MAVEN

Mars Atmosphere and Volatile EvolutioN Mission

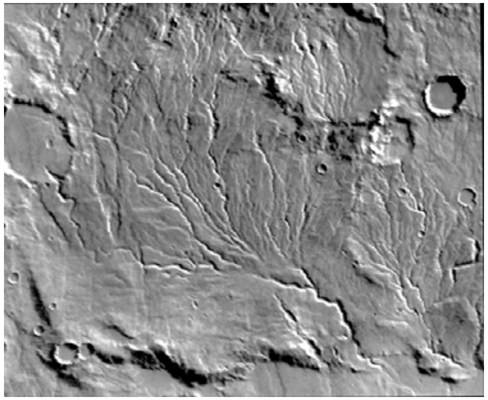
GSFC Project Scientist: Joe Grebowsky

P.I. Bruce Jakosky
University of Colorado

Dep. P. I. Bob Lin, University of California, Berkeley

Prepared for Mars III Workshop Les Hoches, France, 2010

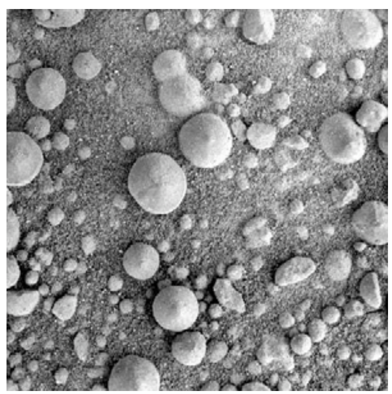
Science Drivers



Tributaries

Meanders

Sedimentary Layering



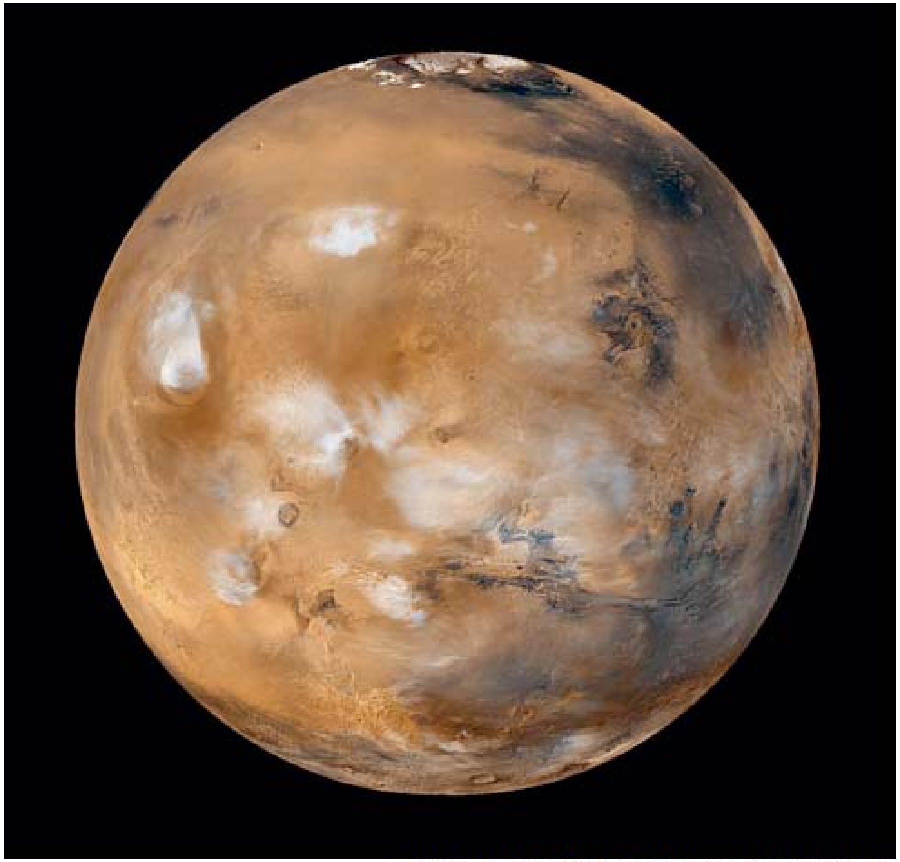
Blueberries

- History of liquid water and of the atmosphere determine Mars' past potential for life
- Abundant evidence for climate change and atmospheric loss to space:
    - o Geological evidence for liquid water- requires a dense, warm atmosphere
    - o Consistent pattern of depletion of lighter isotopes
    - o Theoretical models and analogies with escape measurements at Venus (PVO and VEX)
    - o Direct observation of escaping atoms (MEX)
- Loss of atmospheric CO_2, N_2, and H_2O to space leads to atmospheric evolution

The MAVEN mission will determine the rate of escape to space today and the history of loss through time.

MAVEN's Science Questions

- What is the current state of the upper atmosphere and what processes control it?
- What is the escape rate at the present epoch and how does it relate to the controlling processes?
- What has the total loss to space been through time?



Photograph by NASA/JPL/Malin Space Science Systems

Only by understanding the role of escape to space can we fully understand the history of the atmosphere, climate, and water.

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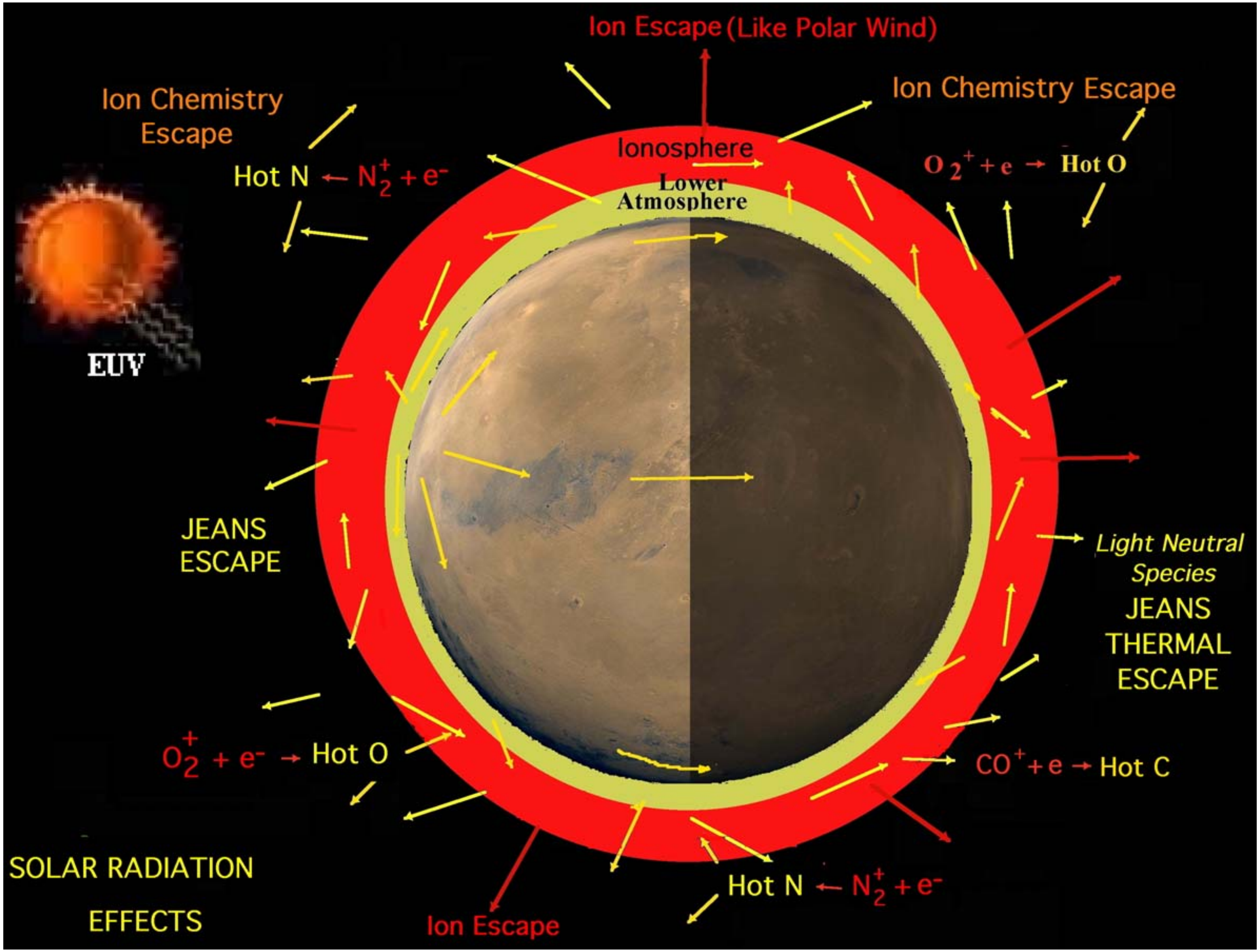
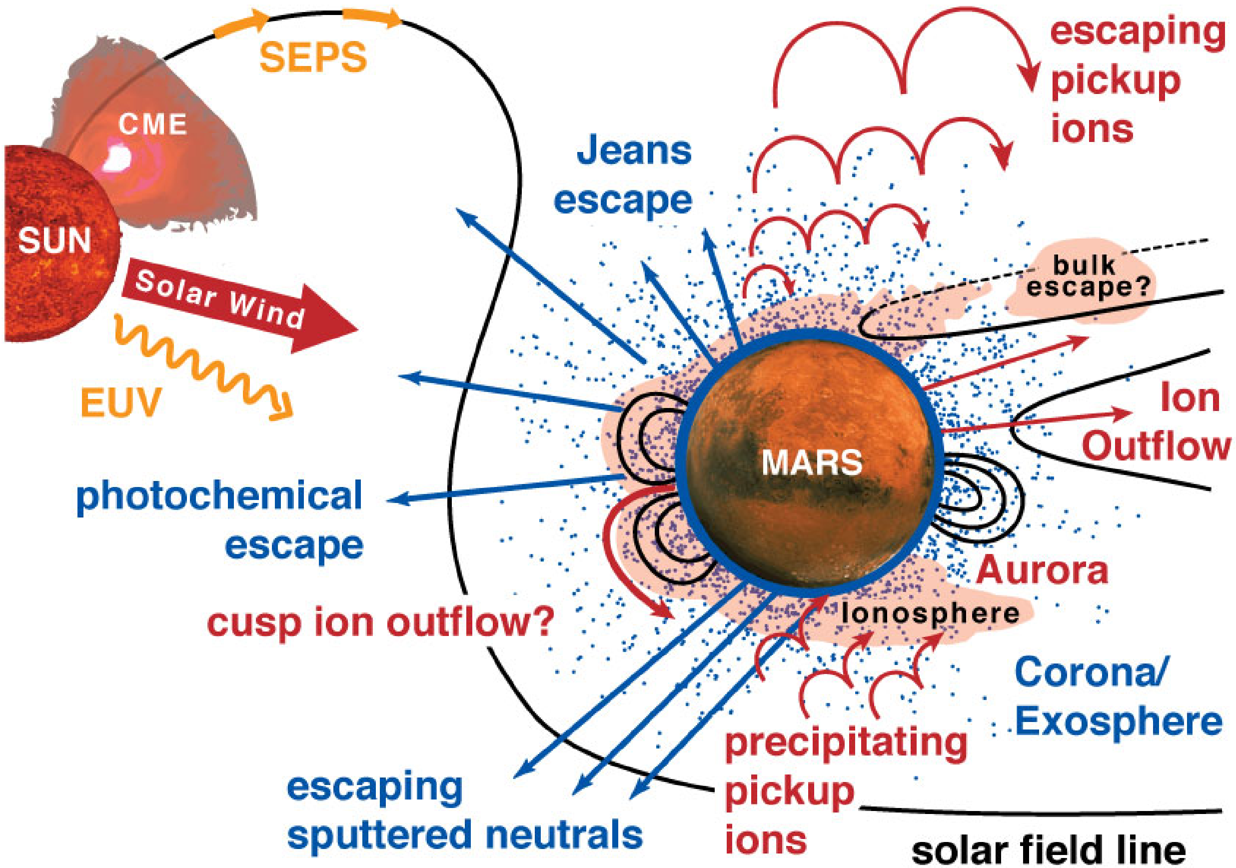
To Satisfy Mission Objectives

- Goal: Current State of Upper atmosphere and Controlling Processes
    - *Measure upper atmosphere-plasma and magnetic field over all local times and from N. polar cap to S. polar cap regions*
    - *Measure from solar wind-ionosheath to below exobase (turbopause) and within ionospheric density peak.*
    - Goal: Escape Rate at Current Epoch and Controlling Processes
    - *Measure particles with escape speed and species that chemically produce escape speeds along with solar radiation and solar wind inputs on same orbits.*
    - Goal: Total loss through time
    - *Measure isotope ratios*
    - *Determine correlation of each escape process to solar energy inputs and remanent magnetic fields.*

Solar EUV Driven Escape
Without Solar Wind and Magnetic Fields



Solar Wind and Magnetic Fields Expands the Escape Scenarios



- Absence of intrinsic magnetic field exposes parts of atmosphere to solar wind/IMF - driven escape

- Remanent magnetic field regions with aurora may have wave-driven loss processes

Summary of Atmospheric Removal Processes

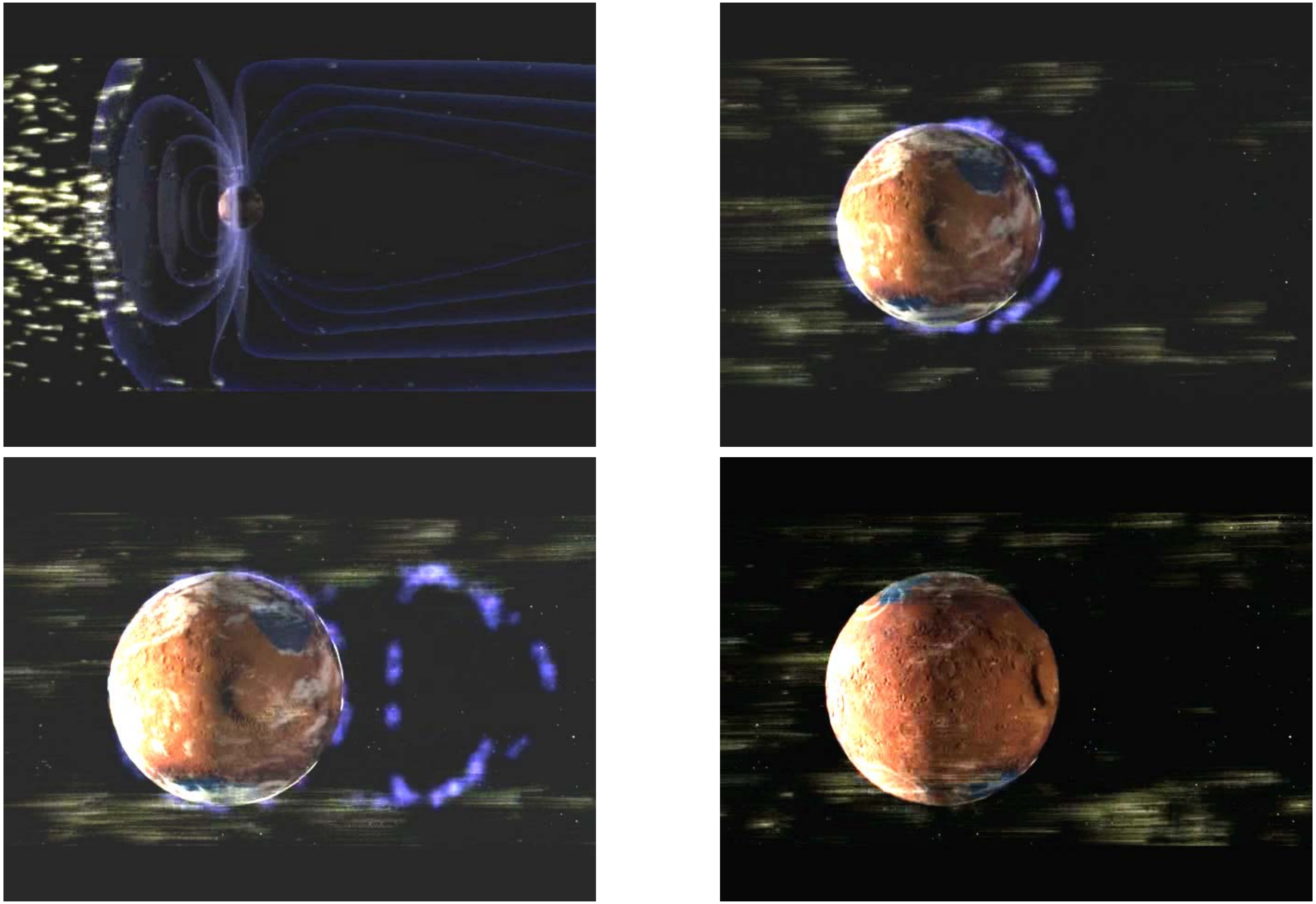
THEN:

- **Magnetic field held off solar wind**
- **Hydrodynamic blow off of dense hot atmosphere**
- **Large body impacts**
- **Formation of carbonate minerals on surface and in the subsurface**

NOW:

- **Thermal escape - H and He only**
- **Photochemical loss by dissociative recombination - N, C, and O**
- **Solar-wind stripping - upper-atmospheric ions swept away by solar wind**
- **Energetic neutrals from recombination of pickup-ions (KEV's) and Solar Energetic Particles, SEP, (~MEV's) sputter atmosphere species into space.**

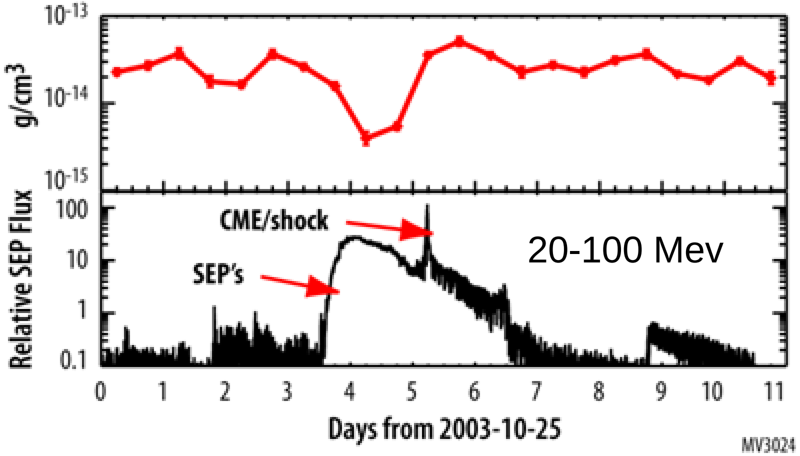
Possible Scenario for Early Atmosphere Loss



Some of the Experimental Evidence for the Importance of Loss to Space

- Isotopic fractionations that cannot be explained except by loss to space.
- Direct detection of energetic ions moving away from the planet by *Mars Express*.
- Energetic pickup ions detected on the *Phobos Mission*
- *Mars Global Surveyor* observations of dramatic atmospheric depletion in response to a solar energetic particle (SEP) event.

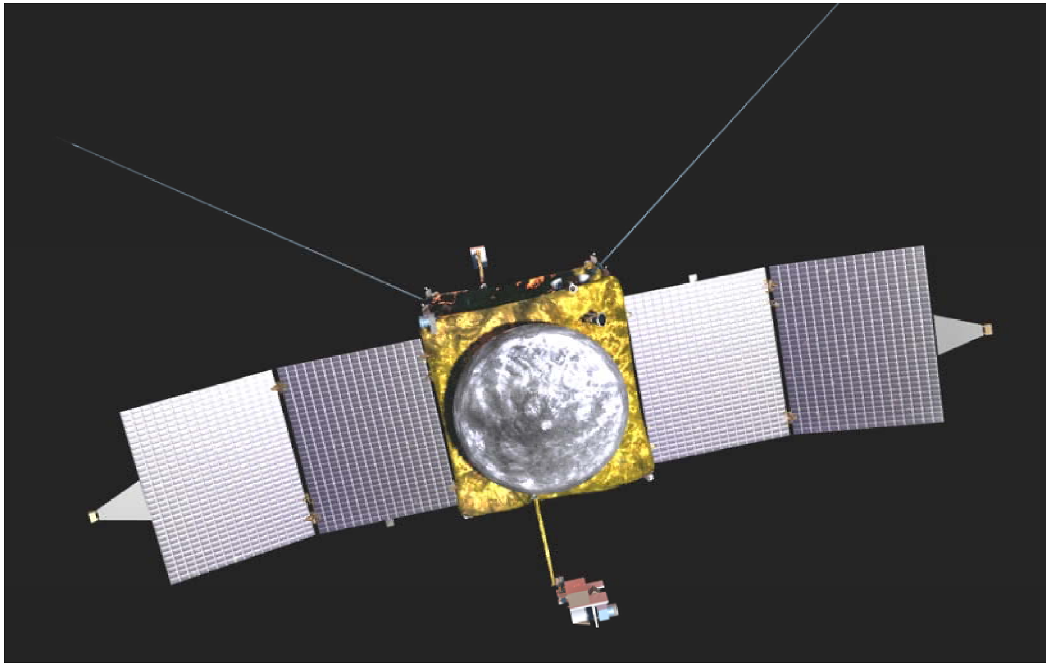
Neutral density at 195 km at 2 am



Some Mission Facts

- 3-axis-stabilized,
  sun-pointing spacecraft
  (Lockheed Martin)

- Articulated pointing platform carrying 3 instruments desiring ram-, limb-, nadir- and Sun-pointing on different phases of orbit.



- Two 6 meter booms for spherical Langmuir Probe Wave instruments.

- Eight science instruments
  (CU/LASP, UC Berkley/SSL,GSFC)

- Project Management: GSFC, Navigation: JPL.

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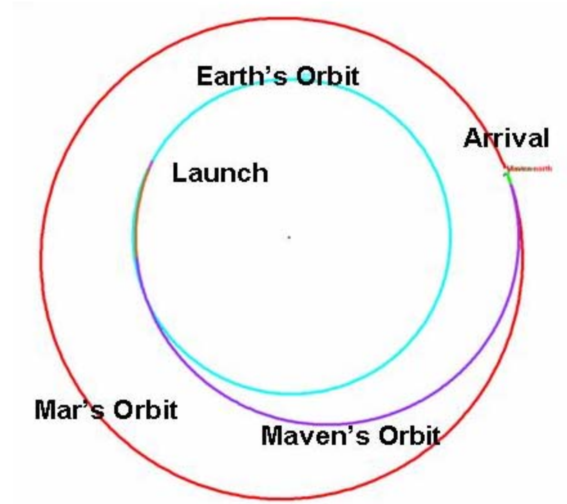
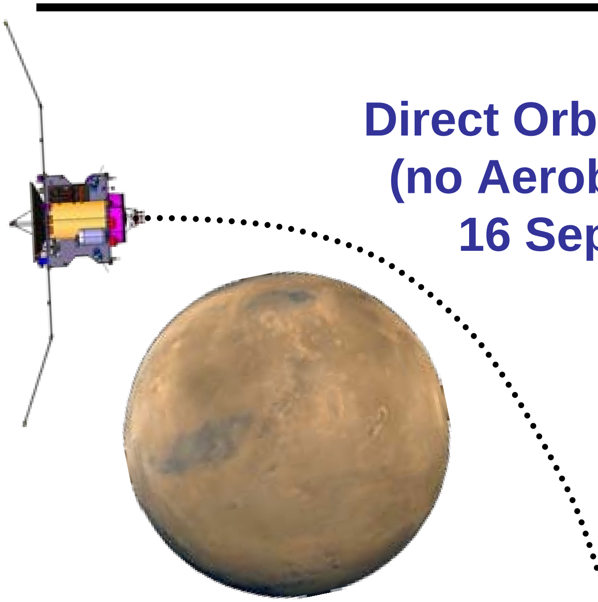
MAVEN Mission Architecture

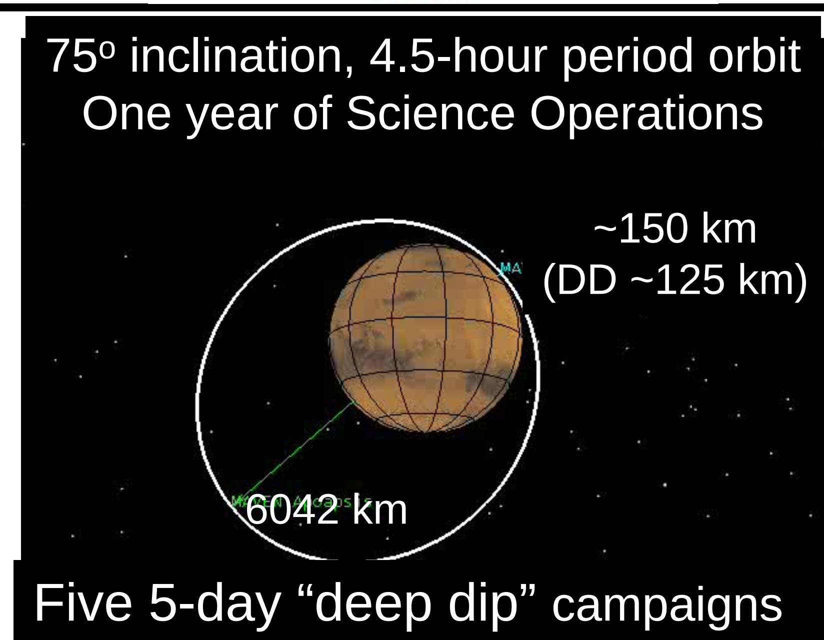
Launch
November 18, 2013
(Latest December 7)

Ten Month Ballistic Cruise to Mars



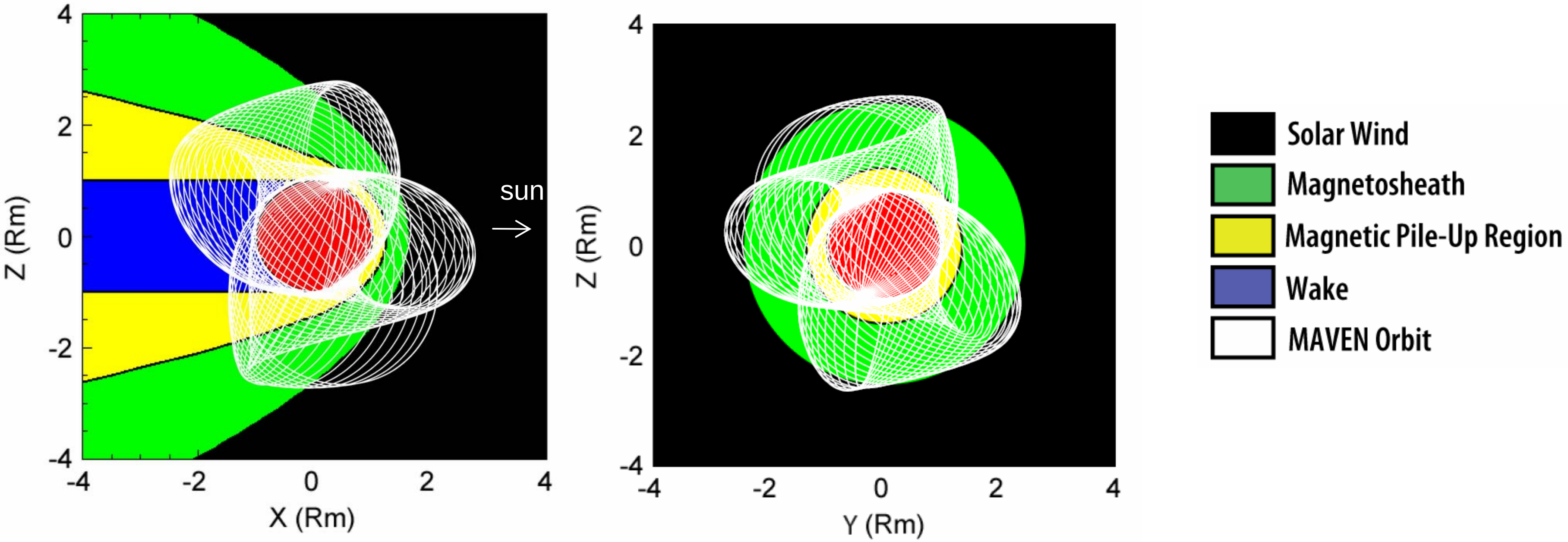


Direct Orbit Insertion
(no Aerobreaking):
16 Sept 2014



MAVEN Orbit and Primary Mission

- Elliptical orbit provides coverage of all important regimes
- The orbit precesses in both latitude and local solar time
- One-Earth-year mission: thorough coverage of near-Mars space and maximum variation of incident solar EUV due to Mars heliocentric variation

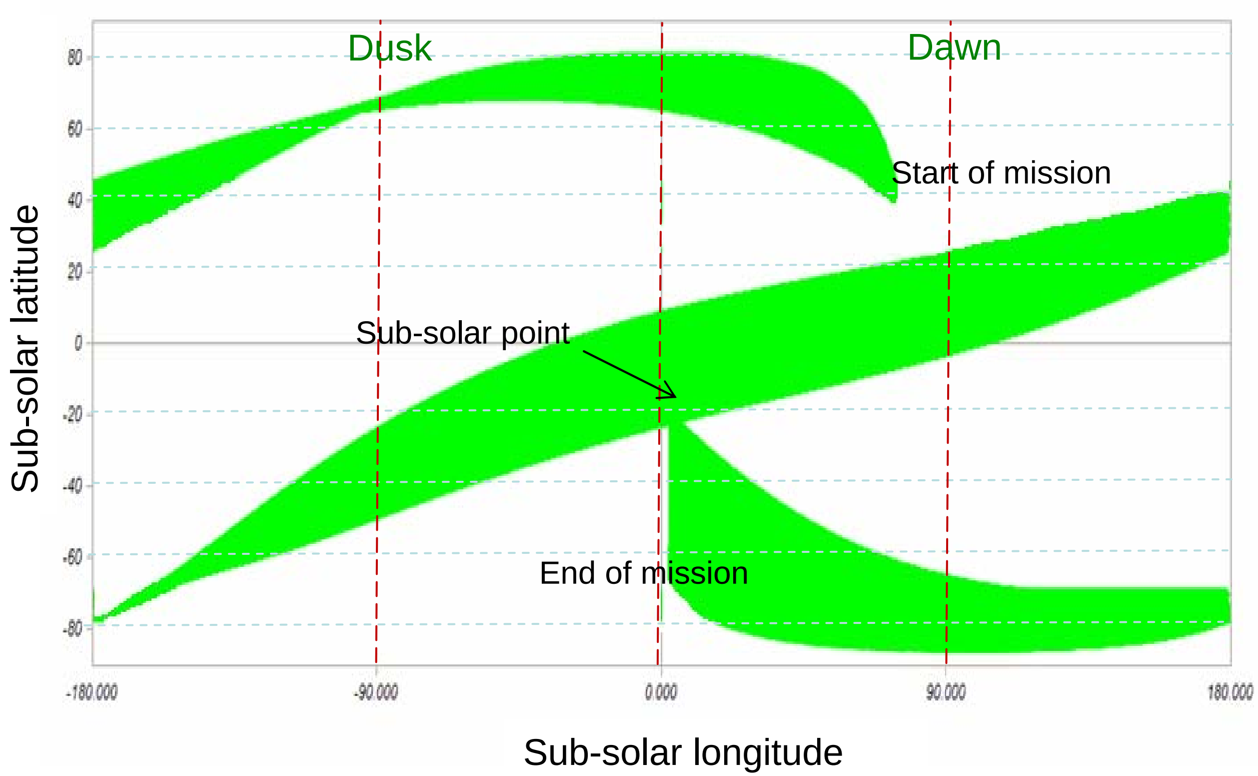


Looking down on N polar cap

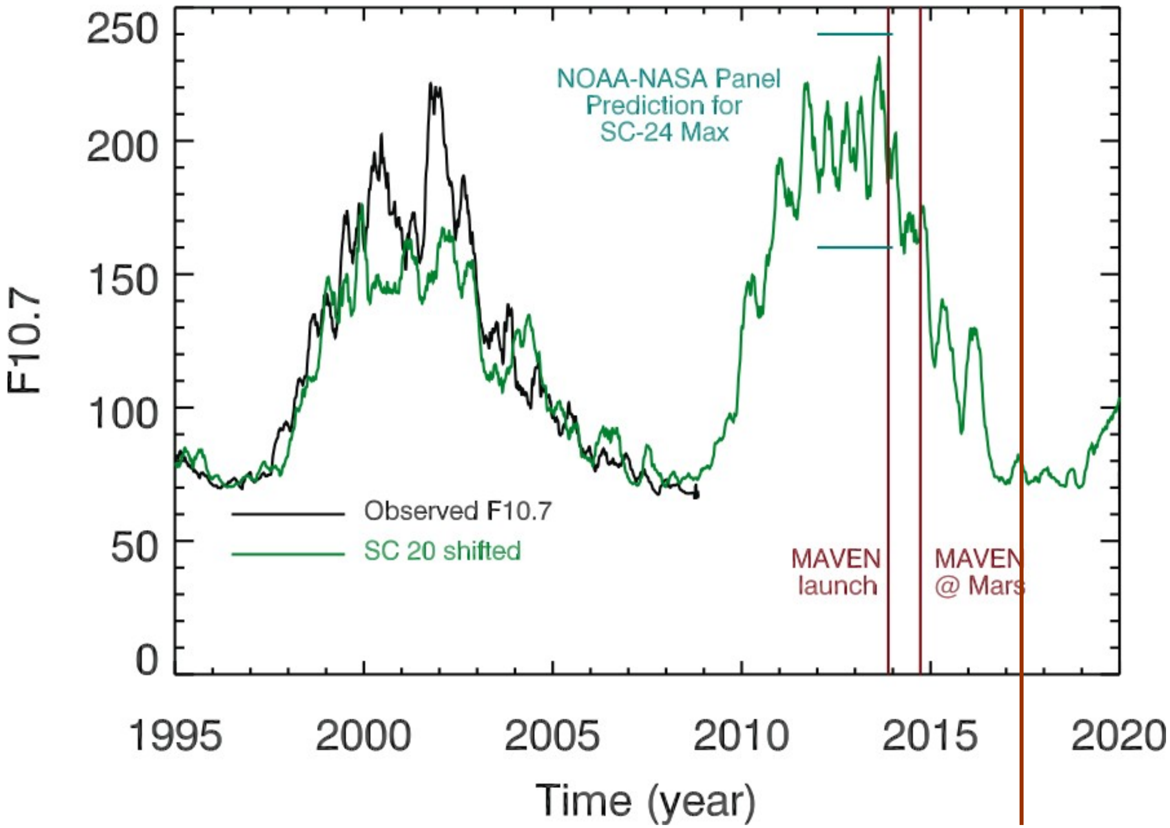
Looking toward Sun

Latitude and Local Time Coverage

- One-Earth-year mission provides coverage of all local solar times and most latitudes.
- Figure shows periapsis regions (spacecraft altitudes below 250 km). (Apoapsis is, of course, on the opposite side of the planet.)



MAVEN's Place in the Solar Cycle



•MAVEN will be observing on the declining phases of the solar cycle, when EUV flux varies the most and when solar storms are abundant.

•Due to eccentricity of Mars orbit average EUV will also vary by ~45%

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Measurements

Neutrals	
• **NGIMS**	**In situ, composition, isotopes**
• **IUVS**	**Global, composition, isotopes – D/H**
Ions	
• **NGIMS**	**In situ, thermal, high resolution mass composition**
• **STATIC**	**Thermal, outflow, composition, conics, pick-up ions**
• **SWIA**	**Solar wind, magnetosheath**
• **SEP**	**Solar energetic particles**
Electrons	
• **LPW**	**Thermal**
• **SWEA**	**Solar wind, ionosheath, auroral, photo-electrons**
Photons	
• **LPW (EUV)**	**Soft X-rays, extreme UV, Lyman-α**
Fields	
• **MAG**	**Magnetic fields, low frequency magnetic waves**
• **LPW**	**Wave electric fields**

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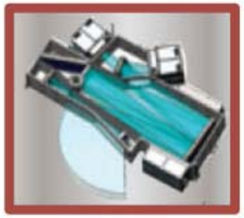
The MAVEN Science Instruments

Mass Spectrometry Instrument

NGIMS

Neutral Gas and Ion Mass Spectrometer; Paul Mahaffy, GSFC

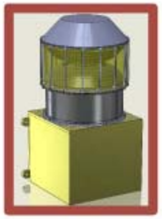
Remote-Sensing Package



IUVS

Imaging Ultraviolet Spectrometer; Nick Schneider, LASP

Particles and Fields Package



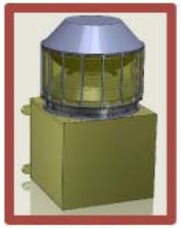
STATIC

SEP

SupraThermal And Thermal Ion Composition; Jim McFadden, SSL

Solar Energetic Particles; Davin Larson, SSL

SWEA

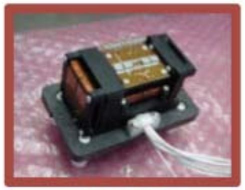


SWIA

Solar Wind Electron Analyzer; David Mitchell, SSL

Solar Wind Ion Analyzer; Jasper Halekas, SSL

LPW



MAG

Langmuir Probe and Waves; Bob Ergun, LASP

Magnetometer; Jack Connerney, GSFC

MAVEN instruments are all closely based on similar instruments flown on previous missions.

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Some Instrument Details

- MAG

Magnetic field ~0.1 to ~60,000 nT, 0-10 Hz

SWIA

H^+ and He^{++} ~10 ev to 25 kev/q, 3D bulk flow from ~50 to >~2000 km/s, density, temperature,

- SWEA

Electrons 5 eV to 6 keV energy and angular distributions

- STATIC

Major ions, 1 eV-30 keV. Pick-up ion fluxes and composition at higher energies; density velocity and velocity for lower energies

- SEP

Ions: 30-KeV to 12 MeV ions, Electrons: ~25 to 400 keV

- NGIMS

Thermal ion, neutral concentrations. High mass resolution.

- LPW

Thermal electron density and temperature
Electric field 1-10 Hz

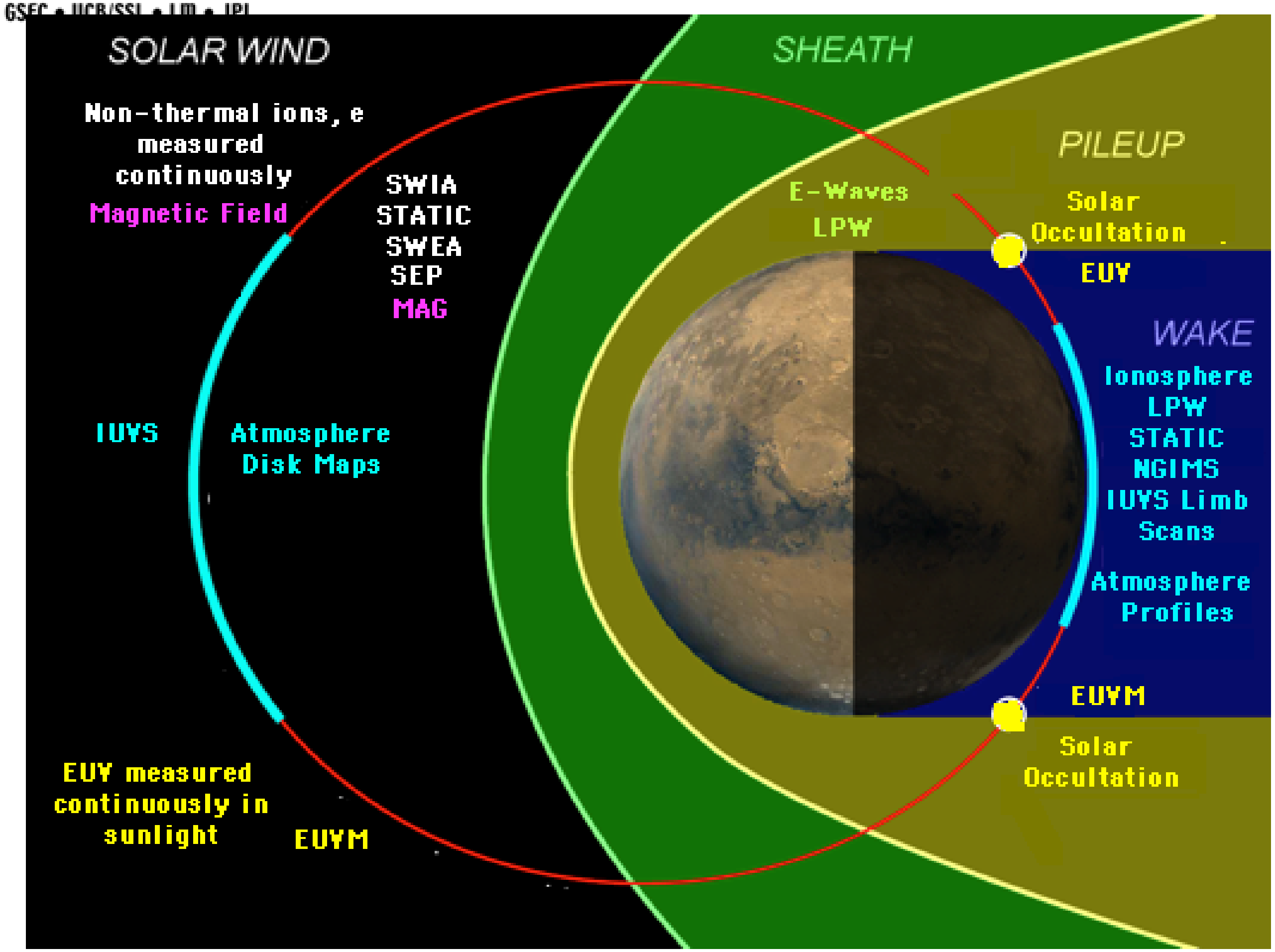
- EUV

3 channels – Lyman alpha, solar corona, hot corona

- IUVS

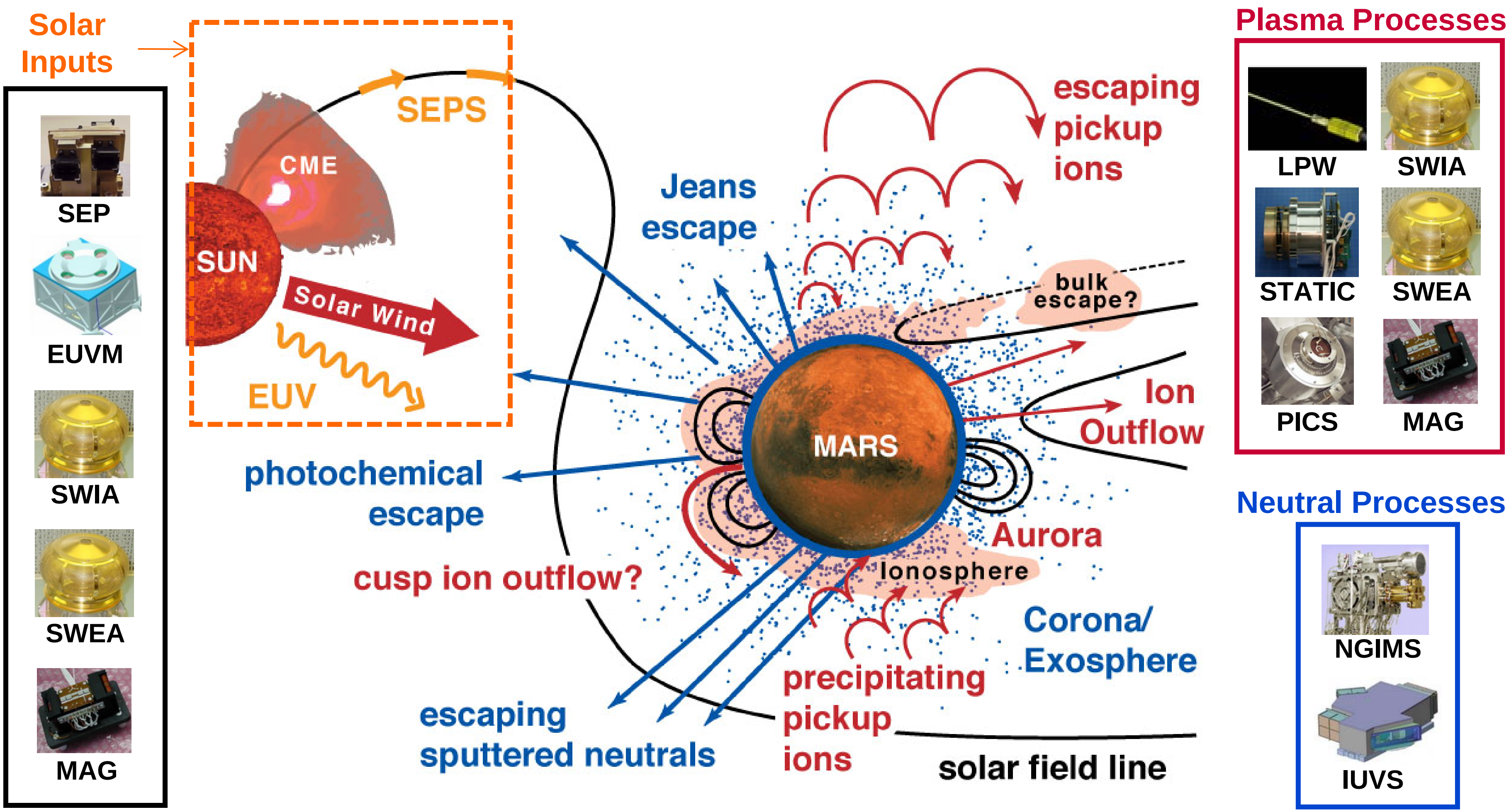
D/H Coronal Scans
Planetary mapping
Coronal mapping
Stellar occultations
Periapsis limb Scans
Regional Images – aurora

Coordinated Measurements



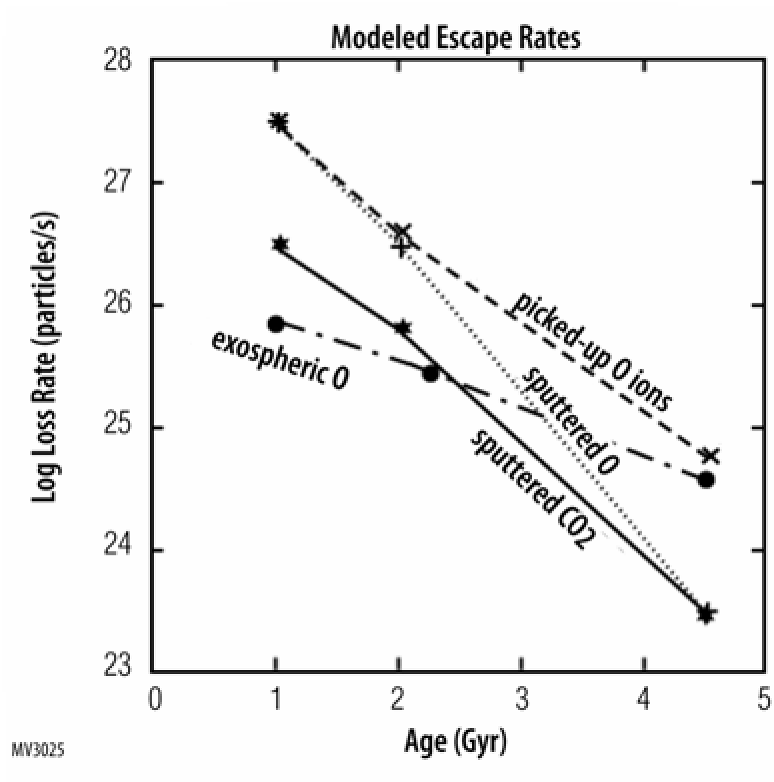
•Solar EUV and Solar Wind (ionosheath)/ IMF measurements provide context for atmospheric/ ionospheric structure measured remotely by IUVS and in situ by NGIMS, LPW and STATIC and ion losses measured by STATIC and SWIA.

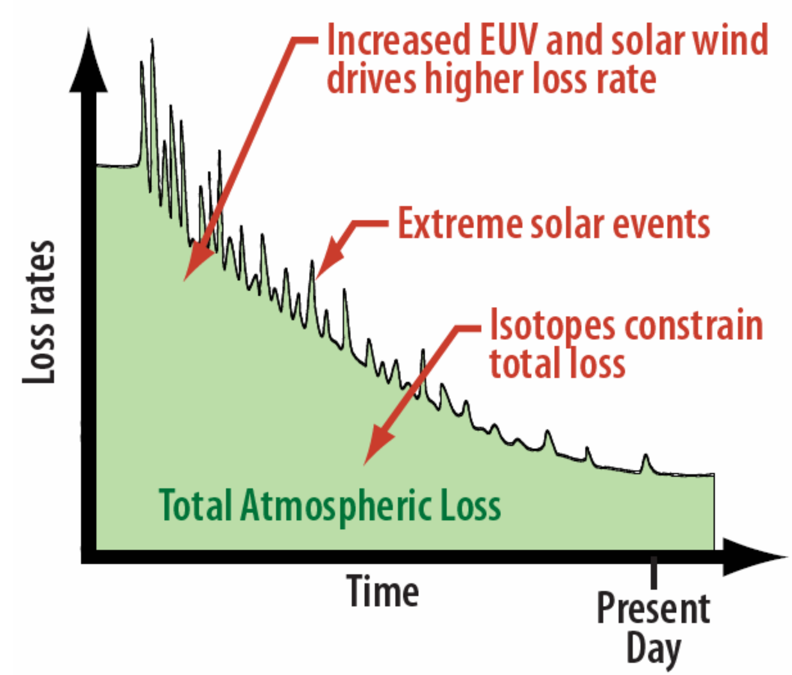
Measuring Drivers, Neutral and Ion Reservoirs, and Escape



- MAVEN will determine the present state of the upper atmosphere and today's rates of loss to space and dependencies on solar energy inputs

Constraining the Total Atmospheric Loss Through Time

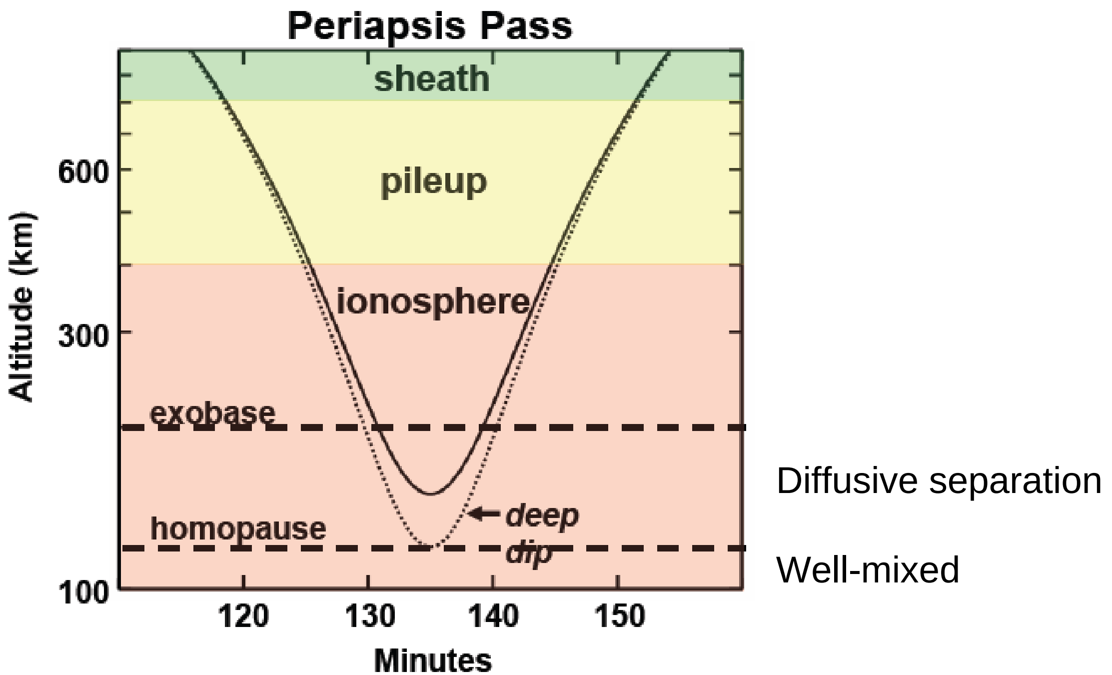




From the history of solar activity and MAVEN's measurement of "all" escape processes and their dependence on solar wind and EUV, modeling back in time will constrain losses.

Deep-Dipping Campaigns

- Nominal periapsis near 150 km (actually density range 0.05 - 0.15 kg/m³).
- Five 5-day “deep-dip” (really “toe dip”) campaigns with periapsis near 125 km (to a density of 2 kg/km³) – subsolar, antisolar, terminator, nonmagnetic polar cap and magnetic anomaly regions are targets.



•Nominal mapping orbits penetrate below exobase where neutral collisions rule

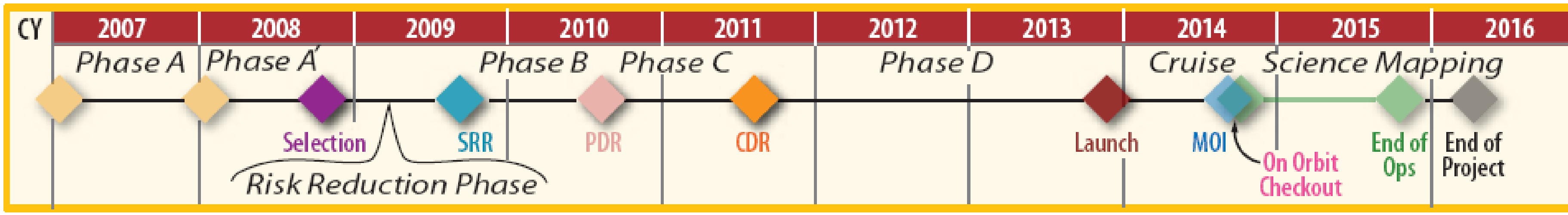
•The deep dips penetrate to the homopause where the gases are well-mixed

Reasons for Going Low

- Homopause region - where well mixed gases begin to be released.
- Improve capability to measure minor isotopic species.
- Insure penetration into the main ionospheric peak to determine the physics of the ionosphere, In particular :
  - -Nightside ionosphere ill defined
  - -Minor ionospheric species chemistry (e.g., odd nitrogen) sets conditions for exosphere populations,
  - - Electrical conductivity of the layer controls fields.
- Serendipitous events:
  - -Altitude decay of SEP penetration
  - -Solar flare atmospheric-ionospheric perturbations.

Key Measurements: NGIMS (neutral and ion composition), LPW (electron density, temperature, E waves?), SEP (energetic particle inputs), maybe STATIC (major ions, ion temperature, motion)

MAVEN Schedule



MAVEN IS ON TRACK

- MAVEN science goals are tightly focused on understanding atmospheric loss to space through time.
- The mission architecture, spacecraft design, and instruments and capabilities were selected specifically for this science mission.
- The team is committed to implement this mission successfully and fully within the Scout cost cap.

MAVEN will provide a comprehensive understanding of Martian volatile escape and atmospheric evolution along the path to understanding "where the water went".