Technology and Science for NASA's Journey to Mars

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Presentation Outline

- Introduction
- Brief NASA History
- NASA Today
- Journey to Mars
  - Evolvable Mars Campaign
  - Technologies Required
- NASA Technology Transfer
- How Can YOU to Get Involved

NASA History: Established in 1958

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

NEW YORK, SATURDAY, OCTOBER 5, 1957.

FIVE CENTS

SOVIET FIRES EARTH SATELLITE INTO SPACE;
IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.;
SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

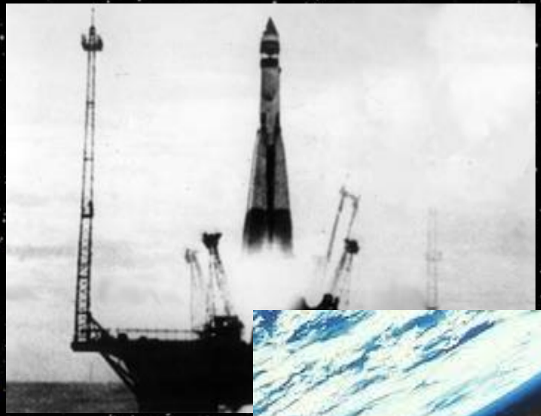
HOFFA IS ELECTED TEAMSTERS HEAD;

COURSE RECORDED

Navy Picks Up Radio

560 MILES HIGH

Visible With Simple



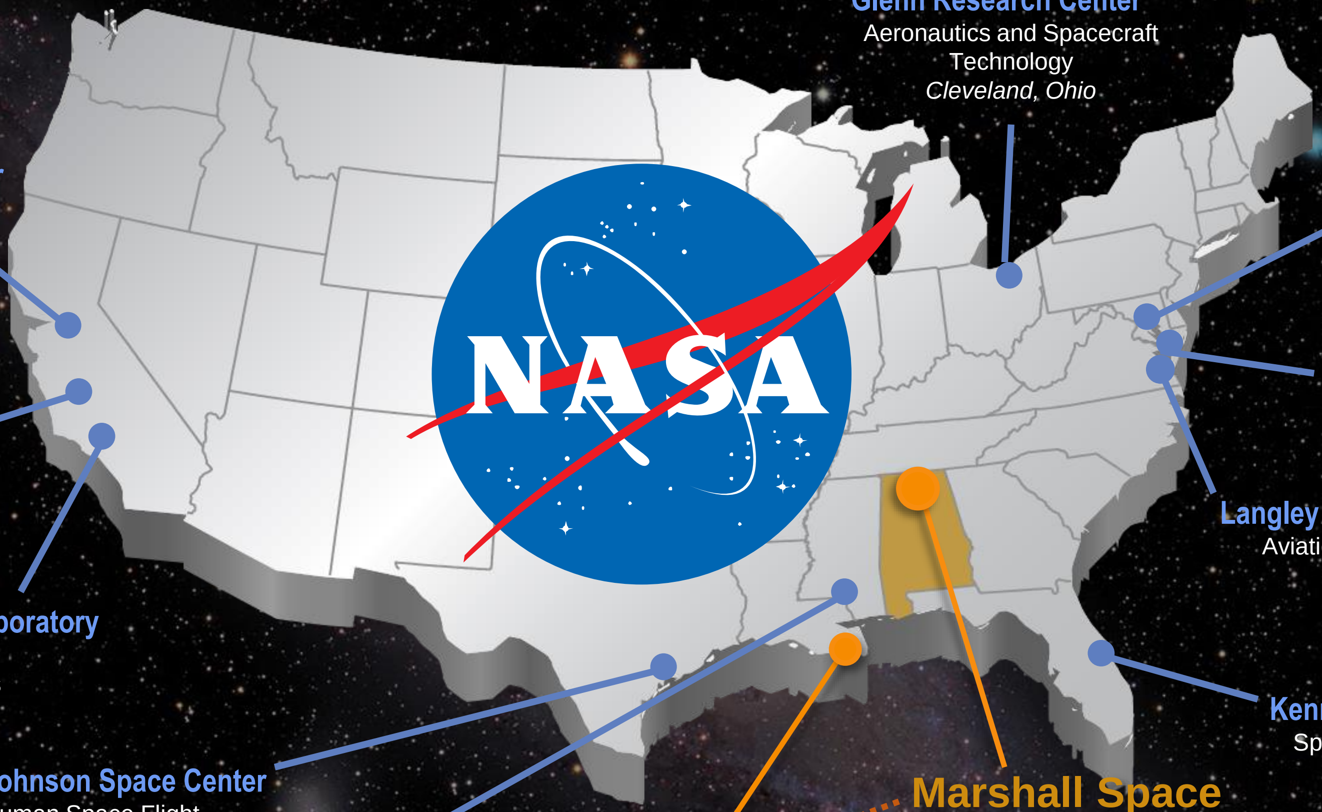
- In response to the Soviet Union's launch of Sputnik 1 on 04 Oct. 1957, the Eisenhower administration signed the National Aeronautics and Space Act of 1958, creating the National Aeronautics and Space Administration (NASA).
- Among other things, the Space Act charges NASA with the responsibility to conduct "activities as may be required for the exploration of space."

E Pluribus Unim NASA

- NASA was established to comprise several existing agencies and commands.
  - **NASA Headquarters** (Washington, DC)
  - Four centers from the National Advisory Committee on Aeronautics (NACA), which had been researching flight technology for more than 40 years prior.
    - **Langley Research Center** (Hampton, VA)
    - **Ames Research Center** (Moffit Field, Mountain View, CA)
    - Lewis Research Center (Renamed **Glenn Research Center**, Cleveland, OH)
    - Dryden High Speed Flight Test (Renamed **Armstrong Flight Research Center**, Mojave, CA)
  - One Department of Defense Agency.
    - Army Ballistic Missile Agency (Renamed to **Marshall Space Flight Center**, Huntsville, AL)
  - One academic institute.
    - **Jet Propulsion Laboratory** (California Institute of Technology, Pasadena, CA)
  - Four Centers established to fulfill functions:
    - **Goddard Space Flight Center** (Greenbelt, MD)
    - Manned Space Center (Renamed **Johnson Space Center**, Houston, TX)
    - **Kennedy Space Center** (Cape Canaveral, FL)
    - **Stennis Space Center** (Southern MS)

As a federal agency, NASA has been considered to operate as a "loose confederation of semi-autonomous fiefdoms."

NASA Today: Field Center Locations



NASA History: Support of Aeronautics and Research

- NASA continued the aeronautics research pioneered by NACA as a theme of research.
- It also conducted purely scientific research and worked on developing applications for space technology, combining both pursuits in developing the first weather and communications satellites.

Echo II: 135’ balloon satellite launched 25 Jan. 1964


Telstar – First Communication Satellite


Syncom: First Geosynchronous Satellite


Rogallo wing in 7’x10’ Tunnel, June 1959.

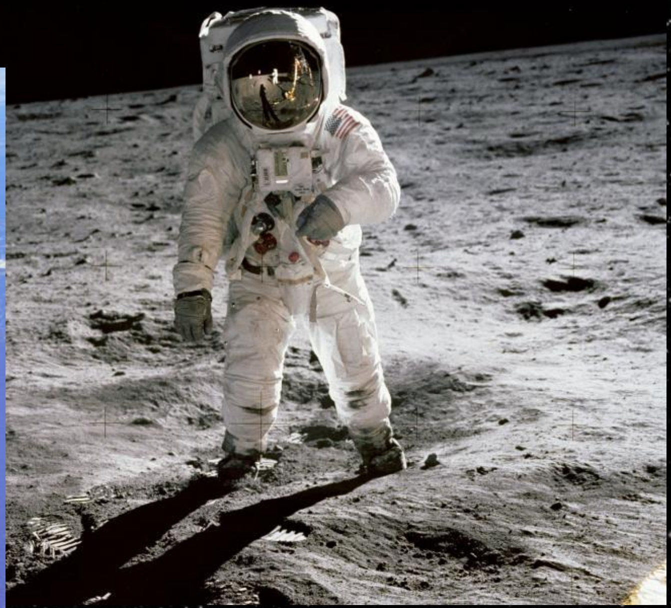
X-24A lifting body, circa 1969

NASA History: Early Manned Space Missions

"Mercury 7" Announced by NASA on 09 April 1959

- President John F. Kennedy focused NASA and the nation on sending astronauts to the moon by the end of the 1960s.
- Through the Mercury and Gemini projects, NASA developed the technology and skills it needed for the journey.
- On July 20, 1969, Neil Armstrong and Buzz Aldrin became the first of 12 men to walk on the moon, meeting Kennedy's challenge.

President Kennedy at Rice University, 12 Sep. 1962



NASA History: The Space Shuttle and ISS

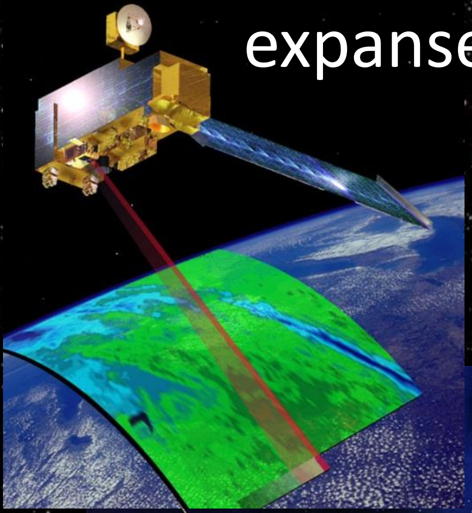
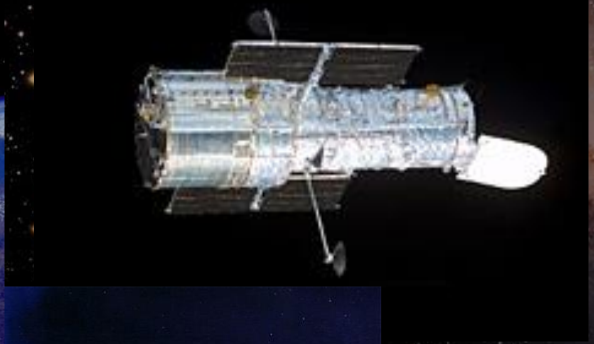
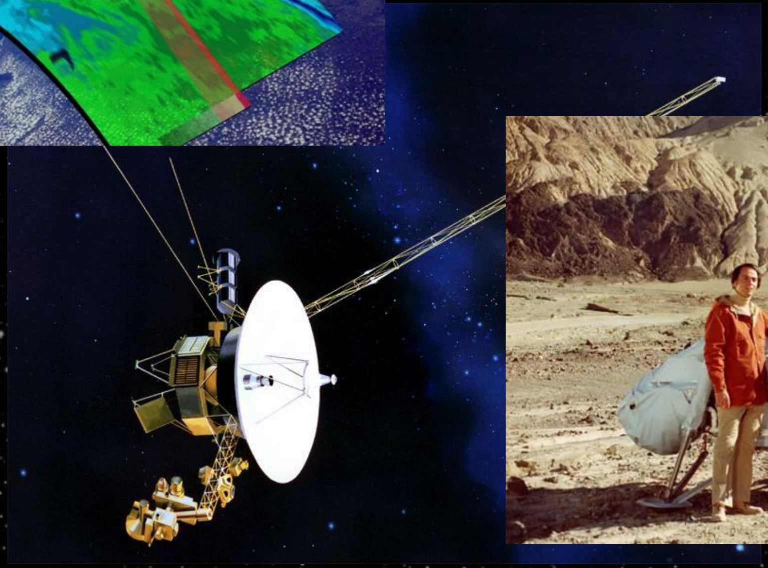
- After Apollo, NASA focused on creating a reusable, man-rated launcher to provide regular access to space: the Space Shuttle.
  - First launched in 1981, the space shuttle flew more than 130 successful flights before retiring in 2011.
- In 2000, the United States and Russia established permanent human presence in space aboard the International Space Station (ISS), a multinational project representing the work of 16 nations.
  - The ISS is still a vital part of NASA's Exploration Program with continuing research conducted on living and working in the space environment.

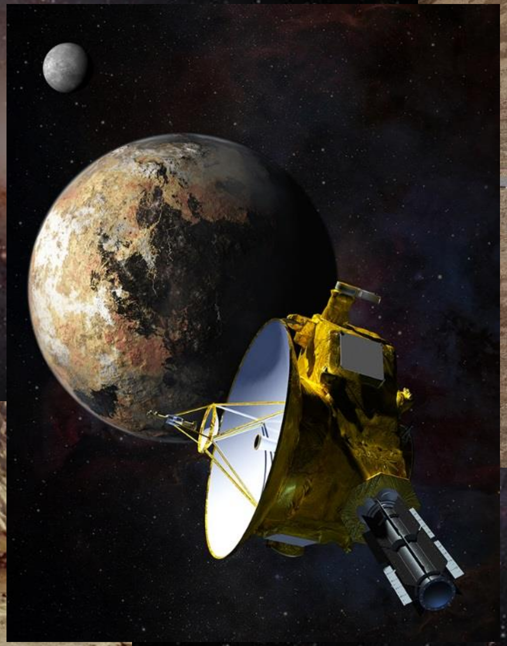
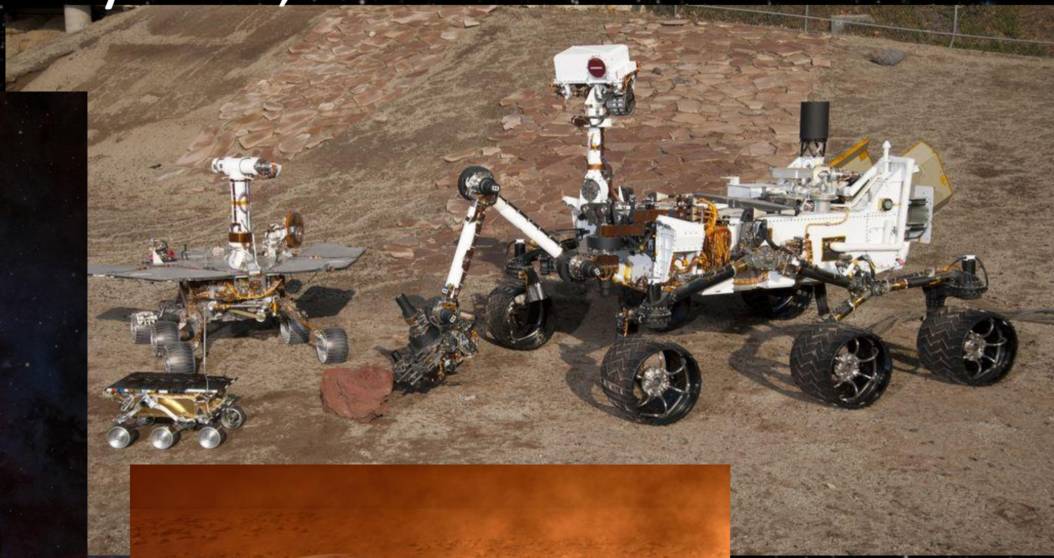
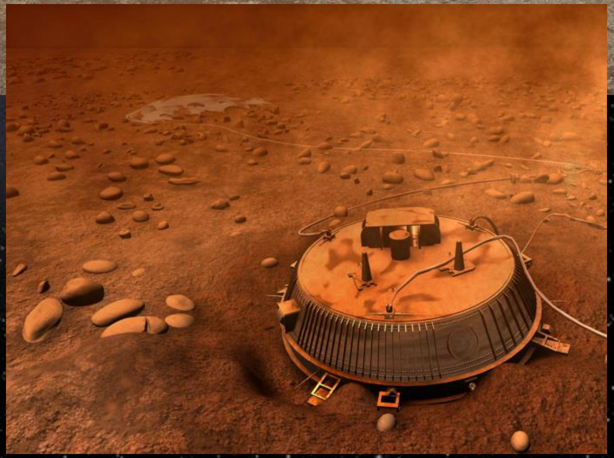
STS-1: 12 April 1981

International Space Station

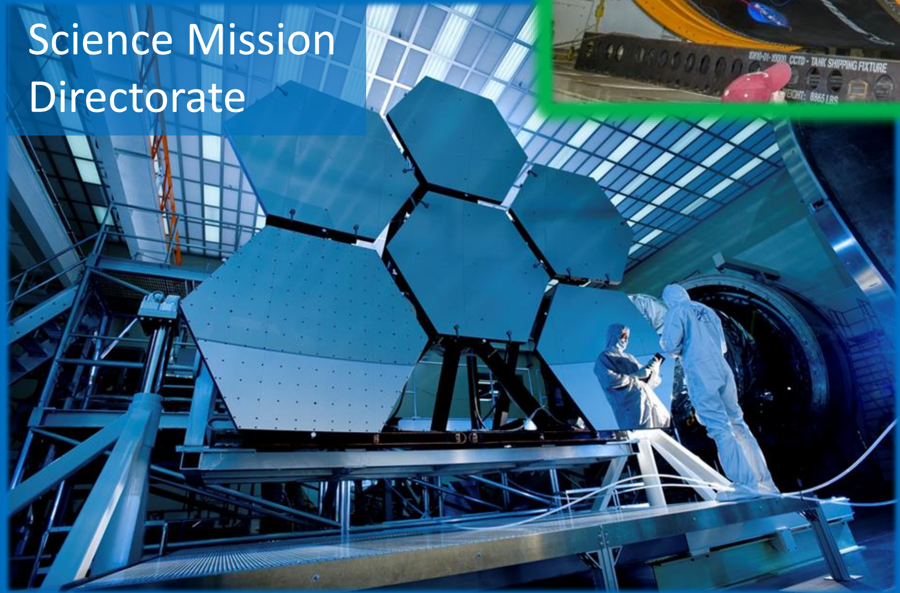
NASA History: Earth and Space Science Heritage

- NASA also has continued research in Earth and Space Sciences.
- Multiple orbital and deep space missions have observed critical information about Earth, the Sun, our Solar System, and the vast expanse of our universe.

NASA Mission Directorates



Marshall heavily supports three of four NASA Mission Directorates.

NASA Themes and Priorities

Earth Right Now. *Your planet is changing. We're on it.* #EarthRightNow
NASA's fleet of satellites, its airborne missions and researchers address some of the critical challenges facing our planet today and in the future: climate change, sea level rise, freshwater resources, and extreme weather events.

Science

ISS. *Off the Earth, for the Earth.* #ISS
The International Space Station is a blueprint for global cooperation and scientific advancements, a destination for growing a commercial marketplace in low-Earth orbit, and a test bed for demonstrating new technologies. The space station is the springboard to NASA's next great leap in exploration, including future missions to an asteroid and Mars.

Exploration

Mars. Join us on the journey. #JourneytoMars
We are on a journey to Mars. Today our robotic scientific explorers are blazing the trail. Together, humans and robotics will pioneer the next giant leap in exploration.

Exploration

Technology. *Technology drives exploration.* #NASATech
We develop, test and fly transformative capabilities and cutting edge exploration technologies. Our technology development provides the onramp for new ideas, maturing them from early stage through flight and giving wings to the innovation economy.

Technology

Aeronautics. *NASA is with you when you fly.* #FlyNASA
Every U.S. aircraft and air traffic control tower uses NASA-developed technology. We're committed to transforming aviation by reducing its environmental impact, maintaining safety, and revolutionizing aircraft shapes and propulsion.

Aeronautics

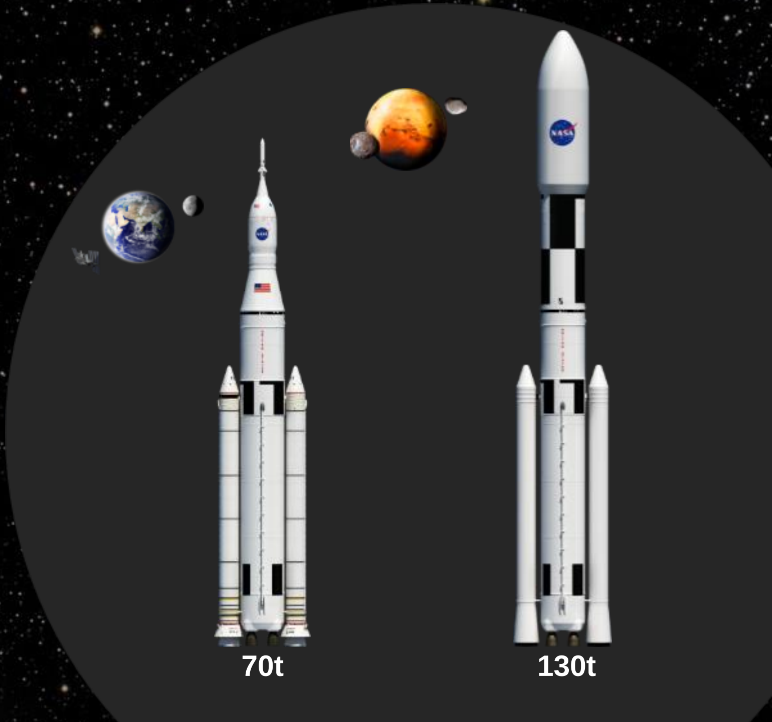
Solar System and Beyond. *NASA: We're Out There.* #NASABeyond
NASA's exploration spans the universe. Observing the sun and its effects on Earth. Delving deep into our solar system. Looking beyond to worlds around other stars. Probing the mysterious structures and origins of our universe. Everywhere imaginable, NASA is out there.

Science

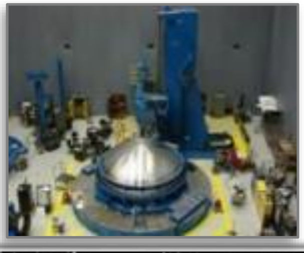
NASA's Space Launch System

SLS – America's Human-Rated Heavy-lift Rocket

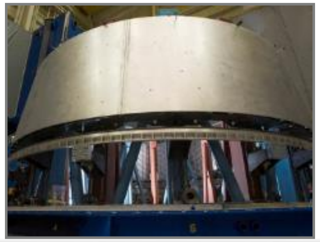
- Provides initial lift capacity of 70 metric tons (t), evolving to 130t.
- Initially powered by twin five-segment solid rocket boosters and four RS-25 liquid propellant engines, as well as a modified version of an existing upper stage.
- Carries the Orion Multi-Purpose Crew Vehicle (MPCV) and significant science payloads.
- Supports national and international missions beyond Earth's orbit, such as near-Earth asteroids, cis-lunar operations, and eventually Mars.
- Builds on the proven success of Saturn and Shuttle.

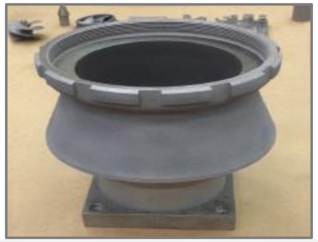



Solid Rocket Booster Test


Friction Stir Welding for Core Stage


Shell Buckling Structural Test

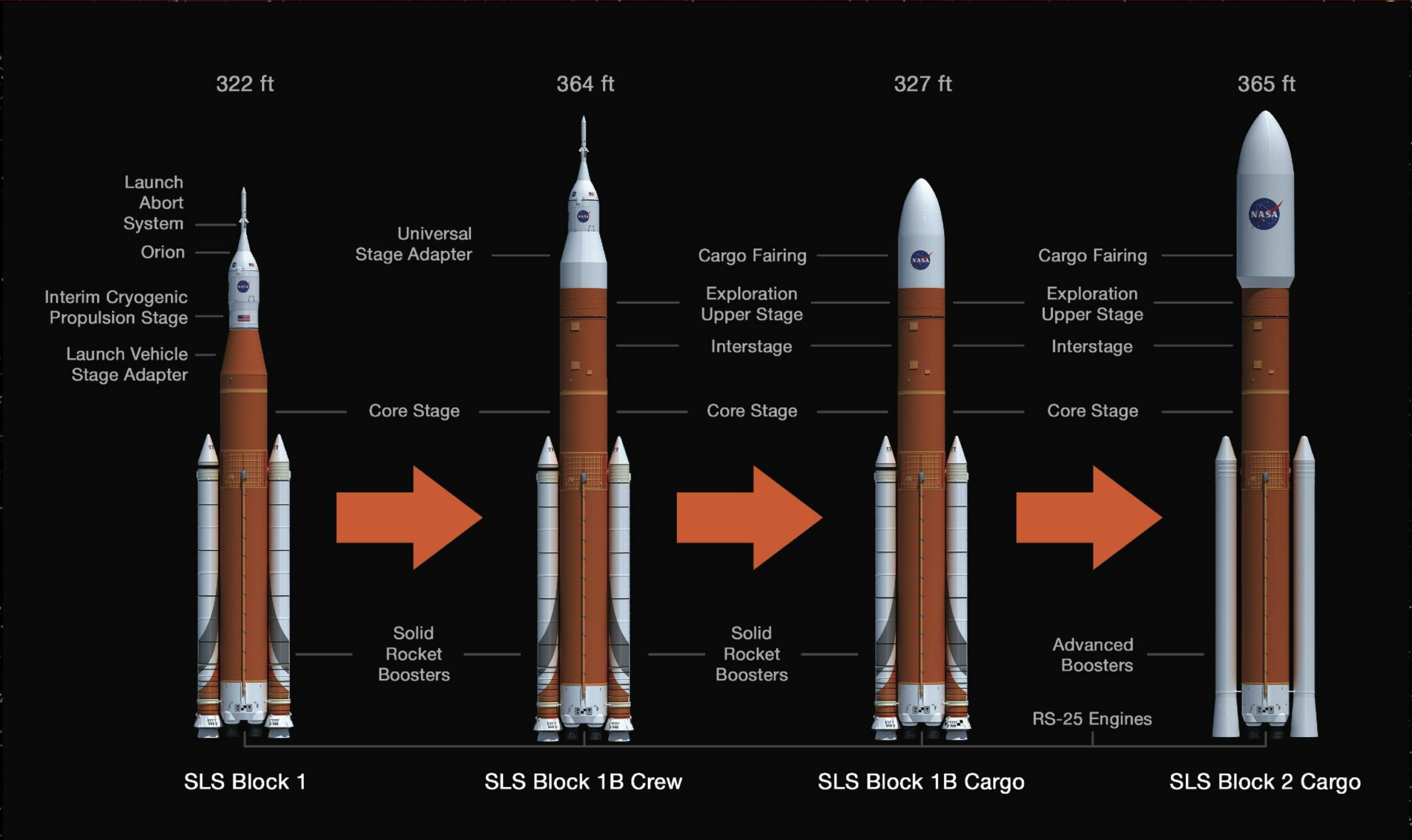

MPCV Stage Adapter Assembly


Selective Laser Melting Engine Parts

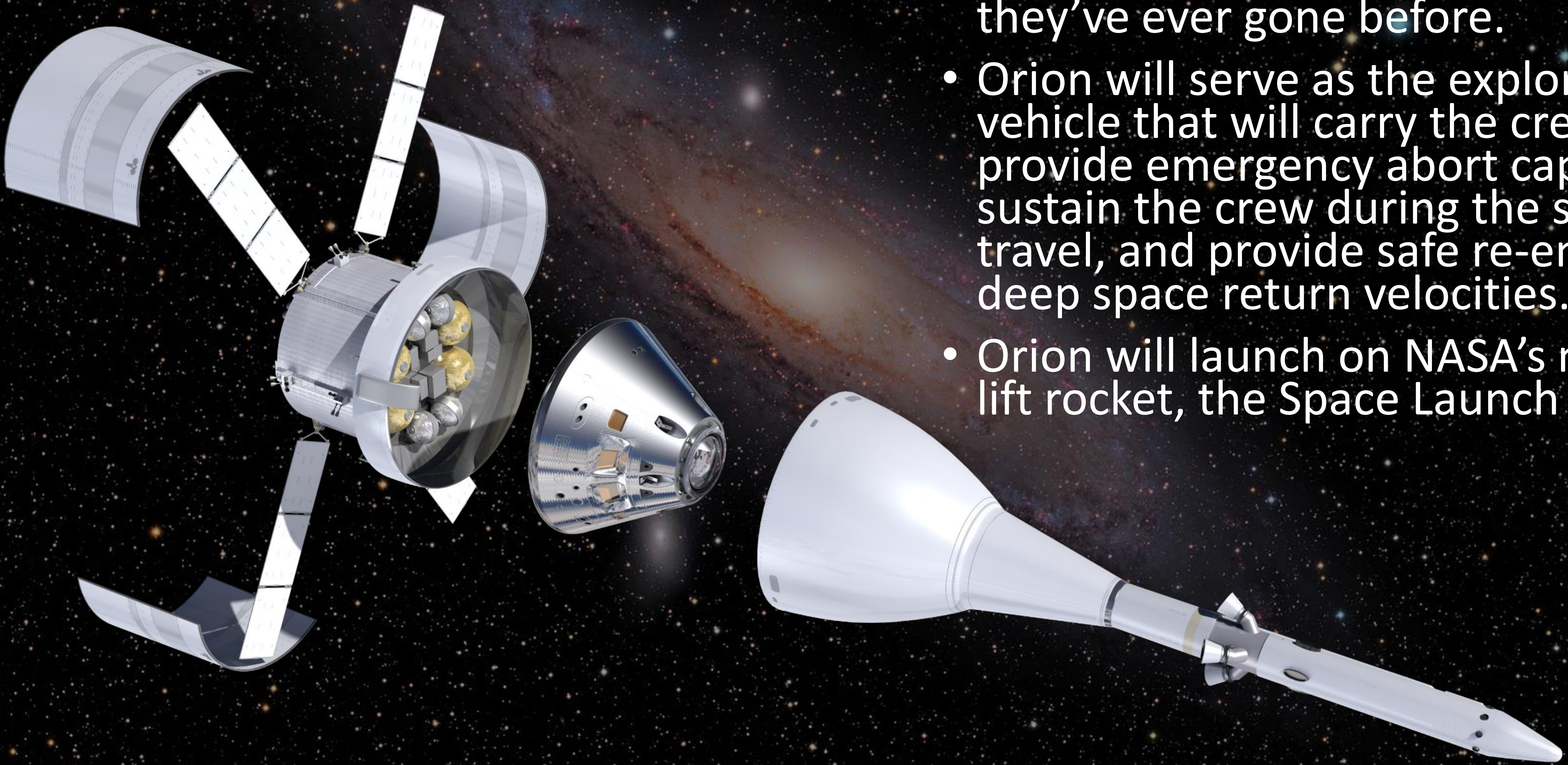

RS-25 Core Stage Engines in Inventory

SLS is essential to the nation's space exploration goals.

Future Evolution Plans for Space Launch System (SLS)



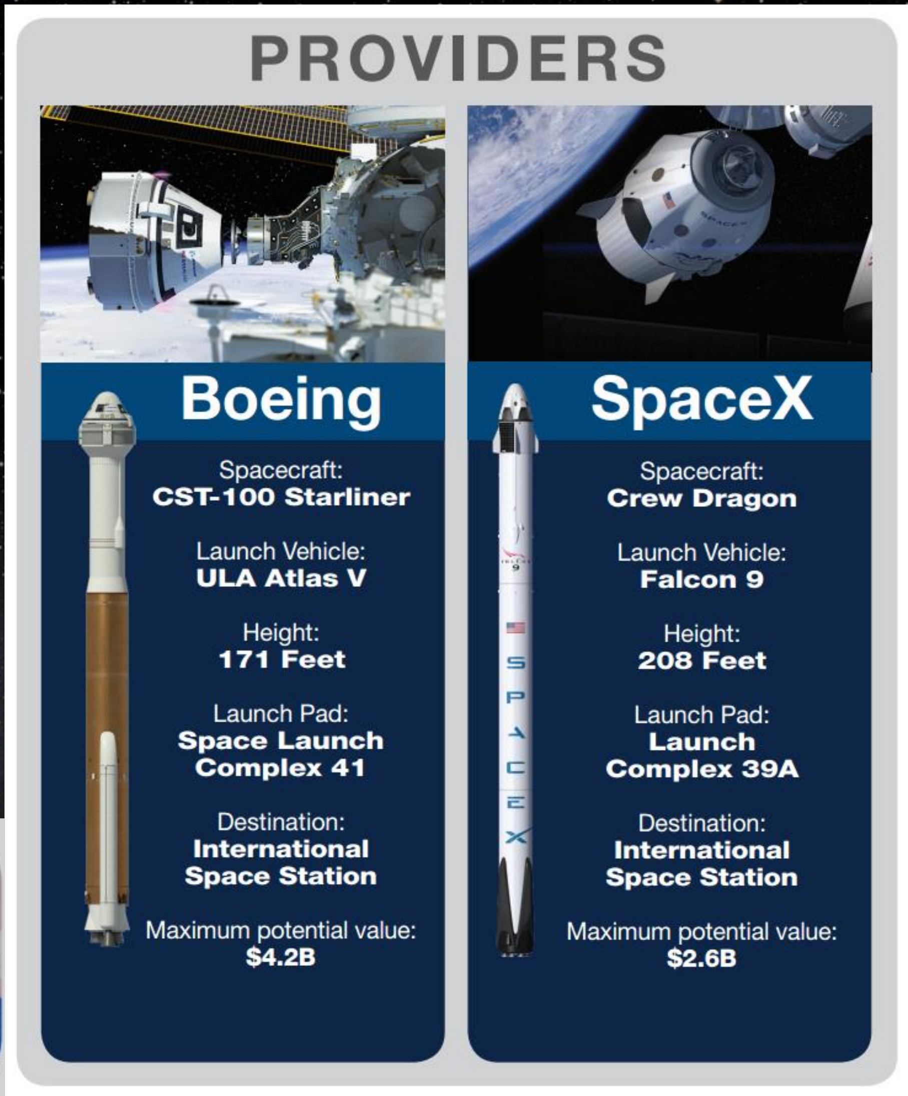
NASA's Orion Multi-Purpose Crew Vehicle



- The Orion Multi-Purpose Crew Vehicle is designed to take humans farther than they've ever gone before.
- Orion will serve as the exploration vehicle that will carry the crew to space, provide emergency abort capability, sustain the crew during the space travel, and provide safe re-entry from deep space return velocities.
- Orion will launch on NASA's new heavy-lift rocket, the Space Launch System.

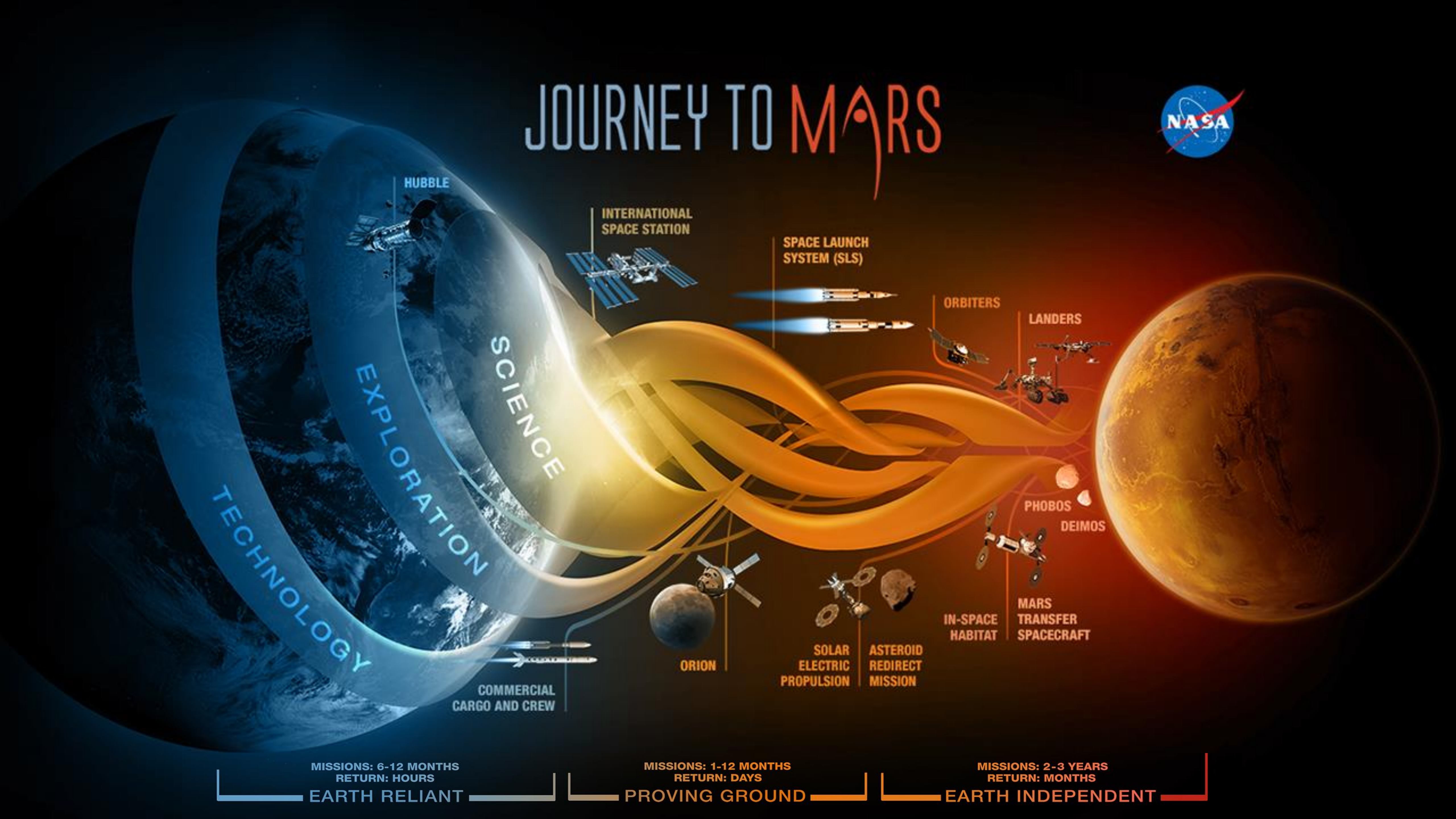
Commercial Crew Program

- Facilitate the development of U.S. commercial crew space transportation systems to provide safe, reliable, cost-effective access to and from the ISS and low-Earth orbit from America.
- Transport pressurized scientific research and cargo and increase the station crew, enabling twice the amount of scientific research to be conducted.
- By encouraging private companies to provide human transportation services to and from low-Earth orbit, NASA can expand its focus on building spacecraft and rockets for deep space missions on our journey to Mars.



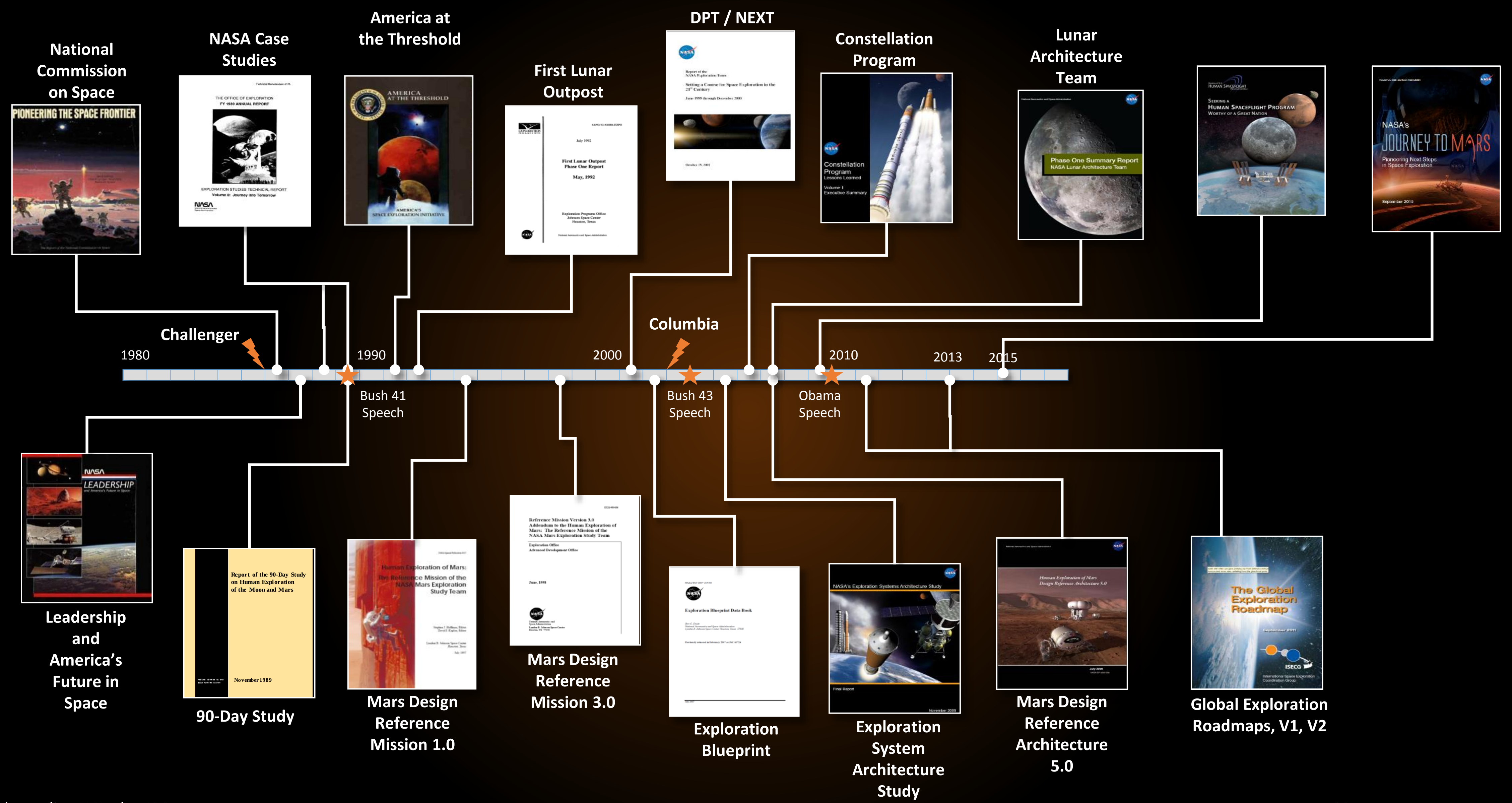
Commercial Launch Services

- A little more than two years after the end of the Space Shuttle Program, SpaceX and Orbital ATK began successfully resupplying the space station with cargo launched from the United States.
- The companies developed the rockets and spacecraft through public-private partnerships under the agency's Commercial Orbital Transportation Services (COTS) program
- NASA then awarded Orbital ATK and SpaceX commercial resupply services contracts to each deliver at least 20 metric tons of cargo to the orbiting laboratory.
- The companies are successfully resupplying the space station, and more missions to deliver scientific investigations and cargo are planned.
- This partnership is changing the way NASA does business,
    - helping build a strong American commercial space industry, and
    - freeing NASA to focus on developing the next-generation rocket and spacecraft that will allow us to travel farther in space than ever before.



JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

Human Exploration Studies Beyond LEO - Toward Mars



Slide credit – B Drake, JSC

Strategic Principles for Sustainable Exploration Campaign

- **Implementable in the near-term** with the buying power of current budgets and in the longer term with budgets commensurate with economic growth;
- **Exploration enables science and science enables exploration**, leveraging robotic expertise for human exploration of the solar system
- Application of **high Technology Readiness Level (TRL) technologies** for near term missions, while focusing sustained investments on technologies and capabilities to address challenges of future missions;
- **Near-term mission opportunities** with a defined cadence of compelling and integrated human and robotic missions providing for an **incremental buildup of capabilities** for more complex missions over time;
- Opportunities for **U.S. commercial business** to further enhance the experience and business base;
- **Multi-use, evolvable space infrastructure**, minimizing unique major developments, with each mission leaving something behind to support subsequent missions; and
- Substantial new **international and commercial partnerships**, leveraging the current International Space Station partnership while building new cooperative ventures.

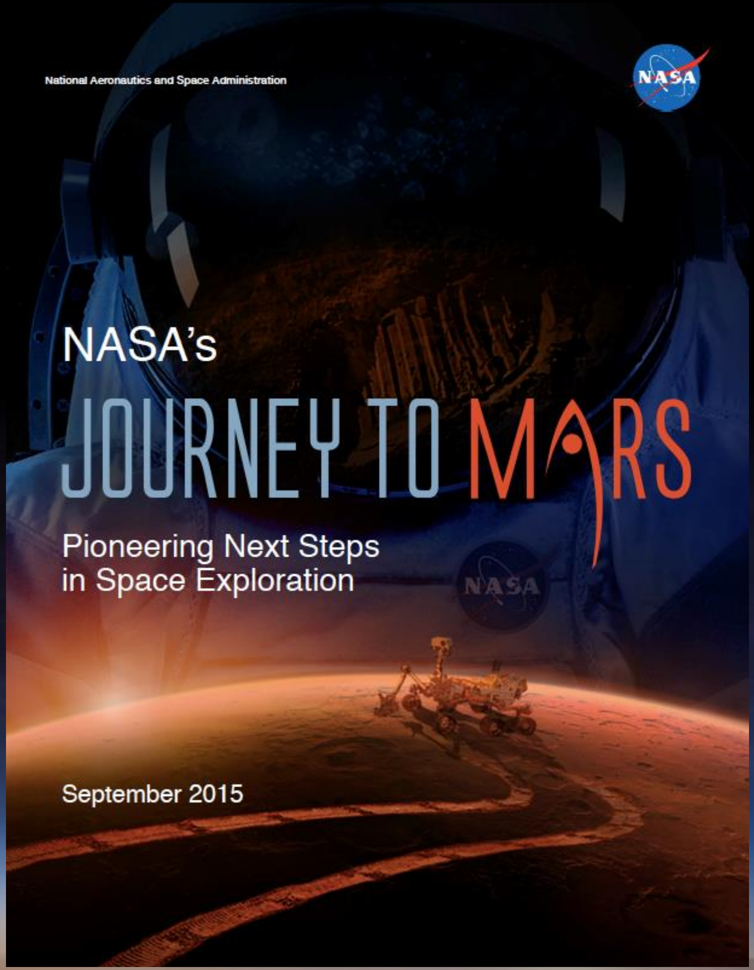
Plan Outlining Next Steps in the Journey to Mars

Draft versions – 18 months

- Revised by internal & external stakeholders

Overall Flow

- Introduction and Goals
- Our Approach – Pioneering Principles
- Three Phases for J2M
- Our Strategy for the Journey to Mars
  - Cislunar steps
  - Science and human exploration
- Our Progress and Plans
  - Earth-Reliant – ISS, Commercial Crew/Cargo
  - Proving Ground – SLS, Orion, SEP, habitats
  - Earth-Independent – Robotic missions, evolving architectures
- Pioneering Challenges
  - Transportation
  - Working in Space
  - Staying Healthy
- Summary



http://go.nasa.gov/1VHDXxg

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Key Capabilities for the Human Exploration of Mars

- Common Findings from Multiple Studies:

1,100 Days

Total time crew is away from Earth

Maximum surface stay for any given mission

500 Days

12 km/s

Highest Orion Earth entry speed

130 t

Heavy-Lift Mass

Multiple

Launches per mission

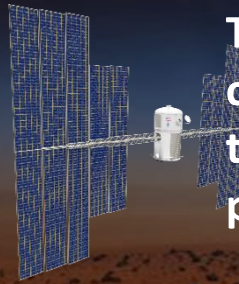
44 min

Maximum two-way communication time delay

100 km

Distance for long-range routine exploration

100-200 kWe



Total continuous transportation power

20-30 t

Ability to land large payloads

20 t

Oxygen produced for ascent to orbit

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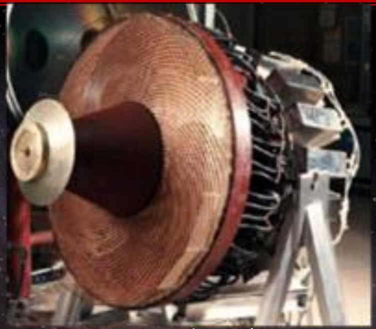
Capabilities and Platforms for Mars Exploration

		ISS	Cis-lunar Short Stay (e.g. ARM)	Cis-lunar Long Stay	Mars Orbit	Mars Surface, Short Stay	Mars Surface, Long Stay
Working in Space and On Mars	In Situ Resource Utilization & Surface Power						X
	Surface Habitat & Mobility					X	X
	Human/Robotic & Autonomous Ops		X	X	X	X	X
	Exploration EVA		X	X	X	X	X
Staying Healthy	Crew Health	X	X	X	X	X	X
	Environmental Control & Life Support	X	X	X	X	X	X
	Radiation Safety		X	X	X	X	X
Transportation	Ascent from Planetary Surfaces					X	X
	Entry, Descent & Landing					X	X
	In-space Power & Prop (incl. SEP, Hybrid)		X	X	X	X	X
	Beyond LEO: SLS (w/ EUS) & Orion		X	X	X	X	X
	To LEO: Commercial Cargo & Crew	X					
	Comm & Navigation	X			X	X	X

MSFC Technology Emphasis Areas

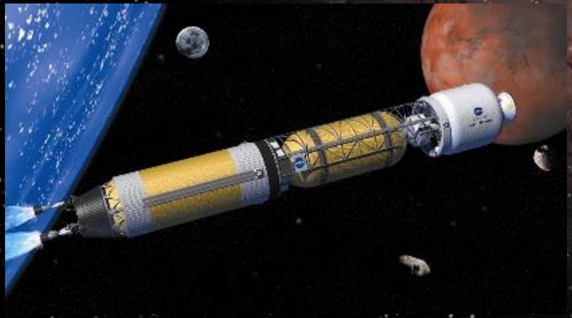

In-Space Propulsion with Emphasis on Cryogenics


In-Space Propulsion (Green Propellants, Electric)

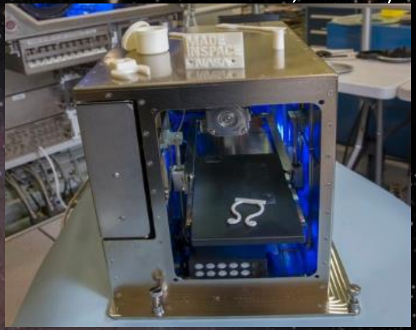

In-Space Propulsion (Nuclear)


In-Space Propulsion (Solar Sails, Tethers)


Propulsion Testbeds and Demonstration Missions


Habitats and Technologies for “Beyond Low Earth Orbit” Exploration

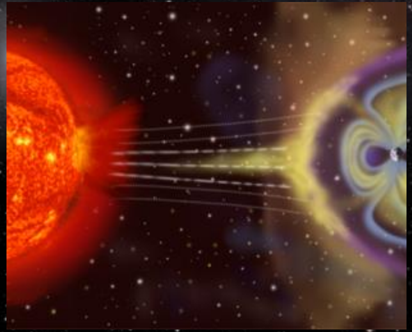

Technologies Supporting Utilization of ISS


Advanced Manufacturing with Emphasis on In-Situ Fabrication and Repair


Human Habitation Elements and Life Support Systems


Technologies for Small payload Launch


X-ray Astrophysics; Scientific Instrument Dev.


Space Environments and Space Weather, Research to Operations


Small Spacecraft and Enabling Technologies


Rapid/Affordable Manufacturing with Emphasis on Propulsion Components

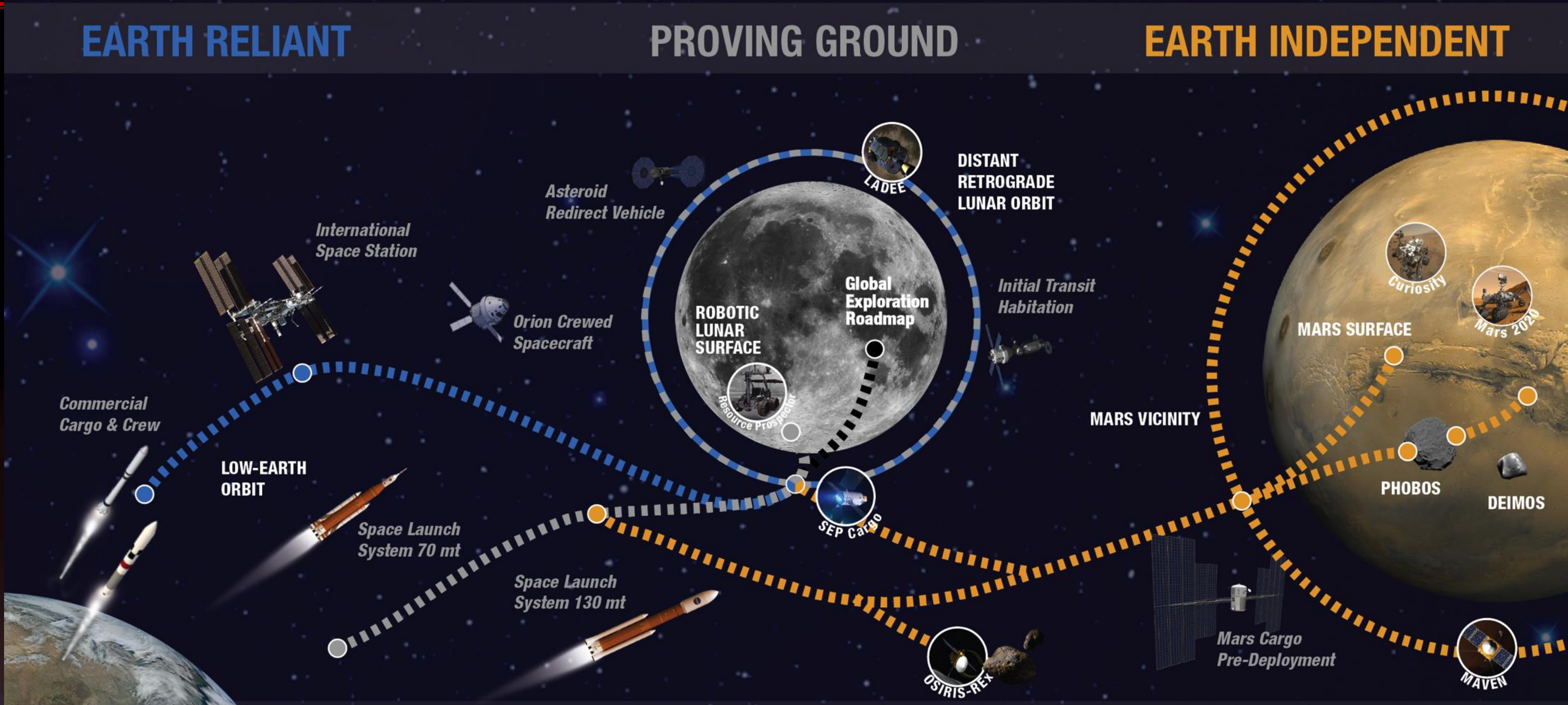
Evolvable Mars Campaign

EMC Goal: Define a pioneering strategy and operational capabilities that can extend and sustain human presence in the solar system including a human journey to explore the Mars system starting in the mid-2030s.

- Identify a plan that:
  - Expands human presence into the solar system to advance exploration, science, innovation, benefits to humanity, and international collaboration.
  - Provides different future scenario options for a range of capability needs to be used as guidelines for near term activities and investments
    - In accordance with key strategic principles
    - Takes advantage of capability advancements
    - Leverages new scientific findings
    - Flexible to policy changes
  - Identifies linkages to and leverage current investments in ISS, SLS, Orion, ARM, EAM, technology development investments, science activities
  - Emphasizes prepositioning and reuse/repurposing of systems when it makes sense
    - Use location(s) in cis-lunar space for aggregation and refurbishment of systems

EVOLVABLE MARS CAMPAIGN

A Pioneering Approach to Exploration



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

Cis-lunar 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

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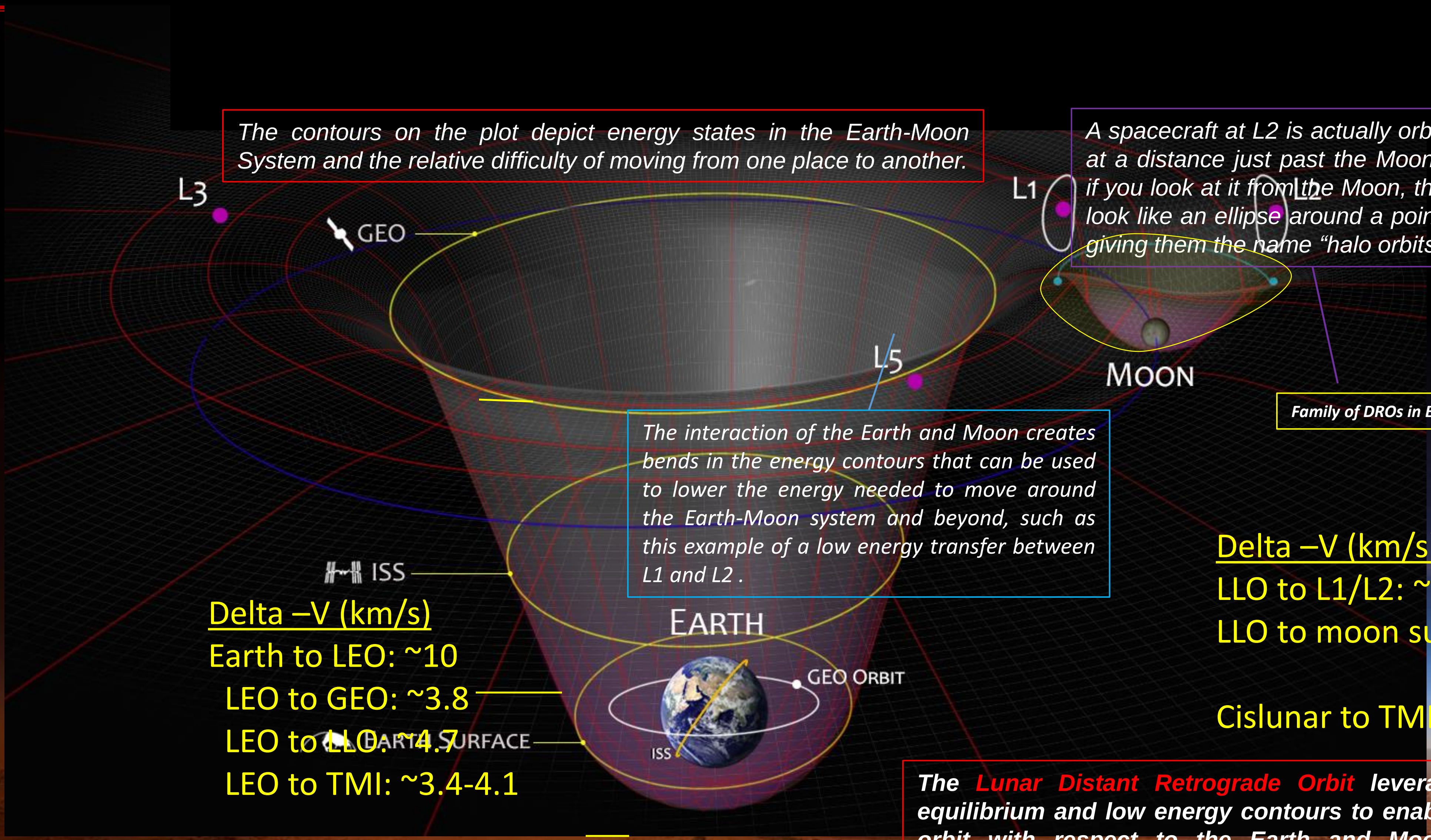
Why Cislunar Space?
The 'Gravity Well' Advantage

The contours on the plot depict energy states in the Earth-Moon System and the relative difficulty of moving from one place to another.

A spacecraft at L2 is actually orbiting Earth at a distance just past the Moon, however if you look at it from the Moon, the orbit will look like an ellipse around a point in space giving them the name "halo orbits".



Family of DROs in Earth-Moon Plane

The interaction of the Earth and Moon creates bends in the energy contours that can be used to lower the energy needed to move around the Earth-Moon system and beyond, such as this example of a low energy transfer between L1 and L2 .

<u>Delta –V (km/s)</u>

Earth to LEO: ~10

LEO to GEO: ~3.8

LEO to LLO: ~4.7

LEO to TMI: ~3.4-4.1

<u>Delta –V (km/s)</u>

LLO to L1/L2: ~0.7

LLO to moon surf: ~2

Cislunar to TMI: ~0.7-1.2

The Lunar Distant Retrograde Orbit leverages these equilibrium and low energy contours to enable a stable orbit with respect to the Earth and Moon, that is accessible with about the same energy as L1 or L2.

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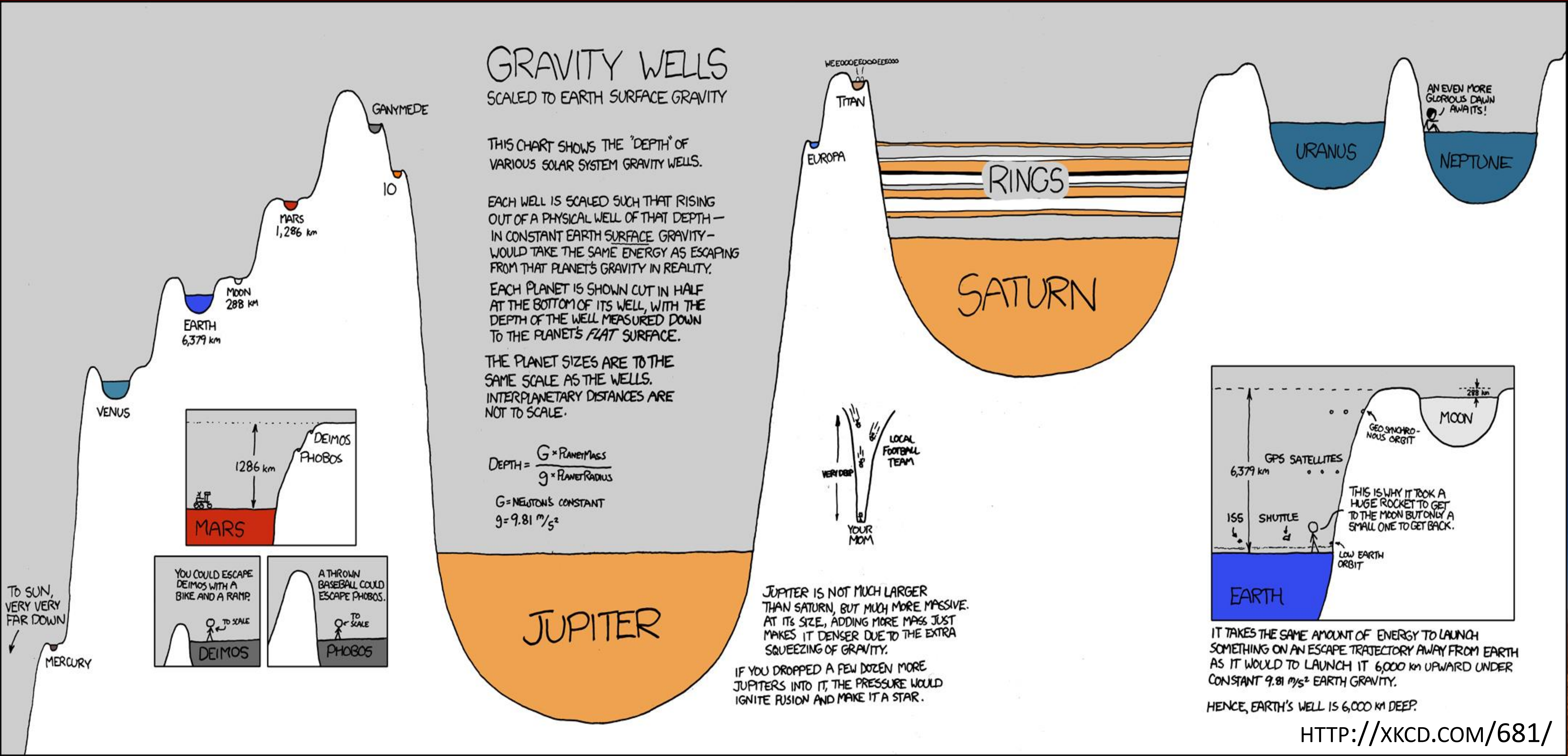
Gravity Wells Explained
xkcd.com by Randall Munroe



HTTP://XKCD.COM/681/

PROVING GROUND OBJECTIVES

Using Cislunar Resources to Enable Human Missions to Mars

TRANSPORTATION | WORKING IN SPACE | STAYING HEALTHY

- **Heavy Launch Capability**: beyond low-Earth orbit launch capabilities for crew, co-manifested payloads, large cargo
- **Crew**: transport at least four crew to cislunar space
- **In-Space Propulsion**: send crew and cargo on Mars-class mission durations and distances

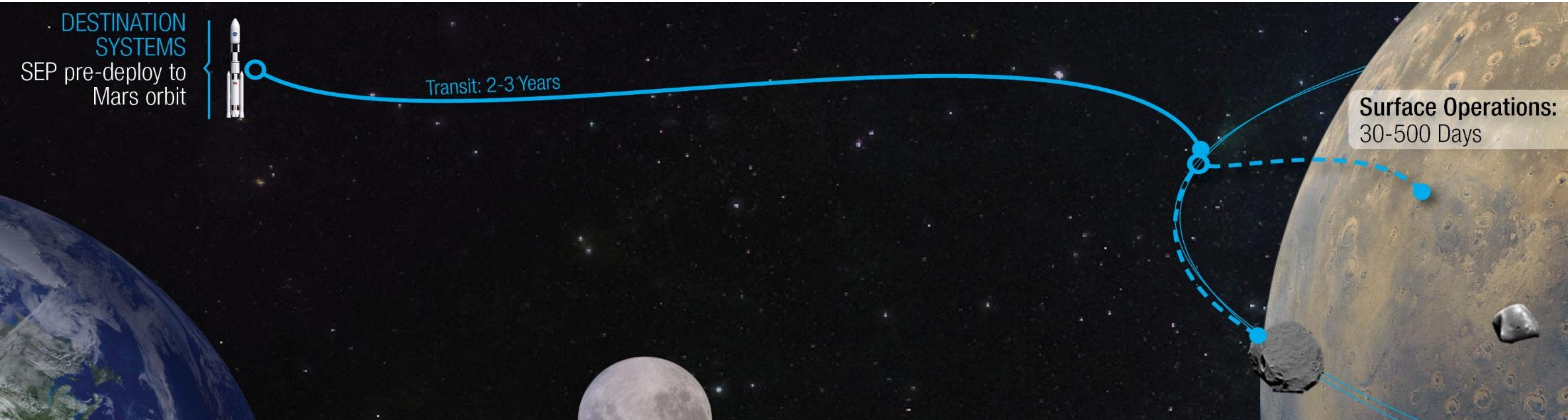
- **ISRU**: Understand the nature and distribution of volatiles and extraction techniques and decide on their potential use in human exploration architecture.
- **Deep-space operations capabilities**: EVA, Staging, Logistics, Human-robotic integration, Autonomous operations
- **Science**: enable science community objectives

- **Deep-Space Habitation**: beyond low-Earth orbit habitation systems sufficient to support at least four crew on Mars-class mission durations and dormancy
- **Crew Health**: Validate crew health, performance and mitigation protocols for Mars-class missions

Address Strategic Knowledge Gaps with cislunar missions

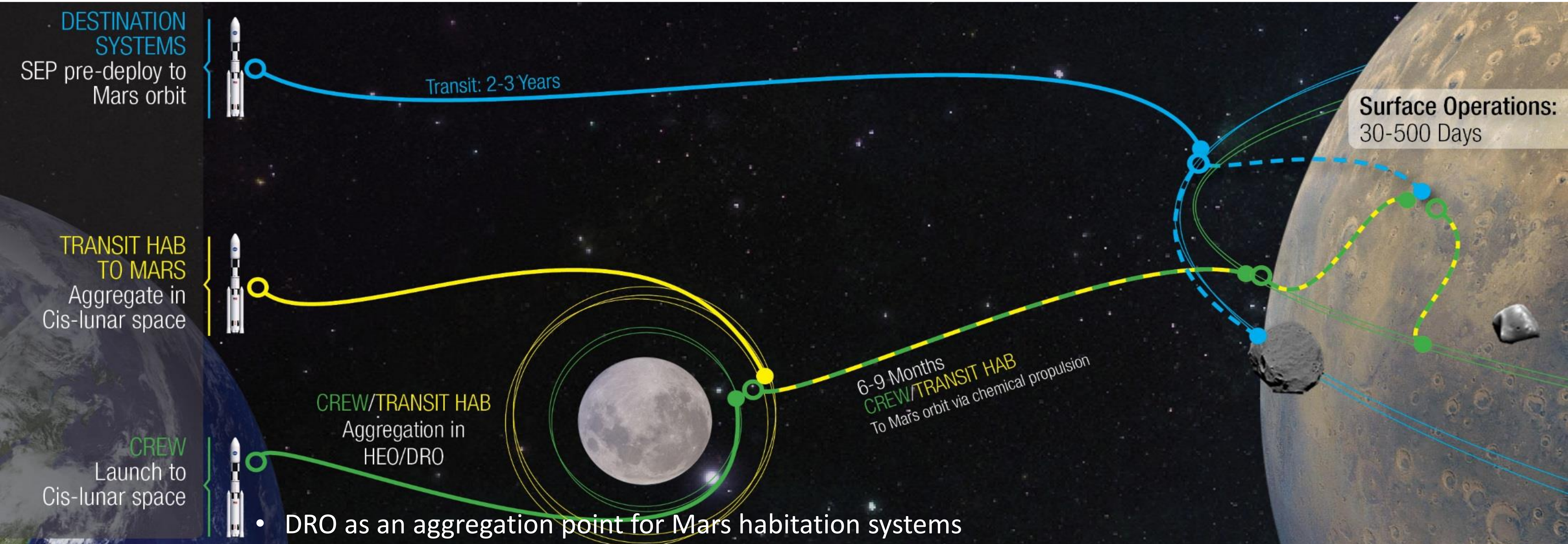
#JOURNEYTO

Split Mission Concept



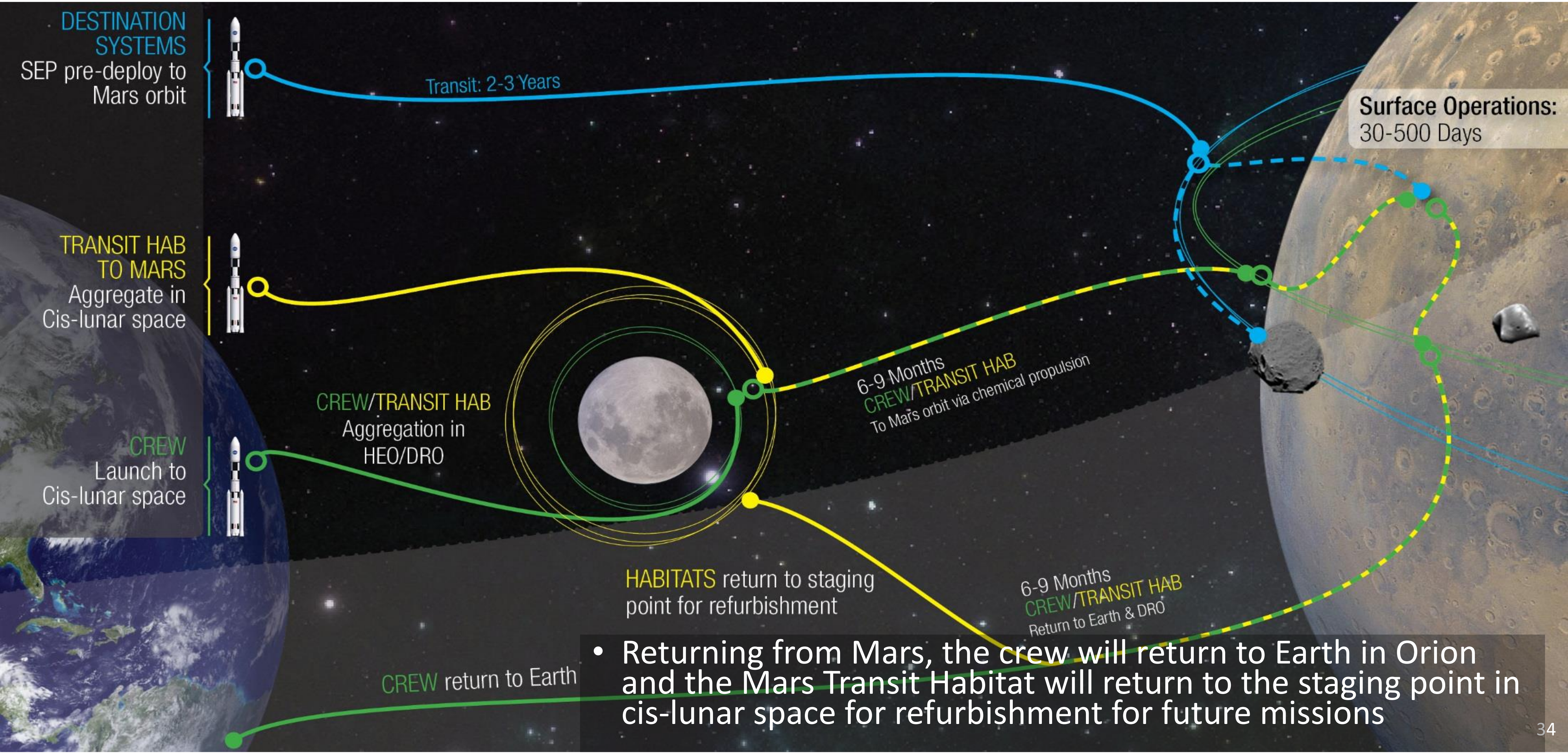
- Using SEP for pre-emplacement of cargo and destination systems enables sustainable Mars campaign
- Minimizes the cargo needed to be transported with the crew on future launches
- Enables a more sustainable launch cadence
- Pre-positions assets for crew missions allows for system checkout in the Mars vicinity prior to committing to crew portion of mission

Split Mission Concept



- DRO as an aggregation point for Mars habitation systems
- Provides a stable environment and ease of access for testing Proving Ground capabilities
- Allows for Mars transit vehicle build-up and checkout in the deep-space environment prior to crew departure
- Able to transfer Mars Transit Vehicle from DRO to High Earth Orbit with small amount of propellant to rendezvous with crew in Orion – HEO is more efficient location to leave Earth-moon system for Mars vicinity

Split Mission Concept



- Returning from Mars, the crew will return to Earth in Orion and the Mars Transit Habitat will return to the staging point in cis-lunar space for refurbishment for future missions

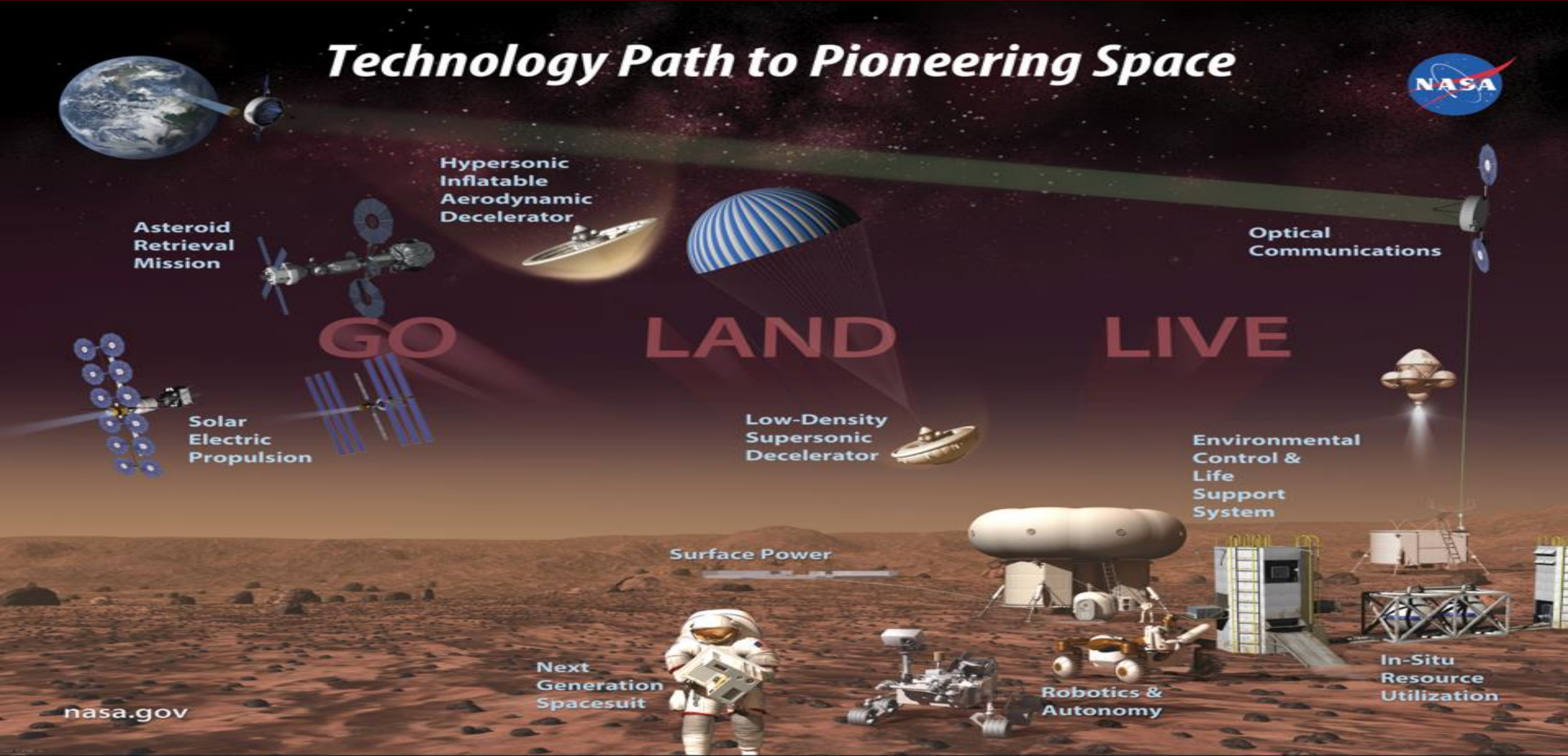
EMC – Major Results to Date

- **Regardless of Mars vicinity destination, common capability developments are required**
- **ISS provides critical Mars mission capability development platform**
- **Lunar DRO is efficient for aggregation and potential refurbishment due to stable environment**
  - Use of gravity assist trajectories enable use of DRO
- **Orion Block 1 is sufficient for Mars architectures with reusable habitats**
- **SLS co-manifested cargo capability increases value of crewed missions and improves cadence**
- **Deep-space habitation serves as initial starting point regardless of destination**
- **ARV derived SEP vehicle can serve as an effective tool for human Mars missions**
  - Reusability can enable follow-on use in cis-lunar space
  - Refuelability under study to enable Mars system follow-on use
  - Current SEP evolvability enables Mars system human missions
- **Mars Phobos /Deimos as initial Mars vicinity mission spread out development costs and meets policy objectives of Mars vicinity in 2030's**
  - Common crew transportation between Mars Phobos / Deimos and Mars Surface staging
  - Phobos provides 35% reduction of radiation exposure compared to other Mars orbit missions
  - Provides ability to address both exploration and science objectives

#JOURNEYTOMARS

Mars Technology Video

Technology Needs for Deep Space Exploration



Space Technology Portfolio and Programs

Transformative & Crosscutting Technology Breakthroughs

Technology Demonstration Missions
bridges the gap between early proof-of-concept tests and the final infusion of cost-effective, revolutionary technologies into successful NASA, government and commercial space missions.

Small Spacecraft Technology Program
develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration and space operations.

Game Changing Development
seeks to identify and rapidly mature innovative/high impact capabilities and technologies that may lead to entirely new approaches for the Agency's broad array of future space missions.

Pioneering Concepts/Developing Innovation Community

NASA Innovative Advanced Concepts (NIAC)
nurtures visionary ideas that could transform future NASA missions with the creation of breakthroughs radically better or entirely new aerospace concepts–while engaging America's innovators and entrepreneurs as partners in the journey.

Space Technology Research Grants
seek to accelerate the development of "push" technologies to support future space science and exploration needs through innovative efforts with high risk/high payoff while developing the next generation of innovators through grants and fellowships.

Center Innovation Fund
stimulates and encourages creativity and innovation within the NASA Centers by addressing the technology needs of the Agency and the Nation. Funds are invested to each NASA Center to support emerging technologies and creative initiatives that leverage Center talent and capabilities.

Creating Markets & Growing Innovation Economy

Centennial Challenges
directly engages nontraditional sources advancing technologies of value to NASA's missions and to the aerospace community. The program offers challenges set up as competitions that award prize money to the individuals or teams that achieve a specified technology challenge.

Flight Opportunities
facilitates the progress of space technologies toward flight readiness status through testing in space-relevant environments. The program fosters development of the commercial reusable suborbital transportation industry.

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)
Programs provide an opportunity for small, high technology companies and research institutions to develop key technologies addressing the Agency's needs and developing the Nation's innovation economy.

Enabling Future Exploration Missions

Space Technology focus investments in 8 thrust areas that are key to future NASA missions and enhance national space capabilities.

In- Space Propulsion

Create improvements in thrust levels, specific power, and alternatives to traditional chemical propulsion systems for destination-agnostic, deep space exploration spacecraft systems.

External Application: *Enhanced* propulsion capabilities for Commercial and OGA Satellites

High Bandwidth Space Comm

Substantially increase available bandwidth and data rates for near earth and deep space, currently limited by power and frequency allocation limits. Assure robust and reliable interconnected space network.

External Application: High bandwidth for Commercial and OGA Satellites

Advanced Life Support & Resource Utilization

Human exploration missions beyond low earth orbit will require highly reliable technologies (e.g. reclaiming water reuse of trash, air revitalization) to minimize resupply requirements and increase independence from earth.

External Application: Mining Industry and other closed environments; OGA

Entry Descent and Landing Systems

Permits more capable science and future human missions to terrestrial bodies. Includes, hypersonic and supersonic aerodynamic decelerators, next- gen TPS materials, retro-propulsion, instrumentation and modeling.

External Application: Returning commercial assets from space and research from ISS

Space Robotic Systems

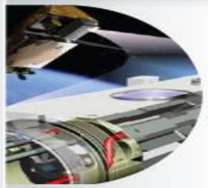
Extends our reach by helping us remotely explore planetary bodies, manage in-space assets and support in-space operations by enhancing the efficacy of our operations.

External Application: Human-safe Robotics for industrial use, disaster response, & overall autonomous operations

Lightweight Space Structures

Targets large decreases in structural mass for launch vehicles and spacecraft materials using nanotech, composites and in space manufacturing capabilities.

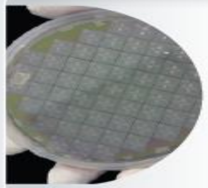
External Application: Industrial Materials and Composites for large structures (rockets, aircraft)



Deep Space Navigation

Allows for more capable science and human exploration missions; enables more precise entry trajectories for inserting into orbits around planets and bodies like Mars, Europa, and Titan.

External Application: Next Generation GPS and build new industrial base



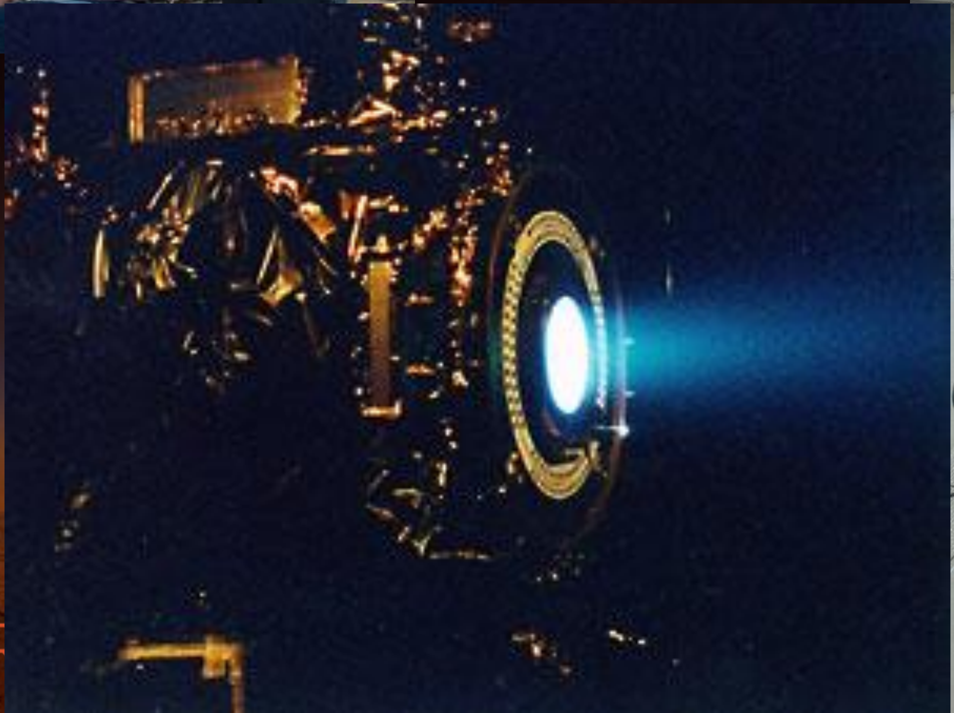
Space Observatory Systems

Allows for significant gains in science capabilities including: coronagraph technology to characterize exo-planets, advances in surface materials and better control systems for large space optics.

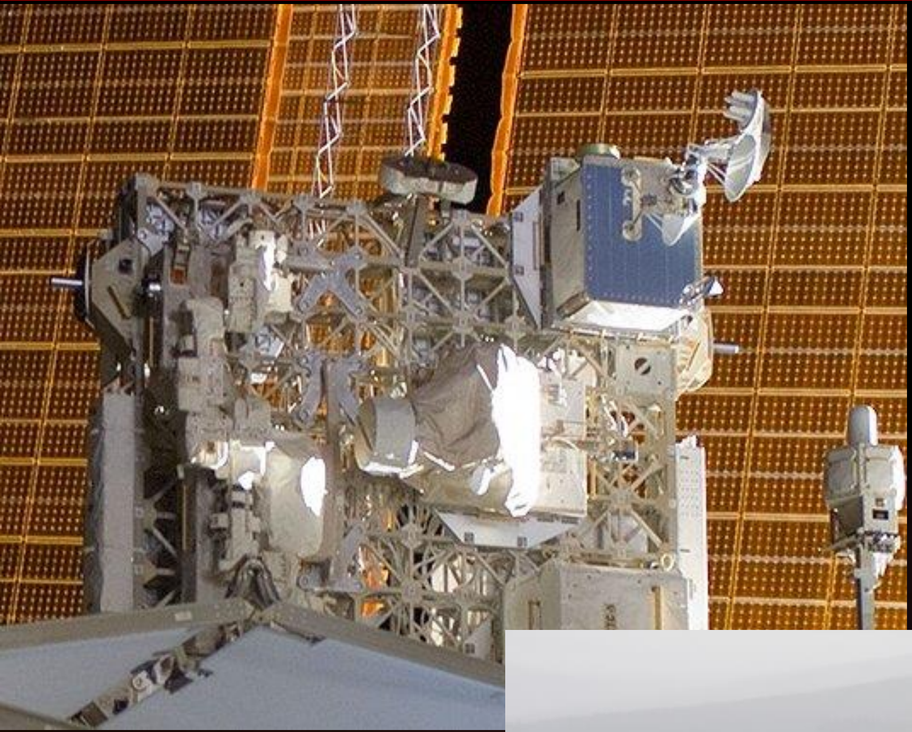
External Application: Industrial Materials, Earth Observation

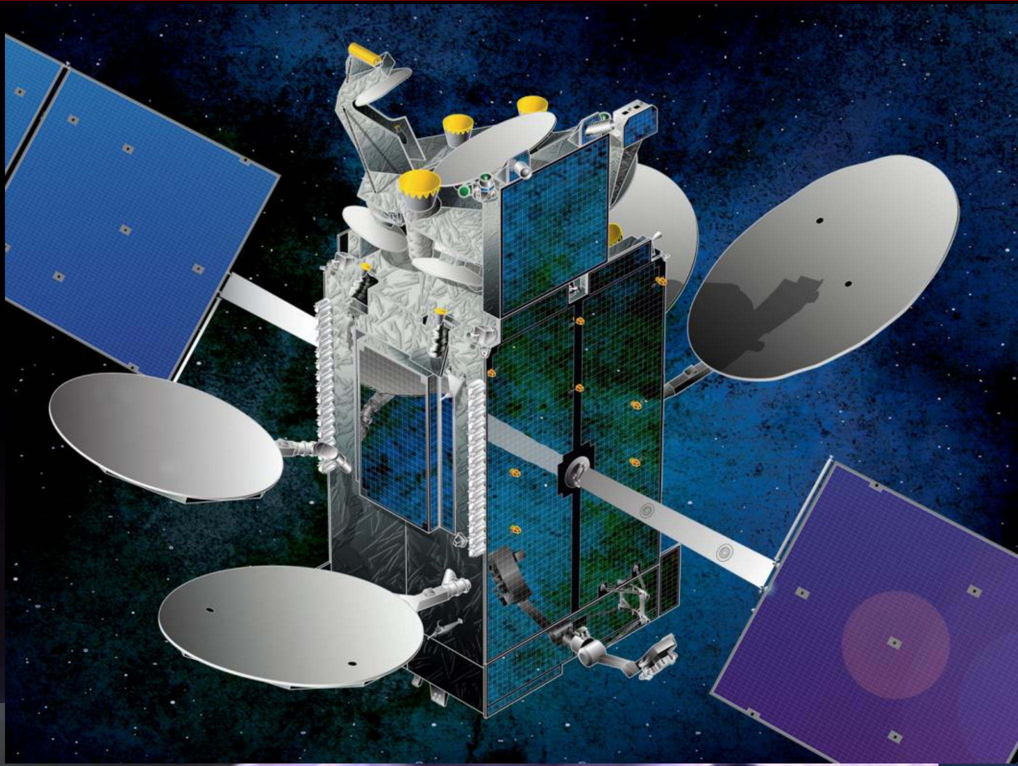
THRUST AREAS

Propulsion Research



Communications





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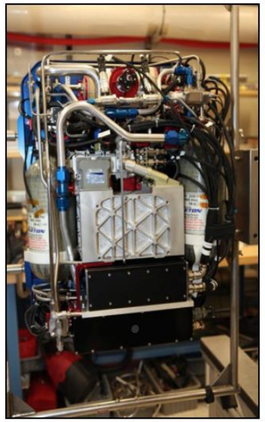
Next Generation Space Suits

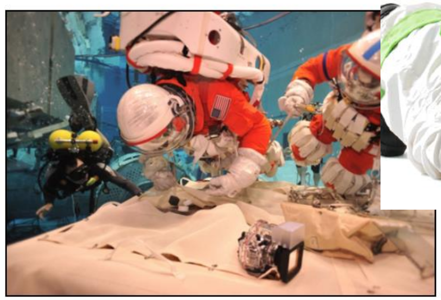
Crew Mobility Systems Domain

Advanced EVA: Development and testing of next generation space suits and portable life support systems (JSC).



Portable Life Support System 2.0 incorporates new technology components for CO_2 removal, thermal management, pressure regulation, and energy storage.

Z-2 Space Suit



Testing Modified Advanced Crew Escape Suit (MACES) in Neutral Buoyancy Lab for Asteroid Redirect Mission.

Growing Plants in space

Scott Kelly
@StationCDRKelly
Follow

#SpaceFlower out in the sun for the first time!
#YearInSpace

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Staying Healthy – Human Research Program (HRP)

ISS Medical Project

Human Health and Countermeasures

Exploration Medical Capabilities

Behavioral Health And Performance

Space Human Factors And Habitability

Science Management

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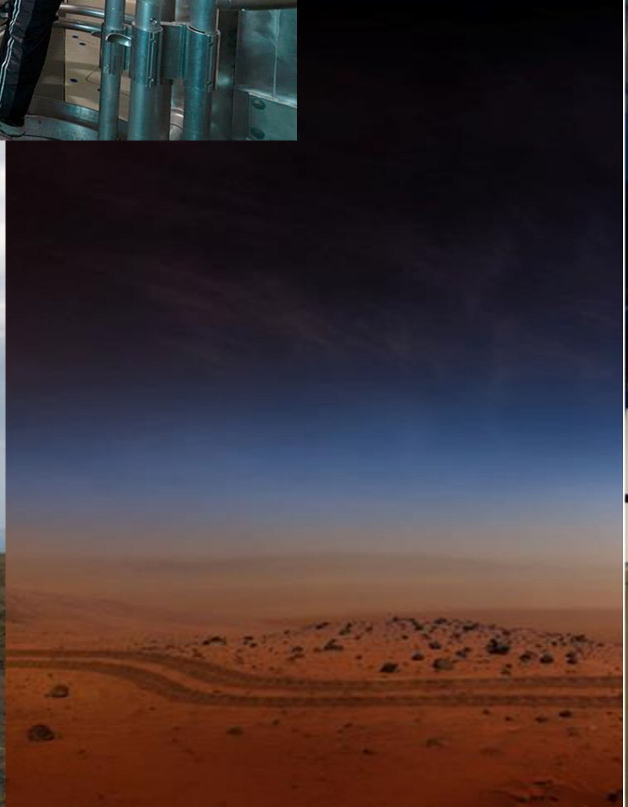
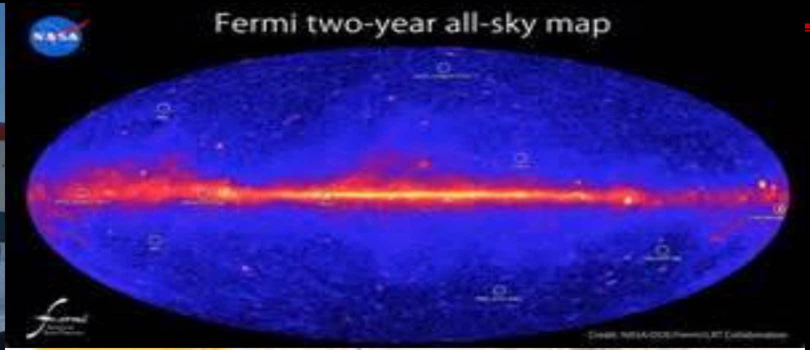
Habitat studies



Radiation studies



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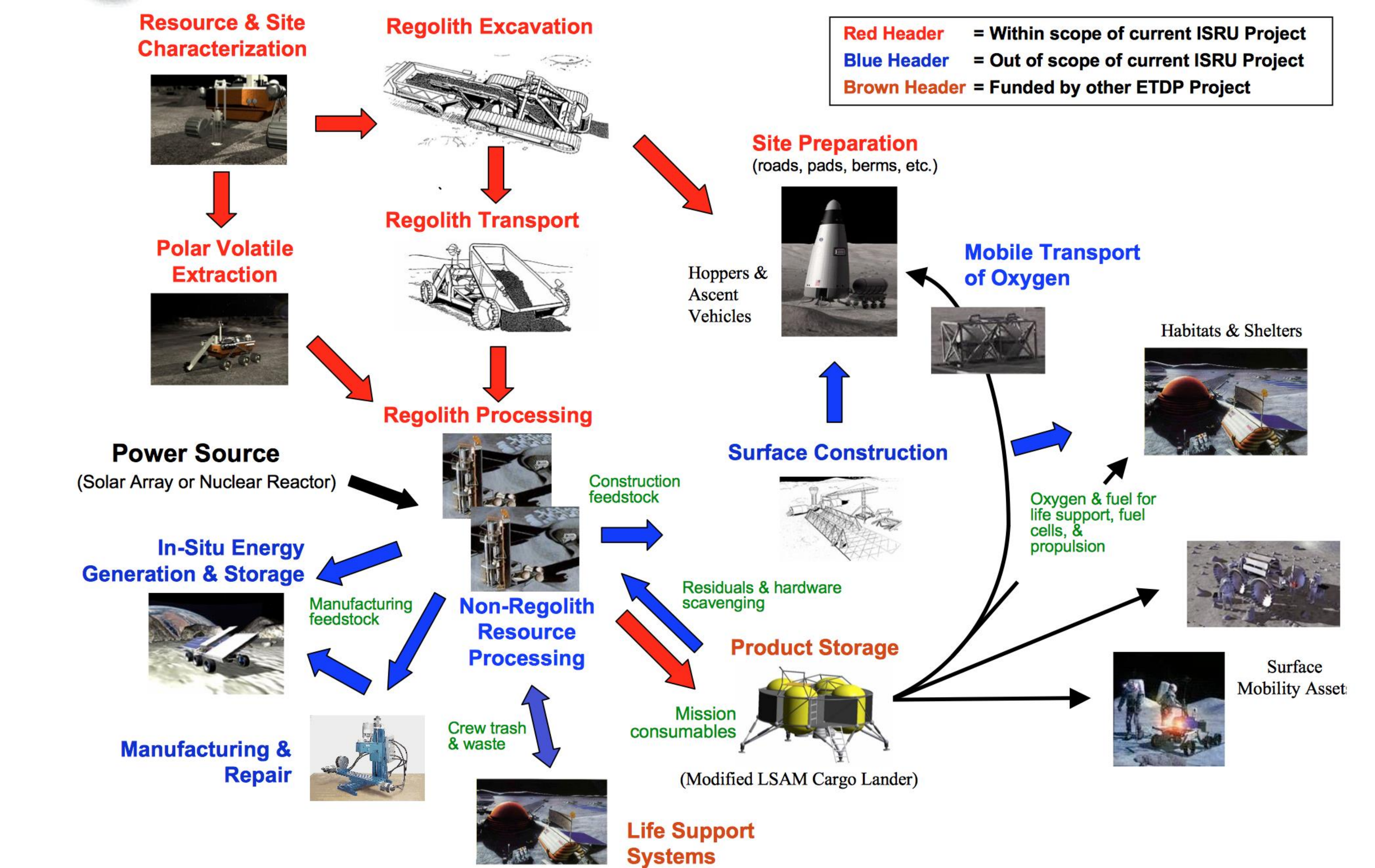
In Space Resource Utilization



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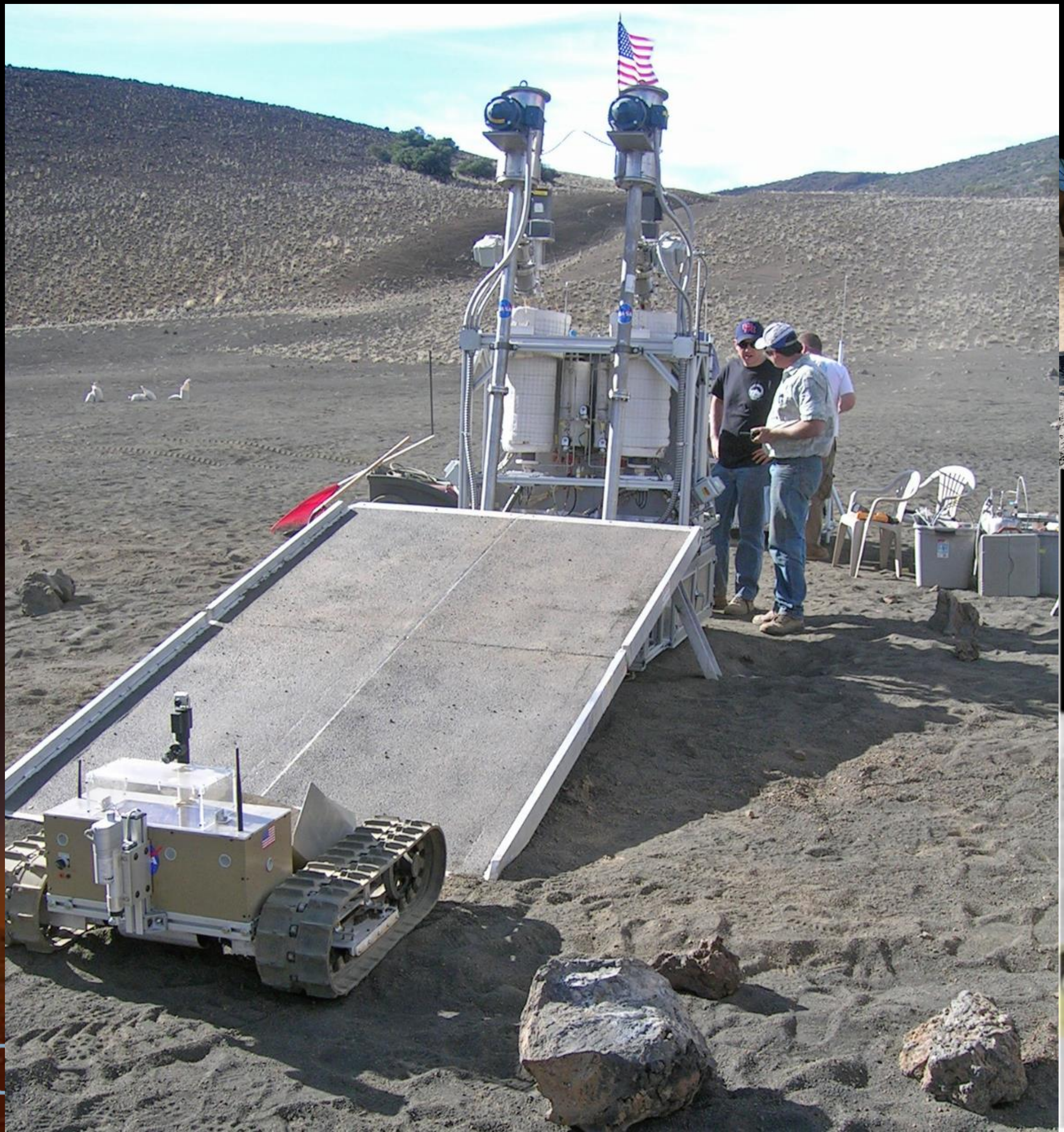
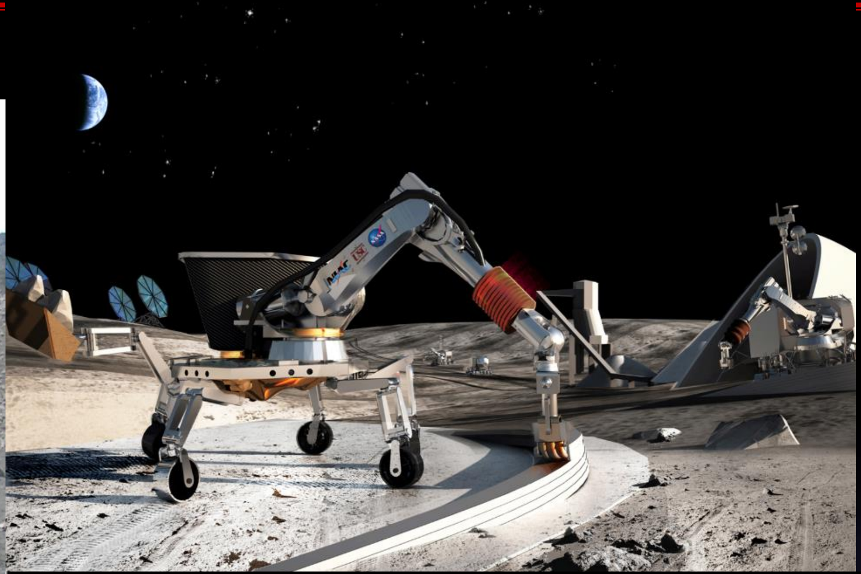
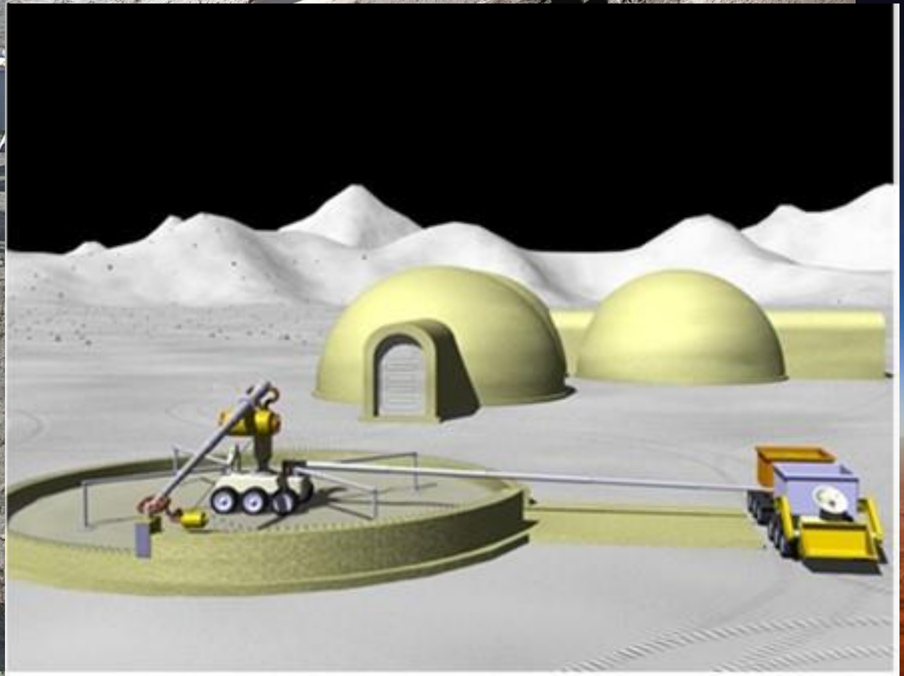
In Space Resource Utilization







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Surface Power and Mobility

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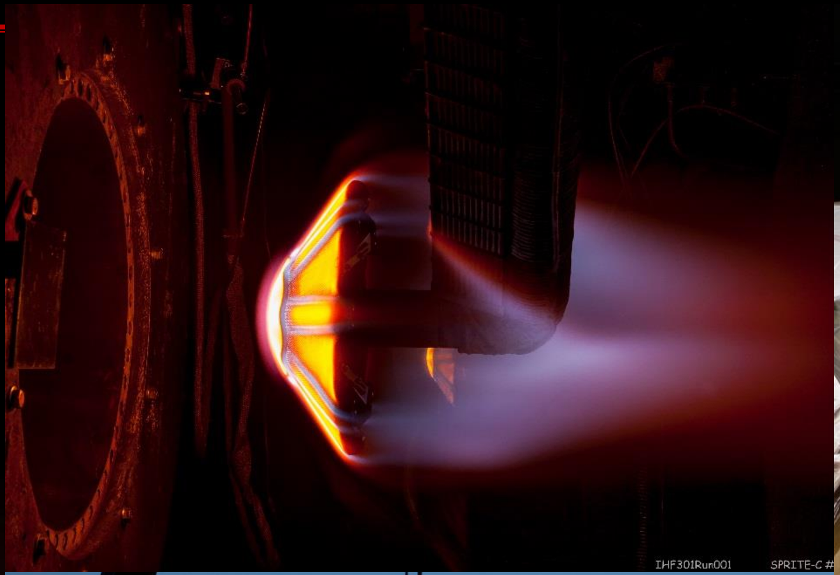
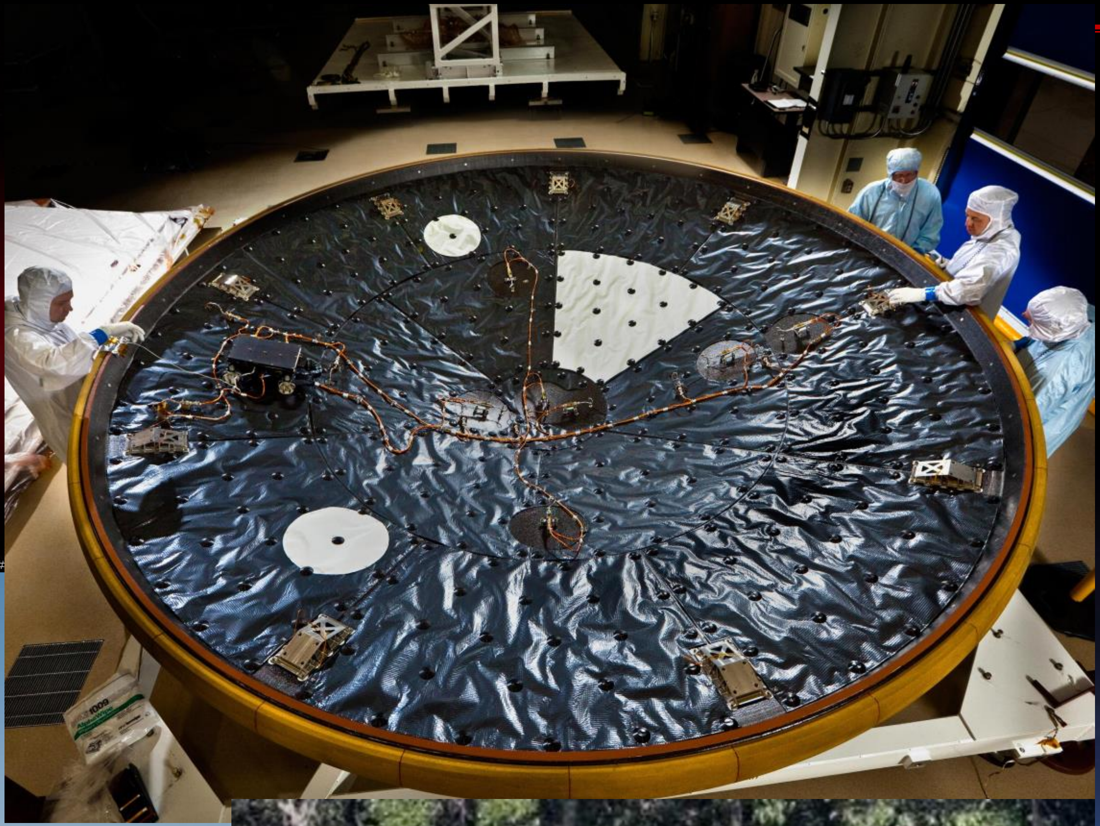
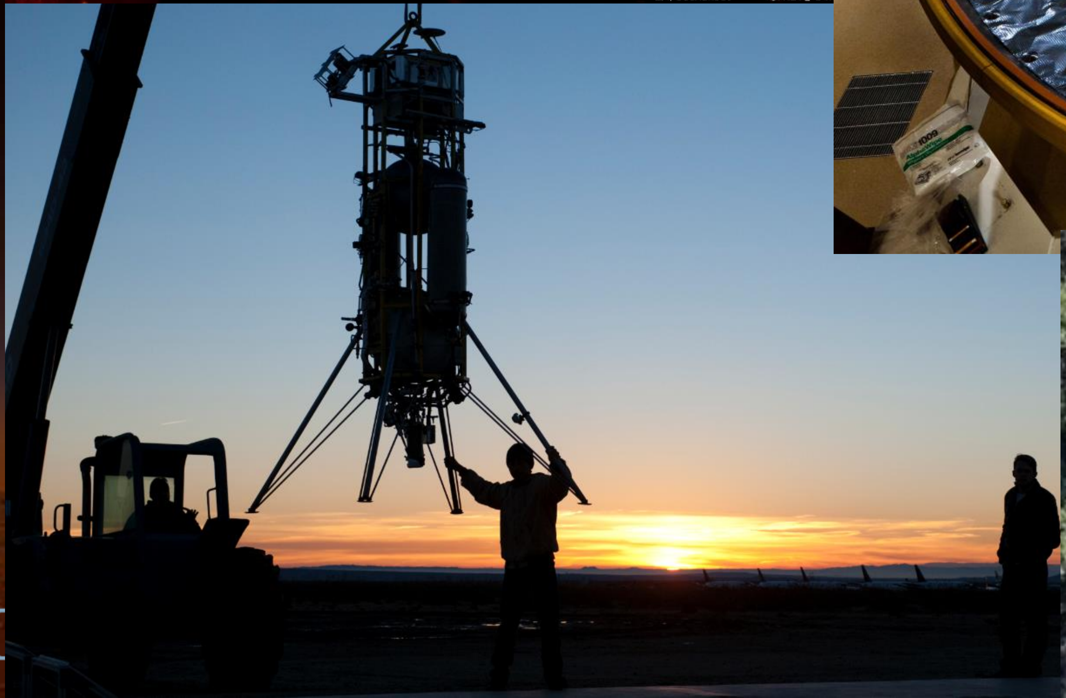
Ascent and Descent







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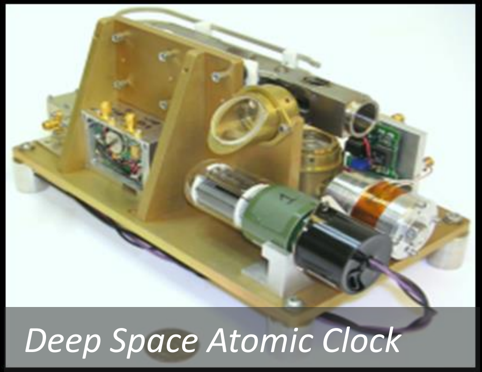
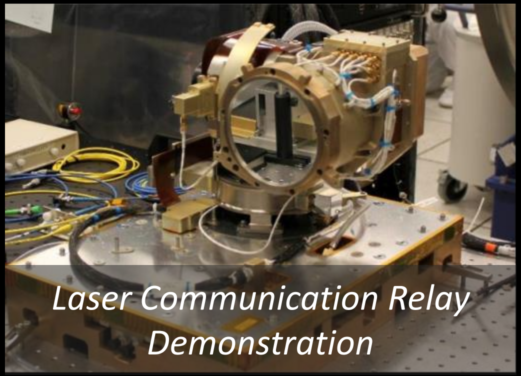
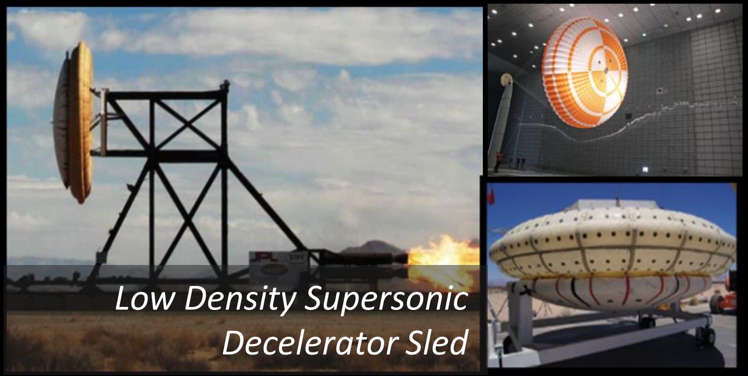
Supporting Exploration & Science

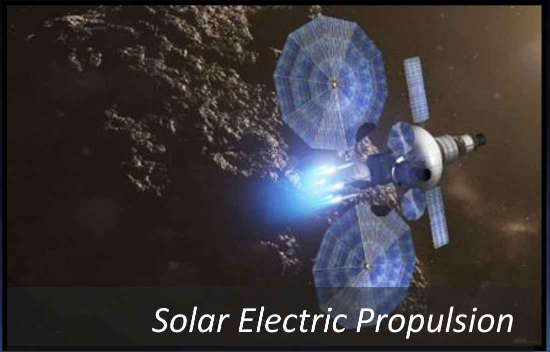

Deep Space Atomic Clock


Laser Communication Relay Demonstration


Low Density Supersonic Decelerator Sled


Human Robotics Systems


Hypersonic Inflatable Aerodynamic Decelerator


Solar Electric Propulsion


Environmental Control and Life Support System


Composite Cryogenic Propellant Tank

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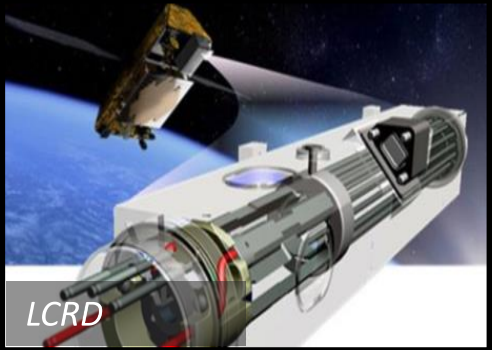
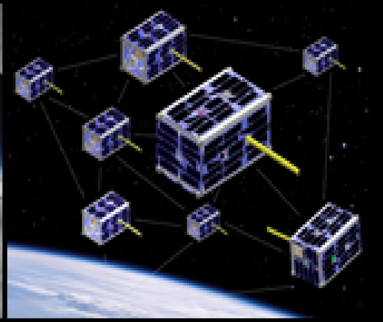
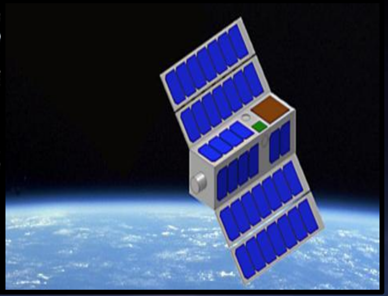
Technology & Enterprise


LCRD


SBIR/STTR



Small Spacecraft Technology

Additive Manufacturing/ 3-D Printers


Flight Opportunities


Green Propellant Infusion Missions


Centennial Challenge

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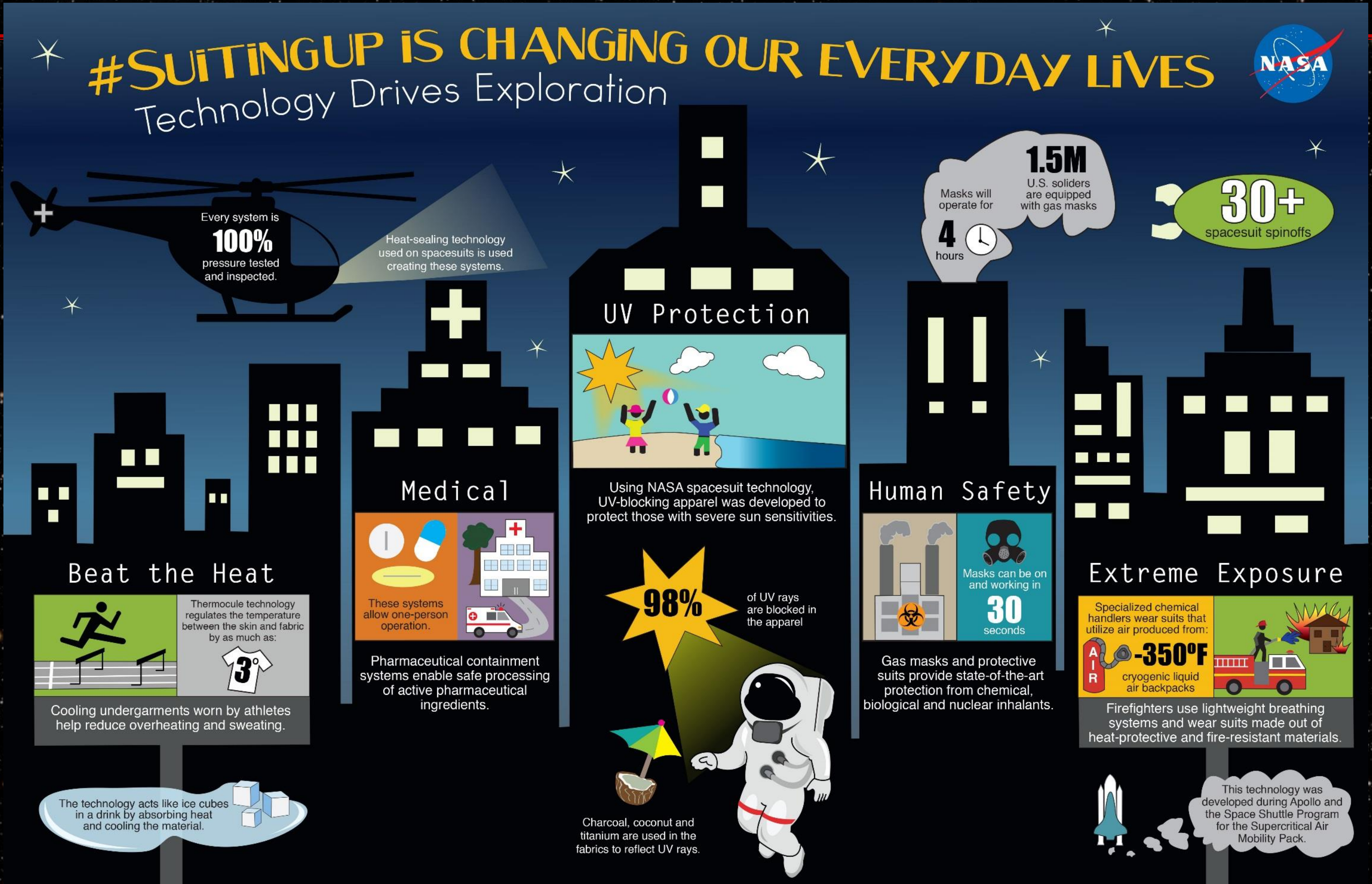
Technology Transfer

Technology Transfer Examples



NASA Today: Federal and NASA Budget

FY16 US Federal Budget

(estimated outlay) = $3.919T

NASA's FY16 Appropriated Budget = $19.3B

Federal Discretionary spending = $1.15T

In FY15, NASA's budget is 0.48% of the full federal budget outlay.

From 1958 through 2015 inclusive, NASA's cumulative budget is

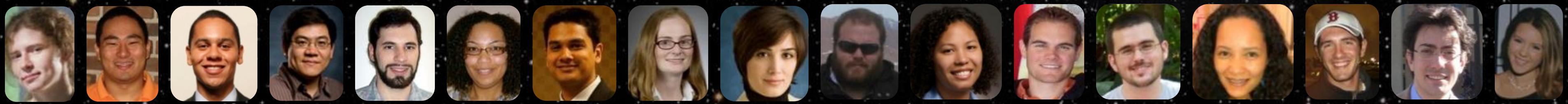
0.75%

of cumulative US Federal Budget Spending.

Space Technology Research Grants Program

Engage Academia: *tap into **spectrum** of academic researchers, from graduate students to senior faculty members, to examine the theoretical feasibility of ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable.*

- **NASA Space Technology Research Fellowships**
  - Graduate student research in space technology; research conducted on campuses and at NASA Centers and not-for-profit R&D labs
- **Early Career Faculty**
  - Focused on supporting outstanding faculty researchers early in their careers as they conduct space technology research of high priority to NASA's Mission Directorates
- **Early Stage Innovations**
  - University-led, possibly multiple investigator, efforts on early-stage space technology research of high priority to NASA's Mission Directorates
  - Paid teaming with other universities, industry and non-profits permitted



NASA SPACE TECHNOLOGY

National Aeronautics and
Space Administration

RESEARCH FELLOWSHIPS 2016

CALL FOR FELLOWSHIP APPLICATIONS

Learn, collaborate, discover, achieve…

The NASA Space Technology Mission Directorate seeks to sponsor graduate student researchers pursuing or planning to pursue master's and doctoral degrees in relevant space technology disciplines who show significant potential to contribute to the strategic goals and missions of NASA in the area of **space technology.**

The fellowship, up to $74,000 per year, will coincide with the start of the fall 2016 term. In addition to providing a $36,000 annual stipend, the fellowship provides support for tuition, health insurance and the faculty advisor. The fellowship also provides support for onsite tenure at NASA Centers across the country.

To date, NASA has awarded these prestigious fellowships to 301 students from 83 universities across 36 states and one U.S. territory. Fellowship recipients will collaborate with leading experts in space technology to provide a more robust national capability for aerospace activities and contribute to the Nation's innovation economy.

The solicitation opened on *September 10, 2015*
Student applications will be due by 6:00 p.m. ET on **November 05, 2015**

Applications will be accepted via NSPIRES after September 10, 2015:
http://tinyurl.com/NSTRF2016

U.S. citizens and permanent residents only.
PS-00885-1012

NASA Space Technology Research Fellowships

Eligibility Requirements for NSTRF16

1. Pursuing or seeking to pursue advanced degrees directly related to space technology.
2. Are U.S. citizens or permanent residents of the U.S.
3. Are or will be enrolled in a full-time master's or doctoral degree program at an accredited U.S. university in fall 2015.
4. Are early in their graduate careers.

NSTRF**16**: http://tinyurl.com/NSTRF2016.
NSTRF**15**: http://tinyurl.com/NSTRF2015.
NSTRF**14**: http://tinyurl.com/NSTRF14.
NSTRF**13**: http://tinyurl.com/NSTRF13.
NSTRF**12**: http://tinyurl.com/NSTRF12-OCT.
NSTRF**11**: http://tinyurl.com/NSTRF11-OCT.

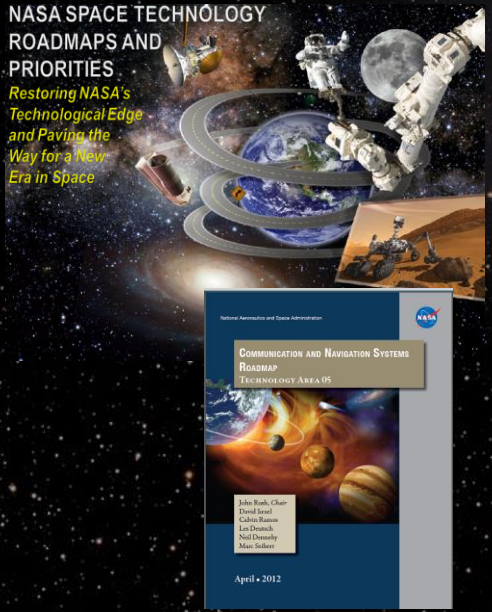
Application Components

1. Proposal Cover Page (Program Specific Data Questions)
2. Personal Statement
3. Project Narrative
4. Degree Program Schedule
5. Curriculum Vitae
6. Transcripts
7. GRE General Test Scores
8. Three Letters of Recommendation

Award Value

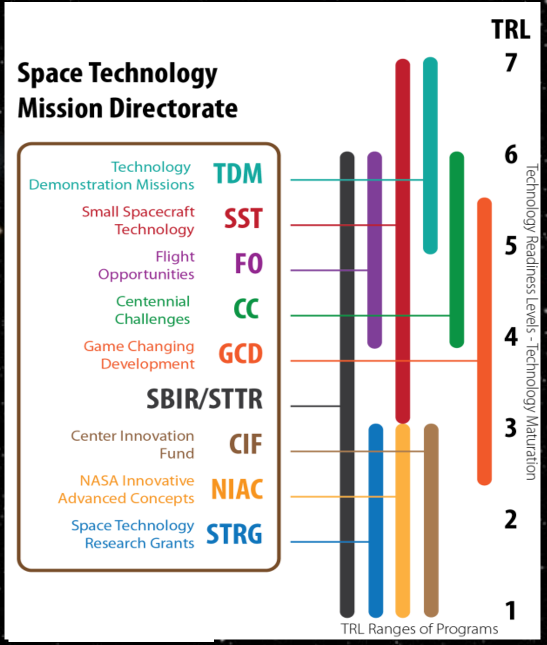
Fellowship Budget Category	Max value
Student Stipend	$36,000
Faculty Advisor Allowance	$10,000
Visiting Technologist Experience Allowance	$10,000
Health Insurance Allowance	$1,000
Tuition and Fees Allowance	$17,000
TOTAL	**$74,000**

Early Career Faculty and Early Stage Innovations Opportunities



Technical Characteristics:

- Unique, disruptive or transformational space technologies
- Low TRL
- Specific topics tied to Technology Area Roadmaps
- Big impact at the system level: performance, weight, cost, reliability, operational simplicity or other figures of merit associated with space flight hardware or missions



http://tinyurl.com/NASAECF http://tinyurl.com/NASA-14ECF http://tinyurl.com/NASA-15ECF http://tinyurl.com/NASAESI
http://tinyurl.com/NASA-13ESI http://tinyurl.com/NASA-14ESI www.tinyurl.com/NASA-15ESI

Eligibility Summary:

Both ECF and ESI proposals must be submitted by accredited U.S. universities

Early Career Faculty

- PI must be recent Ph.D. (last 7 years)
- Untenured assistant professor and on tenure track
- U.S. citizen or permanent resident
- No co-investigators

Early Stage Innovations

- PI must be from proposing university
- Co-investigators are permitted
- ≥ 50% of the proposed budget must go to the proposing university
- ≥ 70% of the proposed budget must go to universities

NSPIRES Solicitation Source (https://nspires.nasaprs.com/)

NSPIRES NASA Solicitation and Proposal Integrated Review and Evaluation System

Home NASA Research Help Login

|NSPIRES Time: Mar 13, 2016 03:54PM EDT

NSPIRES Home

- Solicitations

Getting Started

- NSPIRES Help
- Getting an Account

Help Desk

If you need help or have any questions regarding the NSPIRES website, please contact the NSPIRES Help Desk at (202) 479-9376 Monday through Friday, 8:00 AM to 6:00 PM EST/EDT, or by email at nspires-help@nasaprs.com.

NASA Web Sites
Click for Links

NASA Research Opportunities

Supporting research in science and technology is an important part of NASA's overall mission. NASA solicits this research through the release of various research announcements in a wide range of science and technology disciplines. NASA uses a peer review process to evaluate and select research proposals submitted in response to these research announcements. Researchers can help NASA achieve national research objectives by submitting research proposals and conducting awarded research. This site facilitates the search for NASA research opportunities.

NASA Research

Solicitations

Search for and view open, closed, past, and future NASA research announcements. The full text of the solicitation announcements can be viewed and downloaded.

Solicitations and selected proposals for years prior to NSPIRES implementation, January 1, 2005, were posted manually; therefore, some postings for years 2000-2004 may not be as complete as those posted through the NSPIRES system from 2005 to the present.

Getting Started

To submit a research proposal to NASA, individuals and the organizations with which they are affiliated must be registered in NSPIRES. Individuals may register at any time.

Organizations are required to have a valid registration with the System for Award Management (SAM) before they can register in NSPIRES. See Registration Information for more details on user and organization registration.

Research.gov

Research.gov is a partnership of federal research-oriented grant making agencies. Research.gov is led by the National Science Foundation.

WARNING:
This is a U.S. Government computer. By accessing and using the computer system, you are consenting to the use of system monitoring. Unauthorized use of, or access to, this computer system may subject you to disciplinary action and criminal prosecution.

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Site News

New NASA Grants and Cooperative Agreements Regulations and Guidance
New regulations and guidance has been released.
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NRA/CAN Proposer's Guidebook
Available online
› Continue Reading

Gmail and NSPIRES email
Your Gmail could be flagging NSPIRES emails as Spam.
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