Volatile, organics composition, endogenic activity, heat budget, env</td>
<td>In situ, distributed network, subsurface (e.g., penetrators)</td>
<td>MassSpec, micro-XRF, Geophysics Inst., imaging, IR spec, seismometer</td>
</tr>
<tr>
<td>Processes</td>
<td>Atmospheric structure, dust, fields, geology</td>
<td>Close proximity, in situ, distributed networks</td>
<td>Cameras, IR spec, Mag, Transponders, Langmuir probes, MassSpec, TLS, dust counter, plasma</td>
</tr>
<tr>
<td>Human Exploration (SKGs)</td>
<td>Dust, fields, radiations, Dynamical properties, Mechanical properties, ISRU (composition)</td>
<td>Close proximity, in situ, extreme environments</td>
<td>Dust Counter, imaging, APXS, Geophysics Inst., accelerometers Subsurface probing, neutron spec, IR spec, radar, seismometer</td>
</tr>
</tbody>
</table>

Green = exists  Orange = in development  Red = does not exist yet
Current Capabilities and Investments

Iris V2 Transponder

0.5m HGA

Reflect-array

Iris V2 Transponder

Propulsion

LEON 3 Rad-hard Computer

Copyright 2016 California Institute of Technology. Government sponsorship acknowledged.
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
INSPIRE Flight Spacecraft

Completed I&T on Cost and Schedule in June 2014

Predecisional - For Discussion Purposes Only
**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.

**Teaming:**

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

**Orbit:**

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

**Milestones/Phases**

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

Predecisional - For Discussion Purposes Only
Mars Cube One (MarCO)  
8 kbps EDL telecom relay for InSight

Two Spacecraft in 14 months

Pre-decisional – for discussion purposes only
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

Mission Concept - Pre-Decisional – for Planning and Discussion Purposes Only
Recent Studies

Europa

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

Predecisional - For Discussion Purposes Only
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