National Aeronautics and Space Administration

Briefing to the Small Bodies Assessment Group:

FY 2011 Exploration Precursor Robotic Missions (xPRM) Point of Departure Plans

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Background and Context

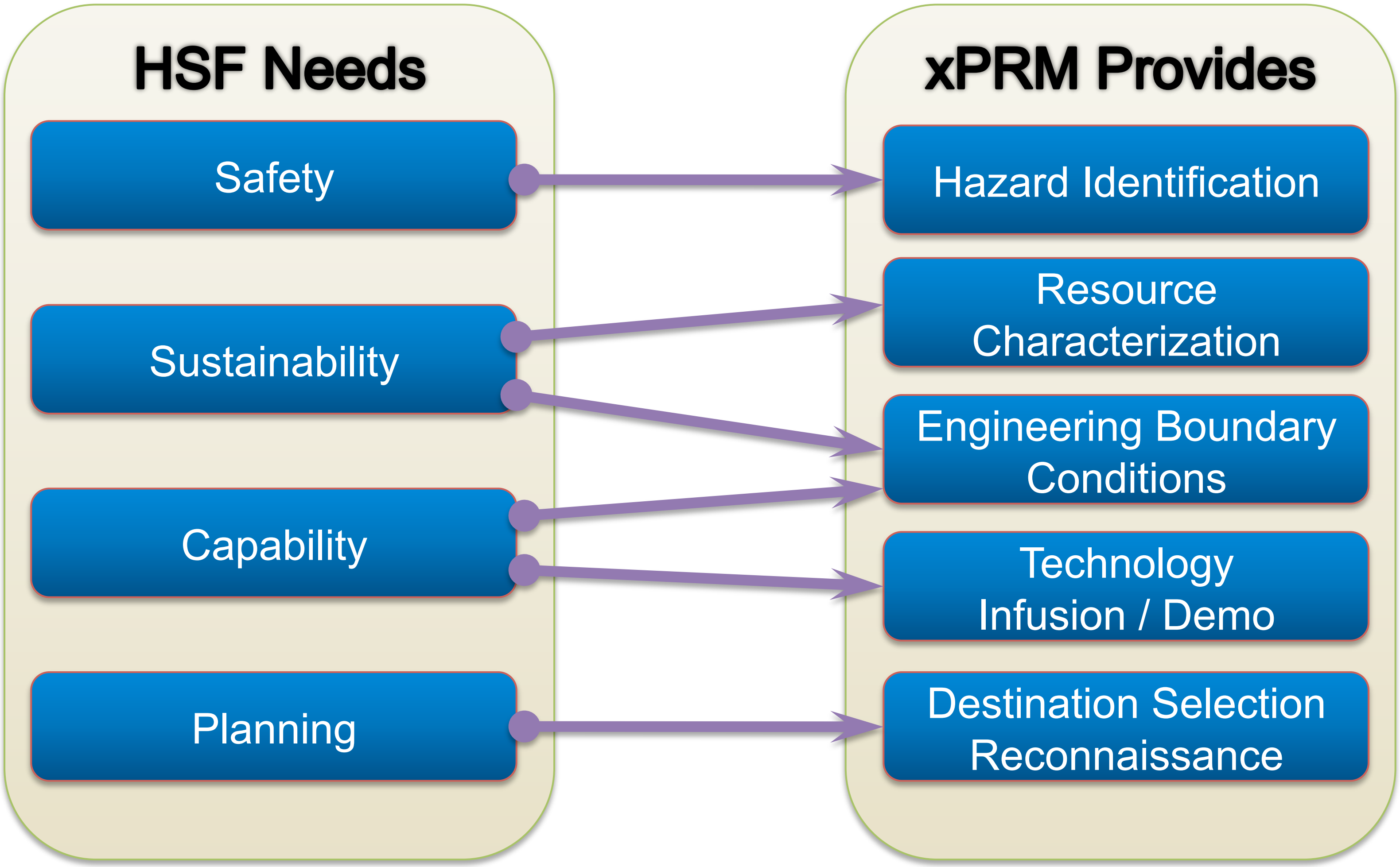
- **Human Exploration precursors were essential to the success of Project Apollo in the late 1960's to early 1970s:**
  - *Robotic precursors such as Surveyors and Lunar Orbiters defined the engineering boundary conditions and environments for human exploration of the Moon, as well as potential hazards*
- **More recently, human exploration precursors have been designed and flown in support of the 2004 National Space Policy Directive 12 Plan:**
  - *LRO and LCROSS are recent/current human exploration robotic precursors designed to provide applied knowledge essential for the safe and cost-effective return of humans to the lunar surface*
- **No matter the human spaceflight destination beyond low Earth orbit (LEO), exploration robotic precursors are essential to ensure human health and safety:**
  - Comments to this effect were made by the Augustine Committee in 2009
  - Exploration Precursor Robotic Missions to future human destinations are particularly important in the decade from 2010 to 2020 to characterize:
    - *Near Earth Objects (NEOs)*
    - *Lunar resources (esp. volatiles)*
    - *Mars orbit and surface (resources, hazards, dust, toxicity)*

Introduction

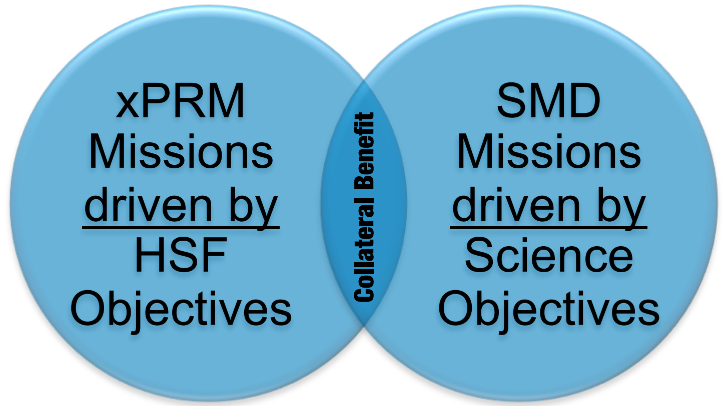
- NASA Planning for FY11 calls for *a* ***"steady stream of [Exploration] Robotic Precursor missions"*** and related activities:
  - We define this effort as Exploration Precursor Robotic Missions (xPRM)
  - The xPRM effort would consist of **two Programs:**
    - **xPRP:** set of linked flight missions, instrument developments, and R&D for the purpose of acquiring applied precursor knowledge for human spaceflight (HSF)
      - Cost range $500M to $800M (total mission life cycle cost with launch)
    - **xScout:** focused, less-expensive, higher-risk missions, with cost cap of $100M to $200M including launch
  - These proposed program lines include a portfolio of missions traceable to HSF Precursor Requirements

Why xPRM? *Enabling HSF proactively…*

- xPRM uniquely and specifically addresses HSF priority needs.



xPRM uniquely complements SMD missions



- Science Mission Directorate (SMD) missions are driven almost entirely by science objectives set by the National Academies Decadal Survey process, and therefore do not typically address high-priority Exploration precursor/HSF objectives
- xPRM missions will be designed to conduct the precursor measurements/experiments to quantitatively inform and support HSF objectives
  - These are different objectives that lead to different activities in many cases
- There are exceptions in both directions
  - Where synergy exists, we will work to take smart advantage of it

Sample Topic: Oxygen content of lunar regolith	
HSF/xPRM Questions:	**SMD/Science Questions:**
Where is it localized and at what form and concentration? Can it be accessed? How to best access and process it into a HSF “resource”?	How does spatial distribution of Oxygen inform the investigations of volatile sources and sinks within the solar system? [includes Oxygen-bearing molecules]

xPRM Top Level Objectives and Principles

- To conduct **precursor measurements/experiments*** in support of human exploration:
  - Quantify the engineering boundary conditions associated with the environments of human exploration beyond LEO.
  - Indentify hazards (to ensure safety)
  - Identify resources (to facilitate sustainability, lower launch mass, and “living off the land”)
  - Provide strategic knowledge to inform the selection of Human Exploration destinations
- To provide a platform for **technology flight demonstrations** which support human exploration.

- To **coordinate** with other NASA directorates.
  - Avoid overlap, identify complementary objectives, leverage dual-use opportunities
- To **foster competition** in mission/payload/investigation selections.
- To foster opportunities for **international collaboration** which benefit human exploration.
- To foster **participatory exploration** opportunities

*An HSF priority **precursor measurement/experiment** is a necessary component of any xPRM mission.

DRAFT xPRM Level 0 Requirements

The xPRM shall:	
1	Develop robotic flight missions to the Moon, near Earth objects, Mars, or to the moons of Mars as a precursor to future human exploration activities.
2	Be comprised of two programs: (i) the Exploration Precursor Robotic Program (xPR) generally consisting of missions costing less than $800M lifecycle cost (LCC); and (ii) the xScout Program generally consisting of missions costing less than $200M LCC.
3	Have a combined average launch rate of one mission every 18 months, with a goal of one every year, commensurate with the availability of adequate funding.
4	Identify and characterize potential human exploration destinations and specific local sites at such destinations by conducting experiments and quantitative measurements relevant to human exploration needs, goals and objectives.
5	Within the xPRM mission portfolio, conduct a lunar surface mission with a near-real-time video imaging capability and a teleoperated mobile element.
6	Quantify hazards associated with potential human exploration destinations including radiation, toxicity, dust, and impediments to safe operations.
7	Infuse flight-ready technologies into systems, provide flight opportunities for technology demonstrations, test operational concepts and capabilities.
8	Conduct a robust research and analysis program element to enable human exploration and gain strategic knowledge about future destinations, the challenges associated with them, quantified risks, and potential solutions.
9	Provide opportunities to engage the public in participatory exploration and offer STEM education activities.
10	Establish partnerships with other NASA Directorates, other agencies and international entities as appropriate to achieve xPRM objectives.

Exploration Precursor Robotic Program (xPRP)

- **Exploration Precursor Robotic Program (xPRP)** managed by MSFC
  - Flight Missions:
    - Precursor measurements/experiments to enable safe and effective HSF beyond LEO
    - Platforms for technology demonstration
  - Instrument Development (Missions of Opportunity)
    - Enhance investigation opportunities and promote partnerships with Internationals, other Agencies, or SMD
    - Instruments will generally be competed with approximately annual SALMON-like call or perhaps in partnership with SALMON (SMD's Stand Alone Missions of Opportunity)
    - Fly on non-xPRP missions
  - Research and Analysis for Exploration
    - Turn data into Strategic Knowledge for Exploration
      - Engineering Information, Visualization, Dissemination
      - Institutes, Workshops, Research Investigations

xPRP Element: Research and Analysis for Exploration

- Exploration Mapping & Modeling Project (xMMP)
  - Based on Lunar Mapping & Modeling Project (LMMP) **value-added data reduction/integration/display** activities
  - Extended beyond the Moon (would include Mars, NEO's)
- Data Systems
  - Contribution for **Planetary Data System (PDS) storage of Exploration datasets**
- Institute/Workshops
  - Recast NASA Lunar Science Institute to **broader Exploration needs** or start new institute.
  - Specialty Exploration **destination-oriented workshops**
- Research Investigations
  - Grants (for non hardware R&D)
  - Modeled after Research Opportunities in the Space and Earth Sciences (ROSES) annual call within SMD
  - Provides **foundational knowledge** needed to interpret mission results and inform the planning of future missions

xScout Program

- Principal Investigator (PI)-led or small, center-led approach to reduce costs
- Budgeting $100-$200 M per mission
  - Includes approx. $50M for access to space (e.g.: Dual-Payload Attachment Fitting, co-manifest or small Expendable Launch Vehicle)
- Co-manifest with xPRP missions where practical
- First launch 2014
  - Stretch-goal of 2013 launch readiness (requires dedicated launch)
- 18-24 month cadence
- Higher risk tolerance

- **Mission content**:
  - Focused scope in support of HSF objectives:
    - Could **be threshold measurements** or existence-proof experiments
  - xScout AOs written to **complement xPRP portfolio** with the goal of accomplishing **common xPRM objectives**

Point of Departure xPRM Portfolio

- xPRM would be uniquely poised to provide critical Strategic Knowledge for Exploration from a diverse set of destinations.
  - **xPRM starting in this decade would enable Human Exploration in the next.**
    - Analogous to robotic Surveyor landers ahead of Apollo human missions
  - Proposed scope **uniquely focuses on HSF objectives** while leveraging unique capabilities of partners.
    - No other program would fulfill this objective.
  - Fully consistent with current best estimate objectives for future HSF at NASA

CY →	2014	2015	2016	2017	2018
xPRP	NEO 	Lunar Lander 		NEO 	Mars 
MOOs	MOO1	MOO2	MOO3	MOO4	MOO5
xScouts	xS1 - NEO	xS2		xS3	xS4

NOTIONAL Point of Departure – Subject to Change

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NEO Campaign (Notionally 2014 and 2017)

- $640-840M LCC mission allocations
- 2025 HSF Asteroid mission would **likely only afford two xPRP opportunities** to inform the HSF architecture, while maintaining other xPRP objectives.
- Need to coordinate with HSF objectives definition teams to determine the appropriate campaign approach, and which combination/sequence of candidate missions:
  - "Shotgun" of 3 or 4 very small spacecraft to rendezvous with separate destinations with a limited focused-measurement payload on single launch
    - Would likely focus on top-level hazards and destination selection criteria
  - "Stack" of 2 "small-Discovery"-Class spacecraft to rendezvous with separate destinations with moderate payload on single launch.
    - Would likely focus on hazards, selection criteria, and more rigorous characterization.
  - Single Discovery-class spacecraft with HSF Objectives
    - More in-depth measurements and investigations at expense of target diversity.
  - NEO IR Telescopic Survey
    - Helio-centric orbit inside of 1AU
    - Would likely focus on identification and remote characterization (size, spin, albedo, thermal inertia, roughness, trajectory determination, etc) to provide robust slate options for HSF exploration.

- All options have potentially strong collateral value to science and planetary defense.
- As mission definition matures, possible international partnerships will continue to be explored.

NEO IR Telescopic Survey (NITS) Mission Option

- Current slate of HSF NEO Candidates may not be sufficiently robust.
- Per JSC analysis: 44-known NEOs are reachable humans aboard an Atlas V; However:
  - All but 17 may be deemed “too small” to visit by humans
  - Of those, 15 have opportunities in the (very) wide timeframe of interest
  - Of those, only 3 have mission durations on the order of 180 days
  - Of those, only 1 has a launch window in 2025 (the next being 2036 & 2046)
  - There are additional risk factors which could further eliminate candidates (spin rate, binary system, dormant comets)
- NITS could discover 1000’s of additional objects >100m providing a more robust set of candidate targets.
- **Need to determine if this current slate of candidates is “sufficient” and if size and mission duration limits are valid assumptions.**

NEO Rendezvous Mission Objectives

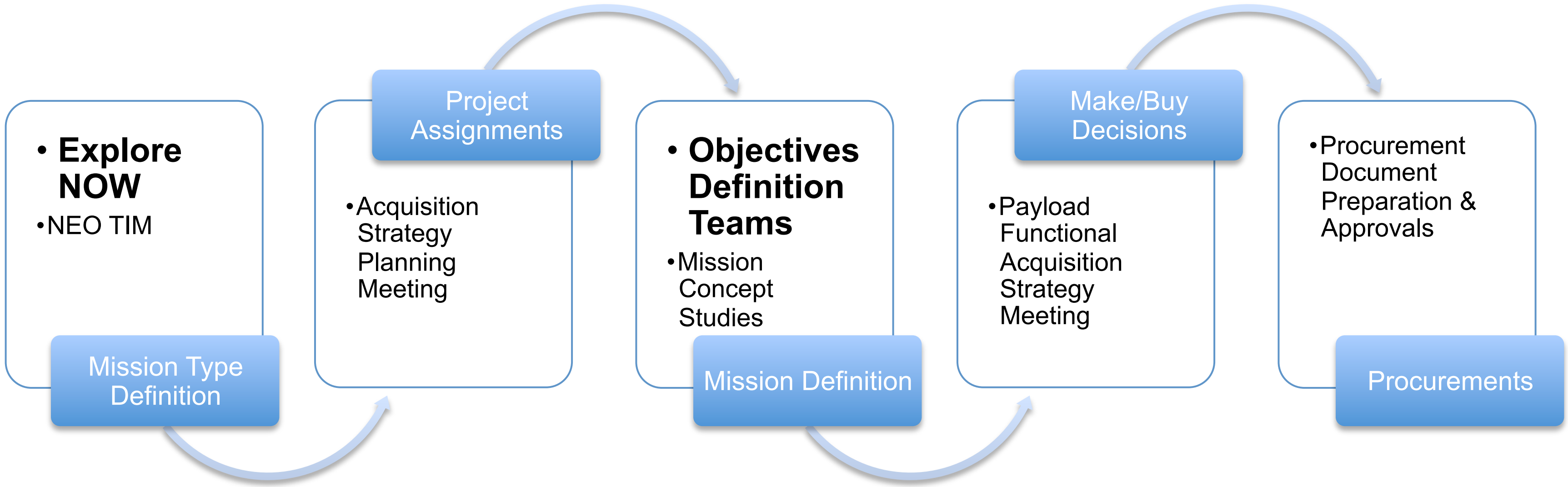
- Rendezvous missions would need to influence engineering concepts for HSF NEO missions in 2025
- Paucity of HSF objectives for NEOs; assumed xPRM Objectives would focus on:
  - Hazards, Prox-Ops, Quantify engineering boundary conditions

- Measurements (potential candidates):
  - Sub-meter-per-pixel imaging in multiple colors (possibly <10cm/pixel)
  - Geodetic imaging lidar altimetry (meter-scale topography)
  - Compositional mapping: Gamma-ray/Neutron Spectrometry (GRNS) best if low altitude orbit can be established for months
  - Small sounding-imaging-radar or long-wavelength sounder for internal structure
  - 2-way RF ranging for gravity field

- Additional Options:
  - Proximity remote sensing, beacon placement, small hoppers, touch & go, grappling, sample return

- Net investigations would be a balance of measurement scope versus target diversity within funding limits.

Near-term Planning Activities



- **Near-term planning activities will continue to refine objectives, mission types and concepts**
- **Public input solicited at Explore NOW and in upcoming Objective Definition Teams.**

Summary

- xPRM would be uniquely poised to provide critical Applied Knowledge for Exploration from a diverse set of destinations.
  - xPR Missions starting in this decade would enable Human Exploration in the next
    - Analogous to robotic Surveyor landers ahead of Apollo human missions
  - Uniquely focuses on HSF objectives while leveraging unique capabilities of partners.
    - No other program fulfills this objective
  - Fully consistent with direction and best estimate objectives for future HSF at NASA
- Study content is responding to recent change toward NEO focus
- Objective Definition Team Activities and System Engineering Analyses are necessary to refine definitions of mission scope and specific content
- Human Exploration Framework Team products to be folded in as available.

Backup

2015: Lunar Lander

- $850M Allocation derived from on-going Robotic Lunar Lander (RLL) efforts
- Target (via LRO information): Sunlit polar region (<100h night) with Earth visibility and confirmed hydrogen enhancement signature
- Objectives: Resources (including volatiles), hazards (including dust, trafficability and radiation), con-ops (teleops, hi-bandwidth comm and surface mobility), ground-truth LRO observations.
- Static Lander instruments (possible candidates)
  - 3D HD, wide-field, zoom camera with video frame rate (similar to MSL)
  - Dynamic albedo neutron spectrometer with active Neutron source
    - Measuring H down to 1 m depth
  - Volatile analysis mass spectrometer
  - In situ radiation experiment
  - ISRU sub-system demonstrator
  - Sampling arm possibly with multicolor microscopic imager
  - Allotment for partnering experiments (TBR)
- Surface mobility experiment : Sojourner class “rover” at ~35kg with 1-2 instruments (2kg)
  - Context camera, Dust particle size analyzer, Alpha Particle X-ray Spectrometer
  - Fetch capability (TBR)
- Lifetime would be more than 2 months (goal of 1 year)

2018: Mars Lander Option

- $870M LCC Allocation (currently) based upon tailored re-build of Mars Phoenix Lander
  - Very limited scope commensurate with $800M mission budget “limit”.
  - Contingent upon budget projections beyond FY2016.
  - Looking to “upgrade” to at least MER-level mobility and instrument capacity.
    - Estimated to be in excess of $1.2B
- 2018 geometry offers about 3X the mass to Mars as 2016 launch window
  - 2020 offers similar *though slightly less* performance.
- Several concepts in discussion, but not at consensus.
  - Later position in portfolio permits more rigorous mission definition process in FY11 and FY12
  - **2018 could be slated as orbiter** (next page) as HSF planning evolves.
    - Could possibly follow with 2020 lander / mobility.
  - Possibility of addressing many of the critical NRC “Safe on Mars” issues associated with human landed access to Mars (including Planetary Protection) as well as ISRU experiments
- Engaged with OCT, ETDD, FTD for EDL technology opportunities.
- Engaging SMD/MEP to coordinate efforts and seek partnerships.

2018: Mars Orbiter Option

- Mars Resource Explorer with Operational Aerocapture
  - Aerocapture would be critical to mission success, but much more valuable than a smaller fly-along demo.
    - Could perhaps restructure as separate aerocapture demo (though early estimates suggest this option is too expensive)
  - Payload TBD with a Resource Mapping Focus, but likely to be existing or heritage derived designs that could include:
    - Collimated neutron spectrometer
    - Orbital radiation experiment
    - P-band polarimetric SAR with a wide bandwidth for high resolution subsurface sensing
    - Hyper-resolution imaging (5-7 cm/pixel) for landing engineering boundary conditions
    - Possible option: An optical telecommunications demo ("lasercom")

- **Another Mars 2018 Option:** Mars Atmosphere/Dust Sample return with Aerocapture Elements
  - Skim the Mars atmosphere for gas/dust sample for direct return to Earth