Why Go?

Benefit to Citizens

SCIENCE
- Human Research
  - Heliophysics
  - Astrophysics
  - Biological
  - Physical
- Exploration
  - Planetary
- Leadership
  - Economy
  - Human Condition
- Advance S&T Priorities
  - Climate
  - Global Influence
  - International Relationships

INSPIRATION
- STEM
- Careers
- Preserve Humanity
- Cultural Enrichment

NATIONAL POSTURE
- Physical Climate
- Economic Norms
- International Relationships
- Human Research
- Biological Planetary
- Leadership
- Human Condition
- Preserve Humanity
- Cultural Enrichment
M2M Goals and Objectives

• **60+ Top-Level Objectives across 10 Top-Level Goals**
  - 26 Science (6 Goals)
  - 13 Infrastructure (2 Goals)
  - 12 Transportation & Habitation (1 Goal)
  - 12 Operations (1 Goal)

• **Recurring Tenets**
  - Common themes across objectives
ARTEMIS I
The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

1. LAUNCH
SLS and Orion lift off from pad 39B at Kennedy Space Center.

2. PERIGEE RAISE MANEUVER
Systems check with solar panel adjustments.

3. EARTH ORBIT
Orion and second stage separation and deployment.

4. INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL
ICPS commits Orion to moon at TLI.

5. TRANS LUNAR INJECTION (TLI) BURN
Maneuver lasts for approximately 20 minutes.

6. OUTBOUND POWERED FLYBY (OPF)
60 nmi from the Moon; targets DRO insertion.

7. LUNAR ORBIT INSERTION
Enter Distant Retrograde Orbit (DRO).

8. OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS
As necessary, adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).

9. DISTANT RETROGRADE ORBIT
Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.

10. DRO DEPARTURE
Leave DRO and start return to Earth.

11. RETURN POWERED FLYBY (RPF)
RPF burn prep and return coast to Earth initiated.

12. RETURN TRANSIT
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.

13. SPLASHDOWN
Pacific Ocean landing within view of the U.S. Navy recovery ship.

14. CREW MODULE SEPARATION FROM SERVICE MODULE

15. ENTRY INTERFACE (EI)
Enter Earth's atmosphere.

16. MISSION DURATIONS:
Total: 26–42 days
Outbound Transit: 8–16 days
DRO: 6–19 days
Return Transit: 9–19 days
ARTEMIS I
COMMUNICATIONS AND NAVIGATION MILESTONES

1. **Launch**
   - Both the Launch Communications Segment and the constellation of Tracking and Data Relay Satellites will maintain communication between the Space Launch System and Orion.
   - **NSN DTE/NSN TDRS**

2. **Low-Earth Orbit**
   - In low-Earth orbit, NASA’s Near Space Network (NSN) will maintain continuous communications with Orion and the Interim Cryogenic Propulsion Stage (ICPS), which will accelerate Orion fast enough to overcome the pull of Earth’s gravity and set it on a precise trajectory to the Moon.
   - **NSN TDRS**

3. **ICPS Separation**
   - Once Orion no longer needs the ICPS, the Near Space Network will monitor recovery from the ICPS until it is out of range. The ICPS will continue towards the Moon on a heliocentric trajectory, deploying small satellites that provide additional science in transit and orbit.
   - **NSN TDRS/DSN**

4. **Handover to DSN**
   - As Orion prepares to leave the area of near-Earth space covered by the Near Space Network, network engineers will pass communications services to the Deep Space Network.
   - **DSN**

5. **Journey to the Moon**
   - En route to the Moon, the Deep Space Network will be the primary method of communication with Earth, with Near Space Network ground stations providing supplementary tracking and navigation data.
   - **DSN NSN DTE**

6. **Distant Retrograde Orbit**
   - When Orion arrives at the Moon, it will enter a distant retrograde orbit, a highly stable orbit in which Orion travels opposite the direction the Moon travels around Earth. These, NSN will continue to test and demonstrate Orion’s capabilities.
   - **DSN NSN DTE**

7. **Return Transit**
   - Returning from the Moon, the Deep Space Network will be the primary method of communication with Earth, with Near Space Network ground stations providing supplementary tracking and navigation data.
   - **DSN NSN DTE**

8. **Return Trajectory Correction Burn**
   - During the final engine burn that places Orion on target to safely enter Earth’s atmosphere, the Near Space Network will join the Deep Space Network, ultimately taking over communications for the remainder of the mission.
   - **DSN NSN DTE/NSN TDRS**

9. **Re-entry**
   - During re-entry, the enormous heat generated as Orion encounters the atmosphere turns the air surrounding the capsule into plasma. Until it dissipates, this can disrupt communications with the spacecraft.
   - **NSN TDRS/DSN**

10. **Splashdown and Recovery**
    - The Near Space Network maintains communications through the unfolding of parachutes, splashdown in the Pacific Ocean, and recovery of the capsule by military and NSN professionals.
    - **NSN NEAR SPACE NETWORK/NSN DTE/NSN TDRS/DSN DEEP SPACE NETWORK**
ARTEMIS II
First Crewed Test Flight to the Moon Since Apollo

1. LAUNCH
Astronauts lift off from pad 39B at Kennedy Space Center.

2. PERIGEE RAISE MANEUVER

3. APOGEE RAISE BURN TO HIGH EARTH ORBIT
Begin 24 hour checkout of spacecraft.

4. PROX OPS DEMONSTRATION
Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.

5. INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN

6. HIGH EARTH ORBIT CHECKOUT
Life support, exercise, and habitation equipment evaluations.

7. TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE
Lunar free return trajectory initiated with European service module.

8. OUTBOUND TRANSIT TO MOON
4 days outbound transit along free return trajectory.

9. LUNAR FLIGHT
4,000 nmi (mean) lunar farside altitude.

10. TRANS-EARTH RETURN
Return Trajectory Correction (RTC) burns as necessary to aim for Earth’s atmosphere; travel time approximately 4 days.

11. ENTRY INTERFACE (EI)
Enter Earth’s atmosphere.

12. SPLASHDOWN
Ship recovers astronauts and capsule.

13. CREW MODULE SEPARATION FROM SERVICE MODULE

14. PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE

15. CORE STAGE MAIN ENGINE CUTOFF
With separation.
Artemis III Candidate Landing Regions

KEY LANDING REGION CHARACTERISTICS

- Close proximity to the geographic South Pole
- Gentle slope for landing and moonwalks
- Constant view to Earth for communications
- Continuous sunlight throughout the surface expedition of about 6.5 days

Landing Accuracy

- Surface data resolution
- Combined mission vehicle capabilities: Space Launch System, Orion spacecraft, Starship Human Landing System

A landing region is approximately 15 km². Each landing region includes multiple potential landing sites.
ARTEMIS III
Landing on the Moon

1. LAUNCH SLS and Orion 39 from Kennedy Space Center
2. JETTISON ROCKET BOOSTERS, SUSPENSION, AND LAUNCH ABORT SYSTEM
3. CORE-STAGE MAIN ENGINE CUT-OFF With separation
4. ENTER EARTH ORBIT
   - Orient the propulsion system fore-and-aft and solar panel adjustments
5. TRANS LUNAR INJECTION BURN
   - Adjusts trajectory by firing thrusters followed by separation and disposal
6. ORION OUTBOUND TRAJECTORY
   - 60 min from Earth
7. ORION ORBIT INJECTION BURN
   - Establishes rendezvous orbit to Gateway. Opens solar arrays and docking
8. LUNAR LANDING PREPARATION
   - Crew transfers to Gateway, activates Lander's solar wing of Gateway, prepares for Lander departure
9. LUNAR DESCENT
   - Second to lunar touchdown
10. LUNAR SURFACE EXPLORATION
    - Astronauts conduct week-long surface mission and extravehicular activities
11. GATEWAY FOR ORION RETURN LANDING
    - Gateway orbit
12. LANDING ASCENDS
    - Land in low lunar orbit
13. CREW RETURNS TO GATEWAY
    - Orion undocks from Gateway, activates orbital solar panel and disposal
14. GROUND PERIODIC RETURN POWERED FLOW
    - Adjusts trajectory by firing thrusters followed by separation and disposal
15. FINAL RETURN TRAJECTORY CORRECTION
    - Adjustment for Earth entry
16. EARTH INTERFACE
    - Enter Earth's atmosphere
17. SPLASHDOWN
    - Pacific Ocean landing within view of the U.S. Near recovery site
18. LANDER ASCENDS
    - Low lunar orbit
19. ORION OUTBOUND TRAJECTORY
    - 60 min from Earth
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Icons represent the calendar year in which the launch occurs. | Based on FY23 Presidents budget request. | Does not include impact from FY22 appropriations. | Selected Mars forward elements in SMD and STMD included for context.
Starship HLS development in work
NASA will use the HLS Starship for use on Artemis III, the mission that will put the next two Americans on the surface of the Moon. The SpaceX Option A contract includes two lunar surface missions:

- SpaceX Uncrewed Lunar Demo-A
- SpaceX Crewed Lunar Demo-A

Image Credit: SpaceX
Gateway Integrated Spacecraft
Lunar Terrain Vehicle

Requirements definition is in-work
• Ability to traverse from one landing zone to another and increase exploration range beyond maximum suited walking distance
• Reusable and rechargeable for approximate 10-year service life
• Remote operation from Human Landing System, Gateway, and Earth
• Interface with future science instruments and payloads for utilization or pre-deployment of assets
• Ability to survive eclipse periods

Developing LTV: Survive the Night
• The lunar South Pole is massively cratered, with areas bathed in sunlight and shrouded in darkness
• The craters are brutally cold but elevated areas can grow extremely hot
• NASA has initiated a new study to identify options for addressing lunar night survival
• Potential design solutions will be generated by an internal team and industry partners
• LTV will need to survive up to 100 hours of darkness with at least a 10-year lifespan

Pictured left: Artist’s render of LTV on the lunar surface
SPACE TECHNOLOGY PORTFOLIO

EARLY STAGE INNOVATION AND PARTNERSHIPS
- Early Stage Innovation
- Space Tech Research Grants
- Center Innovation Fund
- Early Career Initiative
- Prizes, Challenges & Crowdsourcing
- NASA Innovation Advanced Concepts
- Technology Transfer

SBIR/STTR PROGRAMS
- Small Business Innovation Research
- Small Business Technology Transfer

TECHNOLOGY MATURATION
- Game Changing Development
- Lunar Surface Innovation Initiative

TECHNOLOGY DEMONSTRATION
- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities

Technology Drives Exploration
Low - MID - High
Technology Readiness Level
# STMD Strategic Framework

**STMD rapidly develops, demonstrates, and transfers revolutionary, high pay off space technologies, driven by diverse ideas**

<table>
<thead>
<tr>
<th>Lead</th>
<th>Thrusts</th>
<th>Outcomes</th>
<th>Primary Capabilities</th>
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</table>
| **Go** | Rapid, Safe, and Efficient Space Transportation | • Develop nuclear technologies enabling fast in space transits.  
• Develop cryogenic storage, transport, and fluid management technologies for surface and in space applications.  
• Develop advanced propulsion technologies that enable future science/exploration missions. | • Nuclear Systems  
• Cryogenic Fluid Management  
• Advanced Propulsion |
| **Land** | Expanded Access to Diverse Surface Destinations | • Enable Lunar/Mars global access with 20t payloads to support human missions.  
• Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies.  
• Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards. | • Entry, Descent, Landing, & Precision Landing |
| **Live** | Sustainable Living and Working Farther from Earth | • Develop exploration technologies and enable a vibrant space economy with supporting utilities and commodities  
• Sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations  
• Scalable ISRU production/utilization capabilities including sustainable commodities on the lunar & Mars surface.  
• Technologies that enable surviving the extreme lunar and Mars environments.  
• Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources.  
• Enable long duration human exploration missions with Advanced Habitation System technologies. [Low TRL STMD; Mid High TRL SOMD/ESDMD] | • Advanced Power  
• In Situ Resource Utilization  
• Advanced Thermal  
• Advanced Materials, Structures, & Construction  
• Advanced Habitation Systems |
| **Explore** | Transformative Missions and Discoveries | • Develop next generation high performance computing, communications, and navigation.  
• Develop advanced robotics and spacecraft autonomy technologies to enable and augment science/exploration missions.  
• Develop technologies supporting emerging space industries including: Satellite Servicing & Assembly, In Space/Surface Manufacturing, and Small Spacecraft technologies.  
• Develop vehicle platform technologies supporting new discoveries.  
• Develop technologies for science instrumentation supporting new discoveries. [Low TRL STMD/Mid High TRL SMD.  
SMD funds mission specific instrumentation (TRL 1-9)]  
• Develop transformative technologies that enable future NASA or commercial missions and discoveries | • Advanced Avionics Systems  
• Advanced Communications & Navigation  
• Advanced Robotics  
• Autonomous Systems  
• Satellite Servicing & Assembly  
• Advanced Manufacturing  
• Small Spacecraft  
• Rendezvous, Proximity Operations & Capture  
• Sensor & Instrumentation |

## Ensuring American global leadership in Space Technology

- Advance US space technology innovation and competitiveness in a global context
- Encourage technology driven economic growth with an emphasis on the expanding space economy
- Inspire and develop a diverse and powerful US aerospace technology community
Ensuring American Global Leadership in Space Technology

Technology Drives the Space Economy

Ensuring American Global Leadership in Space Technology

Rapid, Safe, and Efficient Space Transportation
Expanded Access to Diverse Surface Destinations
Sustainable Living and Working Farther from Earth
Transformative Missions and Discoveries

Technology Drives Exploration

- Lunar Surface Innovation Initiative
- Sustainable Power and Surface Utilities
- In Situ Resource Utilization
- Survival in Extreme Environments
- Autonomous Excavation and Construction
- Advanced Robotics and Autonomy
- Low TRL Habitation Systems
- Advanced Propulsion
- Landing Heavy Payloads
- Landing for Science Exploration
- Spacecraft Platform Technologies
- Cryogenic Fluid Management
- Precision Landing
- Atmospheric ISRU
- Flight Opportunities
- Commercial Partners
- NextGen Avionics and Communications
- Satellite Servicing and Assembly
- Advanced Manufacturing
- Small Spacecraft Technologies
Enabling Technologies for Future Science & Exploration Missions

- CLPS
- Intuitive Machines 2: all STMD payloads
- PRIME 1
- EDL Technology
- Cryogenic Fluid Management
- Additive Manufacturing
- Deep Space Optical Communications
- ISRU
- CAPSTONE CubeSat
- Solar Electric Propulsion
- Laser Communications Relay Demonstration
- Intuitive Machines 2: all STMD payloads
- Power
- LSIC Focus Group
- Fission Surface Power
- Solar Electric Propulsion
- PRIME 1
Impact Story: Roll-Out Solar Array (ROSA)

- 2008 First SBIR from AFRL
- 2012 SBIR Phase III for multi-mission space exploration vehicle wings
- 2009 First NASA SBIR Phase I
- 2014 20kW Ground Demo, GCD/ TDM
- 2019 STTR CCRPP
- 2021 ISS Solar Array Deployment
- 2021 Double Asteroid Redirection Test (DART) mission
- 2021 Redwire acquisition of DSS; Planned Redwire Initial Public Offering (IPO)

**Global Ecosystem**

**The U.S. Government**

**The U.S. Space Industry**

**NASA**

**STMD**

**Infusion into NASA Missions**

**Economic Growth, Commercialization & Spinoffs**
Via NASA Tipping Point partnerships, four unique cryogenic fluid management flight demonstrations will take place from fiscal years 2023 to 2025.
Space Technology Lunar Surface Demonstration Strategy

*ISRU, Power, Excavation, and Construction utilizing cross-cutting technologies*

### Reconnaissance, Prospecting, Sampling

- Oxygen extraction
- PRIME, Hopper, LTE Demos
- VIPER (SMD)

### Resource Acquisition & Processing

- Follow The natural resources: Demonstrations of systems for extraction and processing of raw materials for future mission consumables production and storage.
- ISRU O2 Demo
- ISRU Subscale Demo
- ISRU Pilot Excavator
- Construction Demo 1
- Construction Demo 2

### Pilot Consumable Production

- Sustainable exploration: Scalable pilot systems demonstrating production of consumables from in-situ resources in order to better support sustained human presence.
- CT-1
- CT-2
- Fission Surface Power
- ISRU Pilot System*

* ISRU Pilot Plant demo will use Fission Surface Power
Strategic Technology Architecture Roundtable (STAR) Process

Draws directly on Agency Moon to Mars Manifest and SMD Science Needs to identify technology gaps.

Industry Partners participation is obtained through Requests for Information (RFIs) to validate envisioned futures, the current state of the art and the gaps between those two.

STAR process inclusive of Center Chief Technologists, ESDMD and SMD Representation.

Maps to Taxonomy.

STARport is the database of all Capability Area gaps for both STMD and ESDMD. Envisioned Future Priorities (EFPs) are written by SCLT/PT’s to show the future state envisioned and forward planning to inform PPBE Process.