NASA's Planetary Science Program Status

Presentation to Planetary Science Decadal Steering Committee

James L. Green

Director, Planetary Science Division

July 6, 2009

Outline

- FY10 Planetary Budget Overview
- Planetary Missions Overview
- New Frontiers & Discovery
- Mars Exploration (covered by Doug)
- Outer Planets
- Supporting Research & Technologies
- Mission Enabling Technologies
- International agreements

Planetary Science Program

	FY09	FY10	FY11	FY12	FY13	FY14
FY10 President Submit	1,325.6	1,346.2	1,500.6	1,577.7	1,600.0	1,633.2
Discovery	247.0	213.2	234.6	256.8	256.5	264.3
GRAIL	122.4	124.1	104.8	41.4	4.7	
Operating Missions	47.4	50.4	52.8	30.1	12.9	10.1
Research / Management / Future	77.2	38.7	77.1	185.4	238.8	254.2
New Frontiers	263.9	264.1	239.9	294.2	239.8	249.6
Juno	245.0	237.2	174.2	71.4	17.8	18.1
New Horizons / Management / Future	19.0	26.9	65.7	222.8	222.0	231.5
Outer Planets	101.1	98.6	97.1	140.3	117.7	118.5
Outer Planets Flagship	5.1	13.7	20.7	69.3	70.0	70.0
Cassini, Research	96.0	84.9	76.4	71.0	47.7	48.5
Technology	64.9	89.0	98.4	102.1	93.5	91.4
Planetary Science Research	162.1	161.7	193.5	240.2	232.6	254.2
Research & Analysis, PDS, Curation, NEOO	152.8	153.6	163.4	172.5	176.6	180.9
Rosetta, MUSES-C	5.4	6.7	7.0	7.0	7.0	13.2
SMD Administrative	3.9	1.4	23.1	60.7	49.0	60.1
Lunar Quest	105.0	103.6	142.6	138.6	145.5	118.7
LRO extended mission		0.8	21.6	22.2	27.2	
LADEE	30.2	66.5	73.9	31.1		
ILN	10.0	3.7	16.3	48.9	81.2	79.3
Entry, Descent and Landing	0.5					
Lunar Science, Management and Future Msns	64.3	32.5	30.8	36.3	37.0	39.4
Mars Exploration	381.6	416.1	494.5	405.5	514.3	536.7
Phoenix	4.6					
MSL 2009	223.3	204.0	194.6	67.3	65.0	30.0
MAVEN 2013	6.7	53.4	168.7	182.6	138.4	30.6
ExoMars	10.5	9.0	14.0	24.0	20.0	15.0
Management / Future Missions	48.3	45.6	46.1	71.0	227.9	379.4
Operating Missions / R&A	88.1	104.1	71.1	60.6	63.1	81.6
JPL Building Support						

Planetary Science

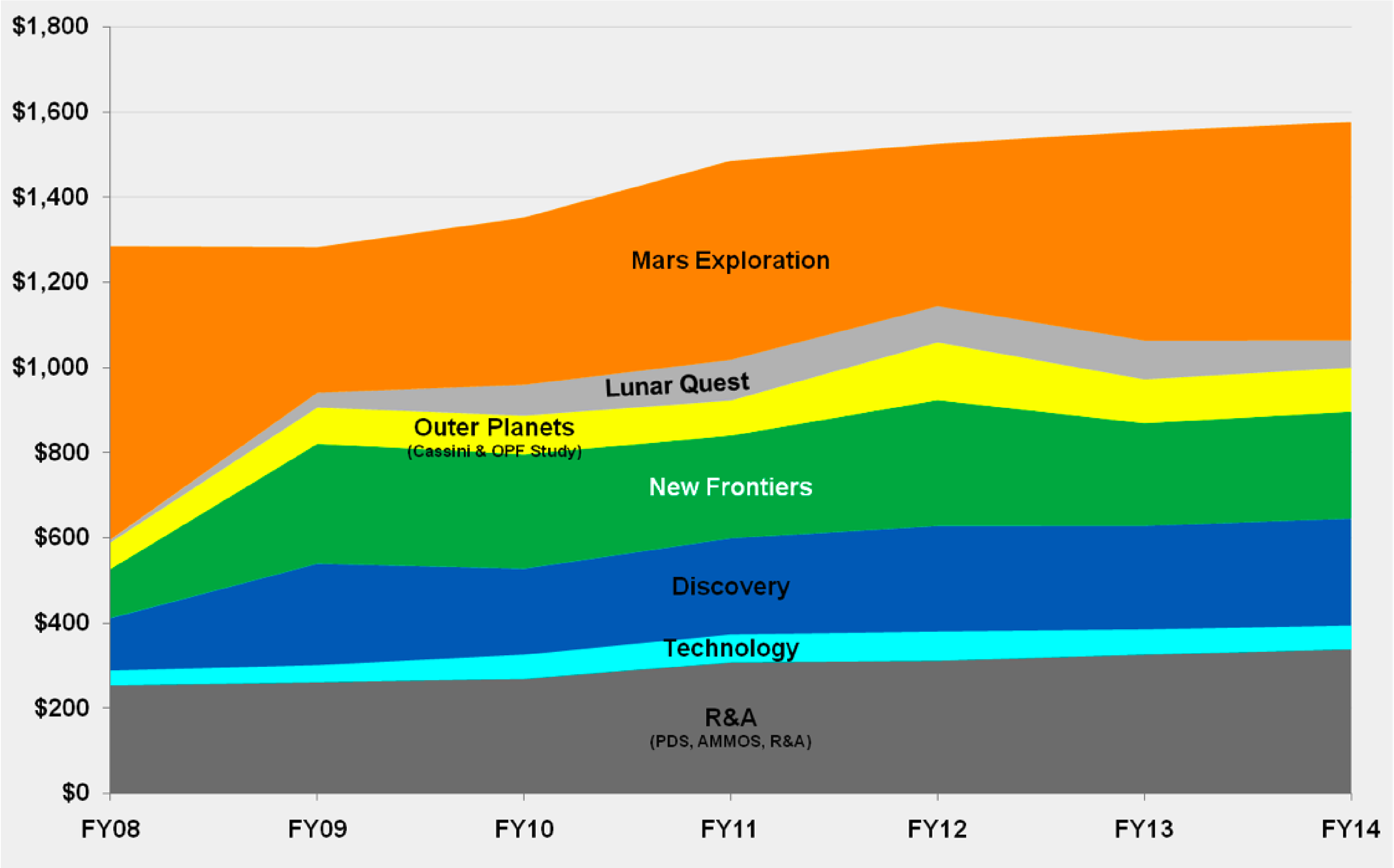
What Changed:

- Outer Planet Flagship (OPF) funded as studies
  - Continue to determine feasibility (science, technical, schedule, cost) and to align with the international partners science, technical and schedule requirements
- Mars Sample Return (MSR) delayed to TBD due to cost realism, budget constraints, and pending negotiation with ESA for partnership
  - Added funds to create executable Mars Exploration Program
  - Launch every opportunity, ~26 month (except 2009) through 2020 with a European Space Agency partnership
- Transferred Lunar Robotics Mgt from ESMD and NEO from ES to PSD
- MSL slipped to 2011, the next launch opportunity for Mars, due to hardware development delays

What's the Same:

- Continue forward with the selected missions in development (Juno and GRAIL) and formulation (MAVEN, LADEE, and ILN) phases.
- Discovery program budget support launch about every 3 years, w/ the next Discovery mission (no. 12) LRD in 2014/2015
- New Frontiers budget supports a launch about every 5 years, w/ New Frontiers 3 LRD in ~2017/2018
- Funded operating missions (Cassini, MRO, MER, MEX, Odyssey, EPOXI, Dawn, MESSENGER, Aspera-3, New Horizons, etc), Research and Technology (ISP and RPS)

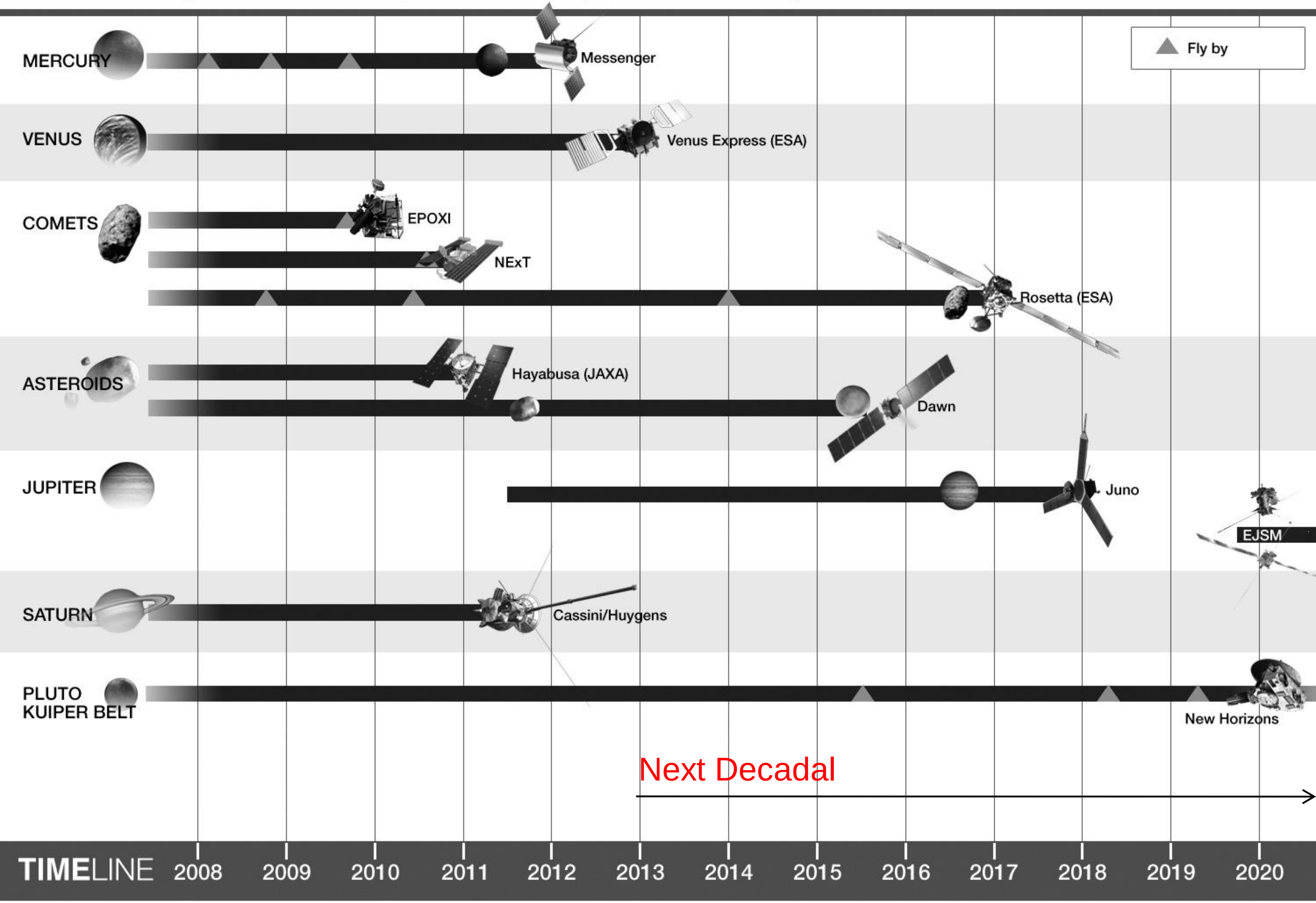
Planetary FY10 Budget



- Use the President’s FY11 budget when issued in Feb ’10
- 1st budget with goals from the new administration

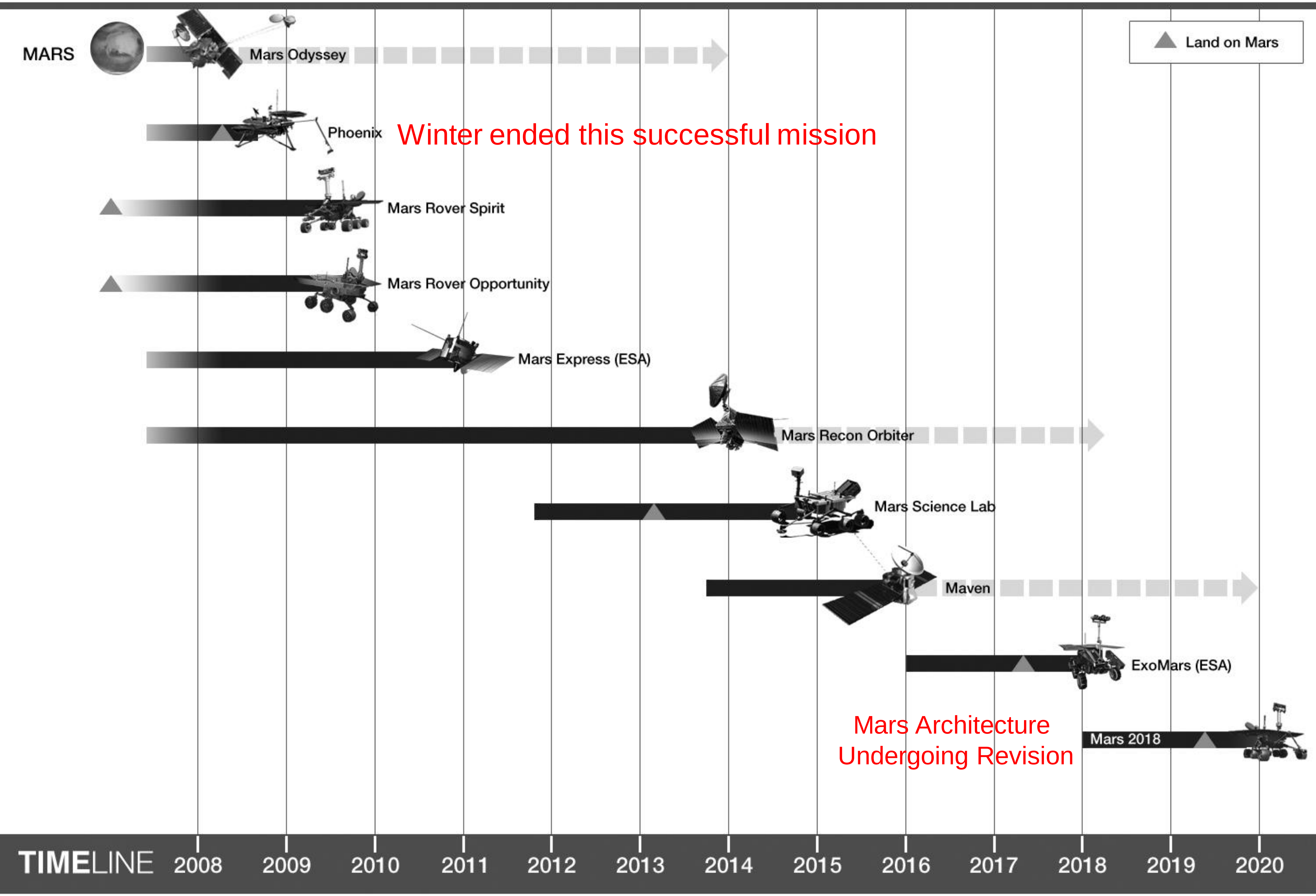
Planetary Missions Overview

Planetary Missions (Non-Mars, Non-Lunar) timeline

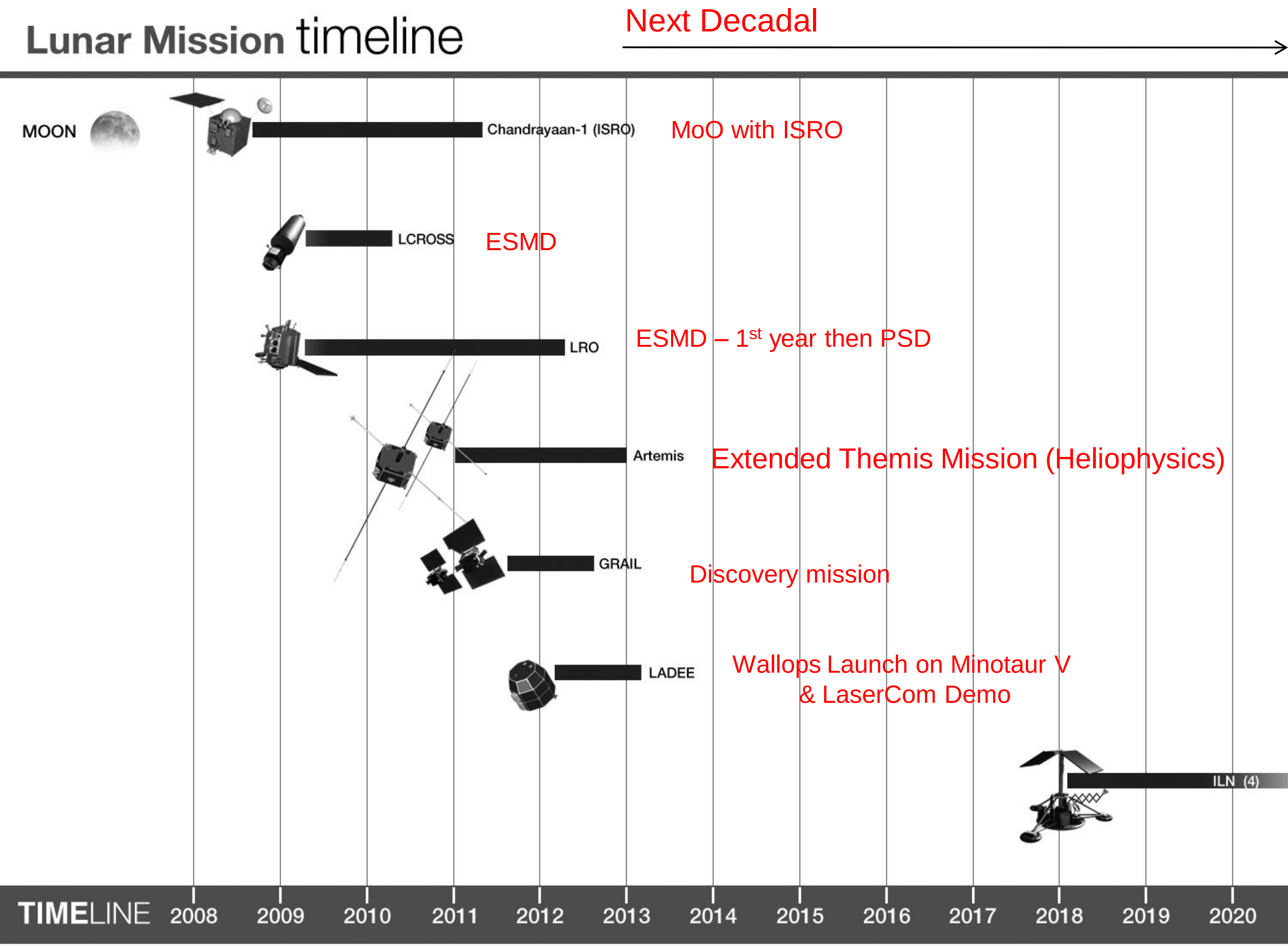


Mars Mission timeline

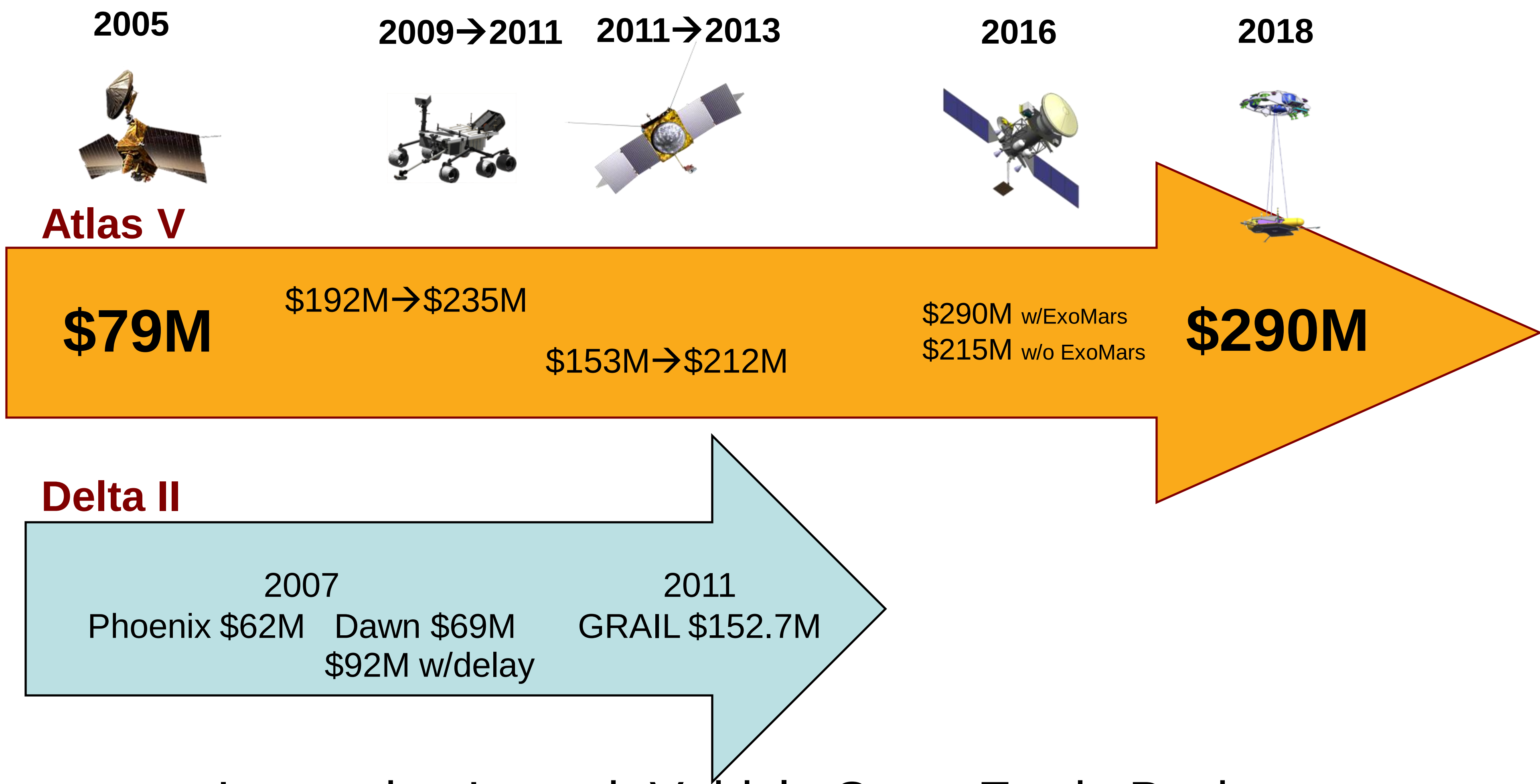
Next Decadal



Lunar Mission timeline



Increasing Launch Vehicle Costs



Increasing Launch Vehicle Costs Erode Buying Power for Missions

New Frontiers & Discovery

PI Mission Opportunities

New Frontiers Program

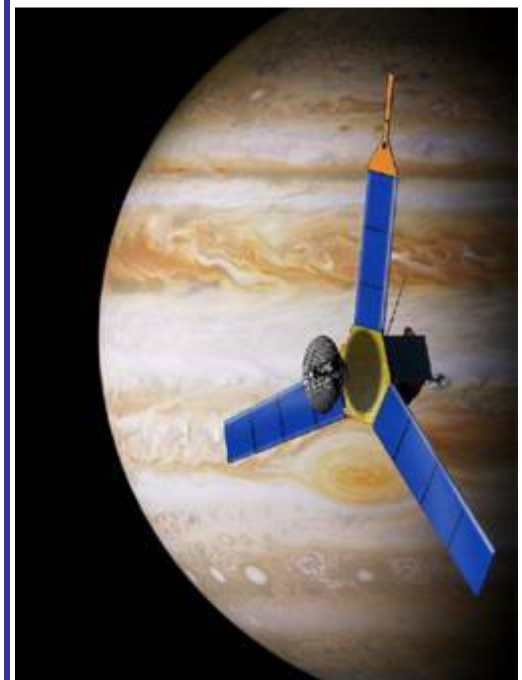
1st NF mission
New Horizons:

Pluto-Kuiper Belt Mission

Launched January 2006
Arrives July 2015

2nd NF mission
JUNO:

Jupiter Polar Orbiter Mission



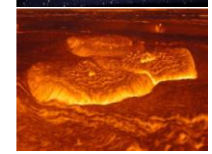
August 2011 launch

3rd NF mission AO

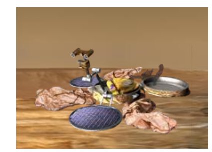
South Pole - Aitken Basin Sample Return

Comet Surface Sample Return

Venus In Situ Explorer



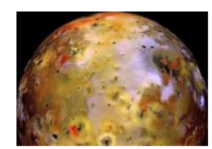
Network Science



Trojan/Centaur

Asteroid Sample Return

Io Observer



Ganymede Observer

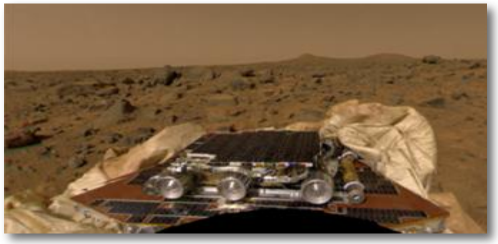
New Frontier-3 Announcement

- Open competition for PI class missions of strategic importance to Planetary Science in the < $1B class
  - Select up to 3 for a 10 mo. Phase-A then a downselect to 1
  - Launch window beginning late CY 2016 ending NLT the end of CY 2018, according to target
  - Technology infusion:
    - NEXT ion propulsion system & Advanced Materials Bi-propellant rocket
- Schedule:
  - AO released April 20, 2009
  - Proposals Due July 31, 2009

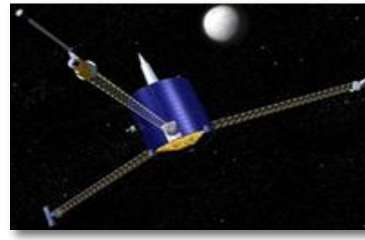
Discovery Program

Completed

Mars evolution:
Mars Pathfinder (1996-1997)



Lunar formation:
Lunar Prospector (1998-1999)

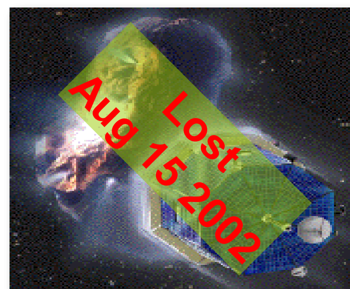


NEO characteristics:
NEAR (1996-1999)

Completed / In Flight

Solar wind sampling:
Genesis (2001-2004)

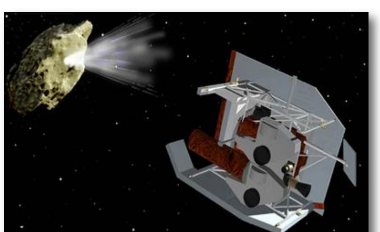
Comet diversity:
CONTOUR



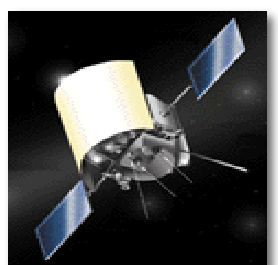
Nature of dust/coma:
Stardust(1999-2006)

In Flight / In Development

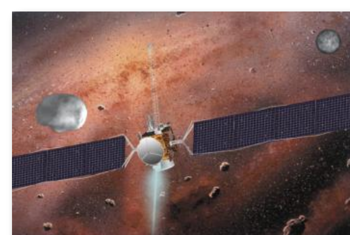
Comet internal structure:
Deep Impact (2005-2006)



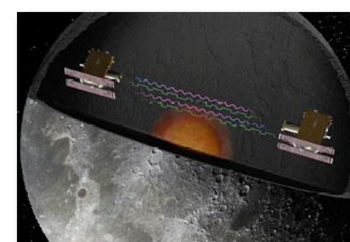
Mercury environment:
MESSENGER (2004-*2012*)



Main-belt asteroids:
Dawn (*2007-2015*)



Lunar Internal Structure
GRAIL (*2011-2012*)



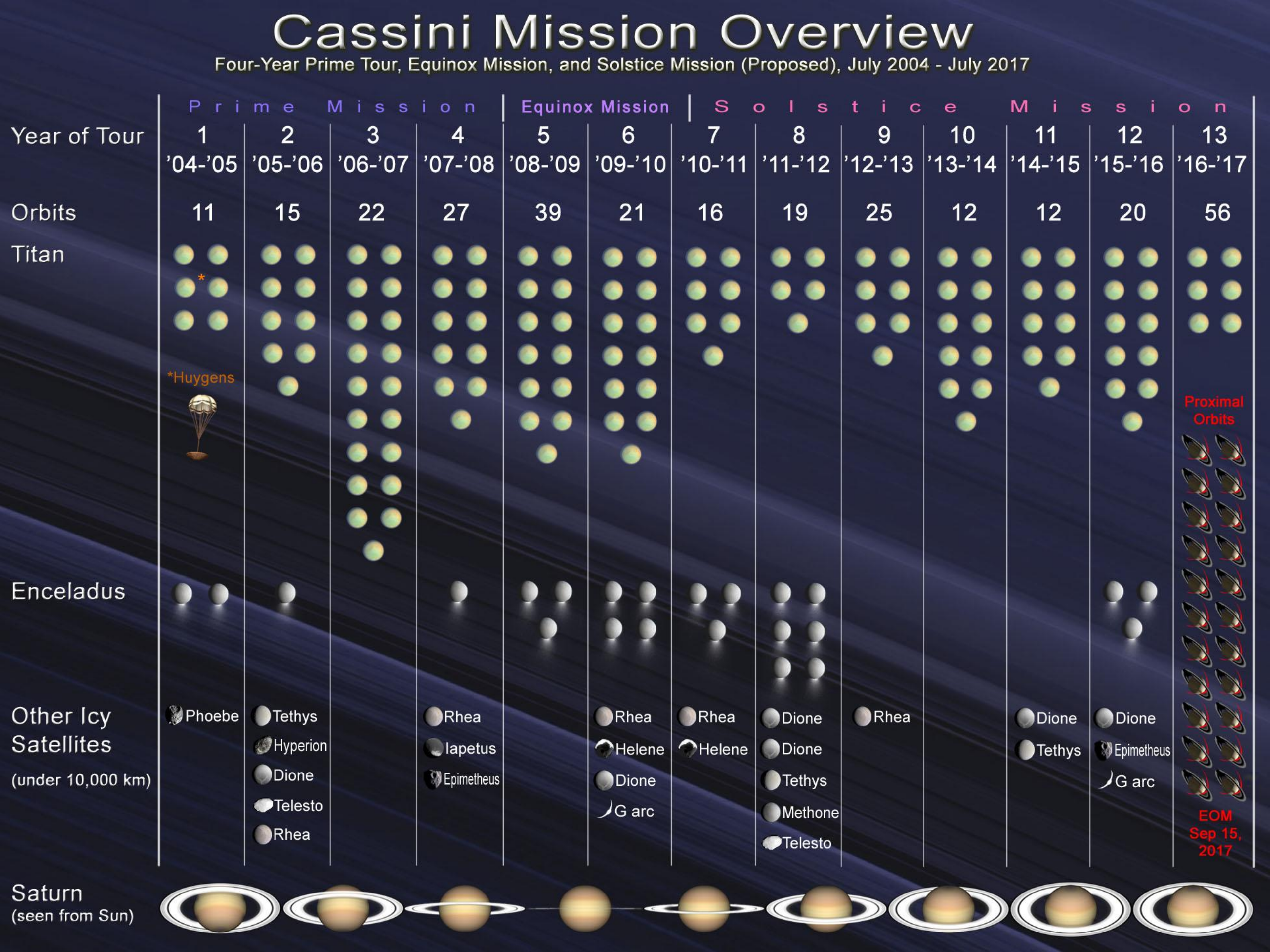
Discovery-12 Announcement

- Planetary Decadal science for PI missions
  - Across entire solar system (including Mars)
  - Cost Cap: $425M FY10 (without LV)
  - Selection: 2 to 3 missions for a 9 mo. Phase-A then downselect to 1
  - Launch date NLT December 31, 2016
- ASRG is provided GFE as an option
  - Funded 9 feasibility studies
- Schedule:
  - Draft AO ~June 2009
  - Final AO ~ November 2009
  - Proposals due 90 days after AO release

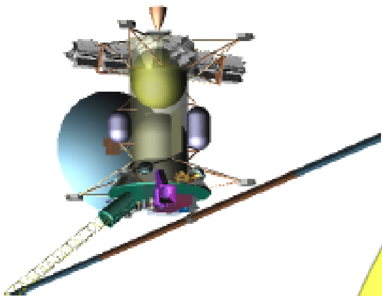
Outer Planets Flagships

Cassini

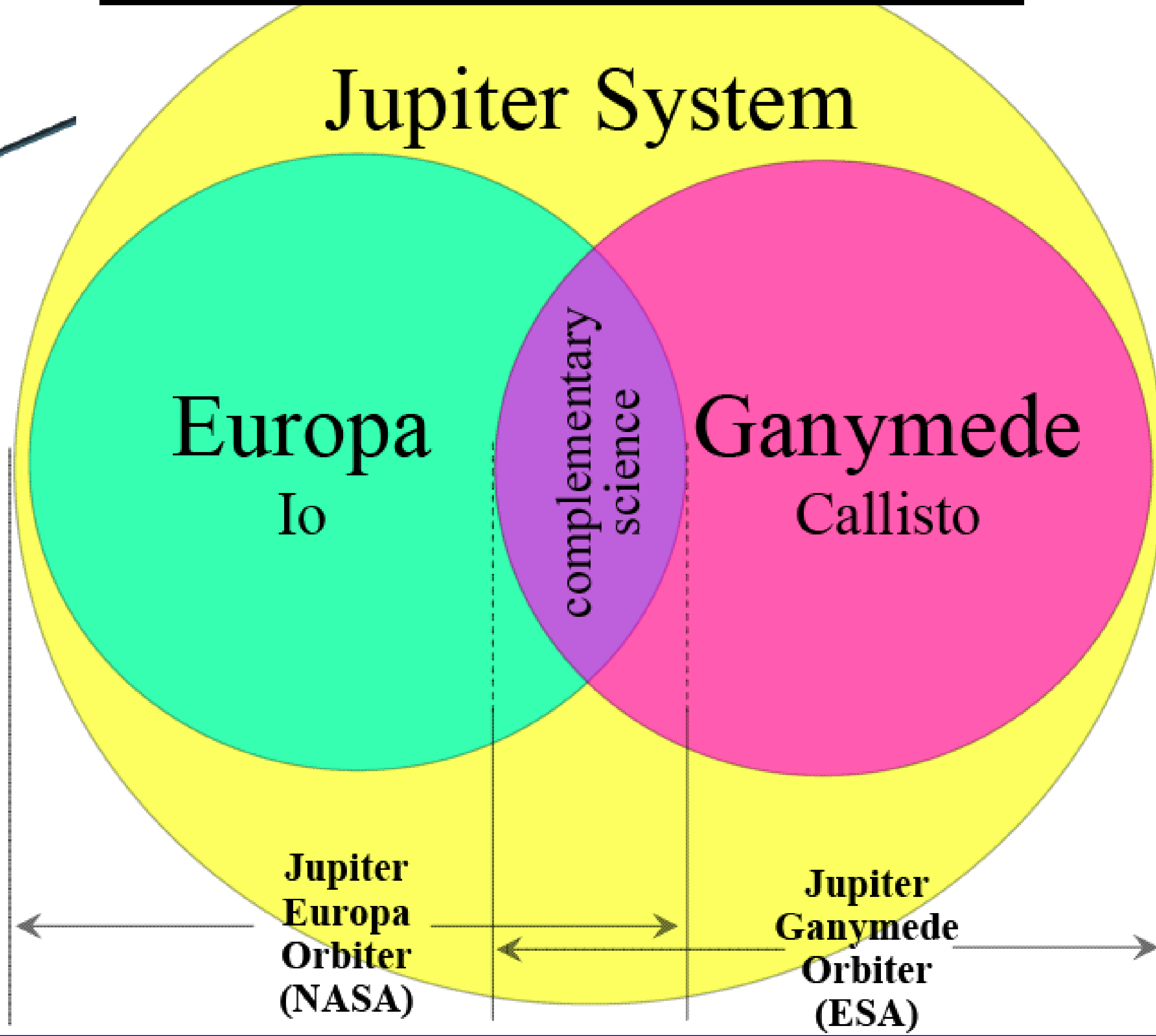
Europa & Ganymede missions

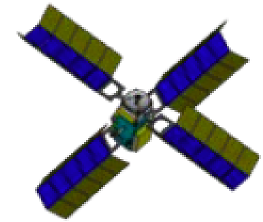

Cassini Mission Overview
Four-Year Prime Tour, Equinox Mission, and Solstice Mission (Proposed), July 2004 - July 2017
Prime Mission
Equinox Mission
Solstice Mission
Year of Tour
1 '04-'05
2 '05-'06
3 '06-'07
4 '07-'08
5 '08-'09
6 '09-'10
7 '10-'11
8 '11-'12
9 '12-'13
10 '13-'14
11 '14-'15
12 '15-'16
13 '16-'17
Orbits
11 15 22 27 39 21 16 19 25 12 12 20 56
Titan
*Huygens
Proximal Orbits
Enceladus
Other Icy Satellites
(under 10,000 km)
Phoebe
Tethys
Hyperion
Dione
Telesto
Rhea
Rhea
Iapetus
Epimetheus
Rhea
Helene
Dione
G arc
Rhea
Helene
Dione
Dione
Tethys
Methone
Telesto
Rhea
Dione
Tethys
Dione
Epimetheus
G arc
EOM
Sep 15, 2017
Saturn
(seen from Sun)

The Emergence of Habitable Worlds Around Gas Giants

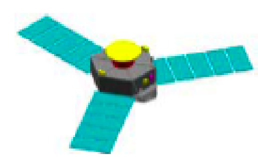


NASA Jupiter Europa Orbiter (JEO)





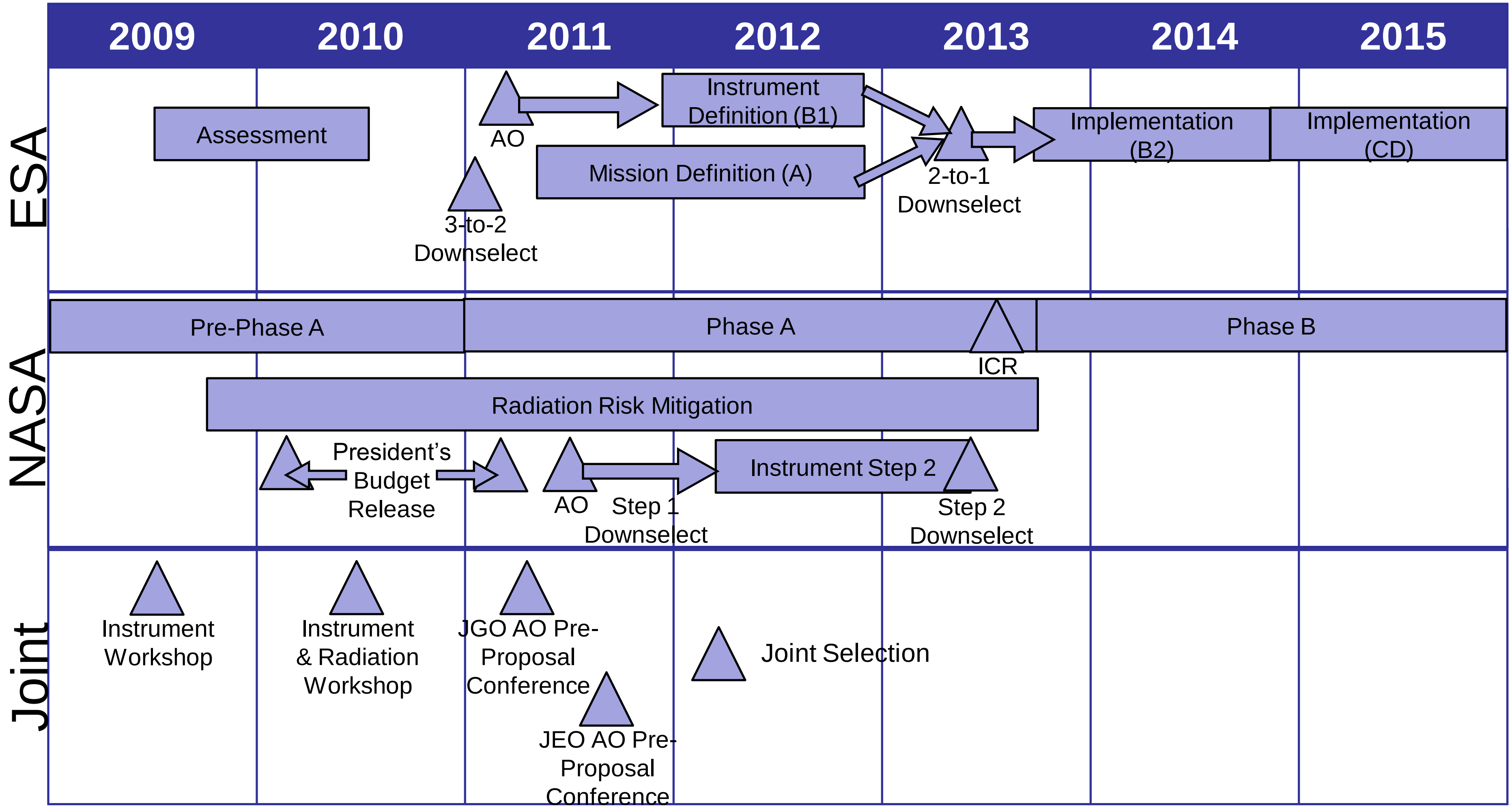
ESA Jupiter Ganymede Orbiter (JGO)



JAXA Jupiter Magnetospheric Orbiter (JMO)

JEO is designed to stand alone or operate synergistically with ESA JGO

NASA and ESA Schedules



- Continued discussions on schedule & AO coordination

Supporting Research & Technology Program

SR&T Program Elements

- Research & Analysis (ROSES)
- Astrobiology Institute
- Lunar Science Institute
- Near Earth Object Observations
- Planetary Data System (PDS)
- Astromaterials Curation Facility (JSC)

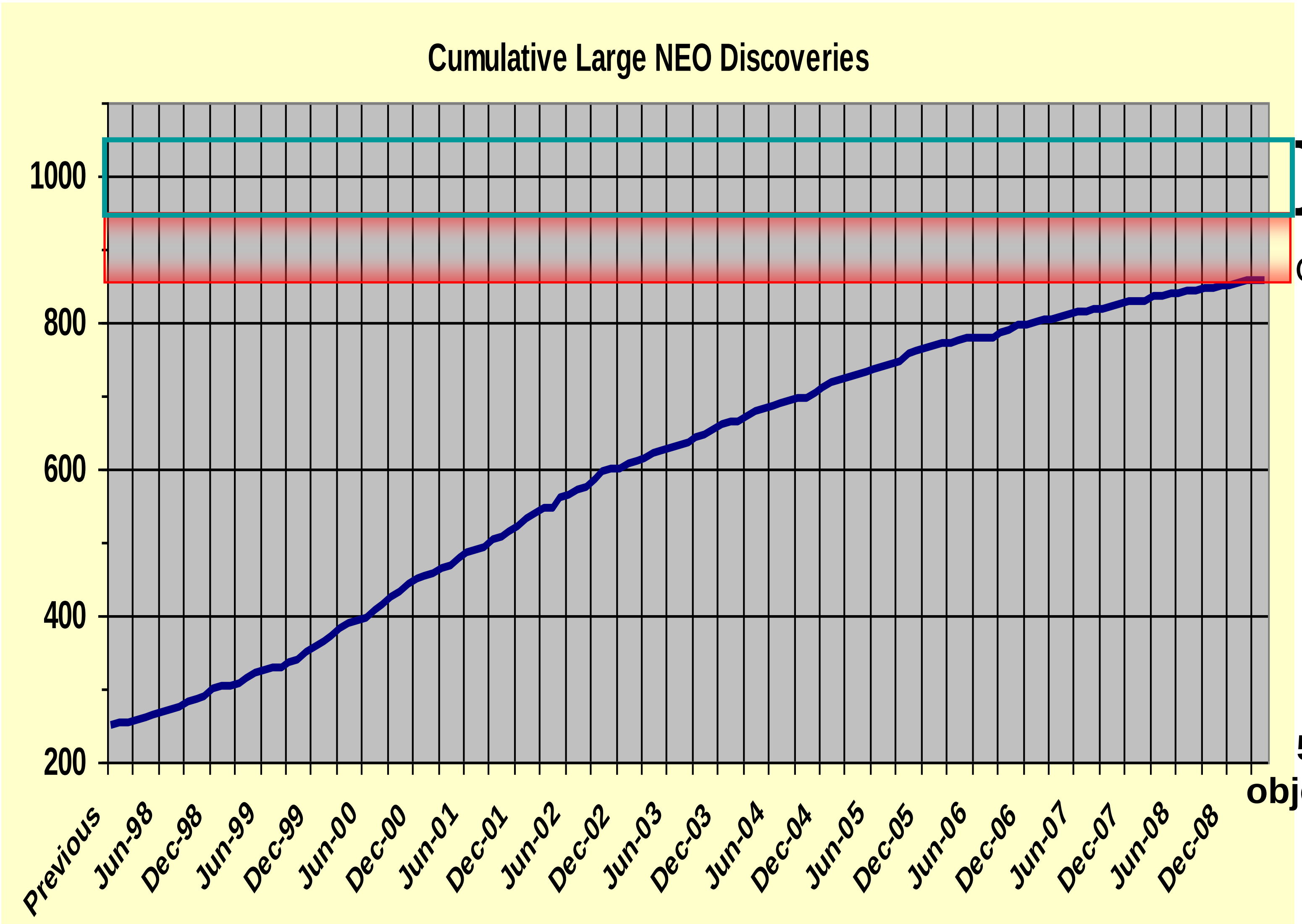
PSD R&A Program for ROSES 2009

- Cosmochemistry
- Laboratory Analysis of Returned Samples
- Planetary Geology And Geophysics
- Origins of Solar Systems (joint with Astrophysics)
- Planetary Astronomy
- Planetary Atmospheres
- Outer Planets Research
- Lunar Advanced Science and Exploration Research
- Near Earth Object Observations
- Cassini Data Analysis
- Planetary Missions Data Analysis
- Mars Data Analysis
- Mars Fundamental Research
- Mars Instrument Development
- Planetary Instrument Definition And Development
- Astrobiology: Exobiology And Evolutionary Biology
- Planetary Protection Research
- Astrobiology Science & Technology Instrument Development
- Astrobiology Science And Technology For Exploring Planets
- Dawn at Vesta Participating Scientists
- Early Career Fellowships
- Planetary Major Equipment
- Moon and Mars Analog Missions Activities

NEO Program

- Current program: Discover 90% NEOs >1 km in size within 10 years (1998 – 2008)
  - Using existing ground-based facilities
  - Arecibo used for characterization
- NASA Authorization Act of 2005 provided additional direction (but no additional funding)
  - "…plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue (based on statistically predicted populations of near-Earth objects) within 15 years after the date of enactment of this Act."
- NEO program has limited assets (~$4M/yr) and will continue to look for opportunities to partner and achieve Congressional goals

NEO Discovery Metric



Estimated Population 940 to 1050

Goal 850 - 940 Achieved minimum goal

864* as of 6/30/09

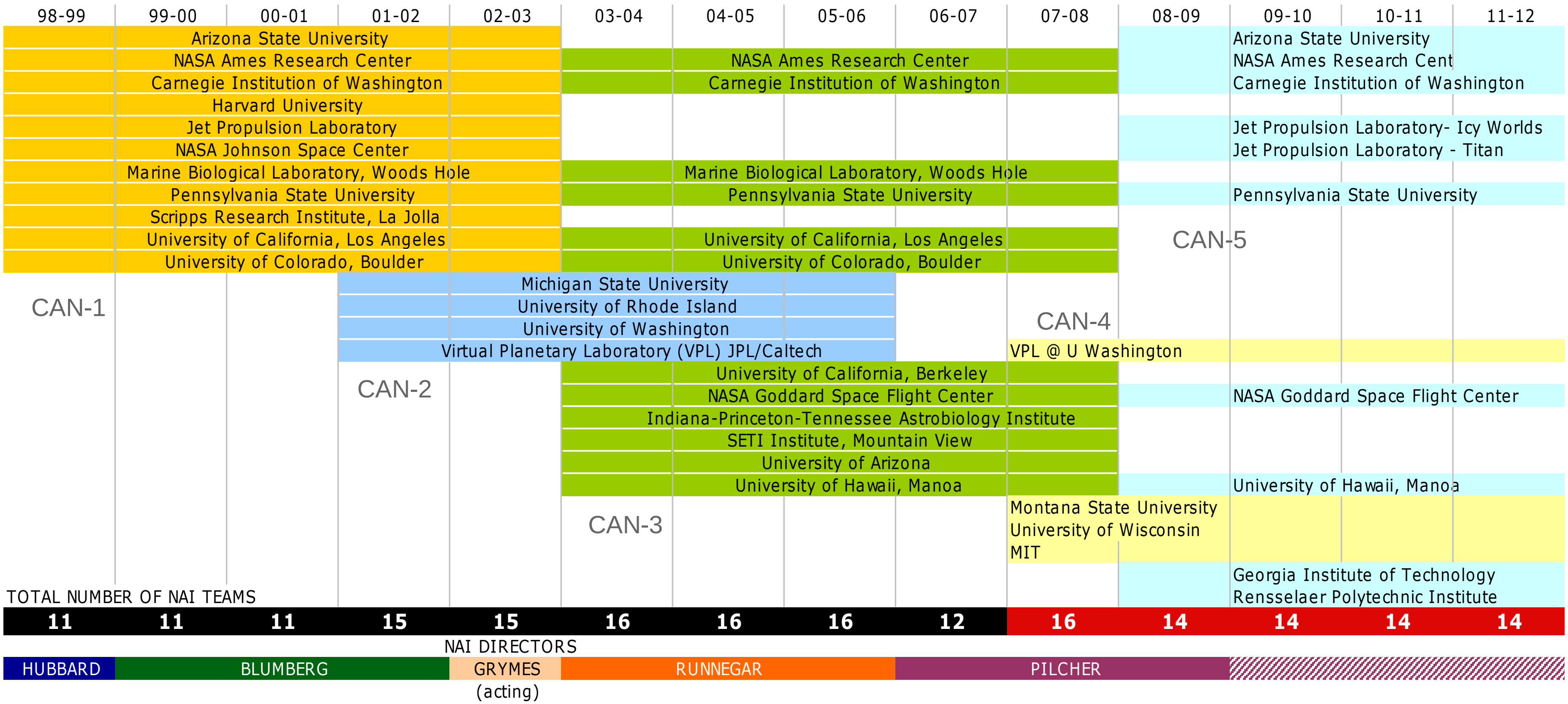
*Includes 84 NECs

5446 smaller objects also found

NASA Astrobiology Institute

- ‘Virtual’ distributed institute ‘without walls’
- 14 competitively-selected interdisciplinary teams
- ~600 members at ~150 participating institutions
  - ~400 “senior” scientists
  - ~200 postdocs and students
  - ~16 members of the US National Academy of Sciences
- Funded through Cooperative Agreements
- Managed by a central office at NASA Ames Research Center
- ~553 papers supported by NAI published in Year 9 (July 2006 – June 2007)
  - » 46 publications in *Science, Nature, PNAS*
- Website: http://astrobiology.nasa.gov/nai

Entering NAI’s 2nd Decade



International Associates

Centro de Astrobiologia (Spain)

Australian Centre for Astrobiology

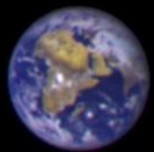
International Affiliates

Astrobiology Society of Britain

Groupement de Recherche en Exobiologie

European Exo/Astrobiology Network Association

Russian Astrobiology Center



NLSI: Teams

NASA LUNAR SCIENCE INSTITUTE TEAMS

Understanding the Formation & Bombardment History of the [illegible]
PI: Bill Bottke, Southwest Research Institute

Impact Processes in the Origin and Evolution of the Moon: New Sample-driven Perspectives
PI: David Kring, USRA/LPI

Dynamic Response of the Environment At the Moon (DREAM)
PI: Bill Farrell, NASA Goddard Space Flight Center

Colorado Center for Lunar Dust and Atmospheric Studies
PI: Mihaly Horanyi, University of Colorado - Boulder

The Moon as Cornerstone to the Terrestrial Planets: The Formative Years
PI: Carle Pieters, Brown University

Scientific and Exploration Potential of the Lunar Poles
PI: Ben Bussey, Johns Hopkins University

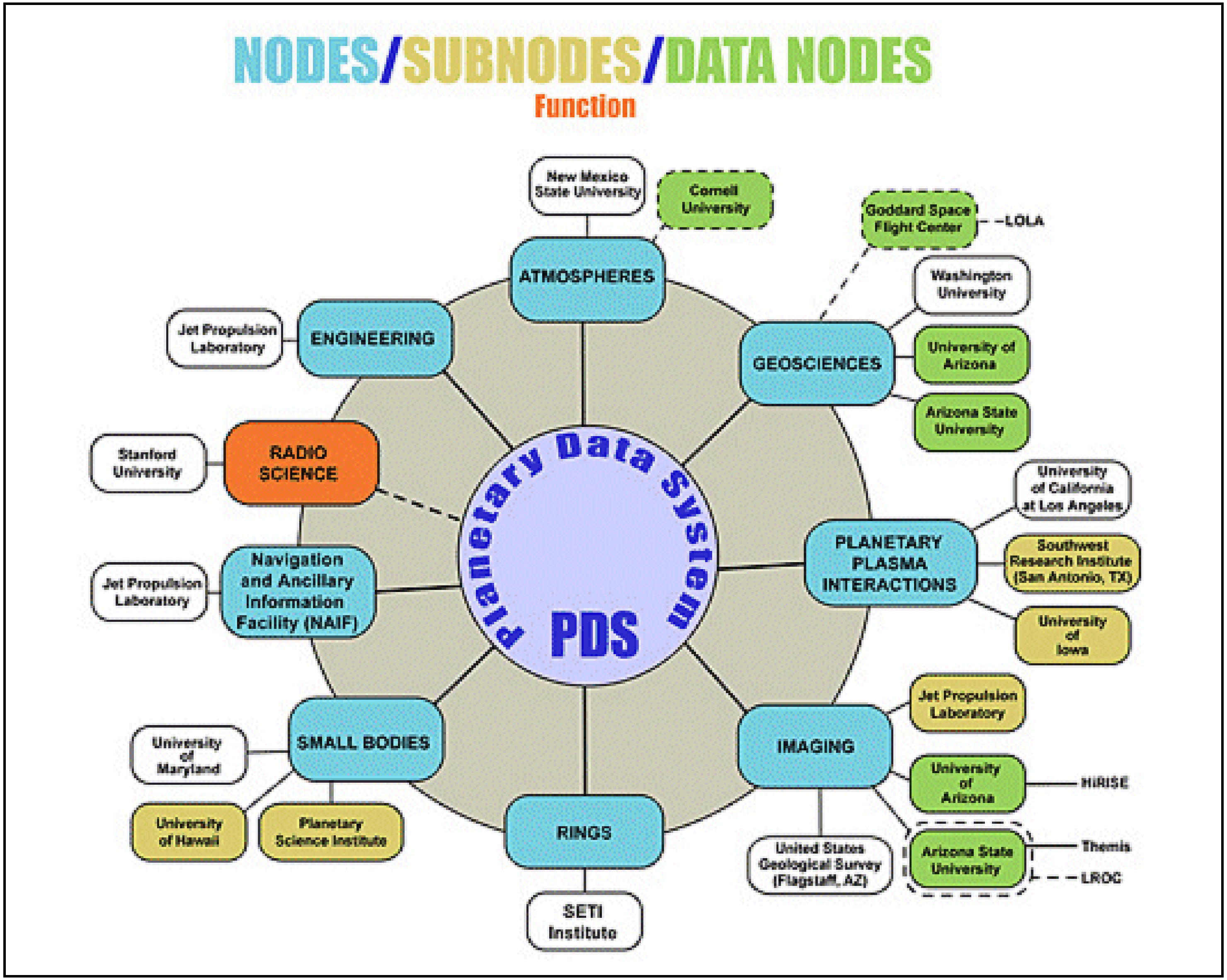
Lunar University Node for Astrophysics Research (LUNAR): Exploring the Cosmos from the Moon
PI: Jack Burns, University of Colorado – Boulder

International Affiliates:

Canada: PI: Gordon “Oz” Osinski, University of Western Ontario

Korea: PI: IM Yong-Taek, Korean Institute for Advanced Science & Technology (KAIST)

United Kingdom: PI: Mahesh Anand, Open University


NODES/SUBNODES/DATA NODES
Function
Planetary Data System
PDS
ATMOSPHERES
New Mexico State University
Cornell University
GEOSCIENCES
Goddard Space Flight Center
LOLA
Washington University
University of Arizona
Arizona State University
PLANETARY PLASMA INTERACTIONS
University of California at Los Angeles
Southwest Research Institute (San Antonio, TX)
University of Iowa
IMAGING
Jet Propulsion Laboratory
University of Arizona
HiRISE
Arizona State University
Themis
LROC
United States Geological Survey (Flagstaff, AZ)
RINGS
SETI Institute
SMALL BODIES
University of Maryland
University of Hawaii
Planetary Science Institute
Navigation and Ancillary Information Facility (NAIF)
Jet Propulsion Laboratory
RADIO SCIENCE
Stanford University
ENGINEERING
Jet Propulsion Laboratory

Mission Enabling Technologies

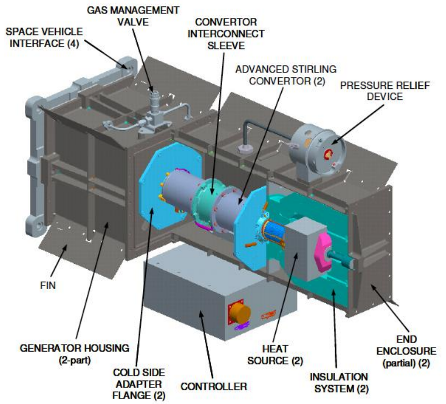
Technology Investment Overview

- Flight mission technologies
  - Radioisotope Power Systems
  - In-Space Propulsion Program
  - Laser Communications (with SOMD)
  - Advanced Multi-mission Operating Systems (AMMOS)
- Mars Technology Program
  - Mission specific technologies for strategic mission
  - Major cutbacks in this program due to MSL overruns
- Instrument Technologies from ROSES
  - Planetary Instrument Development & Definition Program (PIDDP)
  - Astrobiology Science & Tech. for Exploring Planets (ASTEP)
  - Astrobiology Science & Tech. Instrument Development (ASTID)
  - Mars Instrument Development Program (MIDP)

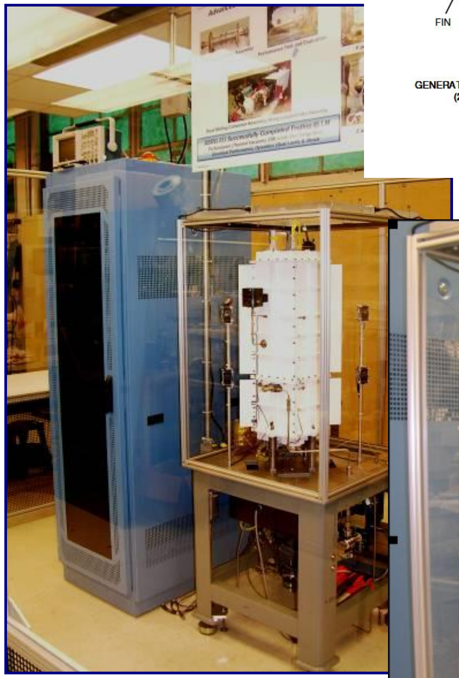
Advanced Stirling Radioisotope Generator Status

- Operation in space and surface of atmosphere-bearing planets & moons
- Characteristics:
  - ≥14 year lifetime
  - Nominal power : > 140 We
  - Mass: ~ 22 kg
  - Specific Power: > 6 W_e/kg
  - System efficiency: > 30 %
  - 2 GPHS (“Pu^{238} Bricks”) modules
  - Uses only 0.88 kg Pu^{238}
- ASRG Engineering Unit (EU) delivered by DOE/LM to NASA Glenn for extended (24/7) operation to provide long-life test
- ASRG EU has operated over 4000 hrs of operation to date (June 09) with no performance degradation identified.
- 2 Flight units to be delivered in 2014

DOE/Lockheed Martin ASRG EU

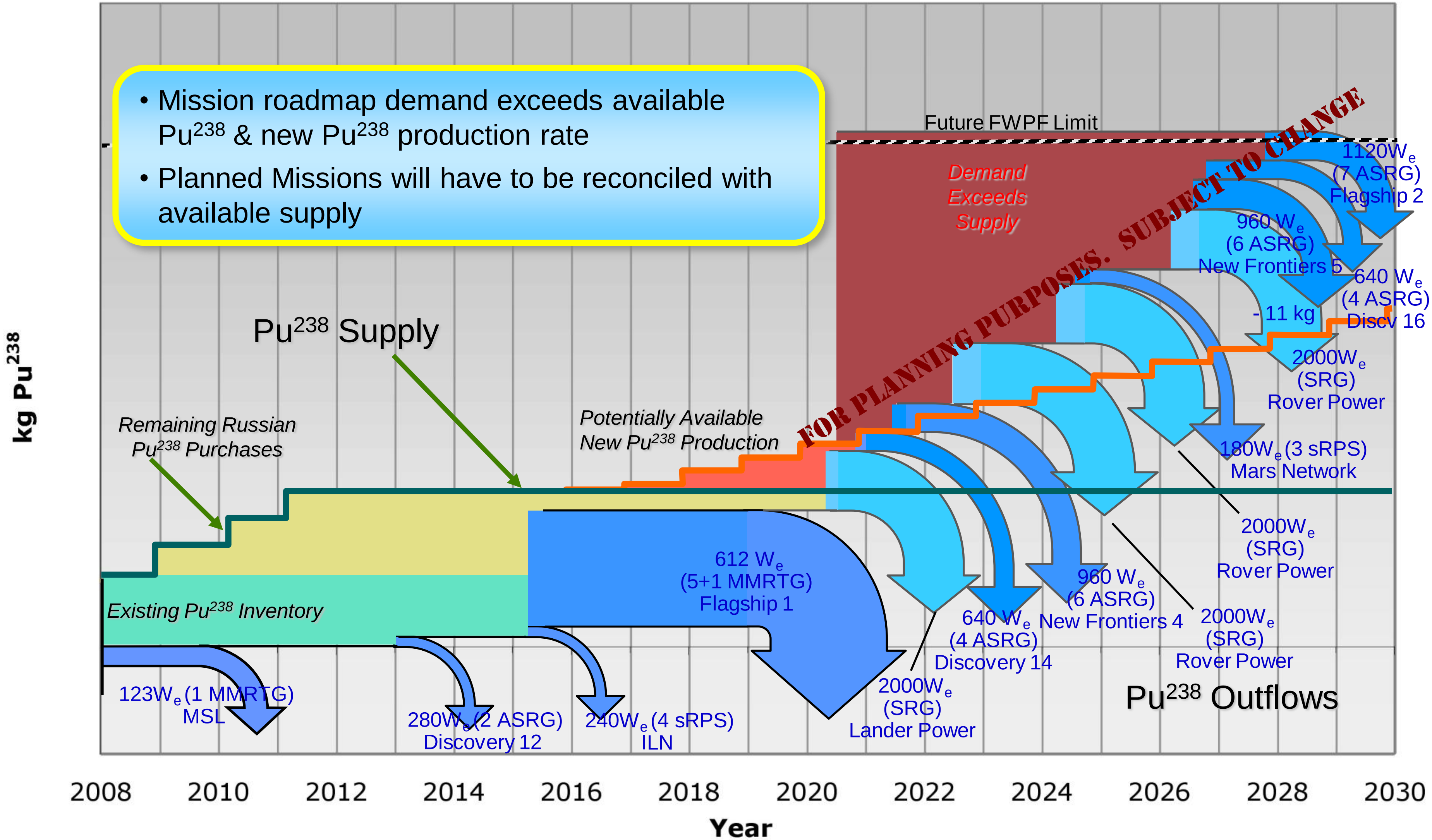


ASRG ENGINEERING UNIT



ASRG EU on test at NASA Glenn

Plutonium Supply vs Potential NASA Demand
Magnitude of the Potential Shortage

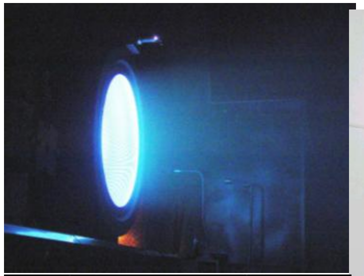


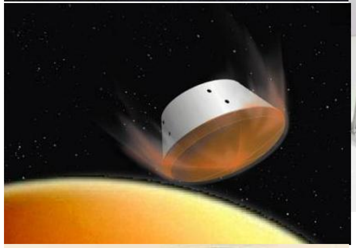
President’s FY10 DOE Budget

The DOE Budget includes funding $30M to start preliminary design and engineering for a domestic capability to produce plutonium-238 for use in radioisotope power systems required for NASA’s space missions and other federal government agencies needs

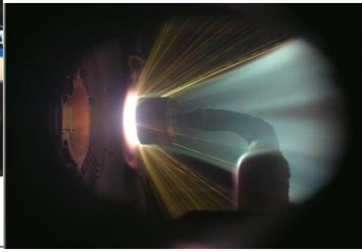
In-Space Propulsion Development

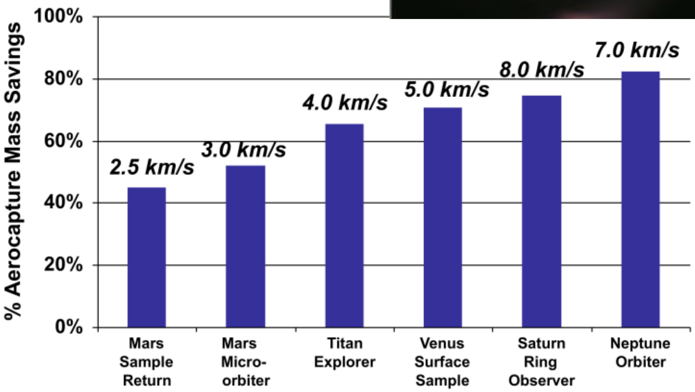
- **Electric Propulsion** – Significantly reduced propulsion/payload mass ratio, reducing planetary trip times, and expanding launch windows
  - NSTAR flying on DAWN
  - NEXT (3x increase in power over NSTAR) undergoing life testing
  - HiVHAC prototype thruster demos completed
- **Aerocapture** - Shorter trip times to outer planets with less propellant; autonomous aerodynamic control technology also enables precision landing.
  - Mission design studies of Mars, Titan, Venus, and Neptune completed
  - Research on materials and sensors on-going, HEAT sensor used on MSL, Lightweight aeroshells
  - Crossover applicability to Orion development





NEXT Thruster

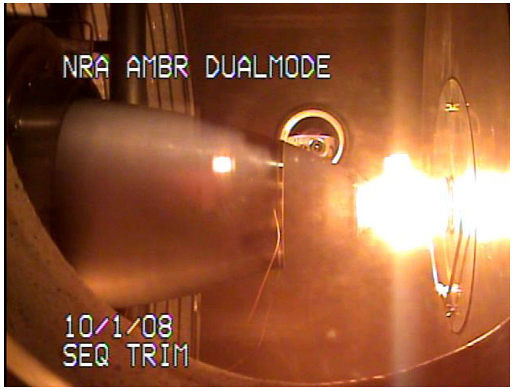




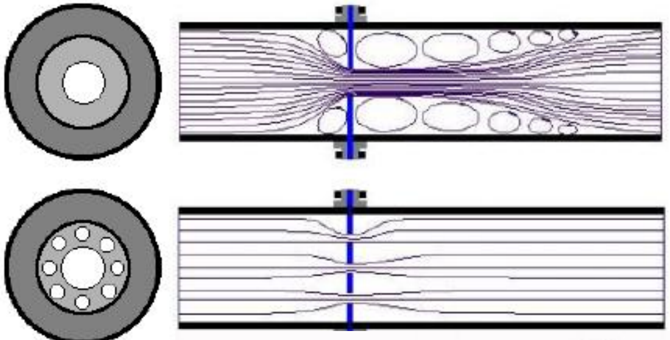
In-Space Propulsion (con't)

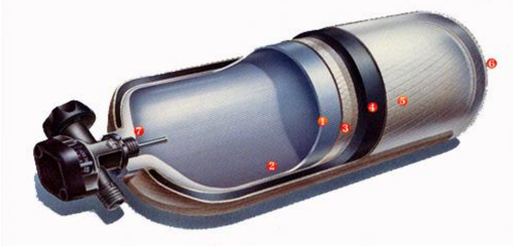
Advanced Chemical Propulsion –
Increased thruster performance to reduce propellant needs and increase payload fraction

- AMBR engine – improving performance from 327 sec to 335 sec Isp w/200 lbf thrust at <70% cost
- Active mixture ratio control and balanced flow meter technology to reduce system inert mass, minimize required residual propellant
- Tank Liquid Volume Instrument enables unique measurement of tank contents in any configuration or gravity environment; enables precise knowledge of state of tank contents during operations and long cruises
- Lightweight tank development



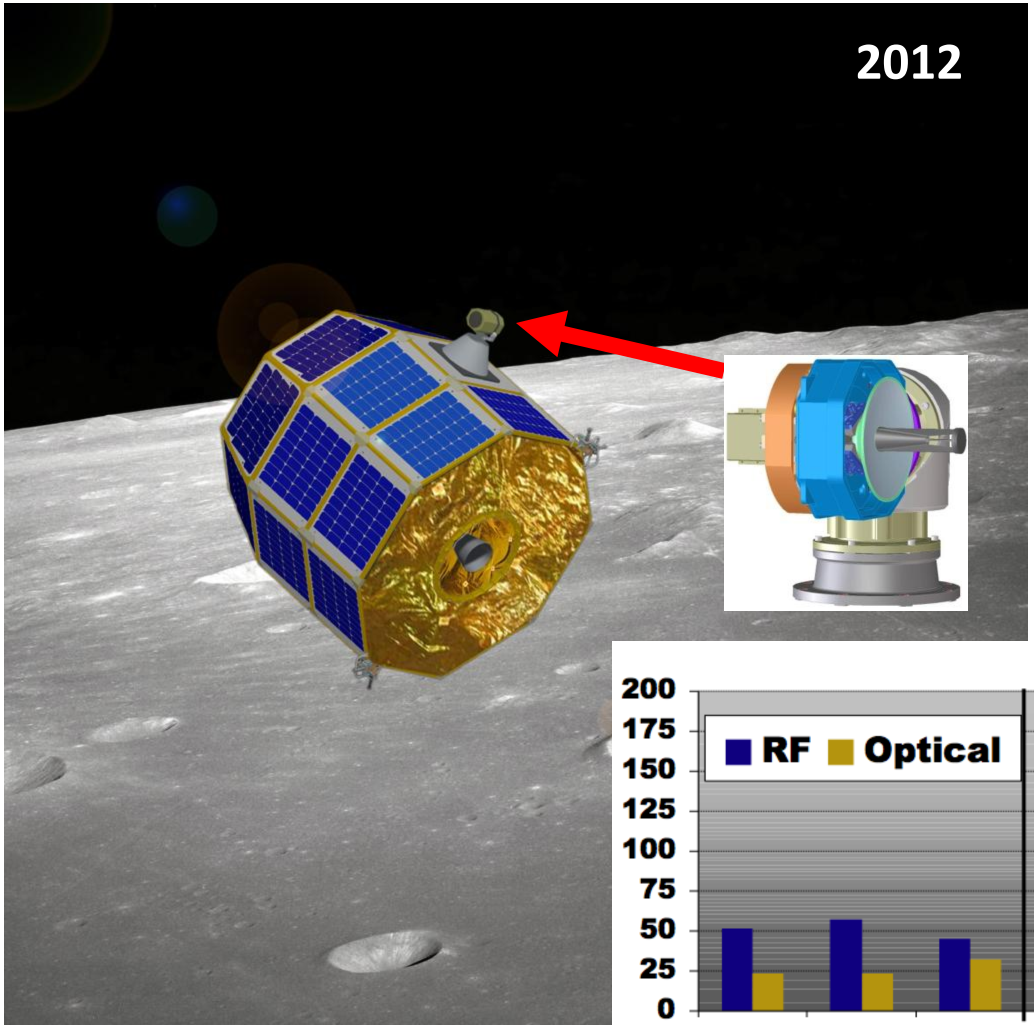
AMBR engine



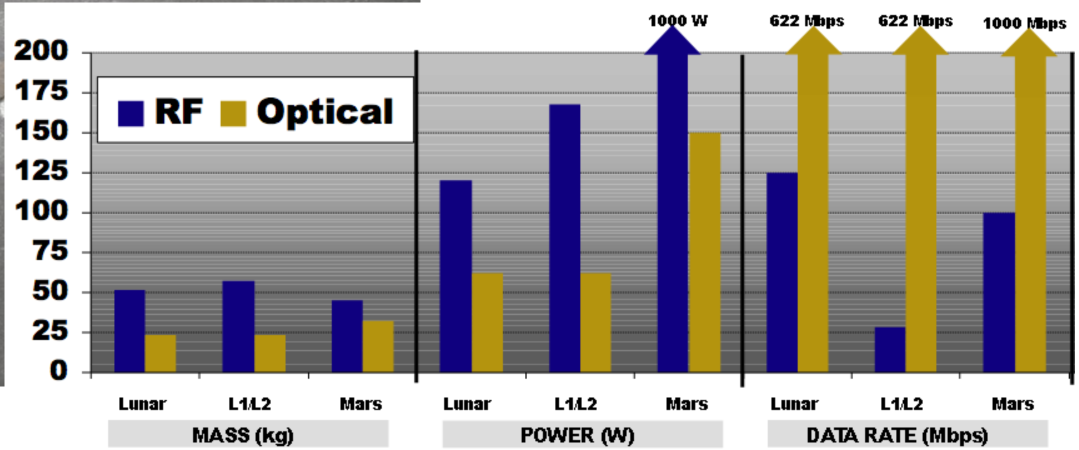


Deep Space Optical Comm Initiative

In Partnership with SOMD, LADEE will fly the 1st DS Optical Comm Demo



- Optical Terminal for LADEE on track
- Earth-based photon-counting technology
- Will provide 600 Mbps from moon
  - 10 cm terminal
  - Earth-based Beacon-aided acquisition & tracking
- LADEE will provide V&V flight time, and post science optical demonstration time
- Science NOT dependent on demo.



International Agreements

International Collaborations

- Many planetary PI missions have foreign instruments (ie: Dawn, Juno…)
- Agreements on foreign missions:
  - ESA: Venus Express, Mars Express, ExoMars, Rosetta
  - ASI: BepiColombo (recently selected)
  - JAXA: Hayabusa
  - ISRO: Chandrayaan-1
  - Statement of Intent – 9 countries for ILN
- Developing Agreements:
  - ESA: OPF, Mars 16, 18, 20 …
  - JAXA: Venus Climate Orbiter

SALMON: Types of Missions of Opportunity

- Traditional MoOs
  - Investigations involving participation in non-NASA space missions (ie: science instrument, technology demonstrations, hardware components …)
- U.S. Participating Investigator
  - Co-Investigator (non-hardware) for a science or technology experiment to be built and flown by an agency other than NASA
- New Science Missions using Existing Spacecraft
  - Investigations that propose a new scientific use of existing NASA spacecraft (ie: NExT, EPOXI …)
- Small Complete Missions
  - Science investigations that can be realized within the specified cost cap (includes all phases from access to space through data publication)
- Focused Opportunities
  - Investigations that address a specific, NASA-identified flight opportunity

NASA's

Planetary Science

Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space

"Flyby, Orbit, Land, Rove, and Return Samples"

Optical Communications Roadmap