MARS GRAVITY RECOVERY, ATMOSPHERE AND CLIMATE EXPERIMENT (MARSGRACE) – A MARS SCOUT MISSION CONCEPT

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Introduction: The last decade has seen a renaissance of Mars exploration. A wealth of scientific knowledge continues to be gathered by both orbital and surface probes. Yet with all of the data collected, fundamental questions regarding the dynamics and composition of the Martian atmosphere still remain unanswered. For example, "What are the sources, sinks and reservoirs of volatiles on Mars?", "How does the atmosphere evolve over long time periods?", and "What are the dynamics of the middle and upper atmosphere of the planet?" [1]. Similarly, many questions remain as to the crustal and internal structure of Mars: What is the origin of the crustal dichotomy? What is the mechanism of support for the Tharsis bulge? What are the regional variations of the crust/lithosphere structure and elastic properties?

These questions are linked through their manifestation in the mass distribution and mass flux on Mars. This poster proposes the investigation of these critical science questions through a Scout class mission to Mars. A detailed spatio-temporal characterization of seasonal mass flux is investigated by making precision gravity measurements using an inter-satellite ranging system. These measurements are supported with IR spectrometry. This gravity measurement technique is currently in use for the terrestrial GRACE mission, and is returning spectacular data being used for ground breaking discoveries in Earth hydrology, climatology and oceanography [2].

Martian Science: *Mass Flux and Climate Dynamics.* The planetary mass flux couples source/sink volatile exchange with lower atmospheric dynamics on present day Mars. The largest mass flux on Mars is due to the seasonal sublimation and deposition of CO_2 ice in the polar caps. Estimates of mass flux, derived from MGS gravity field estimates and MGS TES data, range between 70 and 137 g/cm^2.

MarsGRACE will greatly improve upon this by providing global estimates of the seasonal mass flux with an accuracy better than 1 g/cm^2 at a resolution of 600 km. Equivalently, the atmospheric pressure can be known globally to 0.1 mBar or better at 1500 km resolution. As the dominating effect, gravity field estimates can be directly interpreted as CO_2 ice mass flux and time-variations in the barometric pressure. Unlike previous missions, these gravity measurements include changes in areas not directly overflown by orbit tracks and give coverage of the 3° polar regions excluded from sun-synchronous orbit inclinations of the previous missions. IR-spectrometry augments the mass flux data by providing CO_2 column abundance measurements along the orbit ground track (from which the total atmospheric pressure can be derived) and by identifying regions covered with frost. Used in conjunction with Mars General Circulation Models (MGCM), this knowledge will improve Mars wind and weather predictions, help determine the vertical strucutre of the lower atmosphere, and make possible detailed studies of regional-scale features (such as storm zones).

Thermospheric Dynamics. Upper-atmosphere neutral winds and density are of fundamental scientific concern as they provide insights into the energetics of the planetary atmosphere and its interactions with the solar forcing and solar wind interactions (space weather). Currently, the only available thermospheric density estimates have been derived from accelerometry at limited latitudes and local times during the aerobraking phases of the MGS and Odyssey missions. These estimates have an accuracy of only 35-70% [3]. By contrast, the MarsGRACE estimates will span all latitudes and local hour angles, and will provide absolute densities at all points along the 250 km mapping orbit to approximately 10% accuracy. The density variability will be known with twice this accuracy. The winds will be estimated with accuracy of about 10-20 m/s. The electron density will be known with 2.5×10^8 m^{-3} accuracy.

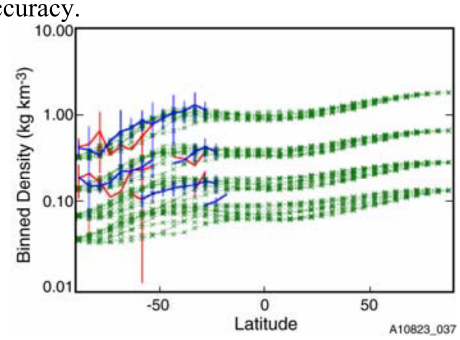

Figure 1. *This image shows the sparsity of measurements from MGS aerobraking (blue and red). Green symbols denote predictions from the ASPEN mode* [4].

Information from MarsGRACE also will provide the spectral content and morphology of tides and gravity waves, and their affects on thermospheric winds and density. This will help create detailed maps of the thermospheric structures such as the "polar vortex" and the "density wall". These results are of fundamental importance to both understanding Martian upper atmosphere interactions with the solar forcing as well as providing risk reduction data for future Mars Entry, Descent & Landing activities.

Crustal and Interior Structure. The most obvious and large-scale feature on Mars is the topographic/physiographic difference between the northern and southern hemispheres [5]—the hemispheric dichotomy. Studies of the origin of this planetary feature have focused on external (large meteorite impacts) and internal (plate tectonics, mineral phase changes, or convective overturn) causes. Since the key to the origin lies in the long-wavelength structure of the planet's interior [6], the more accurate and higher resolution global gravity fields from MarsGRACE will be able to detect variations in the Martian mantle with smaller density variations and at greater depth. The origin and supporting force for the large Tharsis bulge, the second most prominent topographic feature, is likely deep-seated and may be the result of static (crustal buoyancy or flexure [7]) or dynamic (convection [8]) forces. MarsGRACE will provide a highly accurate gravity field (~1 mGal) which will help to discriminate between these supporting mechanisms.

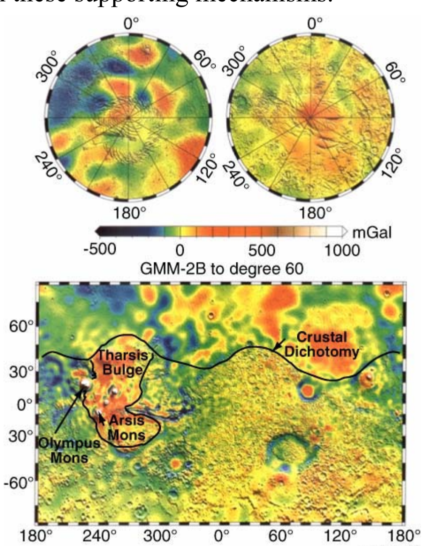

Figure 2. *Mars crustal gravity anomalies from model GMM2B to degree 60 overlaid on shaded relief from MOLA data. MarsGRACE will significantly improve the spatial scale of this comparison. (From* [9]*)*

While MGS/MOLA has provided detailed topography maps of Mars with meter-level accuracy, the knowledge of the Mars gravity field is still comparatively deficient. There is also topographic evidence of ridges and other features that are likely relics of ancient tectonism [10]. Tectonic activity would be expected to have a connection with gravity-driven flow (mantle convection), and evidence of present or past convection may be revealed with improved static field models. MarsGRACE will allow investigation of the structure and composition of the many impact and other features (≥80 km in diameter) that are evident in the MOLA topographic map.

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