Multiple SmallSats in orbit at Mars can accomplish bulk atmospheric escape, aka plasma clouds? 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.

**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.

**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

![Image 1](https://example.com/image1)

**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.

**Science: Ionoosphere 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?

![Image 2](https://example.com/image2)

**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**
  - PI: Rob Lillis, UC-Berkeley
- **MARS-CAT**
  - Mars Array of Ionoospheric Research Satellites Forming the Constellation for Aeronomy and Tomography
  - PI: Edgar Bering, U. of Houston
- **M4**
  - Multi-point Measurements of the Martian Magnetosphere, 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, a la Swarm

![Image 3](https://example.com/image3)

**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.

![Image 4](https://example.com/image4)

**Fig.4** Mars-Cat  MISEN  M4