# Mars Atmosphere and Volatile EvolutioN Mission Science Community Workshop

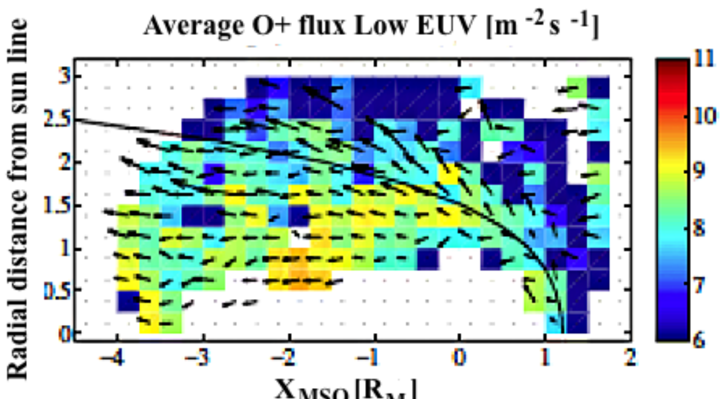
## Science Overview

J. M. Grebowsky

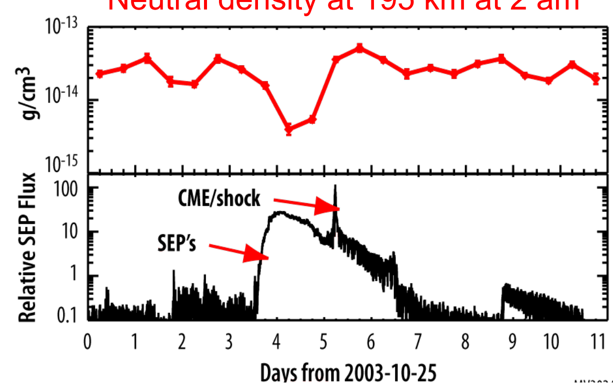
# Determine The Rate Of Escape Today and the History of Loss Through Time.

## Evidence for the Loss to Space Today

- Detection of energetic ionospheric ions moving away from the planet by *Mars Express* and *Phobos* Missions
- Mars Global Surveyor inferred observations of decrease in upper atmosphere density in response to a Solar Energetic Particle event




MEX Escape (Nilsson et al., 2010)




MGS Atmosphere Depletion (Lillis et al., 2006)

## Variation of Escape Through Time

- Absence of water
- Current atmospheric Isotopic ratios favor lighter species compared to cosmic abundances.
- Ion escape fluxes dependent upon solar evolution - at solar max (Phobos) ~ 10X larger ion escape than during solar minimum (Mars Express)

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

# Current Mars Volatile Escape Mechanisms

- Thermal (Jean's) escape : e.g. H

- Non-thermal escape:

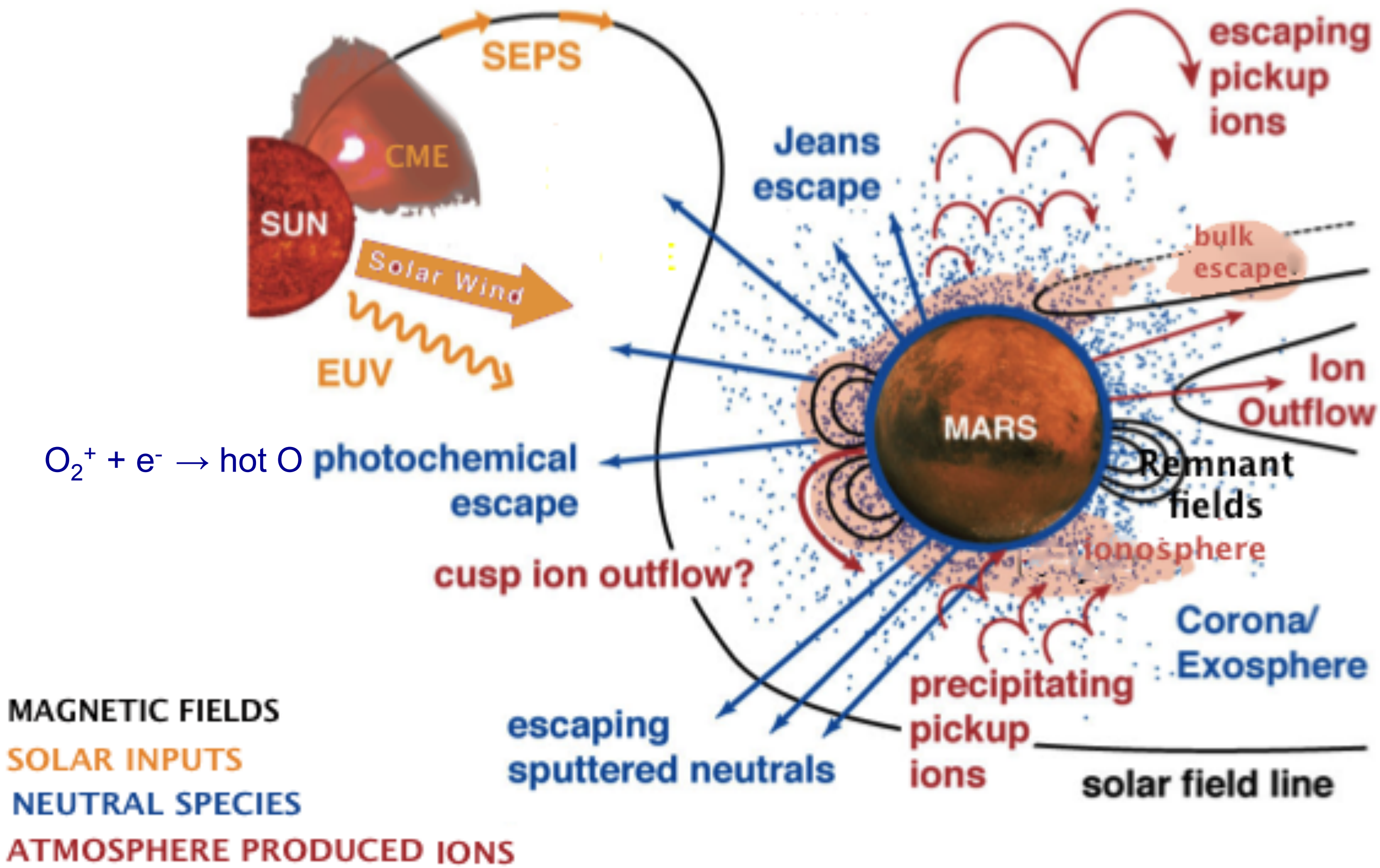
(1) *Photochemistry* : Dissociative recombination of $O_2^+$, $N_2^+$, $CO^+$ with $e^-$ forming energetic (hot) atoms (e.g. O, N, C) with escape energies

(2) *Pick-up ionization* : ions produced in the extended atmosphere (photoionized or charge exchange) are dragged along by solar wind electric field to partially escape ($O^+$, $H^+$, $C^+$…)

(3) *Ionospheric outflows*: planetary ions are accelerated by SW induced ionospheric EM-fields and lost in the wake (e.g. $O_2^+$)

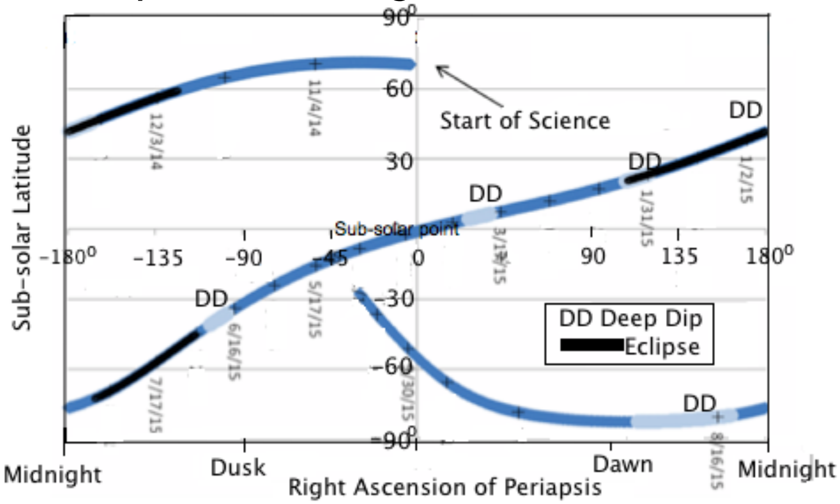
(4) *Ion sputtering*: a portion of SW and pick-up ions impact the neutral atmosphere with enough energy to eject neutral atmospheric particles at/above the exobase (e.g. $CO_2$, $N_2$, CO, O, N, C...).

# Magnetic Field Once Protected Atmosphere
# Now, Solar Wind/IMF Penetrates the System

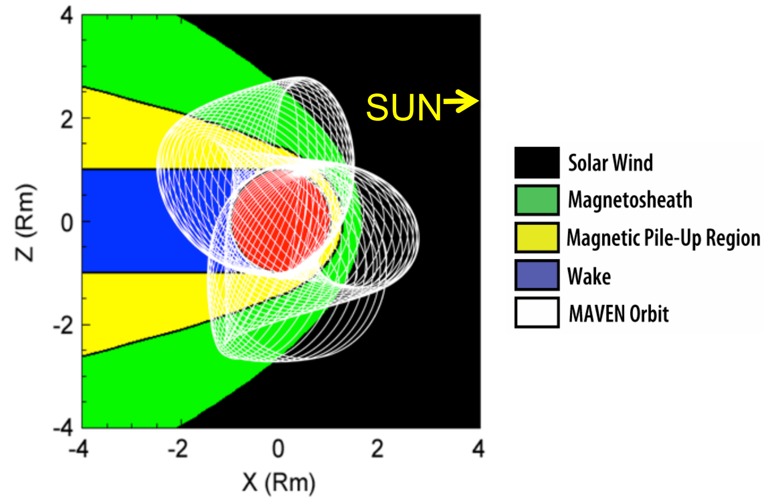


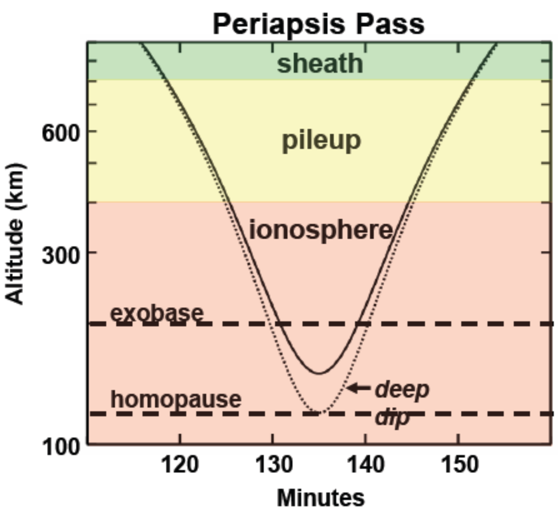
# Orbit was Judiciously Selected

*Periapsis Coverage of Latitude-Local Time*




*Looking Down on Polar Cap*




- Continuous orbit-to-orbit measurements
- Comprehensive diurnal coverage and periapsis passages through SH remnant magnetic field zones
- Traversal of all important magnetosphere – solar wind regions (apoapsis in solar wind; periapsis below exobase)
- Five Deep-dip campaigns to explore noon, midnight, polar cap and terminator regions.

# MAVEN Measurement Aims

## Reservoirs

- Characterization of upper atmospheric composition, structure, variability
- In situ measurements down to below the exobase
- Measurement of ionospheric thermal state

## Escape

- Measurement of ions from low (non-escaping) to high energies
- Track escaping ions down to exobase, to constrain driving loss processes
- Determination of relationship of state  properties and of escape to locally magnetized regions and to direction of IMF
- Measurements of all charged particle populations with improved measurements compared to the pathfinder MEX mission (e.g. improved angular resolution, energy range, and pitch angle measurements for all instruments)

## Evolution

- Measurement of isotope ratios that relate to atmospheric evolution
- Simultaneous measurements of energy inputs (EUV, E/M waves, Solar Wind, Solar Energetic Particles) to correlate escape variation with solar changes

# The Measurements

# EUV Monitor on Langmuir Probe And Waves (LPW)

Frank Eparvier, LASP

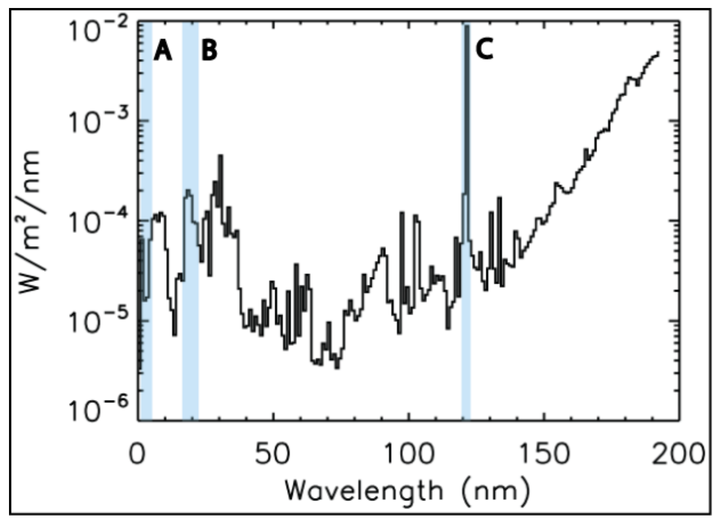
EUV MONITOR FLIGHT MODEL

***Measurement Objectives:***

- Solar EUV irradiance variability at wavelengths important for ionization, dissociation, and heating of the upper atmosphere (wavelengths shortward of HI Ly-α 121.6 nm)

***Technical details and heritage:***

- Three photometers at key wavelengths representing different temperature solar emissions (0.1-7, 17-22, and 121.6 nm)
- Heritage from TIMED, SORCE, SDO and rocket instruments
- Full spectrum (0-200 nm) derived from measurements using Flare Irradiance Spectral Model (FISM).



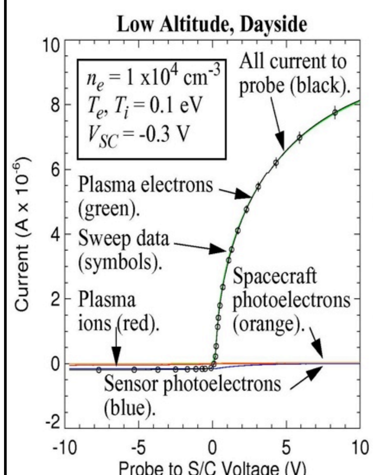
# Langmuir Probe and Waves (LPW)
## Bob Ergun, LASP

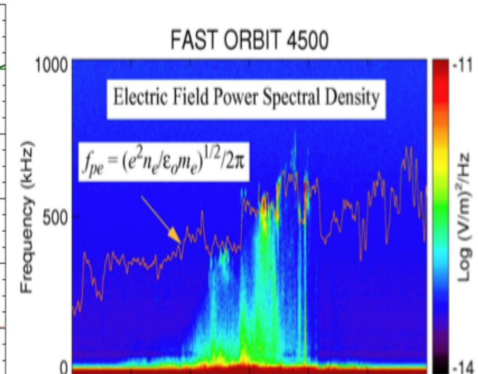
*Stacer booms to be used for deployment*

***Measurement Objectives:***
- Electron temperature and number density throughout upper atmosphere
- Electric field wave power at low frequencies important for ion heating
- Wave spectra of naturally emitted and actively stimulated Langmuir waves to calibrate density measurements

*Includes EUV monitor, described earlier*

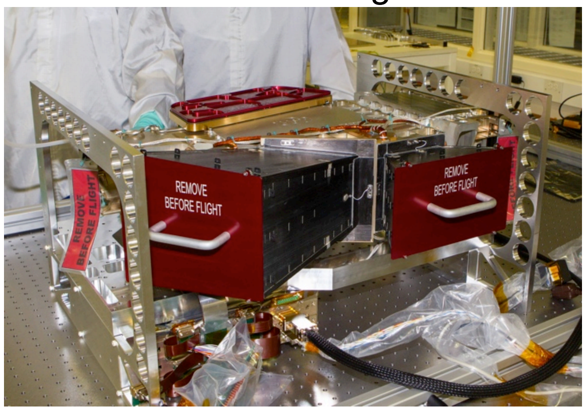
***Technical details and heritage:***
- Cylindrical sensors on two 7-meter booms
- Sensor I-V sweeps (at least ±50 V range)
- Low frequency (f: 0.05-10 Hz) E-field power
- E-Spectra measurements up to 2 MHz
- White noise (50 kHz-2 MHz ) sounding
- Heritage from THEMIS and RBSP



# Imaging Ultraviolet Spectrometer (IUVS)
## Nick Schneider, LASP

IUVS and DPU Flight Models

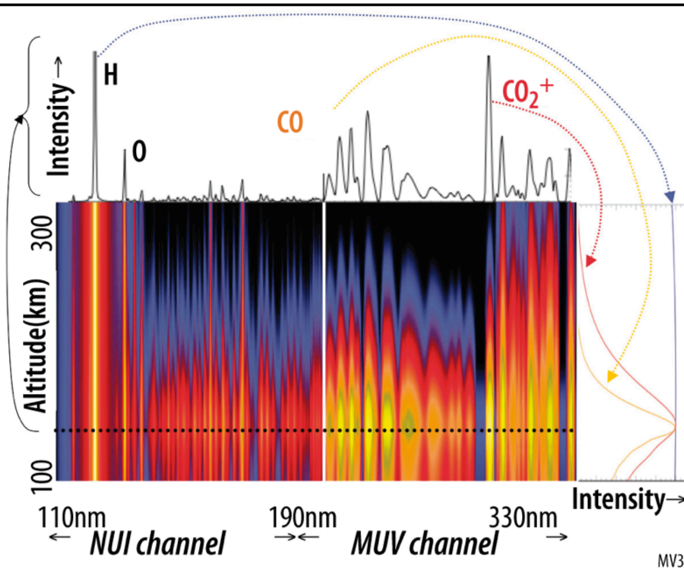



***Measurement objectives:***

- Vertical profiles of neutrals and ions through limb emissions and stellar occultations.
- Disk maps from near apoapsis.
- D/H and hot oxygen coronal mapping.
- Atmospheric properties below homopause.

***Technical details and heritage:***

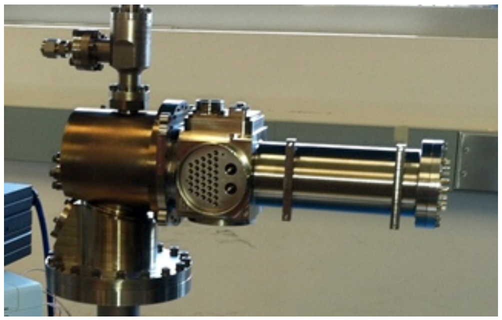
- Imaging spectroscopy from 110-340 nm, with resolution of 0.5 – 1.0 nm.
- Vertical resolution of 6 km on limb, horizontal resolution of 200km
- Most recent heritage from AIM CIPS




*Model spectra and derived profiles*

# Neutral Gas and Ion Mass Spectrometer (NGIMS)

Paul Mahaffy, GSFC



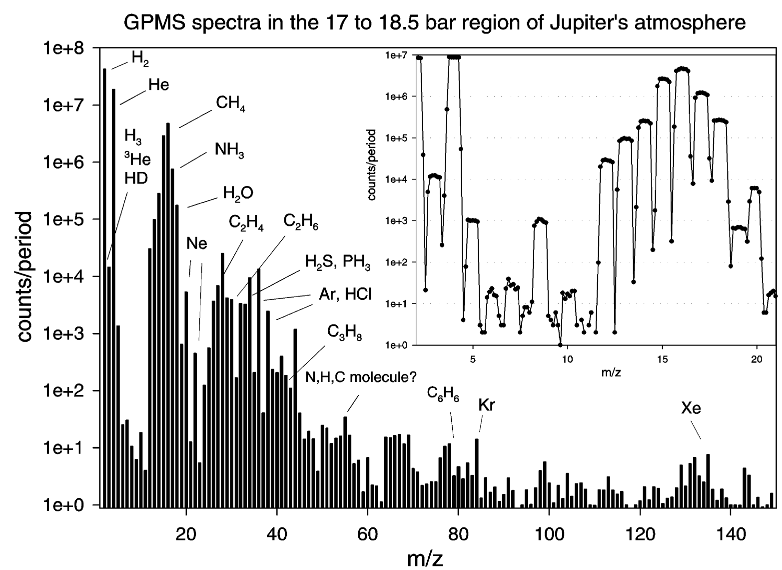
NGIMS Quadrupole Mass Spectrometer Sensor

**Measurement Objectives:**

- Basic structure of the upper atmosphere (major species He, N, O, CO, $N_2$, NO, $O_2$ Ar and $CO_2$) and ionosphere from the homopause to above the exobase
- Stable isotope ratios, and variations

**Technical Details:**

- Quadrupole Mass Spectrometer with open and closed sources.
- Closed source: non-reactive neutrals
- Open source: neutrals and ions
- Mass Range: 2 - 150 Da
- Heritage: Galileo GPMS, Pioneer Venus ONMS, CASSINI INMS, Contour NGIMS



# Accelerometer Science (ACC)
Rich Zurek (JPL)

Inertial Measurement Units (IMU)
[Accelerometers]

**Measurement Objectives:**

Vertical profiles of atmospheric density and temperature; possible wind profiles

**Technical Details:**

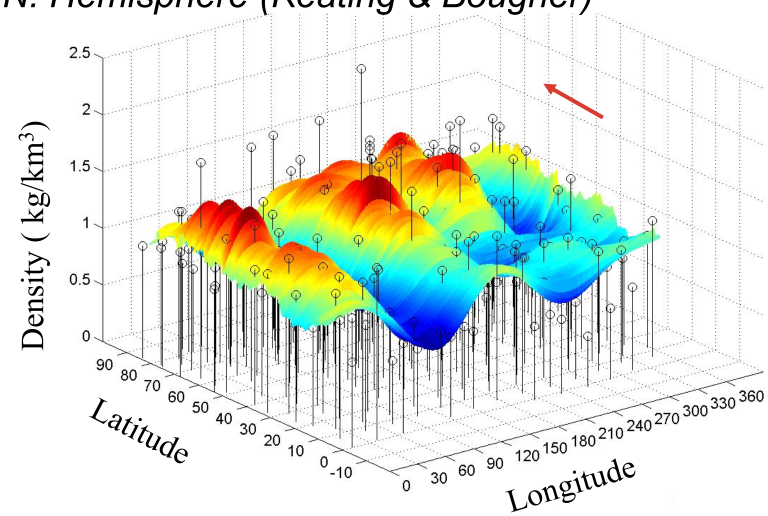
– Density derived from acceleration data $a_d$

$$\rho = \frac{2ma_d}{C_d S v^2}$$

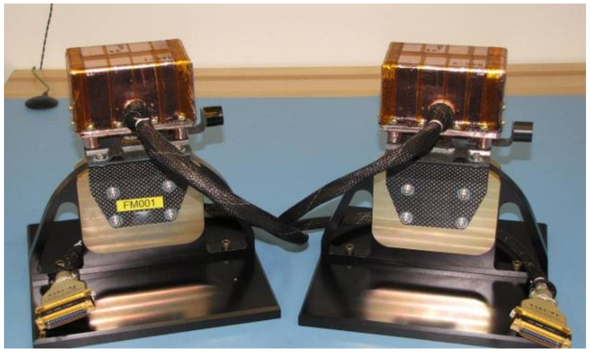
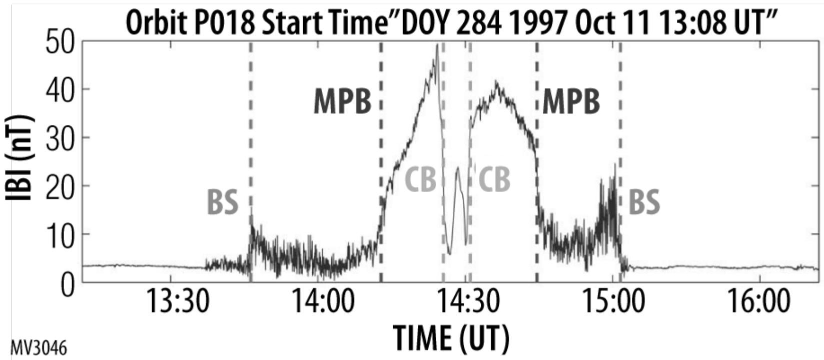
*m, S, v, & $C_d$ = spacecraft mass, X-section, velocity, & drag coefficient*

– Winds derived from NAV and ACS data

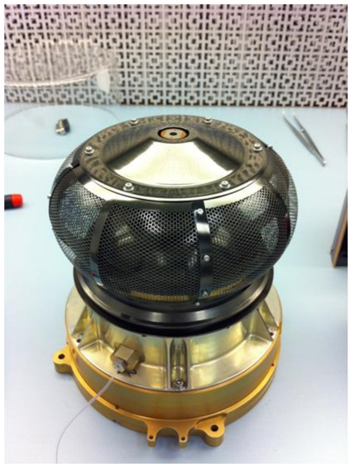
***Atmospheric Structure:*** *Odyssey saw large amplitude waves during early morning in the N. Hemisphere (Keating & Bougher)*



# Magnetometer (MAG)
## Jack Connerney, GSFC

| Magnetometer Sensors | ***Measurement objectives:*** |
| --- | --- |
|  | - Vector magnetic field in the unperturbed solar wind (B ~ 3 nT), magnetosheath (B ~ 10-50 nT), and crustal magneto-spheres (B < 3000 nT), with the ability to spatially resolve crustal magnetic cusps (horizontal length scales of ~100 km). |
| ***Technical details and heritage:***<br>-2 sensors, outboard of solar array<br><br>-Magnetic field over a dynamic range of ~ 60,000 nT; resolution 0.05 nT<br><br>-Heritage: *MGS, Voyager, AMPTE, GIOTTO, CLUSTER, Lunar Prospector, MESSENGER , STEREO,* Juno, RBSP | *MGS* MAG measurements:<br> |

# Solar Wind Electron Analyzer (SWEA)
## David L. Mitchell, SSL

<table>
<tr>
<td><br>SWEA Flight Model</td>
<td>Measurement objectives:<br>- Measure energy and angle distributions of electrons in the Mars environment<br>- Determine electron impact ionization rates<br>- Measure magnetic topology via loss cone measurements<br>- Measure primary ionospheric photoelectron spectrum<br>- Measure auroral electron populations<br>- Evaluate plasma environment</td>
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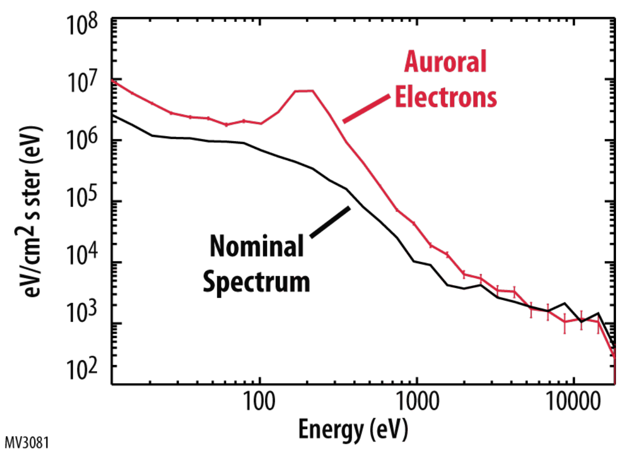
<tr>
<td>Technical details and heritage:<br>- Hemispherical Electrostatic Analyzer<br><br>- Electrons with energies from 5 eV to 5 keV<br><br>- FOV 360° X 130°<br><br>- Based on STEREO SWEA.</td>
<td>MGS measurements of auroral electrons:<br><br></td>
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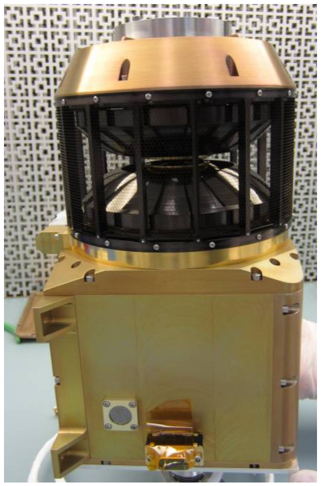
# Solar Wind Ion Analyzer (SWIA)
## Jasper Halekas, SSL



Flight Model

***Measurement objectives:***

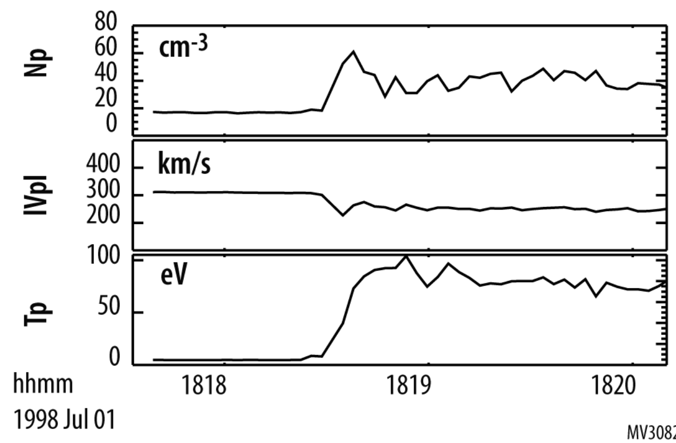
- Density and velocity distributions of solar wind and magnetosheath ions to determine the charge exchange rate and the bulk plasma flow from solar wind speeds (~350 to ~1000 km/s) down to stagnating magnetosheath speeds (tens of km/s).

***Technical details and heritage:***

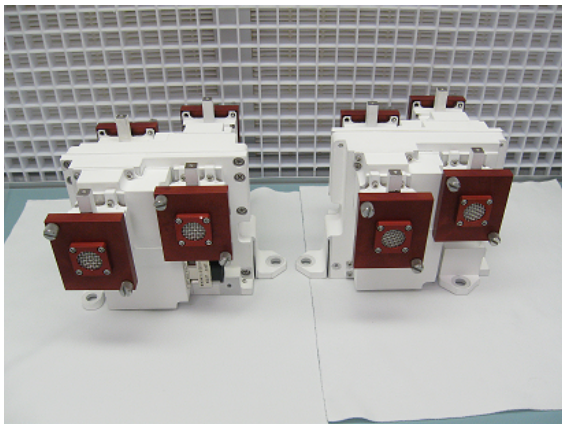
- Proton and alpha particle velocity distributions from <50 to >2000 km/s, density from 0.1 to >100 $cm^{-3}$

- Heritage from Wind, FAST, and THEMIS.

Similar measurements provided by *Wind*:



# Solar Energetic Particle (SEP) Analyzer
Davin Larson, SSL



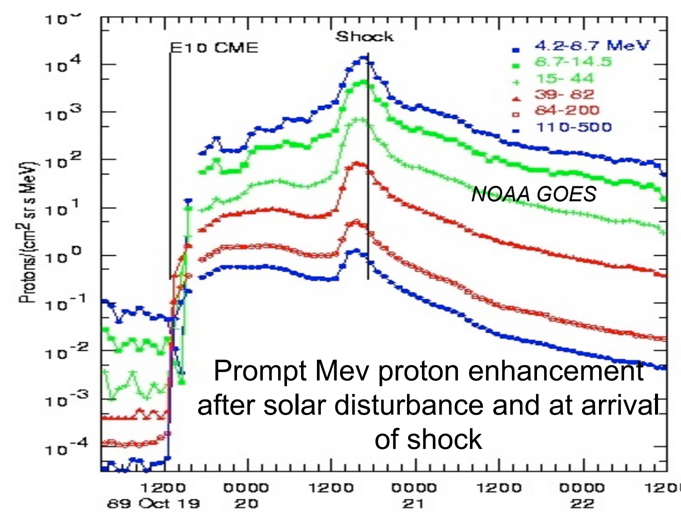
Flight Models

***Measurement objectives:***

- Characterize solar particles in an energy range that affects upper atmosphere and ionospheric processes (~120 – 200 km)

***Technical details and heritage:***

- Two dual double-ended telescopes
- Protons and heavier ions from ~25 keV to 12 MeV
- Electrons from ~25 keV to 1 MeV
- Nearly identical to SST on THEMIS.




Reams 1999, Space Sci. Rev., 90, 413

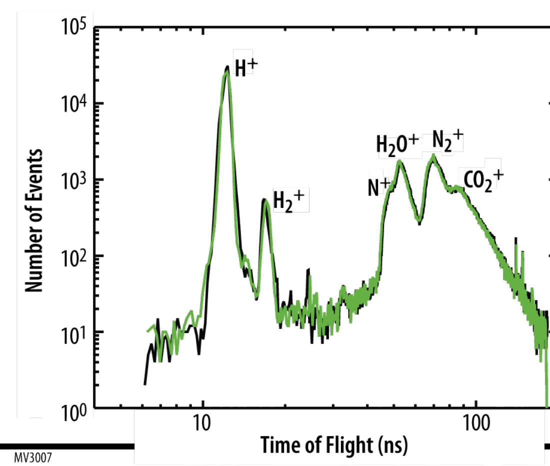
# Suprathermal and Thermal Ion Composition (STATIC)
## Jim McFadden, SSL

Flight Model

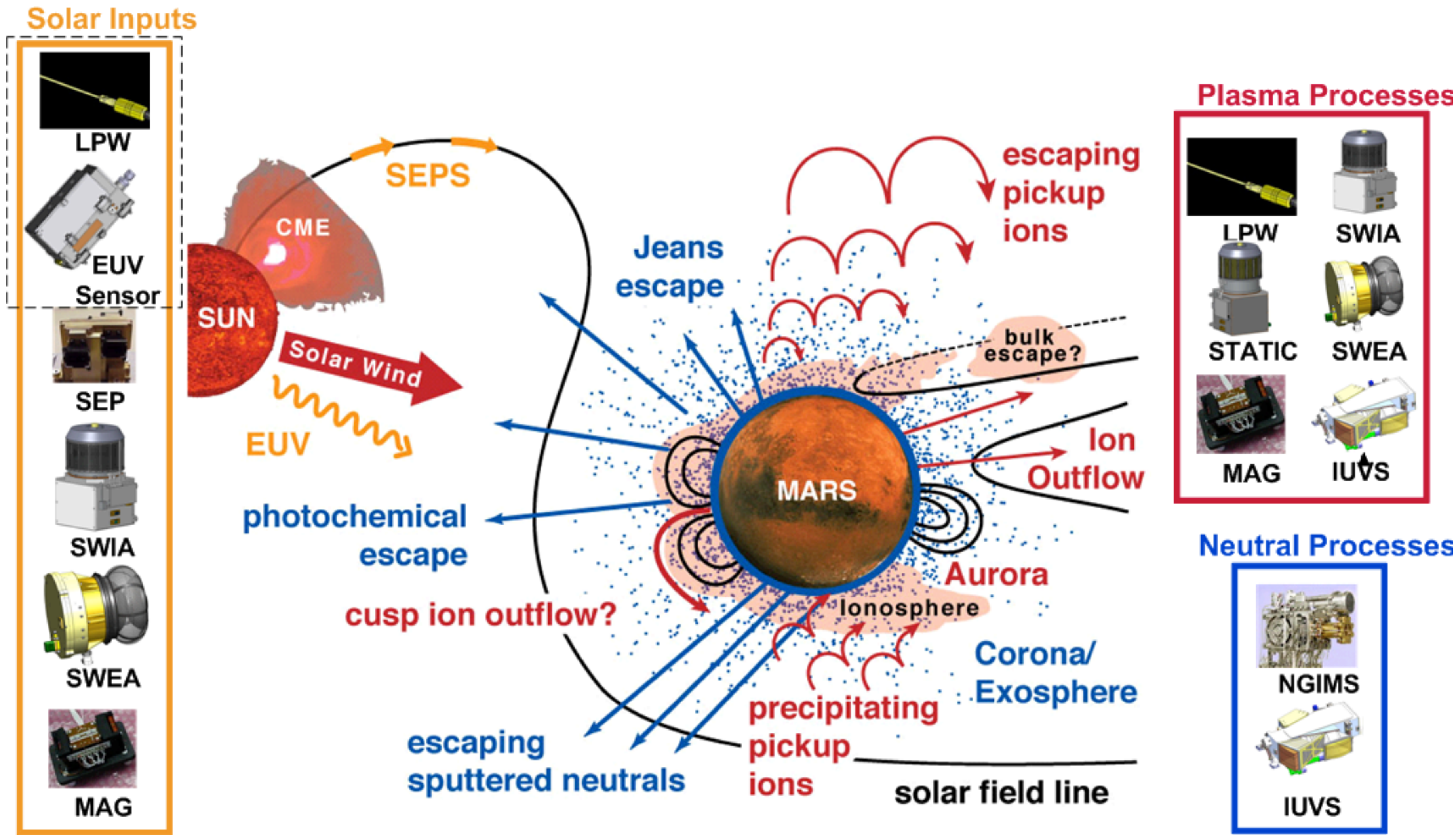
***Measurement objectives:***
- -Escaping ions and processes
- -Composition of thermal to energetic ions; energy distributions and pitch angle variations
- -Ionospheric Ions 0.1-10 eV
- -Tail Superthermal ions (5-100eV)
- -Pick-up Ions (100-20,000 eV)
- -Key ions $H^+$, $O^+$, $O_2^+$, $CO_2^+$

***Technical details and heritage:***
- –Toroidal Electrostatic Analyzer with Time of Flight section
- –Mass Range 1-70 AMU, $\Delta M/M > 4$
- –Energy range ~1 eV to 30 keV, $\Delta E/E$~15%
- –FOV 360º X 90º
- –Heritage from Cluster CODIF.

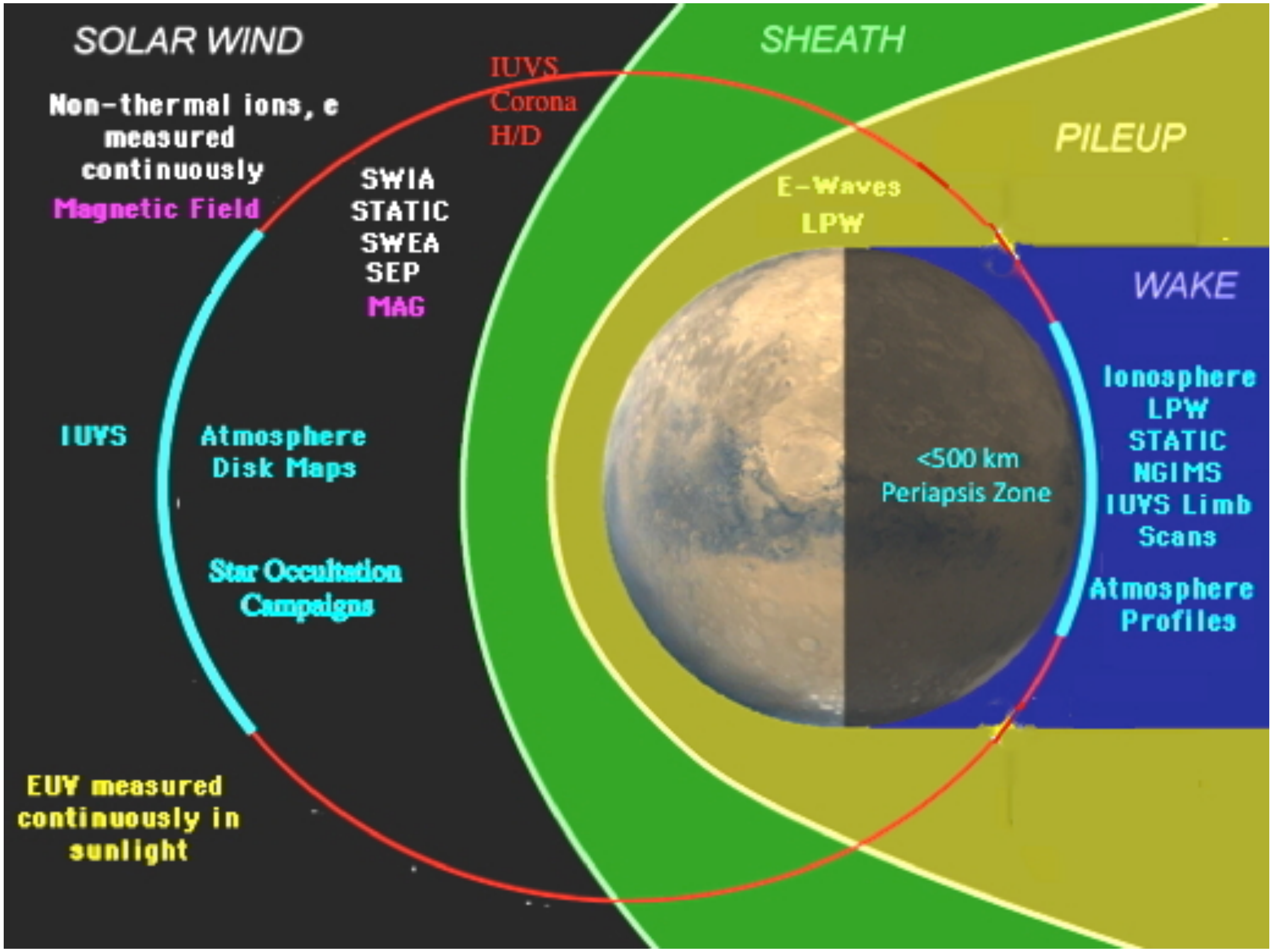
Laboratory spectrum from Engineering Development Unit



# Instruments Sample all the Relevant Physics



# Integated Sequencing of Measurements



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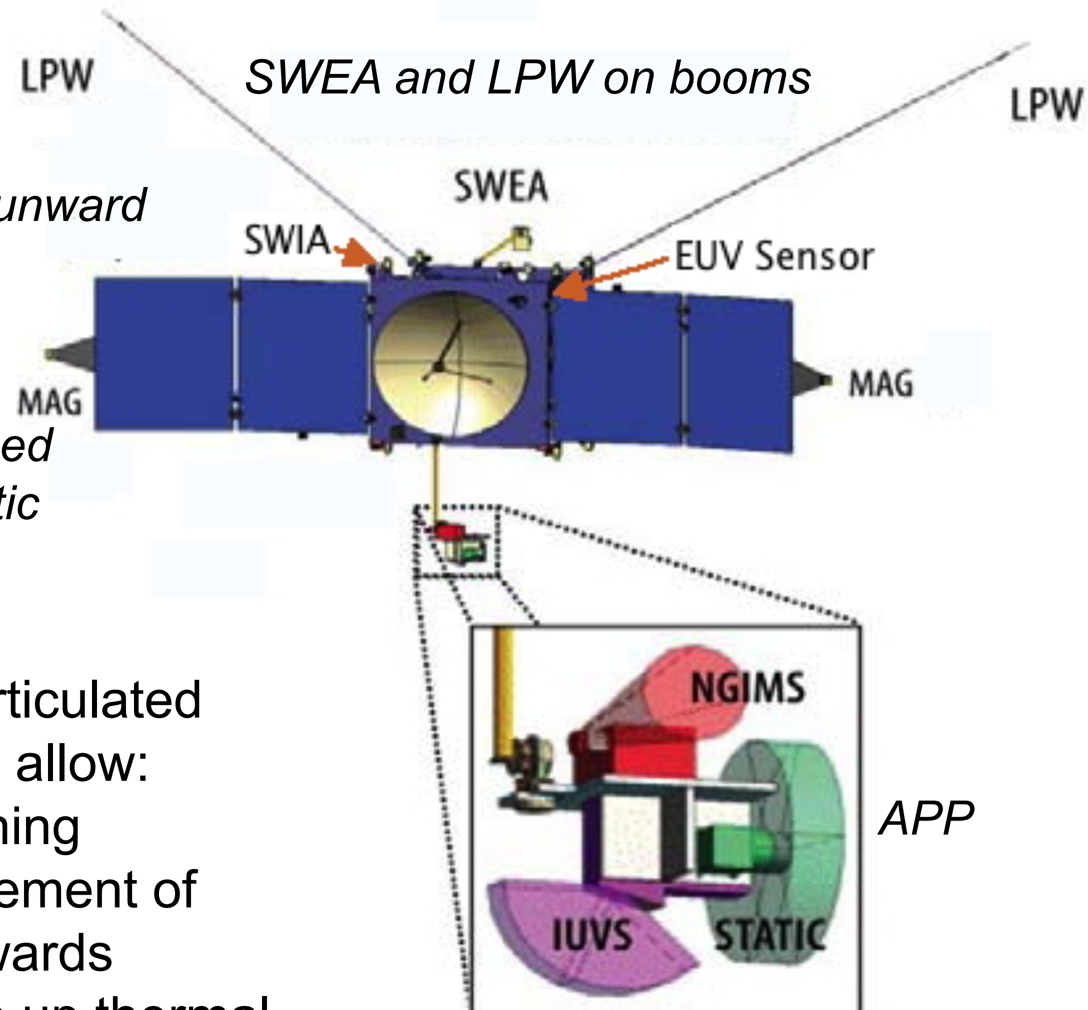
# Instrument Placements

SWEA and LPW on booms

SWIA and EUV point sunward

Magnetometers positioned away from array magnetic perturbations




APP

Field-of-views

- Three instruments on Articulated Payload Platform (APP) allow:
  1. IUVS limb scanning
  2. STATIC measurement of ions escaping upwards
  3. NGIMS to scoop up thermal species in s/c ram direction

# SUMMARY

- MAVEN's orbital period, inclination, and periapsis altitude will provide the best comprehensive coverage of Mars escape-related regions possible for a one Earth-year mission
- The instruments, which have high heritage, will sample all escape processes
- Phasing of the mission on the declining phase of the solar cycle maximizes the range of solar variability inputs needed for extrapolating loss vs. solar inputs backwards in the history of the solar system
- In addition theoretical modeling efforts are planned to provide closure in understanding