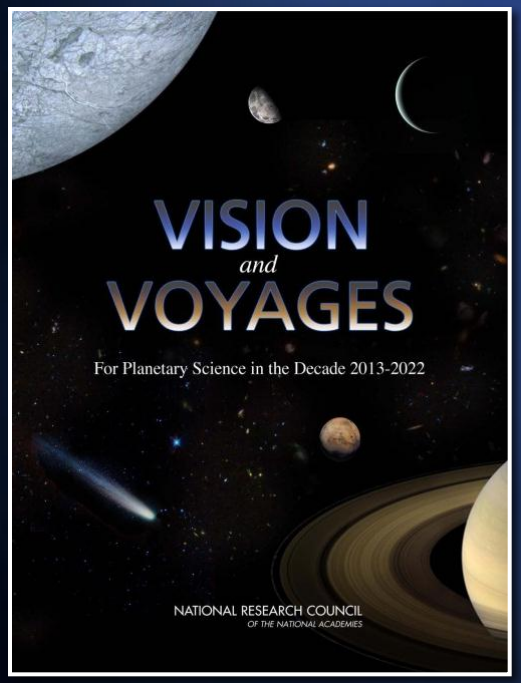
Science Questions and Broad Outline of Technology Needs of the Decade 2013-2022



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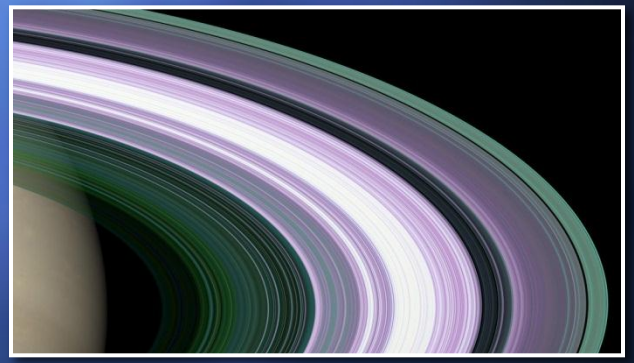
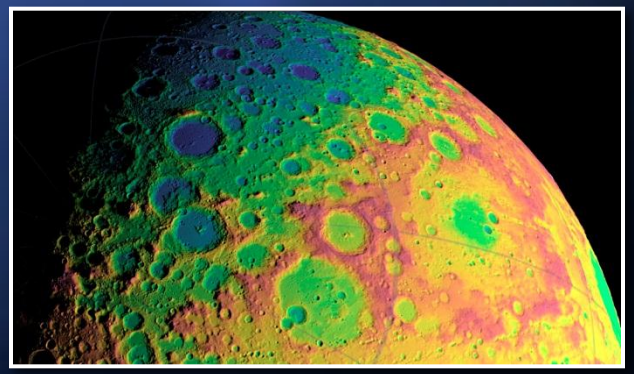
Crosscutting Themes

- The community inputs led to identification of three Crosscutting Themes for planetary science:
  - Building New Worlds: Understanding solar system beginnings
  - Planetary Habitats: Searching for the requirements for life
  - Workings of Solar Systems: Revealing planetary processes through time
- The Decadal report expands on these themes, identifying key scientific questions for each.

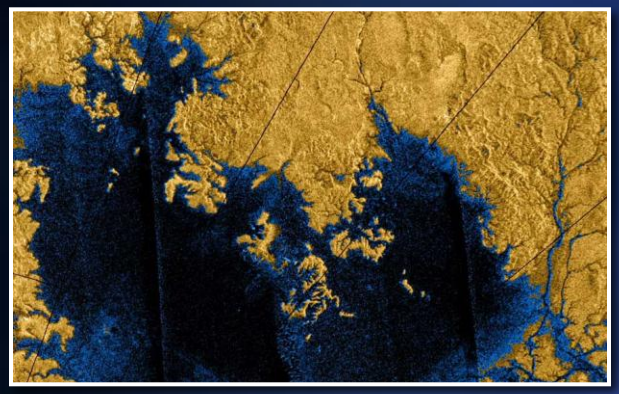
Building New Worlds

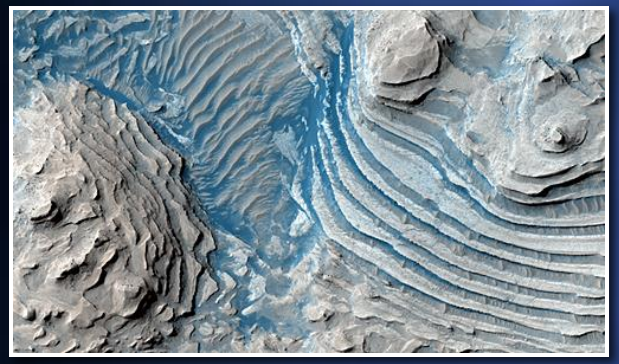
- What were the initial stages, conditions and processes of solar system formation and the nature of the interstellar matter that was incorporated?
- How did the giant planets and their satellite systems accrete, and is there evidence that they migrated to new orbital positions?
- What governed the accretion, supply of water, chemistry, and internal differentiation of the inner planets and the evolution of their atmospheres, and what roles did bombardment by large projectiles play?

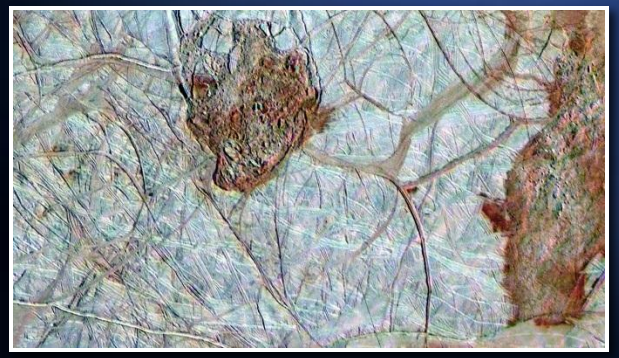




Planetary Habitats



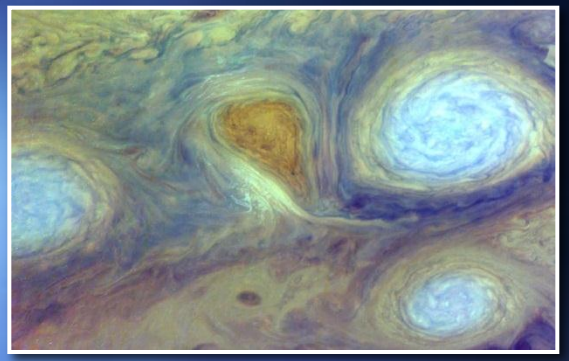




- What were the primordial sources of organic matter, and where does organic synthesis continue today?
- Did Mars or Venus host ancient aqueous environments conducive to early life, and is there evidence that life emerged?
- Beyond Earth, are there modern habitats elsewhere in the solar system with necessary conditions, organic matter, water, energy, and nutrients to sustain life, and do organisms live there now?

Workings of Solar Systems

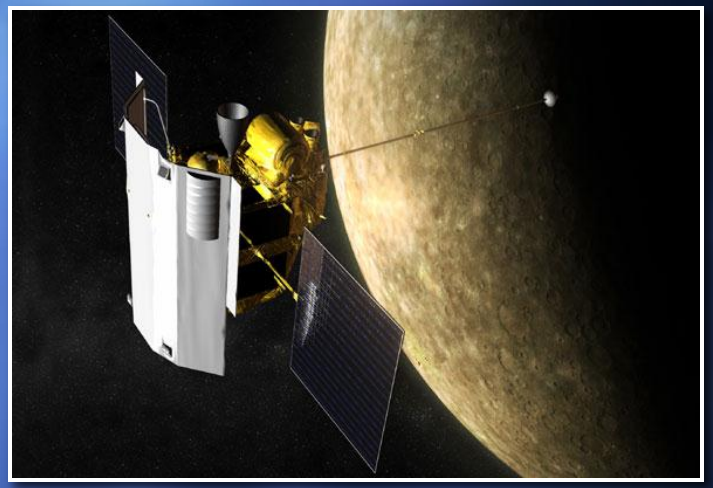
- How do the giant planets serve as laboratories to understand the Earth, the solar system and extrasolar planetary systems?
- What solar system bodies endanger and what mechanisms shield the Earth's biosphere?
- Can understanding the roles of physics, chemistry, geology, and dynamics in driving planetary atmospheres and climates lead to a better understanding of climate change on Earth?
- How have the myriad chemical and physical processes that shaped the solar system operated, interacted, and evolved over time?

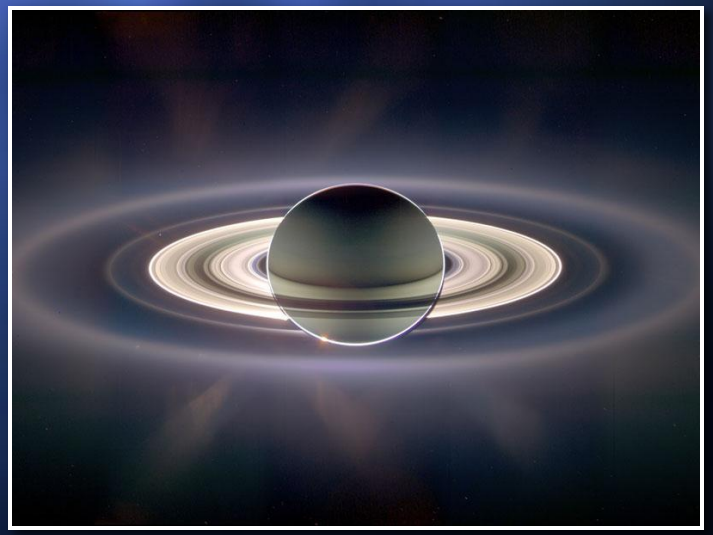


Recommendations of the Decadal Survey

Ongoing and Approved Missions

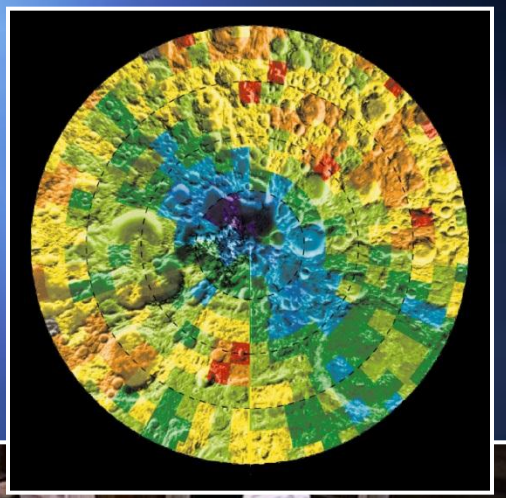
- *Continue missions in development, and missions in flight subject to senior review.*
- Discovery:
  - MESSENGER (in flight)
  - Dawn (in flight)
  - Kepler (in flight)
  - GRAIL (in flight)
  - InSight (in development)
- New Frontiers:
  - NF-1: New Horizons (in flight)
  - NF-2: Juno (in flight)
  - NF-3: OSIRIS-REx (in development)
- Others:
  - Cassini (in flight)
  - ODY/MRO/MER (in flight)
  - LRO (in flight)
  - MSL (in flight)
  - MAVEN (in development)
  - LADEE (in development)

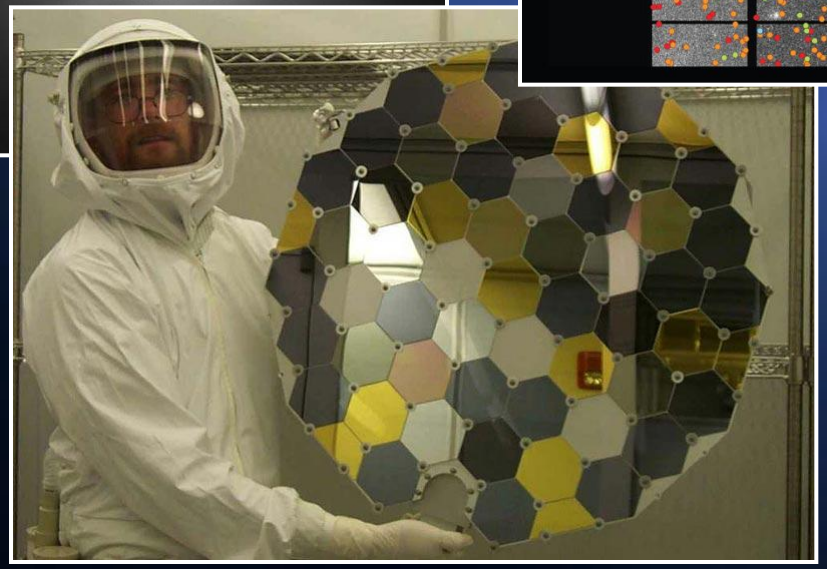




The Discovery Program

- The Discovery Program has produced spectacular and cost-effective science, and can continue to do so well into the future.





The Discovery Program

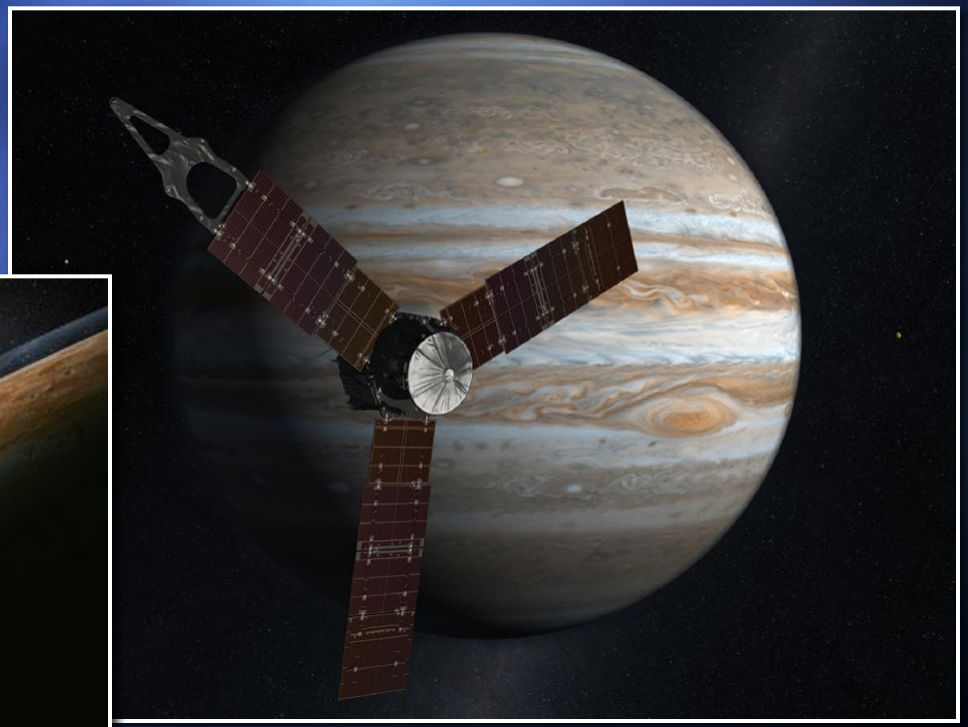
- *Continue the Discovery program at its current funding level, adjusted for inflation, with a cost cap per mission also adjusted for inflation (i.e., to $500 million FY'15).*

- *Assure a regular, predictable, and rapid (≤ 24-month) cadence of Discovery AOs and selections.*

- No recommendations are made for Discovery mission priorities; this is left to the AO and peer review process.

The New Frontiers Program

- New Frontiers missions can address high priority and technically complex science goals that are beyond the capabilities of Discovery missions.



The New Frontiers Program

- The New Frontiers program of PI-led strategic missions has been a success, and should continue.

- *Change the New Frontiers cost cap to $1.0 billion FY'15, excluding launch vehicle costs.*

- *Select New Frontiers missions NF-4 and NF-5 in the decade 2013-2022.*

New Frontiers 4/5 Selection

- Select NF-4 from among:
  - *Comet Surface Sample Return*
  - *Lunar South Pole-Aitken Basin Sample Return*
  - *Saturn Probe*
  - *Trojan Tour and Rendezvous*
  - *Venus In Situ Explorer*

- For NF-5:
  - *The remaining candidates from NF-4*
  - *Io Observer*
  - *Lunar Geophysical Network*

Flagship Missions
(in priority order)

1. Begin NASA/ESA Mars Sample Return campaign: *Descoped Mars Astrobiology Explorer-Cacher (MAX-C)/ExoMars*
   - *MPPG – study of architectures and joint activity with HEOMD, report delivered*

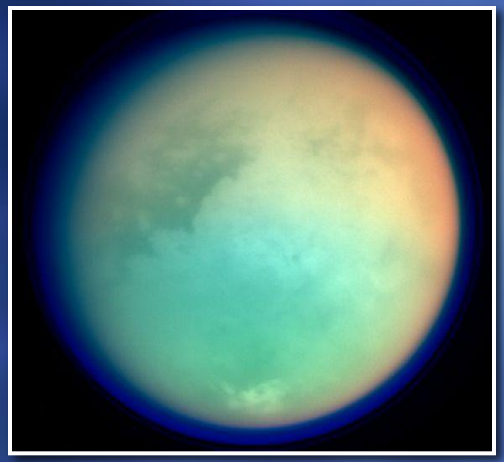
2. Detailed investigation of a probable ocean in the outer solar system: *Descoped Jupiter Europa Orbiter (JEO)*
   - *Descoped missions studied, reports delivered*

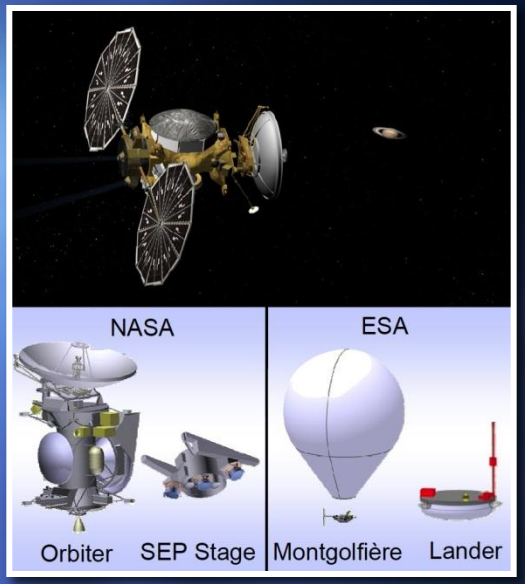
3. First in-depth exploration of an Ice Giant planet: *Uranus Orbiter and Probe*

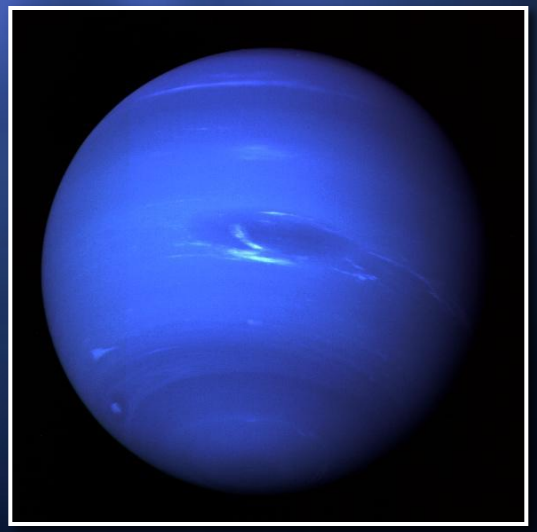
4. Either *Enceladus Orbiter* or *Venus Climate Mission* (no relative priorities assigned)

Future Mission Technology Development Priorities

- High priority missions for future study and technology development:
  - *Titan Saturn System Mission*
  - *Neptune Orbiter and Probe*
  - *Mars Sample Return Lander and Orbiter*







Technology Development

- Technology development is fundamental to a vigorous and sustainable program of planetary exploration:

- *A planetary exploration technology development program should be established, and carefully protected from incursions on its resources.*

- *This program should continue the development of the most important technology items through TRL6.*

- *NASA should continue to provide incentives for NEXT and AMBR propulsion, aerocapture, ASRGs, advanced solar power and optical communication until they are demonstrated in flight.*

If Less Funding Is Available…

- Descope or delay Flagship missions.
- Slip New Frontiers and/or Discovery missions only if adjustments to Flagship missions cannot solve the problem.
- *Place high priority on preserving R&A and technology development funding.*

The Issues Facing Future Missions

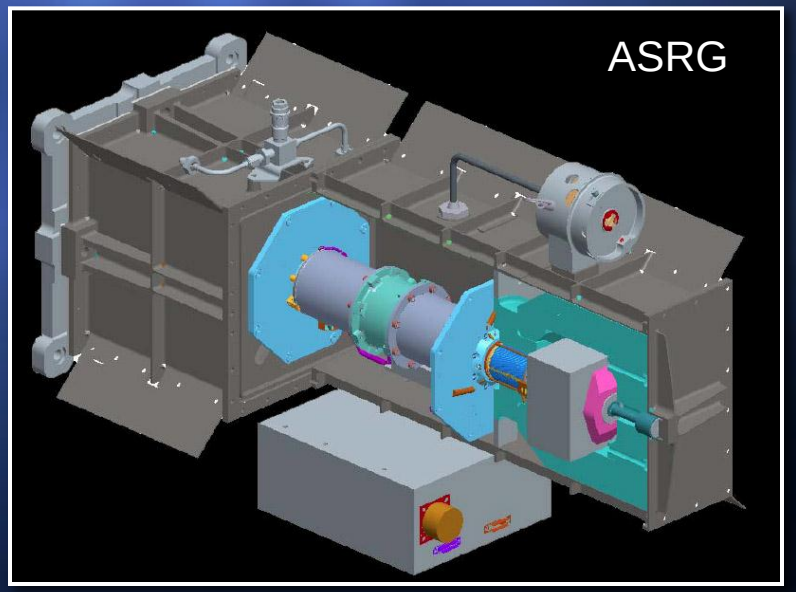
Launch Vehicle Costs

- Launch vehicle costs are rising, and tend to be a larger fraction of mission costs than they once were.

- Steps can be considered to reduce launch costs:
  - Use dual manifesting (two missions on a single launch).
  - Make block buys across NASA, or with other agencies (*e.g.*, DoD).
  - Exploit technologies that reduce flight system mass, allowing use of smaller launch vehicles.

Plutonium-238

- The amount of plutonium-238 available for spacecraft power systems is shrinking alarmingly.
- *Without a restart of plutonium-238 production, it will be impossible for NASA to carry out important planetary missions, particularly in the outer solar system.*
- ASRG development should receive attention comparable to a flight project
- Missions will have lower available power for instruments



The Deep Space Network

- The data problem:

Antenna	Band	Max Data Rate (kbps)[1]	MRO DV (Gbit/8-hr pass)	JEO DV	Cassini DV	Uranus DV	New Horizons DV (@ Pluto)
34-m	X	8400-8500	115		1		0.001
	Ka	31800-32300	86 (non-optimal test case)	*4*		*0.2*	
70-m	X	8400-8500	173		4		0.003
or array	*Ka*	*31800-32300*	*800 (best case)*	*18*		*0.9*	

1 Actual downlink rate depends on s/c transmitter power, HGA size/gain, distance, DSN elevation, weather
2 In downlink limited cases, on-board storage exceeds playback capability

Legend: DOWNLINK LIMITED CASES
Theoretical capability

- *Expand capabilities to meet requirements of recommended missions.*
- *Maintain high-power X and Ka band uplink, and S, X, and Ka band downlink at all three complexes*
- *On-board processing, data compression, data selection could become crucial*

Interaction With Human Exploration

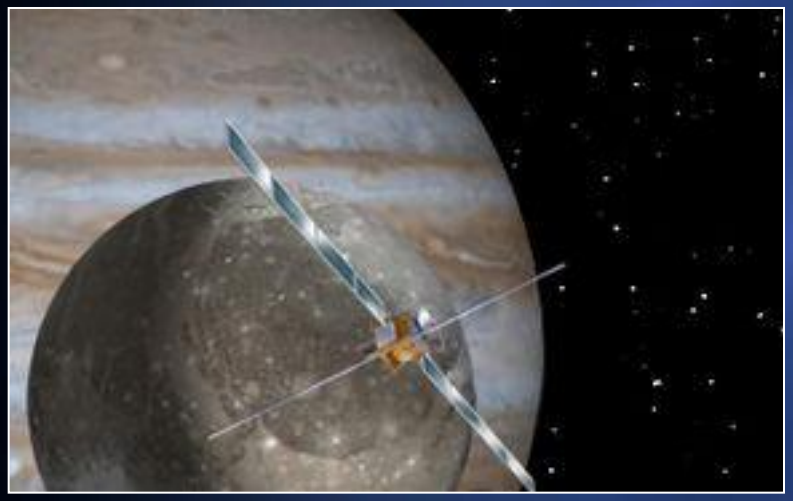
- Some solar system bodies are likely targets of future human exploration:
  - The Moon
  - Asteroids
  - Mars and its moons

- *It is vital to maintain the science focus of peer-reviewed NASA missions to these bodies.*

- Both the Space Science program and the human exploration program can benefit from carefully crafted intra-agency partnerships (LRO is a good recent example).

International Collaboration

- All Decadal Flagship missions assumed international collaboration
  - *e.g.*, Cassini, Mars Trace Gas Orbiter



- Since Decadal:
  - Opportunity to propose instruments for JUICE (~$100M NASA contribution to ESA's L-class mission)

- Expect these types of collaborative missions to continue, and increase, in the future

Since the Decadal…

Many new instrument opportunities

Not just in Planetary…

Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO)

- Supports the development of spacecraft-based instrument systems that show promise for use in future planetary missions
- Conduct planetary and astrobiology science instrument feasibility studies, concept formation, proof of concept instruments, and advanced component technology development to the point where they may be proposed in response to the Maturation of Instruments for Solar System Exploration (MatISSE) Program. (TRL 1-3)
- Likely to be solicited in ROSES-13.
- Budget is ~$3.5 M per year. The average award is ~ $275K per year per proposal.

Maturation of Instruments for Solar System Exploration (MatISSE)

- Supports the advanced development of spacecraft-based instruments that show promise for use in future planetary missions.
- Develop and demonstrate planetary and astrobiology science instruments to the point where they may be proposed in response to future announcements of flight opportunity without additional extensive technology development. (TRL 3-6).
- MatISSE solicited in ROSES-2012 (Appendix C.16) with proposals due by Oct 31, 2012
- Budget is ~$1M per year per proposal

In-Space Validation of Earth Science Technologies (InVEST) Program

- Technologies that require validation in space (TRL5-7).
  - Proposers are responsible for providing their own access to space
- Instruments or subsystems that can advance the technology to enable Earth science measurements; components are specifically excluded from this call.
  - Ready for launch within two years after award.
  - No science measurement is required, but is permitted if it is required to validate the technology.
- *Proposals are due by November 27, 2012, up to $3M for 1-3 years*

Next Steps

- Take advantage of new and existing programs to advance instrument maturity:
  - Planetary: PICASSO, MATISSE
  - Earth science: InVEST, ACT, EVI, IIP
  - HEOMD: ISS, other opportunities
  - Balloons, sounding rockets, etc.
- Be cognizant of current mass and power limitations on most spacecraft
  - Developments that ease the need for resources will help
  - Tech development opportunities with HEOMD