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&A 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.

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**HSF Needs**

- Safety
- Sustainability
- Capability
- Planning

**xPRM Provides**

- Hazard Identification
- Resource Characterization
- Engineering Boundary Conditions
- Technology Infusion / Demo
- Destination Selection Reconnaissance
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.

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**Sample Topic**: Oxygen content of lunar regolith

<table>
<thead>
<tr>
<th>HSF/xPRM Questions:</th>
<th>SMD/Science Questions:</th>
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<tbody>
<tr>
<td>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”?</td>
<td>How does spatial distribution of Oxygen inform the investigations of volatile sources and sinks within the solar system? [includes Oxygen-bearing molecules]</td>
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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.
  – Identify **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.*
• **Exploration Precursor Robotic Program (xPRP)**
  – Flight Missions:
    • Precursor measurements/experiments to enable safe and effective HSF beyond LEO
    • Platforms for technology demonstration
  – Instrument Development (Missions of Opportunity or MOOs)
    • Enhance investigation opportunities and promote partnerships with Internationals, other Agencies, or SMD
    • Instruments would 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
• 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
  – 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: Planned Content

- 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

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<tr>
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NOTIONAL Point of Departure – Subject to Change
NEO Campaign (Notionally 2014 and 2017)

- $640-840M life-cycle cost 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 Telescopic Survey
    - Helio-centric orbit inside the orbit of earth.
    - 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.
Lunar Lander

- 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
- Notional Objectives: Resources (including volatiles), hazards (including dust, trafficability and radiation), con-ops (teleops, hi-bandwidth comm and surface mobility), ground-truth LRO observations.
- Possible Candidate Static Lander instruments
  - 3D HD, wide-field, zoom camera with video frame rate
  - 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)
- Candidate Surface mobility experiment:
  - Sojourner class “rover” at ~35kg with 1-2 instruments
    - Such as: Context camera, Dust particle size analyzer, Alpha Particle X-ray Spectrometer
  - Possible “fetch” capability (TBR)
- Lifetime would be more than 2 months (goal of 1 year)
Mars and Mars Vicinity Mission

• 2018 geometry offers about 3X the mass to Mars as 2016 launch window
  – 2020 offers similar though slightly less performance.
• Several concepts in early discussion, possibly:
  – Phoenix-class lander with atmospheric ISRU focus
  – Lander with MER-class mobility
  – Orbiting resource explorer/mapper with operational aerocapture
  – Mars Atmosphere/Dust Sample return with aerocapture elements
  – Phobos/Deimos rendezvous
• Later position in portfolio permits more rigorous mission definition process in FY11 and FY12
  – 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.
• Opportunities for International Partnerships and collaboration.
Summary

- 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
    - Will continue to update as HSF objectives and architectures mature.

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NOTIONAL Point of Departure – Subject to Change
Backup
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, instrumented impactors, beacon placement, small hoppers, touch & go, grappling, sample return

• Net investigations would be a balance of measurement scope versus target diversity within funding limits.
NEO Telescopic Survey Mission Option

- Current slate of HSF NEO Candidates may not be sufficiently robust.

- Per JSC analysis based on 2008 NEO catalog: 44-known NEOs are reachable humans assuming notional Ares V-class performance; However:
  - All but 17 may be deemed “too small” to visit by humans
  - 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)

- NTS could discover additional objects >100m providing a more robust set of candidate targets.

- However, we need to determine if the current slate of candidates is actually “sufficient”
  - Need to update target analysis to include 2010 NEO catalog
  - Need to validate filtering assumptions

- On-going HSF NEO Target assessments and HSF architecture work will inform xPRM planning.
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.