MAGNETIC ANOMALY ANALYSIS TO DETERMINE PARAMETER SPACE FOR AN AIRBORNE MAGNETOMETER ON MARS. S. Biswas[1], J. Stamatakos[1], R. Grimm[1], and L. Hood[2], ([1]Southwest Research Institute®, 6220 Culebra Road, San Antonio, TX 78238-5166; email: sbiswas@swri.org), ([2]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721)

Introduction: Investigation of the crustal magnetization of Mars is considered a fundamental objective in understanding the evolution of the planet's surface and interior (Mars Exploration Program Analysis Group (MEPAG), [1]). The discovery of strong magnetic anomalies in the southern highlands of Mars [2, 3] was a major achievement of the Mars Global Surveyor mission. The data from this mission, gathered from altitudes approximately at 100 – 400 km, were used to compile global, low resolution magnetic anomaly maps of Mars. The anomalies were surprising because they were up to ten times more intense than those on Earth, and, at present, Mars does not have a substantial main field.

The source characteristics of these magnetic anomalies are poorly understood. These anomalies have generally been modeled as uniformly magnetized large sources [4, 5]. However, because of their ambiguous nature, it is also possible to model these anomalies as resulting from a coalesced effect of smaller multiple sources [6, 7]. There is considerable debate regarding the shape and extent of the sources and their modeled magnetization vectors. The Mars Global Surveyor data were recorded at an average altitude of 150 km above the planet's surface prior to the mapping orbit being established. The resulting anomalies are imprecise because of the attenuation and spatial averaging of the magnetic signals at the altitudes at which the data were collected.

High resolution mapping of magnetic anomalies on Mars requires platforms that are much closer to the planet surface. A Mars Scout balloon could potentially fly over the northern hemisphere of Mars and make observations at altitudes between 2 and 8 km above the Martian surface as it drifts in the Martian atmosphere. A magnetometer onboard this balloon could measure Martian magnetic anomalies with substantially higher resolution than current data. These higher resolution data would greatly improve our understanding of the nature of the sources and depth of crustal magnetization, thereby improving our knowledge of the evolution of the Martian crust.

Approach: We conducted a series of modeling exercises to demonstrate the advantages of magnetic data collected with resolutions possible from a proposed Mars Scout balloon. The modeling also focused on developing methods to better interpret the Mars magnetic data acquired from the balloon. Our technical approach was based on forward modeling of known magnetic anomalies on Mars at altitudes comparable to satellite observation (150 km) and probable balloon altitude (< 10 km). We also completed a series of inverse modeling exercises on synthetic anomalies to better understand the applicability of inverse methods to interpret the Martian magnetic anomaly data.

Results: Anomalies M10 and M3 [5] were chosen for the modeling exercise because they represent different magnetization scenarios. The mono-polar nature of the anomaly M10 suggests that it could be modeled with a high inclination angle magnetization vector. The dipolar nature of anomaly M3 suggests that it could be modeled with a low inclination angle magnetization vector. Figure 1a shows anomaly M10 at 150 km altitude based on the equivalent source method [8]. The contours represent analytic signal. Figure 1b shows a large elliptical prismatic source matching the anomaly M10 at 150 km altitude in Figure 1a. Such an anomaly could also be produced by multiple segmented sources arranged in a linear pattern as shown in Figure 1c at 10 km altitude. Magnetic anomaly observation from satellites at > 100 km altitude has a limited capability to distinguish between these two source types. The distinguishing features of smaller multiple sources are shorter anomaly wavelengths, but these are only evident through observations from lower altitudes. Anomaly M3, which is located at very high latitude in the northern hemisphere of Mars, is likely to be on the path of the balloon trajectory. Figure 1d shows the observed M3 anomaly (based on [8]) at 150 km altitude. Figure 1e shows the observed anomaly (1d) modeled by large polygonal prisms at 150 km. An alternative model with smaller multiple sources is presented in Figure 1f at 6 km. The two types of sources cannot be distinguished effectively from observations at satellite altitude, but again the modeling demonstrates shorter wavelength anomalies will be observable from a balloon at altitude < 10 km (Figures 1c, 1f).

One limitation of observing magnetic anomalies from a balloon trajectory is that magnetic data are collected over single profiles, not in two-dimensional grids. In comparing grid and profile data acquisition, we examined a series of magnetic inversion results from both grid and profile data developed from synthetic anomalies from known magnetic sources. The inversions were done using POTENT v4.08.06 (Geophysical Software Solutions P/L) which uses the method described in [9] for inversion of discrete sources. We note that the accuracy of the inversion depends largely on our initial estimates of the starting source parameters. The accuracy of the inverted results generally deteriorated as we increased the number of inversion variables for both grid and profile data. These results highlight how unconstrained Martian magnetic data are compared to data from Earth. First, we do not yet have reliable information on the nature of the original magnetizing field on Mars (e.g., whether it was a dipole, or a more complicated feature such as a quadrupole or octopole). Second, we do not have reliable insights on the size, shape, or distribution of the sources (e.g., faulted horizontal layers, vertical dikes, irregular intrusives, or irregular bodies of highly altered crust). Third, we do not have a good sense of the nature of magnetized sources (e.g., intensely magnetized volcanic strata, highly altered sedimentary strata, or unrecognized magnetic materials with very intense remanent properties). In contrast, on Earth, direct geologic and mineralogical observations of magnetic sources allow us to independently constrain source parameters, which make application of inversion methods in magnetic anomaly interpretation relatively simple.

In spite of these limitations, we show that high resolution magnetic anomaly data acquired at altitudes < 10 km along random balloon trajectories could lead to the resolution of shallow or deep sources, especially based on anomaly wavelength. The low altitude data have the potential to reveal high amplitude and relatively short wavelength anomalies that would indicate multiple sources or larger, more uniform anomalies characteristic of a single large source. Such a fundamental distinction between these sources is not possible from magnetic data acquired at satellite elevations. Having additional information on the size and shape of the source from the balloon platform at altitudes < 10 km could constrain the likely geologic nature of the sources.

Conclusions: The results of this investigation lead to the following conclusions regarding the data that can be obtained from a balloon-mounted magnetometer: (1) Observation of magnetic anomalies from a balloon platform at < 10 km altitude will reveal shorter wavelengths than observations from satellite orbit. (2) The presence of shorter wavelength anomalies on the northern plains of Mars would signify anomaly sources at shallower depths in the Martian crust that have gone unnoticed by the Mars Global Surveyor satellite. (3) Interpretation of magnetic anomalies using inversion techniques will be affected by large uncertainties in estimating magnetic source properties. (4) The low altitude data collected from the one-dimension balloon trajectories can be combined with higher altitude data to constrain interpretation of magnetic anomalies on Mars.

References: [1] MEPAG, (2005). [2] Acuna M. H. et al. (1999) *Science*, *284*, 790-793. [3] Connerney J. E. P. et al. (1999) *Science*, *284*, 794-798. [4] Hood L. and Zakharian A. (2001) *JGR, 106,* 14601-14619. [5] Arkani-Hamed J. (2001) *GRL, 28*, 3409-3412. [6] Biswas S. B. and Ravat D. (2005) *LPS XXXVI*, Abstract #2192. [7] Biswas S. B. and Ravat D. (2005) *Eos Trans. AGU, 86(52), Fall Meet. Suppl.* Abstract #GP43A-0892. [8] Purucker M. E. et al. (2000) *GRL*, *27*, 507-510. [9] Jupp D. L. B. and Vozoff K. (1975) *Geophys. J. R. Astr. Soc.*, *42*, 957-976.

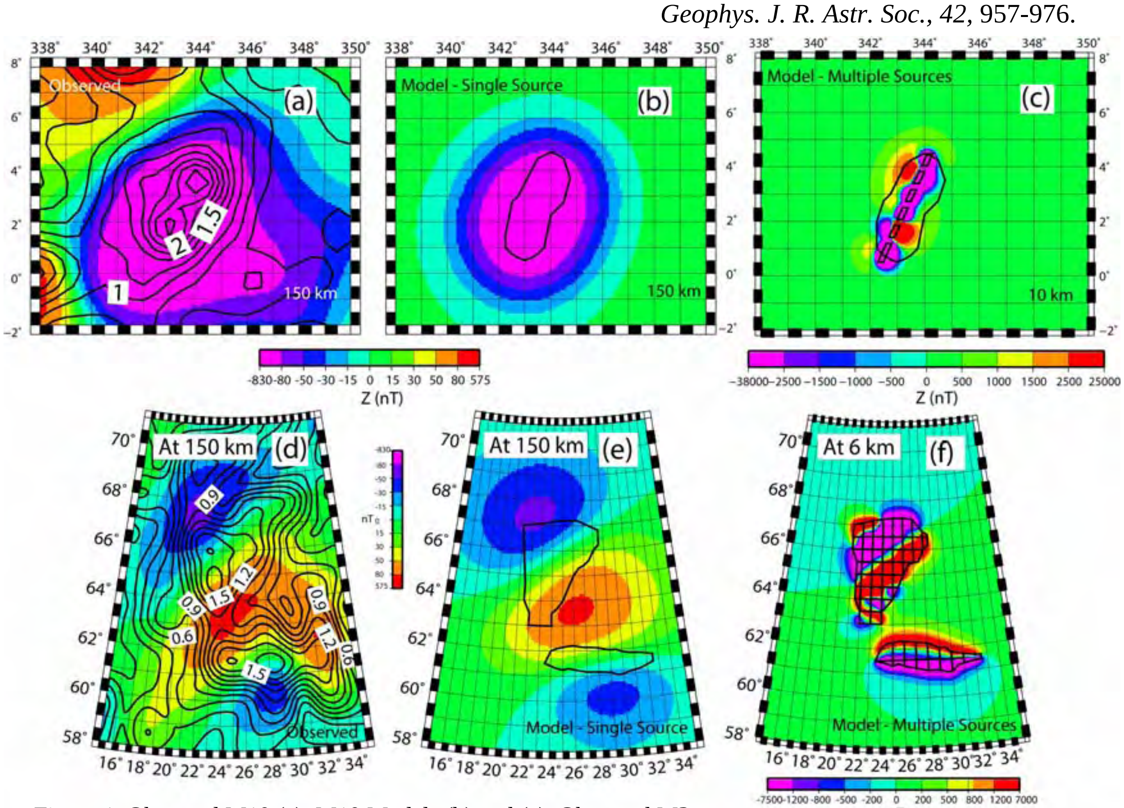

Figure 1. Observed M10 (a). M10 Models (b) and (c). Observed M3 (d). M3 Models (e) and (f). See text for additional details.