National Aeronautics and Space Administration

Briefing to Lunar Exploration Analysis Group:

Exploration Precursor Robotic Missions (xPRM) Point of Departure Plans

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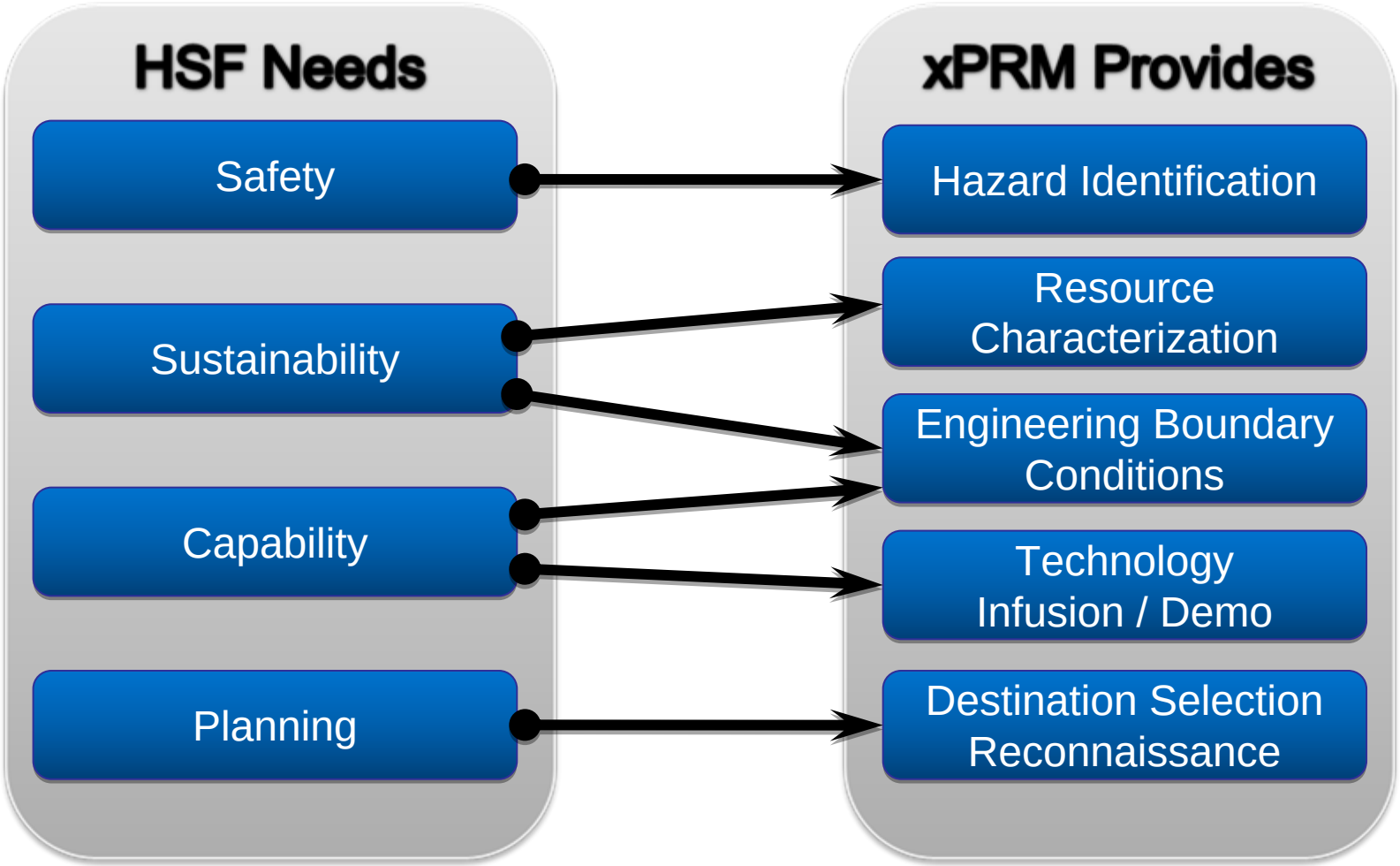
Introduction

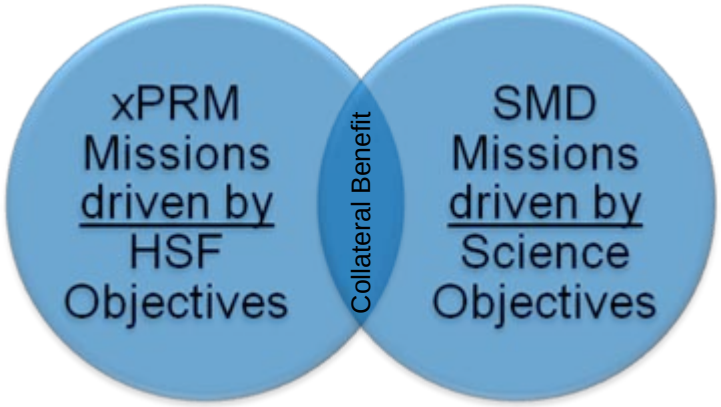
- NASA Planning for FY11 calls for *a **"steady stream of [Exploration] Robotic Precursor missions"*** and related activities:
  - We define this effort as Exploration Precursor Robotic Missions (xPRM)
  - The xPRM effort would consist of **two Programs:**
    - **xPRP:** set of linked flight missions, 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.



xPRM uniquely compliments 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

SampleTopic: 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.

Exploration Precursor Robotic Program (xPRP) Planned Content

- **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

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
  - 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

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

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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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.

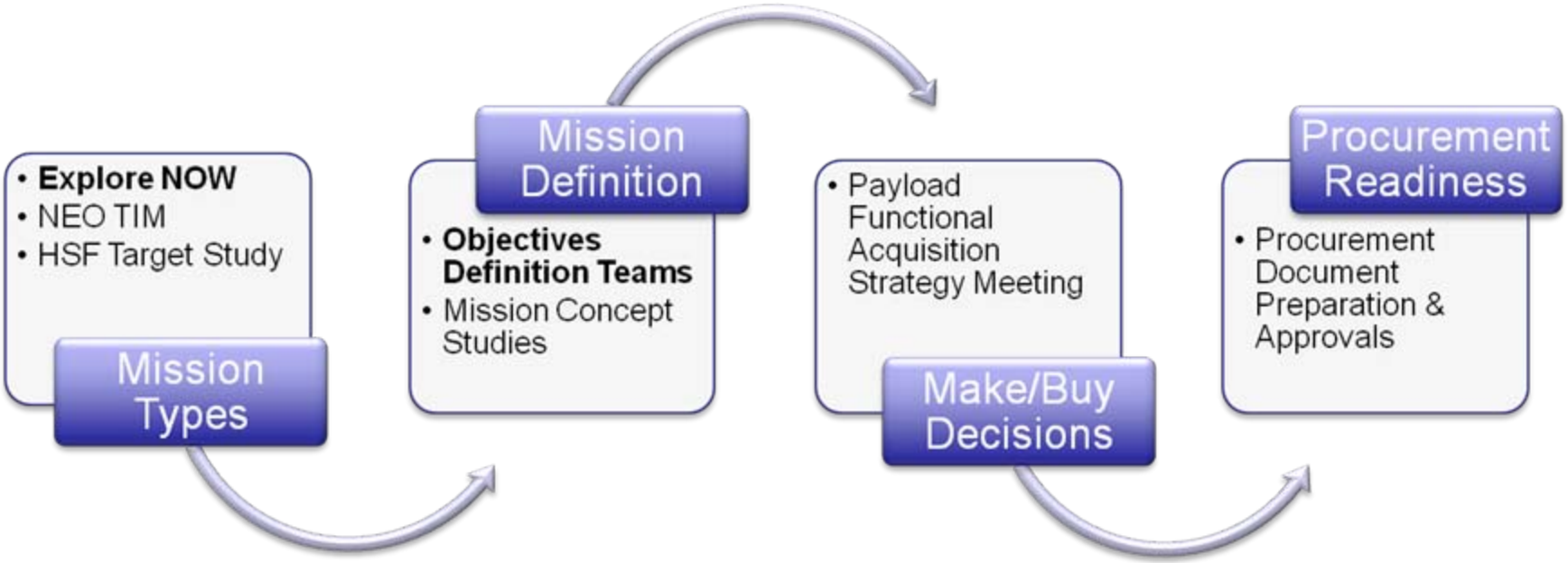
- Per JSC analysis based on **2008 NEO** catalog: 44-known NEOs are reachable humans assuming *notional Ares V-**class***performance; However:
  - All but 17 may be deemed “too small” to visit by humans
  - Of those, only 3 have mission durations on the order of 180 days
  - Of those, only 1 has a launch 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.

- **<u>However</u>, 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.**

xPRM 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.