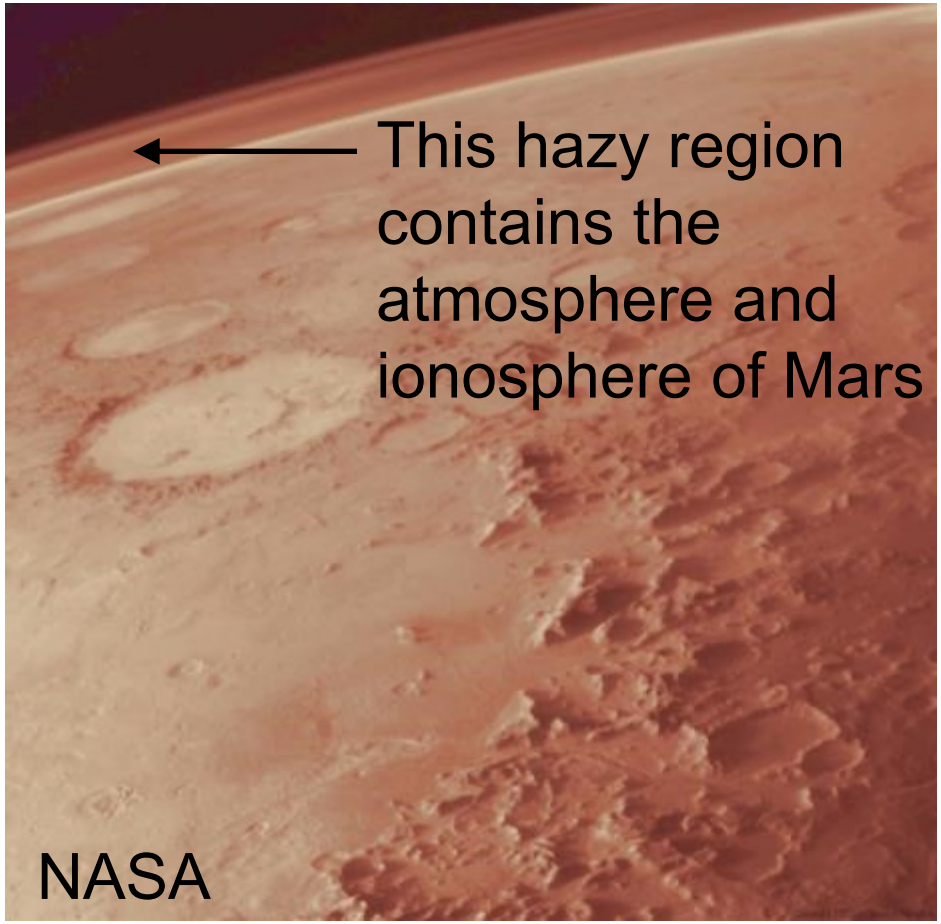
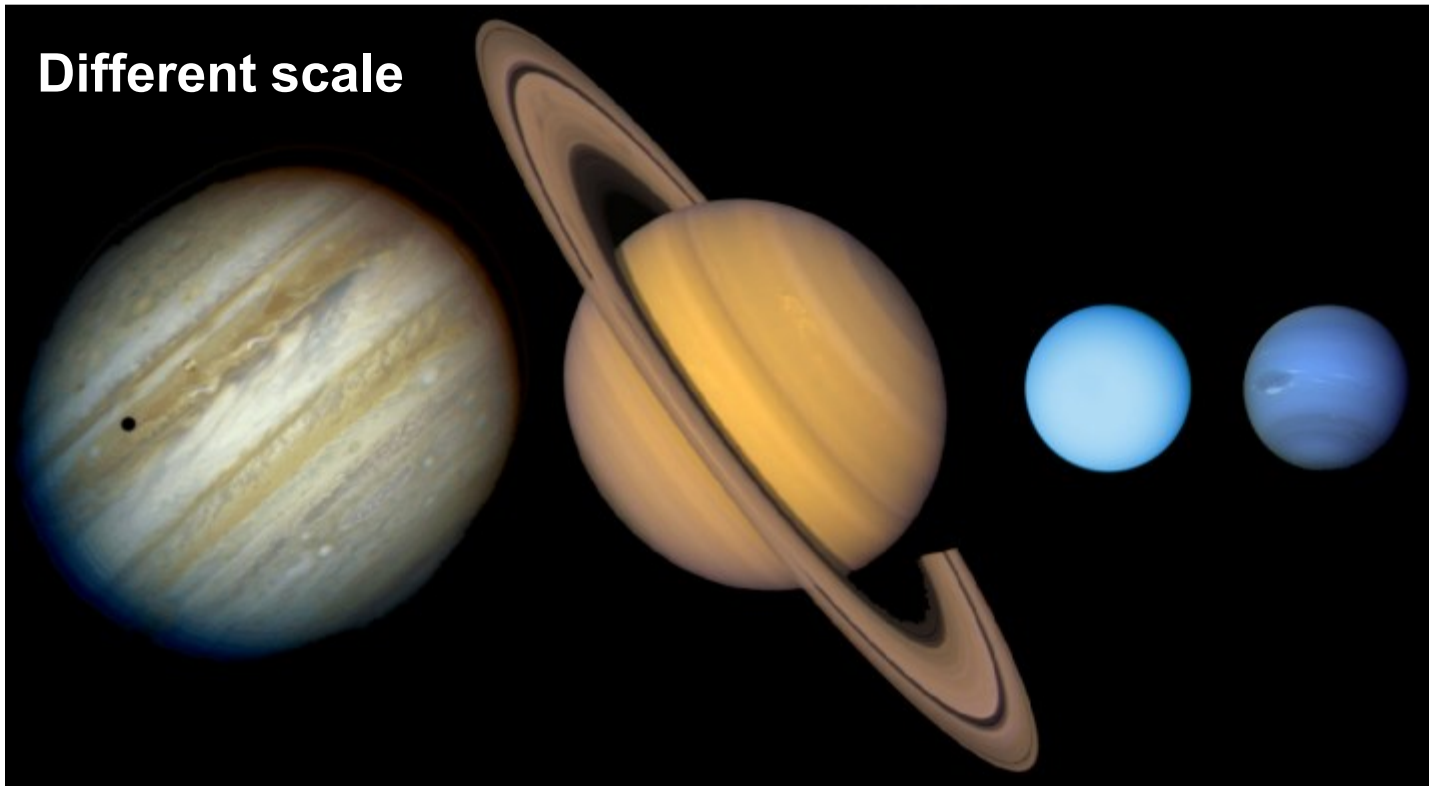
The MAVEN mission to Mars and my role in it



Paul Withers
Boston University
(withers@bu.edu)

BUAS talk

Wednesday 2014.03.05
18:30



www.solarviews.com

This is Mars

0.5 x R-Earth

1.5 AU from Sun

Same rotation rate as Earth

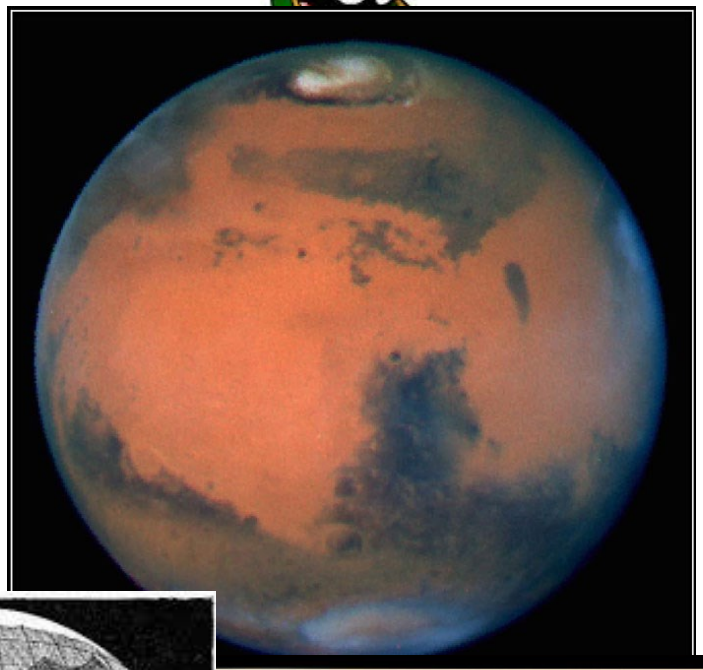
Carbon dioxide atmosphere

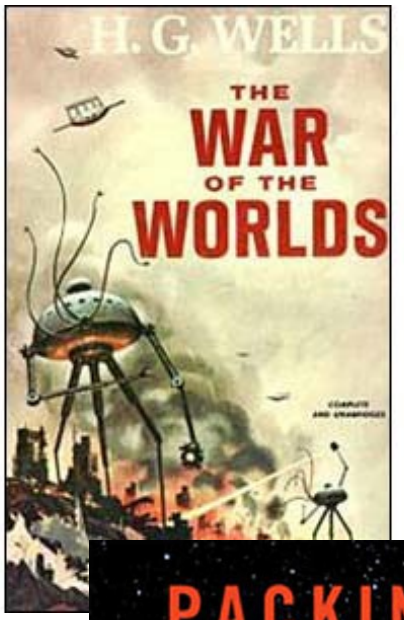
100x smaller surface pressure

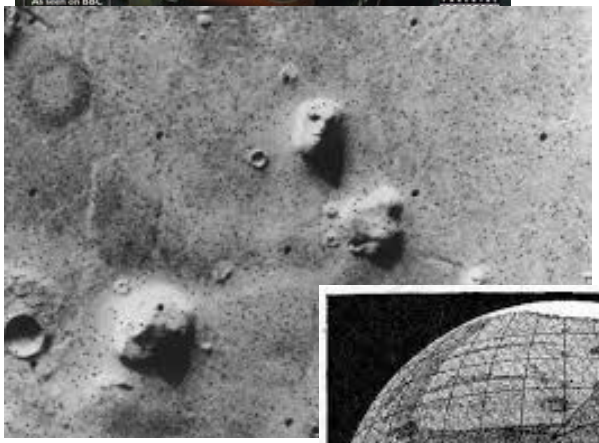
Target of many spacecraft in last 15 years

The 2013 MAVEN Mission: Exploring Mars' Climate History

The Public's Fascination With Mars







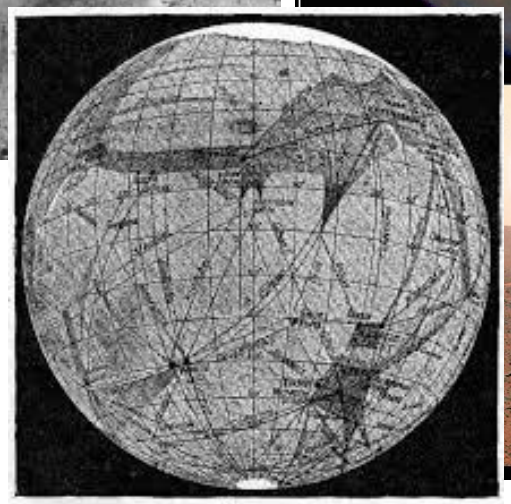
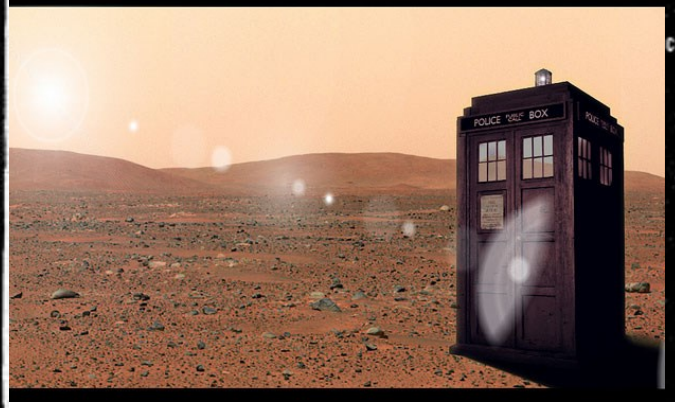
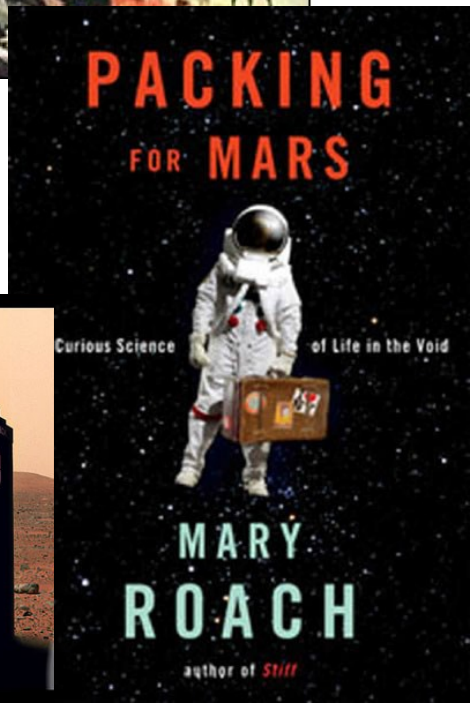


Fig. 2.

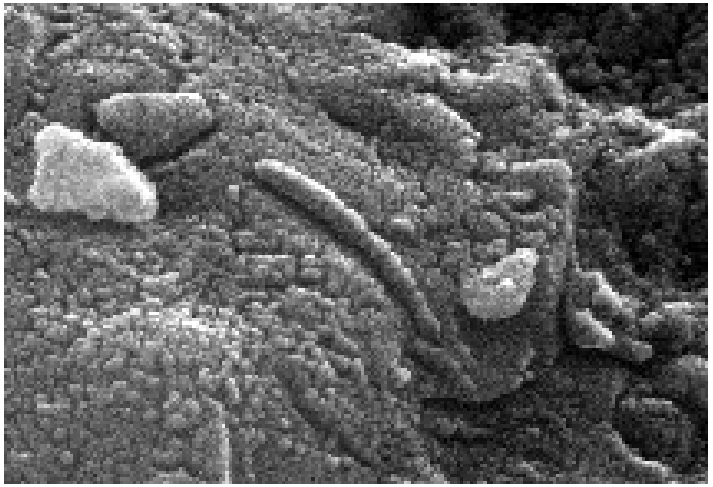




Overarching Question: Did Mars Ever Have Life?

Mars appears to meet or have met all of the environmental requirements for the occurrence of life:

- Liquid water
- Access to the biogenic elements
- Source of energy to drive metabolism



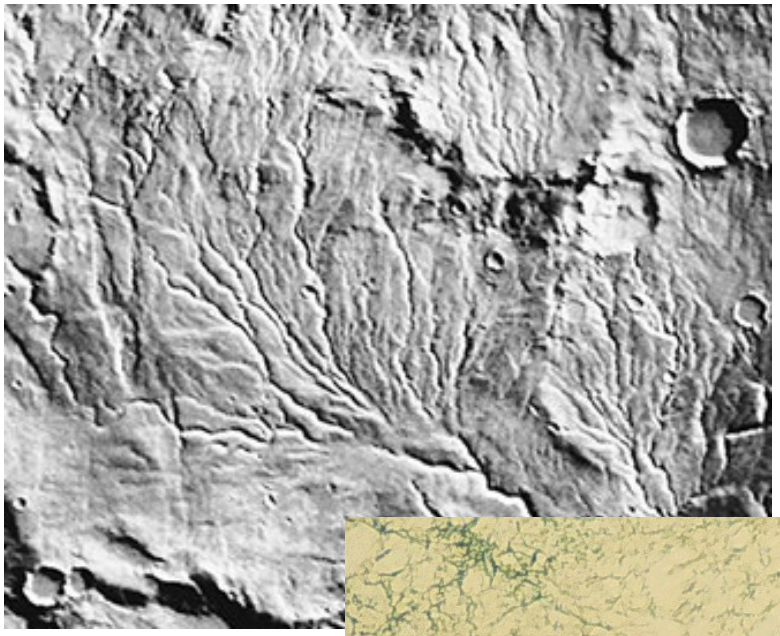
Did Mars ever have life?

How did any life interact with its planetary environment?

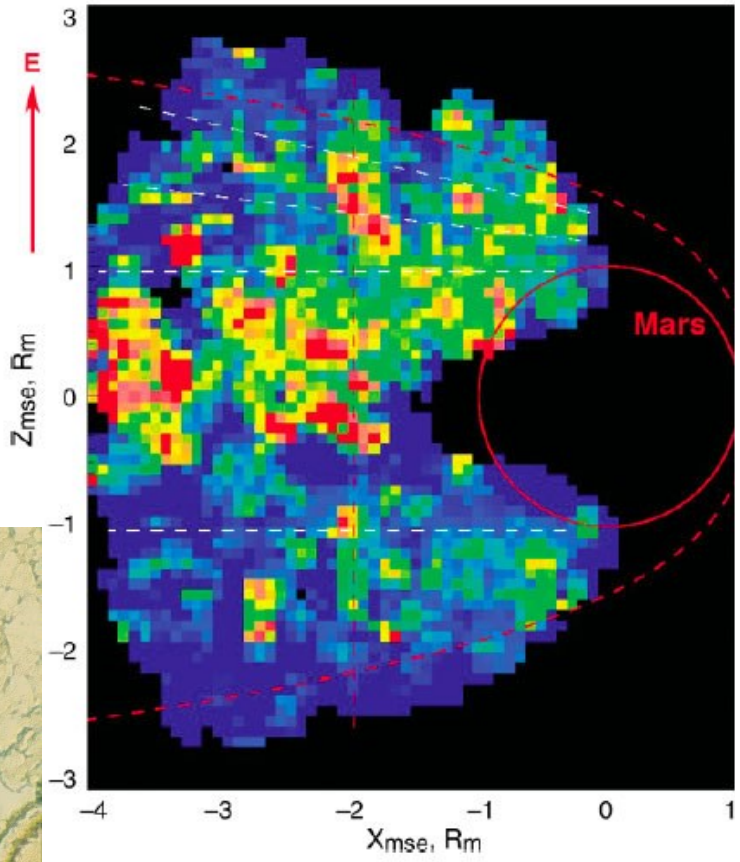
How has the habitability of Mars changed over time?

Evidence for Surface Water on Ancient Mars
Where Did the Water Go? Where Did the CO_2 Go?

Abundant evidence for ancient water

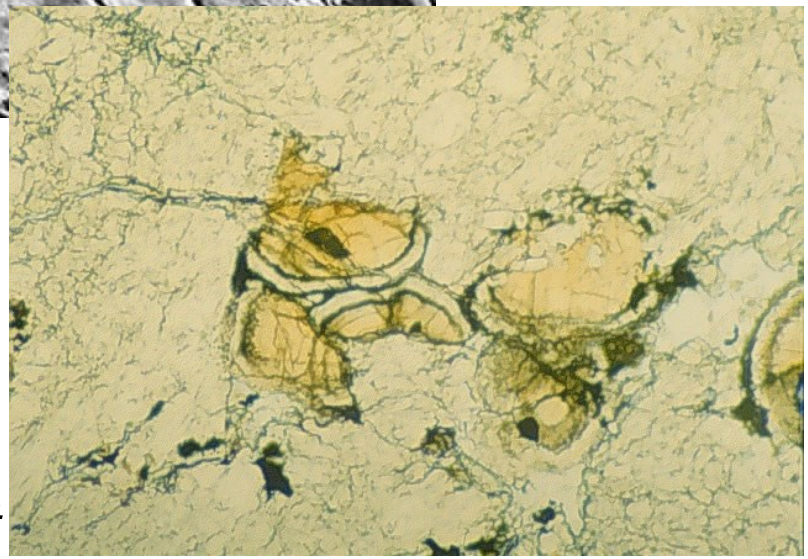


Volatiles can be lost to space



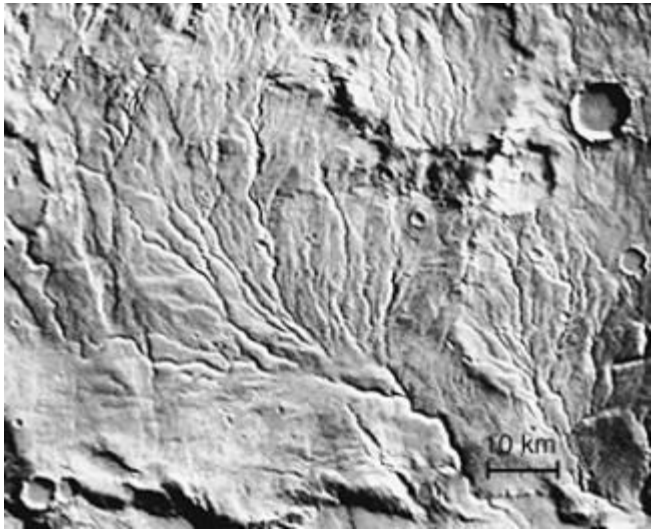
Escaping ions detected from Mars Express

Volatiles can go into the crust

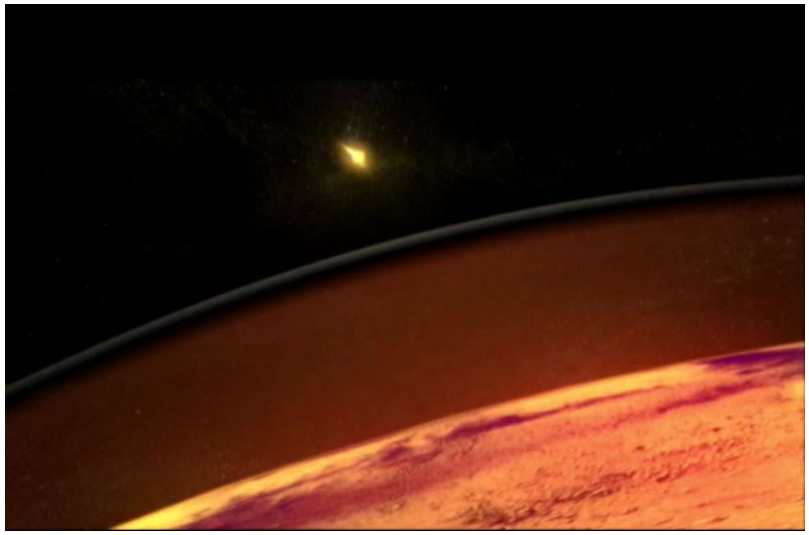


Carbonate deposits in a Martian meteorite

MAVEN Science Objectives



Evidence suggests that early Mars had flowing water on the surface and a thicker atmosphere.

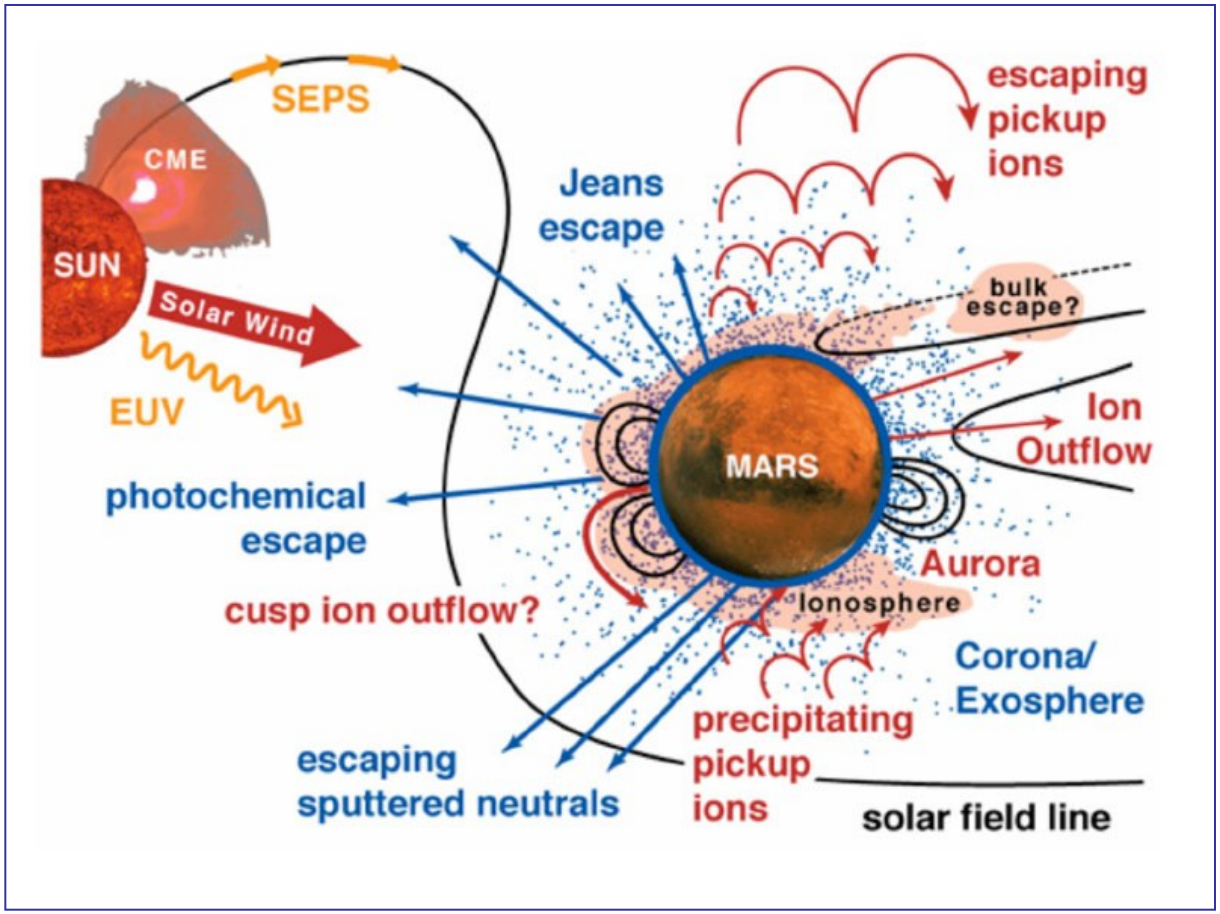


The ancient Sun was more intense and likely drove significant escape of gas to space.

- Determine the structure and composition of the Martian upper atmosphere today
- Determine rates of loss of gas to space today
- Measure properties and processes that will allow us to determine the integrated loss to space through time

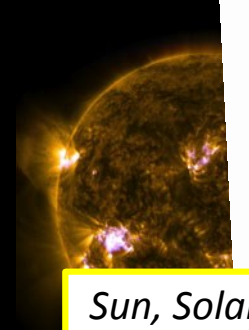
MAVEN will answer questions about the history of Martian volatiles and atmosphere and help us to understand the nature of planetary habitability.

MAVEN Will Allow Us to Understand Escape of Atmospheric Gases to Space



- MAVEN will determine the present state of the upper atmosphere and today's rates of loss to space.
- Measurements will allow determination of the net integrated loss to space through time.

The MAVEN Science Instruments:



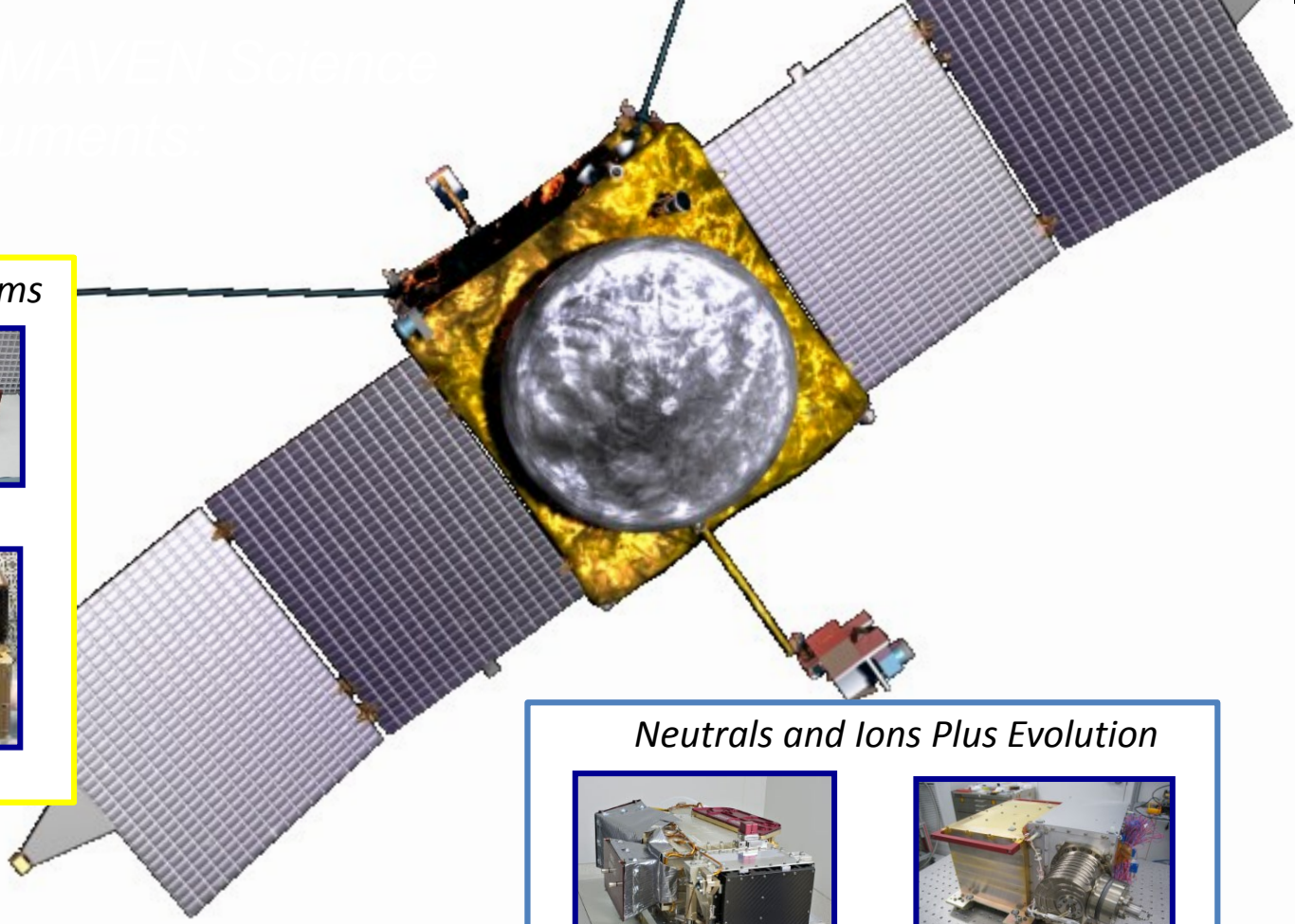
Sun, Solar Wind, Solar Storms

SWEA

SEP

EUV

SWIA



Neutrals and Ions Plus Evolution

IUVS

NGIMS

Ion-Related Properties and Processes

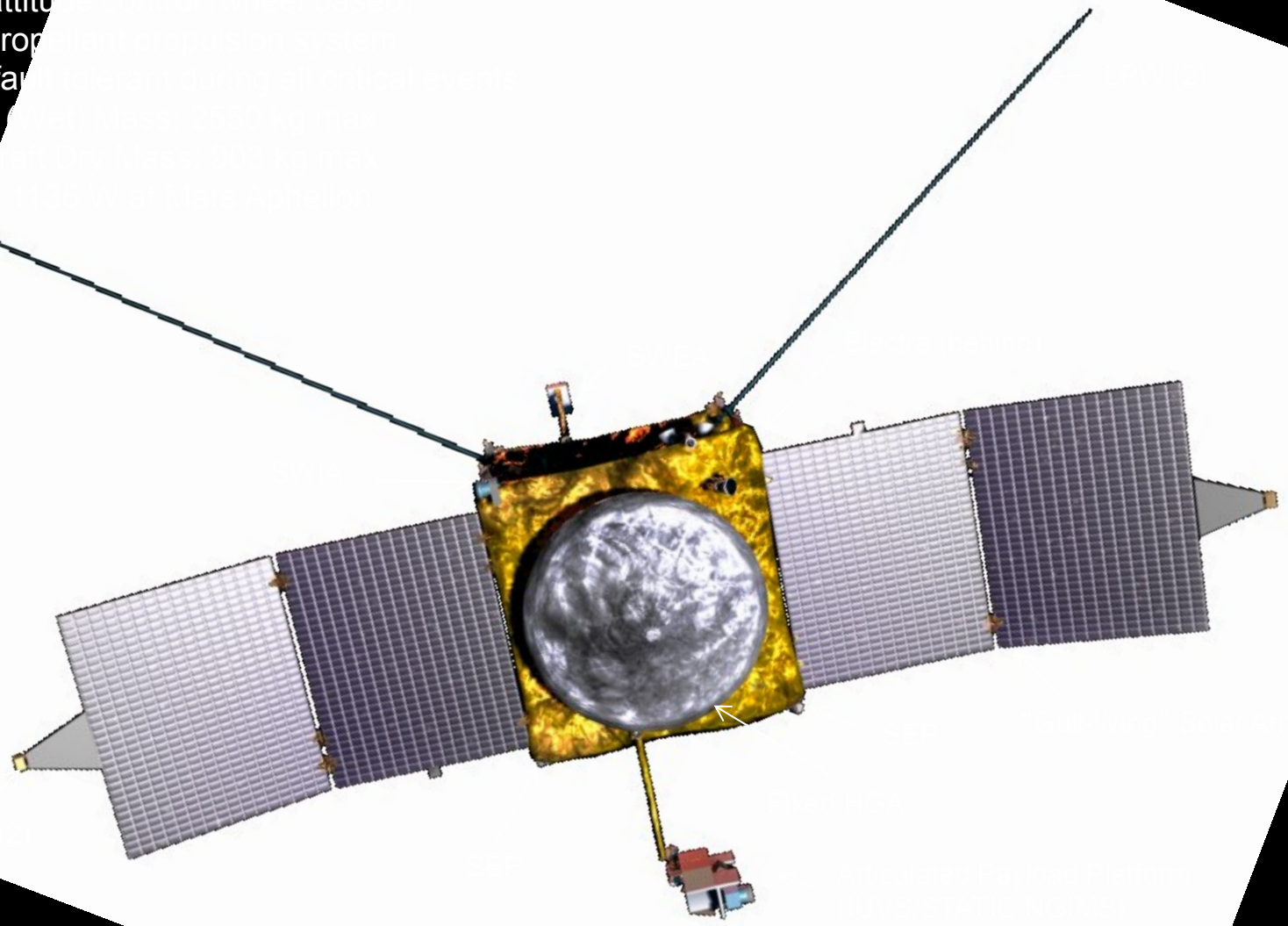
STATIC

MAG

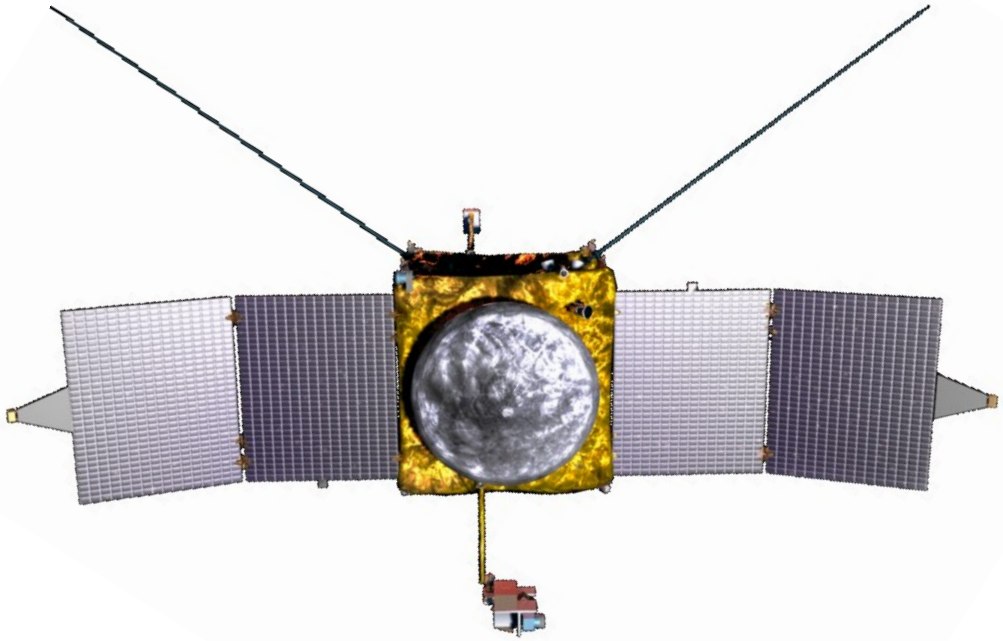
LPW

craft

- 3-axis attitu
- Mono-prop
- Single-fa
- Launch
- Spacec
- Power



'EN Spacecraft



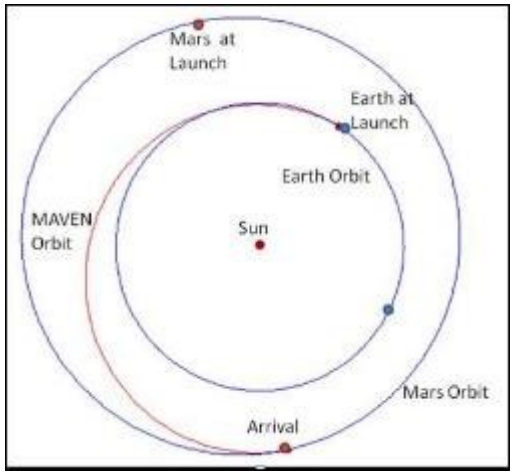
Same weight fully loaded as a GMC Yukon – 2550 kg.

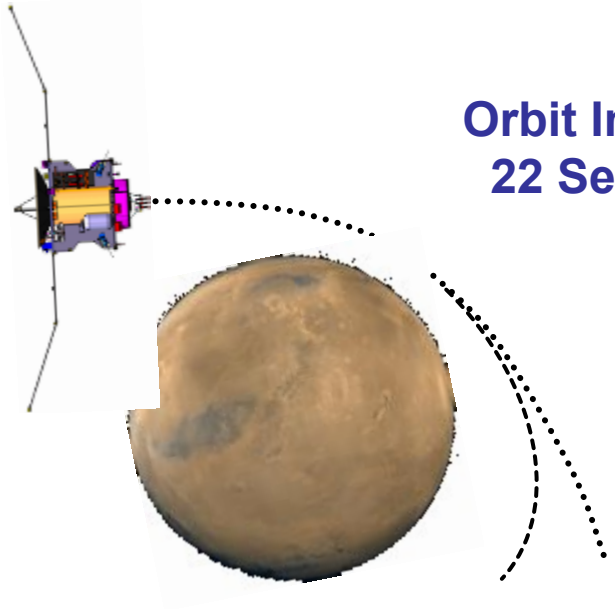
Same length as a school bus – wingtip-to-wingtip length of 37ft.

MAVEN Mission Architecture

Launched on 18 Nov. 2013, first day of its 20-day launch period

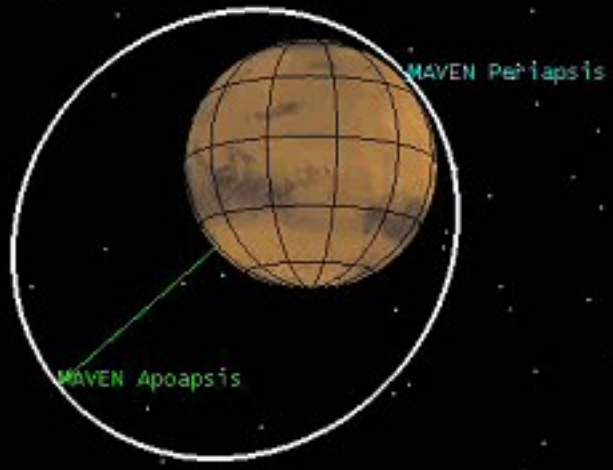
Ten-Month Ballistic Cruise to Mars





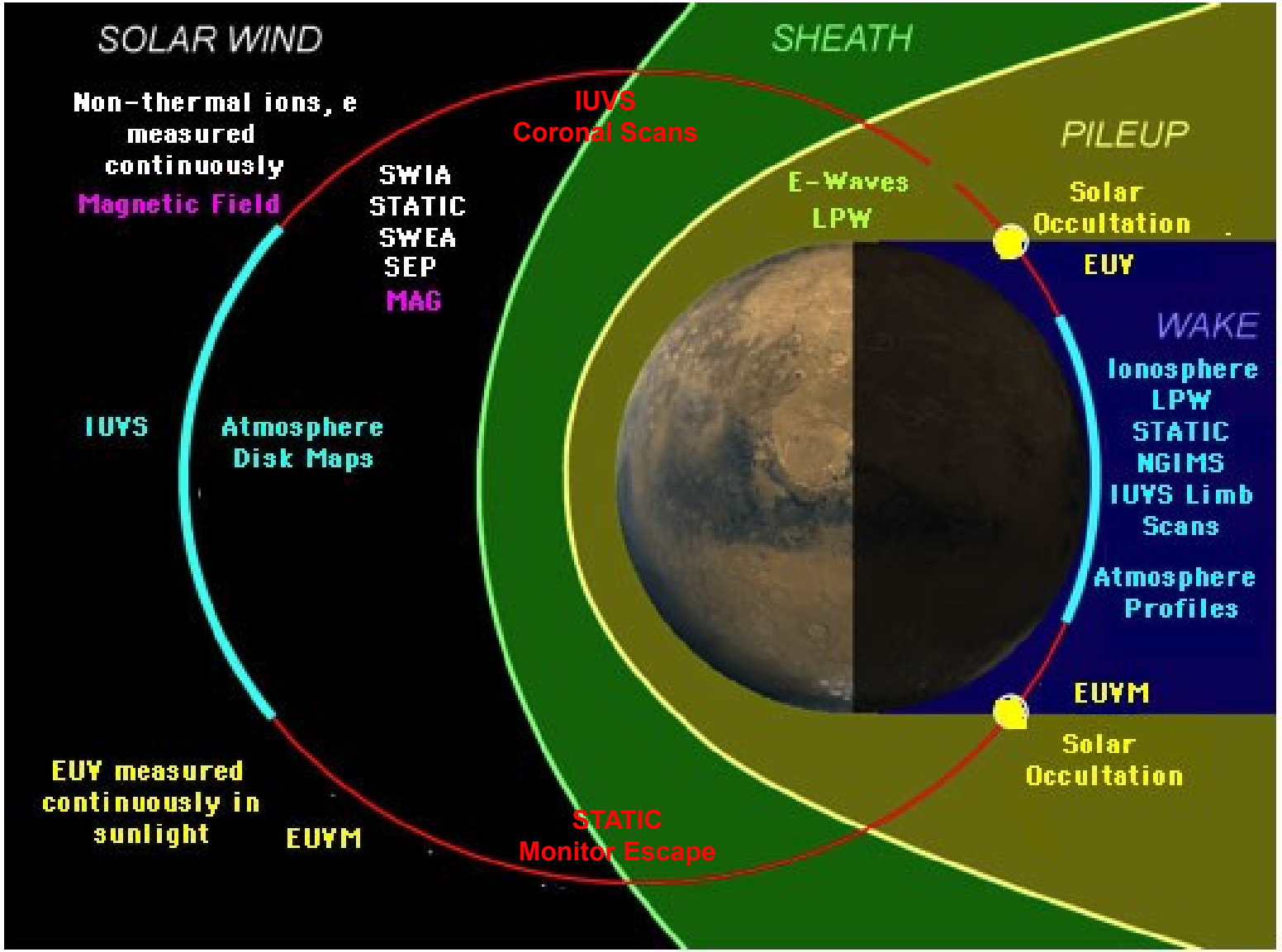
Orbit Insertion: 22 Sept 2014

One Year of Science Operations



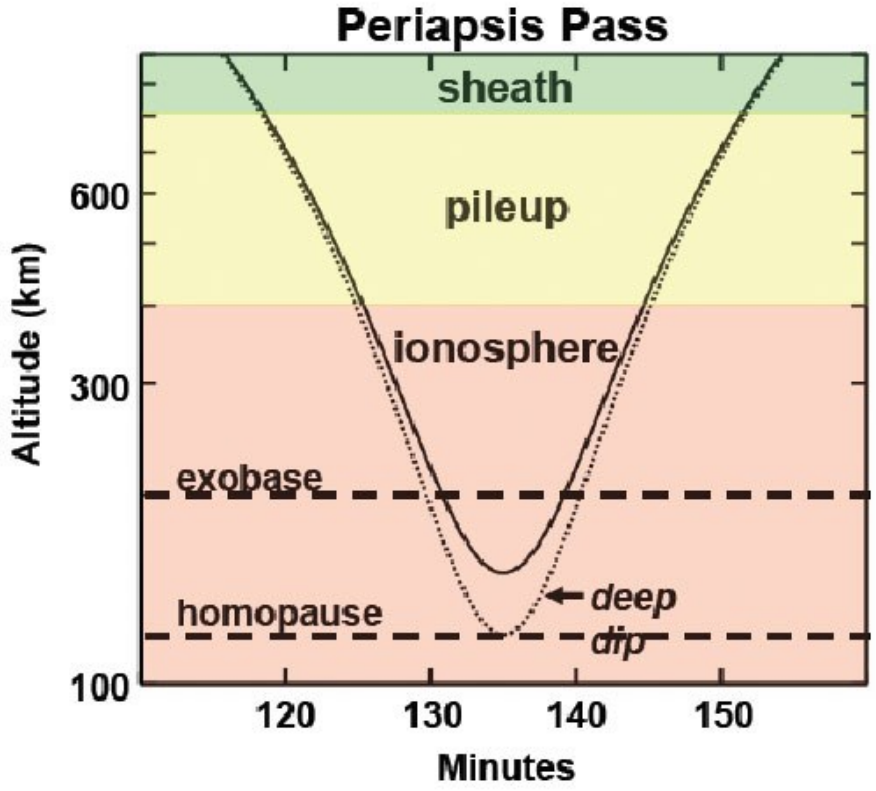
Orbit shown to scale

MAVEN Observes All Regions Of Near-Mars Space Throughout The Orbit



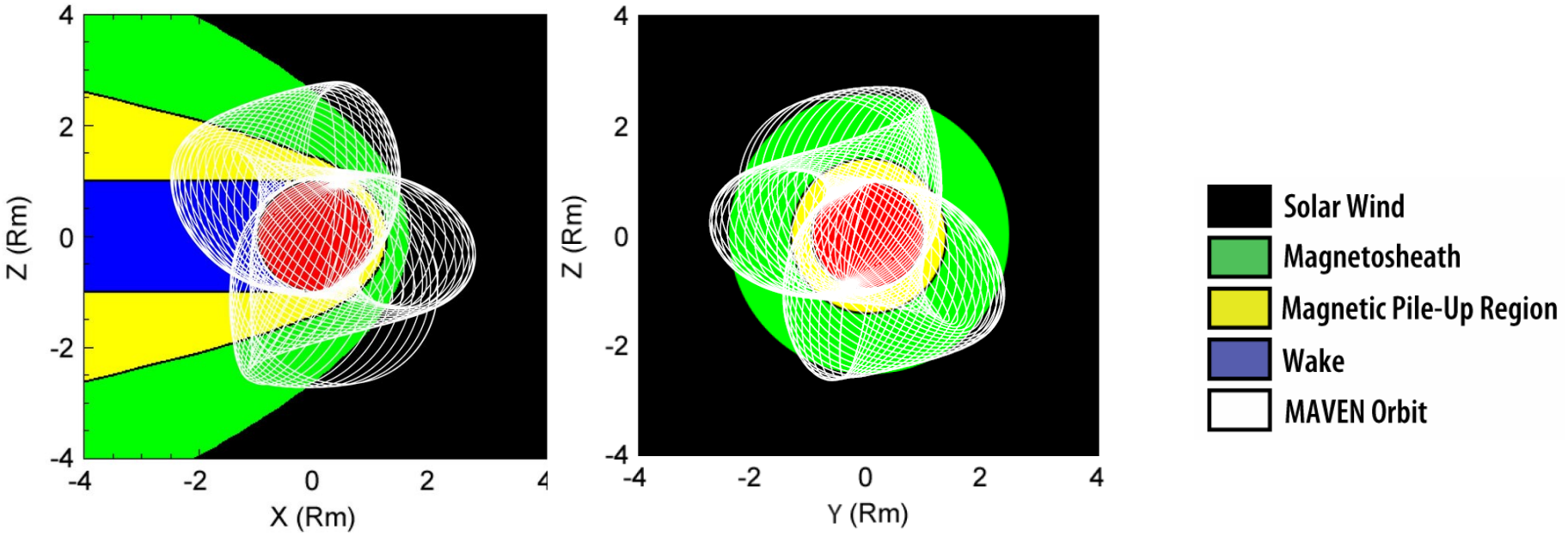
Elliptical Orbit Allows Measurement of All Relevant Regions of Upper Atmosphere

- Nominal periapsis near 150 km.
- Five “deep-dip” campaigns with periapsis near 125 km.
- Provide coverage of entire upper atmosphere

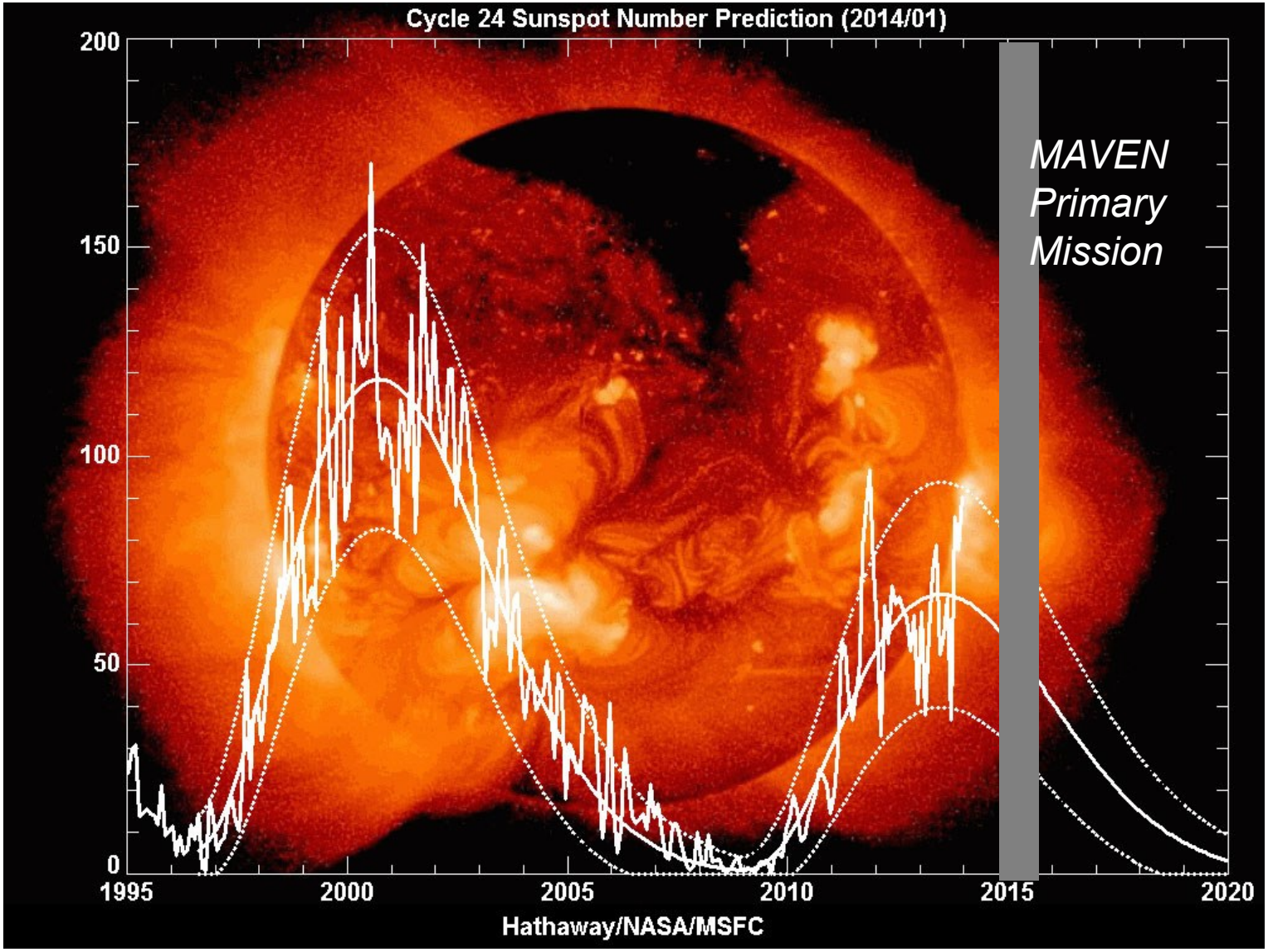


MAVEN Orbit During Primary Science Mission

- Elliptical orbit to provide coverage of all altitudes
- The orbit precesses in both latitude and local solar time
- One-Earth-year mission allows thorough coverage of near-Mars space



MAVEN's Timing in the Solar Cycle

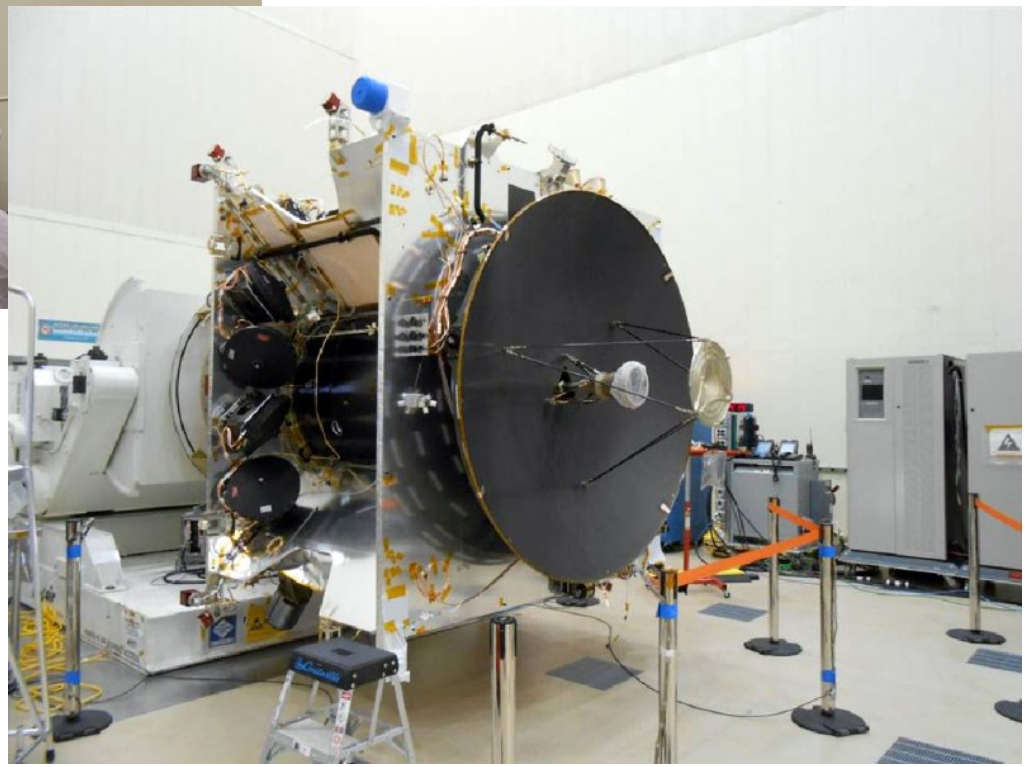


MAVEN's primary mission occurs on the declining phase of the solar cycle, when solar storms are most intense and most abundant.

Proposal, Site Visit, and Presentation at NASA HQ

Reviews Are Held Only On Days That Contain The Word “Day”

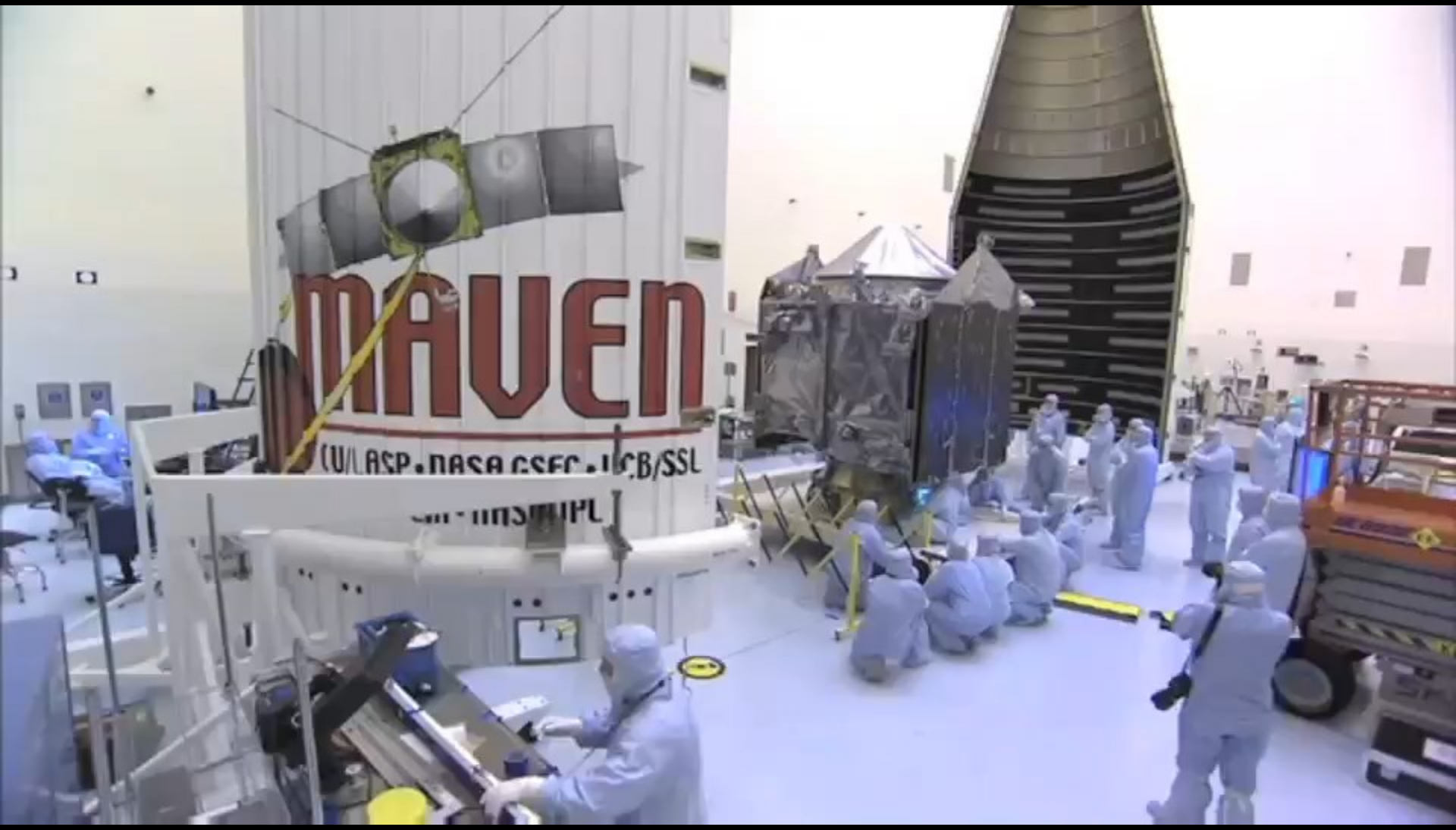
MAVEN Spacecraft Early and Late in Assembly



Starting Its Journey To Mars: From Lockheed Martin To Kennedy Space Center, 2 August 2013

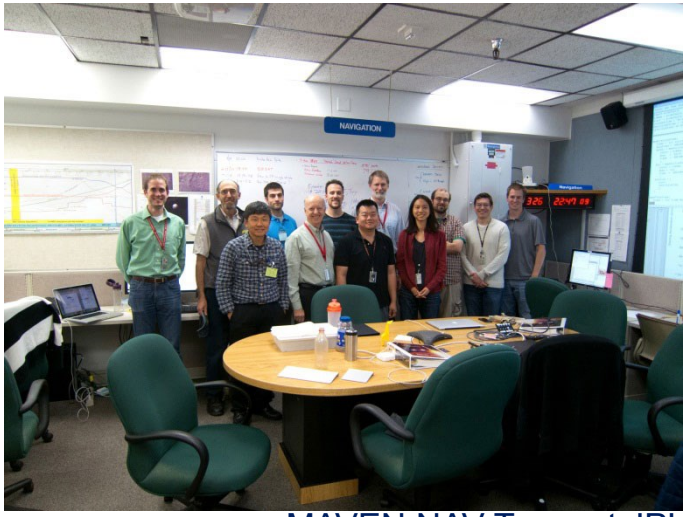
The Spacecraft Undergoes Final Testing

Into the Fairing, Onto the Rocket



MAVEN Team During Launch Week

MAVEN Team at Launch Complex-41, CCAFS



MAVEN NAV Team at JPL

MAVEN DSOC Team at JPL

MAVEN Ops Team in the MSA at LM/Denver

Go Atlas, Go Centaur, Go MAVEN!

- Copy of NASA TV stream from around the launch is available at:
- http://www.ustream.tv/recorded/40890176

- 37:00 - Launch control polls several dozen people, all say "go". This was when it started to feel like something was going to happen.

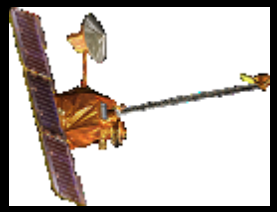
- 43:00 - 30 seconds before launch. "Go Atlas, go Centaur, go MAVEN" - this was when it REALLY started to feel like something was going to happen.


SMOKING IN
DESIGNATED
AREAS ONLY

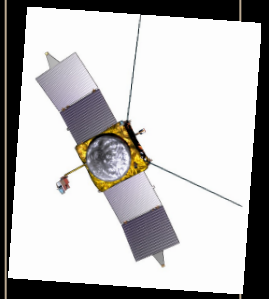
NASA's Mars Exploration Program

Launch Year

Operational / Recent	2009	2011	2013	2016	2018 & Beyond



Mars Express



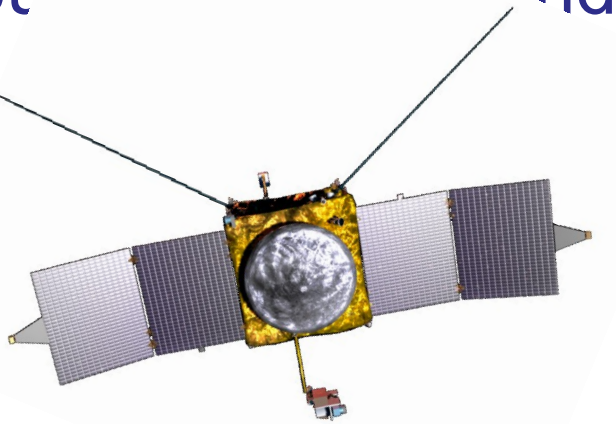
MAVEN

MER

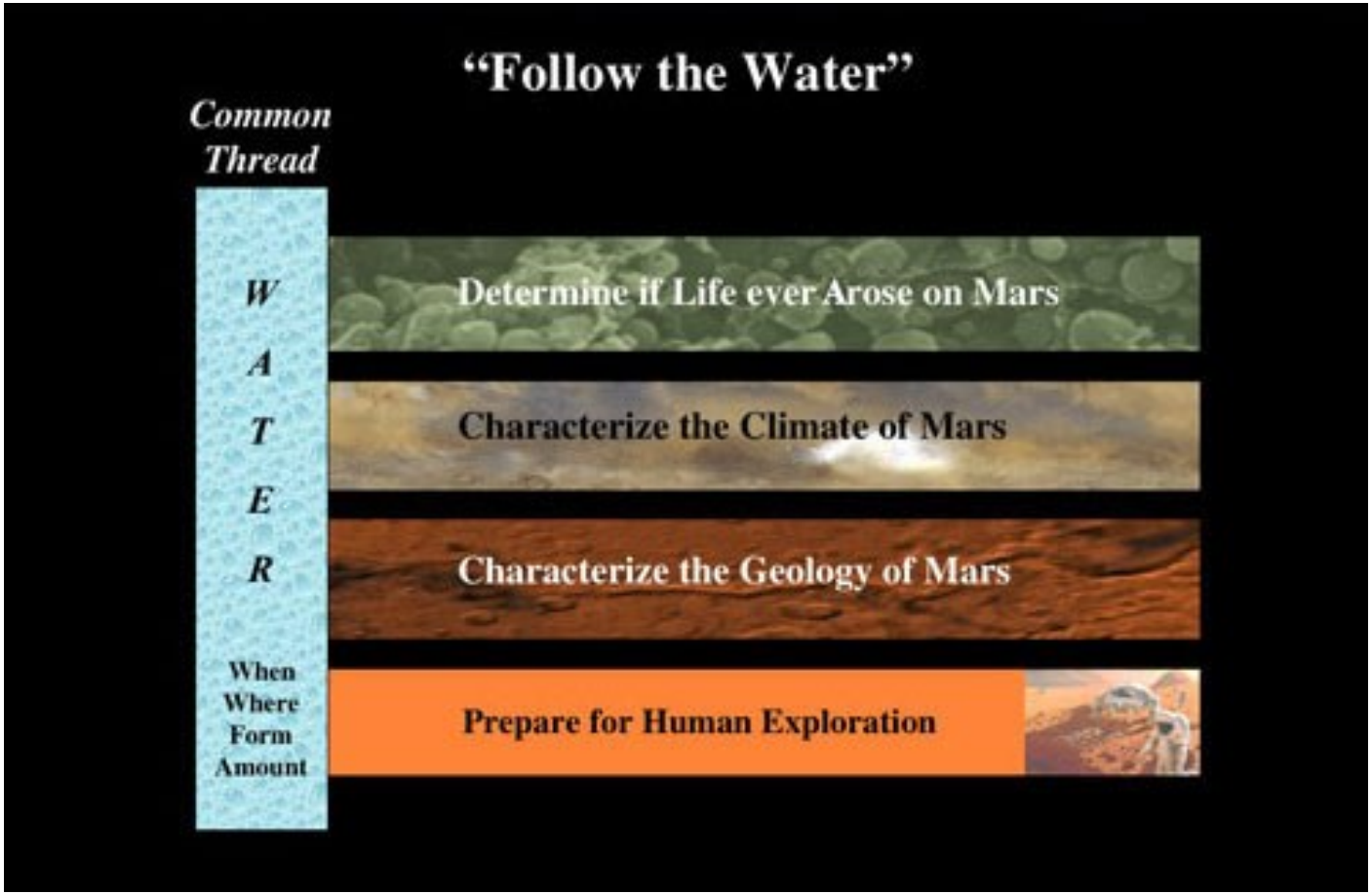
Mars Science Lab

MSL - 2020

Electra Commun as Antenna can Relay Data from Su and Landers



MAVEN Will Continue The Successful "Follow The Water" Theme

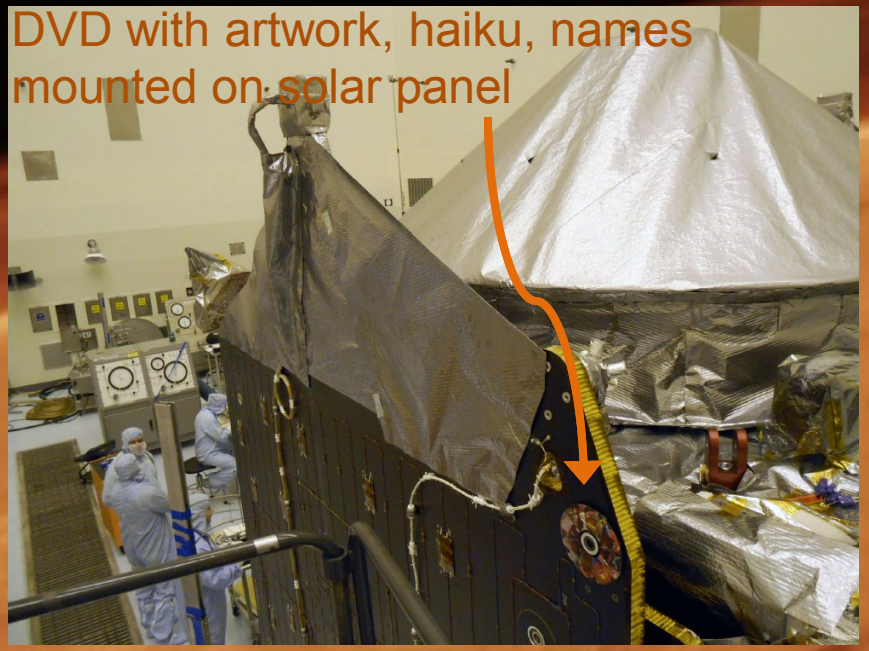


MGS, MPF, ODY, MER, MRO, MEx, PHX, upcoming MSL, are focused largely on the history of the surface. MAVEN's comprehensive approach will provide the history of the atmosphere as the necessary other half of the story.

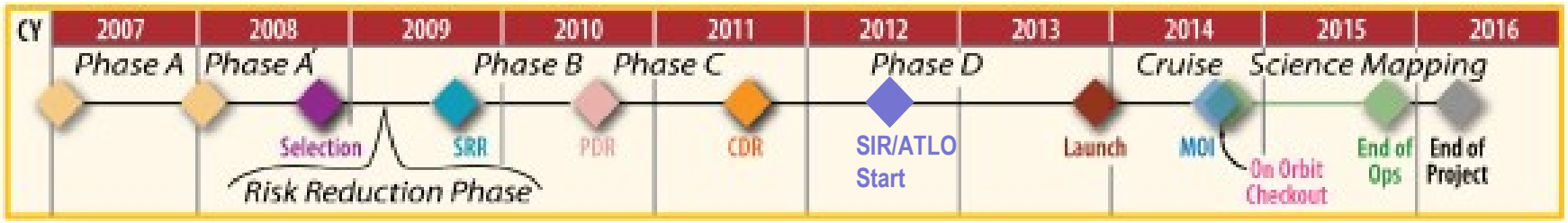
MAVEN Public Engagement: Artwork and Haiku

Thirty-six million
miles of whispering welcome.
Mars, you called us home.

Vanna Bonta USA



MAVEN Schedule



- MAVEN concept developed starting in late 2003
- Proposal submitted for Mars Scout program in 2006
- Selected for competitive Phase A, early 2007
- Selected for development for flight, Sept. 2008
- MAVEN Confirmed for development, October 2010
- Launched, 18 November 2013
- Arrival at Mars, 22 September 2013
- Primary science mission, Nov. 2014 – Nov. 2015

The MAVEN Team Got Us Here: We Are Ready to Carry Out Launch, Operations, and Science!

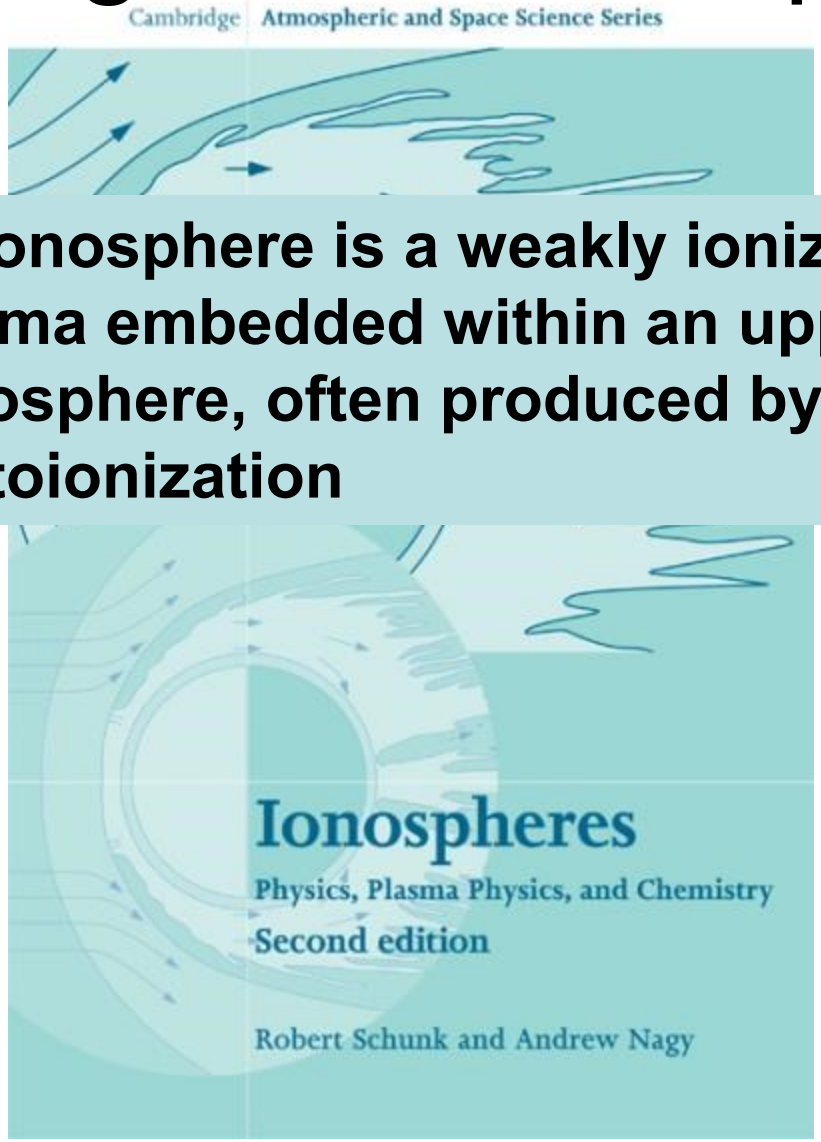
- *MAVEN launched on schedule and on budget!*
- *It arrives at Mars in September!*
- *Science mission begins in November!*

Go MAVEN!

Next stop – Mars!

[Continue to follow us on Facebook and Twitter: MAVEN2MARS]

My role on MAVEN: Looking at the ionosphere



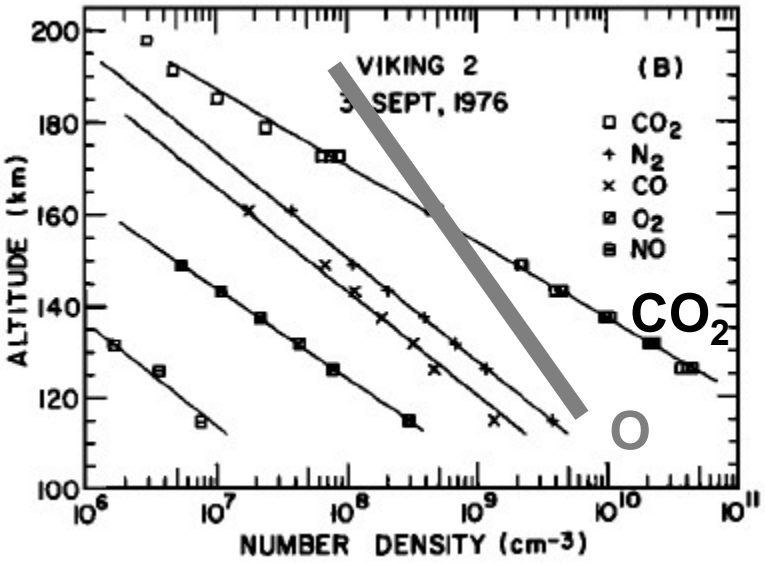
An ionosphere is a weakly ionized plasma embedded within an upper atmosphere, often produced by photoionization

What does that actually mean?

	Atmosphere	Ionosphere	Solar wind
Chemistry			
Gravity			
Sunlight			
Magnetic fields			
Composition	Neutrals	Ions, electrons, and neutrals	Protons and electrons

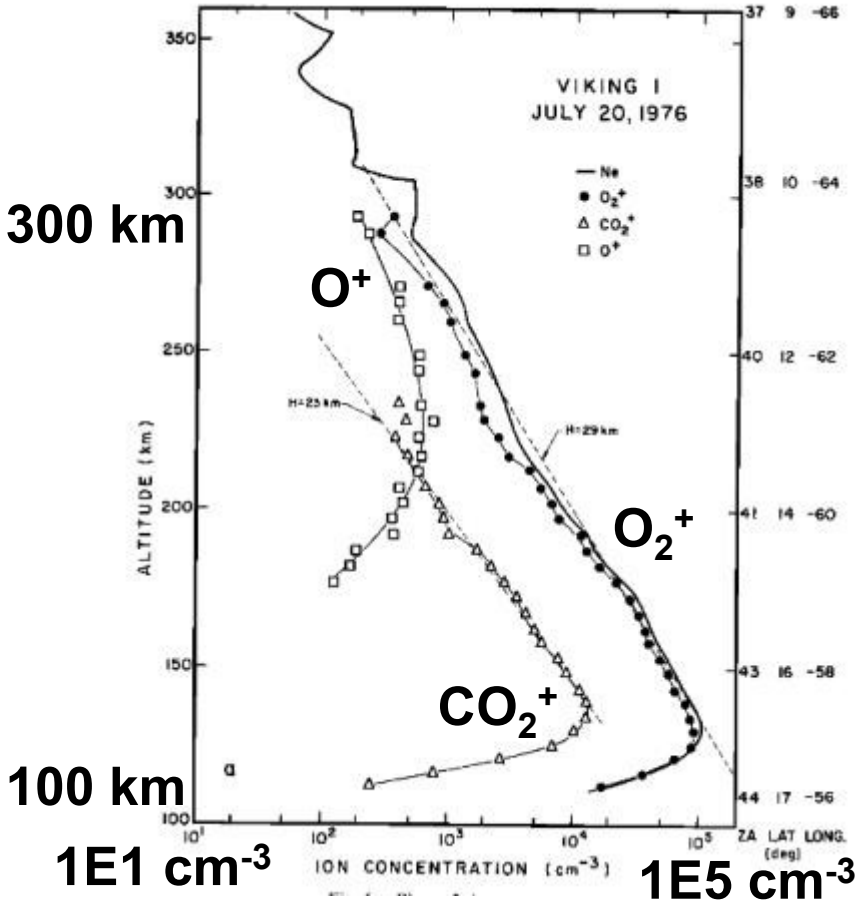
What we know about composition

Neutral species



Nier et al. (1977)

Ion species

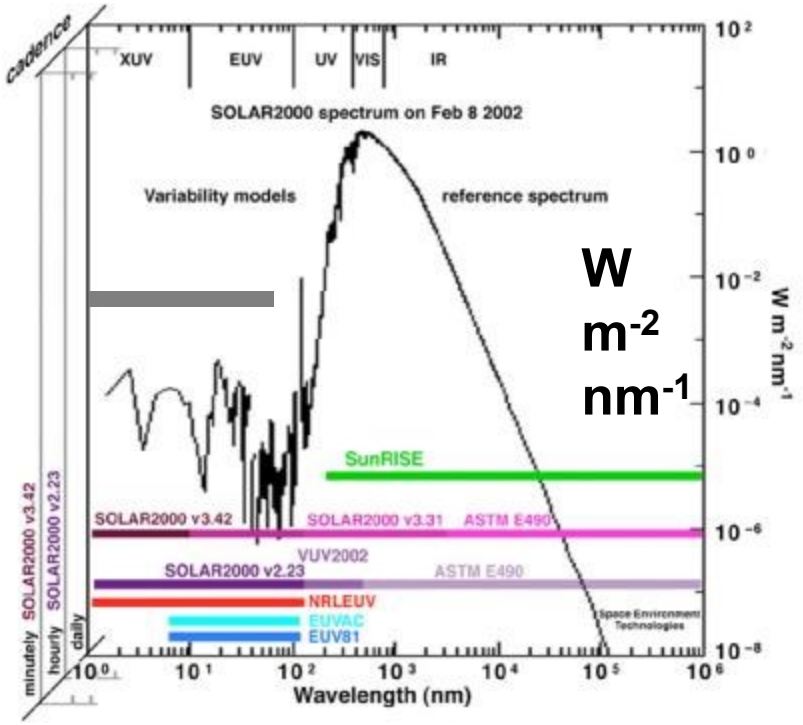


1E1 cm^{-3} 1E5 cm^{-3}

Hanson et al. (1977)

Making ions – Start with sunlight

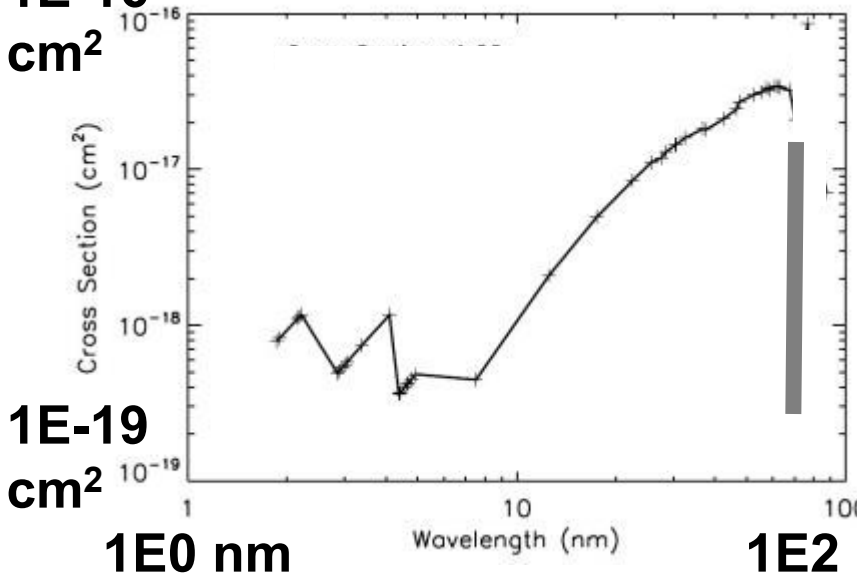
Solar spectrum



1E0 nm **1E6 nm**

www.spacewx.com

Cross-section of CO_2



1E-16 cm²

1E-19 cm²

1E0 nm **1E2 nm**

Soft X-ray (XUV) = 1-10 nm
Extreme ultraviolet (EUV) = 10-100 nm

Making ions – From the top down

- Optical depth(z) = n(z) σ H

- n = neutral number density
- σ = cross-section of carbon dioxide
- H = scale height of neutral atmosphere

Making ions – From the top down

- Optical depth(z) = n(z) σ H
- Flux = Flux-at-infinity x exp(-optical depth)

Making ions – From the top down

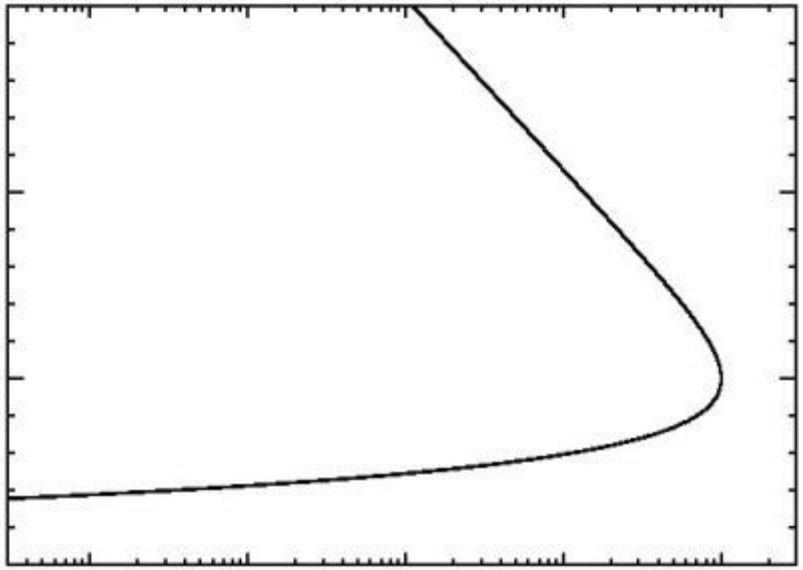
- Optical depth(z) = n(z) σ H
- Flux = Flux-at-infinity x exp(-optical depth)
- Number of ions produced cm^{-3} s^{-1} = F σ n

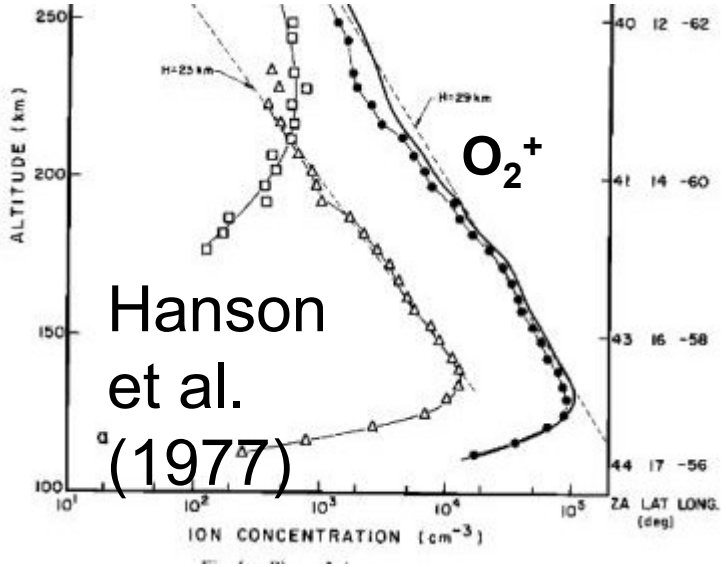
- Flux x cross-section x neutral density

  cm^{-2} s^{-1} cm^{2} cm^{-3}

Making ions – From the top down

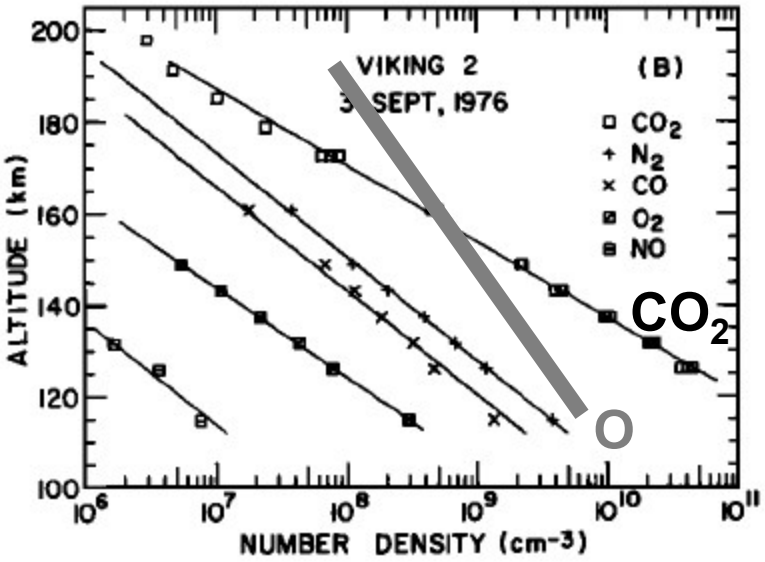
- Optical depth(z) = n(z) σ H
- Flux = Flux-at-infinity x exp(-optical depth)
- Number of ions produced cm^{-3} s^{-1} = F σ n



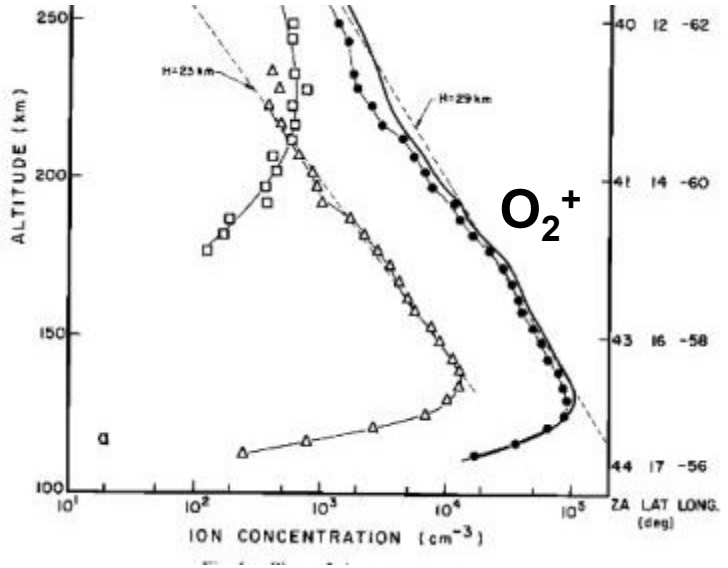


Losing ions

- $CO_2^+ + O \rightarrow O_2^+ + CO$ very fast
- $O_2^+ + e \rightarrow O + O$ few minutes



Nier et al. (1977)



Hanson et al. (1977)

Testable predictions

1 Atmospheric pressure at peak = mn g / σ

2 $F_0/eH = \alpha(Te) \times N\text{-}max^2$

3 $N = N_0 \exp(-z/Hp)$ where

- Hp = 2 k Tn / mn g (no plasma transport)
- Hp = k (Ti + Te) / mi g (transport)
- 20 km or 200 km

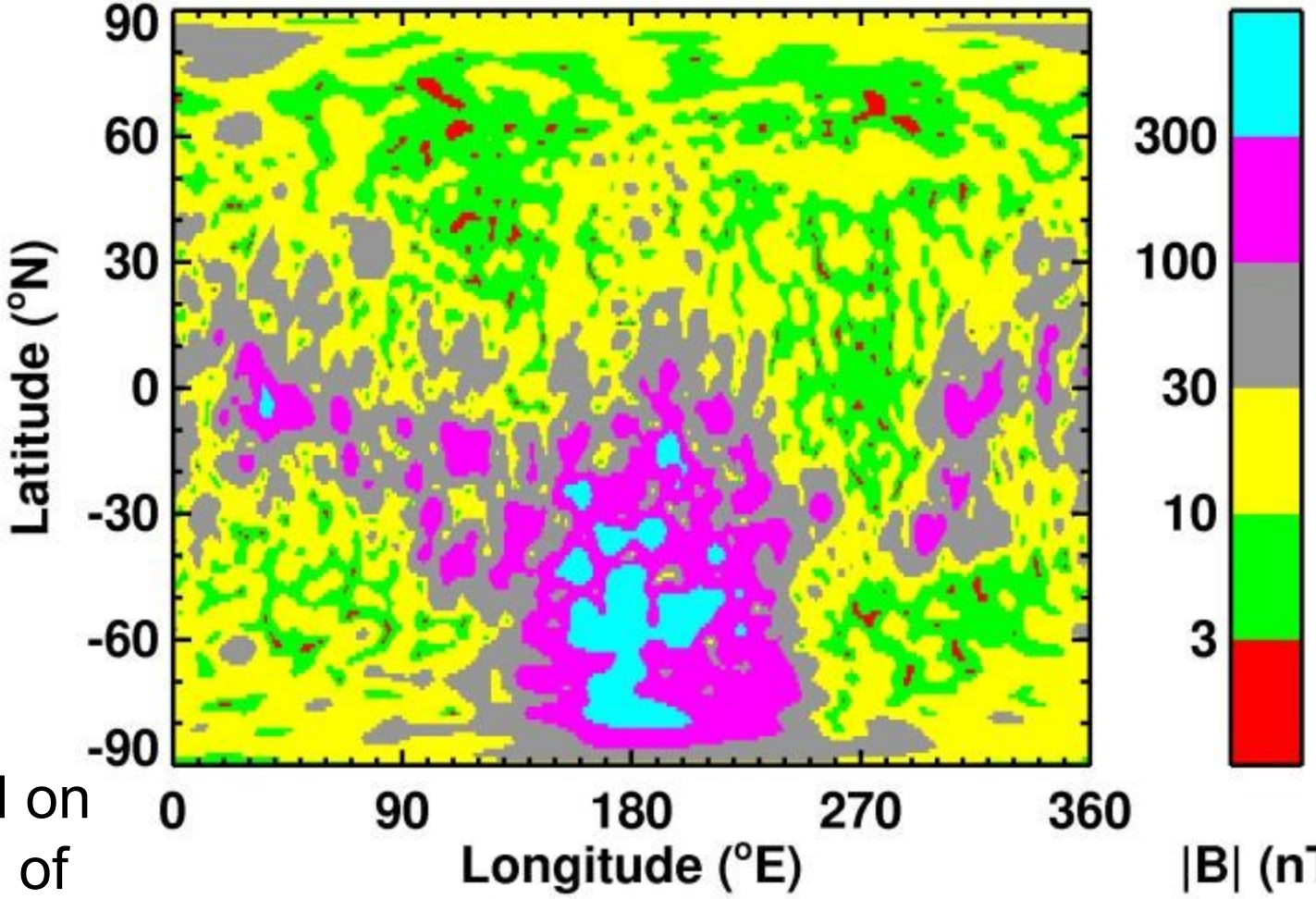
Summary

MAVEN has launched and will arrive at Mars in 6 months time

MAVEN observations will reveal how the dynamic Sun controls the upper atmosphere of Mars and the loss of water to space

BU has significant involvement in the mission
Professors Clarke, Mendillo, Withers

Magnetic field at Mars



Based on model of Arkani-Hamed (2004)