NASA's Exploration Architecture

Doug Cooke
Deputy Associate Administrator
Exploration Systems Mission Directorate
December 8, 2005

A Bold Vision for Space Exploration

- **Complete the International Space Station**
- **Safely fly the Space Shuttle until 2010**
- **Develop and fly the Crew Exploration Vehicle no later than 2014 (goal of 2012)**
- **Return to the Moon no later than 2020**
- **Extend human presence across the solar system and beyond**
- **Implement a sustained and affordable human and robotic program**
- **Develop supporting innovative technologies, knowledge, and infrastructures**
- **Promote international and commercial participation in exploration**

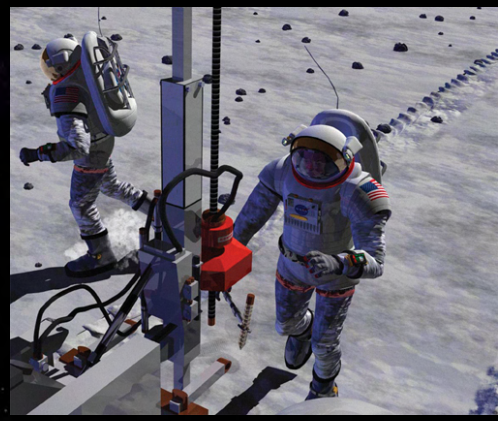
"It is time for America to take the next steps.

Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress – one mission, one voyage, one landing at a time"

President George W. Bush – January 14, 2004

The Moon - the 1st Step to Mars and Beyond….

- **Regaining and extending operational experience in a hostile planetary environment**
  - Long term human exploration- improving productivity
  - Developing reliability in human support systems
  - Reducing logistics- “Living off the land”

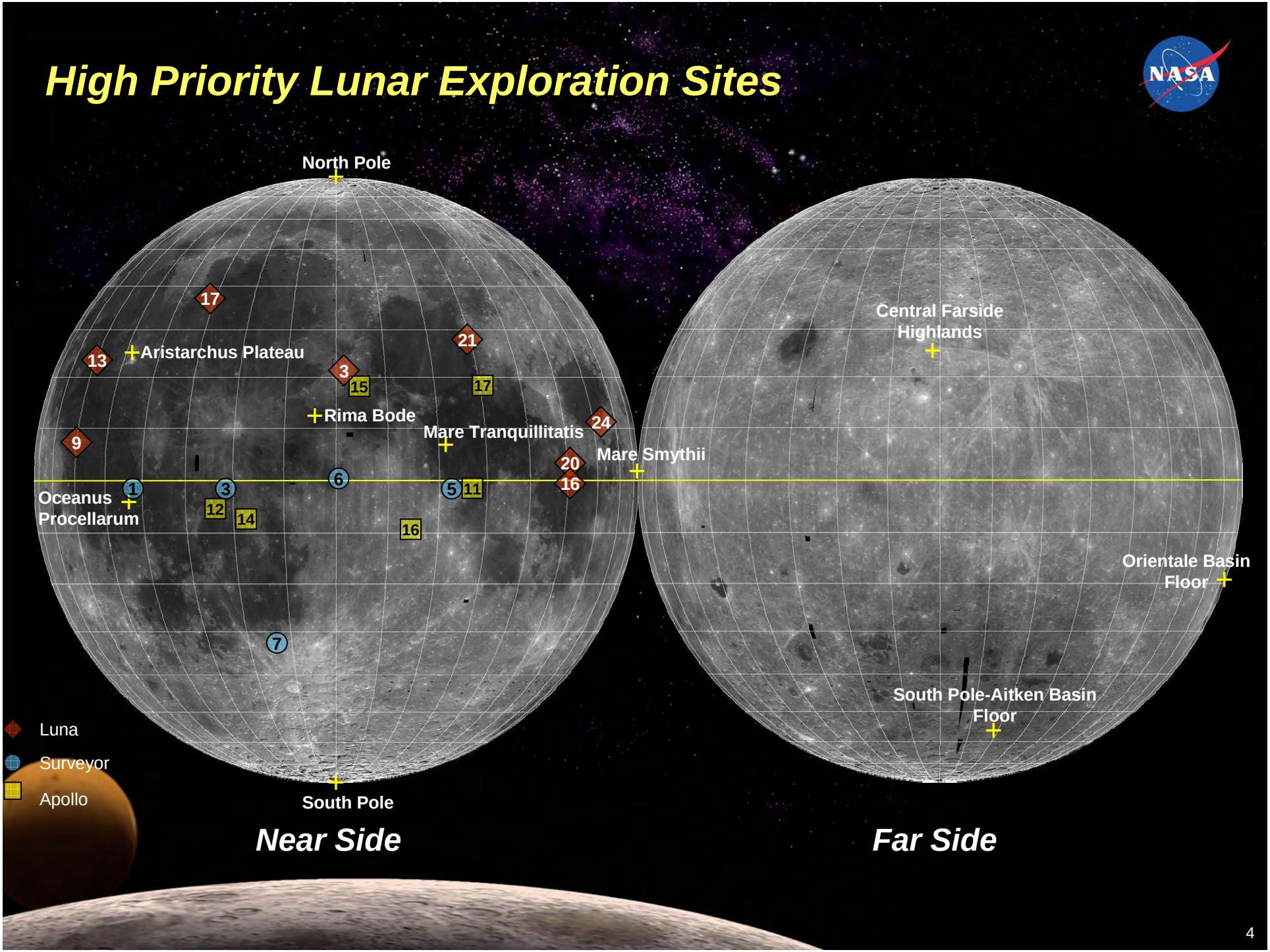


- **Developing capabilities needed for opening the space frontier- preparing for human exploration of Mars**
  - Crew and cargo launch vehicles (125 metric ton class)
  - Earth ascent/entry system – Crew Exploration Vehicle
  - Mars ascent and descent propulsion systems (liquid oxygen / liquid methane)

- **Science operations and discovery**
  - More to learn- Potential for numerous Science objectives
  - Cratering history of Earth-Moon system
  - History of solar wind
  - New locations: South Pole, Aitken Basin

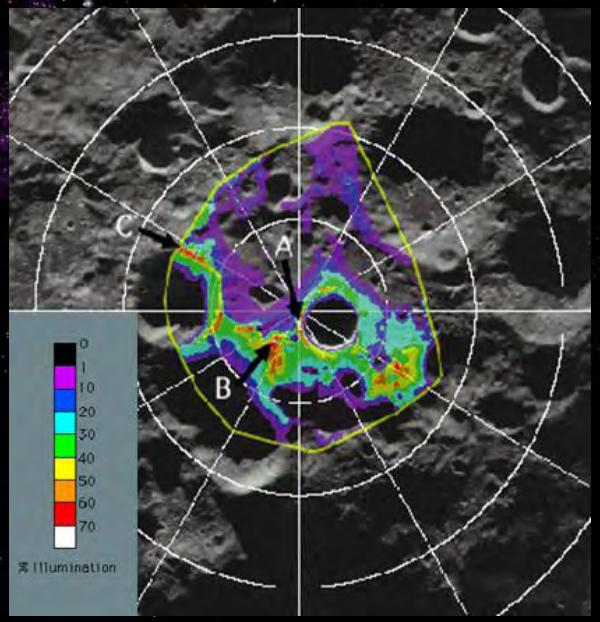
Next Step in Fulfilling Our Destiny As Explorers

High Priority Lunar Exploration Sites



Possible South Pole Outpost

- **Elevated quantities of hydrogen, possibly water ice (e.g., Shackelton Crater)**
- **Several areas with greater than 80% sunlight and less extreme temperatures**
- **Aitken Basin- largest known crater in the solar system**
  - Features unknown during Apollo
  - Exposed mantle?
- **Incremental deployment of outpost –**
  - Power system
  - Communications/navigation
  - Rovers
  - Habitat and laboratory modules



Implementing the Exploration Architecture:

- **Architecture**
  - Administrator Griffin Chartered ESAS April 29
  - ESAS developed the Exploration Architecture
  - Architecture Requirements are being finalized

- **Requirements**
  - Program and projects finalizing requirements for Crew Exploration Vehicle (CEV), Crew and Cargo Launch Vehicles, and ISS Cargo Delivery Vehicles
  - Call For Improvements released - basis for updated Industry proposals

- **Research and Technology programs reduced, focused, and phased to support accelerated CEV/CLV development and lunar missions**

- **Streamlined Organization**
  - HQ directorate is being reformed and downsized
  - Program and Project Offices are being established at the NASA centers

ESAS– Exploration Systems Architecture Study

The Exploration Roadmap

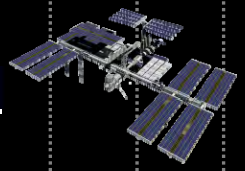
05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

1st Human CEV Flight

Robotic Precursors

7th Human Lunar Landing

Lunar Outpost Buildup



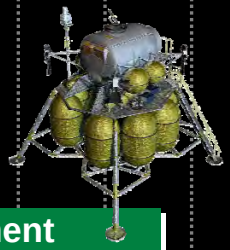
Commercial Crew/Cargo for ISS

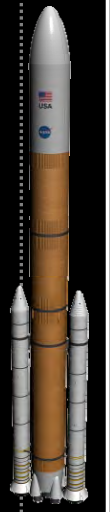
Mars Development

Space Shuttle

CEV Development

Crew Launch Development



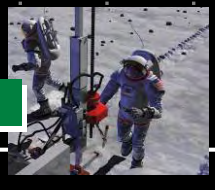


Lunar Lander Development

Lunar Heavy Launch Development

Earth Departure Stage Development

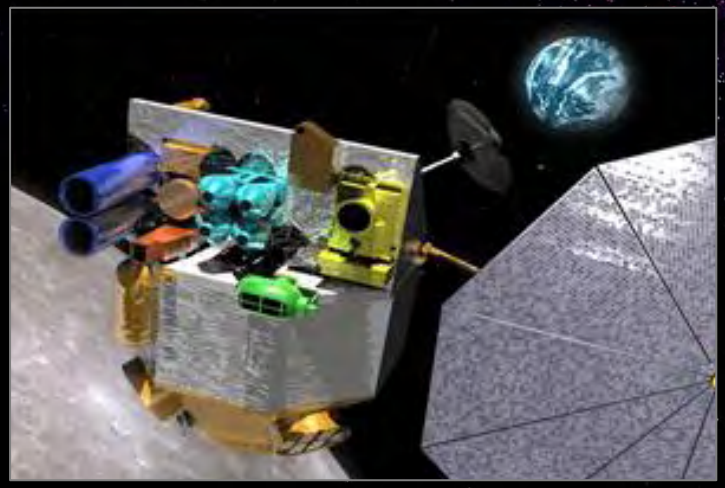
Surface Systems Development



Technology Assessment Groundrules and Assumptions

- Technology developments are traceable to architecture requirements
- Schedule Ground Rules and Assumption - Reference dates will be supported:
  - 2011 CEV human flight to ISS
  - 2018 goal of human mission to the moon including landing, but no later than 2020
  - 2022 goal of permanent human presence on moon
- Technologies will be Technology Readiness Level Six (TRL-6) or better by Preliminary Design Review (PDR).
  - 2007 PDR for CEV and crew launch vehicle
  - 2012 PDR for initial lunar mission elements
  - 2017 PDR for lunar permanent human presence mission elements
- Protect planned ISS flight research payloads except those deleted during the Zero-based review
- Leave in wedge for future lunar and Mars surface systems R&T

Robotic Lunar Exploration Program (RLEP)
First 2 Missions



Lunar Reconnaissance Orbiter (LRO)

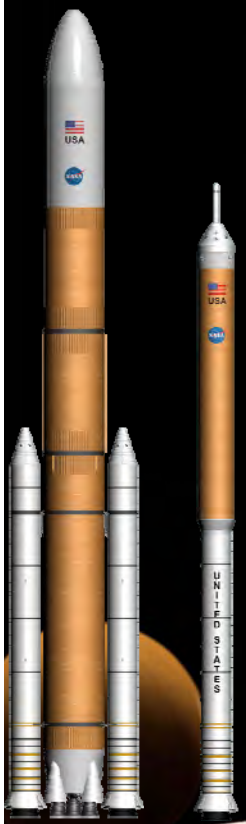
- Lunar mapping, topography, volatile identification, and radiation characterization,
- 50km polar orbit
- Preliminary Design Review: Early 2006
- Launch: October 2008

RLEP-2 Lander

- Mission to Lunar South Pole
- Ground truth for potential water-ice; Automated descent and precision landing, with hazard avoidance; common lander
- Pre-formulation through early 2006
- Launch: 2010/2011

A Safe, Accelerated, Affordable and Sustainable Approach

- **Meet all U.S. human spaceflight goals**
- **Significant advancement over Apollo**
  - Double the number of crew to lunar surface
  - Four times number of lunar surface crew-hours
  - Global lunar surface access with anytime return to the Earth
  - Enables a permanent human presence while preparing for Mars and beyond
  - Can make use of lunar resources
  - Significantly safer and more reliable
- **Minimum of two lunar missions per year**
- **Provides a 125 metric ton launch vehicle for lunar and later Mars missions and beyond**
- **Higher ascent crew safety than the Space Shuttle**
  - 1 in 2,000 for the Crew Launch Vehicle
  - 1 in 220 for the Space Shuttle
- **U.S. system capable of servicing the International Space Station**
- **Orderly transition of the Space Shuttle workforce**
- **Requirements-driven technology program**



Architectural Elements

Earth Departure Stage

Crew Exploration Vehicle

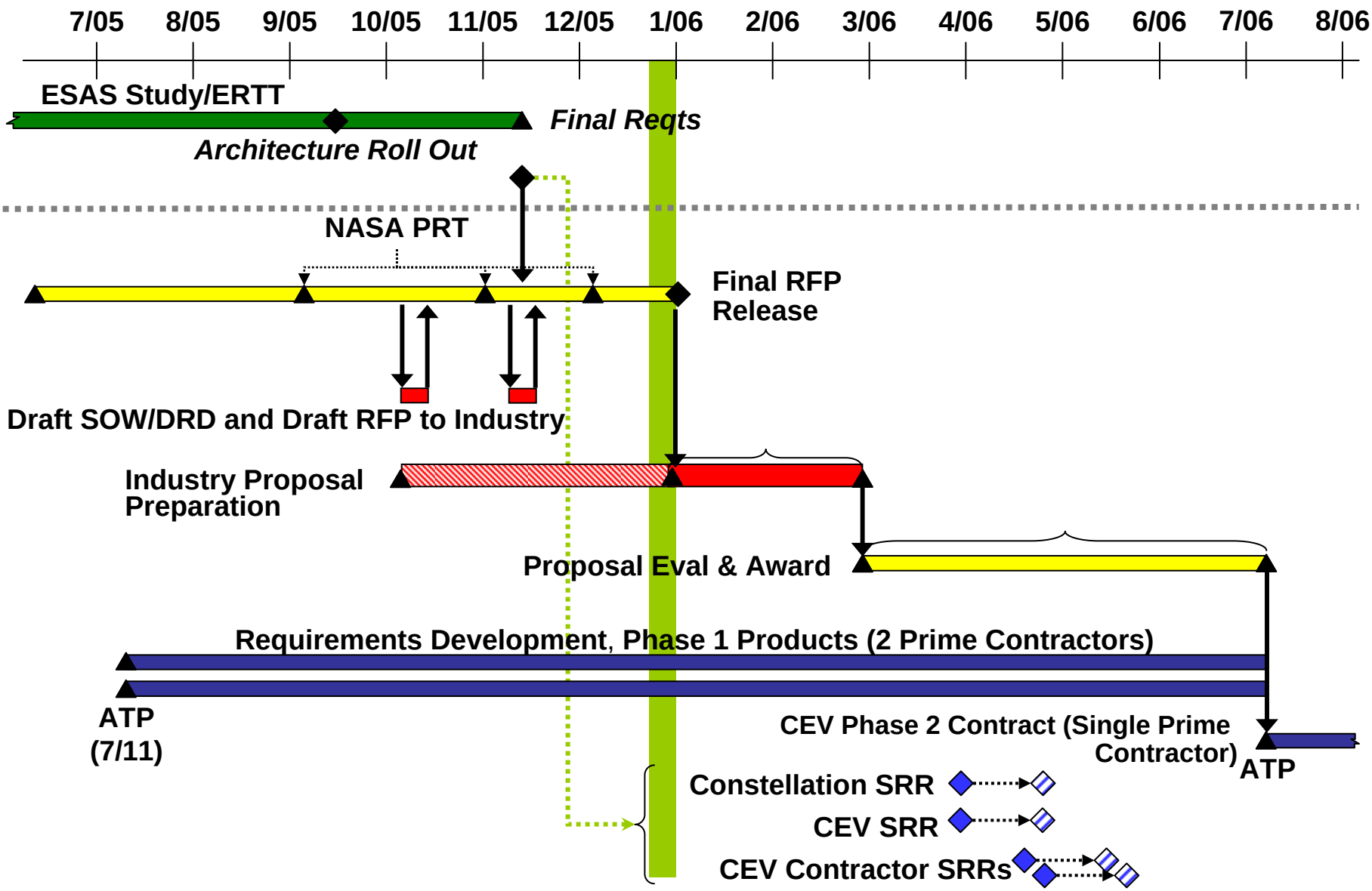
Lunar Lander and Ascent Stage

Launch Systems

Crew Exploration Vehicle

- **A blunt body capsule is the safest, most affordable, with quickest development time**
  - Requirements similar to Apollo
  - Separate Crew Module and Service Module
  - Variable Crew size
    - Up to six for Space Station
    - Four for Lunar missions
    - Six for Mars missions
  - Potential for pressurized and unpressurized cargo to the Space Station
- **Capsule scaled up from Apollo**
  - Significant increase in volume
  - Reduced development time and risk
  - Reduced reentry loads, increased landing stability

Phase 2 RFP Schedule



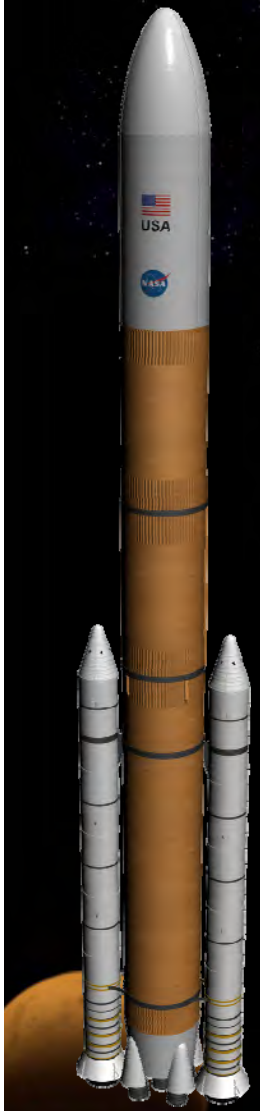
Launch Systems

- **EELV fleet for scientific and International Space Station cargo missions in the 5-20 metric ton range- to the maximum extent possible.**
  - New, commercially-developed launch capabilities to compete
- **Crew Launch vehicle derived from the current Shuttle solid rocket booster and liquid propulsion system**
  - The *safest, most reliable, and most affordable* way to meet exploration crew launch requirements
  - Capitalizes on human-rated systems and existing facilities
  - Synergies with exploration heavy lift
  - Ensures national capability to produce solid propellant fuel at current levels.
- **Cargo Launch Vehicle derived from Shuttle systems- 125 metric ton lift capacity**
  - Minimize on-orbit assembly and complexity – *increasing mission success*
  - Current Shuttle lifts 100 metric tons to orbit on every launch.
    - 20 metric tons is payload/cargo; remainder is Shuttle Orbiter
    - Straight forward evolution to exploration heavy lift
- **Shuttle derived systems allow for maximum synergy and leveraging of designs, manufacturing and work force**

Crew Launch Vehicle

- **Serves as the long term crew launch capability for the U.S.**
- **4 Segment Shuttle Solid Rocket Booster**
- **New liquid oxygen / liquid hydrogen upperstage**
  - 1 Space Shuttle Main Engine
- **Payload capability**
  - 25 metric tons to low Earth orbit
  - Growth to 32 metric tons with a 5th solid segment

Lunar Heavy Cargo Launch Vehicle



- **5 Segment Shuttle Solid Rocket Boosters**
- **Liquid Oxygen / liquid hydrogen core stage**
  - Heritage from the Shuttle External Tank
  - 5 space Shuttle Main Engines
- **Payload Capability**
  - 106 metric tons to low Earth orbit
  - 125 Metric tons to low Earth orbit using Earth departure stage
  - 55 metric tons trans-lunar injection capability using Earth departure stage
- **Can be certified for crew if needed**

Earth Departure Stage

- **Liquid oxygen / liquid hydrogen stage**
  - Heritage from the Shuttle External Tank
  - J-2S engines (or equivalent)
- **Stage ignites suborbitally and delivers the lander to low-Earth orbit**
  - Can also be used as an upper stage for low-Earth orbit missions
- **The CEV later docks with this system and the Earth departure stage performs a trans-lunar injection burn**
- **The Earth departure stage is then discarded**

Lunar Lander and Ascent Stage

- **4 crew to and from the surface**
  - Seven days on the surface
  - Lunar outpost crew rotation
- **Global access capability**
- **Anytime return to Earth**
- **Capability to land 21 metric tons of dedicated cargo**
- **Airlock for surface activities**
- **Descent stage:**
  - Liquid oxygen / liquid hydrogen propulsion
- **Ascent stage:**
  - Liquid oxygen / liquid methane propulsion

Potential Commercial Opportunities

- Commercial services will be purchased where cost effective and meet NASA needs and safety requirements.
- Upcoming Procurement- Commercial services for Space Station crew/cargo delivery and return- Preferred approach
- Innovative acquisitions to encourage entrepreneurs
- Use of government developed capabilities to further commercial opportunities

Potential International Opportunities

- Continue International Space Station cooperation- focused on human exploration
- Collaboration on robotic missions
- Augmenting US developed missions and capabilities
  - In space
  - Lunar surface
- Planning for future mission opportunities

Basic Organizational Roles

Directorate Management (Headquarters)

Associate Administrator for Exploration Systems

- ✓ Strategic and Policy Direction
- ✓ Cross-Program Integration
- ✓ Program Guidance
- ✓ Review and Oversight

Clear Accountability for Deliverables and Reporting

Program Management (Centers)

Various Program Offices NASA Field Centers

- ✓ Cross-Project Integration
- ✓ Assessment and Evaluation
- ✓ Balanced Requirements
- ✓ Insight

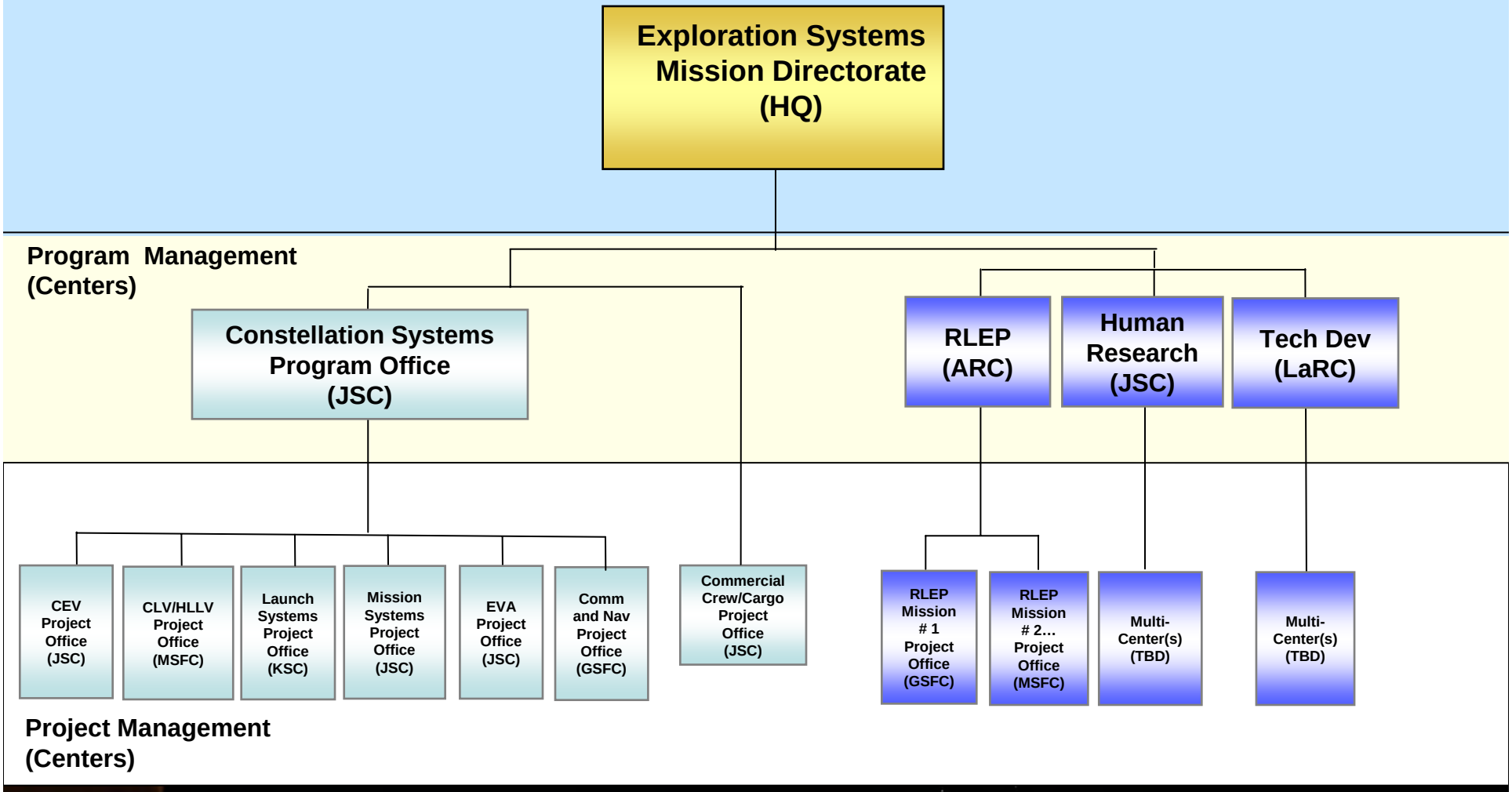
Clear Tasking Protocols; Streamlined Expectations

Project Management (Centers)

Various Project Offices NASA Field Centers

- ✓ Project Implementation
- ✓ Contract Execution

Exploration Systems Organization



Transforming Exploration Systems Mission Directorate (ESMD)

- ESMD has aggressively adopted the recommendations of the ESAS study team
- CEV accelerated to 2011/12 to reduce gap in US human space flight capability while adding ISS servicing capability
- Research, Technology and and Prometheus programs refocused to support phased needs
- Lunar mission architecture defined
- Shuttle-derived launch vehicle family selected
- ESMD Organization streamlined and Program/Project offices established at Field Centers

"We leave as we came, and God willing, as we shall return, with peace and hope for all mankind."
— Eugene Cernan, Commander of the last Apollo mission
The United States must lead the expansion of the space frontier to continue to maintain our world leadership role, and for the security of the nation.
Great nations do great and ambitious things. We must continue to be great.