Enabling Low Cost Planetary Missions Through Rideshare Opportunities

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A Low Cost Approach for Exploration

_CubeSats have revolutionized Earth science mission by providing regular, low-cost access to space through standardization._

Regular access to space provides various ways to lower-cost:

1. Higher Risk Approaches
2. Increased community for operating missions
3. Innovative uses of technology (through standards)
4. More Focused Science Investigations

Can the CubeSat be used for Planetary Science missions to reduce cost?
Two Ways to Approach the Problem

**Stand Alone CubeSat Architectures**

Pros:
- Can utilize current hardware (higher risk approach)
- Ideal for “Swarm” concepts

Cons:
- Limited propulsive capability reduces potential targets
- Long transit durations
- Communication distances
- Reduced number of launch opportunities (only escape launches)

**Mother/Daughter CubeSat Architectures**

Pros:
- Provides opportunities for high priority science at various locations
- Eliminates Deep Space capability issues

Cons:
- Relies on a much more expensive mission
- May require higher quality assurance requirements (ensure doesn’t affect the larger mission)
- Reduced number of launch opportunities

Photo Credit: NASA/JPL

Photo Credit: Stanford
Deep Space Travel is Not Easy!

Stand-alone Planetary CubeSat missions must overcome significant technological hurdles to succeed

Long distance communication requires increased power or antenna area

Propulsion systems require increased potential energy or power

The result is a significant increase in complexity in order to force the Deep Space functionality to fit within the current CubeSat standard
CubeSats As Daughter Craft

*Mother/Daughter architectures maintains the CubeSat standard but sacrifices opportunity*

![Image: CubeSats in orbit with Earth in background]

*Photo Credit: Busek*

Relies on a much more expensive mission (higher quality assurance)

Reduced number of launch opportunities (requires higher reliability)

The reduction of opportunity forces **more consideration for mission reliability and quality assurance, increasing the cost and complexity** of the systems
A New Standard for Planetary Missions

The ESPA ring and lunar gravity assists provide the required standards and opportunity to enable low-cost Planetary Missions

**ESPA Ring**
- The EELV Secondary Payload Adapter (ESPA) provides a standard launch interface for spacecraft <180kg

**Lunar Gravity Assists**
- Lunar gravity assists can be used to customize the departure energy and direction to any potential target of interest including NEOs, Venus and Mars
Potential Platform for Planetary Exploration

The Micro Surveyor spacecraft provides the low cost launch flexibility of a CubeSat with the capability of a traditional Deep Space spacecraft

Two 1.5m² deployable solar arrays provides ~750W of power

CubeSat based avionics and attitude determination provides sufficient computing and pointing

COTS low-power EP system provides up to XXX km/s of ΔV for flight to Mars, Venus or NEOs

Single string spacecraft with a launch mass of <75kg

Capable of delivering up to 15kg of science payload

JPL developed X-band telecommunication system provides navigation and communication
Potential Targets of Interest

*From GTO, Planetary Science mission could potentially be conducted at Venus, Mars and NEOs*

- **Example Mars Trajectory**
  - Launch date: December 2017
  - Time to Earth Departure: 6 months
  - Transfer flight time: ~3 years
  - Mars Arrival Time: March 2021
  - Total Delta V to Mars: 2.8 km/s

- **Venus and NEO Trajectories**
  - NEOs
    - Launch in late 2019
    - Flight time of ~21 months
  - Venus
    - Launch in late 2018
    - Flight time of ~16 months to Venus
Summary

- To reduce cost of Planetary Missions, we must increase the regularity of these missions

- CubeSat form factor has physical limitations, requiring a more capable spacecraft to perform missions

- A program similar to CLI using the ESPA ring would control the standards required for increased launch opportunities

- Micro Surveyor provides a potential compromise between CubeSat and Deep Space technologies