SmallSat Missions to Make Multi-Point Measurements of the Martian Magnetosphere, Ionosphere, and Crustal Magnetic Fields

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Summary

- Multiple SmallSats in orbit at Mars can accomplish important science with particle and fields instrumentation.
- Potential science objectives include :
  - Disentangling the time-variable vs. spatially-variable components of the hybrid, induced martian magnetosphere.
  - Creating detailed crustal magnetic field maps to enhance our understanding of the geophysical history of the martian surface.
- These SmallSat missions can take advantage of otherwise relatively conventional mission architectures .

Fig.1 An exoplanet's atmosphere being stripped by its stellar wind. The details of how this happens during each stage of a planet's and star's evolution depends on understanding of time-variability loss at places like Mars.

Mission Implementations

- ESPA-class SmallSats can use solar electric propulsion to deliver themselves to Mars orbit via a variety of ride-share opportunities.
  - Deployment from a Mars-orbiting primary is relatively easy (e.g. doable with CubeSats).
  - Deployment from a Mars-landing primary requires detaching near Earth (to have time to slow down to orbit capture speed).
  - Deployment from near-Earth-space is doable with current technology.
- Comparatively conventional mission design limits the innovations necessary to accomplish the objectives with SmallSats.
- SmallSats can accommodate world-class particles and fields instrumentation, e.g.:
  - Goddard small flux-gate magnetometer
  - Ion, ENA, and electron particle spectrometers
  - Ultra-stable oscillator for radio occultation

Science: Ionosphere and Magnetosphere

- Key to understanding atmospheric escape to space
  - Martian climate history
  - Climate history at other worlds including exoplanets
- Dynamic plasma laboratory makes it a perfect place to study different types of solar wind interactions
  - Intrinsic magnetosphere (early Mars)
  - Induced magnetosphere (current ionosphere)
  - Mini-magnetospheres (crustal magnetic fields)
- Disentangling time-variable vs. spatially–variable phenomena is the key to full understanding
  - Bulk atmospheric escape, aka plasma clouds?
  - Plasma boundary motion?
  - Magnetic reconnection-driven energization?
  - Mini-ionospheric dynamos?
  - Response of the system to upstream drivers?

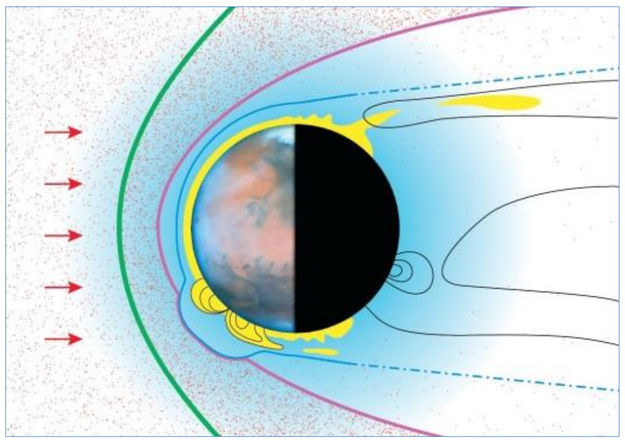

Fig.2 The dynamic plasma laboratory that is the hybrid, induced-crustal magnetosphere of Mars with both time-variable and spatially-variable features.

Proposed Concepts

- Multiple , independent teams have detailed mission concepts proposing these ideas.
  - Clear sign of broad community support
- MISEN
  - **M**ars **I**on and **S**puttering **E**scape **N**etwork
  - PI: Rob Lillis, UC-Berkeley
- MARS-CAT
  - **M**ars **A**rray of Ionospheric **R**esearch **S**atellites Forming the **C**onstellation for **A**eronomy and **T**omography
  - PI: Edgar Bering, U. of Houston
- M4
  - **M**ulti-point **M**easurements of the **M**artian **M**agnetosphere, ionosphere, and crustal fields
  - PI: Jared Espley, Goddard

Science: Crustal Magnetic Fields

- Key to understanding the geophysical history of the surface
  - When did the dynamo cease?
  - Did Mars experience plate tectonics?
  - Extent of volcanic resurfacing?
- Enhanced spatial details allow more detailed geophysical interpretations
  - Smaller scale craters, volcanic demagnetization, and putative transform faults
- Multi-point measurements allow magnetic gradiometry to be performed, ala Swarm

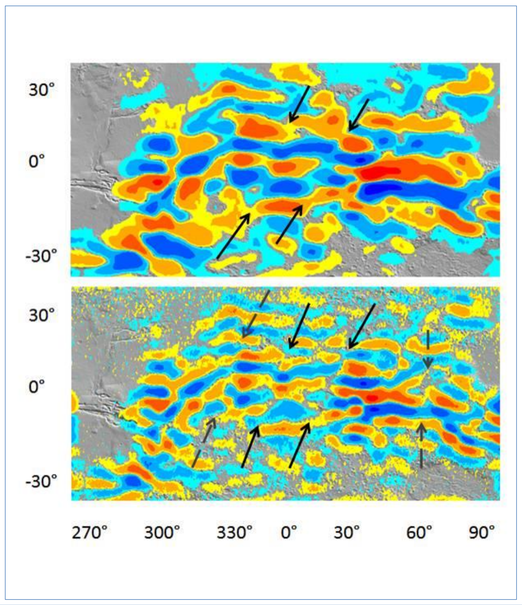

Fig.3 A map of the crustal magnetic fields near Meridiana Planum using (**top**) 400 km MGS data and (**bottom**) downward continued, de-noised MGS data. Putative transform faults (black arrows) are more evident in the enhanced dataset. Gradiometry from multiple spacecraft would offer even more enhanced maps.

What about MAVEN?

- MAVEN has broadly confirmed the hypothesis of atmospheric escape via solar wind erosion but is limited by being a single spacecraft.
  - Its single vantage point means that extrapolating atmospheric escape results from present day Mars to ancient Mars to exoplanets is difficult.
  - Its single point vantage point means that the spatial resolution via magnetic gradiometry is not available.
- MAVEN will shortly be moving into a surface-asset-relay-friendly orbit which means it will lose much of its ability to monitor the upstream solar wind.
  - These mission concepts would allow us to potentially restore this upstream monitoring of space weather at Mars.
  - These mission concepts could work with MAVEN using it as another, even more capable node in the network.
  - These mission concepts could continue MAVEN's observations into another part of the solar cycle.

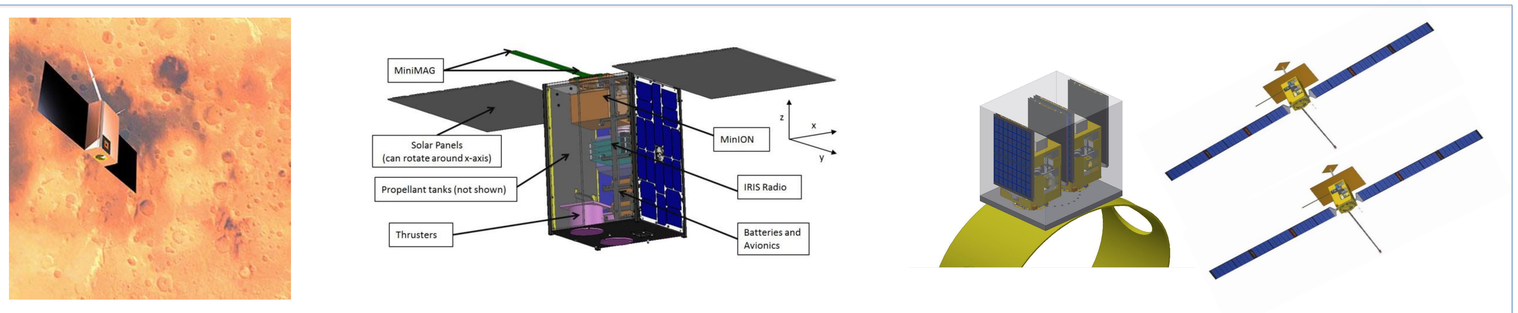

Fig.4 Mars-Cat MISEN M4