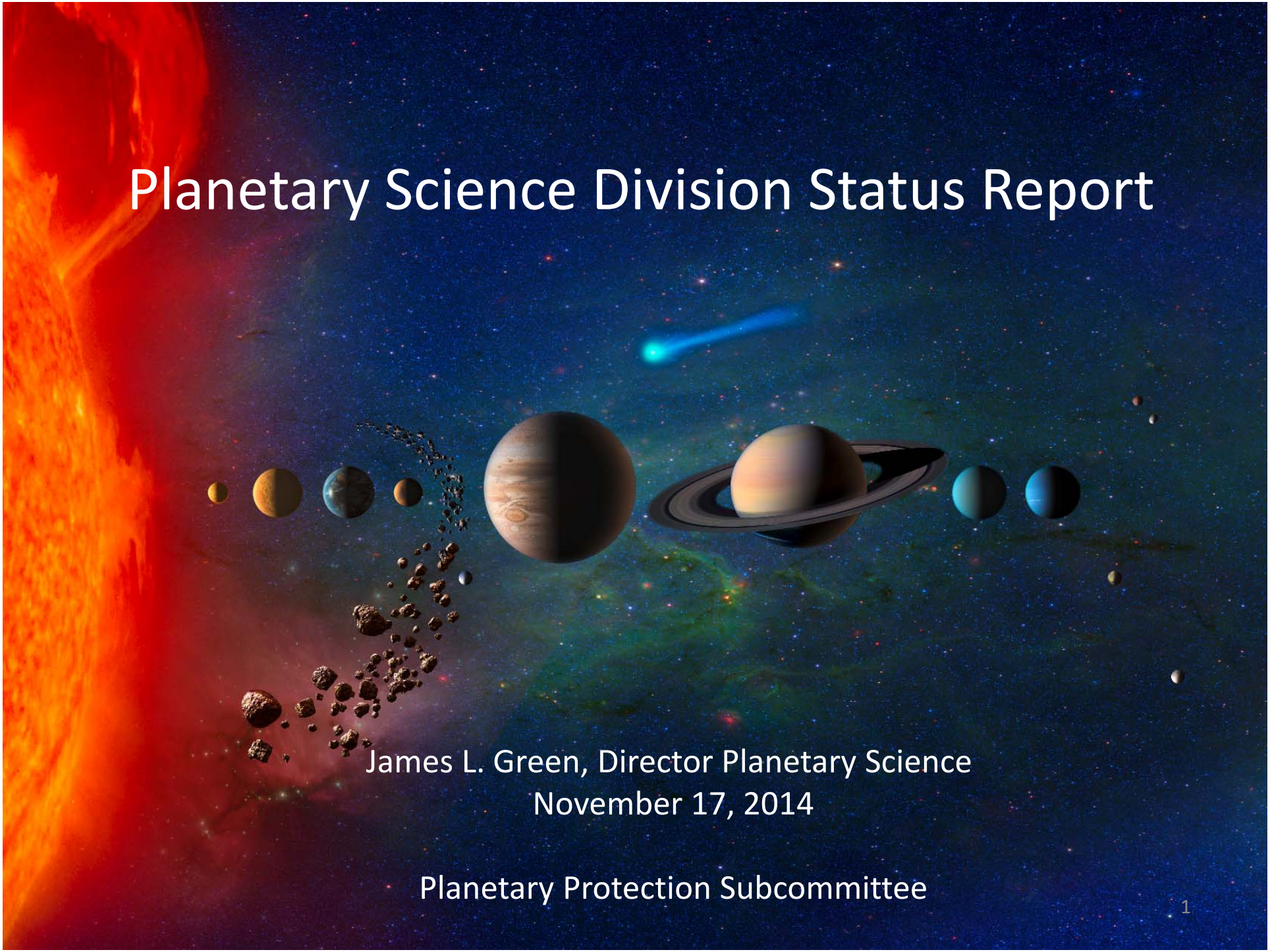
Planetary Science Division Status Report



James L. Green, Director Planetary Science

November 17, 2014

Planetary Protection Subcommittee

Outline

- Planetary Upcoming Mission Events
- Recent Accomplishments
- Senior Review
- R & A Update
- Planetary Technologies
- MAVEN Arrives at Mars
- Comet Siding Spring (CSS) Encounter with Mars

Planetary Science Missions Events *as of July 24, 2014*

2014

July – *Mars2020* Rover instrument selection announcement * **Completed**
August 6 – 2nd Year Anniversary of *Curiosity* Landing on Mars
September 21 - *MAVEN* inserted in Mars orbit
October 19 – Comet Siding Spring encountered Mars
September - *Curiosity* arrives at Mt. Sharp
November 12 – ESA's *Rosetta* mission lands on Comet Churyumov–Gerasimenko
November 30 – Launch of *Hayabusa-2* to asteroid 1999 JU_3

2015

January – Discussions with Indian Space Research Organization (ISRO)
March - *MESSENGER* spacecraft impacts Mercury
Late March – *Dawn* inserted into orbit at dwarf planet Ceres
April - Europa instrument Step 1 selection
May - Discovery 2014 Step 1 selection
July 14 – *New Horizons* flies through the Pluto system

2016

March – Launch of Mars missions *InSight* and ESA's *ExoMars Trace Gas Orbiter*
March - Europa instrument step 2 selection
July - *Juno* inserted in Jupiter orbit
July – ESA's *Bepi Columbo* launch to Mercury
August - Discovery 2014 Step 2 selection
September - *InSight* Mars landing
September – Launch of Asteroid mission *OSIRIS – REx* to asteroid Bennu
September - *Cassini* begins to orbit between Saturn's rings & planet

Recent Accomplishments

- Released Discovery AO – November 5, 2014
  - Step-1 proposals due in February 2015
- Europa Instrument AO – October 17, 2014
  - Currently under review
- 2014 Senior Review completed
  - Report and response posted
  - All missions will continue
- R&A all but one core program has had review since restructuring
  - Community is actively involved and reviewers generally pleased with process

Senior Review

2014 Planetary Mission Senior Review (PMSR)

Planetary Science conducted a review of all operating missions that will have completed prime operations by the end of FY 2014, and could potentially continue as an extended mission in FY 2015. Seven missions were identified for review, most of which were also evaluated in 2012. Deep Impact was not evaluated again, as it was terminated due to a mission anomaly, and MSL was added as it completed its Prime operations in FY 2014. For this review, Cassini was evaluated through its end of mission in FY 2017.

2012 Review	2014 Review
Cassini	Cassini
LRO	LRO
MER	MER
MEX	MEX
Mars Odyssey	Mars Odyssey
MRO	MRO
Deep Impact	MSL

Not reviewed were the Dawn, MAVEN, Juno, and New Horizons missions which are still in prime operations (having not yet arrived at their destinations) through at least all of FY 2015, and MESSENGER which will complete its mission in the first half of FY 2015.

2014 Planetary Mission Senior Review (PMSR)
Review Panel Report

Top Recommendation of the Planetary Senior Review:

"The science value (or science per dollar) of the extended missions exceeds the science gain from any planned mission, and all have important strengths. That is, they all represent added value to the Planetary Science Division and the American taxpayer because they are essentially new missions without the development and launch costs."

Panel Findings and PSD Response (1/3)

Cassini

- The proposed mission has a high likelihood of success based upon past performance, spacecraft condition, and the unique aspect of new observations.
- PSD concurs with the Panel findings, and approves the proposed extended mission plan.

Lunar Reconnaissance Orbiter :

- The second extended mission for LRO will characterize changes in the lunar surface, beneath the surface, and in the exosphere. Some instruments are at the end of their useful science mission, and suggest de-scoping (in order of preference) Mini-RF, LAMP and CRaTER instruments.
- PSD accepts the panel findings and has decided to de-scope (terminate) Mini-RF instrument operations.
- PSD accepts the panel finding that the LAMP and CRaTER instruments are potentially descopable – providing less ground breaking Lunar Science than the other instruments. However, PSD has decided to continue operations of both instruments because of their HIGH programmatic.

Mars Exploration Rover (Opportunity)

- Opportunity continues to make important scientific discoveries on the surface of Mars.
- PSD concurs with the Panel findings, and approves the proposed extended mission plan.

Panel Findings and PSD Response (2/3)

Mars Reconnaissance Orbiter

- The Project was lauded for the high number of quality science publications (~120/year), including many from non-team members.
- PSD concurs with the Panel findings, and approves the proposed extended mission plan.

Mars Express

- The Panel finds only automated aspects of HRSC image processing should be supported at a very low FTE level and all other US support for HRSC be terminated.
- Found that the MARSIS AIS coordinated ionospheric observations with MAVEN should be funded
- PSD concurs with the Panel findings, and approves the extended mission plan without the HRSC science team, and adding the MARSIS AIS collaboration with MAVEN.

Mars Odyssey

- The panel noted that the mission will provide an understanding of the radiation environment; and serve as an observatory for cosmic gamma ray bursts. But that Odyssey may be coming to the end of its productive science life as highlighted by declining rate of publications using Odyssey data.
- PSD decided that the radiation environment/atmospheric science is still a priority for human exploration of Mars, and approves the proposed extended mission plan.

Panel Findings and PSD Response (3/3)

Mars Science Laboratory:

- Although several strengths were noted by the Panel, the panel found problems with the proposal were sufficiently severe they need addressing at the earliest opportunity.
- Panel found that a de-scope in traverse distance with a focus on Paintbrush, Hematite, and possibly the Clay units, and better characterizing these sites, would better serve science.
- PSD concurs with the panel's finding that efficiency of analytical sampling needs to be improved and that greater emphasis be given to in-depth characterization of geologic units.
- PSD approves the extended mission plan, but asks Project to develop a new task plan that.

R & A Update

PSD R&A Program List

Program Name	Step-1 Due Date	Step-2 Due Date
Emerging Worlds	***03/31/2014***	***06/04/2014***
Exoplanets	***03/31/2014***	***05/23/2014***
Exobiology	***04/14/2014***	***06/03/2014***
Solar System Obs.	***04/07/2014***	***06/06/2014***
MatISSE	***04/21/2014***	***06/20/2014***
LARS	***04/28/2014***	***06/27/2014***
Solar System Workings	***05/23/2014***	***07/25/2014***
PDART	***07/17/2014***	***09/17/2014***
Discovery Data Analysis	***07/21/2014***	***09/19/2014***
Cassini Data Analysis	***07/28/2014***	***09/26/2014***
Mars Data Analysis	***08/04/2014***	***10/03/2014***
Lunar Data Analysis	***08/29/2014***	***10/24/2014***
PICASSO	***09/15/2014***	***11/14/2014***
Habitable Worlds	11/24/2014	01/23/2014

Step-1 Proposal

- The time-to-notify after the Step-1 deadline is consistent across the Core programs
- The dominant factor is not the number of proposals, but this year's discussion between program caucuses

Program Name	Submissions	Days to Step-1 Notifications
EW (Emerging Worlds)	219	23
SSW (Solar System Wkgs.)	509	21
Exobiology	186	22
SSO (Solar System Obs.)	99	23
PDART	143	36
CDAPS	101	10
DDAP	32	7
LARS	29	3
XRP (Exoplanets)	168	16
MDAP	139	18
LDAP	82	20
PSTAR	69	17

Time-to-notification is given as calendar days between the Step-1 deadline and when the majority of the NSPIRES notifications were sent.

Planetary Technologies

RPS Status

- Fuel efficiency remains important even with restart of Pu-238 production
- Investments in thermoelectric technology to improve MMRTG capability
  - Enhanced thermoelectric couples could be on-ramped into future MMRTGs with minimal design change (improved couple life, and end-of-mission power)
  - Technology maturation evaluation in 2018 for an eMMRTG flight design
- Assembling Stirling hardware into Engineering Unit for testing
  - A 4x-efficiency improvement via Stirling still desired for certain missions
  - Study team assessing optimal Stirling sizes for Agency RPS and fission usage
- Mission pull continues
  - Heritage RPS on Voyager, Cassini, and New Horizons operating well
  - MMRTG operating well on Curiosity as it enters extended mission
  - MMRTG flight spares allocated for potential use by Mars 2020
  - Ready to support potential 2024 mission launch (possibly eMMRTGs)
  - Future potential for 2028-and-beyond mission launches

NASA-DOE RPS Production Status

- DOE continues its NASA-funded Pu-238 Supply Project
  - Goal of 1.5 kg/year of Plutonium Oxide production capacity by ~2021
  - Technology demonstration efforts continue on schedule
    - Target development, irradiation tests, and Pu-238 chemical recovery continue to be individually developed
    - The first of two integrated end-to-end demonstrations is planned to start in 2015
    - Assessment of Pu-238 product quality will occur at the end of each demonstration
  - The remainder of the project involves scaling up to the 1.5 kg/yr production rate

- NASA is now funding DOE Operations and Analysis (infrastructure)
  - Maintaining worker certifications and performing operational maintenance activities to support future RPS fueling and assembly capabilities at multiple DOE laboratories
  - Augmented funding to accelerate design and installation of a new Hot Press and furnace capability to reduce fuel clad production risk at Los Alamos National Laboratory (LANL)
  - Heat Source Manufacturing for potential Mars 2020 use will begin at LANL in 2015

MAVEN Arrives at Mars

Comet Siding Spring (CSS) Encounter with Mars

MAVEN: Mars Orbit Insertion

Sept 12	13	14	15	16	17	18	19	20	21	22	23
MOI Rel	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1

TCM-4

CLT 27 Hrs
Battery 100%
Pre-MOI Uplinks

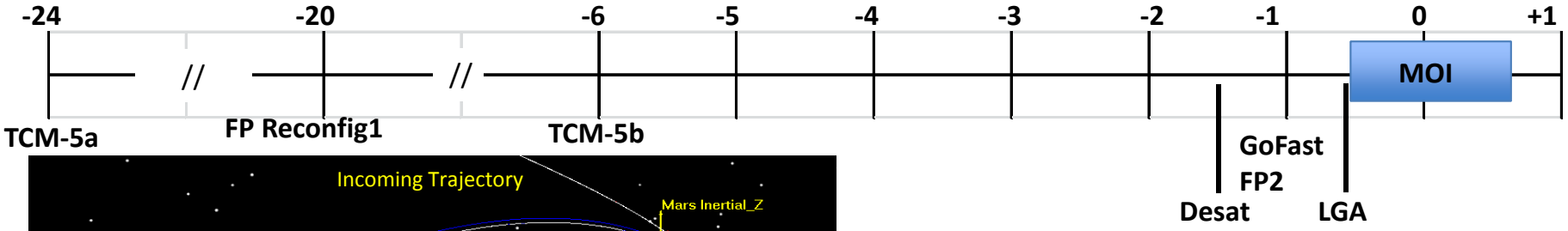
Prop Tank Preheat
CMIC Copies
LV30 Open
Phase = MOI
Start moi_nom

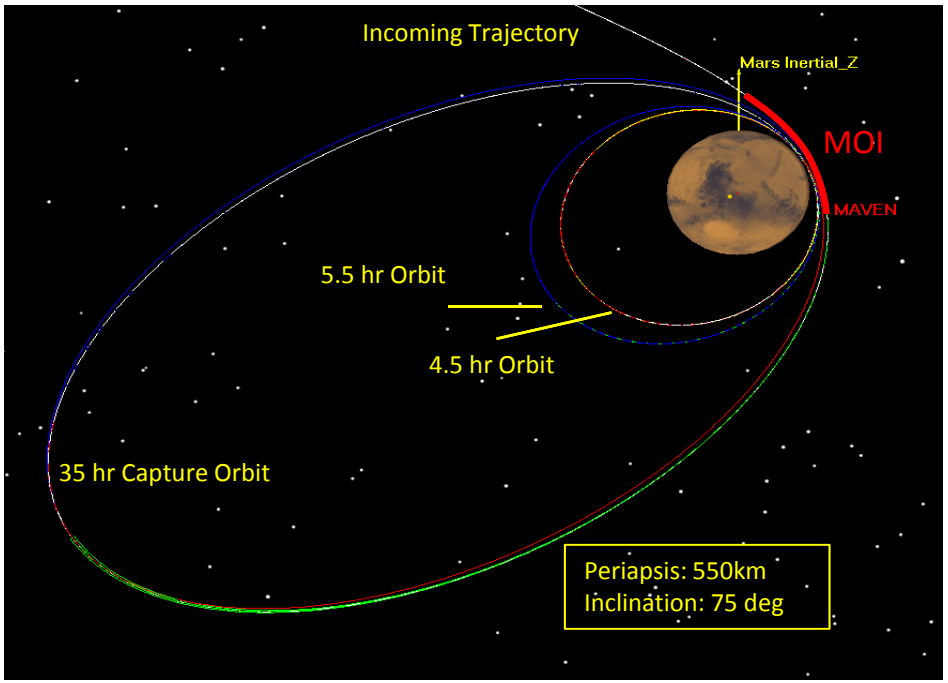
MOI

A1

End
MOI
Phase

MOI Countdown (Hrs)

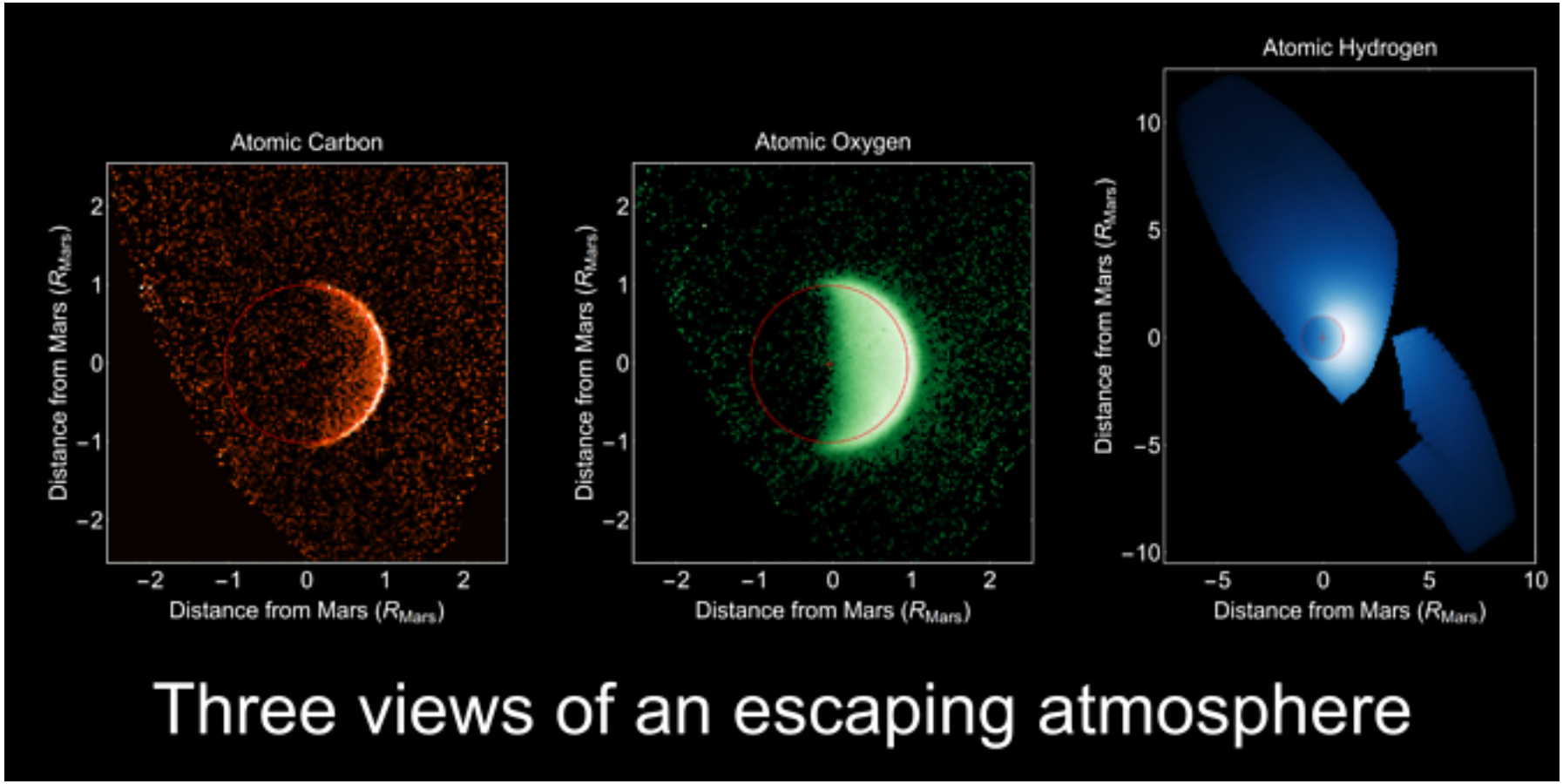


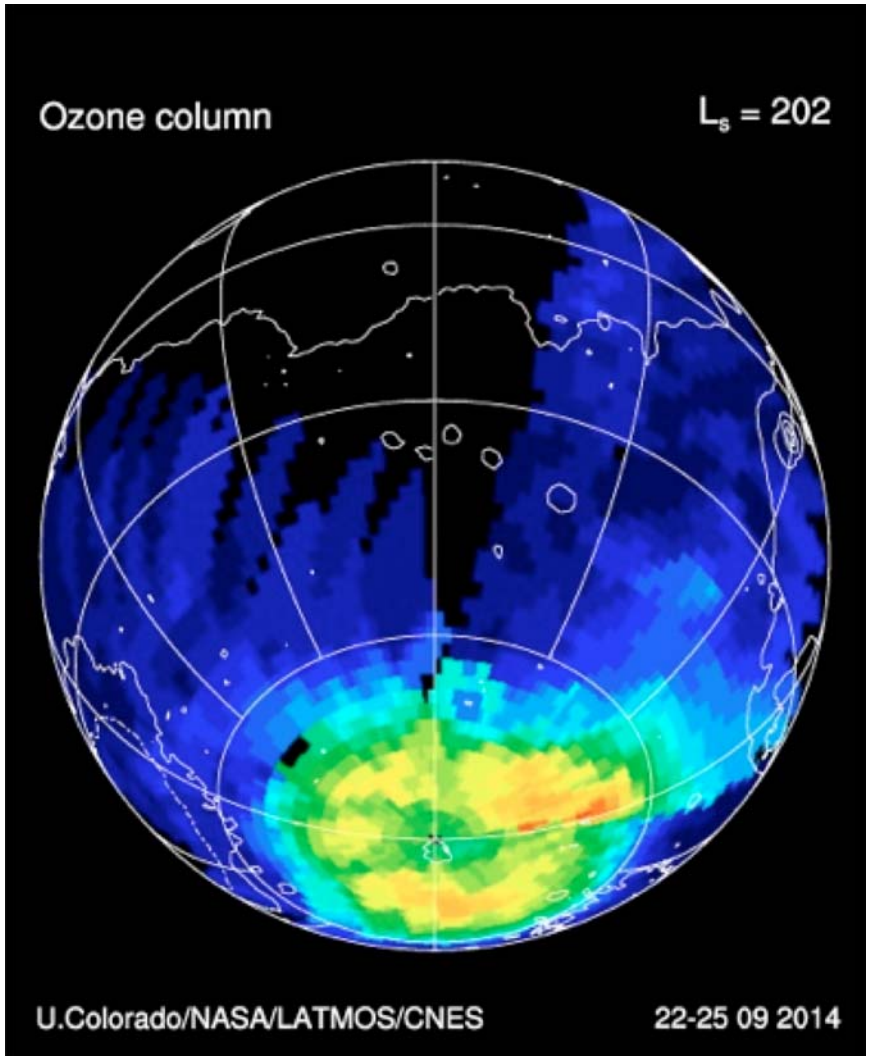


- MOI will occur on 9/21/14 (ET)
- Sequence activates 3 days out
- Emergency TCM 5a and 5b opportunities at MOI-24 hours and MOI-6 hours
- Configure for GoFast Recovery (MOI-1 hour)
- In contact with Earth during the entire burn sequence
- Primary operations at LM-Denver, backup operations at Goddard

Escape of Climate Controlling Gases

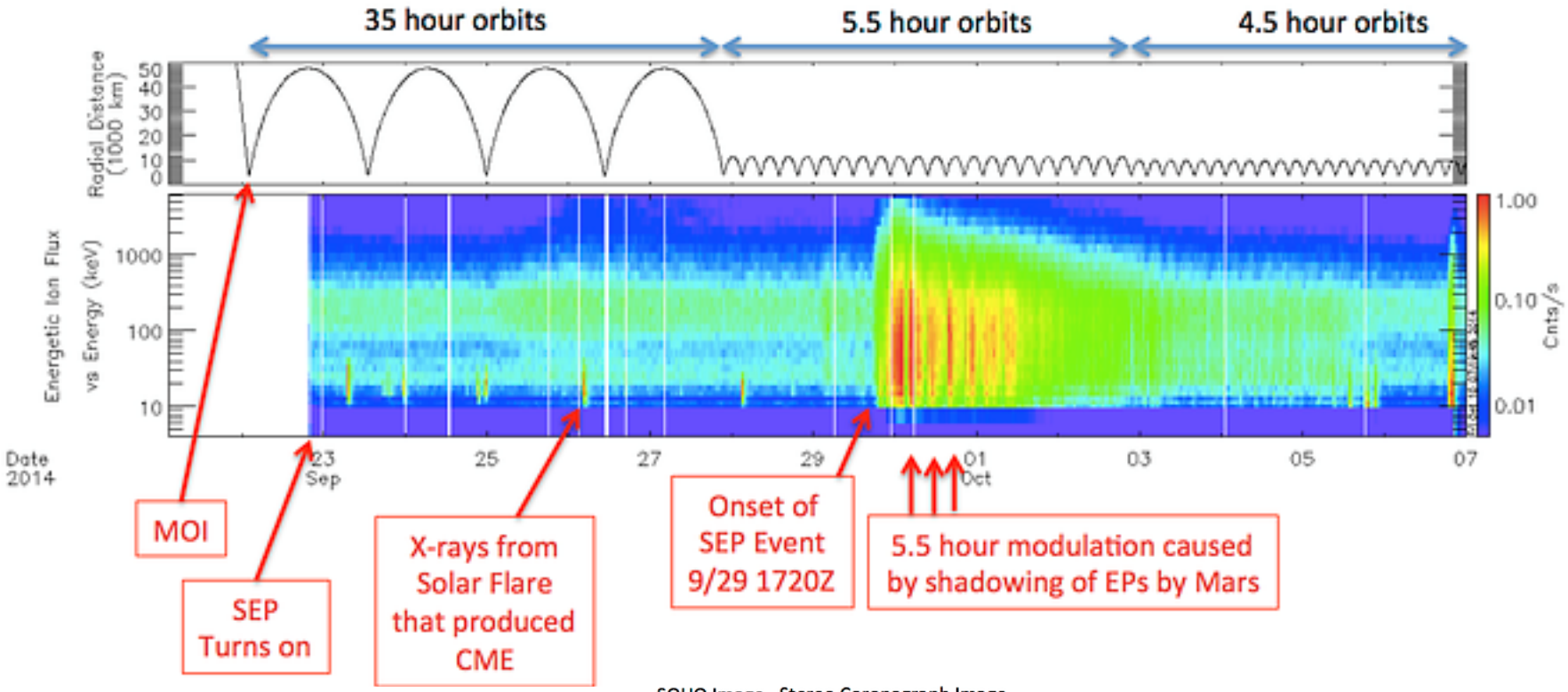
- In 35 hour orbit obtained unique observations

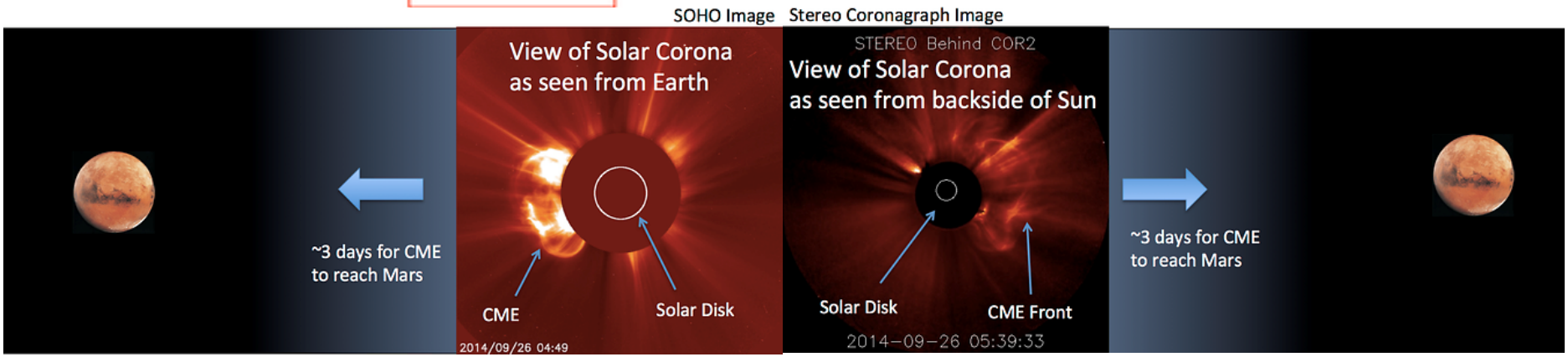


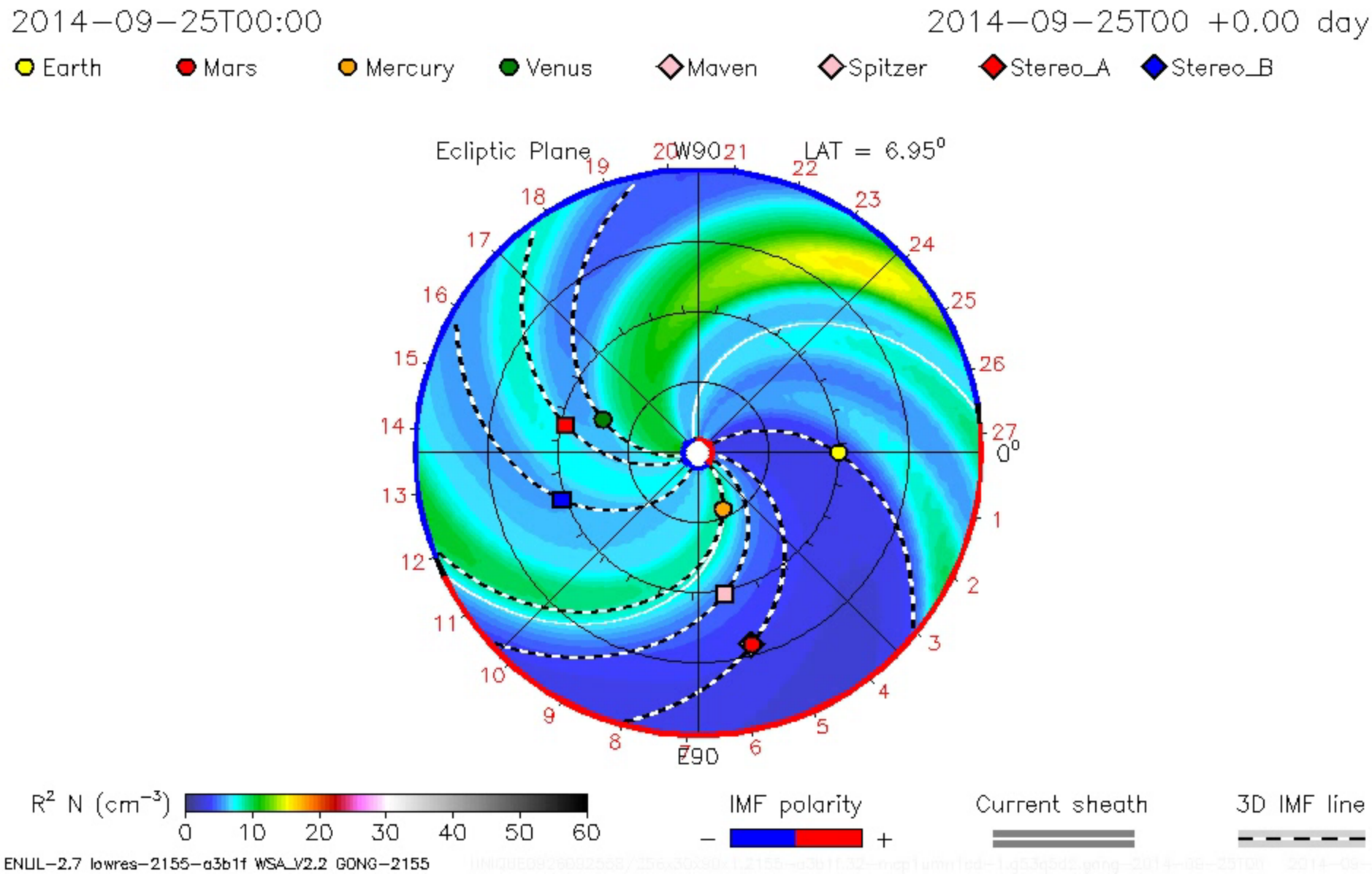


- On Mars, ozone is primarily destroyed by the combined action of water vapor and sunlight. The cold, dark conditions near the pole allow ozone to accumulate there.

First SEP Event Observed at Mars by MAVEN

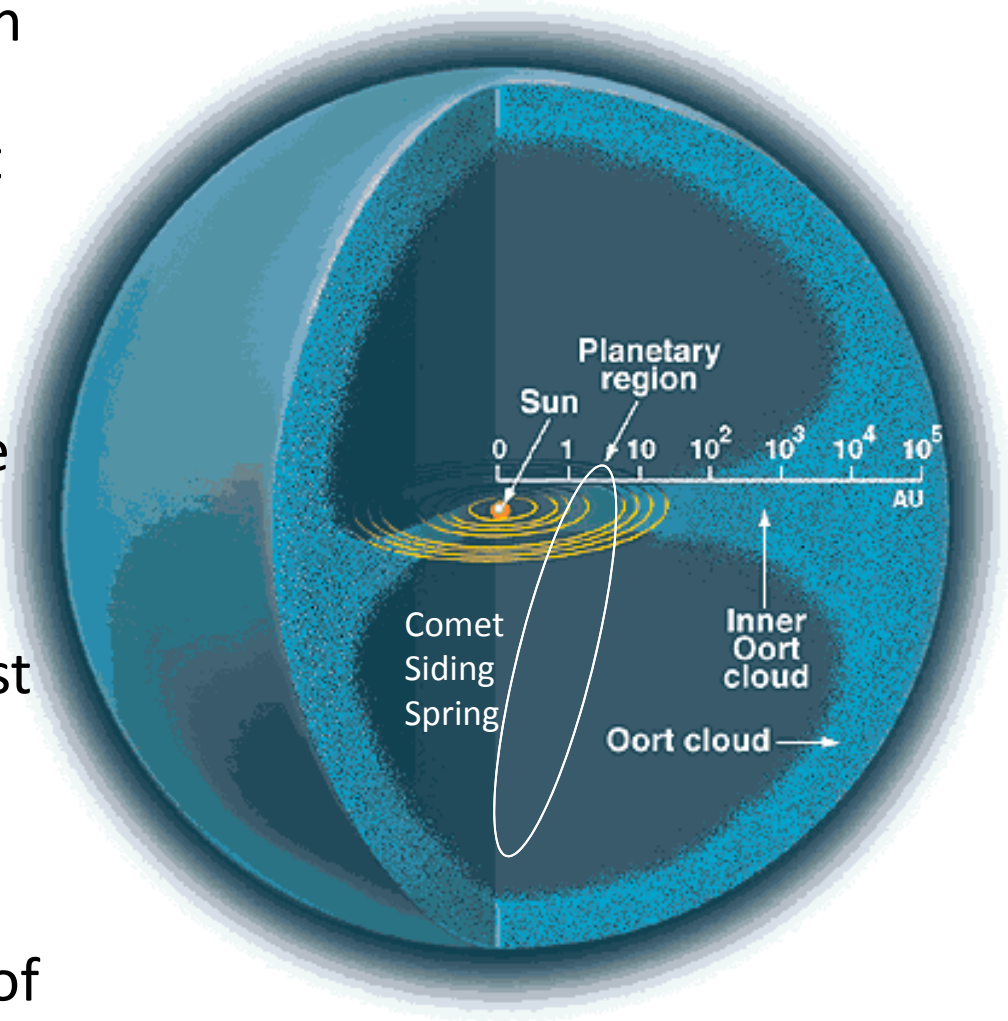





2014-09-25T00:00
2014-09-25T00 +0.00 day
Earth
Mars
Mercury
Venus
Maven
Spitzer
Stereo_A
Stereo_B
Ecliptic Plane
LAT = 6.95°
W90
E90
0°
R² N (cm⁻³)
0 10 20 30 40 50 60
IMF polarity
Current sheath
3D IMF line
ENLIL-2.7 lowres-2155-a3b1f WSA_V2.2 GONG-2155

Overview of Siding Spring

- C/2013 A1 (Siding Spring) is an Oort cloud comet discovered on January 3, 2013, by Robert McNaught at Siding Spring Observatory at 7.2 AU
- Comet C/2013 A1 probably took millions of years to come from the Oort cloud and will return
- It is believed that this is its first passage by the Sun
- On October 19, 2014, passed within 130,000 km from Mars
- Mars will be in the coma/tail of the comet

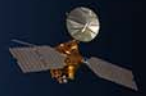


How NASA Assets Observed
COMET SIDING SPRING

Closest Approach to Mars on October 19, 2014

BOPPS, a sub-orbital balloon, observed the comet in September 2014

NASA's Infrared Telescope Facility observed the comet in Jan., Sept. and observed Mars in Oct. 2014



Mars Reconnaissance Orbiter observed the comet in October 2014

Mars Odyssey observed the comet in October 2014

ESA's Mars Express observed the comet and Mars in October 2014

MAVEN observed the comet and Mars in October 2014**

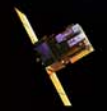
Opportunity Rover observed the comet in October 2014

Curiosity Rover made observations in October 2014

Hubble observed the comet in Oct. 2013 and Jan/Mar 2014,* and observed the comet and Mars in October 2014

Swift observed the comet multiple times since November 2013

STEREO detects the comet in its observations



SOHO detects the comet in its observations

NeoWISE observed the comet in January, July and September 2014

Spitzer observed the comet in March and October 2014

Kepler observed the comet in October 2014

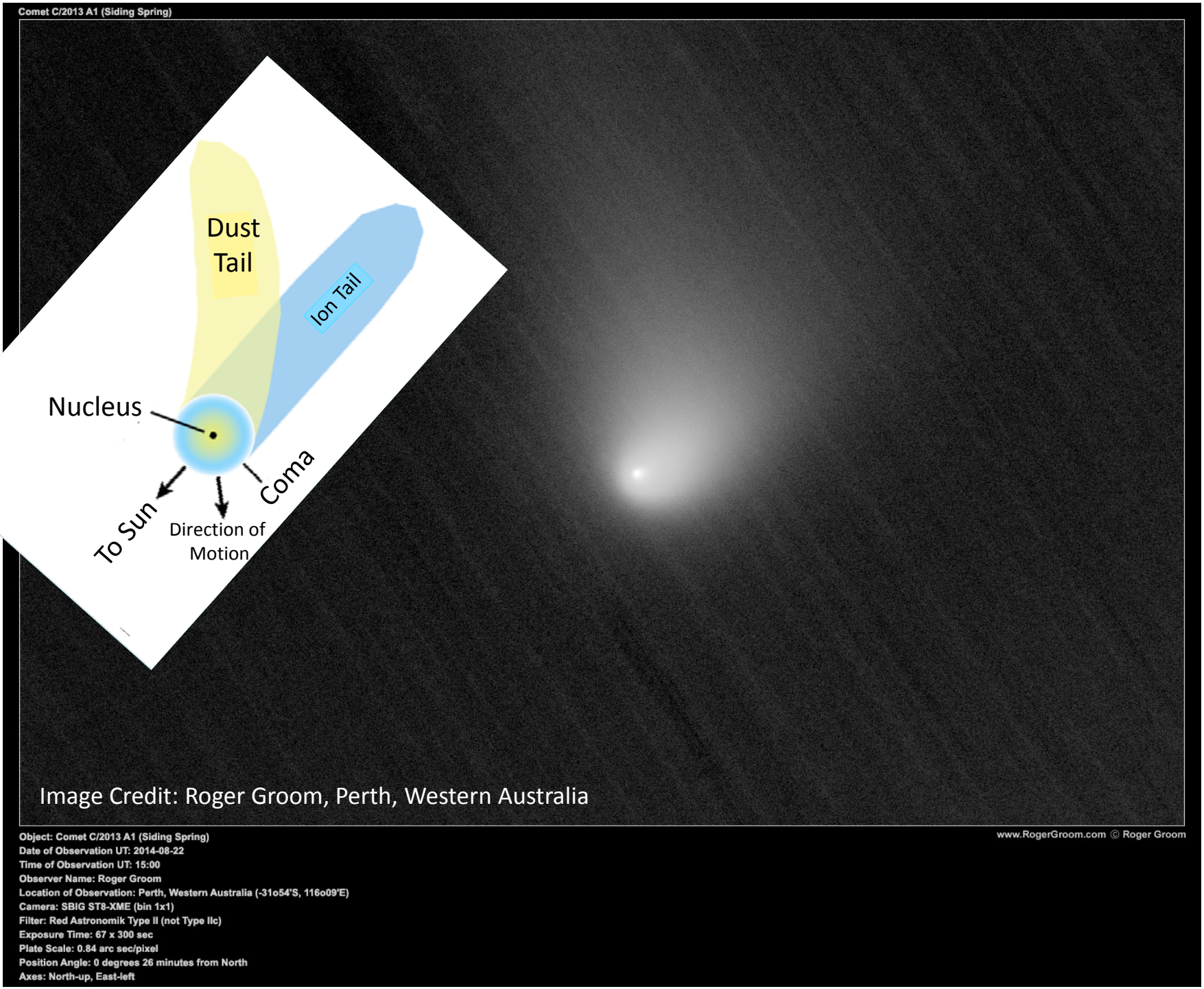
Chandra observed the comet in October 2014

*Comet Image shown was processed by Hubble on March 11, 2014

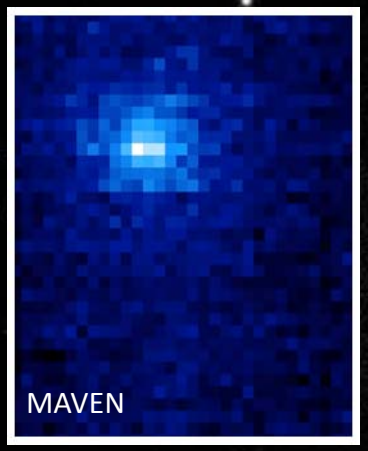
**India's Mars Orbiter Mission obtained orbit 09/24/14

http://mars.nasa.gov/comets/sidingspring
http://cometcampaign.org

#JOURNEYTOMARS


Comet C/2013 A1 (Siding Spring)
Dust Tail
Ion Tail
Nucleus
Coma
To Sun
Direction of Motion
Image Credit: Roger Groom, Perth, Western Australia
Object: Comet C/2013 A1 (Siding Spring)
Date of Observation UT: 2014-08-22
Time of Observation UT: 15:00
Observer Name: Roger Groom
Location of Observation: Perth, Western Australia (-31o54'S, 116o09'E)
Camera: SBIG ST8-XME (bin 1x1)
Filter: Red Astronomik Type II (not Type IIc)
Exposure Time: 67 x 300 sec
Plate Scale: 0.84 arc sec/pixel
Position Angle: 0 degrees 26 minutes from North
Axes: North-up, East-left
www.RogerGroom.com © Roger Groom

First Released Images of Comet Siding Spring Encounter from NASA's Mars and Space Assets

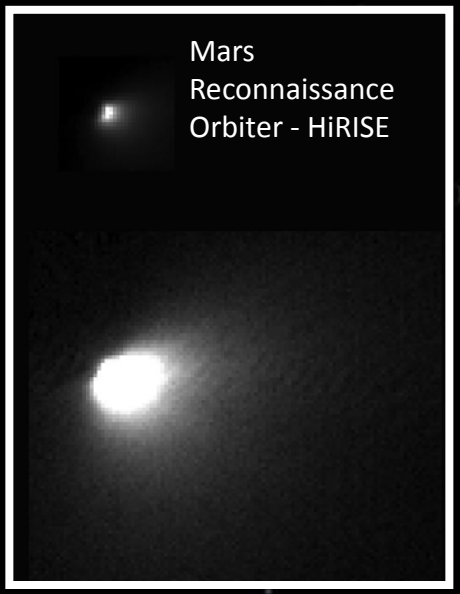


Comet C/2013 A1 Siding Spring made a close approach to Mars on October 19, 2014.

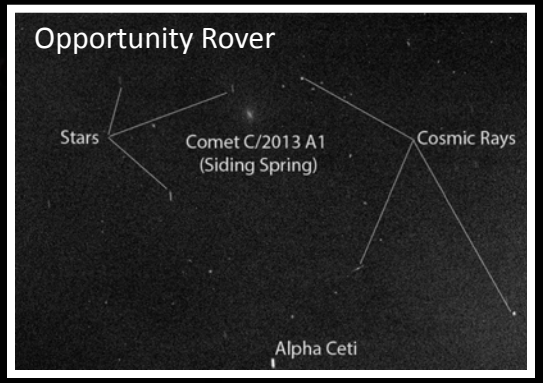
NASA Mars spacecraft took advantage of a unique and unexpected science opportunity for close study of a visitor from the edge of the solar system, along with possible effects on Mars' atmosphere.

Early results probe the size and properties of the comet's nucleus and the properties of dust and gas in the comet's coma. Comet material also blanketed most of the northern hemisphere of Mars.

NASA space observatories that orbit the Earth also observed the comet and Mars during the close encounter.



Hubble Space Telescope composite image



Science Observations - *Preliminary*

NASA Missions

Target	Observation Objective	MRO						ODY		ROVERS		MAVEN[1]		
		HiRISE	CTX	CRISM	MCS	MARCI	SHARAD	THEMIS VIS & IR	HEND/NS	PANCAM	MastCAM CHEMCAM?	IUVS	LPW,MAG, SEP	NGIMS,STATIC SWEA,SWIA
Comet	Comet General Features					❖		❖		◆	◆	◆	◆	
	Comet Nucleus: Size, Shape & Rotation	◆												
	Comet Activity: Jets & Variable Brightness	◆	◆	❖				❖				◆		
	Comet Coma: Variability, particle size, gas composition	◆	❖	◆	◆	◆		◆				◆		
	Comet Tail: Particle Size		◆	❖	❖	❖		❖				◆	◆	
Mars Response	Mars Upper Atmosphere Composition: Neutrals, ions & electrons; meteor trails						❖		❖	◆	◆	◆	◆	◆
	Mars Lower Atmosphere: Temperature and Clouds			❖		❖		❖		❖	❖	❖		

Key: major contribution ◆ contribution ❖

[1]*Conducted only if transition to science orbit is nominal*

Questions?

BACKUP

NASA Contribution to ESA's Rosetta Mission

1. 3 instruments plus a significant portion of the electronics package for another (MIRO, ALICE, IES, and ROSINA DFMS Electronics)
2. 3 Principal Investigators, Interdisciplinary Scientist
3. 40 Co-Investigators and researchers
4. Deep Space Network 70 meter and 34 meter support
5. Scheduling software for science observations
6. Multi-mission Ephemeris Support tool
7. Comet modeling
8. Shadow navigation for flight dynamics verification
9. Outreach and media products
10. Support for ESA's Amateur Ground Observing Campaign

NASA Hardware Contribution

ALICE (an ultraviolet imaging spectrometer) will map the comet's nucleus for pockets of both dust and ice – Alan Stern, SWRI

MIRO (Microwave Instrument for the Rosetta Orbiter) will remotely examine the vicinity for signs of water coming off the nucleus and will construct temperature maps – Sam Gulkis, JPL

IES (Ion and Electron Sensor) will look for examples of direct interaction between the solar wind and the nucleus – James Burch, SWRI

ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) will identify gases sublimating from the comet. NASA is providing ROSINA's DFMS (Double Focusing Mass Spectrometer) Electronics – Stephen Fuselier, SWRI

NASA Participation in the Rosetta Payload

Orbiter Teams

1. ALICE - UV spectrometer
2. CONSERT – tomography/radio sounding
3. COSIMA – chemistry
4. GIADA – dust analysis
5. IES - ion and electron sensor
6. ICA – plasma analyzer
7. MAG – magnetometer
8. MIDAS – atomic force microscope (dust particles)
9. MIP – magnetic impedance probe
10. MIRO - microwave spectrometer / radiometer
11. LAP – Langmuir probe
12. OSIRIS – camera
13. ROSINA – mass spectrometer
14. RSI – radio science
15. VIRTIS – IR spectrometer

Lander Teams

16. APXS – X-ray spectrometer
17. CIVA -lander visible - IR camera (omnidirectional)
18. COSAC – lander mass spectrometer
19. MODULUS – gas analyzer
20. MUPUS – probe
21. ROLIS – lander descent camera
22. ROMAP – lander magnetometer/material magnetism
23. SESAME – seismic data
24. CONSERT (2) – tomography/radio sounding
25. SD2 – drill
26. PTOLEMY – gas analyzer

Legend:
NASA hardware contribution
NASA investigator participation