INTERPLANETARY SAMPLE CANISTER FOR MARS SAMPLE RETURN Nathan J. Strange[1,2], Andrew T. Klesh[1], Colleen M. Marrese-Reading[1], David Y. Oh[1], John K. Ziemer[1], Timothy P. McElrath[1], Damon F. Landau[1], and Daniel J. Grebow[1]; [1]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Dr., Pasadena, CA, 91109-8099), [2]Nathan.J.Strange@jpl.nasa.gov

Introduction: Missions studies undertaken for the Planetary Science Decadal Survey found that the MSR mission would likely be prohibitively expensive [1] with today's technology in today's budget environment. We propose the development of an Interplanetary Sample Canister (ISC) for the Mars Sample Return (MSR) mission using CubeSat technology [2] to enable a lower cost MSR mission. The frenetic pace of CubeSat development in recent years is bringing the technology very close to the level needed for deep space applications. Existing or near-term technology provides the capability for power, communications, thermal control, attitude control, and command & data handling at Mars. The key capability gap is in propulsion, which we propose addressing with the maturation of Microfabricated Electrospray Propulsion (MEP) technology. Once this gap is closed, a ~4 kg spacecraft could be constructed that would be capable of travelling from Mars to Earth. This is within the launch capability of typical Mars Ascent Vehicle (MAV) [3] designs.

The ISC is achievable in the near-term and is targeted at Challenge Area 2. It has the following key characteristics:

- A CubeSat would function as the MSR sample canister that is launched by the MAV.
- MEP would provide the ΔV for Earth return.
- The ISC would return to Earth-Moon L1 or L2 to mitigate Planetary Protection concerns.

Microfabricated Electrospray Propulsion: The Microfluidic Electrospray Propulsion (MEP) thruster is a low-masslow mass, low-power, high specific impulse system ideal for interplanetary CubeSat applications. A MEP thruster consists of microfabricated needle emitters externally wetted with indium propellant, a propellant reservoir, a porous propellant distributor and an integration structure. A thruster prototype is shown in Figure 1. The indium propellant is stored in a solid state in the reservoir, where a heater melts the indium to flow. The liquid propellant is then capillary force driven to the thruster head passively, with no valves or pressurized reservoir. The propellant is wicked along the emitter array chip to the base of the emitters and then along the emitter needles. High electric fields are applied to the emitters to deform the indium into cones at the emitter tips and to extract and accelerate charged particles from the cones. Macroscale emitter indium electrosprays have been flown for spacecraft charge control. Macroscale electrospray thrusters have been flight qualified. Microfabrication of arrays of needle emitters are under development with >100 emitters/cm^2 for thrust scalability of >1 mN/cm^2 (i.e. it fits on a chip). First generation 100 micronewton MEP systems are expected to have a dry mass that is less than 100 grams, which includes the thruster head, feed system, propellant reservoir and power processing unit. This thruster would operate at a specific impulse of 5000 s and power less than 5 W and the components will be batch microfabricated for minimal cost. MEP would enable a 3-4 kg spacecraft (i.e. a 3U CubeSat) that has the ΔV capability for a transfer from Low Mars Orbit (LMO) to the Earth-Moon L1 or L2.

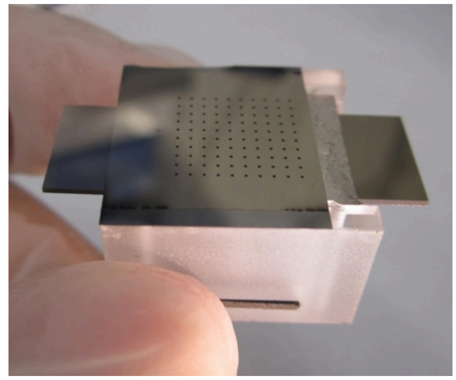

Figure 1: Prototype MEP thruster, feed system, and propellant - only 19x19x14 mm.

Strawman CubeSat Concept: The ISC flight system would be packaged within a 3U CubeSat (as shown in Figure 2), yet be able to provide ~8 km/s of delta-V, and close the link at 10 bps on S-Band at 1AU. A flight computer, based on a TI MSP430 with an LM555-based watchdog timer and RTC, could provide command & data handling for the entire system. Data could be stored on a 4 GB SD card. MEMs gyros and external sun sensors could provide approximately 5 deg of pointing knowledge. The system could be powered by deployable solar arrays providing greater than 40 W at 1AU, and could track the sun with a HoneyBee solar array drive. The power system could have both maximum-power-point-tracking and single-set point capability, with an analog single-set point controller as backup. A Panasonic 4400mAh Li-Ion battery could serve as an energy buffer for flight systems (primarily during communication periods). An Astrodev Lithium UHF radio, along with antenna switch and turnstile antenna system could provide near-omni-directional UHF coverage. The MicroHard

2420 radio and associated amplifier with patch-antenna could provide near-omni-directional S-Band coverage, and able to handle greater than 10W of RF power. Within the structure, a 1U (10 cm x 10 cm x 10 cm) space is available for the payload, including sidewall access for instruments.

The components of this notional flight system would have high heritage from multiple CubeSat flights in LEO, and enough space is available to provide additional shielding for the deep space radiation environment. The flight computer, electrical power system, battery board, antenna switch, UHF radio and S-Band radio have flown on both the RAX and RAX-2 spacecraft, with some components now widely used throughout the CubeSat community. The solar array drive will be flying in 2012. Solar panels and deployable mechanism have flown on the USC Mayflower spacecraft. Technology development for the system is principally limited to the MEP development.

Sample Return to Earth-Moon Lagrange Points: The ISC would not carry an aeroshell for direct entry of the sample at Earth. Instead the sample would be taken to the Earth-Moon L1 or L2 Lagrange points where it could be retrieved either robotically or by a human cislunar mission. Since the ISC would not have an aeroshell, it should be possible to design it to be self-sterilizing upon any unplanned Earth entry. This would allow for any concerns about reverse contamination, i.e. Martian life contaminating the Earth, to be addressed by the human or robotic mission that would retrieve the ISC. Since this retrieval occurs near the Earth, it would be easier to develop a flexible retrieval plan that could be updated based on measurements of the sample.

Technology Demonstration Mission: The technology that enables the ISC could be demonstrated by a CubeSat that launches as a secondary payload to GTO and then flies a small payload to Phobos or Deimos. This would isolate any technology development risk from a larger MSR program, which could be developed after an ISC tech demo mission. Furthermore, a 1 kg imaging spectrometer could be used to determine surface composition of Phobos and Deimos.

References: [1] http://tinyurl.com/Decadal [2] A. Toorian et al., "CubeSats as Responsive Satellites", Paper AIAA-2005-6826 [3] D. Stephenson, "Mars Ascent Vehicle – Concept Development", Paper AIAA-2002-4318.

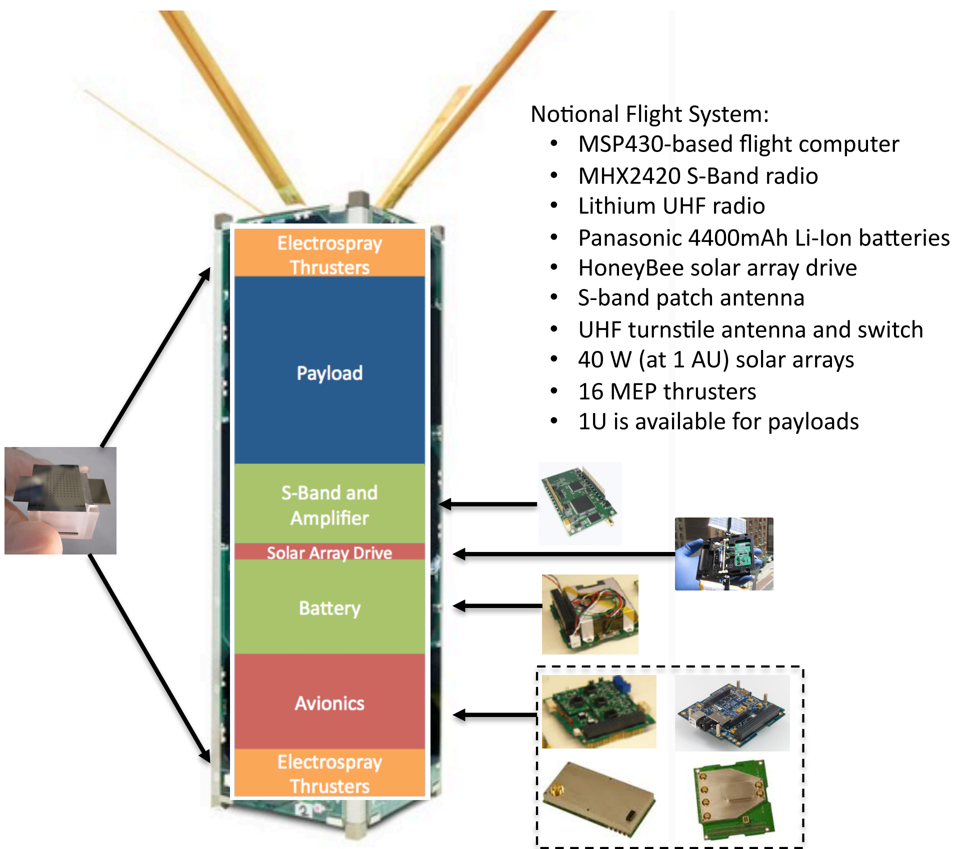

Figure 2: CubeSat and MEP technology could enable a 3-4 kg spacecraft capable of flight between Earth and Mars.