HALL: A PHOBOS AND DEIMOS SAMPLE RETURN MISSION. Pascal Lee[1,2,3], Joseph Veverka[4], Julie Bellerose[5], Marc Boucher[1], John Boynton[6], Stephen Braham[1,7], Ralf Gellert[8], Alan Hildebrand[9], David Manzella[10], Greg Mungas[6], Steven Oleson[10], Robert Richards[11], Peter C. Thomas[4], and Michael D. West[1,12]. [1]Mars Institute, [2]SETI Institute, [3]NASA Ames Research Center, pascal.lee@marsinstitute.net, [4]Cornell Univ., [5]Carnegie Mellon Univ. [6]Firestar Engineering, [7]Simon Fraser University, [8]Univ. of Guelph, [9]Univ. of Calgary, [10]NASA Glenn Research Center, [11]Optech, [12]The Australian National Univ.

Introduction: *Hall* is a proposed NASA-led international robotic lander and sample return mission (SRM) to explore and return samples from the two moons of Mars, Phobos and Deimos. The mission will address the outstanding issues of the origin, nature, and evolution of both Phobos and Deimos, as well as provide unique insights into early solar system processes, planetary formation, and the evolution of Mars itself. *Hall* is being developed as a New Frontiers-class mission and will use solar electric propulsion. *Hall* is named after American astronomer Asaph Hall who, in 1877, discovered the two moons of Mars.

Background: As affirmed by consensus during the *First International Conference on the Exploration of Phobos and Deimos* held at NASA Ames Research Center on 5-7 Nov, 2007, the single most important scientific objective in the exploration of Phobos and Deimos is the determination of their origin [1]. Phobos and Deimos also offer an opportunity to answer key questions about planet and satellite formation, small body formation and evolution, impact cratering dynamics and frequency, Mars surface evolution, and the roles the moons of Mars might play in future Mars exploration, from Mars Sample Return to human exploration missions [1-10].

There are two principal competing hypotheses concerning the origin of Phobos and Deimos [11]: 1) *Circum-Mars Formation*: Phobos and Deimos are circum-Mars formed bodies, or the collisional remnants of one or two once larger bodies formed around Mars; 2) *Capture*: Phobos and Deimos are captured small bodies (asteroid or comet), or the collisional remnants of one or two larger captured objects. Additional possibilities include more complex mixes of both hypotheses. The issue can be settled in a definitive way *only* by conducting detailed compositional analyses - including isotopic analyses – on materials *representative of the bulk* of Phobos *and* Deimos. Large blocks present today at the surface of Phobos and Deimos represent material that was excavated by impacts from the interior of these moons [12-14]. They offer the only reliable targets for acquiring samples that will yield representative materials of Phobos and Deimos's bulk.

If Phobos and Deimos are captured asteroids, it remains unclear what population of objects they represent. Their spectra have been likened to that of diferent types of primitive asteroids, but their surfaces also present lateral variations in albedo and color, suggesting possible variations in the composition and/or weathering state of their regolith.

Samples from Phobos and Deimos, if they were to include soils as well, would allow detailed investigations of the nature and evolution of their regolith. In this regard, an intriguing prospect is that their regolith should include meteoritic signatures from Mars [7-9, 11], asteroids, comets, and interplanetary dust particles (IDPs). Sampling Phobos's regolith could therefore provide access to a wide variety of martian and other planetary and interplanetary materials.

The Hall mission: The goal of the *Hall* mission is to rendezvous with both Phobos and Deimos, land – or "*rock dock*" - in the immediate proximity of some of their large blocks, conduct in-situ obervations, collect up to 1 kg of samples in total (small rocks from the boulders and soil from the regolith), and return these samples to Earth for detailed analysis (Fig.1).

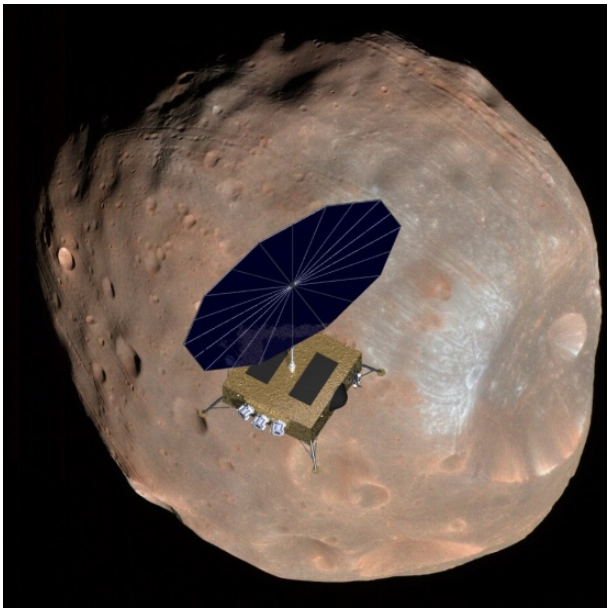

Fig.1. The *Hall* spacecraft near Phobos. (Phobos image credit: NASA/MRO/HiRISE).

The *Hall* mission will also allow detailed measurements of the density of Phobos and Deimos, and an assessment of the hydrogen content of their near-

surface regolith, from which the overall H_2O content of these objects will be estimated.

The *Hall* mission concept began as a study of a Phobos-Deimos SRM concept using electric propulsion conducted at NASA Glenn Research Center (GRC). Early mission design concepts were developed and evaluated by NASA GRC's COMPASS (*Collaborative Modelling and Parametric Assessment of Space Systems*) Team. The mission was found to adequately fit under the cost cap of a New Frontiers mission.

The *Hall* mission design includes the use of a lidar system derived from the PRIME (*Phobos Reconnaissance and International Mars Exploration*) mission concept study led by Optech-MDA and the Mars Institute, and supported by the Canadian Space Agency [2-5]. The lidar will enable high-precision rendez-vous, descent, and landing operations, as well as detailed topographic mapping and terrain texture surveys.

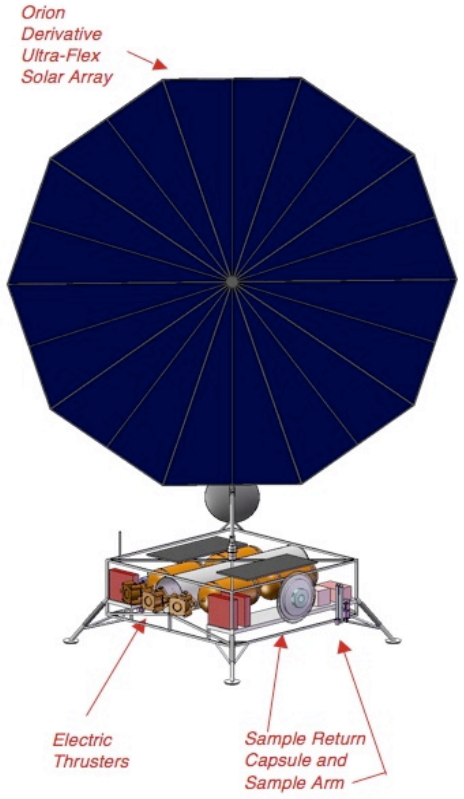

Fig. 2. Schematic of the *Hall* spacecraft showing its electric thrusters, sampling system elements, and Constellation Program (CxP)-derived solar array.

Science Payload. In addition to the lidar, *Hall*'s science payload will include a high-resolution color panoramic and microscopic imager (CHAMP or *Camera Hand-lens and Microscope Probe*) [15,16], a carbon-sensitive APXS (a MER alpha particle x-ray spectrometer with alpha channel in vacuum) [17], a neutron detector/gamma-ray spectrometer (NDX-GRS), and a radiation dosimeter (RAD). CHAMP and APXS will be mounted on the spacecraft's sampling arm, while the lidar, NDX-GRS and RAD will be body-mounted (Fig. 2). Samples will be characterized in-situ using CHAMP and APXS for context, then collected by the arm and delivered to a sample return cell with multiple compartments.

Science Team. *Hall* will be an international mission with Co-Investigators and Payload Element Leads from the US and other countries.

Mission profile. *Hall* is a relatively short duration mission with a first favorable launch opportunity in Summer 2015 on an EELV Atlas 401 or Falcon 9 rocket. Durations for the outbound transfer to Mars, stay in Mars orbit, and return transfer to Earth will be of order 200, 550, and 270 days, respectively. *Hall* will land on Phobos in at least two distinct locations ("red" terrain units and "blue" terrain units) and in one location on Deimos. Touchdown locations and dates will be chosen to optimize science return, power, and communications. For a 2015 launch, samples could return to Earth by 2020. Later launch dates are options as well. The returned samples will be curated at the NASA Johnson Space Center and the Smithsonian Institution and made available to the international science community after initial characterization at NASA. In addition to returning important and unique science, *Hall* will help prepare for Mars Sample Return.

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