Today’s Talk

- The Road to Mars
- Strategic Knowledge Gaps
- Advanced Exploration Systems
- Robotic Precursor Domain Status
  - SLS Secondary Payloads
  - EM-1
  - Resource Prospector
  - Lunar CATALYST
- Collaboration with SMD
  - Mars 2020
  - Goldstone Radar Improvements
  - SSERVI
- Status of Chief Exploration Scientist position
The Road to Mars
NASA sets the stage today for this to happen. It is a starting point for the future of Mars Exploration.
Evolvable Mars Campaign: A Pathways Approach to Exploration

Earth Dependent
- International Space Station
- Low-Earth Orbit
- Space Launch System (SLS) initial configuration

Proving Ground
- Exploration Augmentation Module
- International Crewed Lunar Surface
- Distant Retrograde Lunar Orbit
- Asteroid Redirect Vehicle

Earth Independent
- Mars Surface
- Mars Vicinity
- Mars Cargo Pre-Deployment
- MAVEN

The Trade Space

Across the Board
- Solar Electric Propulsion
- In-Situ Resource Utilization (ISRU)
- Robotic Precursors
- Human/Robotic Interactions
- Partnership Coordination
- Exploration and Science Activities

Cislunar Trades
- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

Mars Vicinity Trades
- Split versus monolithic habitat
- Cargo pre-deployment
- Mars Phobos/Deimos activities
- Entry descent and landing concepts
- Transportation technologies/trajectory analyses
Strategic Knowledge Gaps
Strategic Knowledge Gaps

- A Strategic Knowledge Gap (SKG) is an unknown or incomplete data set that contributes risk or cost to future human exploration missions.
  - Apollo example – Footpads oversized due to poor knowledge of lunar soil bearing strength.
- SKGs are not unique to human exploration; all NASA missions are designed based upon what is known and what is not.
  - Science measurements are the greatest source of strategic knowledge that has benefitted future human exploration.
- SKGs are the basis of an investment strategy for HEOMD’s limited R&A and robotic precursor mission funds.
NEA SKGs
- For any NEA to be visited by humans, at minimum:
  - OCC, Spin Rate, Near Surface Composition
- For NEA Exploration:
  - OCC, Spin Rate, Orbital Mechanics
  - Near Surface Composition and Structure
  - Volatiles and Resources (composition and availability)
  - Particulate Characterization

No data, Most “unknowns”

No unknown data sets, Object adequately characterized
Advanced Exploration Systems
Advanced Exploration Systems (HEOMD)

- Advanced development of exploration systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit.

- Demonstrate prototype systems in ground test beds, field tests, underwater tests, and International Space Station flight experiments.

- Pioneer and use innovative approaches and public-private partnerships for affordable rapid systems development and provide hands-on experience for the NASA workforce.

- Maintain critical competencies at the NASA Centers and provide NASA personnel with opportunities to learn new and transform skills.

- Infuse new technologies developed by Space Technology Mission Directorate / Exploration Technology Development into exploration missions.

- Support robotic missions of opportunity to address SKGs for potential destinations for human exploration.
Rapid development and testing of prototype systems and validation of operational concepts to reduce risk and cost of future exploration missions:

- **Crew Mobility Systems**
  - Systems to enable the crew to conduct “hands-on” surface exploration and in-space operations, including crew excursion vehicles, advanced space suits, and crew egress

- **Deep Space Habitation Systems**
  - Systems to enable the crew to live and work safely in deep space, including deep space habitats, reliable life support, radiation protection, and fire safety

- **Vehicle Systems**
  - Systems for in-space propulsion stages and small robotic landers, including nuclear propulsion, modular power systems, lander technology test beds, and autonomous precision landing

- **Operations**
  - Systems to enable more efficient mission and ground operations, including integrated testing, autonomous mission ops, integrated ground ops, and logistics reduction

- **Robotic Precursor Activities**
  - Acquire strategic knowledge on potential destinations for human exploration to inform systems development, including prospecting for lunar ice, characterizing the Mars surface radiation environment, radar imaging of NEAs, instrument development, and research and analysis

**Summary for FY14**
- AES has established 64 milestones for FY14
- Over 60% include flight demonstration elements
- Goal to achieve at least 80%
- AES included 559 civil servants in FY14
Robotic Precursor Domain Status
SLS Secondary Payload Capability

Large support base across the agency, external government and the international community for this capability

- AES (already working on 3 payloads for EM-1)
- SMD updated ROSES AO (1 payload)
- STMD (issuing Centennial Challenge for up to 5 payloads – Lunar Propulsion and Communications)
- Other: Office of the Chief technologist, Space Technology Program/Navy, AFRL/Air Force, several International partners and many national Universities

Requirements for Secondary Payload Accommodations on Exploration Missions were approved January 2014 with first flight on EM-1

- SLS will provide mounting adaptors for payload-provided deployers and payload instruments
- Payload can ‘do no harm’ to launch vehicle, crew vehicle or other payloads
- No Payload access or services after installation
• 19 NASA center-led concepts were evaluated and 3 were down-selected for further refinement toward an Mission Concept Review (MCR) planned for August 2014

• Primary selection criteria:
  - Relevance to Space Exploration Strategic Knowledge Gaps (SKGs)
  - Life cycle cost
  - Synergistic use of previously demonstrated technologies
  - Optimal use of available civil servant workforce

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<th>Payload</th>
<th>Strategic Knowledge Gaps Addressed</th>
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| BioSentinel\nARC/JSC  | Human health/performance in high-radiation space environments
  • Fundamental effects on biological systems of ionizing radiation in space environments | Study radiation-induced DNA damage of live organisms in cis-lunar space; correlate with measurements on ISS and Earth |
| Lunar Flashlight\nJPL/MSFC | Lunar resource potential
  • Quantity and distribution of water and other volatiles in lunar cold traps | Locate ice deposits in the Moon’s permanently shadowed craters                   |
| Near Earth Asteroid (NEA) Scout\nMSFC/JPL/LaRC/JSC/GSFC | Human NEA mission target identification
  • NEA size, rotation state (rate/pole position)
  How to work on and interact with NEA surface
  • NEA surface mechanical/geotechnical properties | Flyby/rendezvous and characterize 1 or more NEAs that are candidates for a human mission |
The Resource Prospector searches for, processes, and analyzes volatile components such as water and/or hydrogen that could be used in human exploration efforts.

Major Mission elements:

- Launch vehicle (TBD – Medium Class)
- Lunar lander (International Contribution)
- Mobility and Sampling and analysis payload (NASA Primary Contribution)
  - Drill (potential International Contribution or SBIR Phase 3)
  - Small oven to heat the sample
  - Miniature gas chromatograph and mass spectrometer to characterize the volatiles extracted from the lunar regolith.
  - Neutron spectrometer and a near-infrared spectrometer to guide the search for regions of high hydrogen concentration
  - Simple mobility system

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The Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) is commercial partnership for joint development of lunar landing capability.

April 30, 2014 – NASA Selects three Lunar CATALYST Partners:

- Astrobotic Technology, Inc.
- Masten Space Systems, Inc
- Moon Express, Inc.

Astrobotic Technology’s Griffin lander. 
*Credit: Astrobotic Technology, Inc.*

Masten’s XEUS lander. 
*Credit: NASA/Masten Space Systems, Inc*

Moon Express’s MX-1 Lander. 
*Credit: Moon Express, Inc.*
Asteroid Data Hunter Challenge

- The first of a series of challenges in NASA’s Asteroid Grand Challenge
- Collaboration between the NASA Tournament Lab (NASA, Harvard, and TopCoder) and Planetary Resources, Inc. (PRI)
- Near-viral media attention

- First algorithm challenge -- Correctly identify false positive detections in software
  “If we can offload repetitive tasks from our observers, but keep a high degree of confidence in our ability to discriminate false detections from real asteroids, then that only serves to increase the efficiency and sensitivity of the survey.” E. Christensen, Catalina Sky Survey (CSS)
  - Completed May 2; 100% detection score, improved rejections compared to CSS

- Second algorithm challenge -- Detection pipeline from astronomical image to the Minor Planet Center
  “A moving object detection pipeline that works out of the box will be a great benefit to amateur astronomers interested in getting involved in asteroid detection work.” E. Christensen, CSS
  - Launch date: 11 August

topcoder.com/asteroids
NASA sees prize competitions as a valuable tool to continue fostering innovation and American competitiveness:

- Stimulating technology breakthroughs, commercial markets, and new opportunities for business and jobs to form
- Enabling NASA to realize new cost savings and encourage the development of better products and solutions “on demand”
- Enabling NASA to bring out-of-discipline perspectives to bear and reach beyond the “usual suspects” to increase the number of minds tackling NASA’s problem

NASA has a decade of experience with prizes and challenges but is seeking to spread their strategic use within NASA even more broadly:

- Centennial Challenges Program
- NASA Tournament Lab
- Innovation Pavillion
- Center of Excellence for Collaborative Innovation
- NASA@Work
- Education Challenges
- Collaborative Innovation Efforts (International Space Apps Challenge)

NASA sees open innovation / prize competitions as another tool in the agency toolkit for problem solving and innovation.
Collaboration with SMD
Mars 2020 will seek signs of past life on Mars, collect and store a set of soil and rock samples that could be returned to Earth in the future, and test new technology to benefit future robotic and human exploration of Mars.

HEOMD / SMD / STMD are jointly sponsoring investigations to address high priority strategic knowledge gaps and technology development objectives for Human Exploration

- Mars Entry, Descent and Landing Instrumentation (MEDLI) to refine atmospheric entry models to inform future landing system design
- Exploration technology payloads that make significant progress towards filling at least one major Strategic Knowledge Gap.
Goldstone Radar NEO Imaging

Objectives:
Image and characterize 18 NEAs at 3.75 m resolution using the Goldstone radar ‘chirp’ technology. Image candidate NEAs for human exploration and newly detected NEAs as opportunity arises. Augments ongoing SMD-NEOO support.

SKGs Addressed: NEA orbit condition, size and spin mode information, surface structure characterization (when SNR is strong enough)

Status:
• Project transferred to PSD/NEOO in March 2014; future work will be absorbed into the NEOO program

Accomplishments:
• Imaged twice the number of NEAs in last calendar year than any previous year
• Goldstone radar astrometry refined Apophis’ orbit which removed any potential of an impact in 2036
• Transferred digital receiver to Arecibo to complement Goldstone capability
• Purchased new digital receiver for Greenbank for additional bistatic observation capability
SSERVI provides scientific, technical and mission-defining analyses for relevant NASA programs, planning and space missions, including:

The role of the Moon, NEAs, Phobos & Deimos in revealing the origin and evolution of the inner Solar System

- Moon, NEA, and Martian moon investigations as windows into planetary differentiation processes
- Near-Earth Asteroid characterization for potential science and human destinations
- Lunar structure and composition
- Regolith of Target Body(s)
- Dust and plasma interactions on Target Body(s)
- Volatiles (in its broad sense) and other potential resources on Target Body(s)
- Innovative observations that will advance our understanding of the fundamental physical laws, composition, and origins of the Universe
### Science emphasis

- Role of Target Body(s) in revealing the origin and evolution of the inner Solar System
- Target Body structure and composition
- Innovative observations that will advance our understanding of the fundamental physical laws, composition, and origins of the Universe
- Moon, NEA, and Martian moon investigations as windows into planetary differentiation processes
- Dust and plasma interactions on Target Body(s)
- Near-Earth asteroid characterization (including NEAs that are potential human destinations)
- Geotechnical properties (Moon, NEAs, Mars)
- Regolith of Target Bodies
- Radiation
- Volatiles (in its broad sense) and other potential resources on Target Body(s)
- In-Situ Resource Utilization (ISRU)/Prospecting (Moon, NEAs, Mars)
- Operations/Operability (all destinations, including transit)
- Human health and performance (all destinations, including transit)

### Exploration emphasis (SKGs)

- Science emphasis
Thank You For Your Kind Attention, and

QUESTIONS?