Mars Atmosphere and Volatile EvolutioN (MAVEN)

MAVEN Community Meeting
IUVS: The Imaging UltraViolet Spectrograph

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Outline

• The Big Picture - Requirements
• Instrument Overview
• Observing Modes
• Science data processing
MAVEN Remote Sensing (IUVS)

Imaging Ultraviolet Spectrograph

Wavelength range
  - FUV: 110 – 190nm
  - MUV: 180– 340nm

Detectors: Image-intensified 2-D active pixel sensors

Mass ~27kg, Dimensions 71x33x15cm

Observations
  - Limb scans near periapsis
  - Disk maps near apoapsis
  - D/H and O coronal mapping
  - Stellar occultations

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IUVS Requirements

Composition and structure mapped over planet:

- **Neutral Atmosphere & Corona:** Profiles and column abundances of H, C, N, O, CO, N₂, and CO₂ from the homopause up to two scale heights (H~750 km for coronal H and O, H~12 km for CO₂) above the exobase with a vertical resolution of one scale height for each species and 25% accuracy.

- **Ionosphere:** Profiles and column abundances of C⁺, CO⁺, and CO₂⁺ from the ionospheric main peak up to the nominal ionopause (~ 400 km) with one O₂⁺ scale height (H~60 km) vertical resolution and 25% accuracy.

- **Isotopes:** D/H ratio above the homopause with sufficient accuracy (~30%) to capture spatial/temporal variations (factor of 2) and compare with measured D/H in bulk atmosphere.

- **Lower Atmosphere:** CO₂ profiles of lower atmosphere using stellar occultations.
IUVS Roles in MAVEN

IUVS provides global 3D models of major molecules, atoms, ions and isotopes in the atmosphere & corona, with derived properties such as exobase and ionosphere altitudes. IUVS also provides major constraints on escape processes and measures the lower atmosphere.

- Vertical profiles to characterize composition & structure
  - Multispecies periapsis limb scans
- Global images to characterize spatial distribution & variability
  - Multispectral 2-dimensional apoapsis Images
- Coronal Scans
  - Deuterium/Hydrogen ratio vs. altitude to constrain escape processes
  - “Hot Oxygen” vertical profile to quantify a major escape process
- Vertical CO$_2$ profile to characterize the underlying atmosphere
  - Stellar Occultations

The IUVS approach uses fixed observing sequences which depend only spacecraft pointing capabilities through the mission (e.g., power constraints and pointing control singularity avoidance)
Instrument Overview
During most normal operations, the spacecraft flies with solar arrays and body-mounted instruments exactly sun-pointing. IUVS, NGIMS and STATIC are located on the Articulated Payload Platform (APP) which uses two gimbals to orient one instrument axis. The other APP-mounted instrument axes can be aligned using spacecraft roll, though there are operational limitations.
IUVS: Key Features

- UV imaging spectrograph
  - 10x0.06 degree slit with occultation apertures at ends
  - FUV: 110 – 190nm at 0.6nm resolution
  - MUV: 180 – 340nm at 1.2nm resolution
- Instrument mounted on APP for continuous planet-pointing
- Two fields-of-regard for nadir or limb viewing
- Scan mirror for constructing altitude profiles or disk images
- Selectable high- or low-resolution grating for full-spectrum observations or Lyman Alpha spectrum for D/H ratio
- Separate MUV and solar-blind FUV sensors for optimal sensitivity and stray light rejection
- Data binned in spectral and spatial dimensions to fit in downlink bandwidth
IUVS was delivered to Lockheed Martin shortly before Thanksgiving, on time and under budget
Observing Modes
IUVS’ Four Observing Modes

- Each mode has specific pointing strategies, optical and detector settings
- Periapse Imaging and Coronal Scans alternate with orbits STATIC and NGIMS at a predetermined cadence.
- Coronal Scans for O and D/H use identical pointing (inwards on the ascending leg, outward on the descending leg)
- Stellar Occultations occur during dedicated 1-day campaigns
1: Periapse Limb Scans: Overview

- Periapse scans are acquired looking sideways out our Limb Field-of-Regard (FOR)
- Observation goals include FUV, MUV airglow altitude profiles

![Diagram of Periapse Limb Scans]
1: Periapsis Limb Scans: Scan Construction

Scan mirror motion

Small Occultation Keyhole

~1 km slit width

Large Occultation Keyhole

4 km observation spacing

100 km

Mapping Slit

225 km

Spacecraft motion
1: Periapse Limb Scan: Spectral/Spatial Req’ts

- The figure shows a simulated high-level data composite assembled from a full vertical scan
- Spectral coverage requirement flows from list of atmospheric species to measure
- Spectral resolution requirement flows from the need to separate emissions from different species
- Spatial coverage requirement flows from altitude range of detectable emissions
- Spatial resolution requirement flows from need to independently sample each atmospheric scale height

**Figure E.2–2**: The tremendous capability of the IUVS is shown in this simulated limb scan, which provides spectra for each limb altitude (sample spectrum at top) and derived vertical profiles for H, CO, CO$_2^+$ (at right).
2: Apoapsis Images: Overview

- IUVS apoapsis images are acquired using inertial pointing & nadir FOR
- Science goals include FUV airglow and MUV reflected sunlight (ozone, dust, clouds)
2: Mars Apoapsis Images: Image construction

- Image Pixel
- 1.43 deg 155km
- 1200 km
- ~3 deg 320 km
- 7800 km
- 6800 km
- 155 km
- 7800 km
- 320 km
- 1200 km
- 1.43 deg
3: Coronal Scans: Overview

- “InScan” measures corona + interplanetary background, “OutScan” measures background alone. Same pointing plan used for O and D/H coronal scans
- Science goals include D/H and Hot O (related to photochemical escape)
3: D / H Coronal Scans: Spectral Req’ts

- Spectral resolution requirement flows from need to minimize intensity in wings of the bright H Lyman alpha line at the position of D Lyman alpha.

**Figure E.2–3:** Simulated observation of H and D Lyman-α emissions in 222nd order. The lines are well-resolved yielding SNR~10 in <1 hr. The dominant noise source is photon noise in the grating-scatter wings of H. Simulation includes noise and uses actual STIS measurements of the scatter from the grating to be used.
4: Stellar Occultations: Overview

• IUVS will perform occultation campaigns lasting 5 consecutive orbits occurring every ~2 months. Selected stars will vary campaign-to-campaign but will be observed repetitively during the 5 consecutive orbits.
• Of order 15 events per orbit will be observed, maximizing coverage in latitude and local time.
• Mars completes one rotation during 5 orbits, giving full longitude coverage.
• Science goals include measurement of CO$_2$, O$_3$, dust, clouds below the spacecraft altitude
Science data processing and products
IUUVS will provide global 3D models of major molecules, atoms, ions and isotopes in the atmosphere & corona, with derived properties such as exobase and ionosphere altitudes

- Periapsis Limb Scans
  - Multispecies vertical profiles, multiple profiles along-track per pass
- Apoapsis Images
  - Multispectral 2-D images, one set per apoapse
- D / H & O Coronal Scans
  - 1-D Deuterium, Hydrogen, Oxygen vertical profiles, single profile per orbit
- Stellar Occultations
  - Vertical CO\textsubscript{2} profile; single profile per occultation

IUUVS provides critical global descriptions essential for the interpretation of in situ data
Science Data Products – All Modes

- **Periapsis Limb Scans**
  - Level 1A/B: two-dimensional spectra in counts/intensities
  - Level 2A: tangent column abundances $N_i(z)$ (adjacent to periapse track)
  - Level 2B: densities $n_i(z)$, and temperatures $T(z)$
  - Level 3: integrated global models of $n_i$, $T$ as functions of local time, season, time

- **Apoapsis Images**
  - Level 1A/B: images in counts/intensities for multiple emissions
  - Level 2: vertical column abundance maps
  - Level 3: integrated global models as functions of local time, season, time

- **Coronal Scans**
  - Level 1A/B: two-dimensional spectra in counts/intensities
  - Level 2A/B: D, H, O tangent column abundances, densities & temperatures (radially from planet)
  - Level 3: integrated global models as functions of local time, season, time

- **Stellar Occultations**
  - Level 1A/B: raw absorption spectrum in counts/normalized intensity spectrum
  - Level 2: atmospheric density profile
  - Level 3: integrated global model as functions of local time, season, time

MAVEN requires high-level derived geophysical quantities within days to weeks of data receipt. Pipeline processing must be in place before orbit insertion!
IUVS Science Data Flow (Periapse Data Example)

**Level 0**
- **Raw Packets**
  - + Ancillary Data

**Level 1**
- **1A** 2D Spectra (Counts)
  - + Calibration
  - + Background Subtraction
- **1B** 2D Spectra (Intensities)
  - + Band System Summing
- **1C** Integrated Line/Band Intensities

**Level 2**
- Tangent Column Abundances $N_j(z)$, densities $n_j(z)$ and Temperature $T(z)$

**Level 3**
- Integrated Global Models of $n_j$ and $T$ as functions of local time and season

- Interpolation
- Resampling

All data products to be archived on the Planetary Atmospheres node of the PDS
Data Products from Periapse Limb Scans

**Single Emission Example**

- Counts maps will be converted to intensity maps based on instrument calibrations.
- Intensity maps will be converted to limb column abundances using computer models and inputs from other instruments (e.g., LPW/EUV).
- Column abundance maps will be converted to vertical density profiles \( n(z) \) and temperature profiles \( T(z) \).
- Local profiles will be integrated into global profiles vs. local time, season, time.

*Figure F.5–2:* IUVS limb profiles will allow accurate determination of critical atmospheric properties, even for the weakest essential emissions.
Periapse Data: From Emissions to Derived Quantities

<table>
<thead>
<tr>
<th>Species</th>
<th>HI</th>
<th>OI</th>
<th>NI</th>
<th>CI</th>
<th>CII</th>
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<td>Wavelength</td>
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<tr>
<td></td>
<td>297.2</td>
<td>165.7</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

- **Solar FUV Dependent**:
  - HI, OI, NI, CI, CII
  - O Density Profiles
  - C Density Profiles
  - H Density Profiles
  - N Density Profiles
  - C Density Profiles
- **Solar EUV Dependent**:
  - CO\(^2\)(B-X) UV Doublet
  - CO\(^2\)(A-X) FDB Bands
  - CO\(^2\) Density Profiles
  - N Density Profiles
  - C Density Profiles
  - H Density Profiles

Other potentially observable features include the N\(_2\) V-K band system, CO\(^+\)(B-X), and the 131.7nm feature of CO(A-X). Spectral regions marked in grey are blended emissions and will not be used in pipeline processing.
Summary

- IUVS offers UV capabilities never before used at Mars
- The instrument's four modes address fundamental science in the upper atmosphere, ionosphere, corona and middle atmosphere
- The instrument will obtain an unprecedented dataset of consistently mapped UV data spanning at least one Earth year
- Pipeline processing will produce extensive high-level data in geophysical units (densities, temperatures)
- The data, when combined with MAVEN’s other instruments, will address the current state of the atmosphere, ongoing escape processes, and the integrated loss to space over time