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MARS GEOPHYSICAL LANDER MISSION: A MISSION CONCEPT FROM THE 2003 NASA PLANETARY SCIENCE SUMMER SCHOOL. Brian R. Shiro[1], Daniel W. Kwon[2], Emily M. Craparo[3], Samantha I. Infeld[4], Jennifer L. Heldmann[5], and Fraser S. Thomson[6]. [1]University of Hawaii (bshiro@hawaii.edu), [2]Orbital Sciences, [3]Naval Postgraduate School, [4]Analytical Mechanics Associates, [5]NASA Ames, [6]Space Systems Loral.

Introduction: 2013 marks the 25th anniversary of the NASA Planetary Science Summer School (PSSS) [1], which is held every summer at the NASA Jet Propulsion Laboratory to provide postdocs and Ph.D. students with an intensive interdisciplinary experience in planetary robotic mission design under the tutelage of JPL's Advanced Projects Design Team ("Team X") [2].

This abstract summarizes the work of the 2003 PSSS student team 10 years after creating a mission proposal authorization review for the “Mars Geophysical Lander” (MGL). MGL is aimed at studying the martian interior in search of past habitability and future exploration support. Some of the design elements proposed for MGL have now been realized in NASA’s recently selected InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission, which is scheduled to go to Mars in 2016 [3].

Mission Goals: MGL explores geophysical properties of Mars utilizing a suite of instruments for determining the nature of the martian subsurface, and for characterizing the interaction of the atmosphere with the martian surface. Missions objectives are to:

- search for subsurface water sources at landing site,
- determine crustal structure & shallow stratigraphy,
- characterize the atmospheric boundary layer,
- characterize seismic activity and deep interior, and
- search for minor atmospheric species.

Science Payloads: The lander carries five scientific experiments: GESA, SEMI, ISIE, MACE, and BLAME.

GESA: Geophysical Exploration for Shallow Aquifers. GESA characterizes the shallow subsurface stratigraphy to search for a water-rich layer. During descent, MGL drops 12 Short Period Micro-Seismometers (SPMS), or “geodarts,” to form a linear array with 100 m spacing covering a 1.6 km spread. The SPMS are small, low power, 3-axis MEMS sensors sensitive to frequencies of 0.01 to 10 Hz and were developed by the JPL Microdevices Laboratory for the Rosetta and Netlander missions [4]. The descending lander also drops 5 explosive sources that can later be set off to impart seismic energy into the subsurface. A 9 m Ground Penetrating Radar (GPR) antenna with Netlander heritage operating at 15 MHz can probe down to tens of meters to discern electrical properties of the layers [5]. See Figure 1.

SEMI: Seismic Exploration of the Martian Interior. SEMI consists of a 3-axis Very Broadband Seismometer (VBB) developed by CNES for the Netlander and ExoMars missions that is sensitive to frequencies of 0.05 mHz to 50 Hz and can operate for one martian year [6]. It is designed to study the deep martian interior and early evolution by observing Phobos-induced tides to obtain core properties, observing free oscillations to constrain mantle properties, using receiver functions to measure crustal thickness, and measuring attenuation to characterize water content and thermal variations. It also measures seismicity, providing estimates of event locations and constraints on meteorite influx to calibrate Martian geologic timescales. NASA’s InSight mission also includes the VBB payload [7].

ISIE: Inert Seismic Impactor Experiment. Since the natural seismic activity on Mars is unknown [8], ISIE provides a large seismic source at a known location, which the SEMI seismometer can use to answer many of the questions about the deep interior of Mars outlined above. ISIE consists of a 5 kg tungsten sphere dropped from MGL 10 weeks prior to landing.

MACE: Minor Atmospheric Constituents Experiment. The purpose of MACE is to search for and identify minor atmospheric constituents and to study the long-term mixing-ratio variation of boundary layer minor constituents. MACE’s Tunable Diode Laser Spectrometer (TDLS) operates with narrow spectral linewidth between wavelengths of 0.5 – 3.5 microns. It is sensitive to organic molecules such as formaldehyde, which has been tentatively detected in the equatorial region of Mars [9]. MACE also contains a High Resolution CCD Camera (HRCC) with 1024 x 1024 pixel resolution in order to observe dust dissipation and provide orientation information for the TDLS.

BLAME: Boundary Layer Meteorology Experiment. BLAME consists of a highly accurate Meteorological and Atmospheric Monitor (MAM) package developed by the CSA for the Mars Phoenix mission to characterize diurnal and seasonal variations in temperature, humidity, pressure, wind velocity, and solar flux of the atmospheric boundary layer [10]. This provides ground truth for Mars global climate models and provides essential calibration data for the other MGL instruments. BLAME also contains a HRCC.

Mission and System Design: MGL was designed to be a Discovery class mission proposed for the Mars

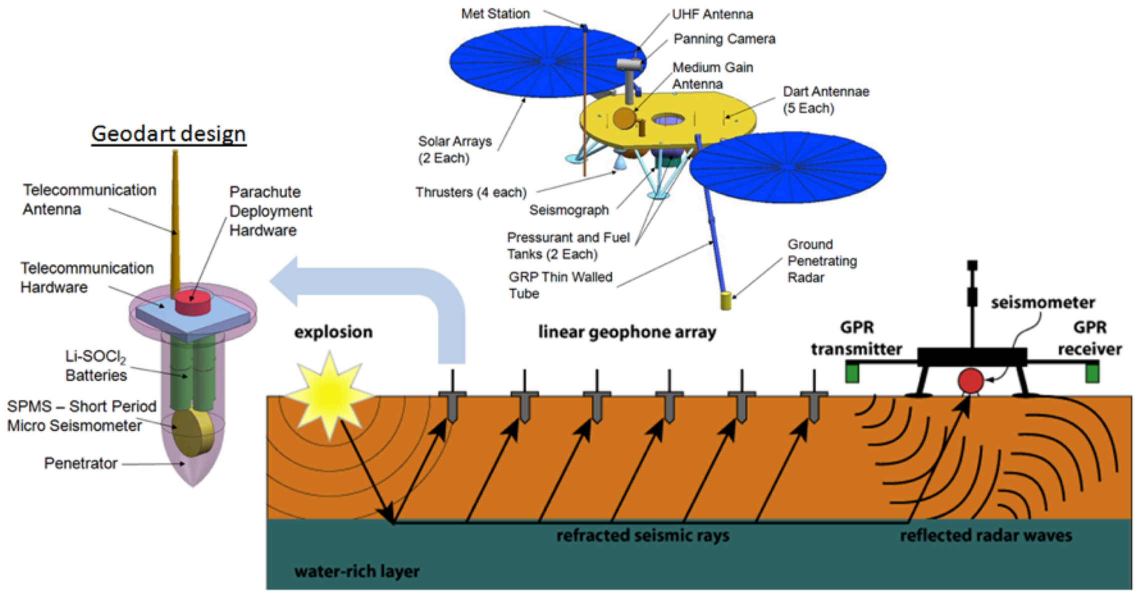

Figure 1: Overview of the Mars Geophysical Lander and GESA experiment.

Scout Program. The estimated mission cost without launch vehicle to achieve the full science objectives is $415M in FY2003 dollars; note that InSight is capped at $425M in FY2010 dollars [11].

Lander Design. The MGL is illustrated in Figure 1 and borrows from the Phoenix Mars Lander heritage [12]. It is not surprising that the upcoming InSight mission shares this same lander design. Basing the spacecraft on Phoenix provides for low risk entry, descent, landing, and mission operations.

Launch and Earth-Mars Transit. The PSSS team calculated a trajectory based upon a Delta II-2925H launch from Cape Canaveral in September 2011 to deliver the 1069 kg fueled MGL spacecraft to Mars in September 2012 using MER heritage cruise and landing sensors.

Entry Descent and Landing. The heat shield (Phoenix heritage) protects the lander as it enters the atmosphere at 5,600 m/s five minutes before landing. Three minutes later, the parachute deploys, and the heat shield jettisons at 7,500 m altitude. The lander then floats downward to 2,500 m when the onboard radar (MSL heritage) acquires the ground. 43 seconds before touchdown, the lander separates from the parachute for powered descent and touchdown at 2.5 m/s.

Geodart Deployment. After parachute separation, the lander trajectory covers approximately 1.6 km of ground surface distance during which time it drops the 5 kg geodarts. Each geodart has its own 1.5 m diameter parachute to ensure it touches down at 30 m/s, which is sufficient velocity to provide safe penetration into the substrate. This penetrator concept was developed by the 2003 PSSS team and is shown in Figure 1.

Landing Site Selection. Power requirements constrain the landing site to be between 30-60°S and poleward of 30°S for likely near-surface water. The geologic setting should be a site of recent fluvial activity near likely seismic activity. The landing site must be flat and devoid of large obstacles. Potential locations include Dao Valles, Gorgonum Chaos, Nirgal Valles, Elysium Planitia, and Newton Crater.

Conclusion: During an intensive week in summer 2003, the PSSS team developed the Mars Geophysical Lander (MGL) mission concept and gained valuable interdisciplinary skills in mission design. The recently selected NASA InSight mission shares MGL's VBB seismometer payload and lander design.

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