Mars Ion and Sputtering Escape Network (MISEN)

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Outline

• The Science Gap: why planetary aeronomy needs multi-point measurements.
• The MISEN Mission Concept for PSDS3
  – Science Objectives
  – Science Payload
  – Mission Design/Architecture
  – Mission ops & spacecraft
  – Mission Team

NOTE: two other similar competing missions for SIMPLEX-II: some details omitted
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[Images showing plasma and magnetic field interactions.]
Plasma & magnetic field measurements in planetary environments: why do we care?

• Understand the structure, composition, variability and dynamics of planetary magnetospheres (e.g. MAVEN).
• Atmospheric Escape Processes: ion and sputtering escape are important for climate evolution of terrestrial planets.
A single measurement platform leaves major questions unanswered

a) spatial and temporal variations in escape fluxes cannot be distinguished
b) responses of escape fluxes to changing solar wind conditions (~1 minute) can only be measured with a time-lag of an hour or (much) more
c) global escape rate variability in response to space weather “storms” (much more common and intense in the early solar system) must be estimated (poorly) from a single orbit track.

MAVEN’s precessing orbit
A Multi-spacecraft Revolution

- The same problem faced terrestrial space plasma physics in the 1980s, early 1990s.
- Single spacecraft couldn’t characterize plasma boundary dynamics.
- Multiple spacecraft allow the 3D, time-resolved measurements to create a realistic picture of the magnetosphere and how solar wind conditions affect it.
- Similarly, multiple spacecraft are the next step in understanding the solar wind interaction with unmagnetized bodies like Mars.
MISEN Objective and Concept

• Science Objective: Characterize the magnitude, structure and variability and real-time response to changing solar wind conditions, of ion escape and precipitation at Mars.

• In-situ measurements of ions, electrons and magnetic field.
• Three smallsats:
  – elliptical orbits (~250 x 7000 km)
  – Spaced in argument of periapsis, RAAN, and phased to ensure:
    • upstream solar wind measurements >90% of the time.
    • Simultaneous measurements of the different plasma regimes surrounding Mars.
Science Payload

**M-MAG (MISEN Magnetometer)**
- Developed by UCLA (C. Russell)
- Clone of Insight Mars magnetometer
- Two mounted on boom (90 cm) i.e. gradiometer configuration
- 0.3U, 144 g, 0.8 W per sensor
- ±8000 nT range
- 48 bits per readout up to 64 Hz

**MESA (MISEN electrostatic analyzer)**
- UCB/SSL heritage design, ion & electron analyzer
- 1.8 kg, 1.7 W.
- $4\pi$ FOV via spinning platform
- $22.5^\circ \times 6^\circ$, 3 eV-25 keV range
- DE/E = 18%
- Light-vs-heavy mass differentiation achieved through pulse height analysis.
Mission Design 1: Cruise

- Separate from primary on lunar or Earth-escape trajectory.
- Point Mission Design is for Psyche ride-share (launch 08/2022).
- 15 month electric propulsion cruise to Mars rendezvous.
- Near-constant thrusting, no spinning.
- Regular DSN contacts.
Mission Design 2: Spiral Down to Science

- Match Mars’ orbit and cross its sphere of influence.
- Each spacecraft guided to its own orbital plane.
- Switch to Mars-centered Conops/Nav
- 11 months of spiraling
- End in science orbits
- Full instrument commissioning

Each spacecraft approaches Mars in its own plane, spiraling to its own target orbit.

Target:
250 x 7000 km

~100,000 km
Mission Design 3: Science Orbits

- Elliptical orbits:
  - High enough to ensure outward particles are escaping.
  - Low enough to ensure inward particles are precipitating.
Mission Design 3: Science Orbits

• Elliptical orbits:
  – High enough to ensure outward particles are escaping.
  – Low enough to ensure inward particles are precipitating.
  – RAANs, AoPs chosen so sufficient coverage of Mars’ different plasma regions is maintained as orbits precess over a 1-year primary mission.

Orbits are stable, though will need ~monthly phasing maneuvers
Spacecraft Ops and architecture

Ops:
• Three axis stabilized until science orbit.
• Spinning at 16s period after that
• Ops are simple: data collection is ‘dumb’ and continues indefinitely
• ~Weekly downlinks

Spacecraft:
• SC volume depends on launch point.
• Gimballed solar panels
• IRIS radio X or Ka-band
• MarCO style antenna
# MISEN Study Team

**UC Berkeley Space Sciences Lab**
- **PI:** Rob Lillis
- **Project Scientist:** Shannon Curry
- **Systems Engineering & Management:** Dave Curtis
- **Ion & electron analyzer:** Davin Larson, Roberto Livi, Phyllis Whittlesley
- **Science advisory:** Janet Luhmann

**UCLA Earth and Space Sciences**
- **Magnetometer:** Chris Russell
- **MHD modeling:** Yingjuan Ma

**Advanced Space LLC**
- **Mission Design & Navigation:** Jeff Parker & Nathan Parrish

**Tyvak LLC**
- **Spacecraft bus & subsystems:** Jordi Suig-Puari, Angelo Lopez

**University of Colorado Boulder**
- **Science advisory:** David Brain
Summary

MISEN will:

• Provide simultaneous multi-point measurements of the Martian plasma environment.

• Elucidate the real-time response of the this environment to solar wind changes & disturbances (CMEs, SEPs etc)

• Reveal for the first time the global structure of ion and sputtering escape and how and why it varies.

• Build on MAVEN’s legacy for a fraction of the cost.

THANK YOU to the PSDS3 Program!
Feasibility Study flowchart
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Credit: M. Marquette