NASA'S EXPLORATION ARCHITECTURE

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A Bold Vision for Space Exploration
NASA
Complete the International Space Station
Safely fly the Space Shuttle until 2010
Develop and fly the Crew Exploration Vehicle no later than 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….

- **Gaining significant experience in operating away from Earth's environment**
  - Space will no longer be a destination visited briefly and tentatively
  - "Living off the land"
  - Field exploration techniques
  - Human support systems
  - Dust mitigation and planetary protection

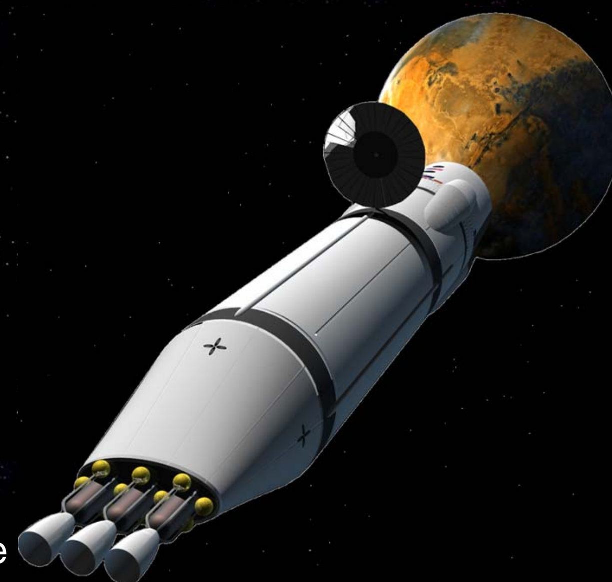
- **Developing technologies needed for opening the space frontier**
  - Crew and cargo launch vehicles (125 metric ton class)
  - Earth entry system – Crew Exploration Vehicle
  - Mars ascent and descent propulsion systems (liquid oxygen / liquid methane)

- **Conduct fundamental science**
  - Astrobiology, historical geology, exobiology, astronomy, physics

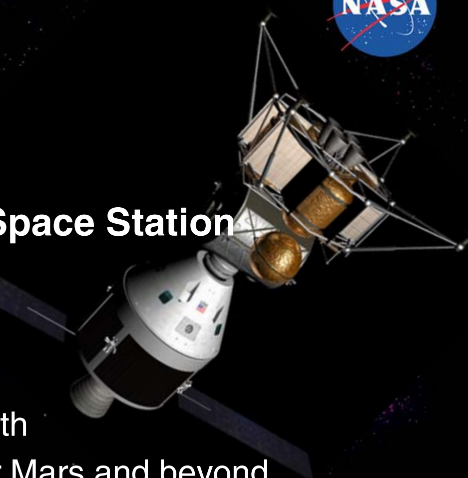
Next Step in Fulfilling Our Destiny As Explorers

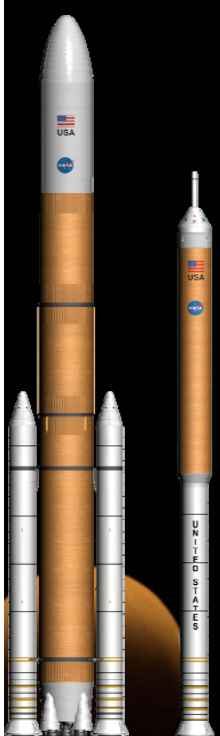
How We Will Get to Mars

- **4 – 5 assembly flights to low Earth orbit with a 100 metric ton class launch system**
- **Pre-deployed Mars surface outpost before the crew launches**
  - Habitat and support systems
  - Power
  - Communications
  - Mars ascent / descent vehicle
- **180 day transit time to/from Mars**
  - 6 crewmembers
  - Dedicated in-space crew transit vehicle
  - Dedicated Earth entry system (CEV)
- **500 days on the surface**
  - Capability to explore large regions of the surface
  - Multi-disciplinary science investigations
  - In-Situ resource utilization
    - Consumables: Oxygen and water
    - Propellants: Liquid oxygen and methane

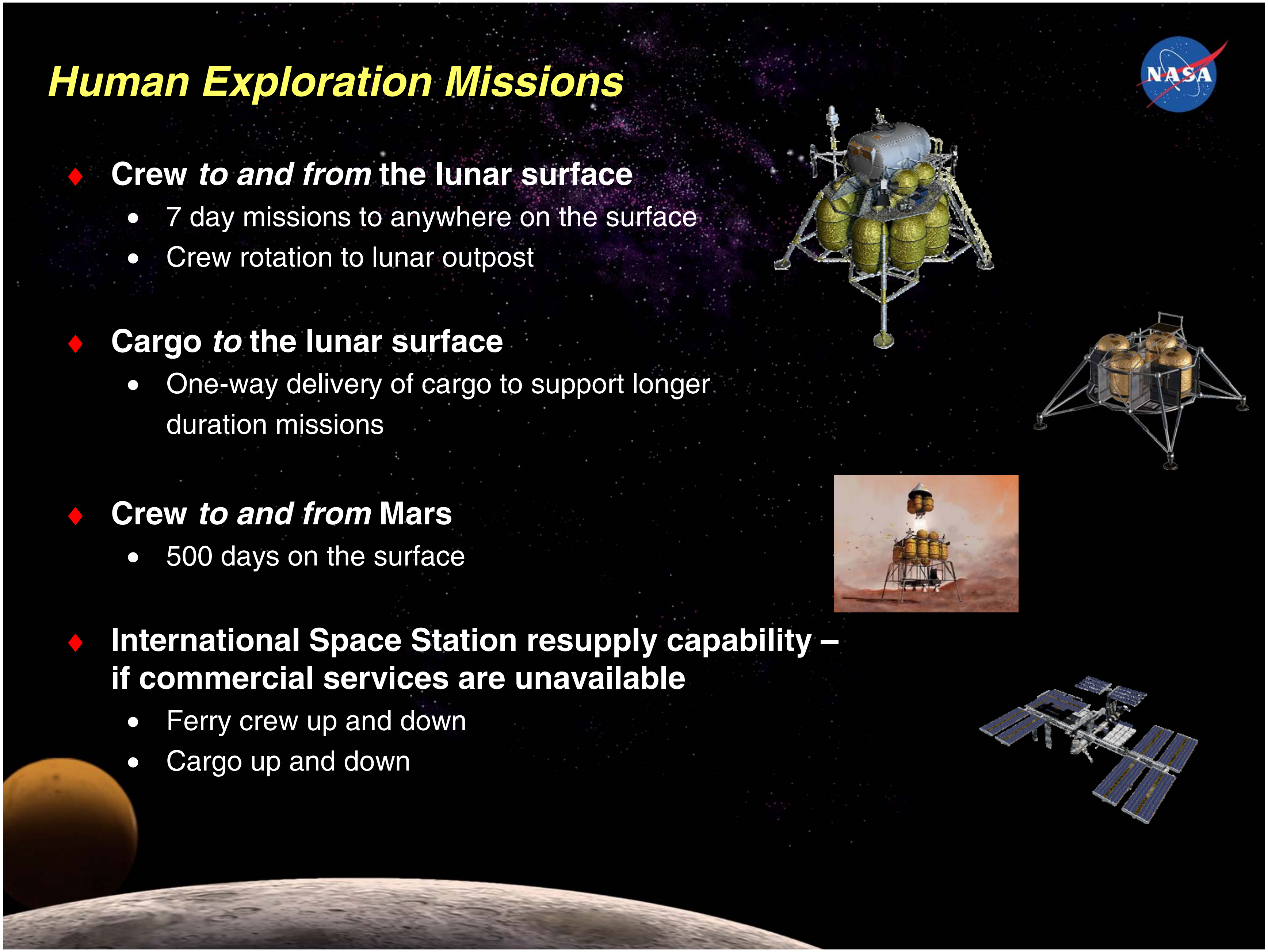


A Safe, Accelerated, Affordable and Sustainable Approach

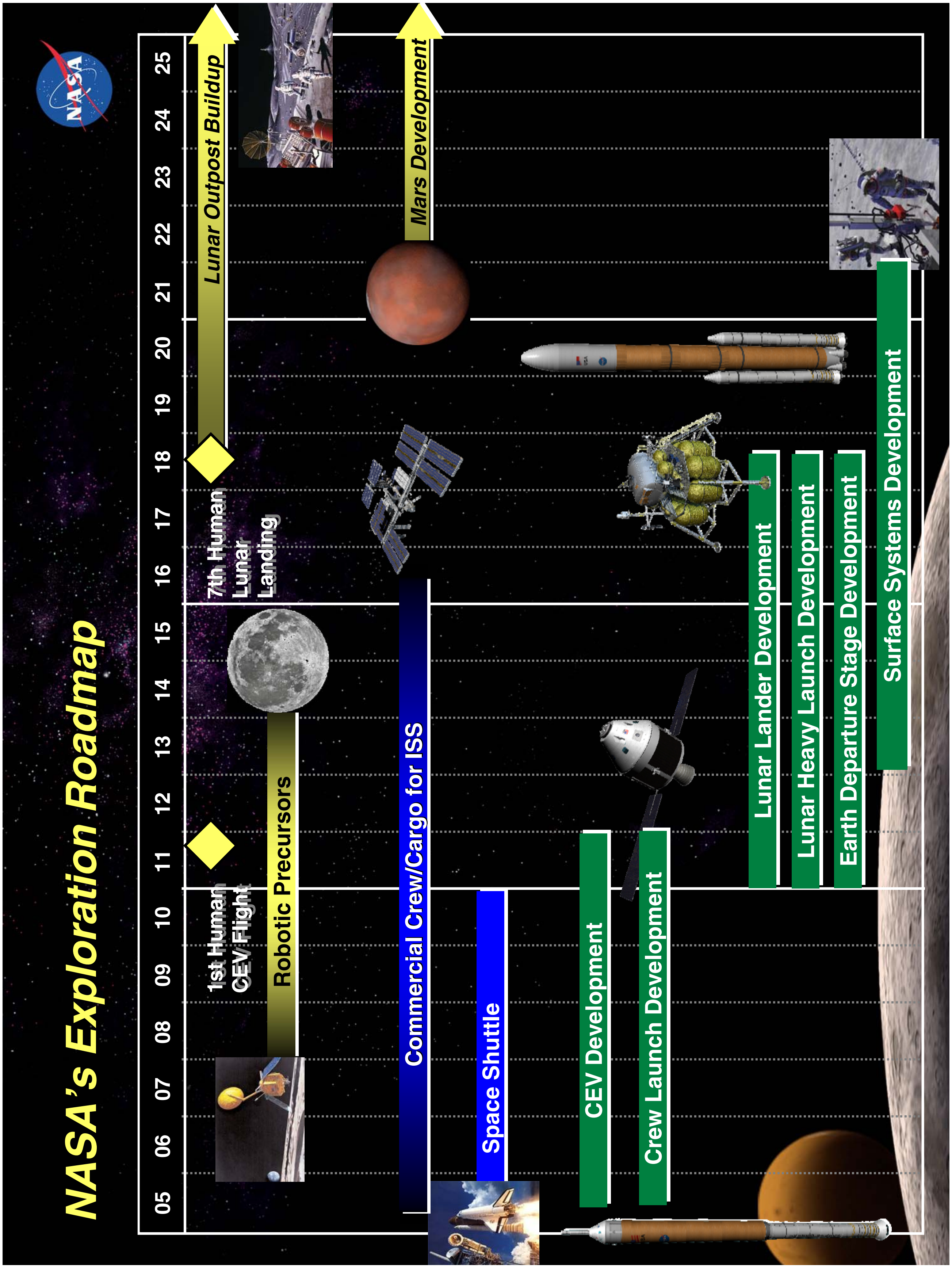




- Meet all U.S. human spaceflight goals
- U.S. system capable of servicing the International Space Station
- Significant advancement over Apollo
  - Double the number of crew to lunar surface
  - Four times number of lunar surface crew-hours
  - Global lunar surface access with anytime return to the 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 (1 in 1,700 to 4,200) for the Crew Launch Vehicle
  - 1 in 220 (1 in 160 to 310) for the Space Shuttle
- Orderly transition of the Space Shuttle workforce
- Requirements-driven technology program



Human Exploration Missions
NASA
Crew to and from the lunar surface
7 day missions to anywhere on the surface
Crew rotation to lunar outpost
Cargo to the lunar surface
One-way delivery of cargo to support longer duration missions
Crew to and from Mars
500 days on the surface
International Space Station resupply capability – if commercial services are unavailable
Ferry crew up and down
Cargo up and down


NASA's Exploration Roadmap
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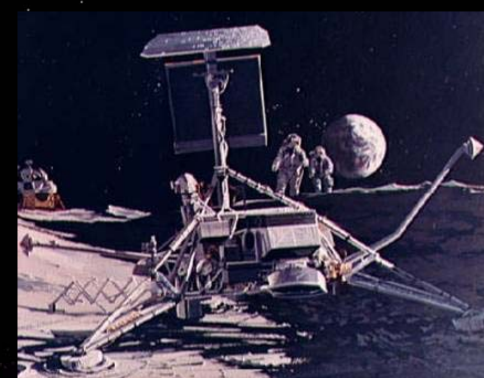
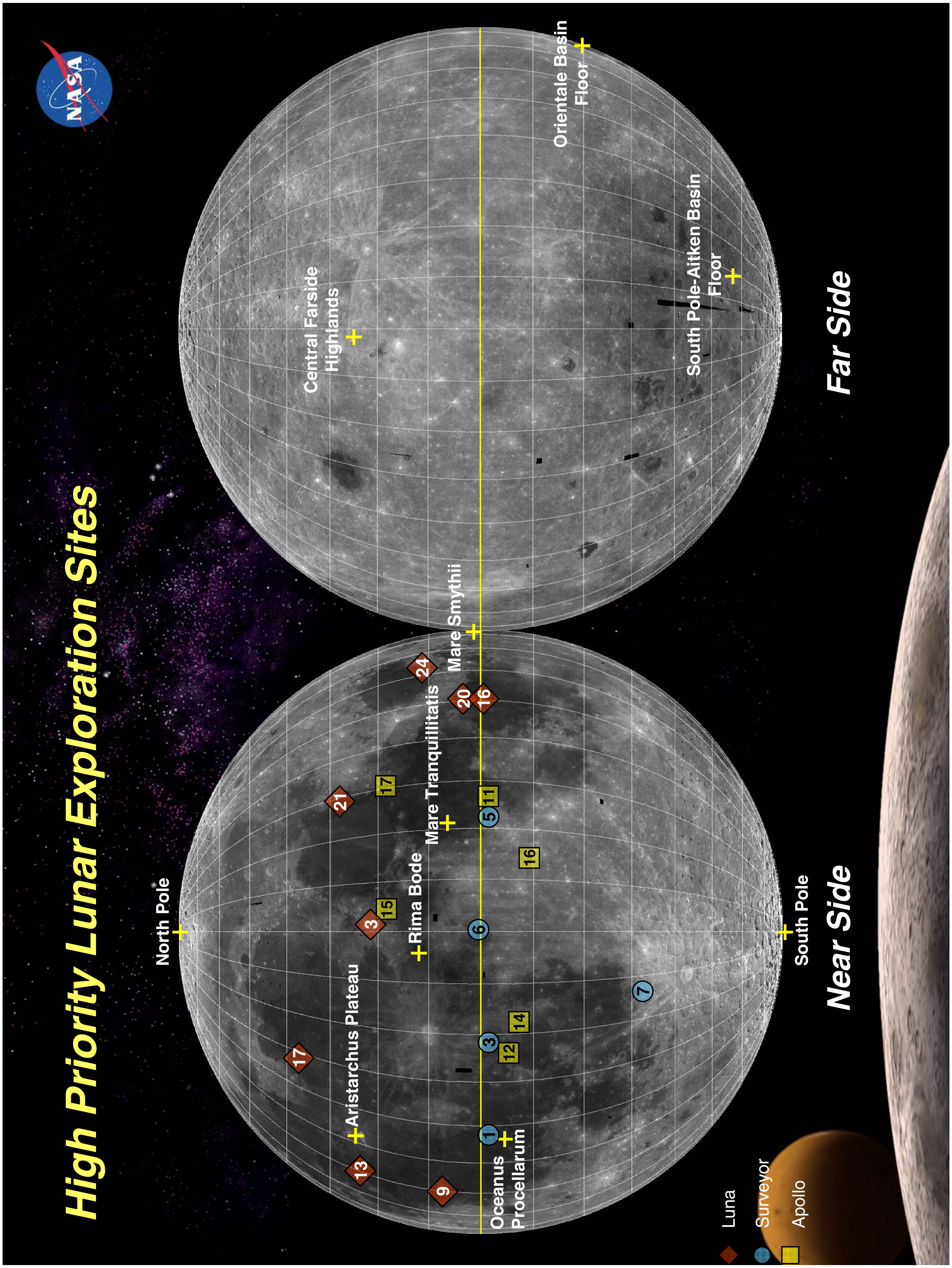
1st Human CEV Flight
7th Human Lunar Landing
Lunar Outpost Buildup
Robotic Precursors
Mars Development
Commercial Crew/Cargo for ISS
Space Shuttle
CEV Development
Crew Launch Development
Lunar Lander Development
Lunar Heavy Launch Development
Earth Departure Stage Development
Surface Systems Development

Paving the Way – Robotic Precursor Missions

- **Provide early information for human missions to the Moon**
  - Key knowledge needed for human safety and mission success
  - Infrastructure elements for eventual human benefit
  - Scientific results to guide human exploration
- **May be evolvable to later human systems**
- **Most unknowns are associated with the North and South Poles – a likely destination for a lunar outpost**
- **Key requirements involve establishment of**
  - Support infrastructure – navigation/communication, beacons
  - Knowledge of polar environment – temperatures, lighting, etc.
  - Polar deposits – composition and physical nature
  - Terrain and surface properties

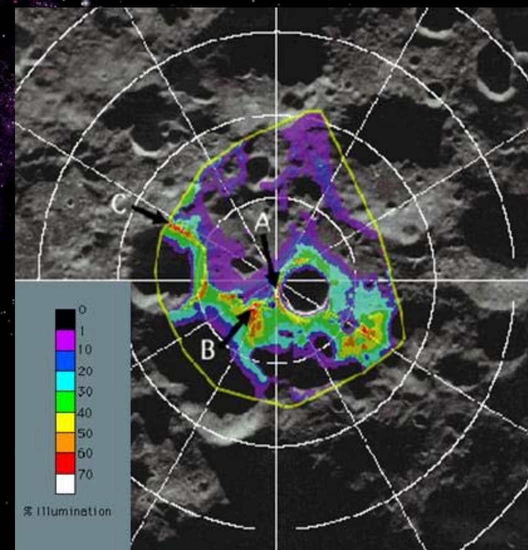




High Priority Lunar Exploration Sites
North Pole
Aristarchus Plateau
Rima Bode
Mare Tranquillitatis
Mare Smythii
Oceanus Procellarum
South Pole
Near Side
Central Farside Highlands
Orientale Basin Floor
South Pole-Aitken Basin Floor
Far Side
Luna
Surveyor
Apollo

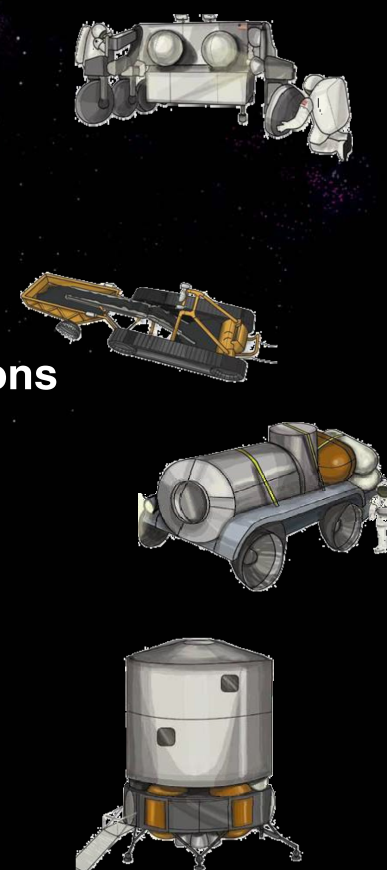
Possible South Pole Outpost

- The lunar South Pole is a likely candidate for outpost site
- Elevated quantities of hydrogen, possibly water ice (e.g., Shackelton Crater)
- Several areas with greater than 80% sunlight and less extreme temperatures
- Incremental deployment of systems – one mission at a time
  - Power system
  - Communications/navigation
  - Habitat
  - Rovers
  - Etc.



Lunar Surface Activities

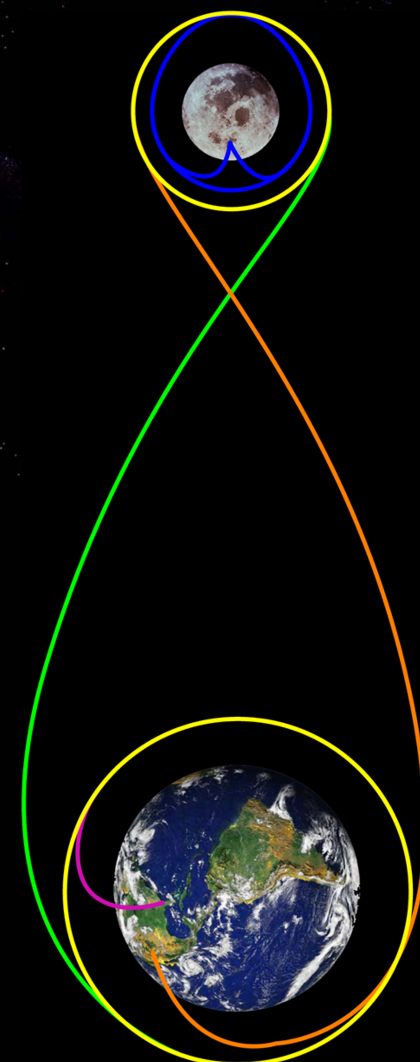
- **Initial demonstration of human exploration beyond earth orbit**
  - Learning how to operate away from the Earth
- **Conduct scientific investigations**
  - Use the moon as a natural laboratory
    - Planetary formation/differentiation, impact cratering, volcanism
  - Understand the integrated effects of gravity, radiation, and the planetary environment on the human body
- **Conduct in-situ resource utilization (ISRU) demonstrations**
  - Learning to "live off the land"
  - Excavation, transportation and processing of lunar resources
- **Begin to establish an outpost - one mission at a time**
  - Enable longer term stays
- **Testing of operational techniques and demonstration of technologies needed for Mars and beyond…..**

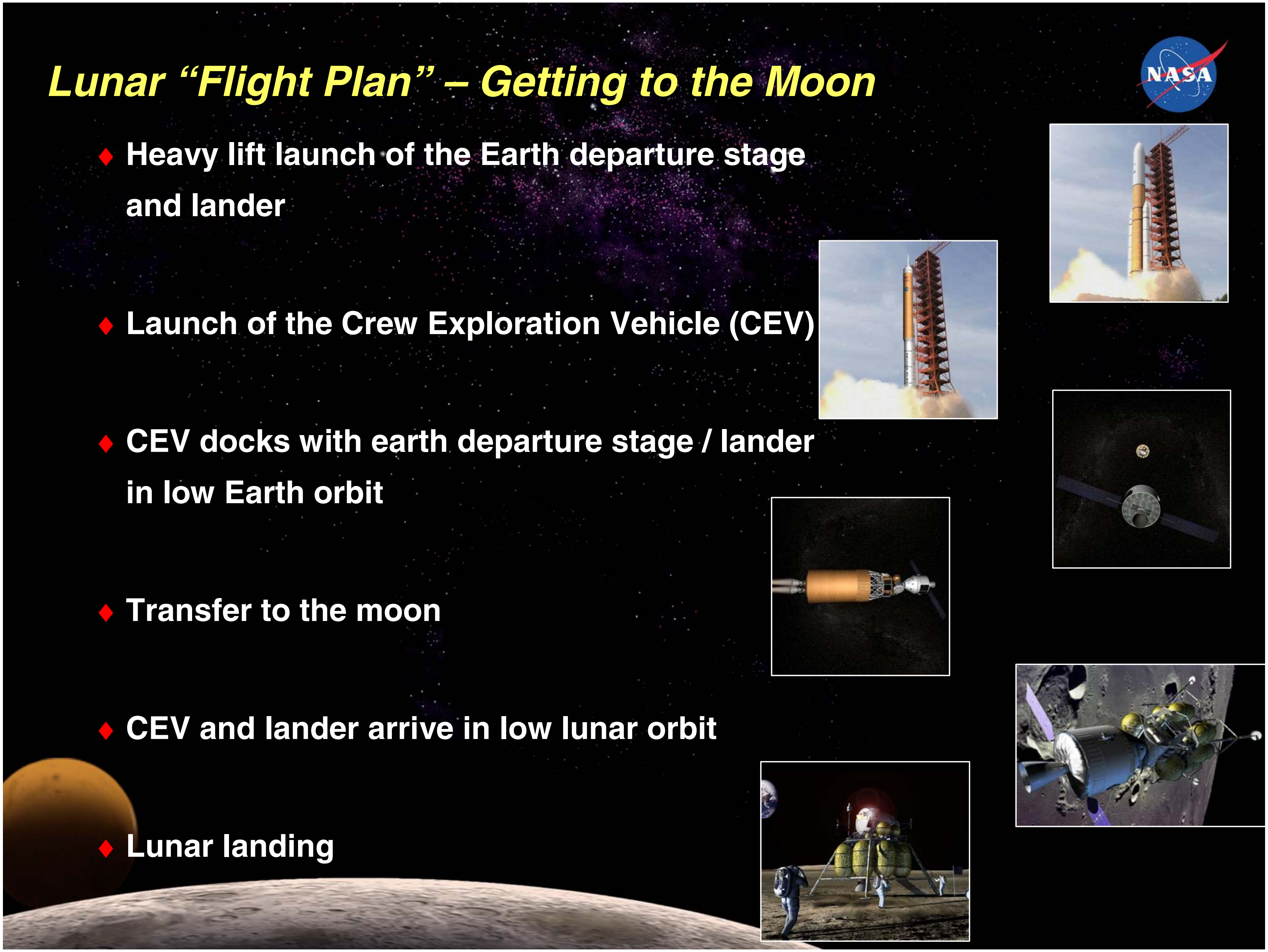


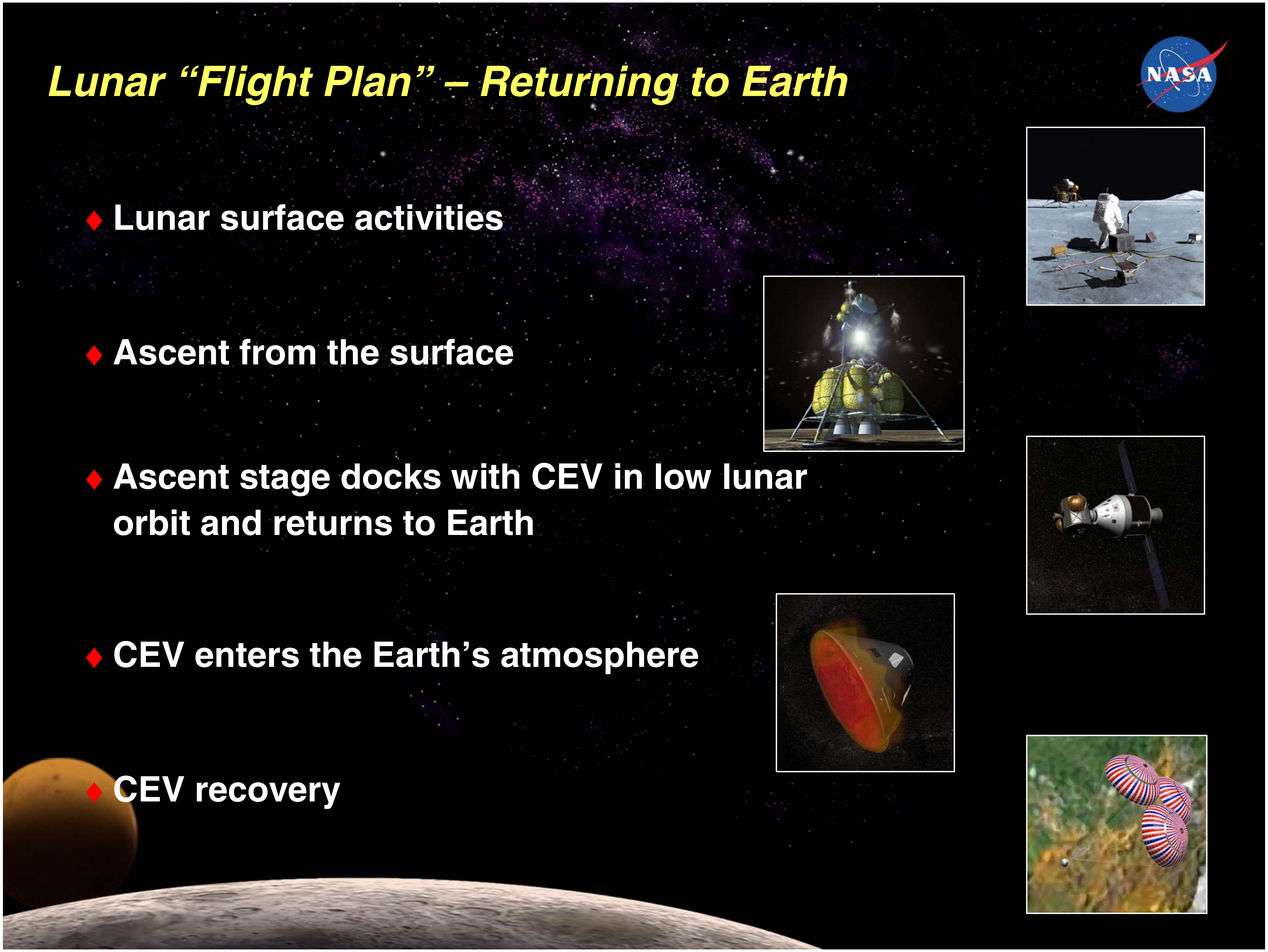
How We Plan to Return to the Moon

Mission Mode – “EOR-LOR”

- **After launch, the elements that take the crew to lunar orbit perform an “Earth Orbit Rendezvous (EOR)”**
- **At the completion of lunar surface activities the elements perform a “Lunar Orbit Rendezvous (LOR)” and return to Earth**
  - “Direct Return” eliminated because it increases crew system complexity, has small margins, has the greatest number of operations issues and highest sensitivity to mass growth
- **High efficiency cryogenic lander propulsion is an enabler**
- **The Crew Exploration Vehicle only *has to be* qualified for one launch system**
- **Mode has the highest calculated mission reliability and safety**




Lunar "Flight Plan" – Getting to the Moon
Heavy lift launch of the Earth departure stage and lander
Launch of the Crew Exploration Vehicle (CEV)
CEV docks with earth departure stage / lander in low Earth orbit
Transfer to the moon
CEV and lander arrive in low lunar orbit
Lunar landing


Lunar "Flight Plan" – Returning to Earth
NASA
Lunar surface activities
Ascent from the surface
Ascent stage docks with CEV in low lunar orbit and returns to Earth
CEV enters the Earth's atmosphere
CEV recovery


How We Plan to Return to the Moon
Crew Exploration Vehicle
A blunt body capsule is the safest, most affordable and fastest approach
Separate Crew Module and Service Module configuration
Vehicle designed for lunar missions with 4 crew
– Can accommodate up to 6 crew for Mars and Space Station missions
System also has the potential to deliver pressurized and unpressurized cargo to the Space Station if needed
5.5 meter diameter capsule scaled from Apollo
Significant increase in volume
Reduced development time and risk
Reduced reentry loads, increased landing stability and better crew visibility
NASA
USA

Servicing the International Space Station

- **NASA will invite industry to offer commercial crew and cargo delivery service to and from the Station**

- **The CEV will be designed for lunar missions**

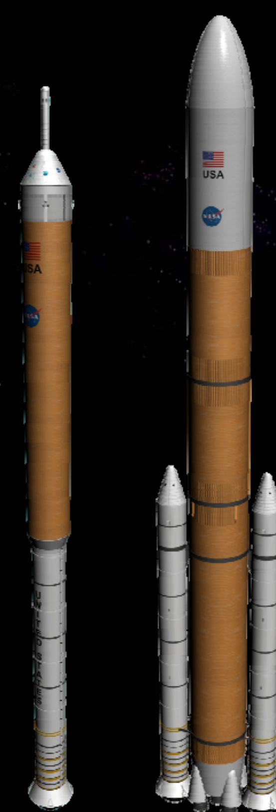
  but, if needed, can service the International Space Station. Annually, the CEV has the potential for:
  - 2 crew flights
  - 3 pressurized cargo flights
  - 1 unpressurized cargo flight

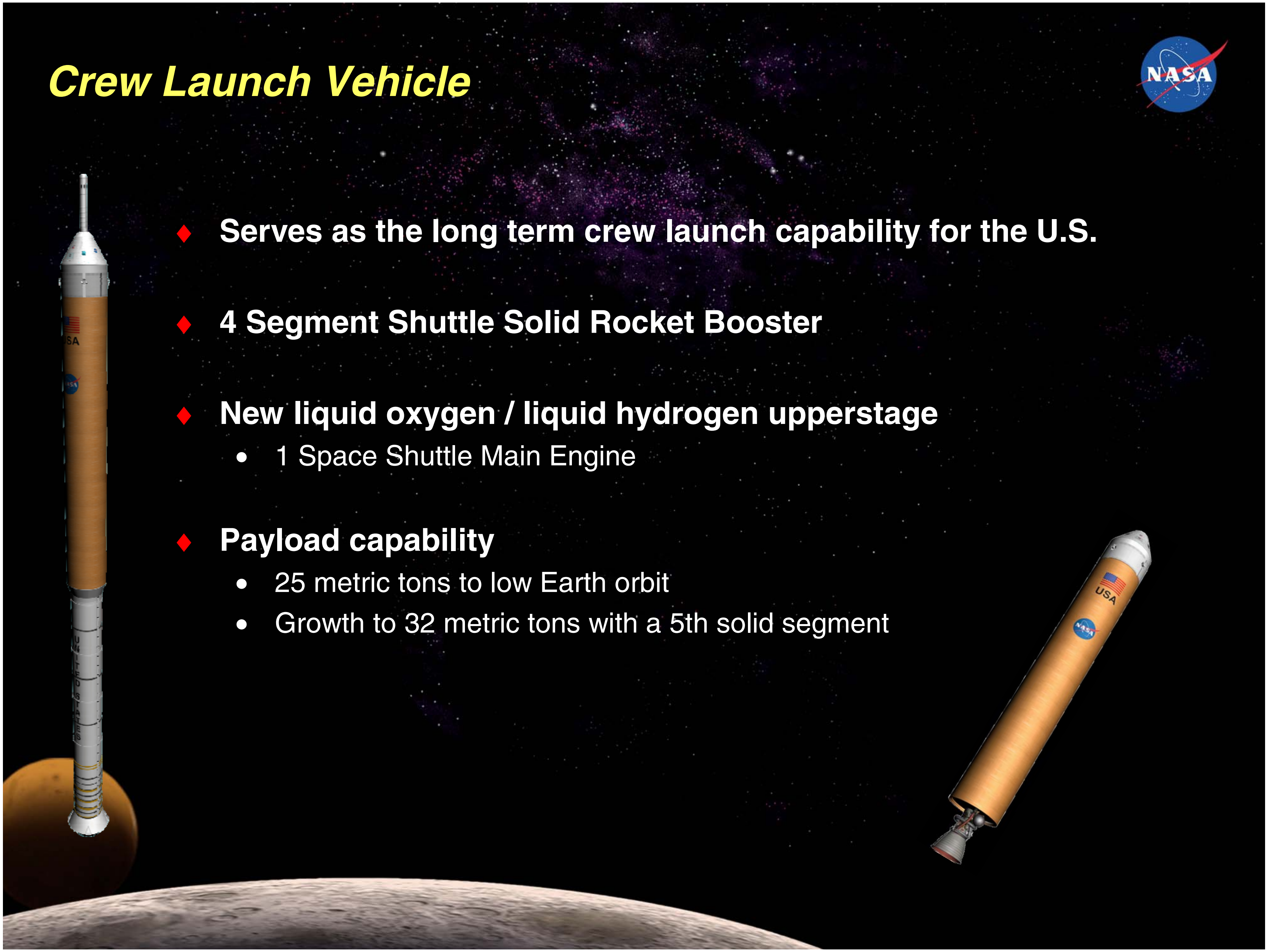
- **The CEV will be able to transport crew to and from the station and stay for 6 months**

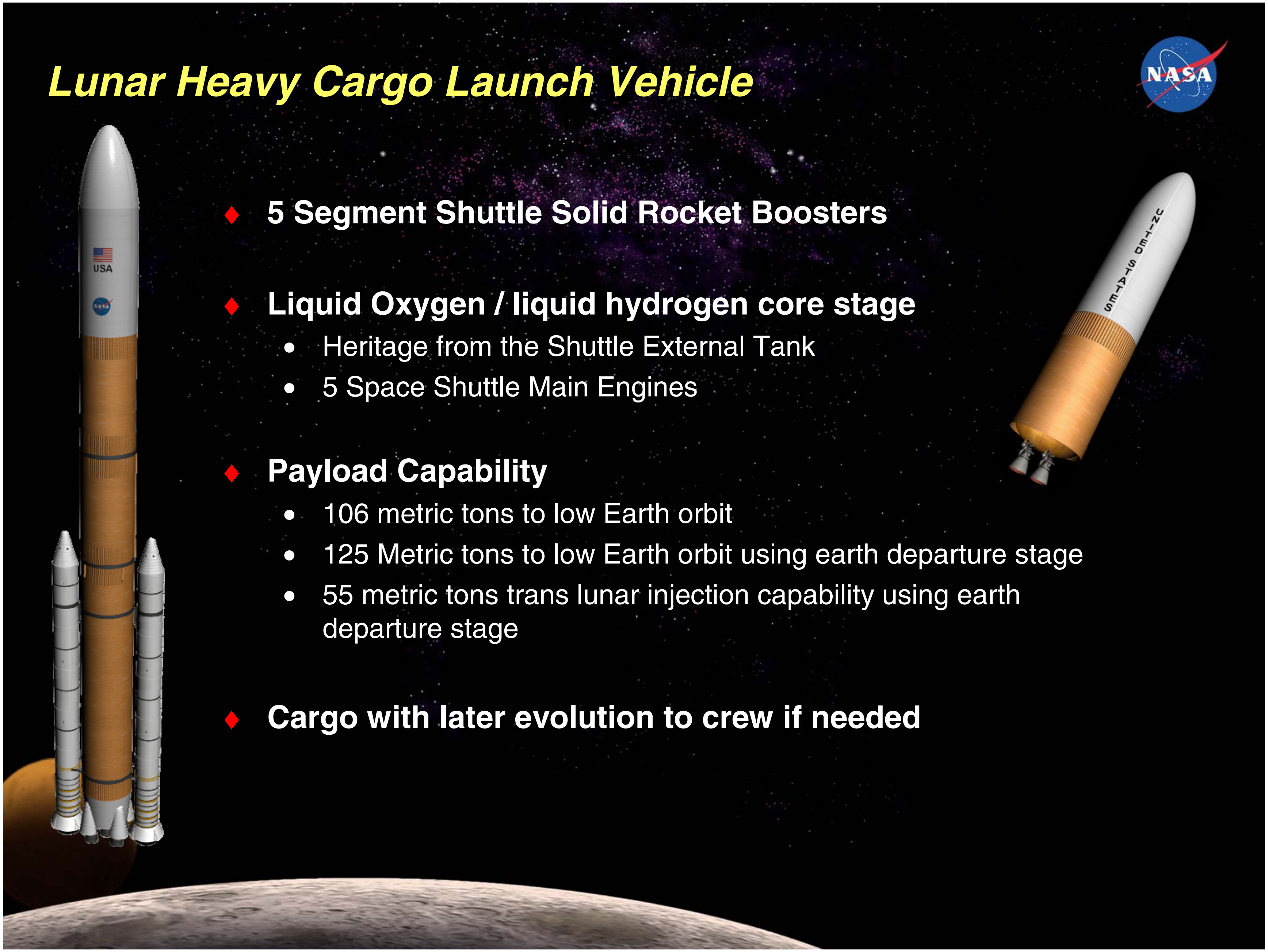
How We Plan to Return to the Moon

Launch Systems

- **Continue to rely on the 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 will be allowed to compete.
- **The *safest, most reliable, and most affordable* way to meet exploration launch requirements is a system derived from the current Shuttle solid rocket booster and liquid propulsion system.**
  - Capitalizes on human rated systems and 85% of existing facilities
  - The most straightforward growth path to later exploration super heavy launch needs.
  - Ensures national capability to produce solid propellant fuel at current levels.
- **125 metric ton lift capacity required to minimize on-orbit assembly and complexity – increasing mission success**
  - A clean-sheet-of-paper design incurs high expense and risk.
  - EELV-based designs require development of *two* core stages plus boosters - increasing cost and decreasing safety/reliability.
  - Current Shuttle lifts 100 metric tons to orbit on every launch.
    - 20 metric tons is payload/cargo; remainder is Shuttle Orbiter.
    - Evolution to exploration heavy lift is straightforward.
      - 125 metric ton capability
      - Lower production costs
      - Easier to human-rate if needed




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
Cargo with later evolution to crew if needed
USA
UNITED STATES

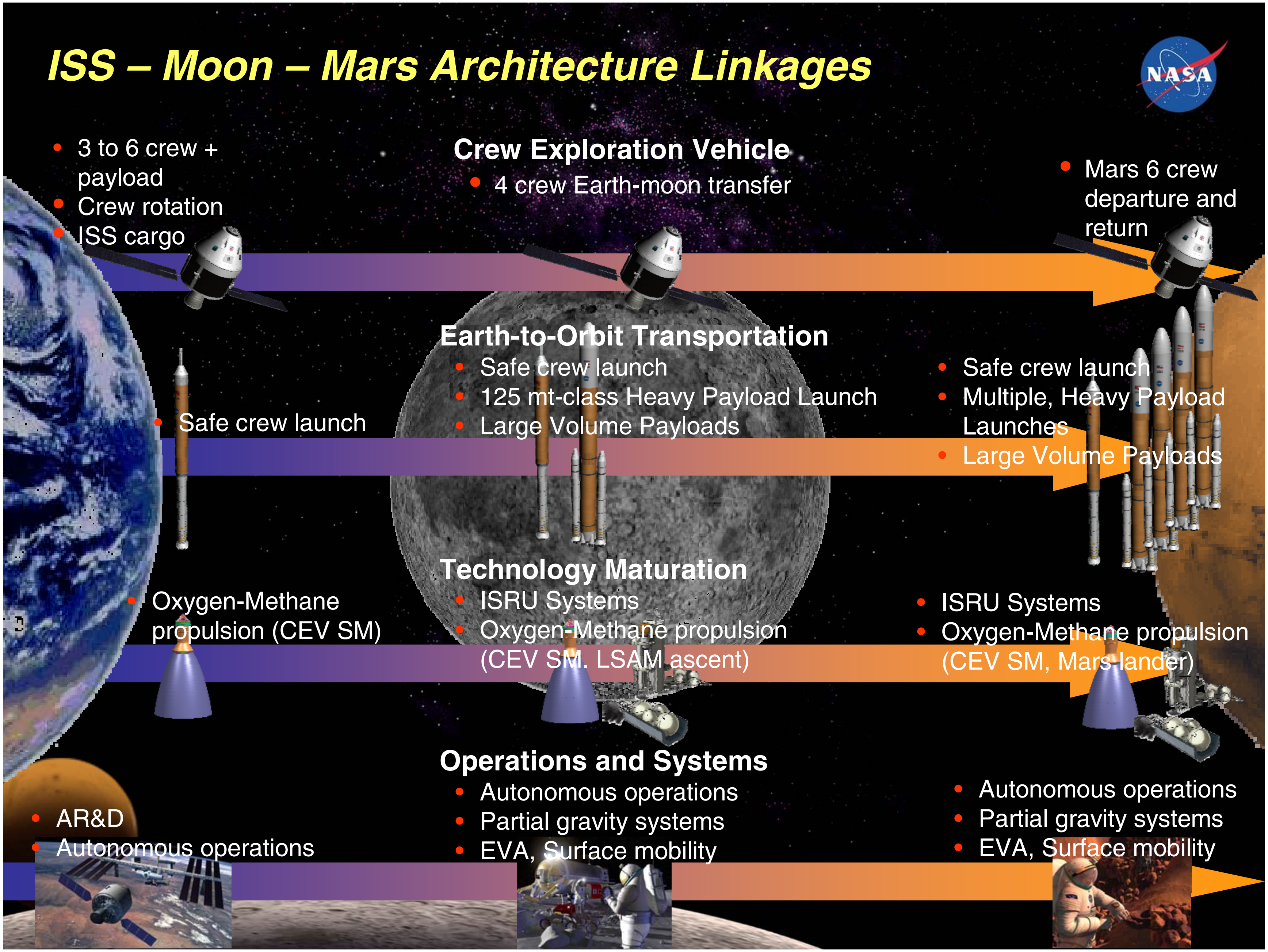
Earth Departure Stage

- **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**

How We Plan to Return to the Moon

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


ISS – Moon – Mars Architecture Linkages
NASA
3 to 6 crew + payload
Crew rotation
ISS cargo
Crew Exploration Vehicle
4 crew Earth-moon transfer
Mars 6 crew departure and return
Safe crew launch
Earth-to-Orbit Transportation
Safe crew launch
125 mt-class Heavy Payload Launch
Large Volume Payloads
Safe crew launch
Multiple, Heavy Payload Launches
Large Volume Payloads
Oxygen-Methane propulsion (CEV SM)
Technology Maturation
ISRU Systems
Oxygen-Methane propulsion (CEV SM. LSAM ascent)
ISRU Systems
Oxygen-Methane propulsion (CEV SM, Mars lander)
AR&D
Autonomous operations
Operations and Systems
Autonomous operations
Partial gravity systems
EVA, Surface mobility
Autonomous operations
Partial gravity systems
EVA, Surface mobility

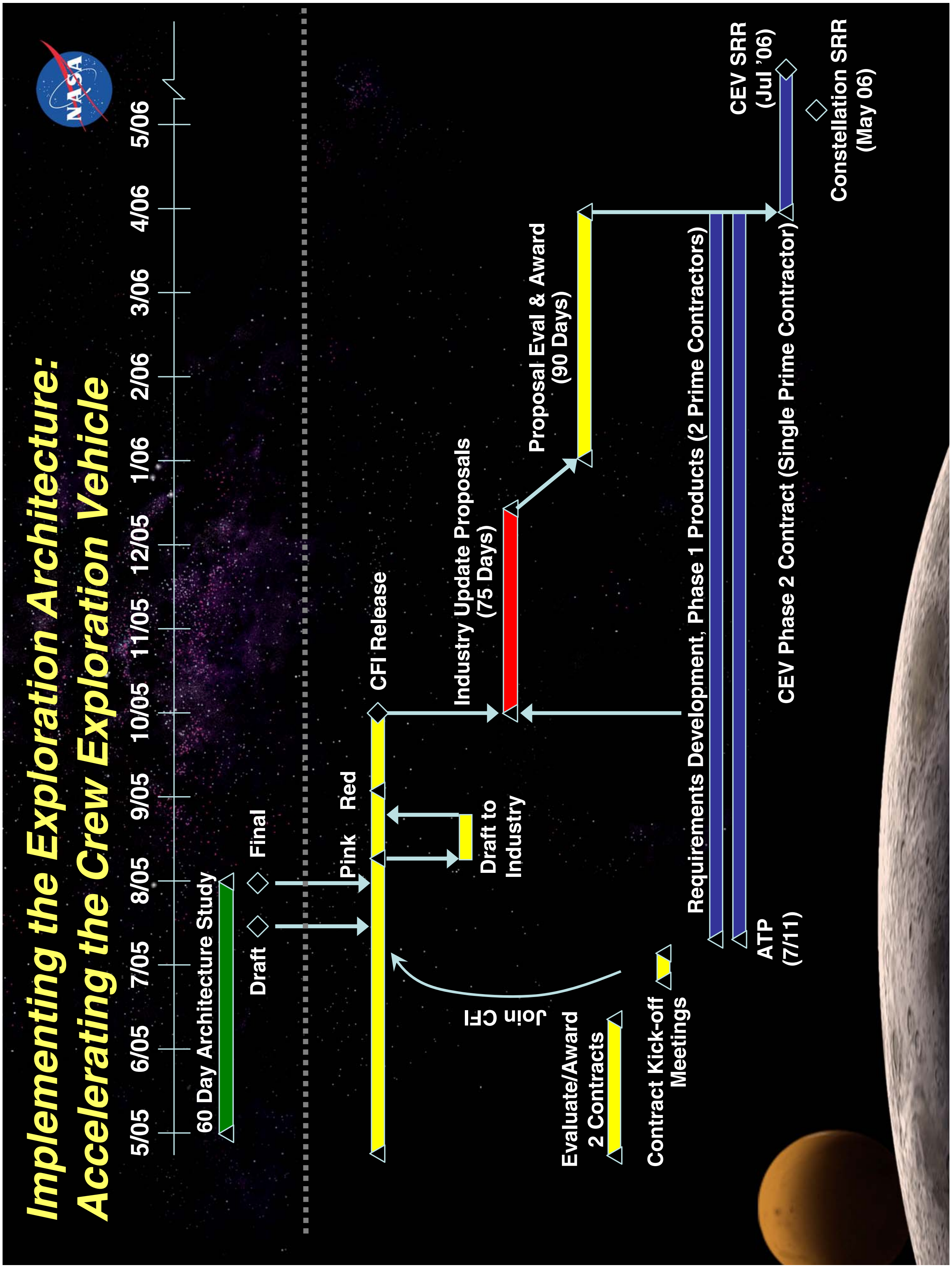

Potential Commercial Opportunities
NASA
Commercial services for space station crew/cargo delivery and return
Purchase launch / communications services as available
Innovative programs to encourage entrepreneurs
Centennial challenges prizes
Low-cost sub-orbital and orbital launch demo
Independent space station cargo re-entry demo
Independent crew transport demo
Space station cargo pathfinder demo
Propellant delivery to low Earth orbit for lunar missions
Propellant depot in low Earth orbit
Propel earth departure stages/lunar lander after on-orbit transfer
Continual commercial replenishment as available
Government guaranteed purchase on delivery a certain price


Potential International Opportunities
Continue International Space Station cooperation re-focused on human exploration
Purchase of additional international partner transportation assets for the space station
Coordination of lunar robotic pre-cursor missions
Cooperate on variety of lunar surface systems
Habitats
Rovers
Power and logistics
Science and in-situ resource utilization equipment
Provide alternate transportation resources
Transportation of international astronauts on the CEV
Cooperation on Mars pre-cursor/science missions
Preparation for joint human Mars missions


A Safe, Accelerated, Affordable and Sustainable Approach
Meet all U.S. human spaceflight goals
U.S. system capable of servicing the International Space Station
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 (1 in 1,700 to 4,200) for the Crew Launch Vehicle
1 in 220 (1 in 160 to 310) for the Space Shuttle
Orderly transition of the Space Shuttle workforce
Requirements-driven technology program
USA
UNITED STATES

Implementing the Exploration Architecture: Transition from ESAS to ESMD

- **Architecture**
  - The Exploration Architecture has been defined
  - An Exploration Architecture Requirements Document will be finalized in September
- **Requirements**
  - Element specifications for the Crew Exploration Vehicle (CEV), Crew and Cargo Launch Vehicles, and ISS Cargo Delivery Vehicles are in draft; will be validated and baselined by October
  - New CEV requirements will be included in the Call For Improvement that be the basis for updated Industry proposals
  - Research and Technology programs will be tightly focused on supporting CEV development and the initial return to the moon
- **Organization**
  - A streamlined HQ directorate is being formed
  - Program and Project Offices are being established at the NASA centers
  - Key individuals from ESAS are joining ESMD



Implementing the Exploration Architecture:
Accelerating the Crew Exploration Vehicle
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6/05
7/05
8/05
9/05
10/05
11/05
12/05
1/06
2/06
3/06
4/06
5/06
60 Day Architecture Study
Draft
Final
Pink
Red
CFI Release
Draft to Industry
Join CFI
Industry Update Proposals (75 Days)
Proposal Eval & Award (90 Days)
Evaluate/Award 2 Contracts
Contract Kick-off Meetings
Requirements Development, Phase 1 Products (2 Prime Contractors)
ATP (7/11)
CEV Phase 2 Contract (Single Prime Contractor)
CEV SRR (Jul '06)
Constellation SRR (May 06)

Our Destiny is to Explore!

- **The goals of our future space flight program must be worthy of the expense, difficulty and risks which are inherent to it.**
- **We need to build beyond our current capability to ferry astronauts and cargo to low Earth orbit.**
- **Our steps should be evolutionary, incremental and cumulative.**
- **To reach for Mars and beyond we must first reach for the Moon.**

A committed and long term lunar effort is needed, and we need to begin that investment now!

"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.