IAF SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – Science, Instruments and Technologies (3B)

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A COMPREHENSIVE GROUND-LEVEL MAP OF MARS CRUSTAL MAGNETISM GATHERED BY A SWARM OF WIND-DRIVEN SURFACE EXPLORATION MOBILE IMPACTORS

Abstract

Even though Mars' global magnetic field likely died out almost 4 bya, large areas of the planet's surface still possess non-negligible amounts of remanent magnetization. Notably, these areas of crustal remanence appear not to be randomly strewn about the surface, instead, they exhibit spatial patterns across both global and local scales. Globally, remanence correlates with the Martian dichotomy, whereas locally, remanence seems to either form linear furrows spanning thousands of kilometers, or groupings of East-West oriented patches. Thus far, satellite measurements have only been capable of providing rudimentary and coarse-grained approximations of crustal magnetic field strength, which has made resolving the true nature of these spatial features challenging. Additionally, recent InSight ground-level magnetic field data indicates that satellite-based measurements may have been off by as much as an order of magnitude.

As such, current methods to resolve numerous knowledge gaps relating to Mars' magnetic field environment, such as paleopole evolution, recurring atmospheric magnetic transients, and the identity of meso- and microscale magnetic surface anomalies, are hamstrung by current trade-offs between accuracy (lacking spatial coverage), or coverage (lacking accuracy).

The objective of this paper is to outline a data collection method that addresses this observational impediment by presenting an approach that - using a swarm of decentralized, wind-driven mobile impactors carrying sensor payloads capable of conducting spatiotemporal magnetic surveys - greatly improves the ability to map crustal remanent magnetization in terms of coverage, relative accuracy, and absolute accuracy.

To this end, our approach consists of a structured evaluation of the capabilities and potential limitations of using magnetometers on board a distributed mobile impactor network, and a detailed technical review of the design requirements necessary to achieve baseline science aims, concluding with a suitability analysis of the Tumbleweed Science Mission architecture.

Consequently, our principal results are a systems engineering-based study of a data collection method in conjunction with an optimal sensing design architecture weighed against mission constraints such as power requirements, volume, mass, and dynamic operability. Additionally, theoretical considerations are supplemented with results acquired from numerical simulations and an experimental testbed.

We finish with a reflection on how the implications of our conclusions relate to critical geological research gaps, and in doing so, we demonstrate that the system design and experimental survey strategy yield a higher resolution and increased coverage for the respective mission cost compared to conventional scientific and technical possibilities currently available to the planetary science and exploration community.