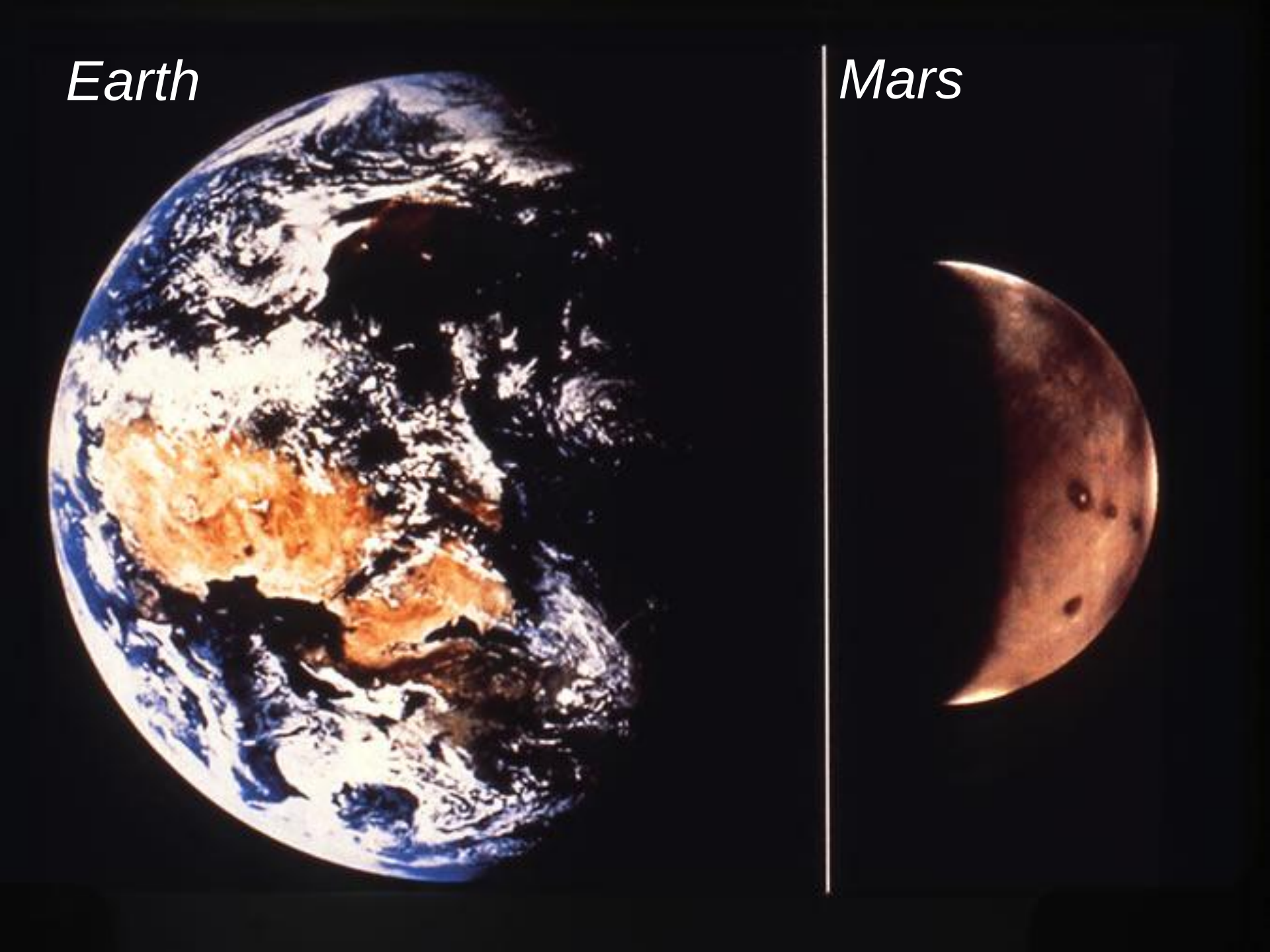
The 2013 Mars Atmosphere and Volatile EvolutioN (MAVEN) Mission

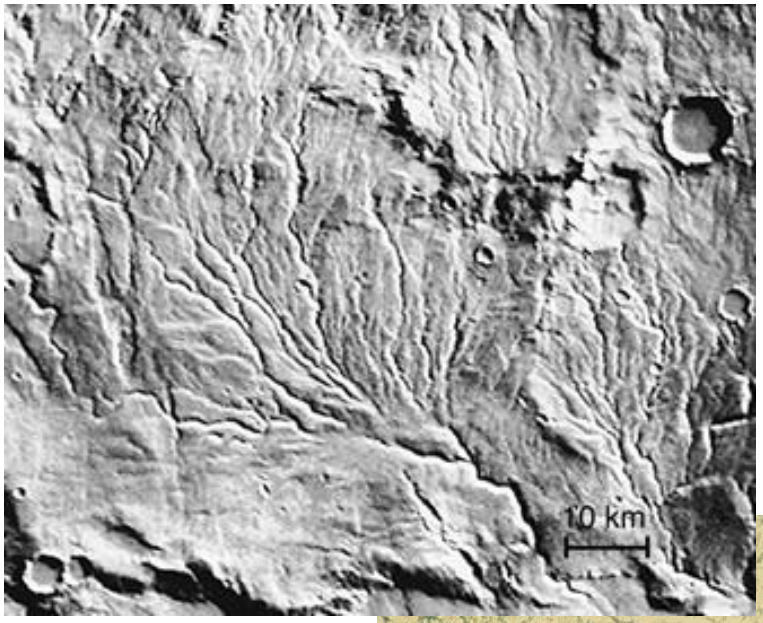
Systems Engineering Seminar
October 7, 2014

Martin B. Houghton
Mission Systems Engineer
NASA-Goddard Space Flight Center

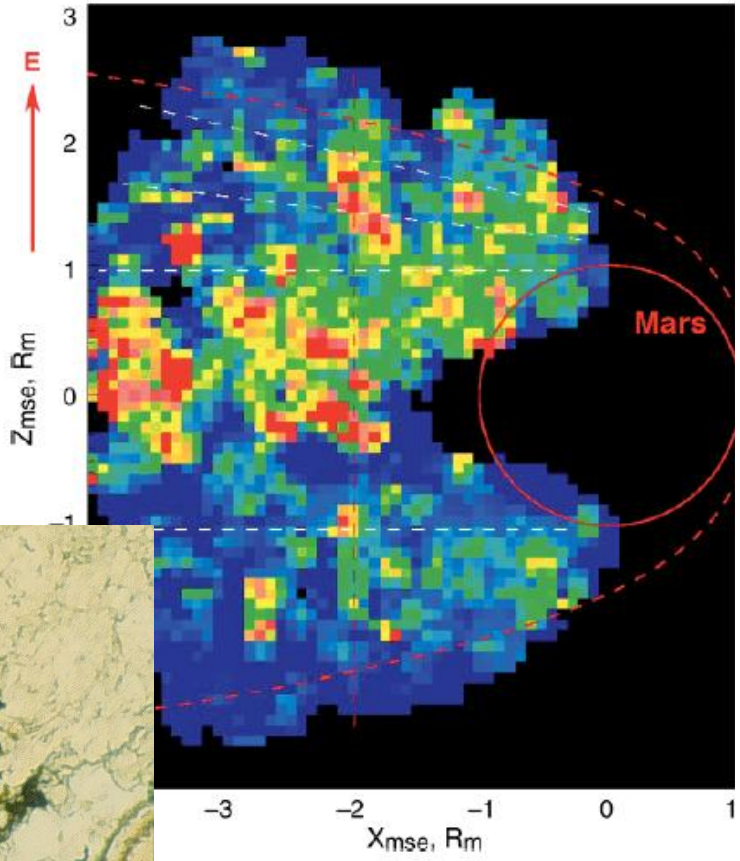

Earth
Mars

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

Abundant evidence for ancient water

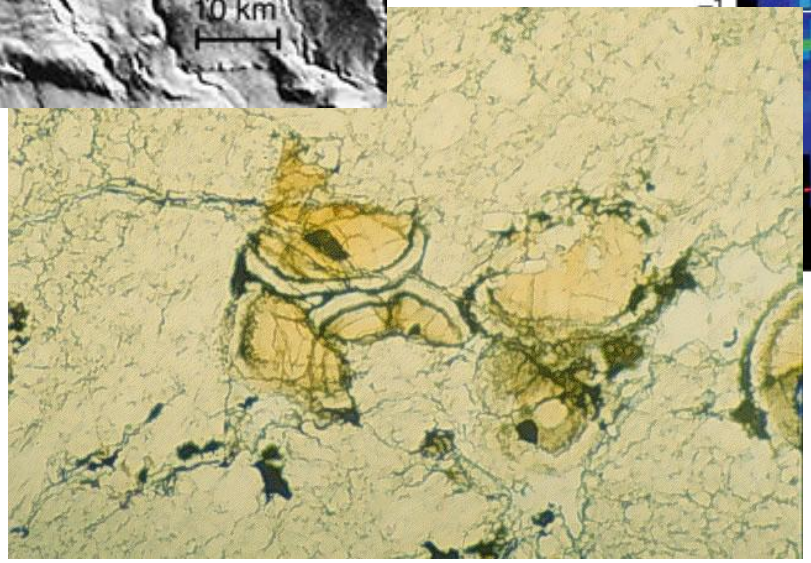


Volatiles can be lost to space



Escaping ions detected from Mars Express

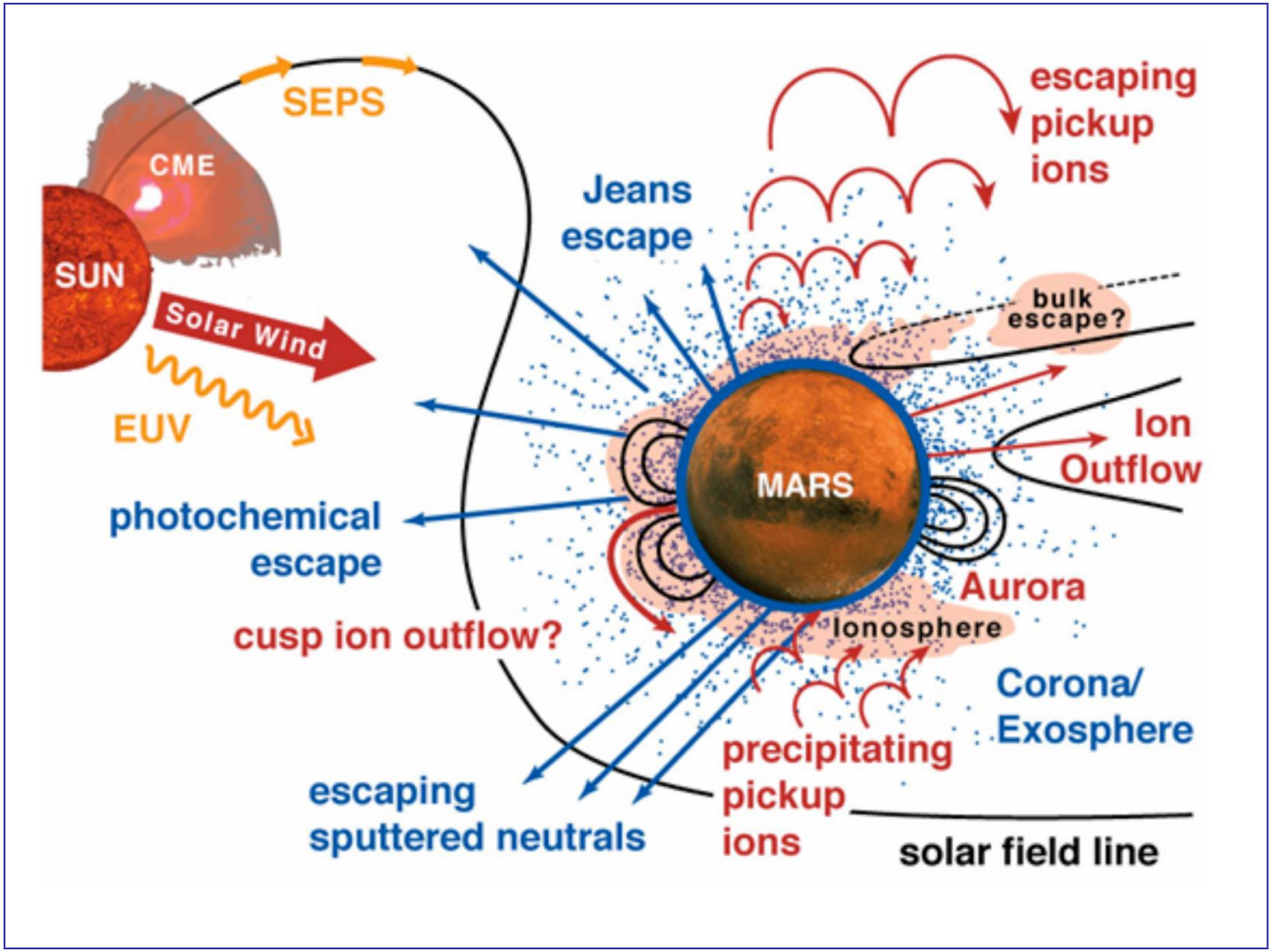
Volatiles can go into the crust



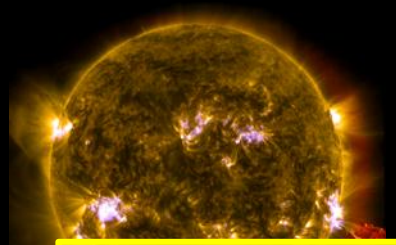
Carbonate deposits in a Martian meteorite

The Solar Wind is Able to Strip Off Gas from the Top of the Atmosphere

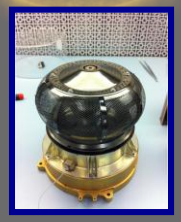
MAVEN Will Allow Us to Understand Escape of Atmospheric Gases to Space



The MAVEN Science Instruments:



Sun, Solar Wind, Solar Storms



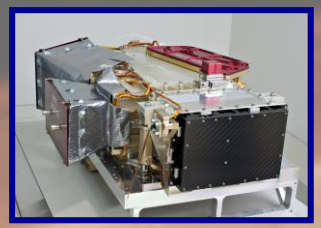
SWEA

SEP

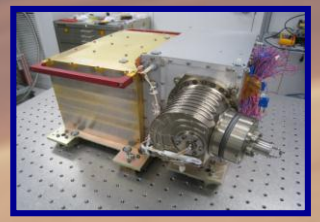
EUV

SWIA

Neutrals and Ions Plus Evolution



IUVS



NGIMS

Ion-Related Properties and Processes

STATIC

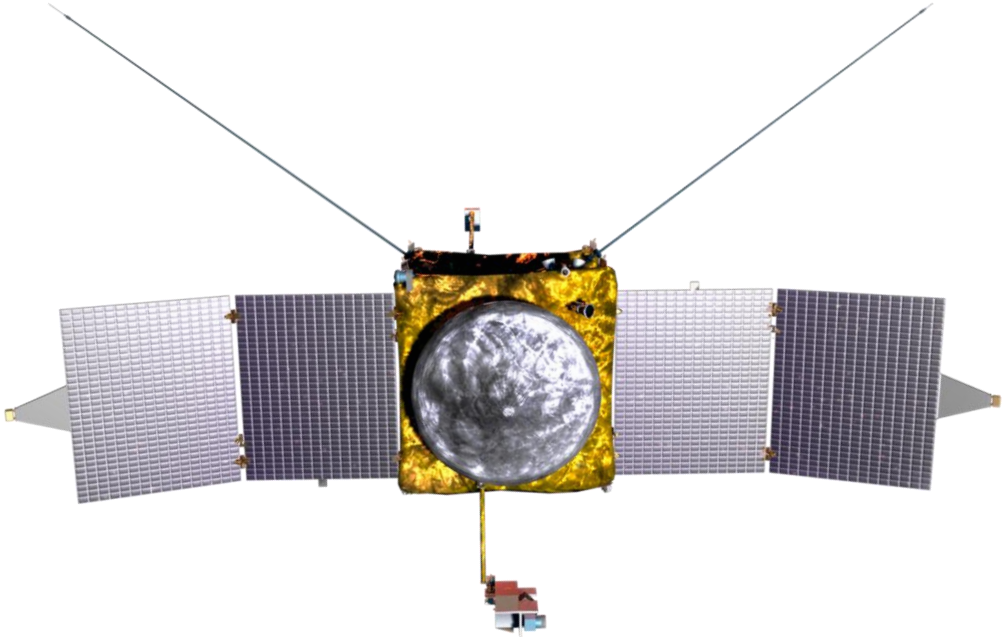
MAG

LPW

The MAVEN Spacecraft

- Launch (Wet) Mass: 2455 kg at launch
- Spacecraft Dry Mass: 810 kg at launch
- Power: 1135 W at Mars Aphelion

MAVEN Compared to “Terrestrial” Vehicles



Same weight fully loaded as a GMC Yukon – 2455 kg.

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

The MAVEN Partners

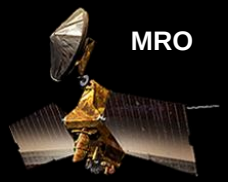
- Principal Investigator (PI)-mode mission, PI in charge
  - PI operates under a separate Laboratory for Atmospheric and Space Physics (**LASP**) contract from NASA Headquarters
- **Goddard** manages the project for the PI
- Instrument development grouped in packages closely aligned with institutional responsibilities
  - **Goddard** – Neutral Gas and Ion Mass Spectrometer (NGIMS)
  - Laboratory for Atmospheric and Space Physics (**LASP**) - Remote Sensing – Imaging UltraViolet Spectrograph (IUVS) and Remote Sensing Data Processing Unit (RSDPU)
  - Space Sciences Laboratory (**SSL**) - Particles and Fields – SupraThermal And Thermal Ion Composition (STATIC), Solar Energetic Particle (SEP), Solar Wind Ion Analyzer (SWIA), Solar Wind Electron Analyzer (SWEA), Langmuir Probe and Waves (LPW) (LASP/SSL provided), Magnetometer (MAG) (**GSFC** provided), and Particles and Fields Data Processing Unit (PFDPU)
- Lockheed Martin (**LM**)-Denver provides the spacecraft, instrument integration and mission operations
- **LASP** provides Science Operations
- Jet Propulsion Laboratory (**JPL**) provides Navigation support, Deep Space Network (DSN), and Electra telecom relay hardware/operations (GFE)

NASA's Mars Exploration Program

Launch Year

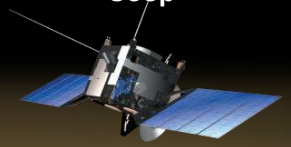
Operational / Recent	2009	2011	2013	2016	2018 & Beyond

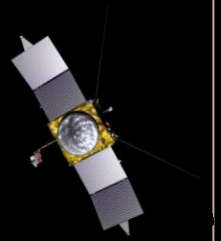
Odyssey



MRO

Mars Express
Coop





MAVEN

MER

Mars Science Lab

InSight

Mars 2020

MAVEN Assembly & Test at LM

MAVEN
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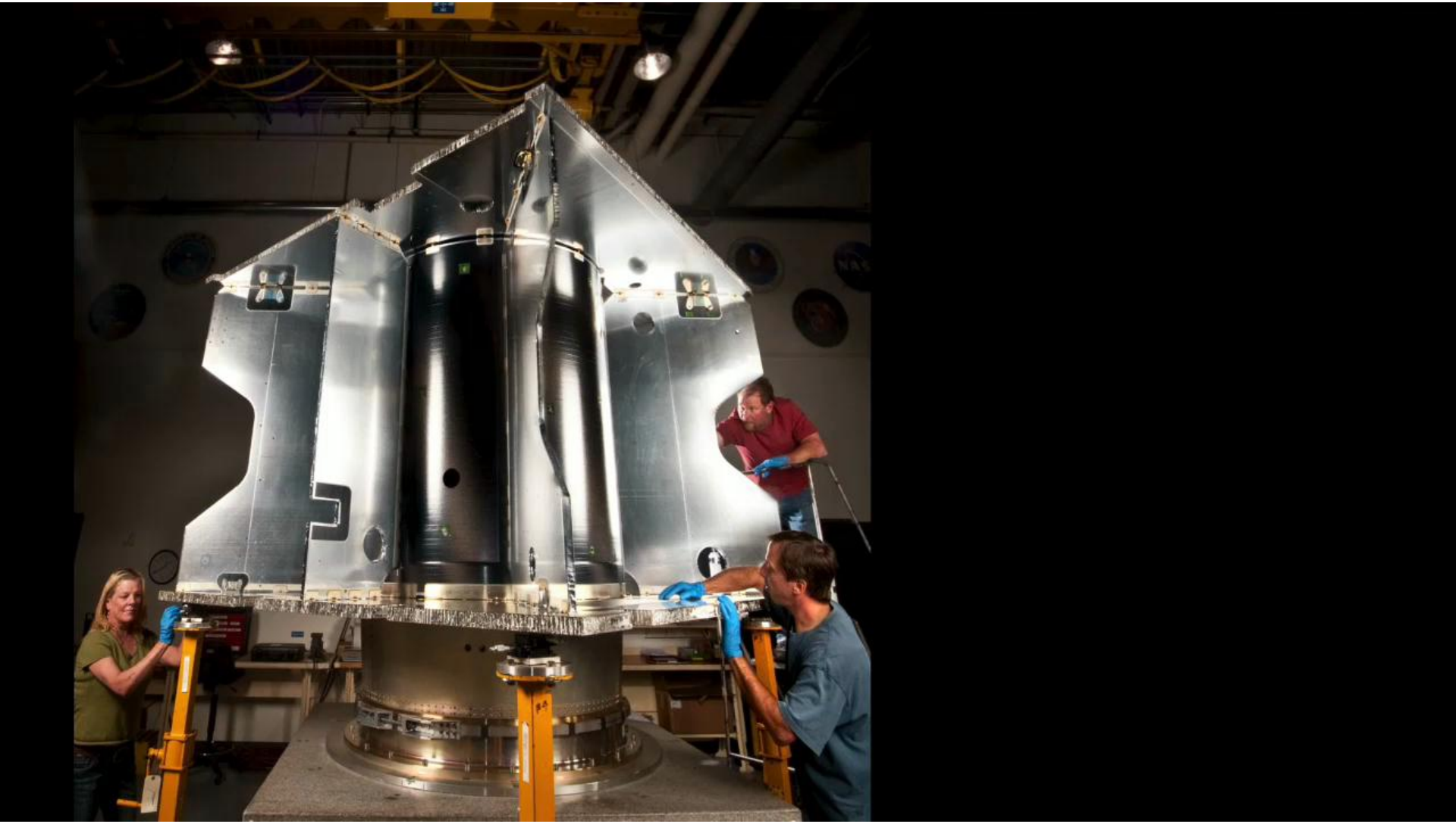
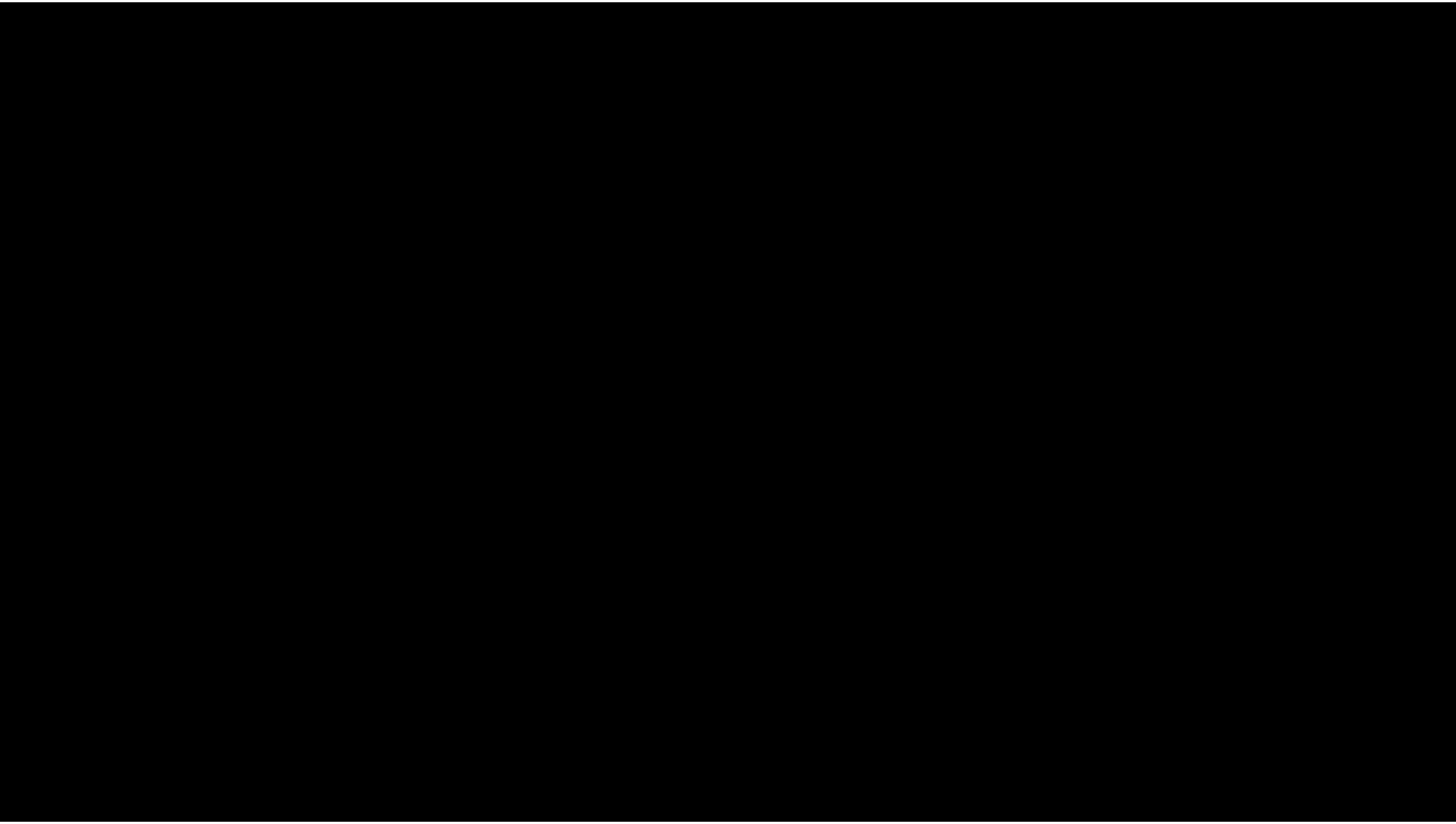
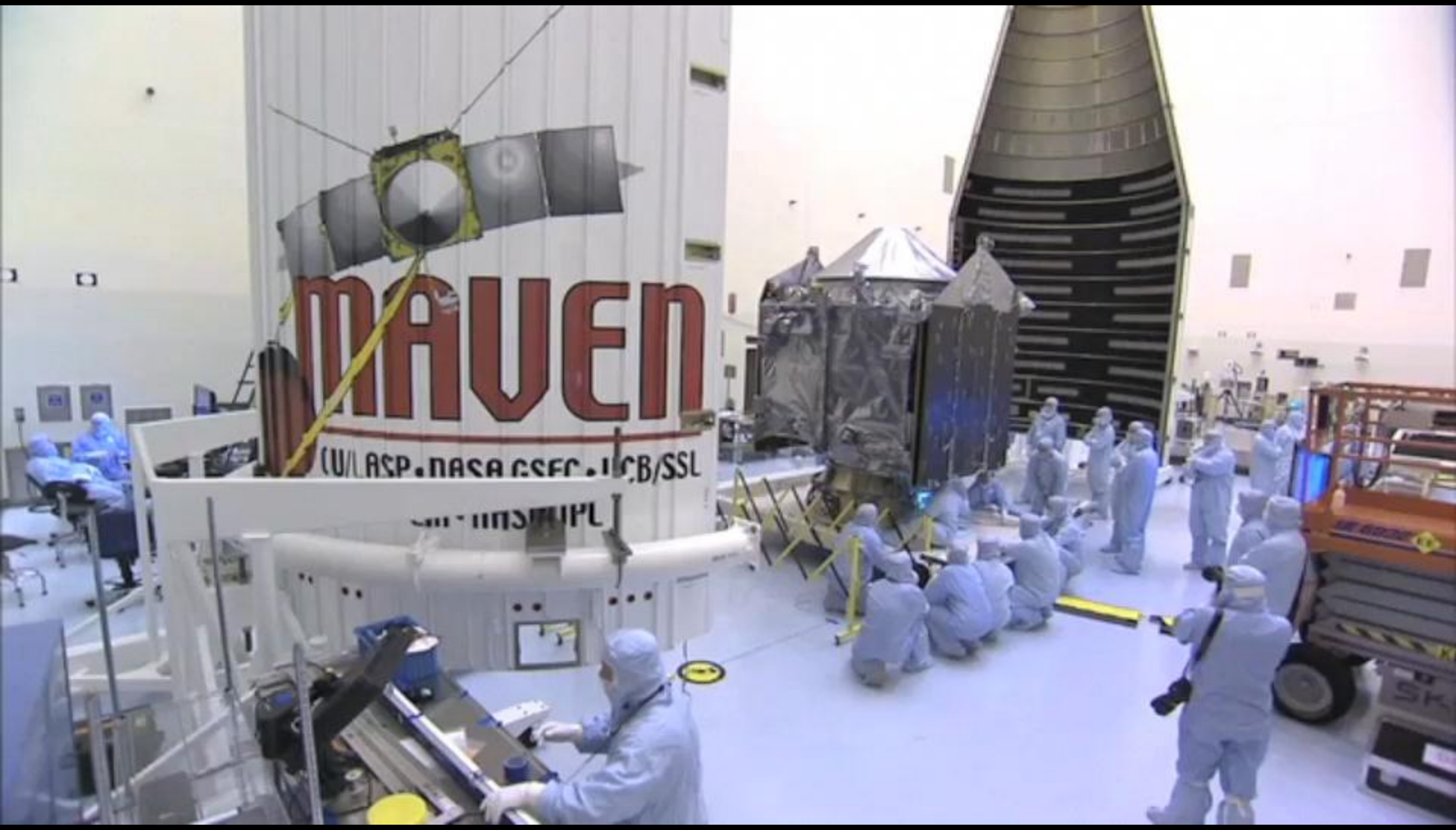


Shipping from Denver to KSC



The Spacecraft Undergoes Final Testing

Getting Ready To Launch



Go Atlas! Go Centaur! Go MAVEN!

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MAVEN Launches, 18 November 2013

From the Earth to Mars in ~10 months

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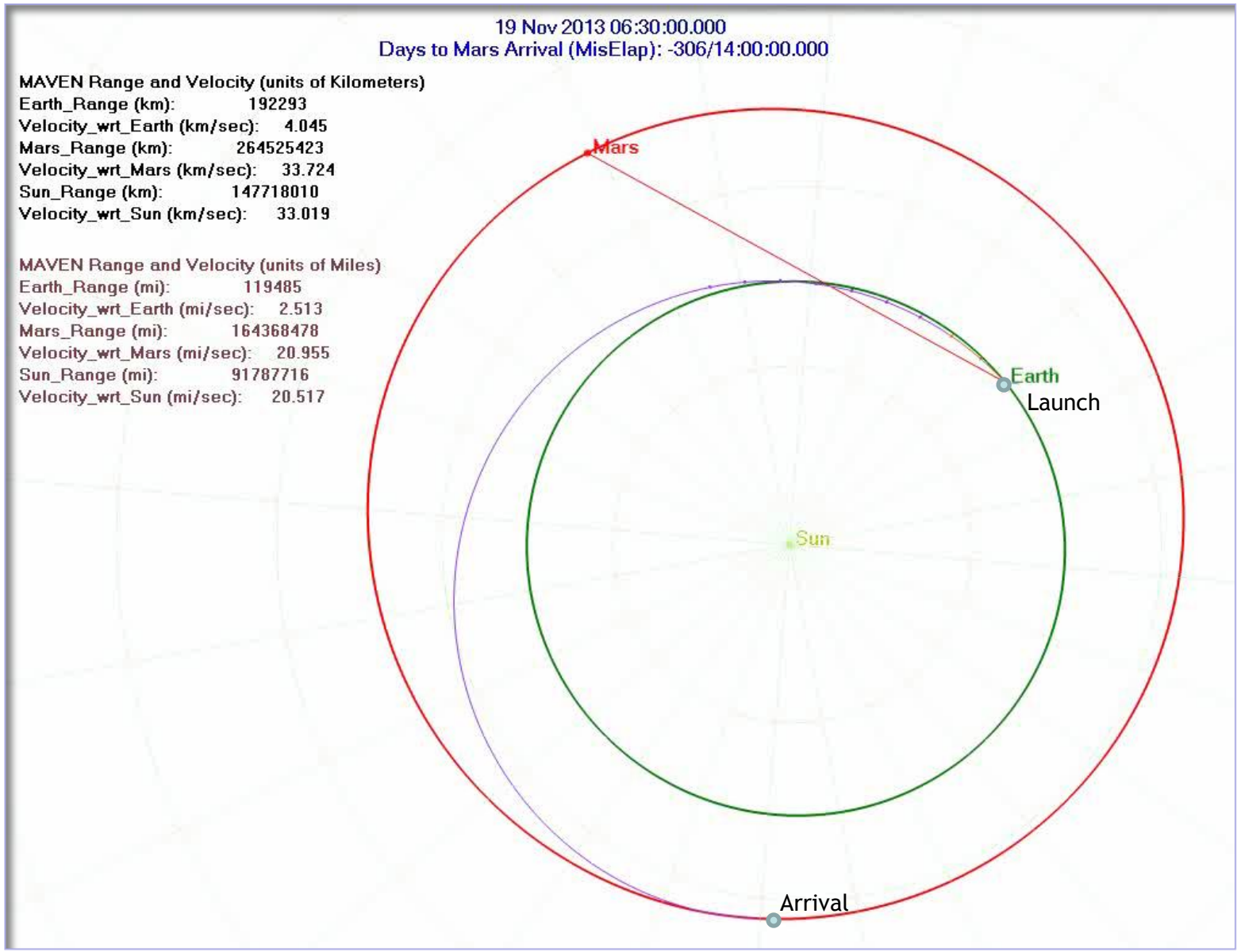
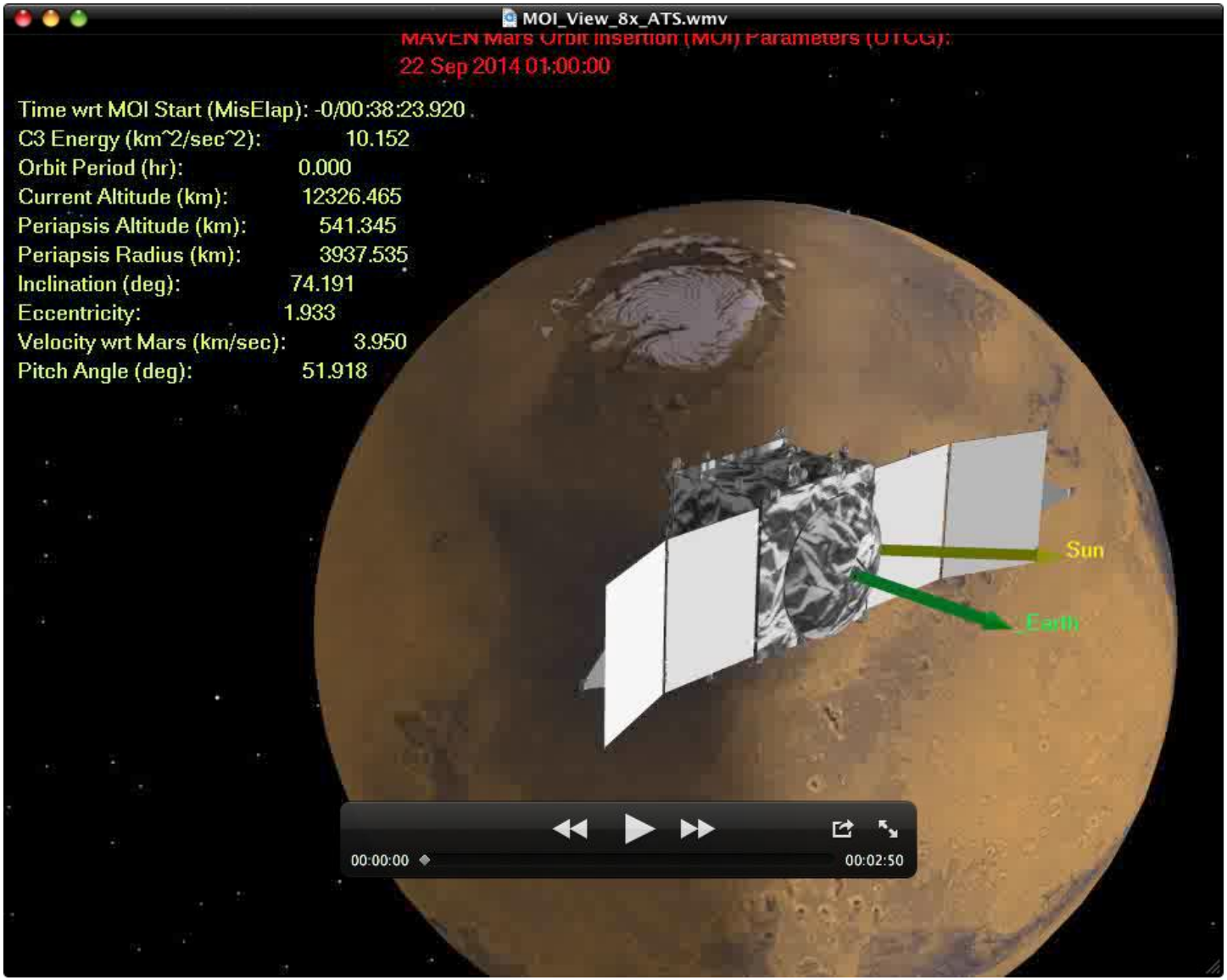
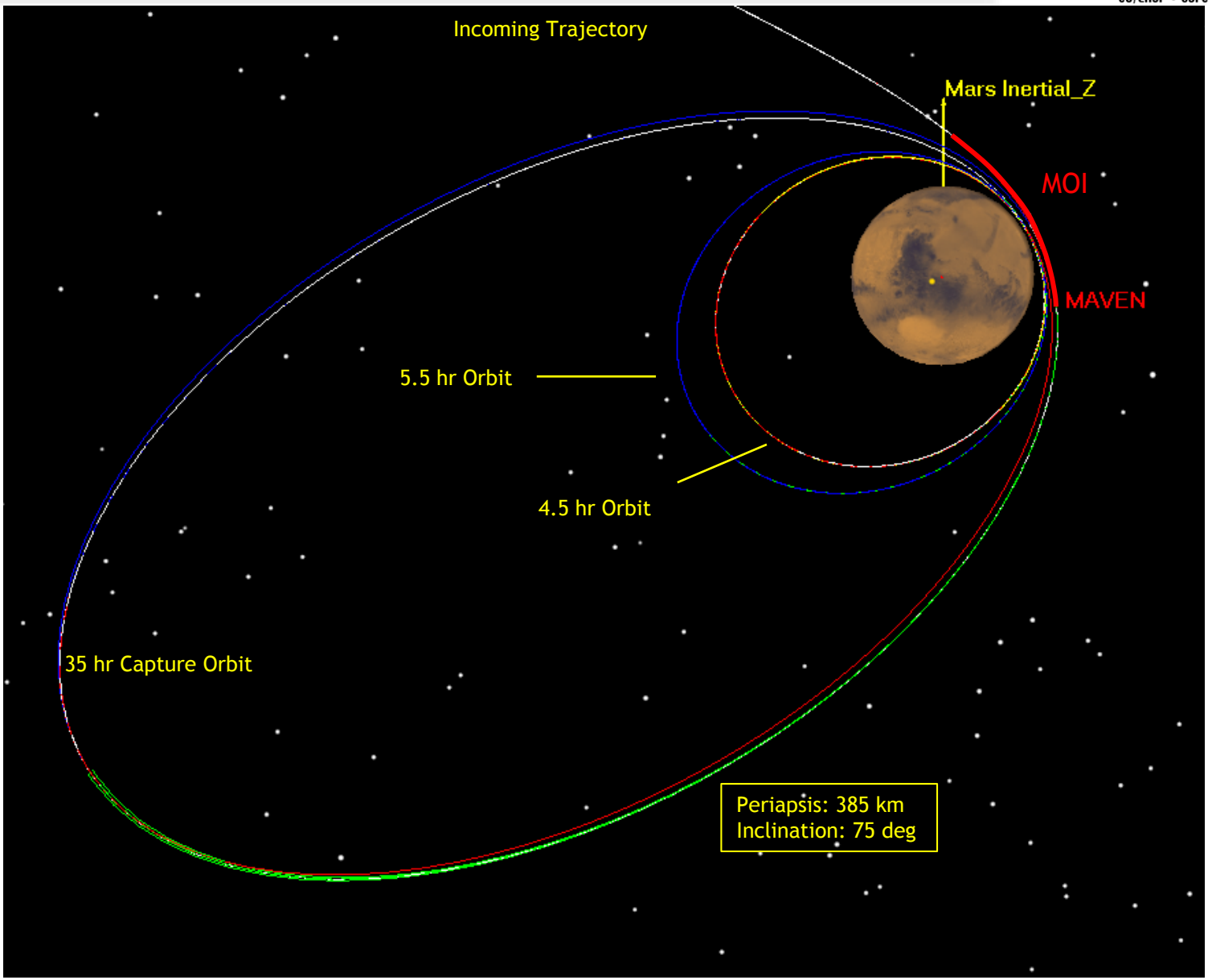


Mars Orbit Insertion

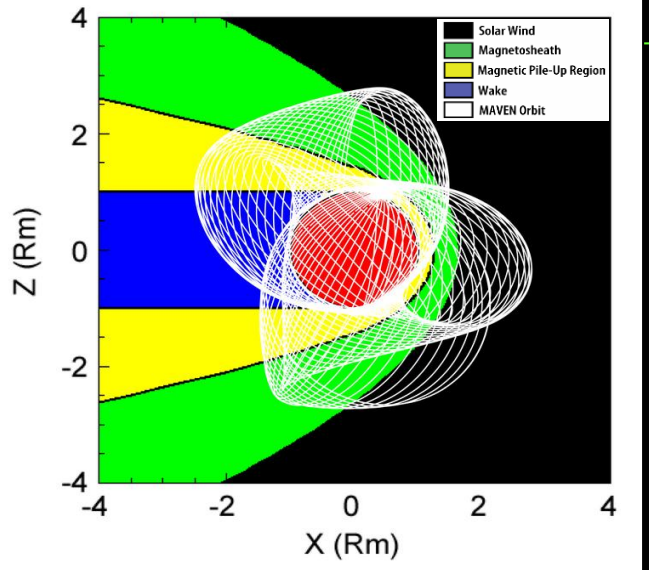
(external movie…)

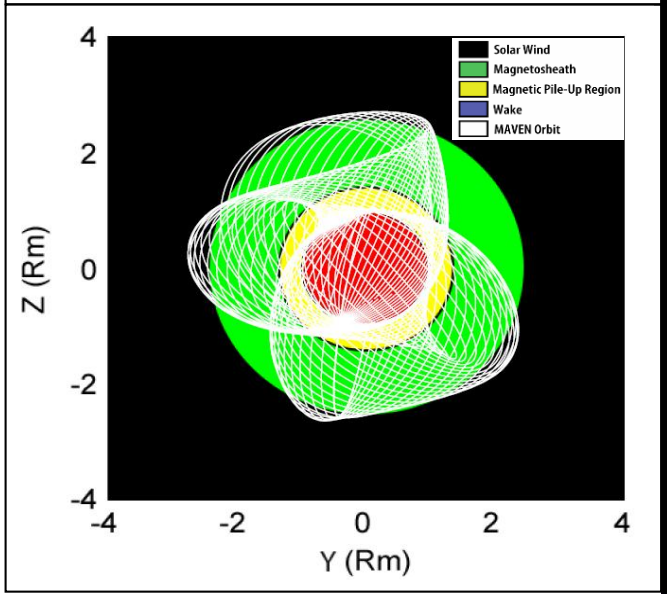


Transition to Science Orbit

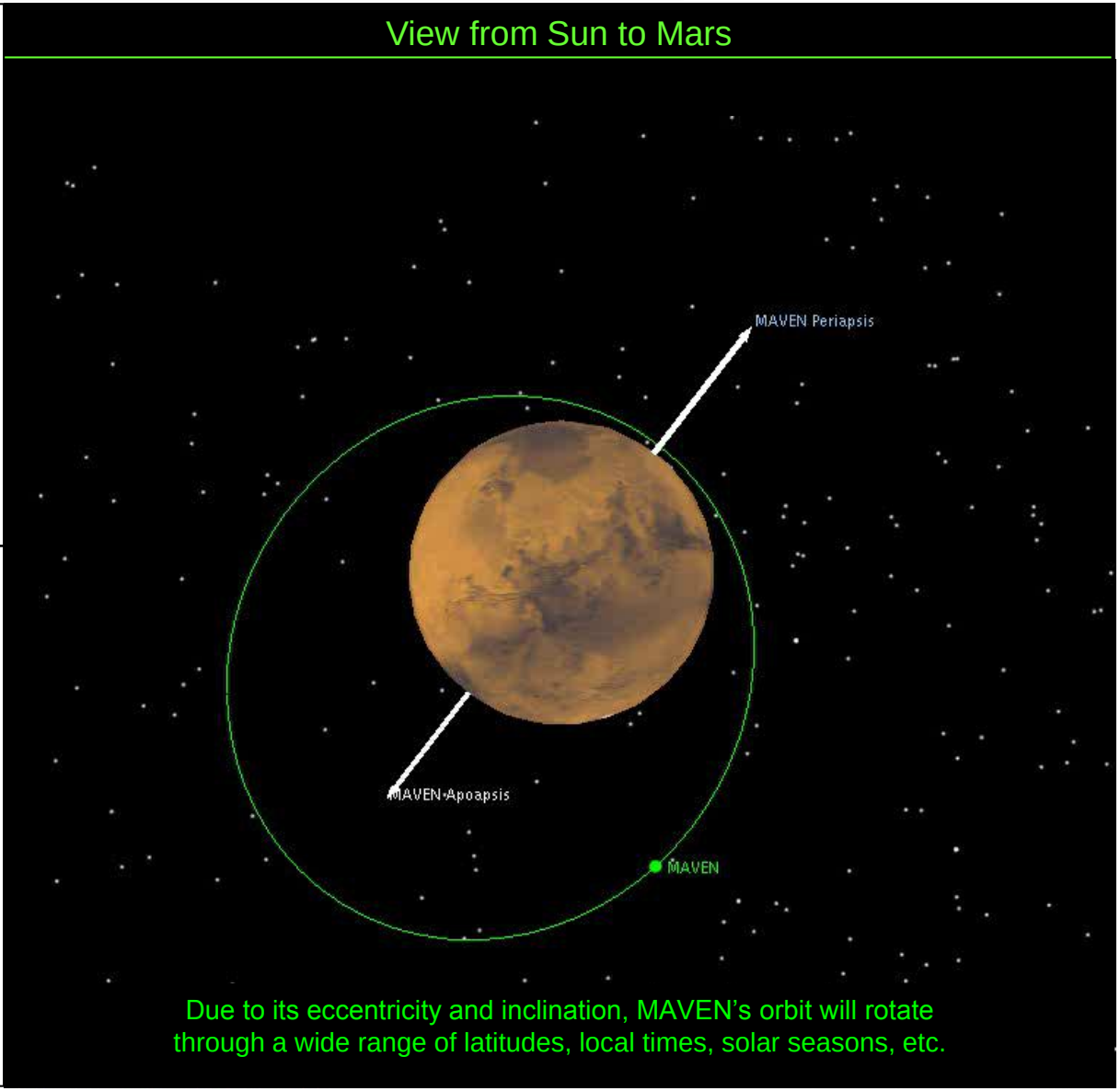


Science Orbit Evolution



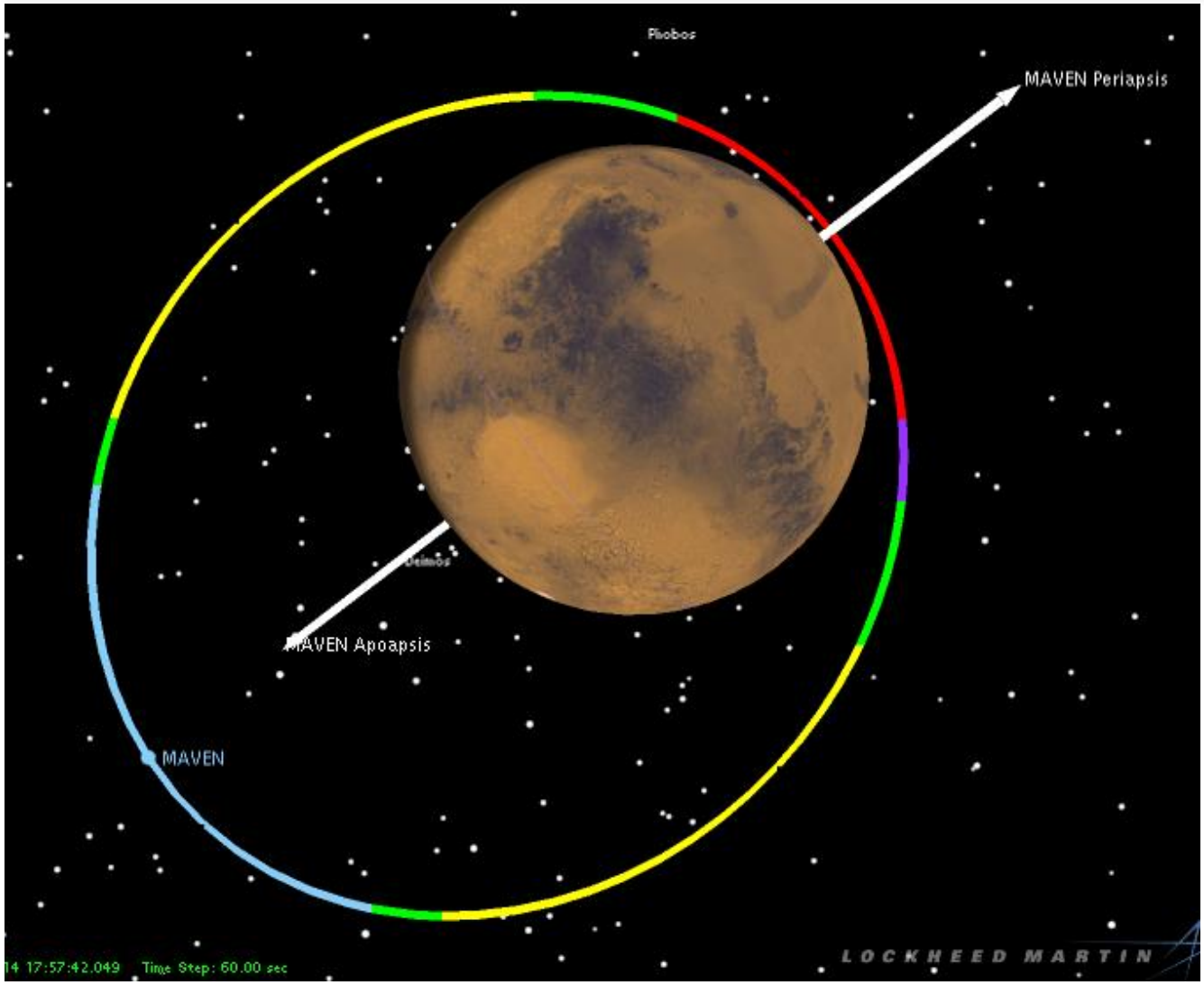


View from Sun to Mars

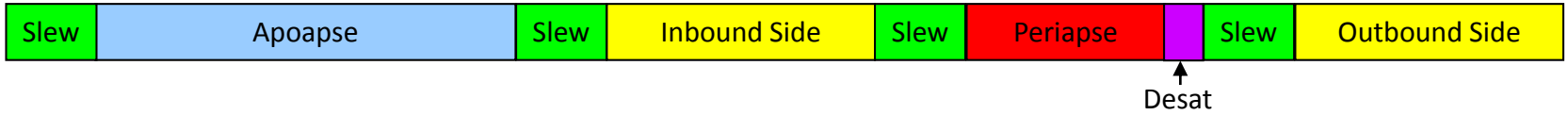


Due to its eccentricity and inclination, MAVEN's orbit will rotate through a wide range of latitudes, local times, solar seasons, etc.

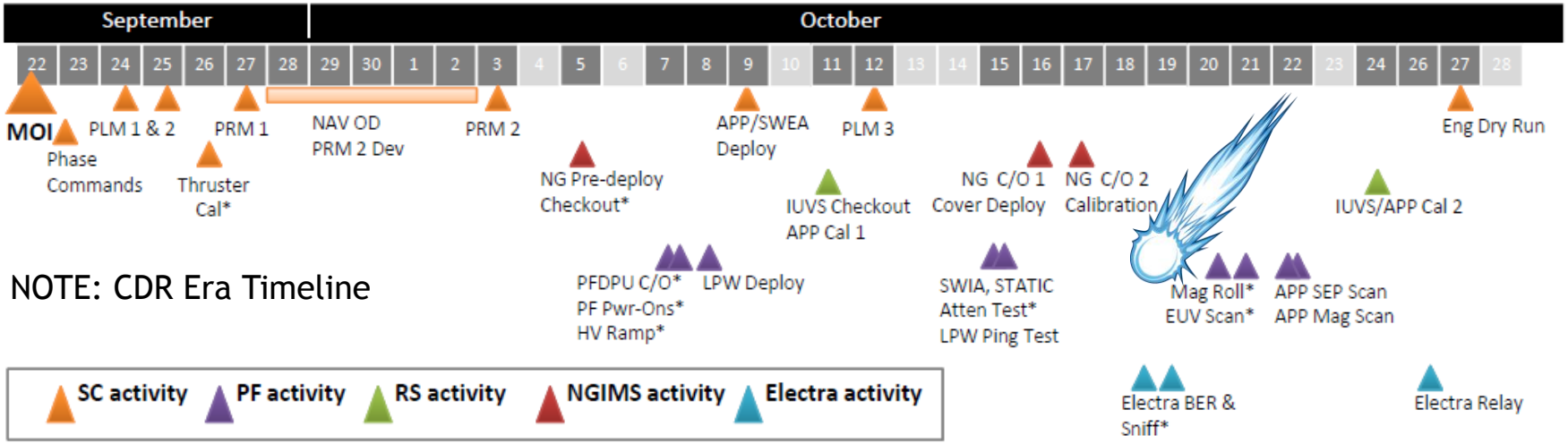
Science Orbit Operations



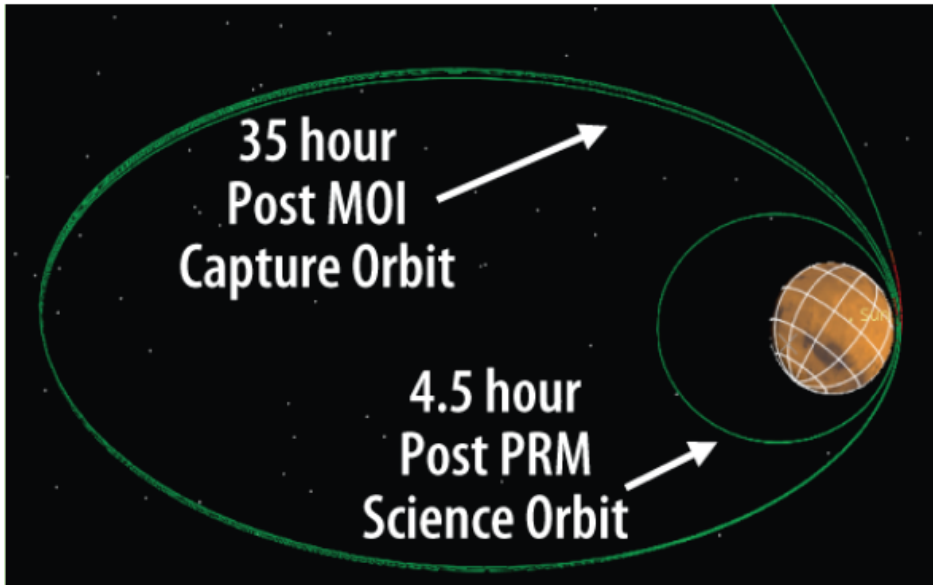
- Standard orbit divided into 4 repeating segments
- Segment operations are coordinated by ops/science
- Fixed set of Sci. Operations Scenarios to choose from
- APP is driven differently in each scenario; max. science
- Spacecraft body (+z) sun-pointed is nominal orientation
- Desat performed every orbit; minimizes science slew times
- 2 x 5-hour DSN passes per week; point to Earth (HGA)
- Daily tracking arcs on LGA to improve continuity of OD
- Periapse maintained to a density of 0.05-0.15 kg/km^3
- 5 x 20-orbit "deep dip" campaigns will lower periapse to a density of 2-3.5 kg/km
- On-board timing maintained to within 20 seconds via PTE



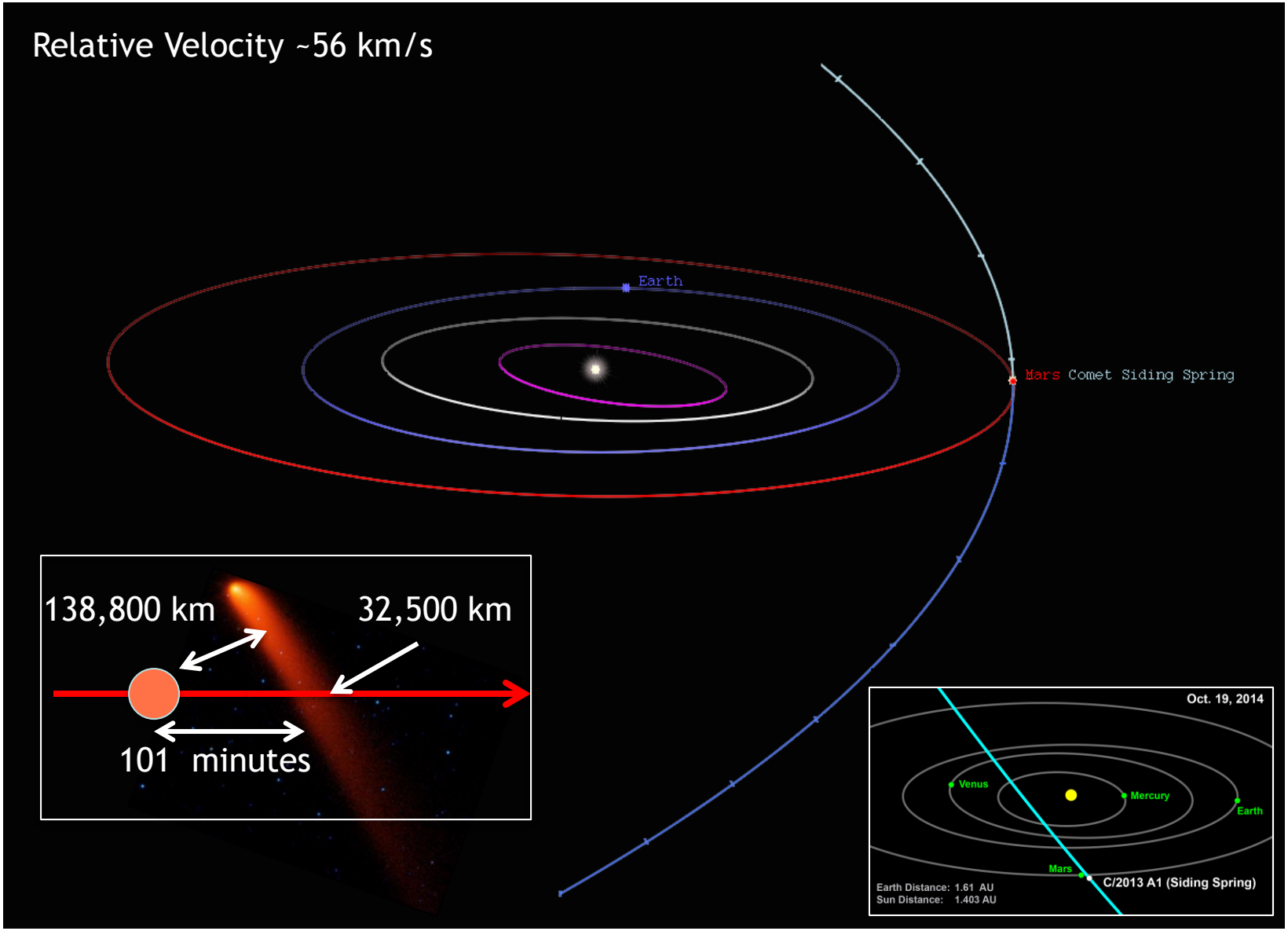
Original Transition Timeline



- Configures orbit & S/C for science ops
- Periapsis Lowering Maneuvers (PLMs) designed to lower periapsis into target density corridor (0.05 - 0.15 kg/km^3)
- Period Reduction Maneuvers (PRMs) designed to reduce period from 35 hours to 4.5 hours (+/- 0.1 hours)
- Boom Deployments & P/L Checkouts



Enter Comet 2013 A1/ Siding Spring



Detailed Observations & Modeling…

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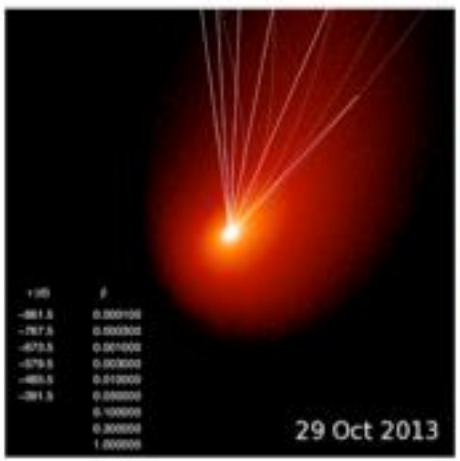
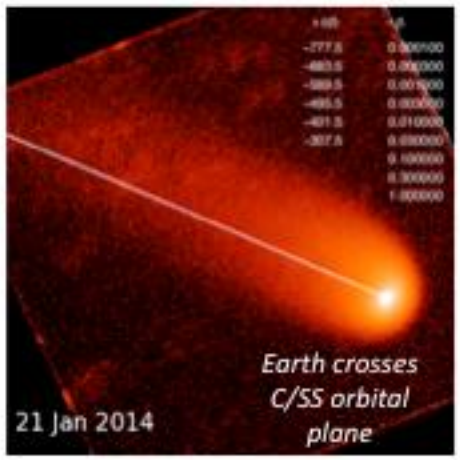
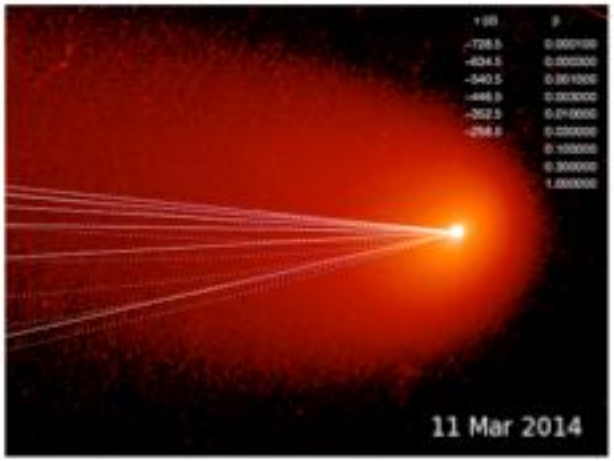
Legend: Syndynes (dashed) - *Loci of constant size*; Synchrones (solid lines) - *Loci of all sizes emitted at the same time*

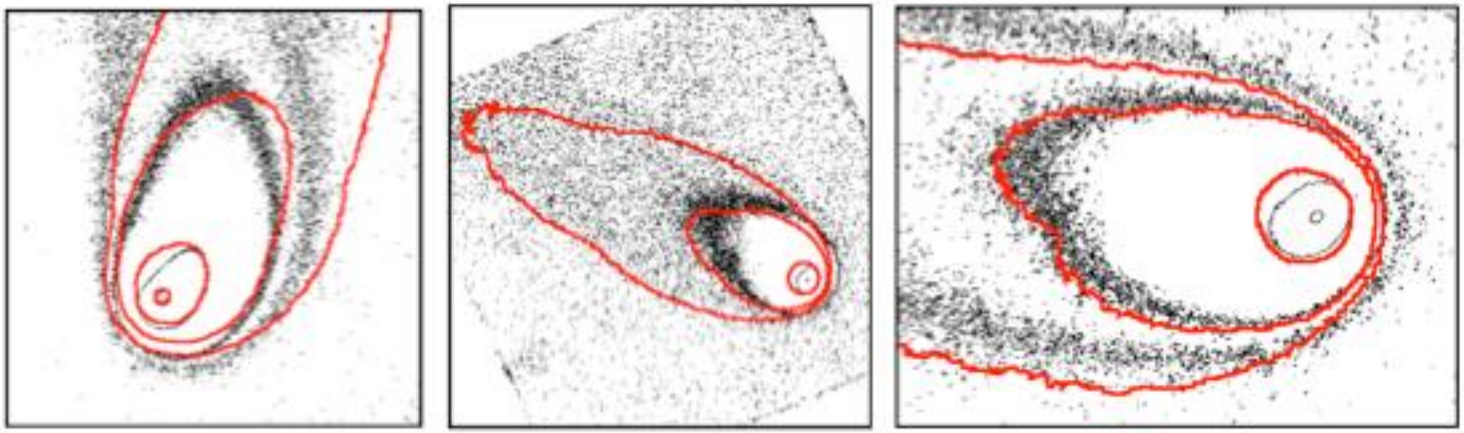






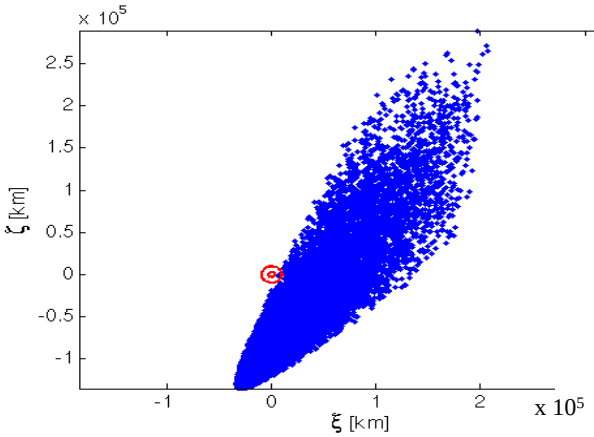
Using HST images to constrain Comet Model Parameters → ***Key Result: Particles are ejected from comet nucleus at relatively low velocities***

Model Versus Observed Brightness Contours



…Show Mars is OFF the Edge

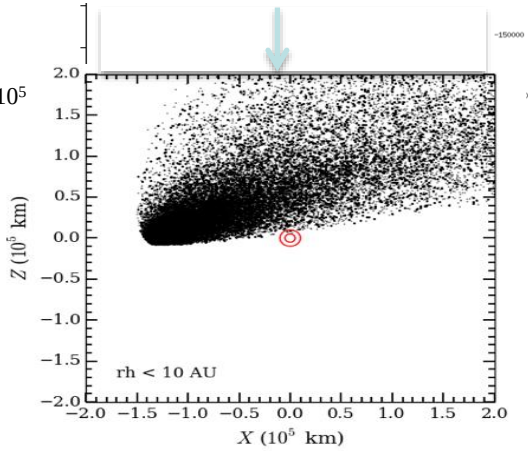
Three (3) independent groups modeling the distribution of dust particles from CSS came to the same basic conclusion: Mars is NEAR, but OFF the edge.

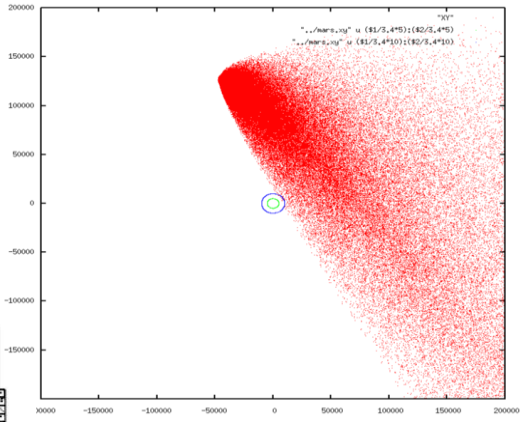


Solar System Dynamics Group
Farnocchia et al.

Note: Calculations are for dust particles > 100 μm diameter

Univ. of Maryland
*T. Farnham, M. Kelley, et al.



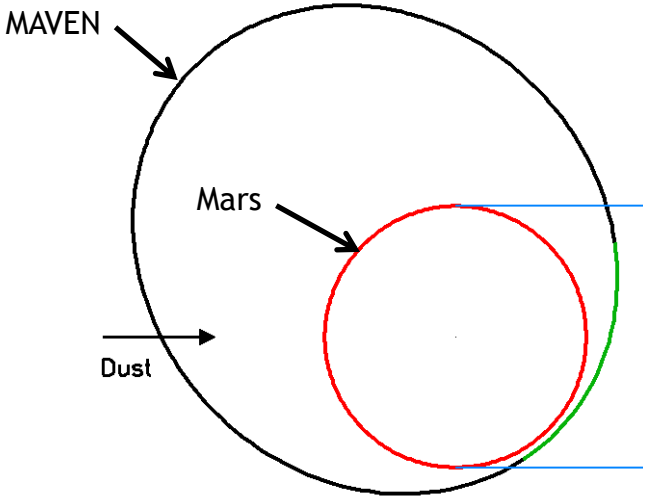


Planetary Sciences, Inc.
*P. Tricarico et al.

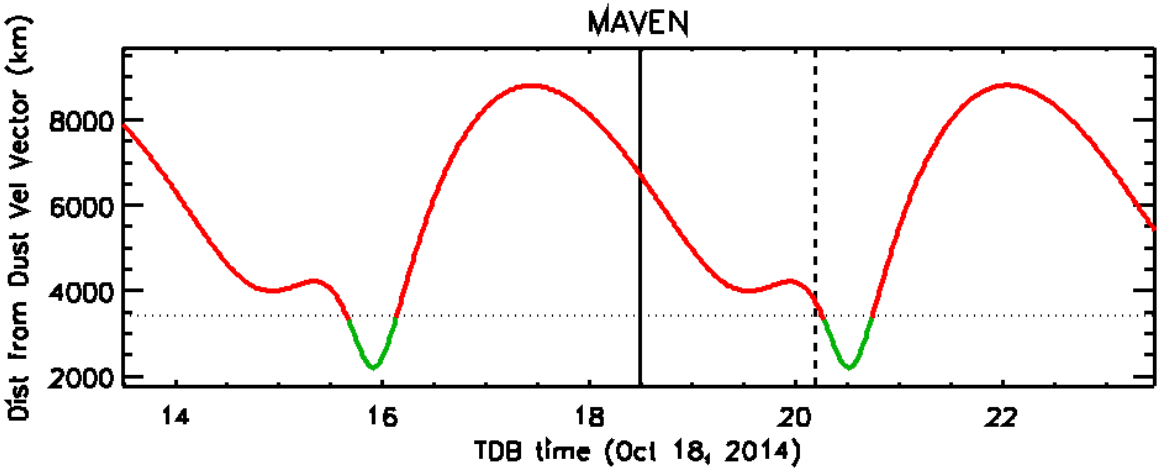
**Supported by the MPO Critical Data Products Program (CDP)*

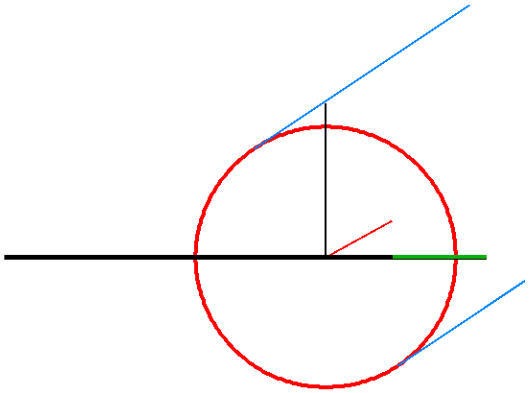
=> Fluence estimates are in the <10e-6 counts/m^2 range.

MAVEN Orbit vs. CSS

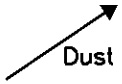


View from above s/c orbit plane





- MAVEN can get into Mars' wake for ~30 min/orbit
- Sharp flux peak makes "phasing to hide" an option

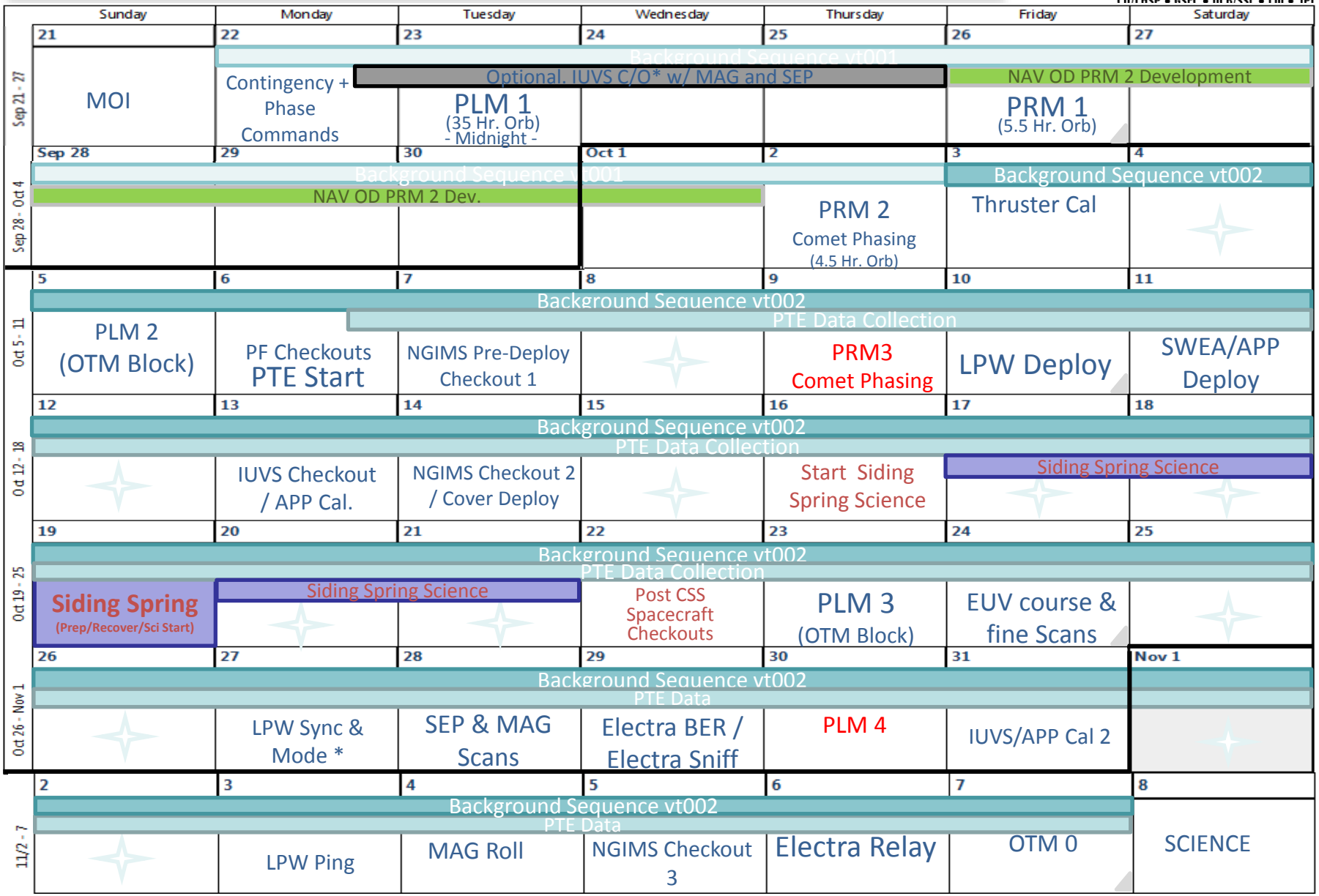


View from s/c orbit plane, with orbit normal and dust velocity vector defining the sky plane

CSS Event Summary

- Low fluence predictions indicate low risk to spacecraft
  - Will proceed with nominal orbit lowering and appendage deployment
- Orbit will be phased to place spacecraft behind Mars at peak flux
  - Eliminates majority of concern
- Selected encounter attitude minimizes cross-sectional area
  - No clear winner among candidate attitudes analyzed
  - Assessment considered intangible risks due to “non-critical” impacts
- No changes to safe mode configuration
  - Nominal science safe mode attitude is fairly close to preferred attitude
  - Safe mode does not move APP
- Selected mitigations offer maximum level of protection, without undo risk, and will defend against unforeseen activity/outbursts
- Combination of opportunistic science observations, mitigations, and margin days will delay start of science mapping by ~ 8 days

Transition Phase Timeline



IUVS Image of Mars ~8 hrs after MOI

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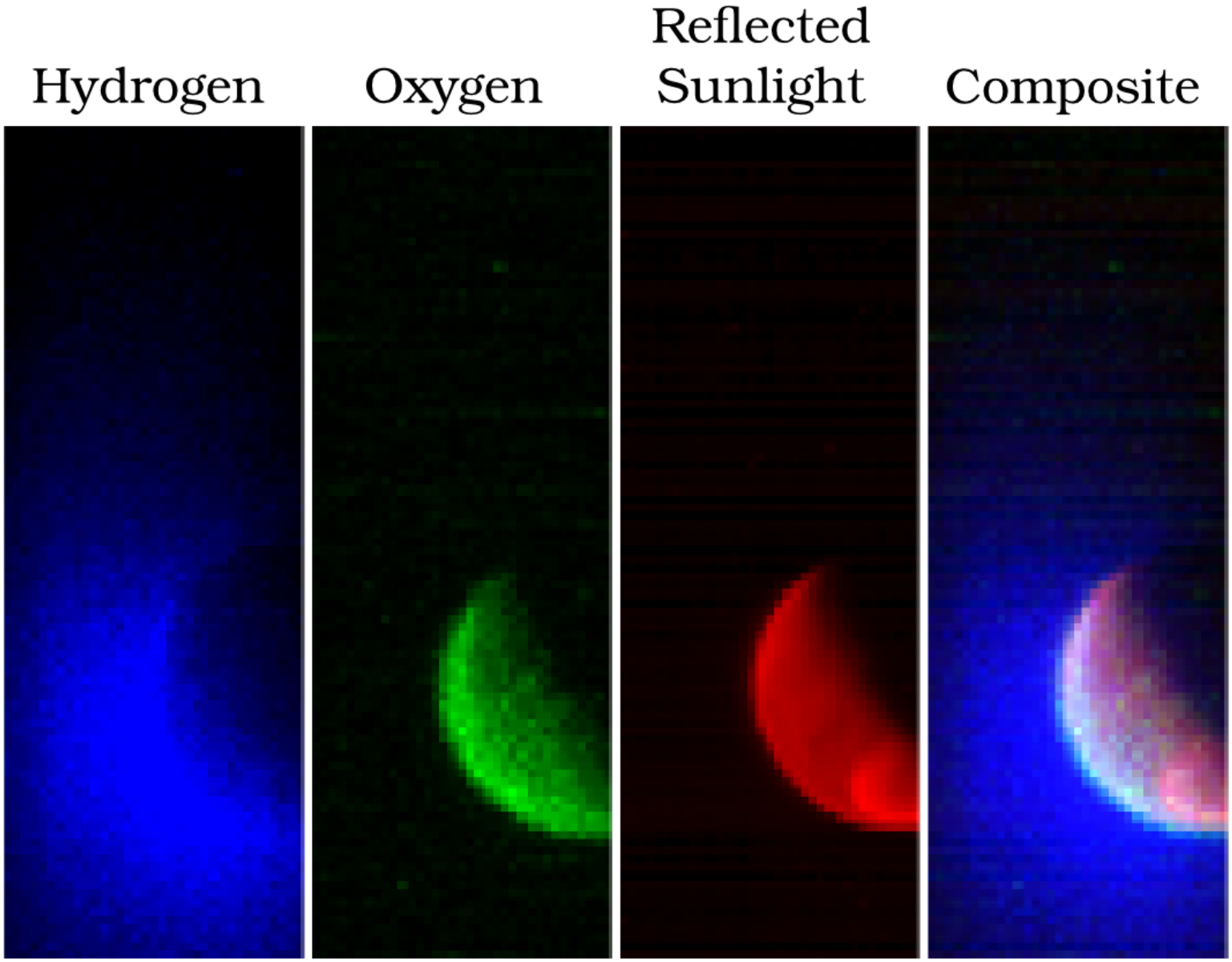


Stay Tuned…
… Our SCIENCE MISSION is about to begin!!!
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