Mars Atmosphere and Volatile Evolution (MAVEN) Mission

MAVEN AGU Workshop
Solar Wind Ion Analyzer
J.S. Halekas and the SWIA Team
Delivered to LM last week (11/26)
Bench checkout nominal

Bolted on to spacecraft tomorrow (12/3)
S/C testing to follow
## SWIA Level 1 Requirements

<table>
<thead>
<tr>
<th>4.1.9: Solar Wind Ions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline:</strong> MAVEN shall determine density and velocity distributions of solar wind and magnetosheath protons (from 1000 km/s to 50 km/s). Better than 15% energy resolution; better than 30 degrees angular resolution.</td>
<td><strong>Rationale:</strong> Solar-wind ion properties determine the solar-wind and magnetosheath properties near Mars and constrain the nature of the solar-wind interactions with the upper atmosphere, determine the ionization rates of neutrals from charge exchange, and determine the pickup acceleration of newly formed ions by the $\mathbf{v} \times \mathbf{B}$ electric field.</td>
</tr>
</tbody>
</table>
SWIA Science Goals

• Primary Goal: Measure solar wind input to the Martian atmosphere
• Additional Goals: Measure basic space plasma processes around Mars
SWIA Science Goals

- Non-thermal ion loss processes are key for MAVEN
  - Reconnection/Flux Ropes/Plasmoids
  - Bulk escape/plasma clouds
  - Polar wind
  - Auroral processes
  - Kelvin Helmholtz/boundary instabilities
  - Pickup escape
# SWIA Measurement Capabilities

<table>
<thead>
<tr>
<th>REQUIREMENT</th>
<th>SWIA Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PF72</strong>: SWIA shall measure energy fluxes from $1 \times 10^7$ to $1 \times 10^{10}$ eV/(cm$^2$ s sr eV) with no worse than 25% precision</td>
<td>SWIA will measure energy fluxes from $5 \times 10^4$ to $7 \times 10^{11}$ eV/(cm$^2$ s sr eV)</td>
</tr>
<tr>
<td><strong>PF73</strong>: SWIA shall measure ion flow velocities from 50-1000 km/s</td>
<td>SWIA will measure from 5-25000 eV (flow velocities from 30-2000 km/s)</td>
</tr>
<tr>
<td><strong>PF74</strong>: SWIA shall have energy resolution dE/E at least 15%</td>
<td>SWIA has energy resolution of 14.5% (13.5% with attenuator)</td>
</tr>
<tr>
<td><strong>PF75</strong>: SWIA shall have angular resolution of at least 30° (10° in Sun direction)</td>
<td>SWIA has angular resolution of 22.5°, with 4.5° sectors in Sun direction</td>
</tr>
<tr>
<td><strong>PF76</strong>: SWIA shall have time resolution of at least 1 minute or better</td>
<td>The basic SWIA measurement cadence is 4 seconds.</td>
</tr>
<tr>
<td><strong>PF77</strong>: SWIA shall have a FOV of 180x40° or better</td>
<td>SWIA has a FOV of 360x90°</td>
</tr>
</tbody>
</table>
SWIA Optics

- Sweeping inner hemisphere voltage selects energy
- Sweeping deflector voltages selects theta angle
- Discrete anodes select phi angle
SWIA Optics Details

Deflector serrations prevent ions from scattering at a shallow enough angle to make it into the optics.

Mechanical attenuator reduces sensitivity by factor of ~15.

Double exit grids prevent field leakage and low-energy sensitivity change.

Photons rejected by blackening (Ebanol-C) and scalloping inner surface of outer hemisphere and top cap.
SWIA Calibration
SWIA Energy Resolution

\[ \Delta E/E = \frac{1.13}{7.8} = 14.5\%, \quad \frac{1.05}{7.8} = 13.5\% \]
SWIA Theta Resolution/Coverage

- Intrinsic theta resolution better than 10° for all deflections
SWIA Phi Resolution/Coverage

- Small dips in response due to ribs at exit of analyzer
  - No rib in in sun direction

- Fine anodes cover “Sweet Spot” in sun direction
- Attenuator allows measurement of intense fluxes without saturation
SWIA Basic Data Products

P0 = Full
Huge data volume
Mainly for calibration purposes

P2 = Fine resolution
48 energies X 10 phi X 12 theta
10% energy res,
4.5 degree angular res
For solar wind measurements

P1 = Coarse resolution
48 energies X 16 phi X 4 theta
20% energy res,
22.5 deg angular res
For magnetosheath/magnetosphere
SWIA Derived Data Products

- PFPDU packetizes P1 and P2 products, with configurable binning/sub-selection in both energy and angle
  - Can trade energy/angle resolution vs. time resolution

- PFDPDU calculates partial moments (n,v,p,T,Q) onboard from either P1 or P2, depending on mode
  - Allows very high cadence measurement of basic plasma parameters

- PFDPDU calculates average energy spectra onboard from P1
  - Very useful survey product
SWIA Telemetry

• PFDPDU automatically switches SWIA telemetry mode based on how localized the distribution is in phase space

• SW Mode:
  – Fine 32E x 6φ x 8θ every 32 s [Covers Solar Wind Flows]
  – Coarse 24E x 16φ x 4θ every 128 s [Survey for Pickup Ions]
  – Energy Spectra every 8 s
  – P2 Moments every 4 s

• Sheath Mode:
  – Coarse 24E x 16φ x 4θ every 32 s for [Covers Sheath Flows]
  – Energy Spectra every 8 s
  – P1 Moments every 4 s

(*) Later in mission, better Earth-Mars geometries allow higher telemetry rates