Mars Atmosphere and Volatile Evolution (MAVEN) Mission

MAVEN Science Community Workshop
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Particles and Fields Package
Solar Energetic Particle Instrument (SEP)
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Overview of SEP events

- **SEPs**: Solar Energetic Particles are ions or electrons of solar or interplanetary origin from ~10 keV to ~1000 MeV (i.e. suprathermal solar wind tail up to GCRs).

- Primary acceleration mechanisms to produce SEPs:
  - Solar flares, causing impulsive events (hours)
  - CME shocks, CIRs, causing gradual events (days).

The largest SEP Events often include a prompt increase in MeV proton fluxes 10s of minutes after the related solar activity, and a second increase arriving with the associated interplanetary shock.

Reames, 1999

\[ \text{Time (UT)} \quad \]
SEP Energy Spectra

- Smaller SEP event spectra can be fitted with power laws of 2-3 for each ion species (e.g. Reames et al., 1997).
- Large gradual events have much harder spectra with exponential rollover at high energies (Tylka et al., 2000).

H, He, and O Spectra at 1 AU from ACE/GOES/SAMPEX
SEPs in the atmosphere: energy partitioning is complicated and energy dependent.

For $E_{\text{primary}} > \text{few MeV}$

Warning: figure not intended to be fully comprehensive!
SEP instrument will measure particles that penetrate to altitudes important for escape processes.

- The bulk of SEP event total energy is generally below 50 keV, deposited mostly between 100 km and 130 km [LeBlanc et al., 2002], though events widely vary.
- We will measure particles that penetrate to 50 km-150 km, providing important constraints on modeling of atmosphere/ionosphere dynamics.
- Energy is partitioned into heating, sputtering, molecular dissociation, ionization, electronic excitation, nuclear excitation and neutron capture.
MAVEN’s goals w.r.t. SEP events

1) Build up statistics of total escape rates for different sizes of SEP events with different energy spectra, field-line anisotropies and IMF orientations (i.e. blackbox input versus output).
2) Validate models with measurements in all regions, inside and outside of the atmosphere.
3) Extrapolate backwards in time using validated models applied to ancient atmosphere composition and best-guess SEP event strength and frequency over time to put firm constraints on Mars’ total integrated atmospheric loss to such events.
SEP instrument overview

- **The Solar Energetic Particle (SEP) instrument** measures the energy spectrum and angular distribution of solar energetic electrons (25 keV–1 MeV) and ions (25 keV-12 MeV).

![SEP instrument diagram]

Al/Polyimide/Al Foil (stops ions <250 keV)

Foil Detector

Thick Detector

Open Detector

Foil Detector

Open Collimator

Attenuator

Sm-Co Magnet (sweeps away electrons <350 keV)
Basic separation strategy: 3 detectors, 2 filters

### Energy ranges for counted events

<table>
<thead>
<tr>
<th>keV</th>
<th>Electrons Foil side</th>
<th>Electrons Open side</th>
<th>Ions Foil side</th>
<th>Ions Open side</th>
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<tr>
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<td>&lt;20</td>
<td>&lt;350</td>
<td>&lt;250</td>
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<td>20-700</td>
<td>X</td>
<td>250-6000</td>
<td>X</td>
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<td>FT</td>
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<td>6000-11,000</td>
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<tr>
<td>O</td>
<td>X</td>
<td>350-700</td>
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<tr>
<td>FTO</td>
<td>&gt;600</td>
<td>&gt;11,000</td>
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Mechanical Overview of SEP

1. Detector Stack
2. Foil Location
3. DFE Board
4. Magnet Assembly
5. Attenuator
6. Collimator
Sensor Units – Summary of last few slides

• Each sensor unit is a:
  – Dual double-ended solid state telescope
  – Each double-ended telescope (1/2 sensor) has:
    • Triplet stack of silicon solid state detectors
    • Foil (on one side)
      – Filters out ions \(<~350\) keV
      – Leaves electron flux \(>~20\) keV nearly unchanged
    • Magnet / Open side
      – Filters out electrons \(<350\) keV
      – Leaves ion flux nearly unchanged
    • Mechanical Pinhole attenuator
      – Protects against against overheating when Sun is in FOV.
      – Reduces count rate during periods of high flux
      – Reduces radiation damage (caused by low energy ions) during periods of high flux
  • Collimators
  • Preamplifier / shaping electronics
MAVEN SEP Detector Stack Design

- ~200 A Polysilicon
- ~200 A Al
- Pixelated side ~1200 A Dead layer
- Outside Grounded
- 300 micron thick detectors
Electronics Block Diagram

- Signal chain: 1 of 6 channels shown

Triplet stack of detectors

A250F Preamp

Gain + shaping

BLR

DFE Board (Inside Sensor)

Test Pulser

Bias Voltage

FPGA Coincidence Logic & Accumulators

Memory

DAP Board (Contained within PFDPU)
SEP & PFP Block Diagram

28V Bus

PFDPU

LVPS A
LVPS B
DCB A
DCB B
C&DH A
C&DH B
C&DH A
C&DH B

Regulated Power

Serial Data Interface

LPW Electronics
SEP DAP x2
MAG Electronics

SWEA Electronics
SWIA Electronics
LPW Boom/Sensor (2)
EUV Sensor
SEP Sensors (2)
MAG Sensors (2)

STATIC Electronics
ESA/TOF Analyzer

SEP has 2 sensors and 2 DAP boards (inside the PFDPU)
Spacecraft Accommodations

FOV centerlines are 45 deg from sunline

SEP FOV Looking in +X dir
Spacecraft Accommodations
Spacecraft Accommodations
Spacecraft Accommodations

FOV centerlines are in YZ plane

SEP FOV Looking in -Z dir
MAVEN SEP Status – near future schedule

- Environments and Calibration Complete
- Instrument Delivered to Lockheed-Martin

- Initial (post transport) bench test functional was successful
- Integration begins 12/3/2012
- First spacecraft electrical tests scheduled for 12/8/2012
Instrument Capabilities
Fit to Noise Spectrum

ADC units are in Full 16 bit ADC units. Extremely good fit to Gaussian response.

10.9 ADC = ~2 keV RMS width

Electronic Threshold ~ 10 keV
SEP Ion Response

SEP1A Flux: 900 Å aluminium, 200 Å dead silicon

E_{inc} E_{lost} Modeled
keV keV keV
25 10.382974 10.2
30 10.851011 10.7
35 11.598116 11.6
40 12.101942 12.2
45 12.402292 No Calc

25 keV

30 keV

35 keV

40 keV
- Response to Electrons
- Ramping electron gun from 0 to 40 keV
- Electron detection threshold is 14 keV
- Efficiency exceeds 50% for energy > 20 keV electrons
SEP Instrument Data Products

- **SEP has one mode:**
  - Differential Energy Flux Spectra for
    - **Electrons**
      - 20 keV – 1 MeV
    - **Ions (no mass discrimination)**
      - 20 keV – 10 MeV
    - Each species has 4 look directions - approximately:
      - Parker spiral
      - Anti-parker spiral
      - ~90deg to parker spiral
      - ~90deg to parker spiral

- **Three different time resolutions based on altitude:**
  - 32 sec
  - 8 sec
  - 2 sec (several measurements per scale height)

- **Energy Bins are configurable (still subject to change)**
  - 1.5 keV width
  - 256 bins/sensor shared between all channels
• End of presentation