NASA Missions: from Concept to Launch

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Overview

- The who, what, when, where and why…
  - Who makes the decisions on missions?
  - What does a person do to get a mission chosen?
  - When are decisions made, missions launched?
  - Where will the next mission go?
  - Why there?
- Roles of various people and skills…

Outline

- Community and Political aspects of mission selection
  - Input in NASA decisions
- Mission classes
  - Flagship and directed missions
  - PI-led missions
- Choosing missions
- Where various degrees and jobs fit into the process
- Proposal and Conceptual Design Process
  - Considerations to include
  - How ideas come get to the next step
  - Technology development needs for individual missions
  - Actual proposal mechanics
- Mission Phases
- Results
- Future

So, you or your team has an idea…

- You can't just build a spacecraft and fly
  - Long and involved process to get a mission approved
  - A lot of background study is required
  - Many deadlines, reviews and requirements must be met
- But it starts out with an idea that meets a need or answers an important question.

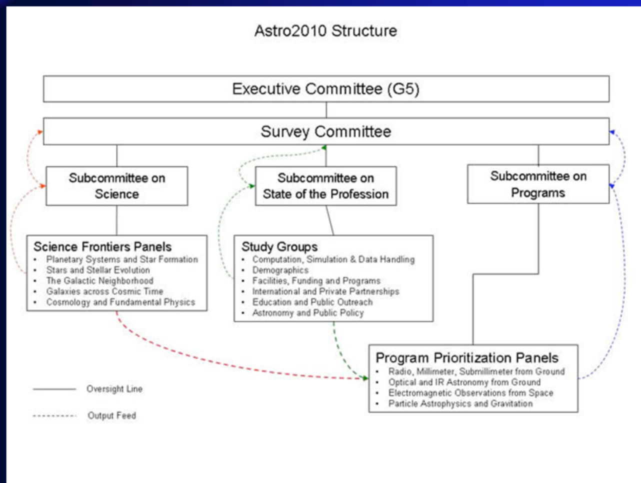
The People & Politics of Space

- Scientists are asked to give input in various forums on where priorities should lie.
  - Produce: Strategic roadmaps, exploration roadmaps, Decadal Surveys, white papers
  - This represents science *community* input on what NASA should do
  - No such thing as true consensus
- NASA is not obligated to follow any of it, but does most of the time.
  - Official advisory structure in place

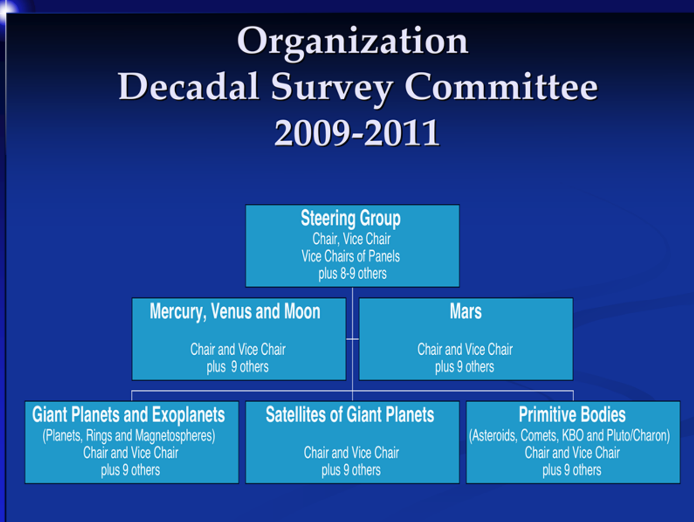
External Input to NASA

- The National Academies (National Research Council) provides independent feedback and studies.
  - Commission and produce Decadal Surveys, other studies, as requested by NASA or White House OSTP
  - Space Studies Board (SSB)
    - Committee on Planetary and Lunar Exploration (COMPLEX)
  - International Committee on Space Research (COSPAR)
  - Decadal studies for each science discipline area

Astrophysics Decadal



Solar System Decadal



NASA Advisory Structure

- The NASA Advisory Committee (NAC) is a federally-appointed committee
  - Subcommittees: planetary and space science (PSS), astrophysics, Earth science, etc.
    - Background, financial interests checks
      - Often the rules prevent them from really providing input (conflicts of interest)
      - Community assessment groups can give input to subcommittees
- All advice filters upward through the NAC chair to the NASA Administrator

Note on External Politics

- The initial Space Race was all about competition with the “bad guys…”
  - That doesn’t work these days, yet some still try to play this card
- Can be difficult working with other countries, because of rules about technology and $$ transfer
  - However many missions have some international aspect
  - ISS obviously, but also many robotic missions
- Congressional lobbying

Note on Human Exploration (non robotic)

- NASA works (and reworks) designs based on congress and Whitehouse goals and budgets.
- Large contract competitions and assigned work to large centers is at stake, so;
  - Very susceptible to budget woes, presidential elections, congressional micromanaging and insights, etc
- Moon landing and eventual base replaced with flexible architecture, capable of expanding to the Moon and Mars landing but designed for now for going beyond low earth orbit to an asteroid or a L2
- Latest approach ;
  - A SLS heavy lift launch vehicle expandable in the future to a SLS2 capable of moon landing
  - ORION crew capsule
  - Mars and small bodies precursor missions – combined effort with science missions

Current NASA Robotic Mission Classes

- Flagship class
  - Large, generally not competed, but directed
  - Biggest of our missions: \$1B-\$3$^+$B
- Principal Investigator class
  - Smaller, proposed, missions
  - Range from very small (SMEX, ~\$120M)
  - To medium (MIDEX, Discovery ~\$475M)
  - To large (New Frontiers, ~\$900M)
    - Congressionally limited to <\$1B
  - Only some mission classes allow radioactove power sources - RTGs/RPSs/ASRGs
    - Must launch on U.S. launch vehicles

Flagship Mission Life Cycle

- Offer in-depth studies, cover many science objectives, etc. Assigned by NASA HQ.
  - LONG development time, can be decades
  - Goals decided by science definition teams
  - Propose instruments, international participation
  - Expensive
  - Expected to last a long time
- Think Voyager, Hubble, Galileo, Cassini, JWST

What are the next Flagships?

Flagships have been reduced in new budget

- **Astrophysics** - James Webb Space Telescope (2018) is it for now, WFIRST (dark energy), and LISA (gravity wave), delayed due to budget
- **Earth Science** - JPSS (Joint Polar Satellite System with NOAA), and a collection of 15 missions over 10 years all at $1B or under so not exactly flagship, but not all competed.
- PACE . ICESAT
- **HelioPhysics** - Magnetospheric Multiscale mission (2014), Solar probe Plus (2018)
- **Planetary:**
  - Mars Science Laboratory (Landed Aug 2012)
  - Mars sample return and Europa-Jupiter System cut with new budget. Replaced by Mars 2020 rover.
  - ESA Cosmic Vision missionJupiter/Ganymede
  - Mars 2020 rover

How did exact version of flagship get chosen?

- Old days: community agrees on a target via decadal process, studies are done, NASA directs the work
- New paradigm
  - Studies were directed to several organizations
    - Science goals and mission concepts studied
  - Down-select to two
  - Final down-select after technical, management, cost review.
  - Budget pressures change the design even after that.

Why there? Decadal Studies Why is Mars and Jupiter/Europa ahead of other icy moons and Uranus and why is Uranus ahead of Neptune?

- They are all scientifically interesting!!
  - Europa may have subsurface water
  - Enceladus has active geysers
  - Titan has a cloud/methane rain cycle, organics
- Some missions have need less technology developments which reduces risk and cost
  - Autonomous landers or surface impactors, balloons
  - Radiation environment mitigation (Europa)
- Some other targets require major technology advances to make those missions more reasonable
  - Aerocapture , nuclear power sources, electric proplusion, laser comm
  - In decadal some practical things effect decision – flight dynamics dictate Uranus is accessible for the next decade and Neptune is not
- Have to balance mission portfolio

Smaller Mission Proposals

- Goals of recurring Announcement of Opportunities (AOs) set by decadal process.
- NASA releases an Announcement of Opportunity
  - Can be for research, instruments for a mission, or an entire PI-class mission
  - Sometimes a draft is pre-released
- First deadline is the Notice of Intent
  - A non-binding statement saying you will propose
- Overall deadline is ~3-6 months later
- Requirements and guidelines are posted
  - Can limit who can submit!
    - May or may not have certain power or propulsions available
    - Targets can be limited based on decadal survey
    - Launch vehicles and dates may be restricted

Mission Teams and partners - Engineers, managers, scientists?

- A proposing institution - mainly GSFC, JPL and APL for robotic missions – creates an internal strategy a few years before an AO based on decadal science goals, predictions of what can win that AO and cost, internal capabilities, etc.
- Chooses partners that include science partners, engineering partners, instrument partners, etc
- Work on preliminary designs on internal money.
- Proposal design, costing, writing and submission.
- Win step 2, do a Phase against one or two other competitors.
- Final down-select
- Form implementation team and go into preliminary design phase

What goes into a proposal?

- EVERYTHING.
  - Science justification
    - Instruments/measurements to meet science goals
    - Chart tying those goals to planning documents
  - Cost & Schedule, of EVERYTHING
  - Trajectory, propulsion, power & other info
  - Risk Assessment
    - Technology, cost, slip of launch date, science return
  - Planetary Protection Assessment

Driving mission requirements, and the resulting top level mission options

- Science needs that could win over competition.
- Driving requirements – systems engineers, science team, other engineers.
- Top level design options to be traded.
- Measurement needs – instrument types and design options –
- Spacecraft type, propulsion, flight dynamics options, mass, power, instrument trades, etc

Choice of Launch Vehicle


- The biggest U.S. vehicles on the current manifest are Atlas V and Delta IV Heavy
  - Saturn V are the biggest we've ever launched (Apollo)
    - Cassini launched on a Titan IVB, with 2 extra solid rockets and a Centaur upper stage
    - New Horizons launched on an Atlas V, 5 SRBs
  - Some smaller commercial options:
    - Airborne: Pegasus (from B-52 or L-1011 aircraft)
    - Falcon 9
    - Taurus, Minotaur,
    - ESA (Ariane), Russia (multiple), Japan (HII)
- Depends on the size, shape and trajectory of spacecraft

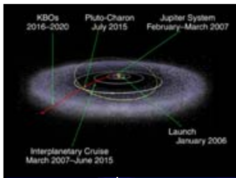
Launch Sites

1 Vandenberg
2 Edwards
3 Wallops Island
4 Cape Canaveral
5 Kourou
6 Alcantara

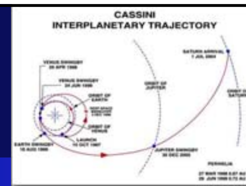
Hammaguir
8 Torrejon
9 Andoya
10 Plesetsk
11 Kapustin Yar
12 Palmachim

13 San Marco
14 Baikonur
15 Sriharikota
16 Jiuquan
17 Xichang
18 Taiyuan

19 Svobodny
20 Kagoshima
21 Tanegashima
22 Woomera



Trajectory



- How will you get there?
- Direct launch to target is most expensive way to get there, timing is critical
  - Most launch vehicles can't get you there
- Minimum energy methods are cheapest (and slowest)
  - Use transfer orbits from Earth to target and flybys of earth or other objects as sling shots
  - "Interplanetary superhighway" uses Lagrange points
- Best method uses gravity assists
  - Usually Venus, Earth and/or Jupiter depending on alignments
  - Other targeting maneuvers can speed up journey

Propulsion

- Chemical propulsion used to be the only game in town – solid rockets and engines
  - Two flavors: Mono-prop, bi-prop
  - Bi-prop more efficient, but more complex
- Ion and solar electric propulsion options
  - Generate high energy ions
  - Constant acceleration to get to high speed
  - Solar requires inner solar system passes, drops solar array near 3 AU
  - Can be used to gradually slow down approaching target, too.
- Have considered nuclear reactors

Spacecraft and Instrument designs

- Measurement needs – instrument types and design options – Optical, mechanical, detector, thermal, performance, maturity, risk and cost trades.
- Iterate to lower level reqs and resulting Spacecraft type and mass, propulsion, flight dynamics options, mass, power, instrument trades, etc)
- Iterate to more detail and then to cost as head towards proposal writing phase.

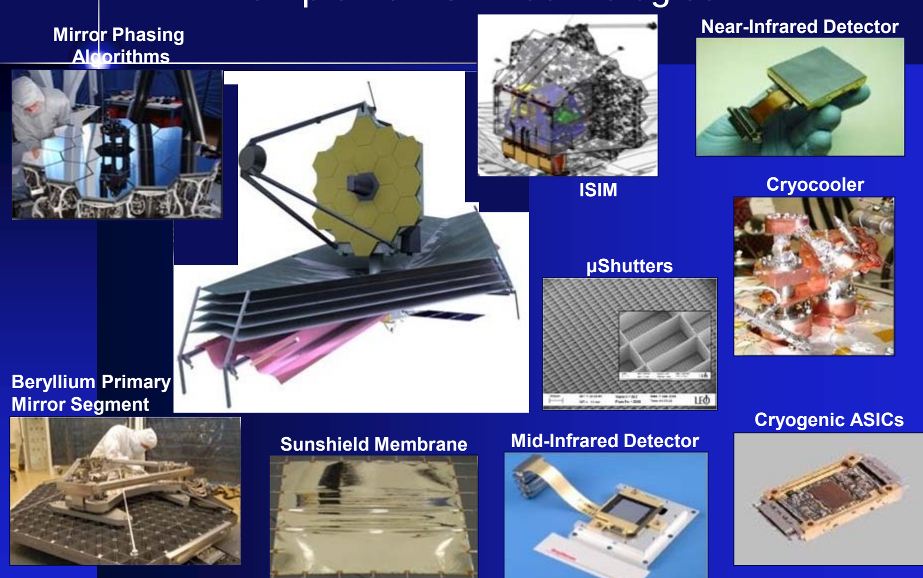
Planetary Protection

- The risk of forward contamination from microbes on the spacecraft, etc.
  - Can ruin some experiments
- OR the risk of contaminating Earth with any returned samples (backward contamination)
- This office also deals with the risks from launch and any Earth flyby(s)
  - Hazardous substances, radiation, etc.
  - Deal with EPA, public concerns

Wait, did you say radiation?

- Solar power and batteries can't be used to power systems on deep space spacecraft.
  - Radioisotope Thermal Generators (RTGs) use plutonium 238 to convert heat into electricity.
  - Now called Radioisotope Power Systems (RPS)
    - Working on newer, better efficiency, converters using less Pu, because we have so little available.
  - Also use Radioisotope Heat Units (RHUs) in some cases
- SO, what if it blew up?
  - Nothing would happen
  - Heavily shielded and if it DID vaporize, it would amount to less than the normal daily radiation
- Some missions, for example, to Jupiter have to be designed to high external radiation levels seen in many Jupiter orbits

Needed Technology Development – Example - JWST Technologies



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James Web Space Telescope- Full scale model at GSFC


NASA Space Technology Programs
Transformative & Crosscutting Technology Breakthroughs
Pioneering Concepts/ Developing Innovation Community
Creating Markets & Growing Innovation Economy
Game Changing Development
Technology Demonstration Missions
Small Spacecraft Technology
Space Technology Research Grants
NASA Innovative Advanced Concepts (NIAC)
Center Innovation Fund
Centennial Challenges
Small Business Innovation Research & Small Business Technology Transfer (SBIR/STTR)
Flight Opportunities
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Turning Science Fiction into Reality

- Goddard engineers won a NASA Innovative Advanced Concepts (NIAC) award to investigate three techniques for trapping and moving objects using laser light
- The technology is a potential technique for gathering particles and transporting them via laser to a scientific instrument for analysis
- If developed, the technique could revolutionize NASA's current sample-collection methods, including aerogels and robotic rovers that drill and scoop samples

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Early Stage Innovations

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Start to finish – part 1

- Pre-proposal work: 1-2 years before AO
  - Take idea, define science goals, instruments
  - Plan your design, figure out partners, who builds what, cost, schedule
  - Technology work may begin 3 to 5 years earlier
- Pre-Phase A: 6 months before AO
  - Serious design and feasibility work
  - Check on all those required areas
- AO until due date 30 days later
  - Write and review

The Decision…(part 2)

- Submit your 100^{+}-page proposal and wait…
- After the proposal deadline, a panel of experts is convened to review them
  - Reviewed for scientific merit and graded
  - Reviewed for risk, cost and feasibility
  - 1-3 concepts selected for further analysis, called Phase A
    - First time you see any money to do this work!
    - 8 to 12 months resulting in Phase A report proposal (~1500 pages) and no weekends or sleep

Phases B-D

- At most, one mission is awarded Phase B money:
  - Detailed mission design and development
  - Risk reduction.
  - Remaining design trades resolved and reviewed
  - Full technical, management, cost oversight review
  - Response to any Phase A weaknesses
  - Preliminary design is reviewed at PDR
- Phase C/D: Design and Development
  - Final design details and long lead item start up.
  - Critical design review ends phase C and begins Phase D where you can start building and testing everything
- Formal reviews done at every stage to determine if you continue or if there are flaws that should be addressed

Integration and Testing

- Each component must be tested separately and together
  - Vibration testing
  - Thermal vacuum testing
    - -300 to +250° F
  - EMF testing
- Validation and Verification
  - Performance tests. Does everything do what it's supposed to do?
  - Completion of all tests for hardware results in readiness for launch vehicle integration

Roles of various disciplines

- **Organizations** - NASA centers, APL, JPL, prime contractors like Ball and LM, universities for scientists- PIs (Principal investigators) and CO-Is and some instruments .
- **Scientists** – PIs, CO-Is with concentrations on the mission, project scientist, deputy PI, instrument provider.
- **Engineers** – Science instrument - (optics, detector, electronic, mechanical, systems, thermal, structural) spacecraft and mission - (control, flight dynamics, mechanical, power, propulsion, structural, thermal, systems, manager).

Phase E: Launch, check out and operations

- No mission is ever safe from cancellation until it is off the launch pad!
  - Yes, missions have been cancelled after being built
  - May seem like a waste of $$, but operating a mission for years and years is also more $$
- Once launched, must manage operations during cruise to target

Final Destination

- You've arrived…
  - For most earth science and many astrophysics and heliophysics missions that starts right away in low earth orbit.
  - For planetary missions If you have a mission that orbits, you must slow down A LOT
    - Complicated operations scenarios
    - May be dependent on engines that haven't fired in 10 years or risky aero-capture maneuvers!
    - Lander must separate from the carrier spacecraft and enter – atmosphere slows them down
  - Flyby missions & probes have short scientific lives
- Must manage science operations, navigation, communication with Earth
  - For deep space missions, most commands sent to the craft ahead of time (days, months)
  - Will have black-out periods where it can't be seen.

GSFC Missions in Development or Recently Launched

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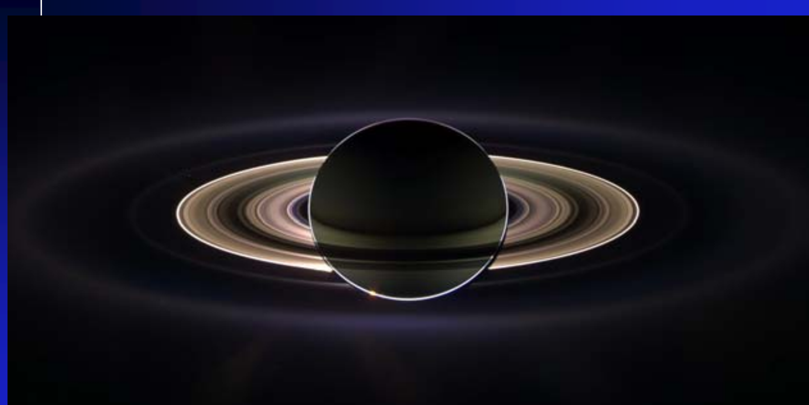
The science results and discoveries are the main goal and payoff

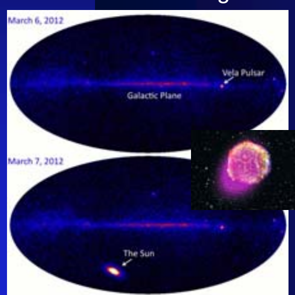


Back-lit Saturn from Cassini

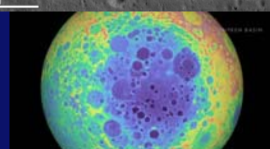
Recent results from missions in the last 12 months

DAWN- Vesta images

Hubble- Double nucleus in Andromeda Galaxy



FERMI Maps

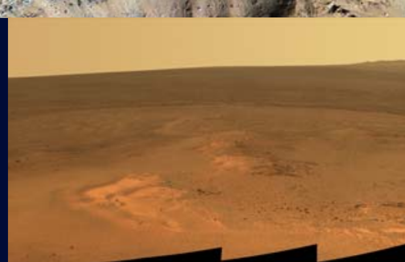


LRO lunar maps

Cassini Enceladus ice Plume

Recent results from missions in the last 12 months

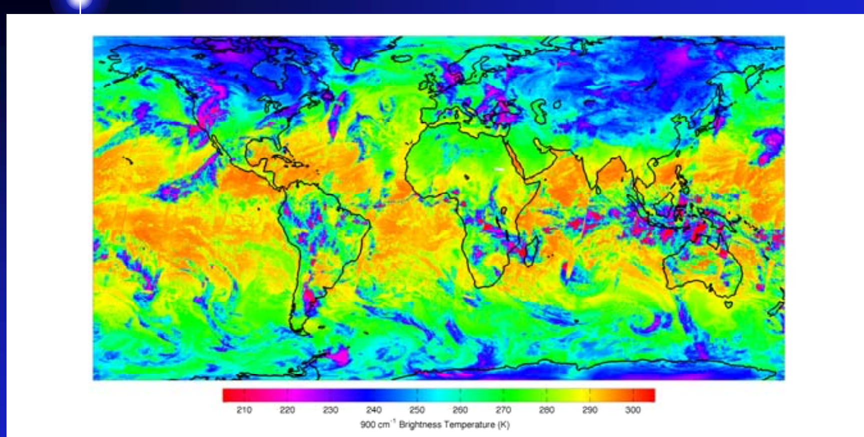
HIRISE orbit image of crater walls, Opportunity rover picture of winter site (left), dust devil caught from orbit.



Recent results from missions in the last 12 months

MSL landing – new lander and rover designs and approach

Recent results from missions in the last 12 months



Suomi NPP infrared sounder- see surface temps -Jan 2012

What comes next: Planetary - New Frontiers, JUICE ESA mission

- New Frontiers 2, Juno, launched2012
- New Frontiers 3 one year ago.
  - 3 missions chosen for Phase A
    - Moonrise, SAGE (Venus), OSIRIS-REx (Asteroid Sample Return)
    - OSIRIS (GSFC) was selected.
- Discovery 12 this year
  - 3 missions chosen for Phase A out of 28 - Insight (Mars), Chopper (Comet hopper), TiME (Titan Boat lander)
  - Insight selected
- JUICE instruments (Jupiter and moons mission)
  - NASA/US parts of ESA instruments selected as part of joint proposals

Planetary - Discovery

- Now launched ~15 missions
- Latest AO resulted in downselect to three missions out of 28
  - At least 30 concepts proposed, TiME (Titan boat lander), Chopper (Comet hopper, UMD and GSFC, go Terps) and INSIGHT (Mars seismology lander) chosen. Step 2 s submitted last week.
  - Two use ASRGs (Advanced Stirling Radioisotope Generator) and not solar panels.
  - Insight selected

Solar physics and astrophysics - Explorers

AO is for Helio (Solar) physics and astrophysics missions, Three down selected for Phase A CSR plus a few attached payloads;

- Atmosphere-Space Transition Region Explorer (ASTRE) and the Ionospheric Connection Explorer (ICON). ASTRE, led by Dr. Robert Pfaff, Jr. of NASA's Goddard Space Flight Center, would study the interaction between the Earth's atmosphere and the ionized gases of space.
- ICON, led by Dr. Thomas Immel of the University of California at Berkeley, would fly instruments to understand the extreme variability in the Earth's ionosphere.
- Transiting Exoplanet Survey Satellite (TESS) team on an astrophysics mission. The proposed TESS mission, led by Dr. George Ricker of Massachusetts Institute of Technology and managed by NASA's Goddard Space Flight Center, would perform an all-sky survey using an array of telescopes to discover planets orbiting nearby stars and seek to identify Earth-like planets.
- NICER – x-ray source detectors and telescope and active x-ray navigation test

Earth science

- Latest AO, EVI, was for EVI instruments on com-manifested rides - Down select due next month.
- Potential Non-JPSS missions in the next 3 years;
  - Orbiting Carbon Observatory-2 for launch in 2013
  - The ICESat mission will provide multi-year elevation data needed to determine ice sheet mass balance as well as cloud property information, especially for stratospheric clouds common over polar areas.
  - Deformation, Ecosystem Structure and Dynamics of Ice, or DESDynI, mission will use specialized sensors to study land surface and climate changes.
  - The PACE mission will make global ocean color measurements to provide extended data records on ocean ecology and global biogeochemistry (e.g., carbon cycle) along with polarimetry measurements to provide extended data records on clouds and aerosols. Understanding of impacts and feedbacks of the Earth system to climate are critical importance.

Planetary Decadal Mission Studies

- Mercury Lander
- Venus Mobile Explorer
- Venus Tessera Lander
- Venus In Situ Explorer*
- Venus Climate Mission
- Lunar South Pole/Aitken Basin Sample Return*
- Lunar Network
- Lunar Polar Volatiles Mission
- Mars Trace Gas Orbiter
- Mars 2018 Skycrane Capabilities
- Mars Network
- Mars Polar Mission
- Mars Astrobiology Explorer-Cacher
- Mars Ascent Vehicle
- Mars Sample Return Orbiter
- Asteroid Sample Return*
- Main Belt Asteroid Mission
- Comet Surface Sample Return
- Europa Jupiter System Mission
- Io Observer
- Ganymede Observer
- Trojan Tour
- Saturn Probe Mission
- Titan Lake Lander
- Titan Saturn System Mission
- Enceladus Flyby/Sample Return
- Chiron Orbiter
- Uranus System Mission
- Neptune/Triton Mission

The Future

- All four main robotic mission areas impacted by budget. List of current missions is likely to have many yet to be done missions in the next decadal which will drive the future budgets.
- Human exploration ? – ask your congress person or presidential candidate – its become a political/budget question