NASA's Planetary Science Program Overview

James L. Green, Director
Planetary Science
September 4, 2013

Outline

- Planetary Budget
- Upcoming Planetary Events
- Outreach Activities
- Planetary Missions Status
- Campaign Science
- NASA’s Asteroid Initiative
- Radioisotope Power Systems & DoE

President's FY14 Planetary Science Budget Plus an Approved FY13 Budget

* Notional

Planetary Science Division	FY 2012	FY 2013	FY 2014	FY 2015 *	FY 2016	FY 2017	FY 2018
Planetary Research	$174,087	$192,672	$220,600	$233,300	$229,100	$230,400	$232,200
Lunar Quest	$139,972	$71,845	$17,700	$0	$0	$0	
Discovery	$172,637	$207,414	$257,900	$268,200	$242,300	$187,500	$215,000
New Frontiers	$143,749	$158,770	$257,500	$297,200	$266,500	$151,000	$126,200
Mars Exploration	$587,041	$369,529	$234,000	$227,700	$318,400	$504,700	$513,200
Technology	$161,899	$123,434	$150,900	$142,800	$144,700	$154,400	$140,000
Outer Planets	$122,054	$147,836	$79,000	$45,600	$24,400	$26,400	$26,000
	$1,501,439	**$1,271,500**	**$1,217,600**	**$1,214,800**	**$1,225,400**	**$1,254,400**	**$1,252,600**

- President's FY14 budget contains:
  - NEO observations enhancement of $20M/yr ($40M/yr total)
  - $50M/yr support of DoE PU-238 infrastructure support

Planetary Science Missions and Outreach Events

* Completed

2013

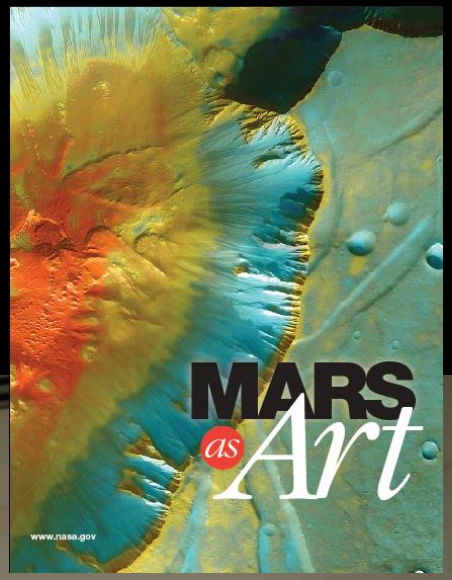
May – November – *Mars As Art* Exhibit at Dulles Airport Gallery
July 19 – Wave at Saturn and MESSENGER's Earth image from Mercury
July 31 – Curiosity Day on the Hill
August 6 – One Year Anniversary of Curiosity Landing on Mars
September 6 – LADEE launch from Wallops Flight Facility, VA
October 1 – Close approach of Comet ISON to Mars – *Campaign Science*
October 9 – Juno flyby of Earth
November 4 – VESPER rocket launch observing Venus
November 18 - Launch of MAVEN from Cape Canaveral, FL
November 28 – Comet ISON Perihelion. Brightest view from Earth of Comet ISON

2014

January – EXCEED-HST observations of Io – *Campaign Science*
August – Rosetta arrive at Comet Churyumov–Gerasimenko
October 19 – Comet Siding Spring encounters Mars

Outreach Activities

Mars as Art at Dulles Gateway Gallery Until November 2013



Recent Mars Events

Curiosity
1st Anniversary

Intrepid Spacefest
NYC, July 25-28, 2013

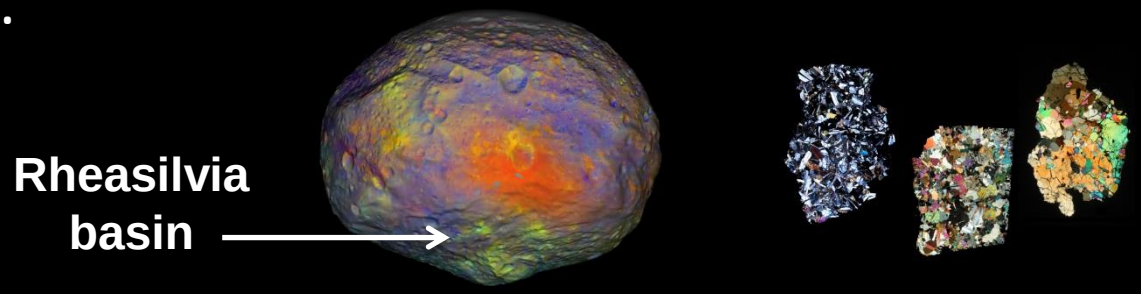
NASM – Mars Day
July 26, 2013

Bennu Naming Contest

- More than 8,000 students, all younger than 18, from more than 25 countries worldwide entered the "Name that Asteroid!" contest last year. Each contestant submitted one name with a maximum of 16 characters and a short explanation for the name.
- Winner was nine-year-old Michael Puzio who suggested the name Bennu, which Egyptians usually depicted as a gray heron, because it means "the ascending one," or "to shine.“
- “It’s great!” Puzio said when told he won the contest. "I'm the first kid I know that named part of the solar system!"

Meteorite from Asteroid Vesta
Presented to White House – June 18, 2013

- **Meteorite specimen is a fine-grained basaltic rock that is from Asteroid Vesta, based on the similarity of the infrared spectrum between eucrites and parts of Vesta.**



- **Presentation item given to White House Official – June 18, 2013**
- **Meteorite was found in Antarctica's Grosvenor Mountains (GRO) on December 17, 1995 in the Transantarctic Mountains. Sample is named GRO 95533.**
- **It likely crystallized from a magma in the early history of the solar system (4.55 billion years ago), and then experienced heating from an impact 3.5 billion years ago that caused recrystallization of the original igneous texture**
- **That impact likely formed the giant Rheasilvia basin on Vesta's South Pole, perhaps 1 billion years ago.**

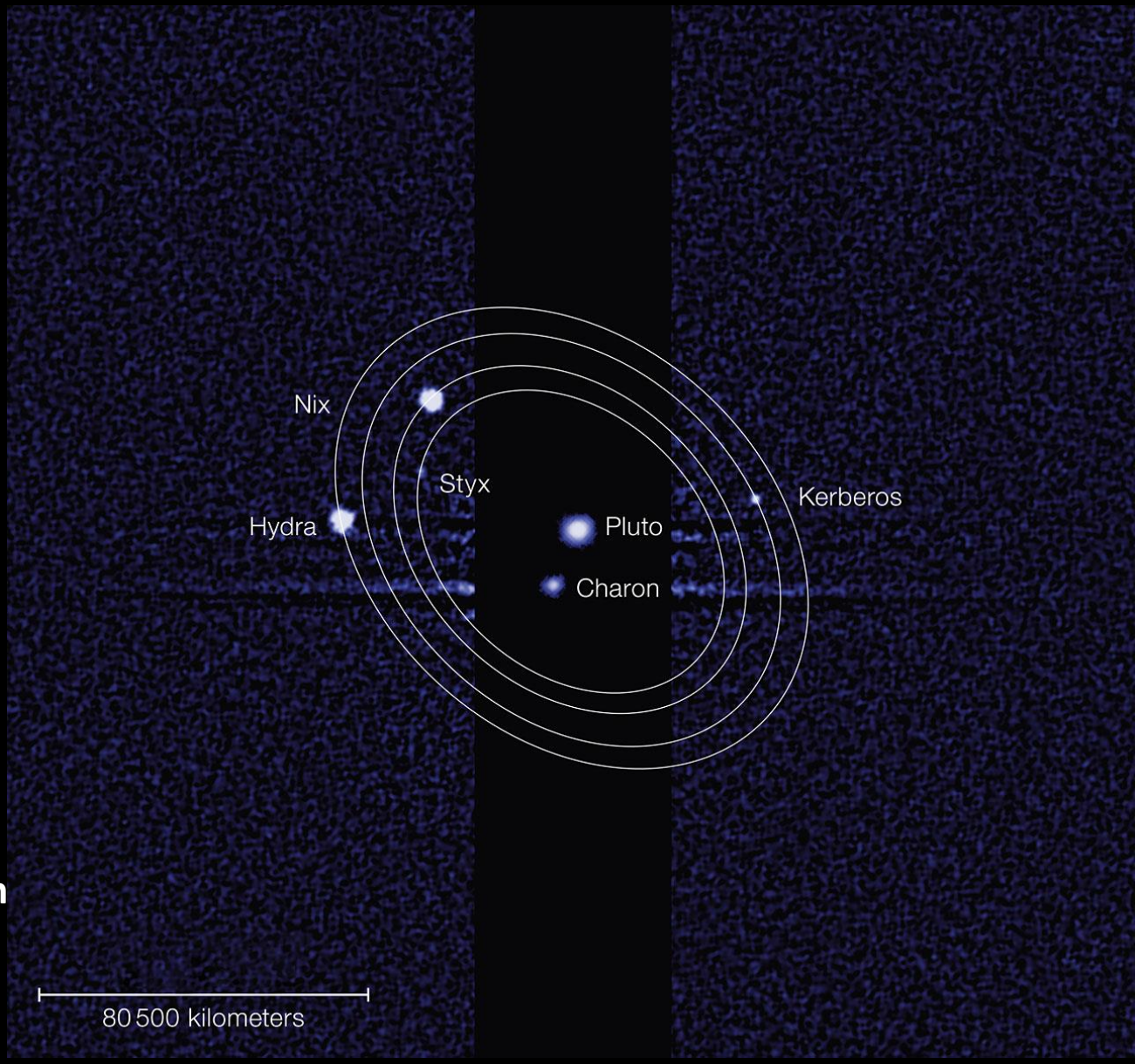
Pluto's Two New Moons Named

Over 500,000 participated in the naming of the new moons P4 & P5, worldwide, in an online contest

Pluto, named after the Roman god of the underworld who had the ability to make himself invisible, remains high in popular culture

Now a total of five moons have been found.

More to find? New Horizons flies through Pluto system on July 14, 2015.



Webbys
Planetary Science Won Four!

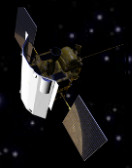
Planetary Science's website
http://solarsystem.nasa.gov
won two Webbys

Curiosity's social media site also
Won two awards

Two Views of Our Home Planet

On July 19th, NASA spacecraft took pictures of Earth from two separate planets, on the same day!
This photo op was brought to us by the MESSENGER spacecraft at Mercury and Cassini spacecraft at Saturn

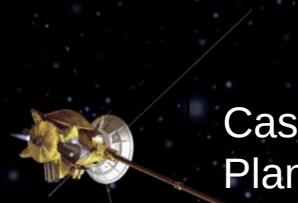
Mercury



MESSENGER imaged our Home Planet on July 19, 2013

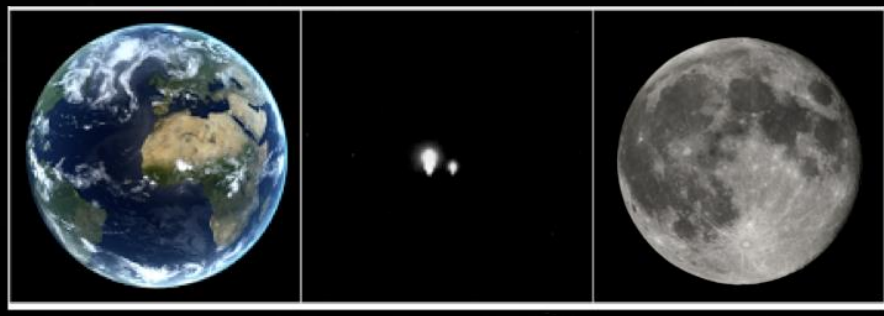
Bonus!

44 Years after Neil Armstrong's first footprints, MESSENGER imaged our Moon on July 20, 2013



Cassini imaged our Home Planet on July 19, 2013

Saturn



View from Saturn (Cassini)
900 million miles away

View from Mercury (MESSENGER)
61 million miles away

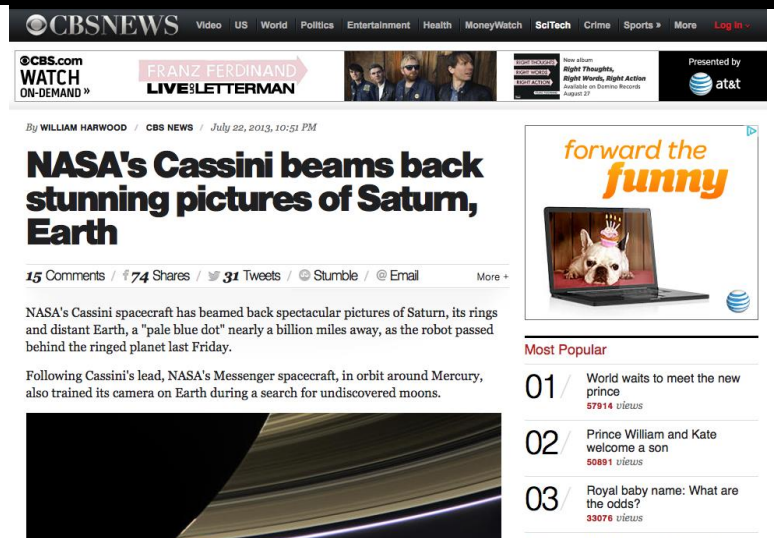
Cassini site on the NASA portal had 236,000 unique page views;
Cassini's Saturn page (saturn.jpl.nasa.gov) had 265,000 unique visitors.
Over 20 countries participated in the Campaign

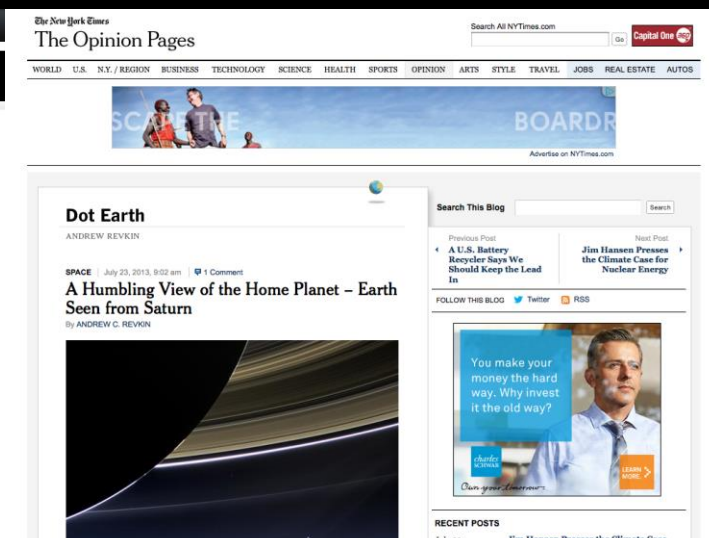
SCI

SCIENCE CENTER OF IOWA & BLANK IMAX® DOME THEATER

Wave at Saturn Media Response

- Coverage before, during and after the event
- International, national and local coverage because outlets could find local groups holding *Wave at Saturn* events





Planetary Missions Status

Lunar Atmosphere and Dust Environment Explorer

Objective:

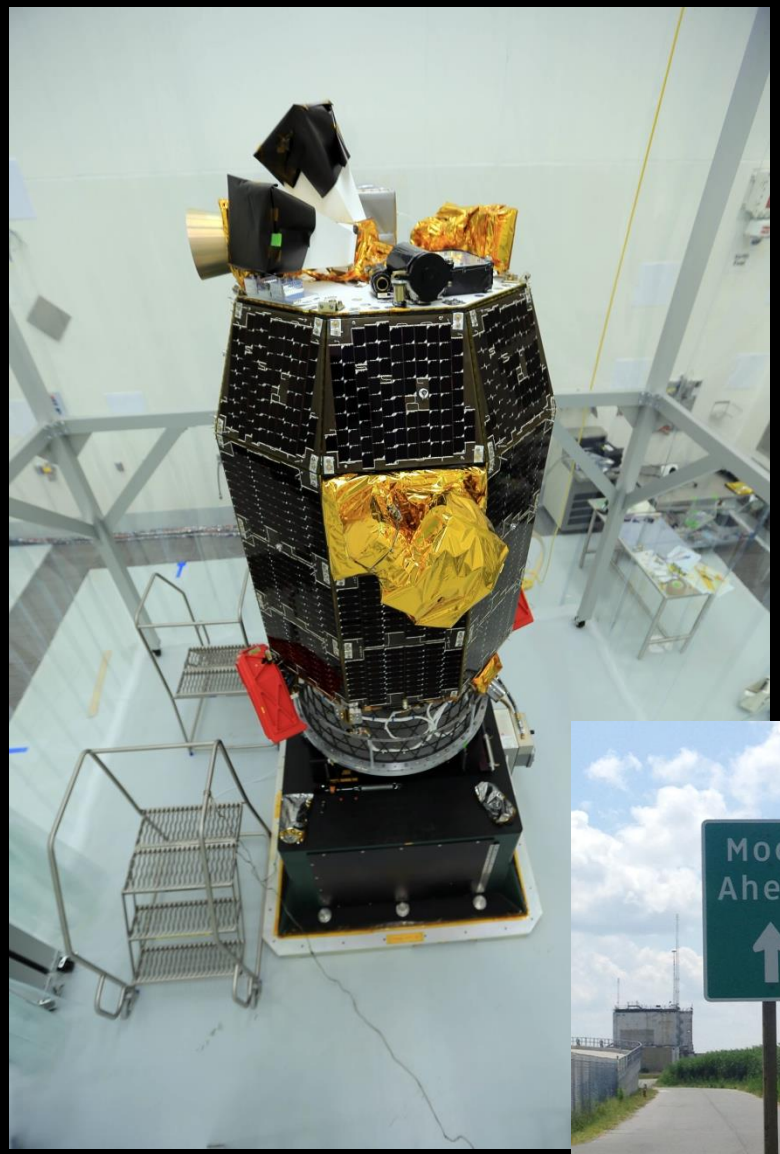
- Measure the lofted Lunar dust
- Composition of the thin Lunar atmosphere

Instruments:

- Science: NMS, UVS, and LDEX
- Technology: Laser Communications

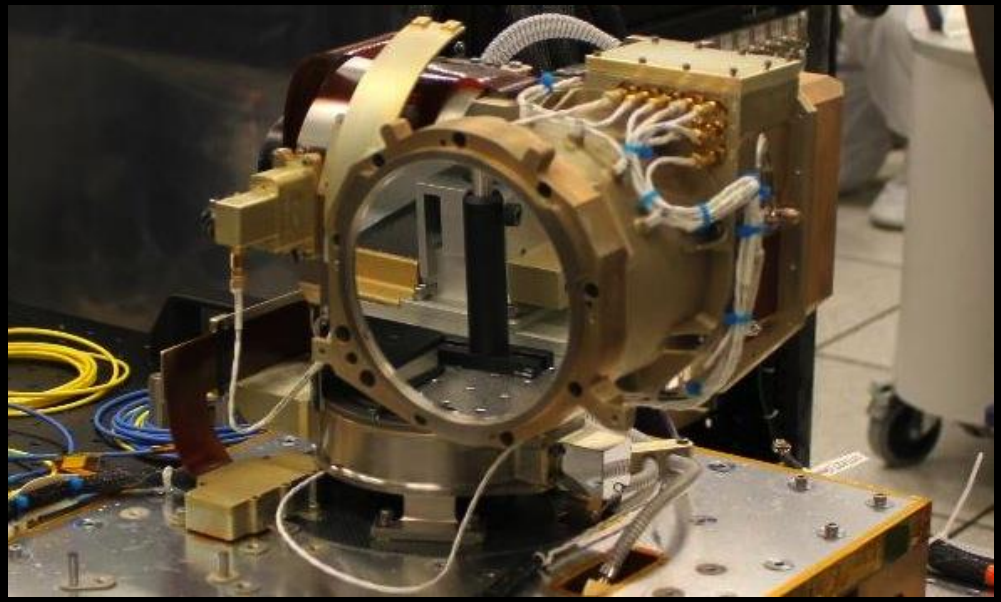
Launch: Sept. 6, 2013 Wallops Flight Facility

LADEE PAF & MLB Mated to Observatory



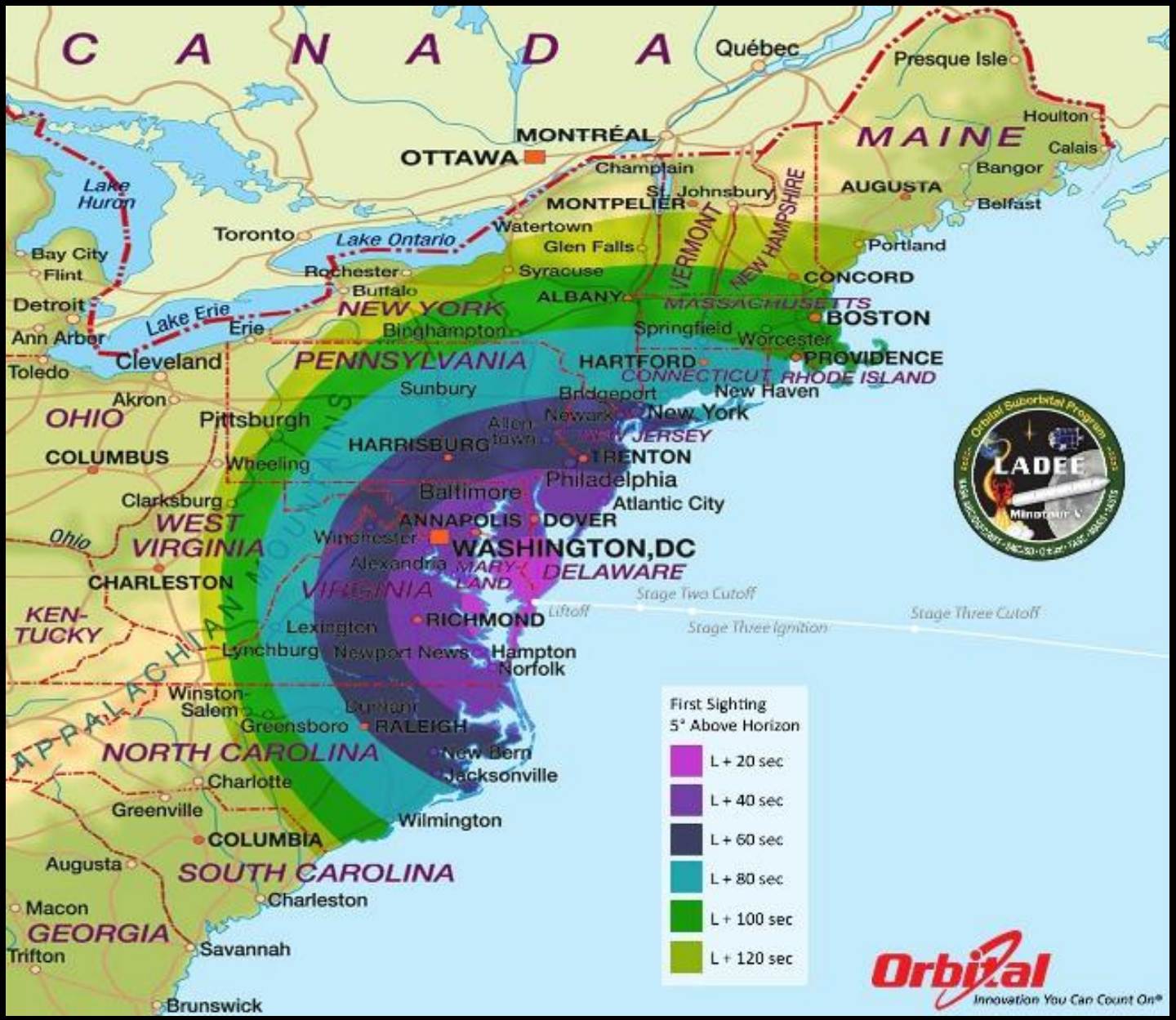
LADEE - A Mission of Firsts

- First Moon launch from WFF
- First launch of Minotaur V rocket
- First demo of Laser Communications
- First mission designed and built by Ames

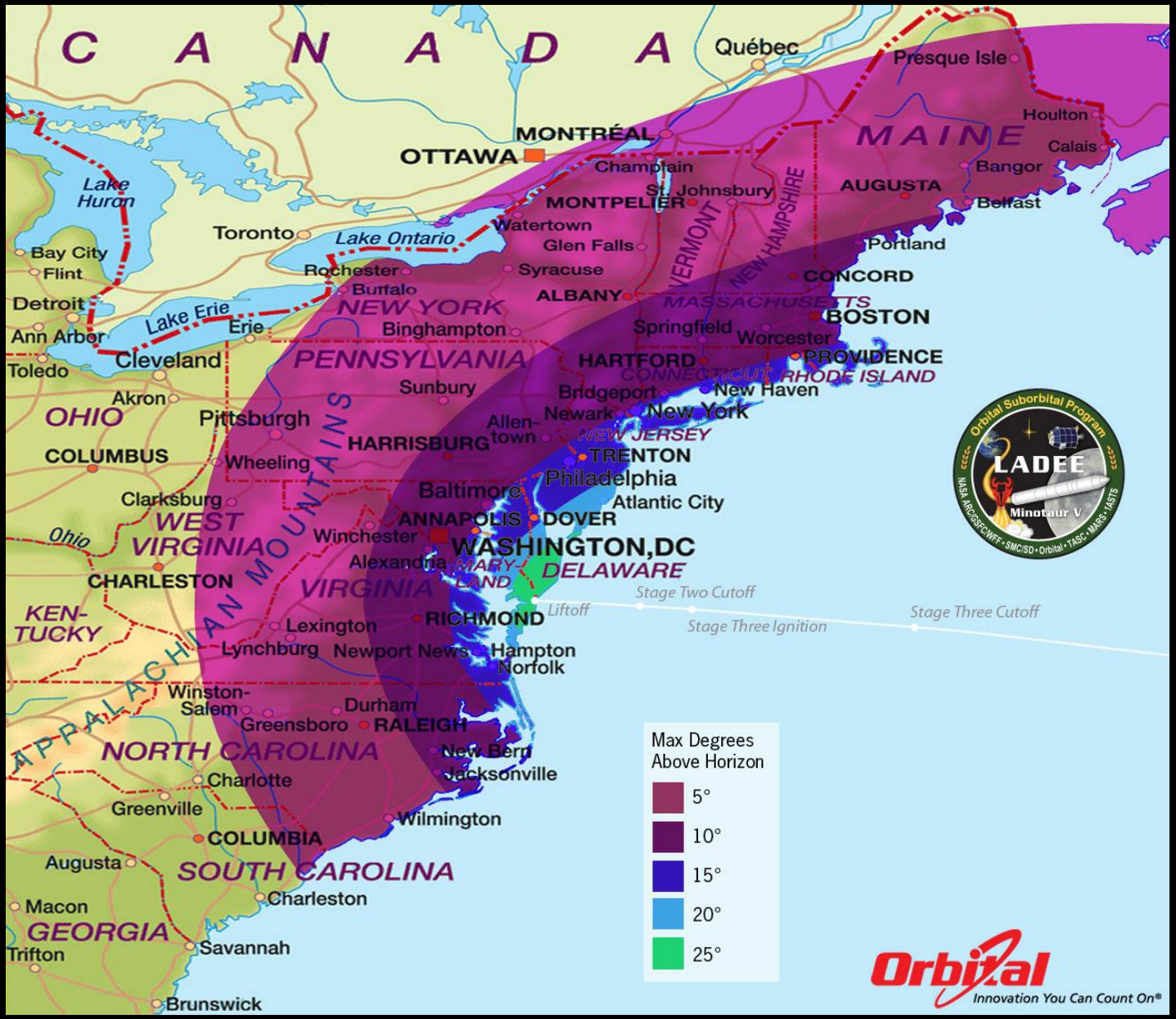


LLCD (Lunar Laser Communications Demonstration) will demonstrate transferring data at a rate of 622 megabits per second, which is about five times the current state-of-the-art from lunar distances.

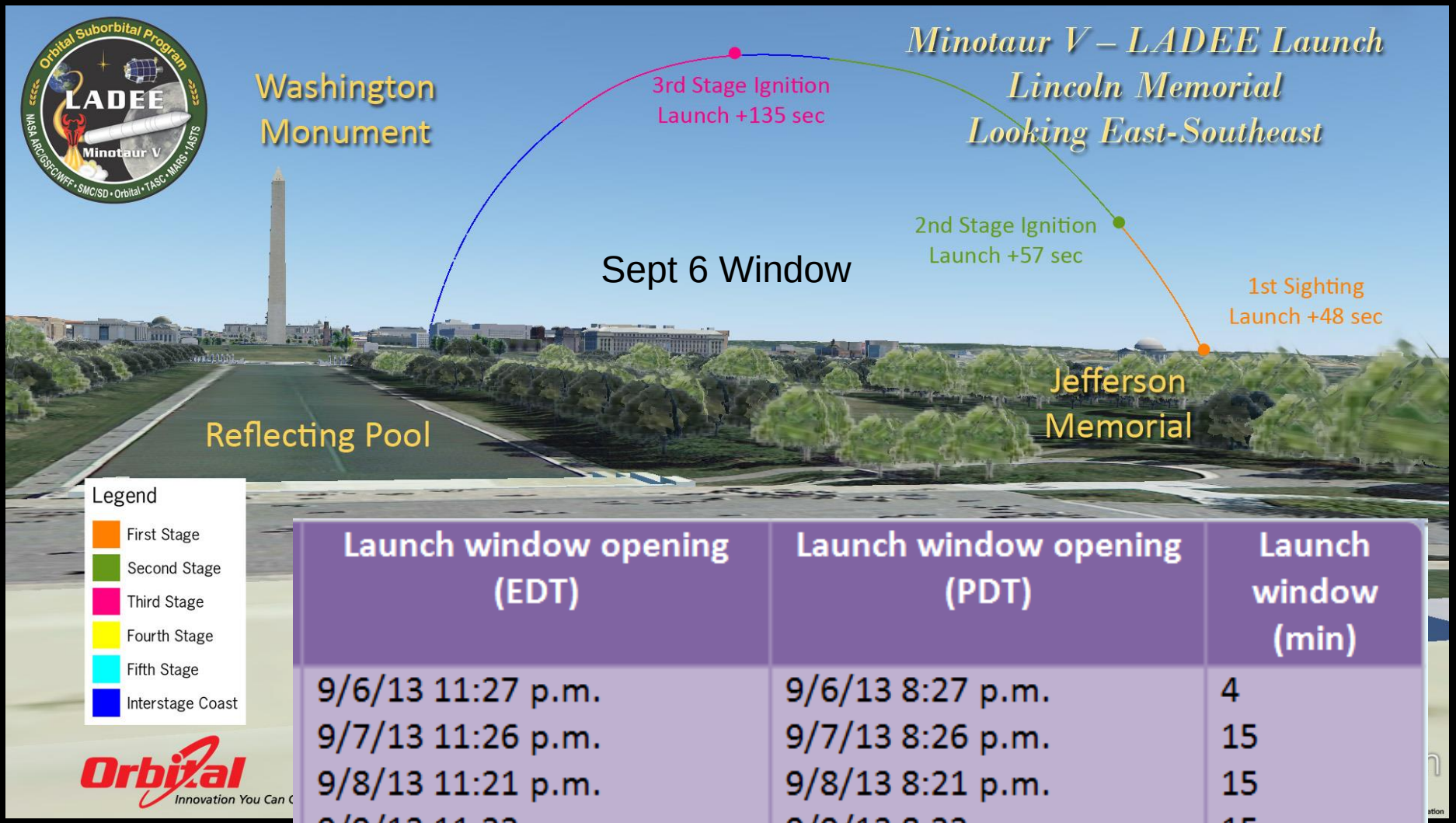
Viewing of the Launch (1/3)



Viewing of the Launch (2/3)



Viewing of the Launch (3/3)



Launch window opening (EDT)	Launch window opening (PDT)	Launch window (min)
9/6/13 11:27 p.m.	9/6/13 8:27 p.m.	4
9/7/13 11:26 p.m.	9/7/13 8:26 p.m.	15
9/8/13 11:21 p.m.	9/8/13 8:21 p.m.	15
9/9/13 11:22 p.m.	9/9/13 8:22 p.m.	15
9/10/13 11:22 p.m.	9/10/13 8:22 p.m.	7

Greet Juno Before It Heads to Jupiter

- Instrument on: Adv. Stellar camera, Juno Cam, Waves
- Shared Amateur/Professional views of the spacecraft, South Africa plus N. Hemisphere that night
- Photo from ISS astronaut crew, if geometry favorable
- Press plans are in place – Pre & Post; Google+hangout

MAVEN

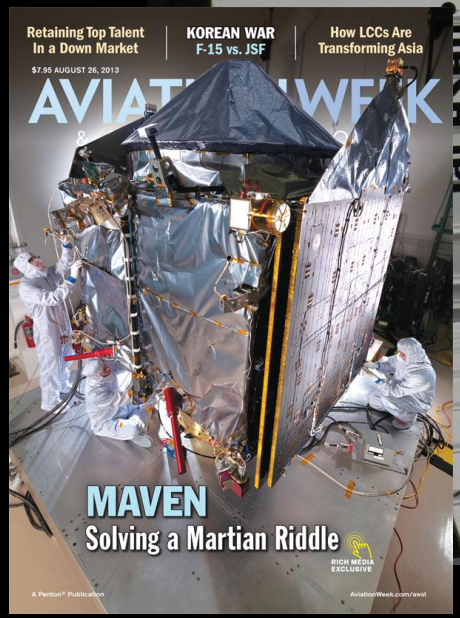
Launch November 18, 2013, from Cape Canaveral on an Atlas V

Mars orbit insertion in Sept. 2014

Science:

- 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

Atlas V Payload Fairing for MAVEN



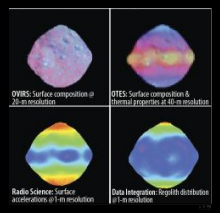
OSIRIS-Rex - Asteroid Sample Return Mission

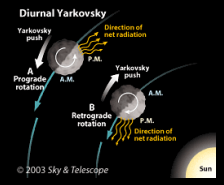
Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer

Bennu

Science Objectives

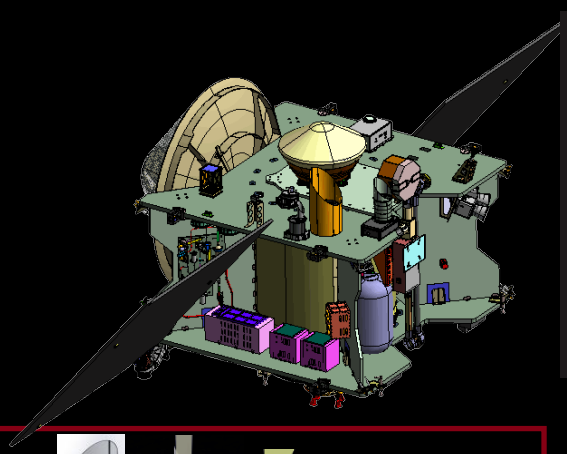
- **Return and Analyze a Sample**
- Create Maps of the Asteroid
- Document the Sample Site
- Measure the Orbit Deviations
- Compare to Telescope-based Observations

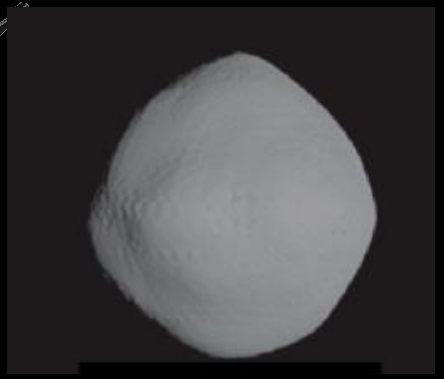




Mission Overview

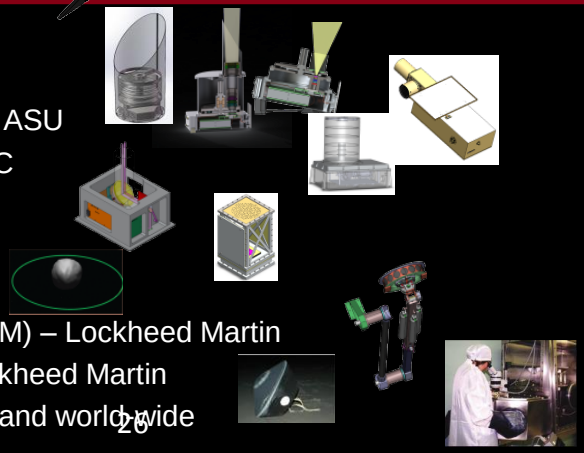
- Principal Investigator: Dr. Dante Lauretta, UA
- Launch in September 2016
- Encounter asteroid Bennu in August 2018
- Study Bennu for up to 505 days
- Obtain at least 60 g of pristine regolith/surface material
- Return sample to Earth in September 2023
- Deliver samples to JSC curation facility



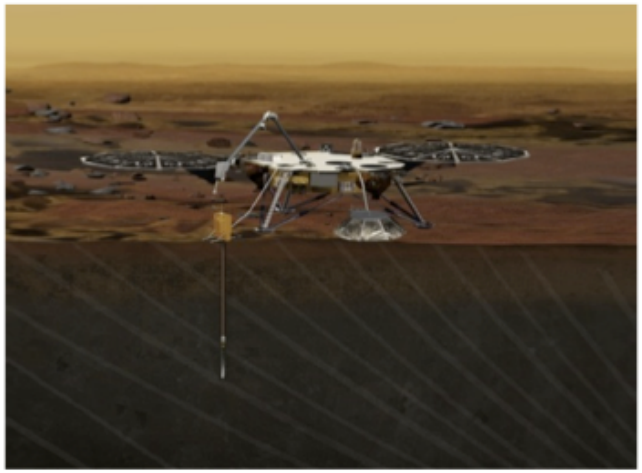


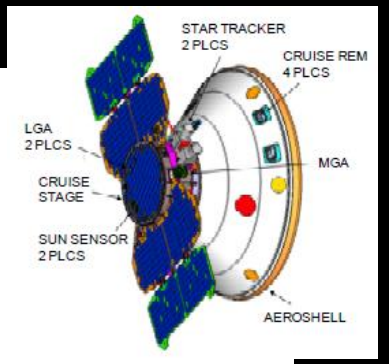
Science Instrumentation and Key Capabilities

- OSIRIS-REx Camera Suite (OCAMS) – UA
- OSIRIS-REx Thermal Emission Spectrometer (OTES) – ASU
- OSIRIS-REx Visible & IR Spectrometer (OVIRS) – GSFC
- OSIRIS-REx Laser Altimeter (OLA) – CSA
- Regolith X-ray Imaging Spectrometer (REXIS) – MIT
- Spacecraft Telecom/Radio Science
- Touch-And-Go Sample Acquisition Mechanism (TAGSAM) – Lockheed Martin
- Sample Return Capsule (SRC, Stardust Heritage) – Lockheed Martin
- Sample Curation and Laboratory Analysis – NASA/JSC and worldwide



InSight: Interior Structure from Seismic Investigations, Geodesy and Heat Transport



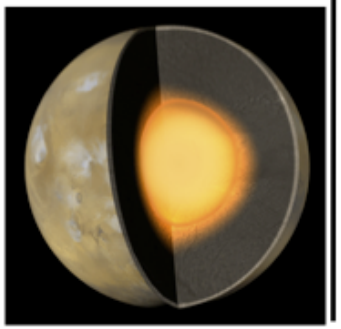


Mission & Science Team:
PI: Bruce Banerdt, JPL
PM: Tom Hoffman, JPL
Deputy PI: Sue Smrekar, JPL
Management: JPL
Spacecraft: Lockheed-Martin
Operations: JPL/LM
Payload: CNES (France), DLR (Ger.), JPL

Mission:
- Geophysical lander mission on Mars using Phoenix heritage spacecraft

Goals:
- Understand formation/evolution of terrestrial planets via interior structure/processes of Mars
- Determine present tectonic activity and meteorite impact rate

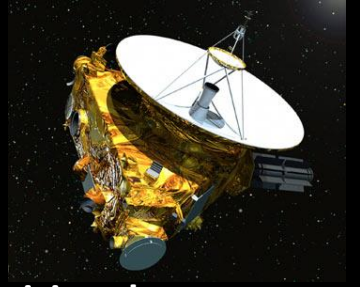
Payload:
- Seismic Experiment for Interior Structure (SEIS)
- Rotation & Interior Structure Experiment (RISE)
- Heat Flow & Physical Properties Probe (HP^3)
- Instrument Deployment System



Mission Details:
- Flight: 3/2016 launch w/ELV, 4m fairing; 9/2016 landing; ~6.5 mo cruise, 1 Mars yr surface ops
- System Features (Phoenix-based design): Phoenix EDL architecture, solar power, UHF relay comm with X-band backup, updated RAD 750-based avionics
- Mass: 597.6kg dry launch, margin ≥31% (depending on ELV)
- Schedule: 43.5 mo B/C/D, 105 days sched. reserve
- Threshold Mission: Descope: HP^3, SEIS SP sensors

New Horizons

Pluto Fly-by Flight Rehearsal (July 5-14, 2013)



- **The flight rehearsal was successful, thoroughly testing the command sequence, exercising the team, and practicing the procedures that will be used in 2015**
- **The command sequence executed from start to finish without a glitch**
  - All subsystems and instruments performed nominally
  - All instruments collected the correct type and amount of data
  - Inserting a time shift had no adverse effects on the system, although one measurement might not have been downlinked as a result of the shift. (This is under investigation…)
- **The extensive DSN support was very good and ground systems were nominal**
  - All three DSN complexes were used repeatedly throughout the rehearsal
  - Aside from occasional drop-outs and one contact that began with a misconfiguration (which was quickly remedied), the support was very good
  - The MOC and SOC both processed all data without delay or data corruption
- **Lessons learned are being collected and will be compiled**
  - Data will be downlinked for another few weeks, and will be examined as it becomes available to confirm detailed pointing, etc.
  - A Flight Rehearsal Lessons Learned Review is scheduled for September 3 at APL

The Venus Spectral Rocket Experiment (VeSpR)

NASA's next Venus flight mission

Scheduled Launch:	**November 4, 2013**
Launch Site:	White Sands Missile Range, New Mexico
Mission Number:	36.261
Principle Investigator:	John Clarke (Boston University) jclarke@bu.edu 617-353-0247

Purpose: To study the present day escape of water from the atmosphere of Venus and relate it to the past abundance of water on Venus

Mariner 10 Image of Venus

Seeking Signs of Past Life

2020 Mars Rover Science Definition Team
http://mars.jpl.nasa.gov/m2020/

CONDUCT RIGOROUS IN-SITU SCIENCE

GEOLOGICALLY DIVERSE SITE

COORDINATED, NESTED CONTEXT AND FINE-SCALE MEASUREMENTS

ASTROBIOLOGY

ENABLE THE FUTURE

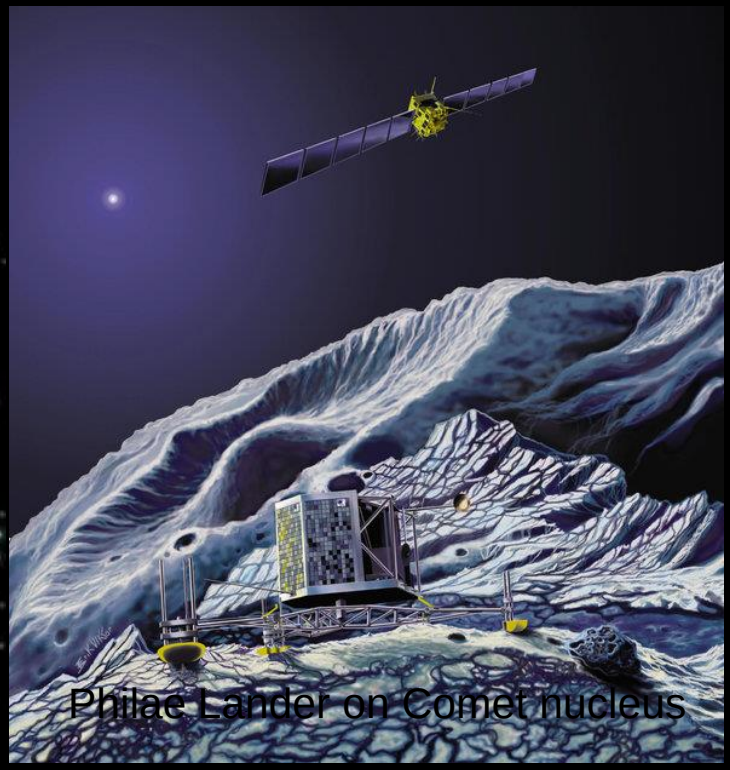
RETURNABLE CACHE OF SAMPLES

CRITICAL IN-SITU RESOURCE UTILIZATION AND TECHNOLOGY DEMONSTRATIONS REQUIRED FOR FUTURE MARS EXPLORATION

- **FBO released August 12, 2013**
- **Working on releasing instrument AO by early October**

MARS SCIENCE LABORATORY HERITAGE ROVER AND MODERATE INSTRUMENT SUITE STAYS WITHIN THE RESOURCE CONSTRAINT

ESA's Rosetta Mission



- Rosetta will arrive at Comet Churyumov–Gerasimenko in Aug 2014 spending 2 years at the Comet
  - Has 11 instruments on the orbiter and 10 on the lander
  - NASA has 3 PI instrument and many CoIs
- Drop off the Philae lander and follow the comet into perihelion
  - Comet CG has an orbital period of 6.45 years

Campaign Science:

Maximize the Science using multiple coordinated observations

ISON - Campaign Science

This is an Oort Cloud Comet – the first in the modern space age!

It is a pristine comet having never visited the Sun

A unique opportunity to make multi-wavelength observations

Key Dates
21 Sep 2012: Discovered
1 Oct 2013: Closest Approach to Mars
28 Nov 2013: Closest Approach to the sun
26 Dec 2013: Closest Approach to Earth? (Only if it survives solar encounter)

ISON Trajectory

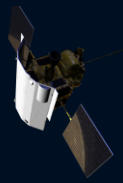
Decadal Survey Questions To Be Addressed

- How does the composition of Oort Cloud comets compare to Kuiper Belt comets?
- What are the chemical routes leading to complex organic molecules in regions of star and planet formation?
- Were there systematic chemical or isotopic gradients in the early solar nebula?
- How did Earth get its water and other volatiles?

Hubble image of ISON, an Oort Cloud comet believed to make its first apparition.

How NASA Space Assets Will Observe Comet ISON

Deep Impact imaged ISON for the first time on January 17 and 18 from 493 million miles away



MESSENGER will be observing ISON as it passes by Mercury on November 19th on its way to the Sun

SOHO will be observing ISON as it passes by the Sun in late November

Hubble observed ISON in April-May and will see it again in October and December (if ISON survives)

STEREO will be observing ISON as it passes by on its way to Sun in late November

Astronauts aboard the International Space Station will be able to observe Comet ISON as it passes by Earth in late November

In January and March, Swift observed ISON when it was 460 million miles away from the Sun

Curiosity will be observing ISON as it passes by Mars. Close approach is October 1st

Opportunity will be observing ISON as it passes by Mars on its way to the Sun on October 1st

In November, Chandra will observe ISON with its X-ray instruments

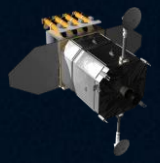
For more information, visit:
http://solarsystem.nasa.gov/ison

Lunar Reconnaissance Orbiter will be observing ISON as it passes by the Moon in late November

BRRISON, a sub-orbital balloon, will be launched mid September to study ISON from above nearly all of the Earth's atmosphere

Spitzer observed ISON on June 13. The comet was 310 miles away from the Sun

FORTIS, a sounding rocket, will be launched in mid-to-late November to obtain ultra-violet spectra from ISON



SDO will have the ability to observe ISON under extreme-ultraviolet light when the comet is closet to the Sun

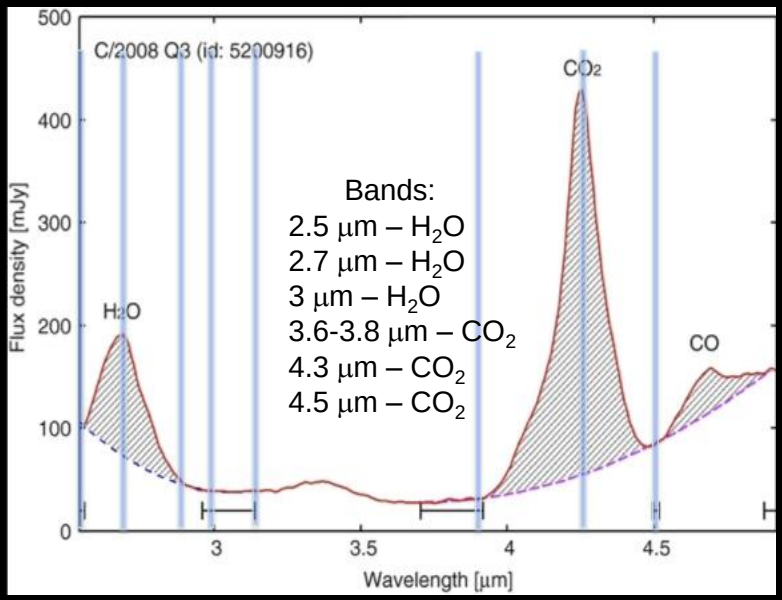
Mars Reconnaissance Orbiter will be observing ISON as it passes by Mars . Close approach is October 1st

BRRISON Overview

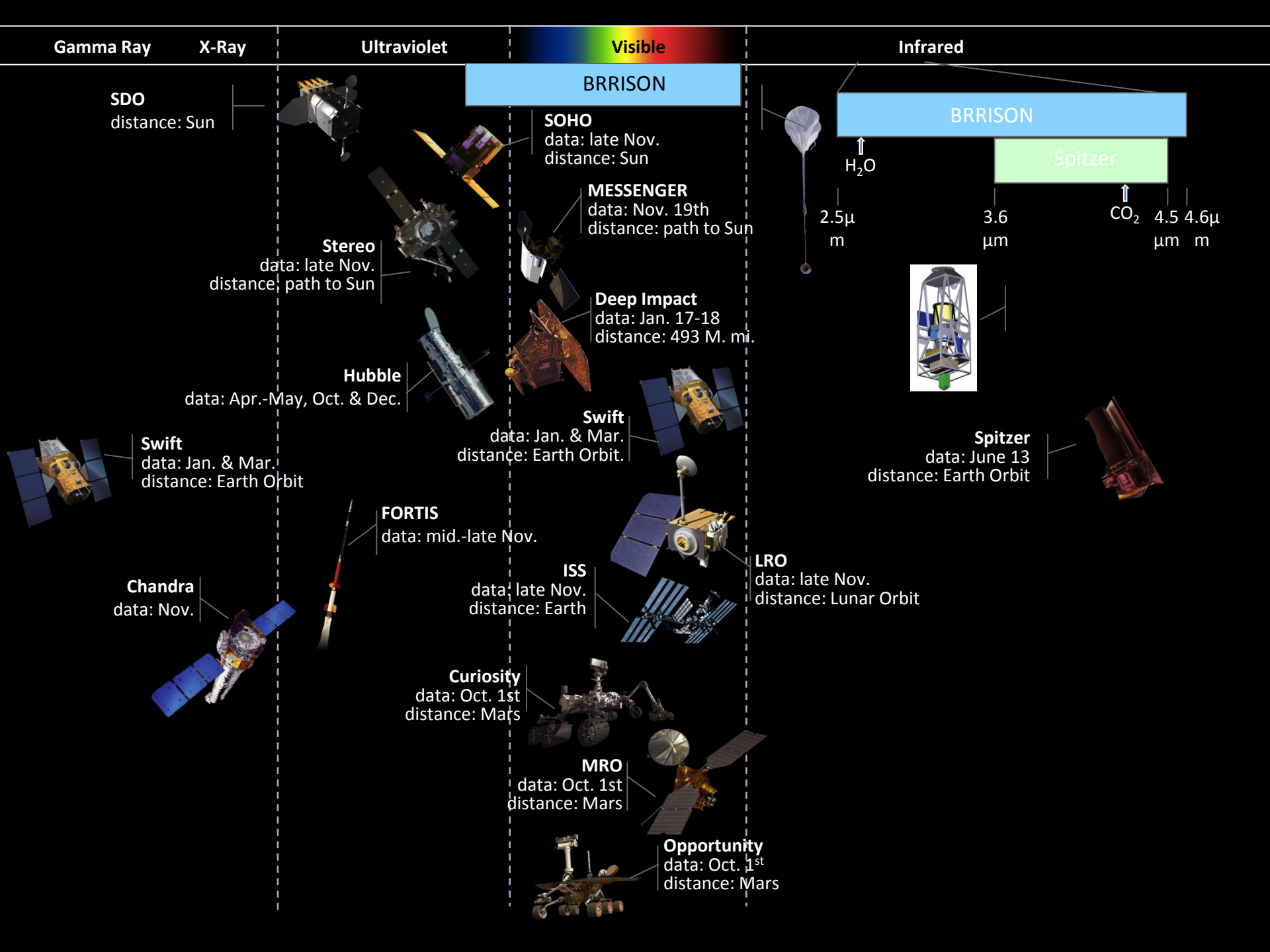
- **Mission**: Gain scientific knowledge of solar system origin by examination of emissions from Oort cloud comet ISON using a balloon-borne telescope with multi-spectral sensitive payload
- **Sponsor: NASA GRC**
  - BRRISON Program Executive: Lindley Johnson (HQ)
  - Project Executive (PE): Tibor Kremic (GRC)
  - Program Manager (PM): Terry O'Malley (GRC)
  - Principal Investigator (PI): Andy Cheng (APL)
  - Dep. Principal Investigator (DPI): Karl Hibbitts (APL)
  - Project Manager (PjM): Dewey Adams (APL)
- **Instruments**
  - APL – IR Payload
  - SwRI – UV/Vis Payload
  - Gondola – APL, new structure with reuse of STO avionics
  - Telescope – APL, refurbishment of STO 0.8 m telescope
- **Flight**
  - Duration: One day (10 – 22 hours)
  - Launch Point: Fort Sumner, New Mexico
  - Nominal Altitude: 120,000 feet
  - Launch Window: 17 Sept – mid Oct

BRRISON: Objectives

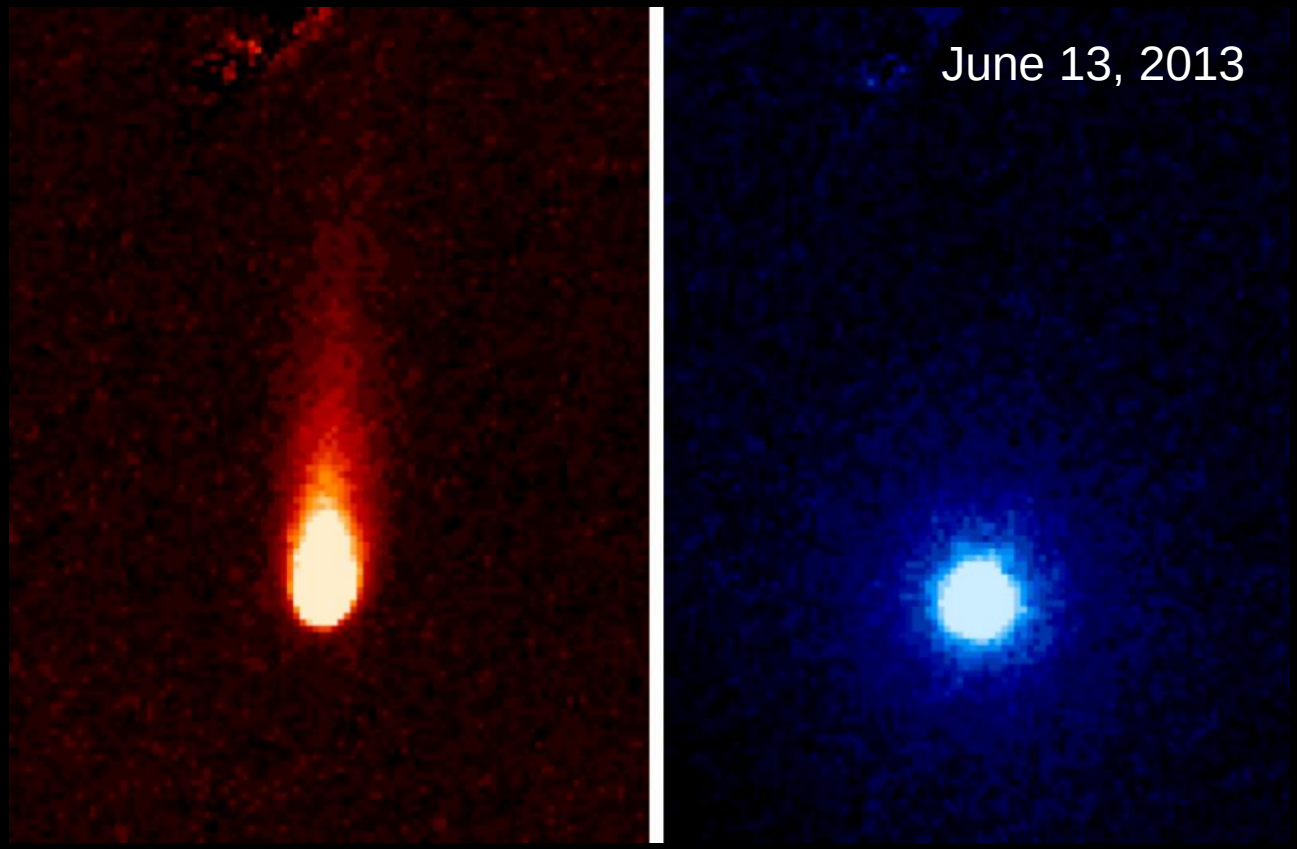
- Provide high-value science from Comet ISON
  - Measure CO_2 and H_2O and determine their ratio
- Develop and demonstrate gondola and payload systems for a balloon-borne platform designed to achieve planetary science decadal survey objectives
  - **Payload systems**: IR imaging of ISON; near-UV/Vis imaging and operation of Fine Steering Mirror for obtaining < arc-sec pointing stability
  - **Gondola systems** for platform capable of lifting a > 1 m aperture telescope to 37 km (120,000 ft) altitude



(***ALSO***, recover this hardware to be utilized in future planetary science missions)

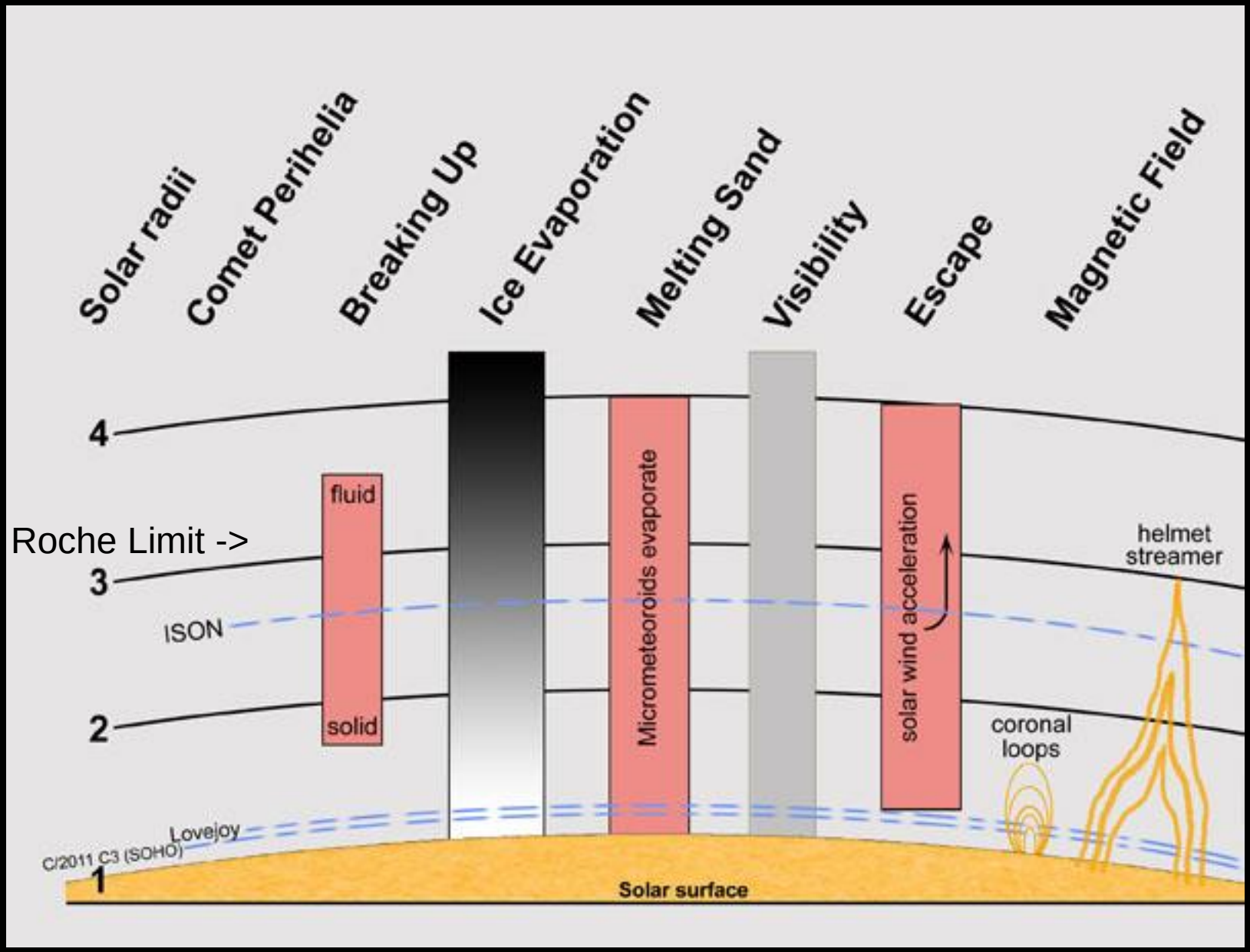

Gamma Ray
X-Ray
Ultraviolet
Visible
Infrared
BRRISON
SDO
distance: Sun
SOHO
data: late Nov.
distance: Sun
MESSENGER
data: Nov. 19th
distance: path to Sun
Stereo
data: late Nov.
distance: path to Sun
Deep Impact
data: Jan. 17-18
distance: 493 M. mi.
Hubble
data: Apr.-May, Oct. & Dec.
Swift
data: Jan. & Mar.
distance: Earth Orbit
Swift
data: Jan. & Mar.
distance: Earth Orbit
FORTIS
data: mid.-late Nov.
Chandra
data: Nov.
ISS
data: late Nov.
distance: Earth
LRO
data: late Nov.
distance: Lunar Orbit
Curiosity
data: Oct. 1st
distance: Mars
MRO
data: Oct. 1st
distance: Mars
Opportunity
data: Oct. 1st
distance: Mars
BRRISON
H2O
Spitzer
2.5µm
3.6 µm
CO2
4.5 µm
4.6µm
Spitzer
data: June 13
distance: Earth Orbit

Spitzer Space Telescope Observations



- Spitzer observations reveal that dust and carbon dioxide gas are streaming off Comet ISON, forming a tail ~300,000 km
- Estimate ISON is emitting ~1 million kg of CO_2 and ~54.4 million kg of dust every day

Will ISON Survive?



Another Fabulous Opportunity

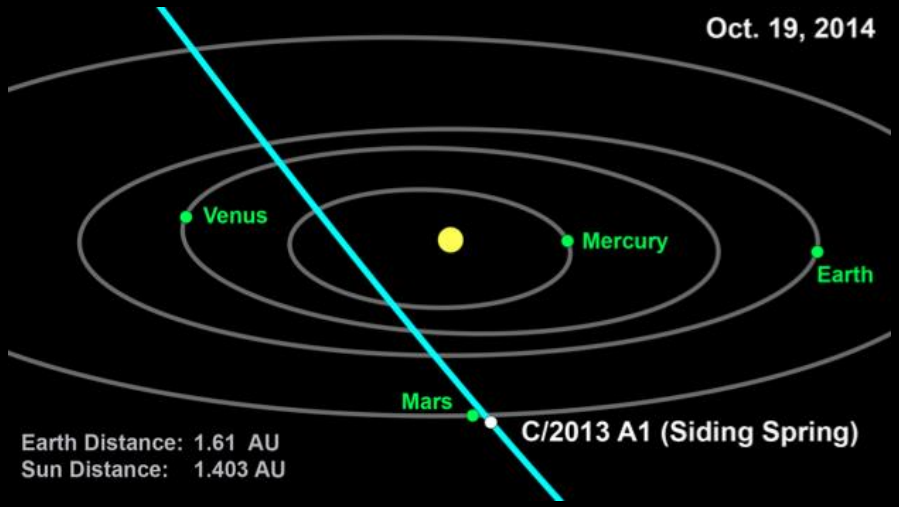
On October 19, 2014, Comet C/2013 A1 (Siding Spring) will pass within 120,000 km of Mars.

This is closer than all known Earth-comet encounters.

A collision has been ruled out, but Mars and its manmade satellites will pass through the coma and tail.

Mars will be showered with meteors and satellites will have an increased risk of meteoroid impacts.

Comet Siding Spring – Oct. 19, 2014



- Oort Cloud Comet
  - Relative speed is 56 km/s
  - Perhelion (1.4 AU) on Oct. 25th
- All Mars orbiters and rovers be comet observers
  - Expect meteor shower
  - Oppy close to local dawn
  - Curiosity close to local dusk

MARS CRITICAL DATA PRODUCTS PROGRAM - COMET SIDING SPRING MODELING

The Mars Exploration Program a Request for Proposals in the Mars Critical Data Products program.

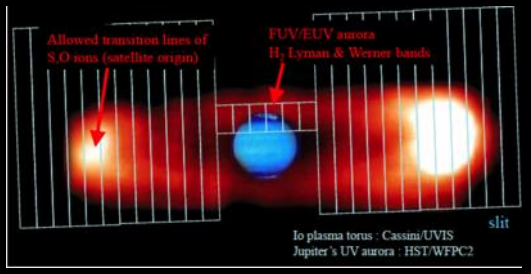
- This RFP provides support of the modeling the dust and particle environment of Comet 2013 A1 (Siding Spring) during its encounter with Mars in October 2014.
- The intent is to provide data products useful for risk assessment and mitigation strategy development for the Mars orbiter missions, due to possible impacts from dust and ion tail particles as this comet encounters Mars.
- Proposals are due on Wednesday, September 11, 2013.

- Details of the RFPs are posted at:

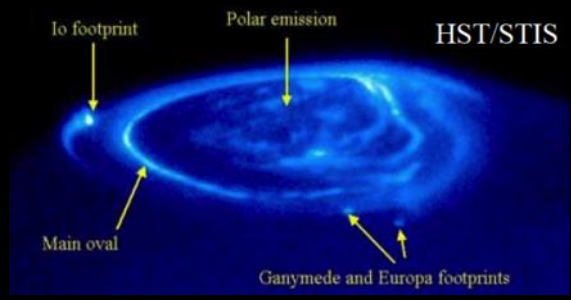
  https://acquisition.jpl.nasa.gov/bizops/

Space-Based Observations of the Jovian System

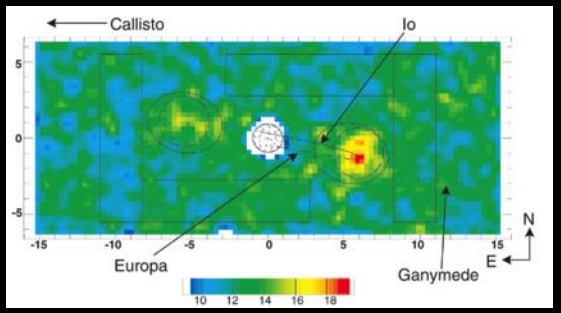
- SPRINT-A/EXCEED – JAXA Launch Sep 2013
  - 50 min. of every 100-min. orbit from November 2013-April 2014
  - FUV spectra of the Io torus and Jovian aurora
  - composition/electron temperature of torus; energy of auroral electrons)



- HST/STIS
  - 24 orbits near Jupiter opposition Jan. 2014
  - Imaging & spectroscopy of Jupiter's and Io's FUV aurora
  - Global morphology, incident auroral electron energy, and Io SO_2 atmospheric maps

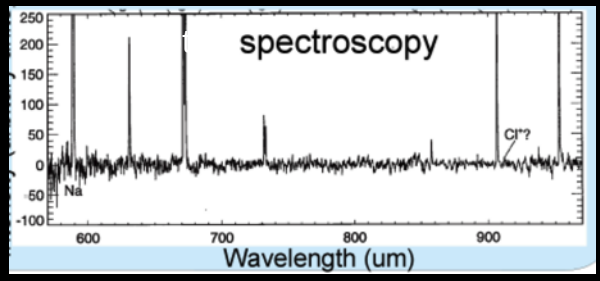


- Chandra X-Ray Observatory/ XMM-Newton
  - 160 ksec in April 2014
  - Imaging & spectra of X-ray emissions from Jupiter and the Io torus
  - Global morphology and energy of auroral x-rays

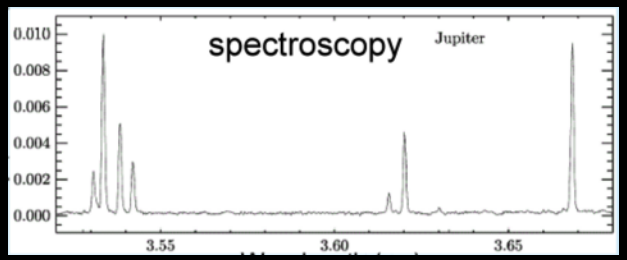


Ground-Based Observations of the Jovian System

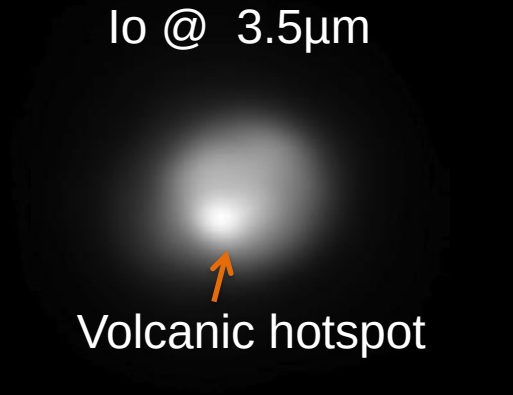
- KPNO 4m
  - 7 half-nights in early Jan. 2014
  - Spectra of optical S^+ & Na emissions from the Io plasma torus (IPT)
  - Electron density in the IPT



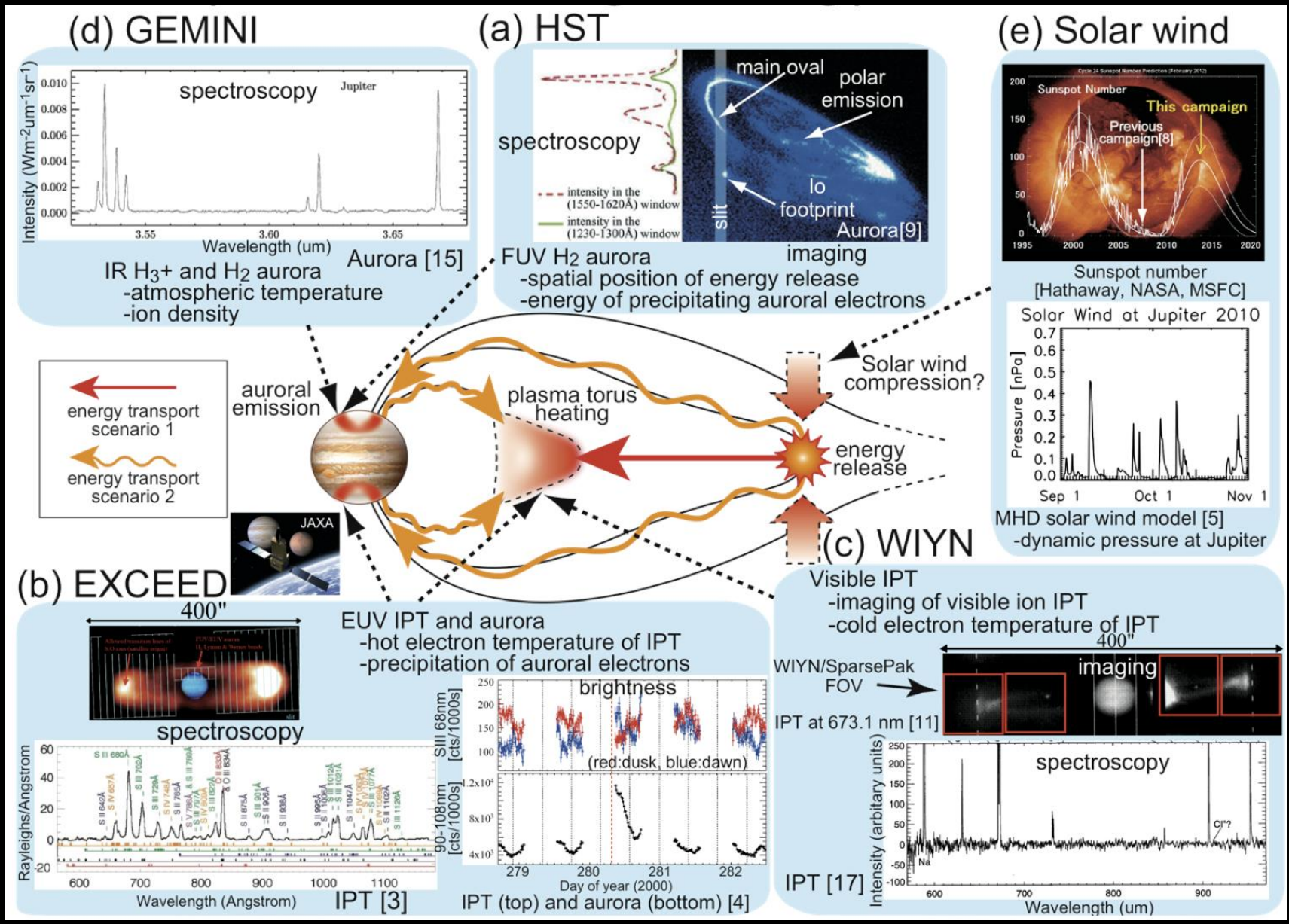
- Gemini North
  - 14 hours in early Jan. 2014
  - H_3^+ and H_2 Near-IR emissions from the Jovian aurora
  - Spatially-resolved atmospheric temperature, column density, and auroral electron energy



- NASA IRTF
  - 3 separate accepted proposals:
  - 1-5 µm imaging of thermal emission from Io's volcanoes
  - Observe Jupiter's aurora H_3^+ @ 4µm
  - Io 3-5 µm spectral monitoring.



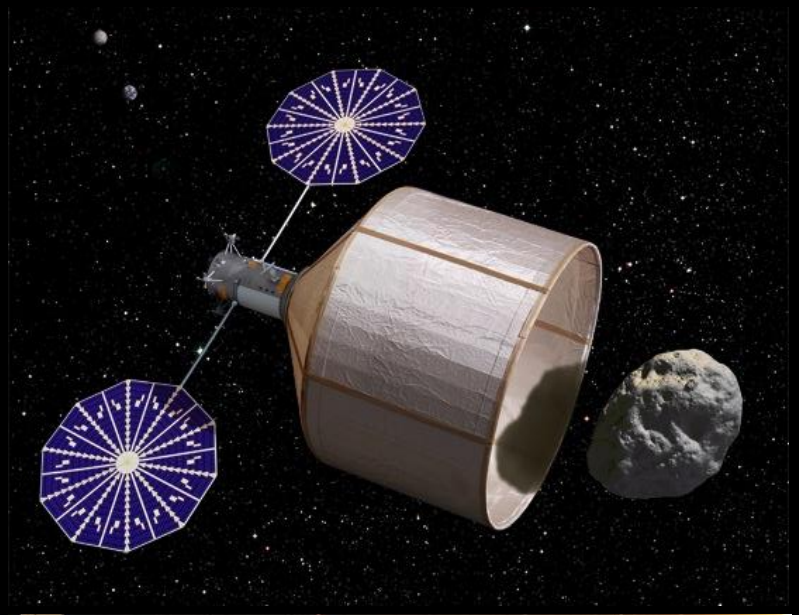
Jupiter Observing Strategy: Jan 2014

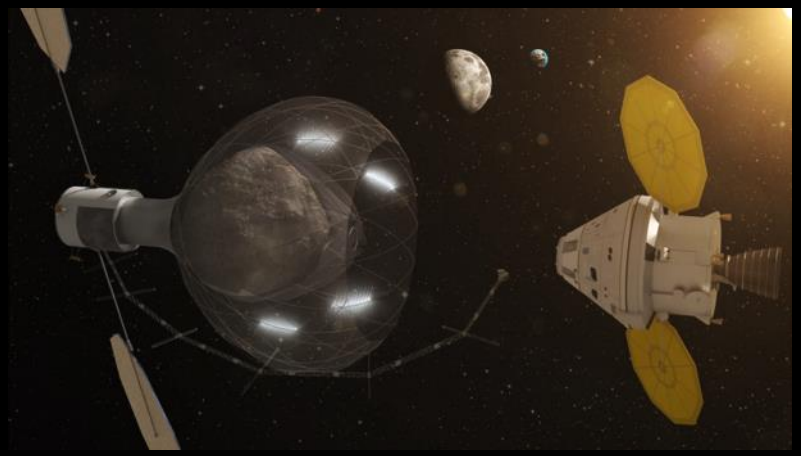


NASA’s Asteroid Initiative

Capture and Redirect an Asteroid

- Capture and redirect a 7-meter diameter, 500-1000 ton near-Earth asteroid to cis-lunar space
- Enable astronaut missions to the asteroid by as early as 2021
- Obtain valuable information for exploration, planetary defense, science, and *in-situ* resource utilization (ISRU)
- Parallel and forward-leaning development approach
- NOTE: This is not a *science* mission but a *technology demonstration* mission





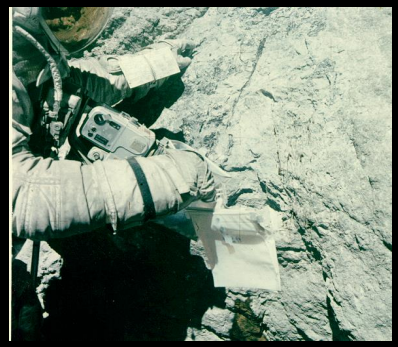
Asteroid Mission Would Consist of Three Main Segments

Asteroid Identification Segment:

Ground and space based NEA target detection, characterization and selection

Asteroid Redirection Segment:

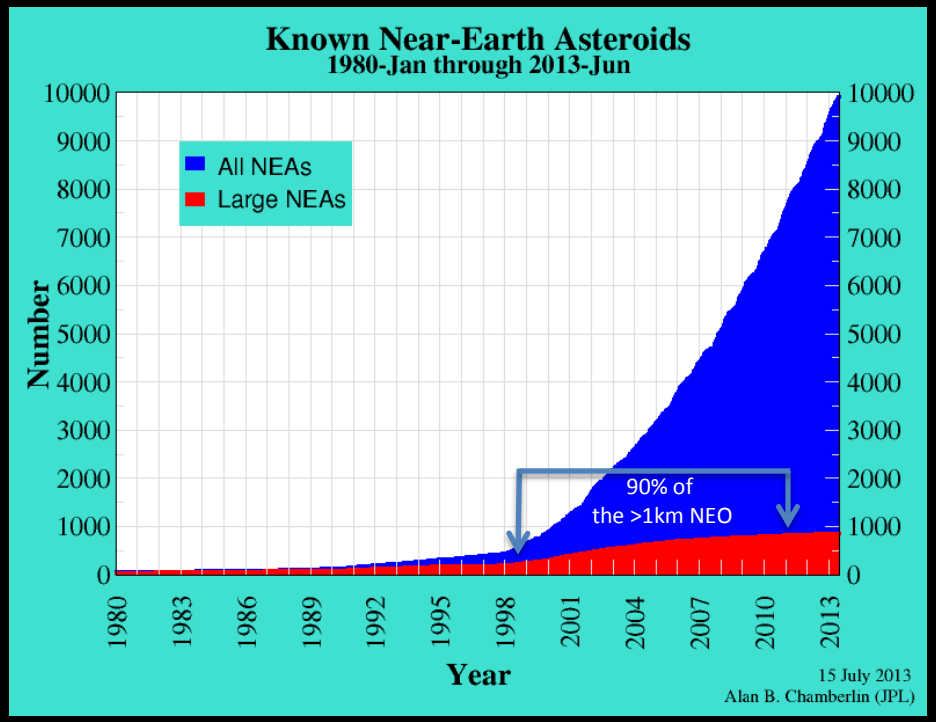
Solar electric propulsion (SEP) based asteroid capture and maneuver to trans-lunar space

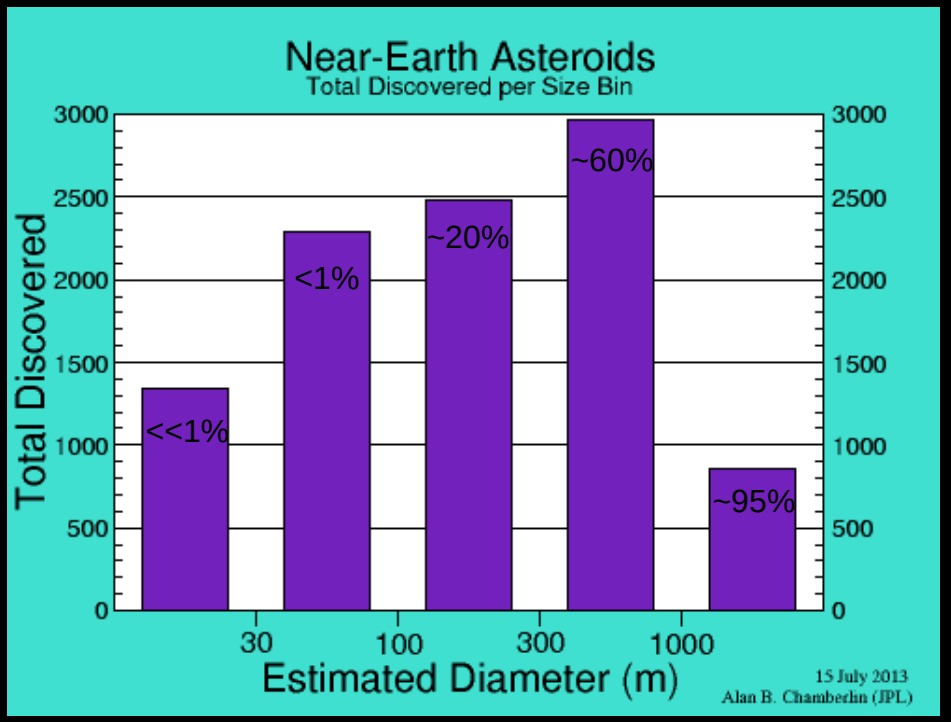


Asteroid Crewed Exploration Segment:

Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid

Quick Status of the NEO Survey Program

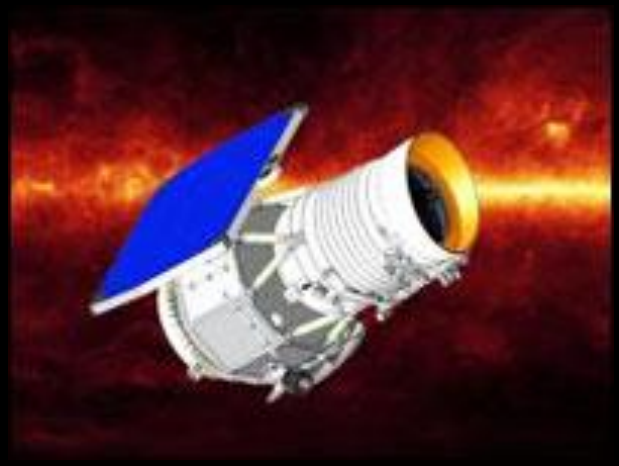




- Congressional Bill 1998 – Find 90% of the >1km NEO within 10 yrs
- Congressional Bill 2005 – Find 90% of the >140m NEO within 15 yrs

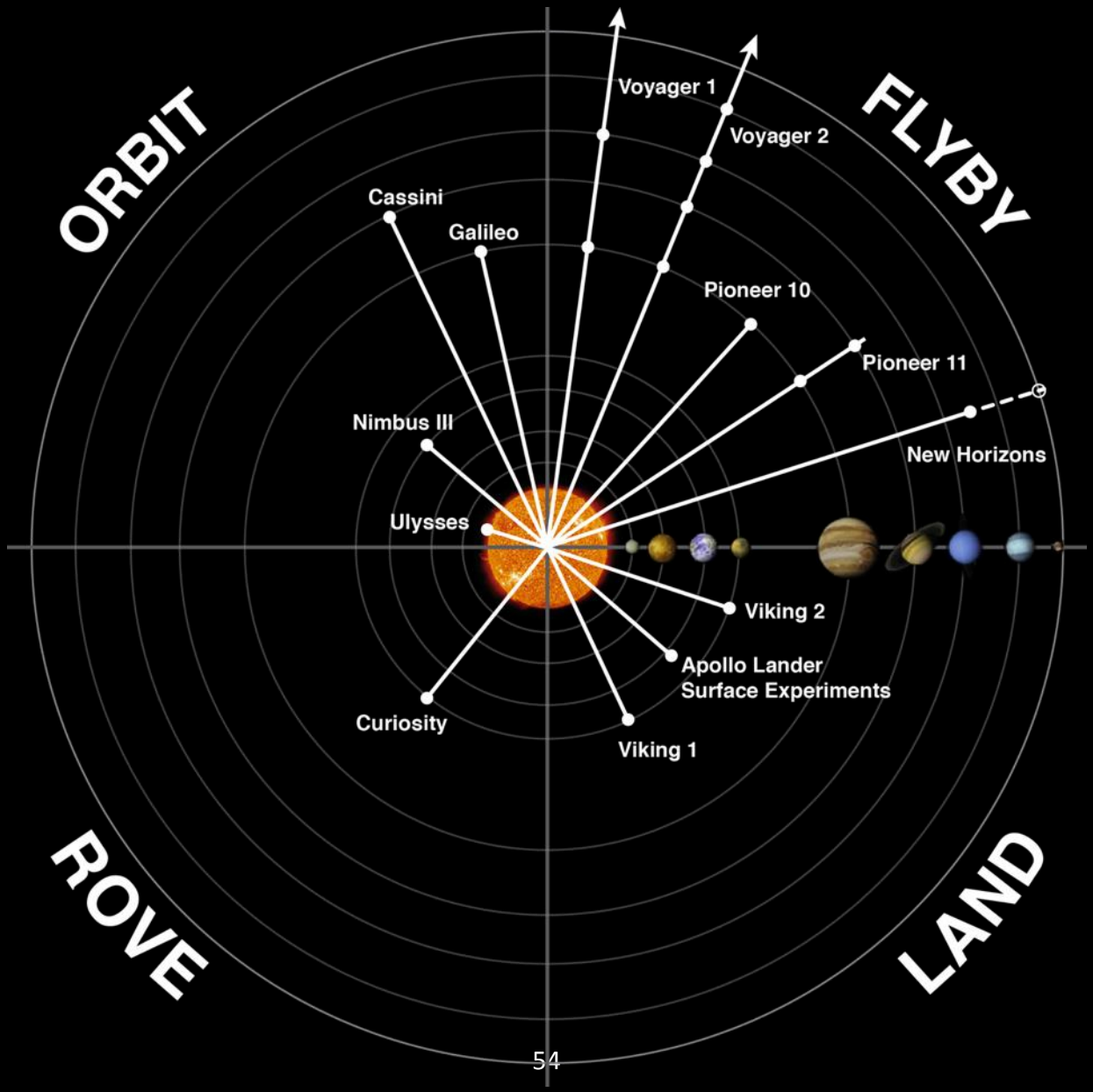
NEO-WISE Reactivation

- Reactivated the WISE spacecraft on 19 August to continue the detection and characterization of NEOs for the time that the WISE spacecraft can remain in effective operations (estimated to be 3 yrs)
- Cool-down will take up to ~ 3 mos before effective operations can begin



Radioisotope Power Systems/DoE

Over 50 years of RPS Missions



FY14 Funding Realignment for RPS

- In FY14, DOE is to transition to a full cost recovery strategy for RPS
- NASA to provide full funding so RPS program requirements and funding are aligned under one Agency
  - NASA is the prime customer for Pu-238
- Funding and justification for sustainment of all necessary supporting infrastructure and capabilities at DOE is in the FY14 NASA budget request
- DOE will be funded by NASA for execution of RPS flight development and to provide production, safety, and management of necessary infrastructure
- To support and advise NASA, a facilities and capability review committee was put together and has started to perform a zero-base review
  - NASA membership: Jim Adams, David Schurr, Hal Bell, Frank Bellinger, Kevin Gilligan
  - Non-NASA consultants: Ralph McNutt (APL), Tim Frazier (former DOE), Aerospace Corporation (Mark Rokey and others)
  - Ex-officio observers: Len Dudzinski (NASA PSD Liaison) and Alice Caponiti (DOE Liaison)
- Review Committee to report findings/recommendations by October 1st

Backup Charts