FIRST RESULTS FROM THE INSIGHT FLUXGATE MAGNETOMETER: CONSTRAINTS ON MARS' CRUSTAL MAGNETIC FIELD AT THE INSIGHT LANDING SITE. Catherine L. Johnson[1,2], Anna Mittelholz[1], Benoit Langlais[3], Philippe Lognonné[4], William T. Pike[5], Steven P. Joy[6], Christopher T. Russell[6], Yanan Yu[6], Matthew Fillingim[7], Véronique Ansan[3], Matthias Grott[8], Christian Krause[9], Tilman Spohn[8], Suzanne E. Smrekar[10] and William B. Banerdt[10]. [1]Dept. of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada, cjohnson@eoas.ubc.ca. [2]Planetary Science Institute, Tucson, AZ 85719, USA, cjohnson@psi.edu. [3]Laboratoire de Planétologie et Géodynamique, UMR-CNRS 6112, Université de Nantes, Faculté des Sciences et Techniques, Nantes, France. [4]Univ Paris Diderot-Sorbonne Paris Cité, Institut de Physique du Globe de Paris, Paris Cedex 13, France. [5]Dept. of Electrical and Electronic Engineering, Imperial College, London, United Kingdom. [6]Earth, Planetary and Space Sciences, University of California, Los Angeles, CA 90095, USA. [7]Space Sciences Laboratory, University of California, Berkeley, CA 94720. [8]German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany. [9]MUSC, German Aerospace Center (DLR), Cologne, Germany. [10]Jet Propulsion Laboratory, 4800 Oak Dr, Pasadena, CA 91109, USA.

Overview: The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission landed successfully on Mars on 26 November, 2018 at 4.50°N, 135.62°E in Elysium Planitia The Insight FluxGate magnetometer (IFG) is part of the Auxiliary Payload Sensor Suite (APSS) of instruments that will monitor environmental conditions at the lander, for the primary purpose of accounting for sources of wind, temperature, pressure and magnetic field noise in the seismic data [1]. The IFG is the first magnetometer to be deployed on the surface of Mars, and thus affords unique opportunities for magnetic field-based studies of the martian interior, the ionosphere, and the extent to which conditions in the solar wind affect the martian surface environment. In this, and a companion paper [2], we summarize initial results from the IFG instrument, including the DC field, daily variations, and higher frequency signals. We compare these results with predictions for *e.g.*, ionospheric [3,4] and crustal [5-7] fields. We report results from approaches for estimating the local crustal magnetic field at the InSight lander, yielding the first surface-based estimates of Mars' crustal magnetic field.

IFG Operations and Initial Data: After initial instrument checkouts, APSS began routine operations on 11 December, 2018. Continuous, vector magnetic field data are provided at a sampling rate f_{sc} = 0.2 Hz. Data have been reduced with an initial pre-flight temperature calibration and ongoing work by the IFG science and instrument team includes refining the temperature calibration and the offsets.

Higher sample rate data, up to 20 sps, can be requested for specific periods of interest. The IFG is designed to a noise requirement of less than 0.1 nT/sqrt(Hz) in the frequency band 0.01 – 20 Hz. However, no magnetic cleanliness program was employed for the spacecraft or instruments, and thus at frequencies above f_{sc} in particular, magnetic signals comprise contributions from both martian and lander sources (see [2] for more details). Initial investigations include careful examination of quiet (no or minimal lander activity) nighttime data, as well as times of specific lander and instrument operations to characterize these high frequency signals.

The Crustal Magnetic Field at the InSight Landing Site: In what follows we summarize what is known about the crustal magnetic field in the region around the InSight landing site from satellite observations. We present three approaches that will be used to probe the surface-based estimates of the local crustal field from InSight data.

Satellite magnetic field observations allow estimates of the surface magnetic field from inversions that include regularization (smoothness) constraints to mitigate the effects of downward continuation. The caveat is that only the field at wavelengths greater than minimum resolvable wavelength in the satellite data can be captured; more spatially localized fields cannot be assessed. The substantial increase in nightside (i.e. quiet) magnetic field data available at altitudes below ~ 250 km altitude from the Mars Atmosphere and Volatile EvolutioN mission (MAVEN) has greatly facilitated construction of crustal field models. New global [5,6,8] and regional [7,8] surface field models, that capture wavelengths greater than ~120 km, suggest surface fields strengths in the vicinity of the InSight landing site of a few hundred nT [4-6]. The actual surface field could be stronger or weaker than this, depending on the nature of shorter-wavelength signals superposed on these regional-scale fields.

Ground-based Estimates of Crustal Fields: We use three approaches to estimate the local crustal field.

(1) IFG Data - DC Field: In theory, IFG data can provide a direct estimate of the crustal field at the InSight landing site through the DC field. However, such estimates require accurate characterization of the DC spacecraft field, with instruments in their deck and/or

deployed configurations. Characterization of spacecraft fields prior to landing provide estimates for the magnitude of the spacecraft field of ~700 nT. Initial results suggest residual DC fields somewhat larger than satellite predictions. If these measured static fields are entirely crustal in origin (i.e. contain no residual spacecraft fields), they suggest modest contributions from wavelengths shorter than ~100 km.

(2) Lander Vibration Approach: Vibrations of the InSight lander in response to the daily winds have been recorded by the Short Period sensors of the seismic experiment SEIS [9]. These high frequency tilts (**ω**) result in accelerations ($\delta\mathbf{a} = \boldsymbol{\omega} \times \mathbf{g}$, where **g** is the local gravity**)** and magnetic field perturbations ($\delta\mathbf{B} = \boldsymbol{\omega} \times \mathbf{B_0}$**,** where $\mathbf{B}_0$ is the static crustal field) that may be detectable on the short-period seismometer, SP, and the IFG respectively. Calculations based on Viking data prior to InSight ground operations suggested that wind speeds of at least 10 m/s, expected at the landing site, would produce lander tilts of $\sim 10^{-4}$ degrees. These small vibrations in turn, could be measured by the SP when it is on the InSight lander deck prior to deployment onto the martian surface. Similarly, the vibrations could produce magnetic field perturbations on the IFG that would be resolvable with at least ~20 hrs of data. Measurement of such horizontal accelerations and horizontal perturbations to the magnetic field in the resonance frequency band of the lander allow a least squares solution for the vertical component, B_{Z0}, of the ambient crustal magnetic field.

Based on these calculations, stochastic testing was performed as follows. Random ground accelerations were generated at 20 sps, for frequencies, f, above 1 Hz, with a root-mean-square (RMS) signal of 10^{-5} ms^{-2}. These simulated lander vibrations were assumed to be due to rotations about a horizontal axis due to horizontal winds. Background surface magnetic fields with a vertical component corresponding to satellite-based predictions (e.g., $B_{Z0} \sim -320$ nT from [5-8]) and somewhat larger values (corresponding to additional contributions from shorter wavelength crustal fields) were used. The corresponding magnetic field perturbations were computed and added to a background random signal with RMS = 0.5 nT (i.e., the assumed noise level). Total signal durations of 10 – 40 hours were investigated. The results (Fig. 1) from 200 trials indicate that crustal fields with a vertical component of ~ 1000 nT magnitude can typically be recovered to within ~10% under the noise conditions used in the inversion. Furthermore, crustal fields with a vertical component magnitude less than ~100 nT are not distinguishable from zero. Accordingly, ~44 hours of SP and IFG data at $f > 1$ Hz, taken simultaneously during the martian day while SP was on the lander deck have been requested for downlink and will be processed.

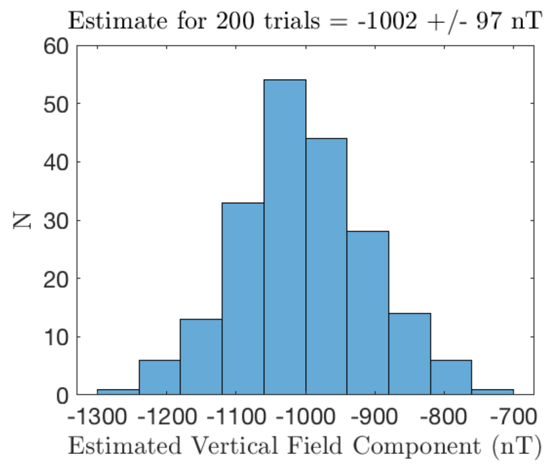

Figure 1: Results for the estimated vertical crustal magnetic field component, B_{Z0}, from simulations of lander accelerations and magnetic field perturbations at ~3-5 Hz monitored over 40 hours. The input B_{Z0} was -1000 nT, and this is recovered to within 10%.

(3) Lander Tilts: Larger, discrete, lander tilts could also result in observable changes in the magnetic field due to rotation of the IFG in the static field. Although expected to be small, some changes in tilt are possible during specific deployment activities, e.g. placement of the seismometer on the ground, deployment of the Wind and Thermal Shield. Measurement of lander tilts are being made before and after such activities, using the static tilt sensors that are part of the Heat Flow and Physical Properties Package (HP^3). These will be examined, together with the IFG data for any discrete changes in the magnetic field associated with changes in tilt.

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