National Aeronautics and Space Administration

Joint Robotic Precursor Activity: Providing Strategic Knowledge to Inform Future Exploration

Science and Human Exploration and Operations Committees
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Joint Robotic Precursor Activity (JRPA) Overview

Goal: Inform the selection of future destinations, support the development of exploration systems, and reduce the risk associated with human exploration while maximizing the mutual benefit to both science and exploration

- **To meet this goal, NASA will jointly fund and conduct Robotic Precursor Activities**
  - These activities will provide the strategic knowledge required to inform human spaceflight (HSF) planning. By developing an integrated set of priorities NASA will leverage mission opportunities, data, and the talents of both the exploration and science communities to enable human missions to NEAs, the Moon, and ultimately Mars.
- **Such activities will include**
  - Develop instruments for NASA and non-NASA missions to destinations relevant to human exploration beyond LEO to gather needed information
  - Fund Research and Analysis efforts to generate strategic knowledge in support of human spaceflight planning and systems development
  - Perform strategic studies and hold joint workshops to further inform and leverage community participation
  - Lay the groundwork for future precursor missions, should funding improve
- **Total annual budget target is $30M ($20M/HEO-AES and $10M/SMD-PSD) formally starting in FY13. HEO-AES devoted $18M in FY12 funding to start these activities**

Acronym List in Backup

Exploration Benefits Science; Science Benefits Exploration

Science and Exploration have a successful history of working together. A selection of past successes includes:

- **Hardware**
  - Lunar Reconnaissance Orbiter (LRO): Joint AO, LRO mission DDT&E
  - Lunar Mapping & Modeling Project (LMMP): originally an exploration centric set of tools, it is an intuitive, capable portal for accessing integrated lunar science data sets for which the lunar science community (national and international) is the biggest user
  - Mars Science Laboratory (MSL) payloads: Radiation Assessment Detector (RAD) and Mars Entry, Descent, & Landing Instrumentation (MEDLI)
- **Initiatives**
  - Joint charters for analysis groups: Lunar Exploration Analysis Group (LEAG), Mars Exploration Program Analysis Group (MEPAG), and Small Bodies Assessment Group (SBAG); the Tempe conference convened by the NASA Advisory Council (NAC) for science and exploration
  - Joint Research & Analysis (R&A): Lunar Advanced Science & Exploration Research (LASER), NASA Lunar Science Institute (NLSI), Stand Alone Missions of Opportunity Notice (SALMON).
  - Joint development of required launch documentation for LRO and Lunar Crater Observation & Sensing Satellite (LCROSS)
- **Personnel Exchange**
  - LRO, Human Exploration Framework Team (HEFT), Exploration Precursor Robotic Missions (xPRM) Study Team, Near Earth Asteroid User Team (NUT), Near Earth Object Observation (NEOO), Blue Sky, Near Earth Asteroid Working Group (NEA-WG), Desert Research & Technology Studies (Desert-RATS).
  - LRO/LCROSS personnel coordination and exchange during development
- **Management Processes**
  - Successful history in executing co-funded projects (LASER, NLSI, Participating Scientists funded by SMD supporting the LRO Exploration mission, ESMD extended funding for LRO PIs during Science mission to support additional data analysis)

From the FY11 NASA Strategic Plan

- **Exploration Strategic Goal 1: Extend and sustain human activities across the solar system.**
  - **Outcome 1.3:** Develop an integrated architecture and capabilities for safe crewed and cargo missions beyond low Earth orbit.
    - **Objective 1.3.3: Identify hazards, opportunities, and potential destinations, to support future safe and successful human space exploration missions.**

- **Science Strategic Goal 2: Expand scientific understanding of the Earth and the universe in which we live.**
  - **Outcome 2.3:** Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere.
    - **Objective 2.3.1:** Inventory solar system objects and identify the processes active in and among them.
    - **Objective 2.3.2:** Improve understanding of how the Sun's family of planets, satellites, and minor bodies originated and evolved.
    - **Objective 2.3.3:** Improve understanding of the processes that determine the history and future of habitability of environments on Mars and other solar system bodies.
    - **Objective 2.3.5: Identify and characterize small bodies and the properties of planetary environments that pose a threat to terrestrial life or exploration or provide potentially exploitable resources.**

Performance Goals (FY12)

Human Exploration and Operations Mission Directorate (HEOMD)

- **Performance Goal 1.3.3.1:** Identify hazards, opportunities and potential destinations, to support future safe and successful human space exploration missions
  - **APG 1.3.3.1: ERD-12-7:** In collaboration with the Planetary Science Division, develop a plan to return data that will support the selection of destinations and reduce risk for future human space exploration missions

Science Mission Directorate (SMD)

- **Performance Goal 2.3.5.1:** Provide national scientific capabilities through necessary skilled researchers and supporting knowledge base.
  - **APG 2.3.5.1: PS-12-12:** Demonstrate planning progress in identifying and characterizing small bodies and the properties of planetary environments that pose a threat to terrestrial life or exploration or provide potentially exploitable resources…

- **Performance Goal 2.3.5.2:** Return data for selection of destinations in order to lower risk for human space exploration beyond low Earth orbit
  - **APG 2.3.5.2: PS-12-13:** Demonstrate planned progress in characterizing potentially hazardous objects that are possible destinations for future human space exploration

JRPA Planning Since Briefing OMB in November

- **Work focused on:**
  - Defining where we most benefit from the joint investment
    - Strategic Knowledge Gaps
    - Identify timelines and 'need-by' dates
  - Writing an Memorandum of Understanding
    - Draft in review in both Mission Directorates
  - Defining, Refining, and Prioritizing Strategic Knowledge Gaps
    - NAC's Analysis Groups vetted and refined draft SKG sets for Moon, NEAs, Mars, and Mars' moons
    - Worked with ISECG (via the Strategic Knowledge Gap Assessment Team, chaired by the Chief Exploration Scientist) and began coordination with international space agencies to identify and prioritize an international set of SKGs
  - Providing background and input to the Mars Program Planning Group and the HEOMD Human Spaceflight Planning Team
  - Identifying near-term opportunities
    - Prioritized by destination and timeline
    - Destination-specific versus advancing state of knowledge
    - Building up to a Mission of Opportunity or other flight opportunity

Ground Rules

- **TheFY13 PBR called for a joint program office funded by Science and Exploration, renamed the Joint Robotic Precursor Activities (JRPA) and managed out of HQ**
- **Flat $30M (RY$, full cost) starting in FY13**
  - $10M from SMD; $20M from HEOMD
  - CS/Procurement to be determined by portfolio
- **Delegated Management/Separate Funding**
  - One office/manager (the JRPA Manager) accountable to both mission directorates
  - HEOMD/AES/JRPA will manage the overall portfolio and keep track of the funding and reporting with concurrence from PSD
- **HEOMD and SMD will, via the JRPA Team**
  - Jointly identify needs and opportunities
  - Collaboratively determine the best approach for specific elements
  - Develop a clear set of implementation guidelines
  - Seek a balanced but incentivizing approach to implementation
- **Steering Committee will:**
  - Concur on plans and funding allocation
  - Recommend portfolio to mission directorates as appropriate
- **Document management decisions in Memorandum of Agreement (MOA), project plans, etc.**
  - Rigorously track progress, actions, and products through application of best-of-practice project management approaches
- **Exploration and Science will hold JRPA commitments as a protected priority the greatest extent possible**

Guidelines

- **Recognize the Planetary Science Decadal Survey guidance: "(it is)…vital to maintain the science focus of such peer-reviewed missions and not to incorporate human exploration requirements after the mission has been selected and development has begun."**
  - JRPA objectives will not undermine SMD processes for competition
  - There are some missions for which it is too late to add an instrument, however, augmenting or supporting an existing instrument may be an option (e.g., LADEE)
  - There are some measurements or experiments that, while revolutionary, will not provide the kinds of information that will support human mission planning
- **Recognize that HEOMD has obligations to employ and train NASA civil servants, to the fullest extent possible**
  - It will sometimes be in HEOMD's best interest to partially or completely direct work to NASA Centers
- **The Chief Exploration Scientist, an integral part of the JRPA team, will be key to maintaining a balance between these two obligations**
- **The Steering Committee is intended to provide advice and guidance, and to assist in decision making where there may be competing priorities**
  - The individual DPMCs for both mission directorates, along with the MDAAs, provide formal approvals

Determining Priorities

- **Criteria**
  - Relevance to Human Space Flight's Strategic Knowledge Gaps (SKGs) for potential human destinations, including the Moon, Near-Earth Asteroids, and Mars
  - The Strategic Knowledge Gaps will translate to sets of measurements and other activities that will be used to guide instrument/mission/R&A investments (see backup for SKGs) and potential collaborations with international partners
- **Processes**
  - JRPA team will collaboratively develop prioritized proposals for funding specific activities
  - The Steering Committee will comment and concur on the proposed plans and funding allocation
  - The scope assignments and associated cost estimates will be documented per MOA signed at the Division level (as appropriate)
  - Once scope is assigned, each directorate is responsible for that scope irrespective of cost

Informing Exploration: Strategic Knowledge Gaps

- **To inform mission/system planning and design and near-term Agency investments**
  - Human Spaceflight Architecture Team (HAT) Destination Leads were asked to identify the data or information needed that would reduce risk, increase effectiveness, and aid in planning and design
  - The data can be obtained on Earth, in space, by analog, experimentation, or direct measurement
- **For some destinations, the needed knowledge is well identified**
  - Analysis Groups, such as LEAG and MEPAG, have identified pertinent measurements to gain the needed knowledge regarding the Moon and Mars
  - Significant advances in filling the knowledge gaps have been made (examples: LRO and MRO, and soon, MSL)
- **The Strategic Knowledge Gaps (SKGs) identified here will:**
  - Provide NASA's foundation for achieving an internationally developed and accepted set of integrated and prioritized SKGs through ISECG's Strategic Knowledge Assessment Team
  - Form the basis for near-term Agency investments in robotic precursor missions and activities through Announcements of Opportunity (AO), competed and secondary missions, etc. A few examples include:
    - Discovery 13 AO
    - NASA Research Institute for Science and Exploration Cooperative Agreement Notice
    - LASER (Lunar Advanced Science and Exploration Research, or equivalent) and SALMON (Stand Alone Missions of Opportunity Notice) calls
    - Development of early flight opportunities

SKGs: Common Themes and Some Observations

- **There are common themes across destinations (not in priority order)**
  - The three R's for enabling human missions
    - Radiation
    - Regolith
    - Reliability
  - Geotechnical properties (Moon, NEAs, Mars)
  - Volatiles (i.e., for science, resources, and safety) (Moon, NEAs, Mars)
  - Propulsion-induced ejecta (Moon, NEAs, Mars)
  - In-Situ Resource Utilization (ISRU)/Prospecting (Moon, NEAs, Mars)
  - Operations/Operability (all destinations, including transit)
  - Plasma Environment (Moon, NEAs)
  - Human health and performance (all destinations, including transit)
- **Some Observations**
  - The required information is measurable and attainable
  - These measurements do not require "exquisite science" instruments but could be obtained from them
  - Filling the SKGs requires a well-balanced research portfolio
    - Remote sensing measurements, in-situ measurements, ground-based assets, and research & analysis (R&A)
    - Includes science, technology, and operational experience

Status and Way Forward

- **Based on the draft version of the Strategic Knowledge Gaps created by the Human Spaceflight Architecture Team (HAT)…**
  - NASA has engaged the external Science and Exploration communities to vet and refine the draft SKGs.
    - Lunar Exploration Analysis Group (Specific Action Team phase 2 results complete; report available on LEAG website, phase 3 [measurements/instruments] in development)
    - Mars Exploration Program Analysis Group (Precursor Strategy Analysis Group, P-SAG, final report being vetted, interim report available on MEPAG web site)
    - Small Bodies Assessment Group (SKG-SAT in progress; final report due by July 31)
  - NASA will establish traceability of the SKGs to its currently planned robotic missions, utilization of ISS, and known opportunities for Research and Analysis efforts, and exploitation of existing ground based assets. (In process)
- **Next Steps:**
  - Integrate results of LEAG, MEPAG, and SBAG using a Specific Action Team comprising membership from all three groups
  - Begin following the delivery of analysis/assessment group final reports
- **Schedule:**
  - To be negotiated with the SAT chair and the chairs of the analysis/assessment groups

Status and Way Forward

- **International Coordination of Strategic Knowledge Gaps**
  - The Strategic Knowledge Gap Assessment Team (SKGAT) has been formed within the Exploration Roadmap Working Group of the International Space Exploration Coordination Group (ISECG) (Chaired by M. Wargo)
  - It has begun the process of identifying, prioritizing and time phasing an “international set of SKGs” tied to the Global Exploration Roadmap mission scenarios, Asteroid First, and Moon First
  - The NASA set of ***draft*** SKGs have been used as the starting point for the assessment
  - The SKGs for Moon, Near Earth Asteroids, and Mars are being vetted by the team member agencies (CNES, CSA, ESA, JAXA, NASA)
    - For content
    - For alignment with existing and planned missions

Status and Way Forward

- **International Coordination of Strategic Knowledge Gaps (cont'd)**
  - Prioritization criteria and methodology have been formulated
  - Test cases for prioritization are being run to evaluate the prioritization criteria
  - **The prioritized "international set of SKGs" will be incorporated into the next revision of the Global Exploration Roadmap**
    - Work will be complete prior to the next ISECG meeting to be held at ESA/ESTEC October 9-12, 2012

Proposed Initial JRPA Portfolio

- **FY12 was a voluntary start in HEO to leverage near-term opportunities**
- **FY 13-14 activities currently include both pre-existing projects and new projects**
  - As a result of the ESMD/SOMD reorganization these pre-existing projects were re-aligned to fit new budget lines
    - Lunar Mapping and Modeling Project (LMMP)
    - RAD on the Mars Science Lab (MSL) has its own separate budget line in AES
    - The NASA Lunar Science Institute (NLSI) is funded by SMD and HEOMD
      - The Institute will expand to other potential human destinations in FY13 via a Cooperative Agreement Notice (in review now)
      - NLSI will be renamed research institute for science and exploration
  - Two HEO-funded AES projects aligned well with the JRPA objectives
    - 4x improvement to the Goldstone radar capability to image NEAs
    - Lunar ice prospecting payload project (RESOLVE)
    - Note: AES projects are funded for 3 years (FY12-14), with yearly decision reviews that determine whether the project should be funded for an additional year.
  - R&A could include participating scientists on robotic missions, competitive calls, and other means to improve our working knowledge of all human destinations

Integrated Budget

- **Instrument/Mission**
  - Initial HEO obligations consume much of available Instrument/Mission line thru FY14
    - Goal for FY15 is to dedicate those funds to new flight opportunity
    - RAD instrument is on SMD-funded MSL, landing 5 August 2012
    - RESOLVE project is a partnership between NASA, Canadian Space Agency, and others to develop, test, and bring to flight qualification status a volatiles prospecting mission
- **Collaborative R&A**
  - Lunar Mapping and Modeling Portal funded in FY12 to complete the product sets available on the portal; future work will include development of education applications
  - Goldstone radar project is advancing the radar state of the art ability to image NEAs and other HSF relevant solar system objects; auxiliary efforts at KSC to map orbital debris and apply new radar characterization techniques; future work will advance radar capability to 1 meter range, and improve Arecibo capabilities
  - R&A includes continued joint support for the NLSI and will provide opportunities for LASER and other R&A calls
- **Strategic Studies**
  - FY12 focused on refining, prioritizing, and integrating Strategic Knowledge Gaps within HEO and internationally
  - FY13 will include an analysis of alternatives for robotic mission 'proposals' to potential destinations:
    - Lunar surface ISRU validation, Mars orbit and/or surface, Phobos, human accessible NEA, 'NEA finder', and other concepts

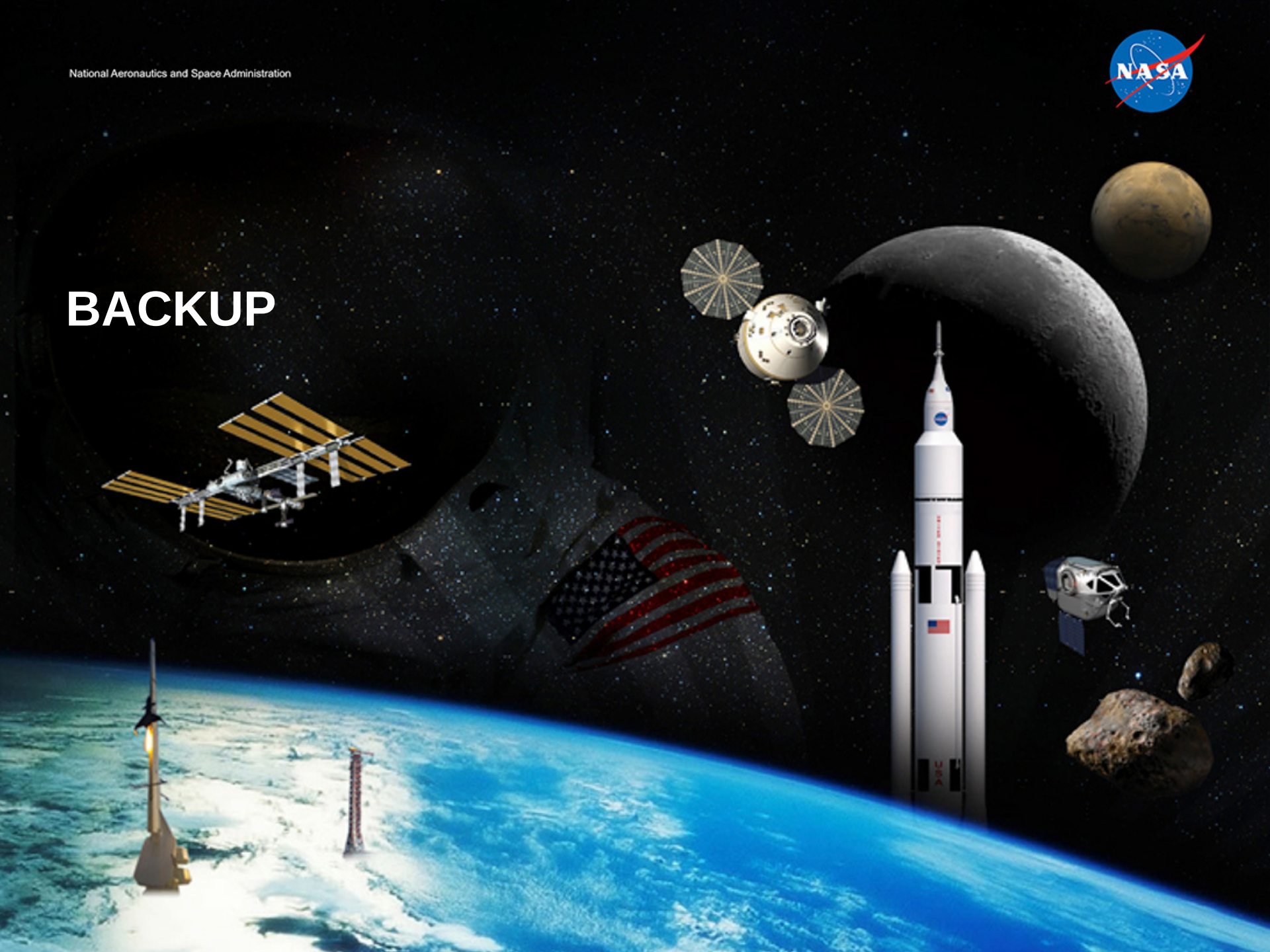
Acronym List in Backup

Challenges

- **Considerable effort is needed to ensure a good start in FY13**
  - The JRPA Team is purposely quite small and there is no program office
    - JRPA Manager: Victoria Friedensen
    - Chief Exploration Scientist: Michael J. Wargo, supports MPPG, ISECG among other responsibilities
    - Detailee Bette Siegel (shared with SAID)
  - Instrument/Mission Decisions Are Pending:
    - Integration and Prioritization of the SKGs across all potential destinations
    - Mars Program decisions
    - SLS/MPCV analyses regarding secondary or deployable payloads
- **Competition/Procurement Decisions**
  - SMD and HEO have differing priorities regarding competition
    - Human spaceflight planning will require near-term decisions that may not meet SMD competition desirements
    - AES has a responsibility to employ NASA civil servants which limits procurement $$s and competition decisions
  - Instrument or mission decisions will need to be made in early 2013
    - Opportunities exist for launches as early as 2015

National Aeronautics and Space Administration

BACKUP



Radiation Assessment Detector

Objectives:
Characterize the radiation environment during interplanetary cruise and on the surface of Mars

Relevance to HSF:
Knowledge of the Mars radiation environment is needed to assess the effects on crew health and to define design requirements for radiation protection

FY12 Milestones:
- Launch RAD on Mars Science Laboratory mission.
- Acquire radiation data during transit to Mars.
- August 5, 2012 landing on Mars

Team
- Lead Center: JPL
- Project Manager: Jeff Simmonds
- Supporting Centers: none
- Partnerships: SWRI, DLR

Resources

	FY12	FY13	FY14	Total
$Millions	4.3	3.0	1.8	9.1

RESOLVE Lunar Resources Prospecting Payload

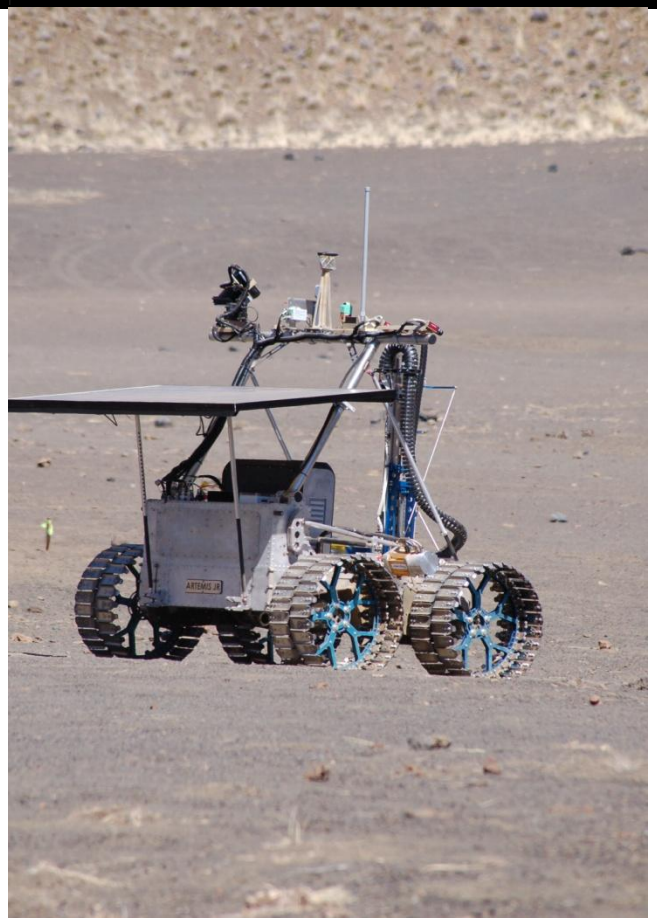
Objectives:
Develop a drilling and miniature chemistry plant integrated with a rover to verify the presence of water and other volatiles on the lunar surface.

Relevance to HSF:
In-situ production of water, oxygen, and propellants from lunar resources could reduce the mass of consumables that must be launched from Earth.

FY12 Milestones:
- Demonstrate operations of integrated payload on a rover in analog field test
- Complete SRR for Vacuum Demonstration Unit

Team
- Lead Center: KSC
- Project Manager: Jackie Quinn
- Supporting Centers: JSC, ARC, GRC
- Partnerships: CSA

OCT Dependencies
- In-Situ Resource Utilization: RESOLVE oven, fluid system, avionics & software



RESOLVE payload integrated on CSA's Artemis Jr. Rover, July 15, 2012

Resources

	FY12	FY13	FY14	Total
$Millions	9.5	9.4	10.3	29.2

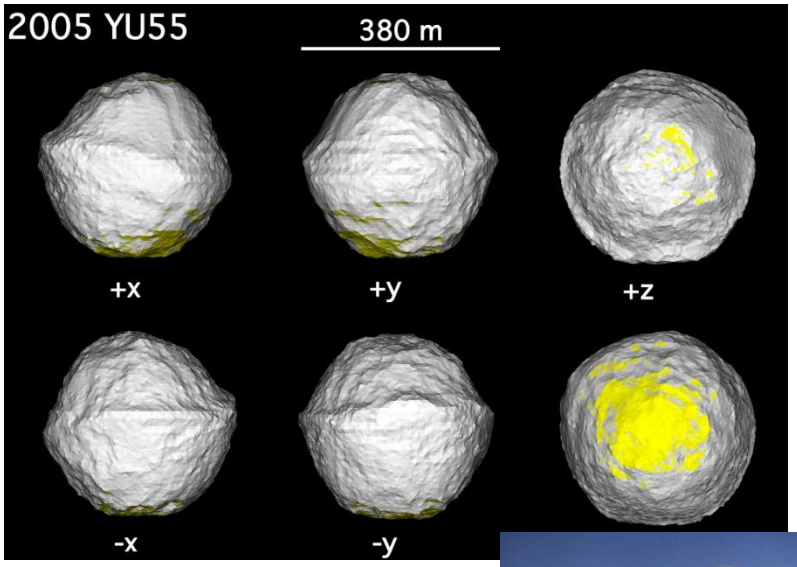
Goldstone Radar Imaging of NEOs

Objectives:
Image and characterize 18 near Earth asteroids at 3.75 m resolution using the Goldstone radar.

Relevance to HSF:
Using radar to determine the size, shape, spin rate, and surface properties of candidate asteroids for human exploration is more cost effective than sending robotic precursor missions.

FY12 Milestones:
- Test and improve the prototype chirp/digital receiver system by observing multiple NEAs
- Order, receive, and integrate the new digital receiver

Team
- Lead Center: JPL
- Project Manager: Lance Benner
- Supporting Centers: JSC, GSFC, KSC



High-Resolution 2005 YU55 Shape Model: 10,000 vertices

Resources

	FY12	FY13	FY14	Total
$Millions	1.5	1.5	1.3	4.3

Lunar Mapping & Modeling Project

Objectives:

Develop software tools for searching, viewing, and analyzing images and other data acquired by lunar robotic precursor missions such as LRO.

Relevance to HSF:

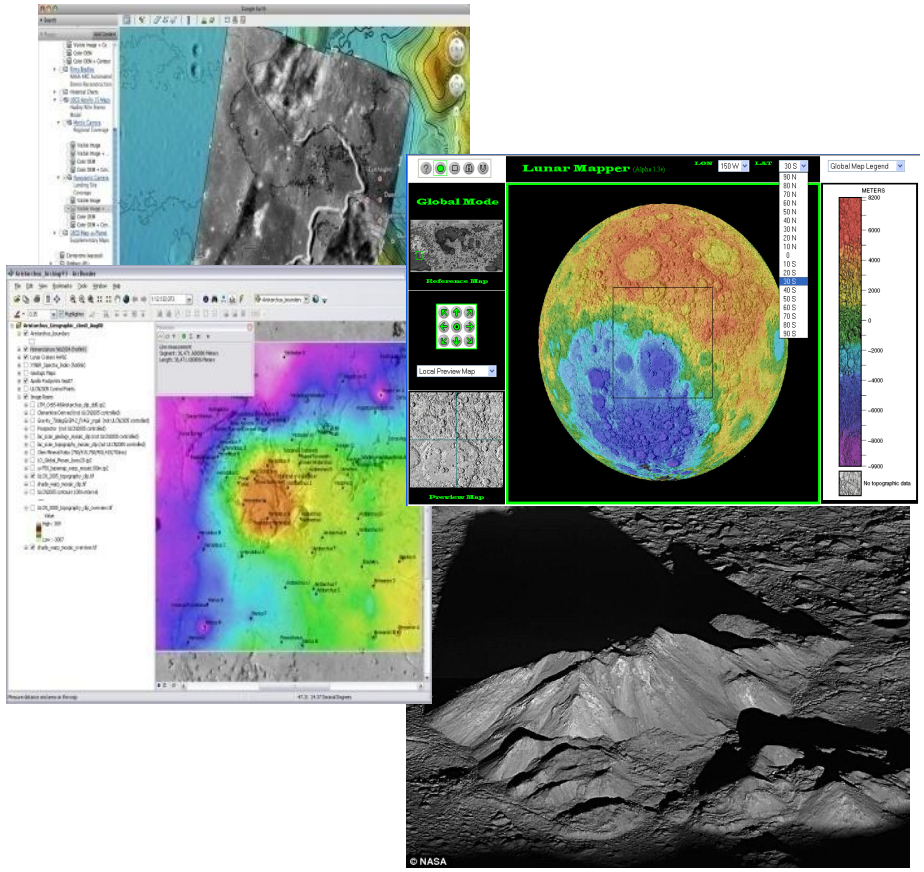
Archives and makes accessible the strategic knowledge needed for design of future lunar exploration missions.

FY12 Milestones:

- Complete the Hazards tool and associated products
- All required products available on the portal; all system functionality requirements completed

Team

- Lead Center: MSFC
- Project Manager: Ray French
- Supporting Centers: ARC, JPL
- Partnerships: USGS, U. S. Army, University of Arizona, Arizona State University.



Resources

	FY12	FY13	FY14	Total
$Millions	1.39			1.39

NASA Lunar Science Institute

NASA Lunar Science Institute (NLSI)

-Initiated in 2008, the NLSI is a virtual institute, funding teams across the U.S. to address major problems in lunar science of, on and from the Moon through collaborative technologies

- Addresses issues of major importance for human exploration, ranging from understanding materials available for potential human use to potential effects of the lunar environment on exploration systems

-Over 100 peer reviewed journal articles in first two years of PI operations

-International partners funded by host countries participate in problems of joint science and exploration interests

-Second PI announcement in 2012 to expand NLSI scope; will include critical science studies of all human destinations on flexible path

Participating Organizations

-NLSI jointly funded by HEOMD and SMD since inception; second PI announcement will increase HEOMD stake in NLSI

-NLSI central office at NASA Ames Research Center responsible for scientific direction, enabling collaborative activities including annual conference, institute management and education/outreach

-Domestic teams run from Univ. Colorado (2), Southwest Research Institute, USRA/LPI, U. Maryland/APL, NASA/GSFC, Brown U.; each includes other institutions

-International teams (no US funds) in Canada, Europe (U.K.; Netherlands; Germany), S. Korea, Israel, Saudi Arabia

Schedule

Second PI announcement:	December 2011
New PIs selected:	June 2012
Annual NLSI Lunar Science Forum:	July 2012
Broadened NLSI begins operations:	**September 2012**

Resources: SMD funds allocated for NLSI are from a general R&A account, not JRPA. Funding levels are contingent on updated CAN and future budget direction.

	FY12	FY13	FY14
HEOMD	0.6	4.3	4.3
SMD	11	9.5	9.5
Total	11.6	13.8	13.8

Acronym List

- AES – Advanced Exploration Systems
- AO – Announcement of Opportunity
- CAN – Cooperative Agreement Notice
- CS – Civil Servants
- DDT&E – Design, Develop, Test, and Execution
- ELV – Expendable Launch Vehicle
- ESMD – Exploration Systems Mission Directorate
- GLXP – Google Lunar X Prize
- GRAIL – Gravity Recovery And Interior Laboratory
- HEFT – Human Exploration Framework Team
- HEOMD – Human Exploration and Operations Mission Directorate
- ISRU – In-Situ Resource Utilization
- JRPA – Joint Robotic Precursor Activities
- LADEE – Lunar Atmosphere and Dust Environment Explorer
- LASER – Lunar Advanced Science and Exploration Research
- LCROSS – Lunar Crater Observation and Sensing Satellite
- LEAG – Lunar Exploration Analysis Group
- LMMP – Lunar Mapping and Modeling Project
- LRO – Lunar Reconnaissance Orbiter
- MD PMC – Mission Directorate Program Management Council
- MEDLI – MSL Entry Descent and Landing Instrument
- MEPAG – Mars Exploration Program Analysis Group
- MOA – Memorandum of Agreement
- MSL – Mars Science Laboratory
- NAC – NASA Advisory Council
- NEA - Near-Earth Asteroid
- NEA-WG – Near-Earth Asteroid Working Group
- NEOO – Near-Earth Object Observation
- NLSI – NASA Lunar Science Institute
- NUT - NEA User Team
- OCS – Office of the Chief Scientist
- OCT – Office of the Chief Technologist
- PBR – President's Budget Release
- PDS – Planetary Data System
- PSD – Planetary Science Division
- R&A – Research and Analysis
- RAD – Radiation Assessment Detector
- RESOLVE - Regolith and Environment Science and Oxygen and Lunar Volatile Extraction
- SALMON – Stand Alone Missions of Opportunity Notice
- SBAG – Small Bodies Assessment Group
- SKG – Strategic Knowledge Gap
- SMD – Science Mission Directorate
- xPRM – eXploration Precursor Robotic Missions