NASA's Space Launch System: Powering the Journey to Mars

FISO Telecon
Aug 3, 2016

AEROJET ROCKETDYNE

Orbital ATK

BOEING

Why the Nation Needs to Go Beyond Low Earth Orbit

- **To answer fundamental questions about the universe**
  - Are we alone? Where did we come from? Where are we going?
  - Human-robot teams exponentially accelerate scientific discovery
- **To ignite innovation and prosperity**
  - Space drives breakthroughs in medicine, electronics, Earth science and robotics
  - Inspire a new generation to pursue STEM, and spark economic growth
- **Because we've never been closer than we are today**
  - Great nations set grand goals and achieve them
  - Generations from now, humanity will look to this moment as a turning point
- **Importance of U.S. leadership in space**
  - Leadership in Space ensures continued economic benefit to the nation
  - $330B annual global market
  - Visible demonstration of world-leading capability to operate in space
  - Over 250,000 high-tech American workers make space exploration possible

2018

2020s

2030s

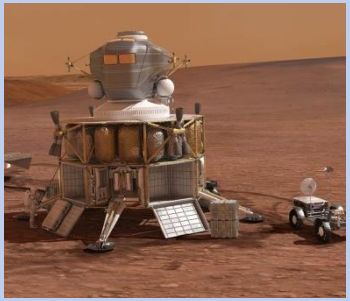


Image credit: NASA & artists
Bob Sauls & Nathan Kogan

What it Takes to Go Beyond Low Earth Orbit

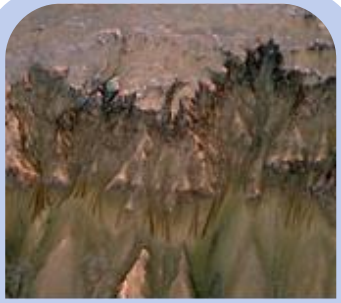
220 MILES
45 MINUTES TO EARTH

240,000 MILES
5 DAYS TO EARTH

34 MILLION MILES
>180 DAYS TO EARTH

Mars is the Logical Next Step for Human Exploration

- ✓ **Robotic exploration has paved the way for human missions**
- ✓ **Mars geology is right for the advantages of direct human interaction and sampling**
  - "A human could do in about 15 minutes what a rover could do in a day," Steve Squyres, Mars Exploration Rover principal investigator
- ✓ **Radiation exposure**
  - "No showstoppers" for trip to Mars
- ✓ **Mars can teach us a lot about Earth, about what can happen in the future to Earth and the possibility of life on other worlds**

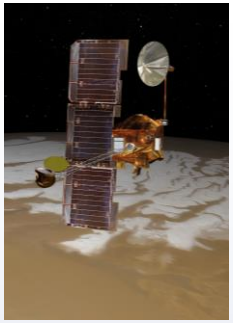


Notable Mars Scientists Agree: We Need Humans on Mars to Make the Search for Life Possible

Precursor Missions Set the Stage for Humans

Viking 1 Lander 1976

Pathfinder / Sojourner 1997



Odyssey 2001

MRO 2006

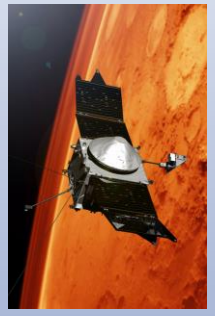
Spirit / Opportunity 2004

Phoenix 2008

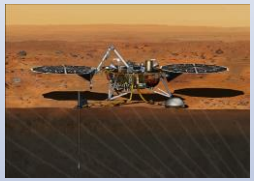
Viking 2 Lander 1976

Global Surveyor 1997

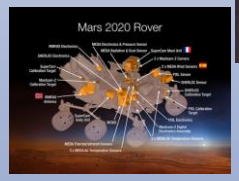
Curiosity / MSL 2012



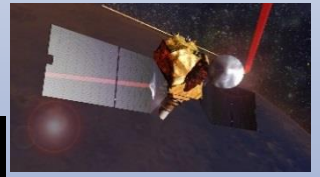
MAVEN 2014



InSight 2018



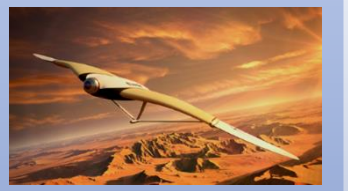
Mars 2020



NeMO 2022

Humans to Mars

Cislunar 2021



Robotic Staging 2026

Mars Surface 2033

1970's 2000's 2020's

Why an Incremental Approach Makes Sense

Phase 0
Demonstrate technologies and conduct research to support exploration

- Deep Space Technologies
- Human Health

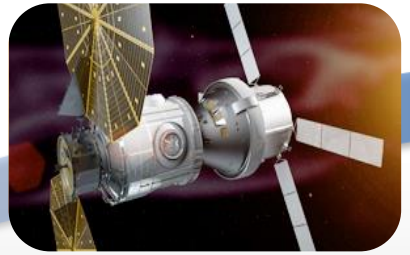
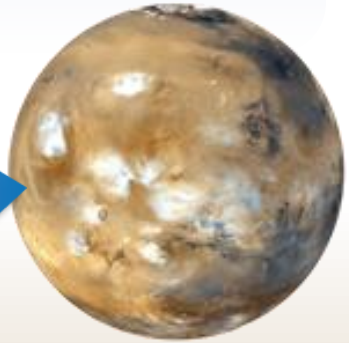
Phase 1
Demonstrate Critical Systems near the Moon
[Early 2020's]

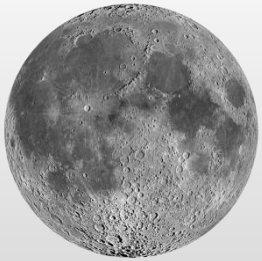
- Orion
- Space Launch System
- Exploration Habitat
- Solar Electric Propulsion

Phase 2
Validate Mars-Class Systems and Operational Readiness
[Late 2020's]

- Lunar Science
- Lunar Landing – International
- Simulated Mars mission

Phase 3+
Journey to the Mars System
[2030+]


Earth Reliant
Missions: 6-12 months
Return: Hours
~250 miles

Proving Ground
Missions: 1-12 months
Return: Days
~240,000 miles

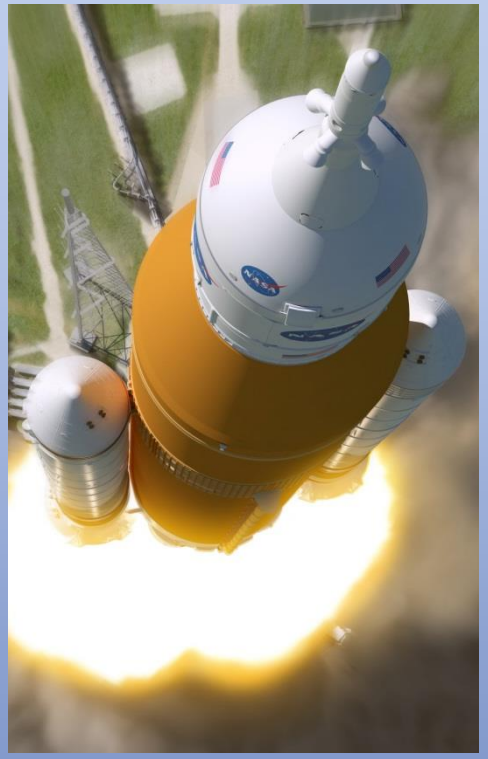
Earth Independent
Missions: 2-3 years
Return: Months
~140 million miles

Size Matters in Rockets

More Mass **– Fewer launches, fully assembled payloads, less complex operations = lower risk**

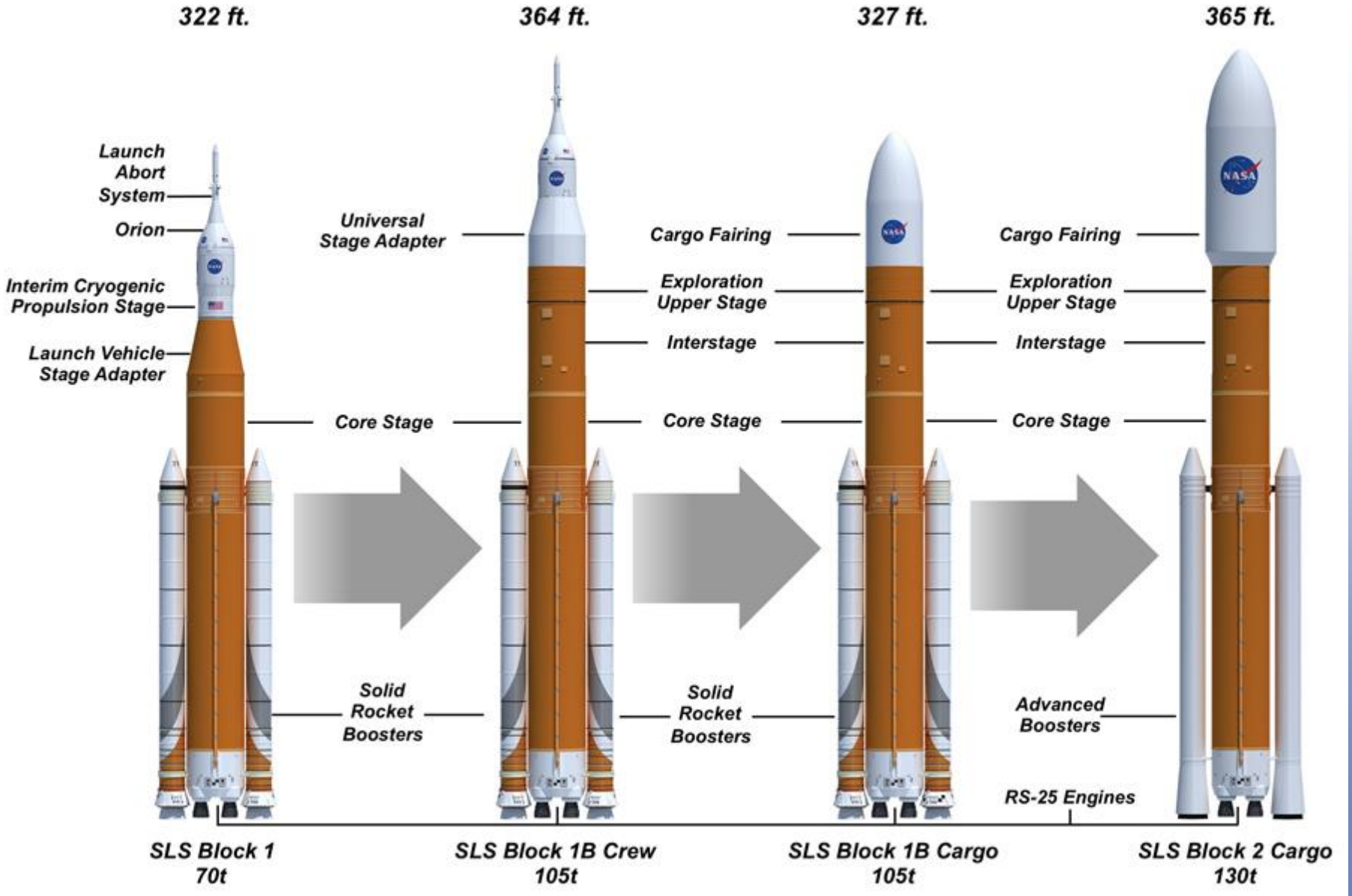
More Volume **– Big mirrors, additional instruments, simple packaging = more science**

More Speed – Get to the outer reaches of Solar System and beyond faster = less radiation exposure for crew and cargo

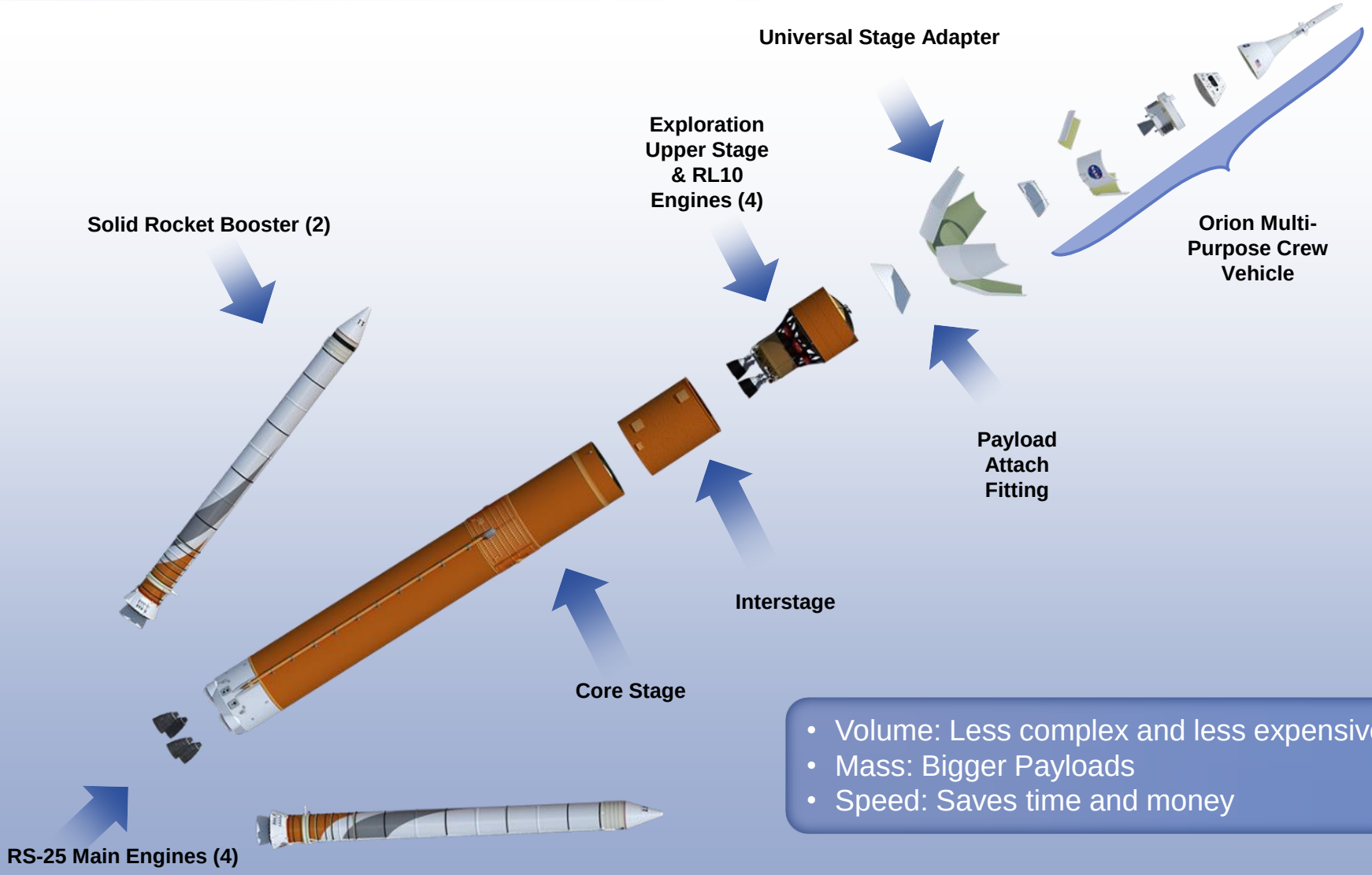


Big Rockets are Enabling for Exploration and Science

Evolvable Rocket



The Anatomy of the Nation's Next Big Rocket

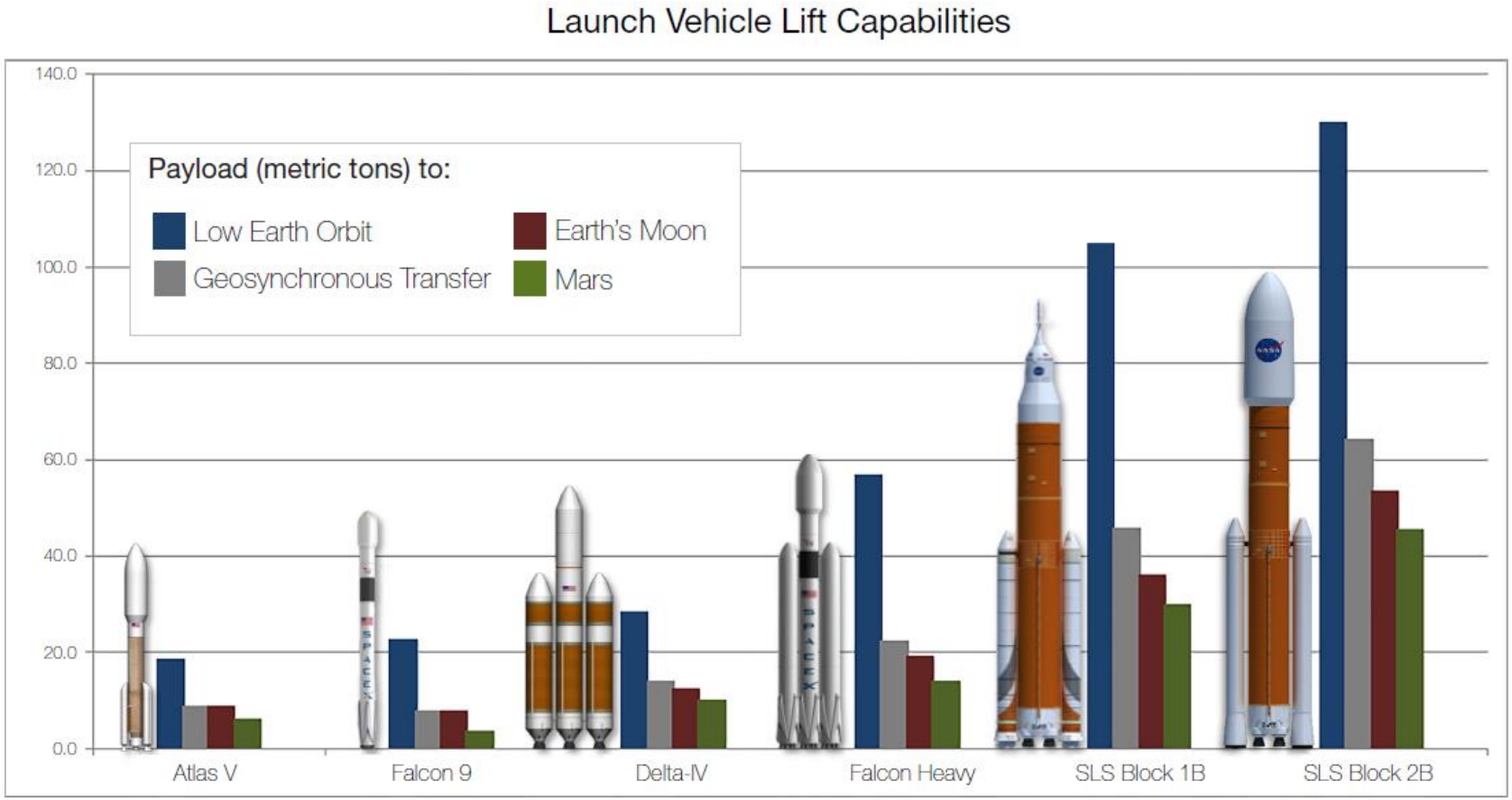


- Volume: Less complex and less expensive
- Mass: Bigger Payloads
- Speed: Saves time and money

Images Courtesy of NASA

How Do We Launch Humans to Mars

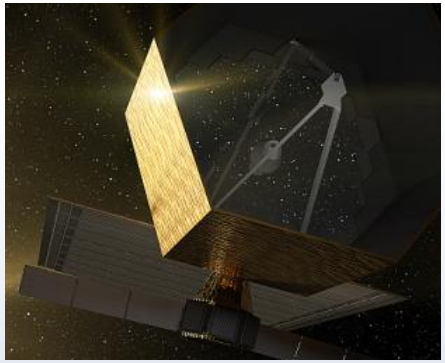
SLS will be the largest, most powerful rocket ever built, capable of launching crew and cargo to deep space, faster and farther



Note: Orion Multi-Purpose Crew Vehicle = 28.0 metric tons

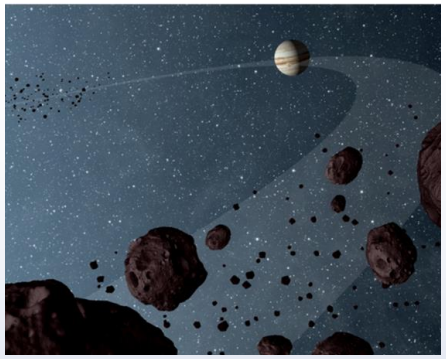
Science Missions Enhanced by SLS

Near Earth & Lunar Science



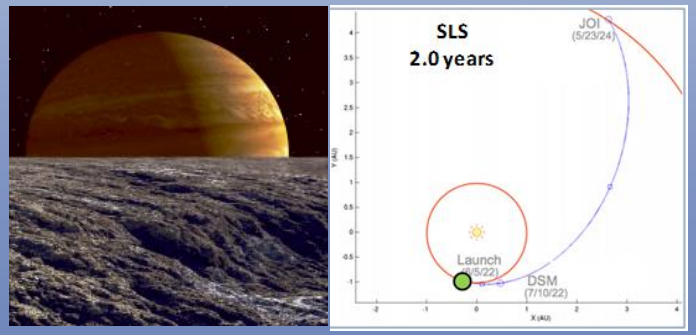
Large Space Telescope

Mars Sample Return



Jupiter Trojan Asteroids

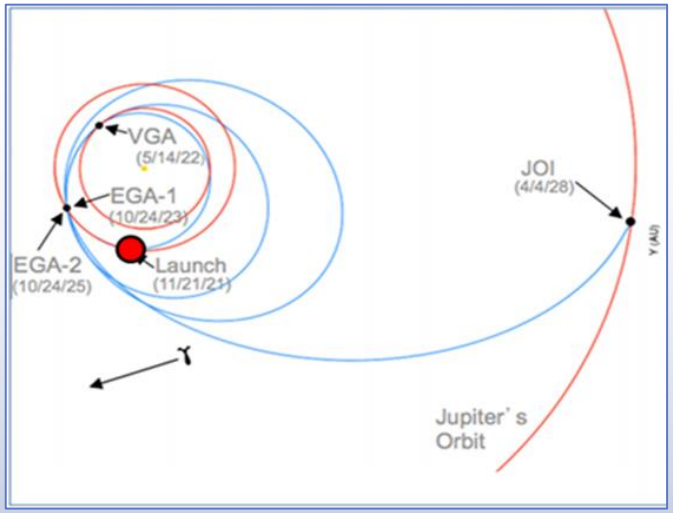
Saturn / Titan / Enceladus



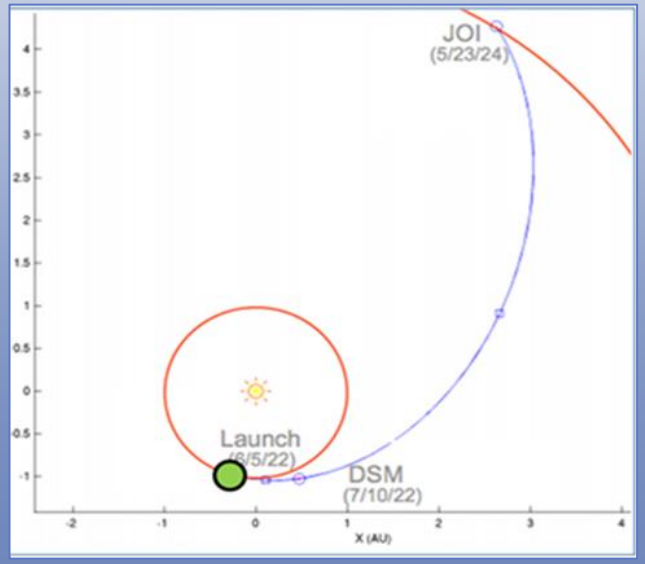
Jupiter / Europa

Mission	SLS Block 1B Benefit
Jupiter/ Europa	Saves 4.5 years and Delivers 2 Times the Payload
Saturn/ Titan Enceladus	Saves 3 Years and Provides 5 times the Payload
Jupiter Trojan Asteroids	Provides 6 times the Payload
Mars Sample Return	1 Launch instead of 3
Comet Sample Return	Saves 2 years and Provides 4 Times the Payload

Europa - In 4.5 Fewer Years than Atlas Launch



Atlas Launch Vehicle:
Cruise Time Earth-Jupiter: 6.5 years

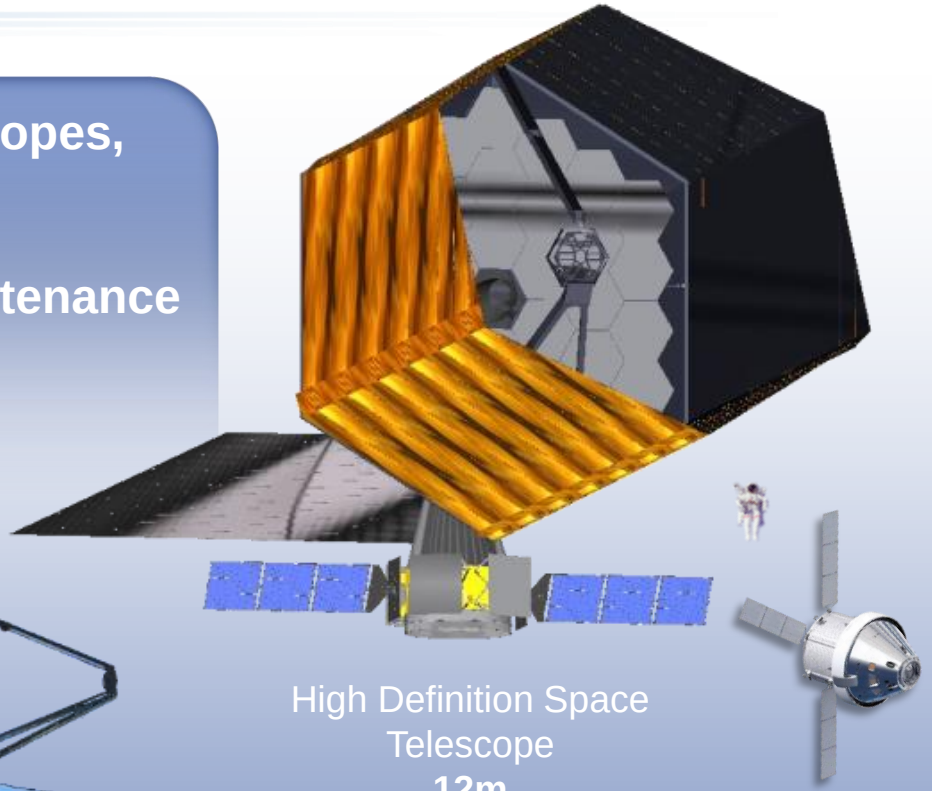


SLS Launch:
Direct trajectory: Cruise time
Earth-Jupiter: 2.0 years

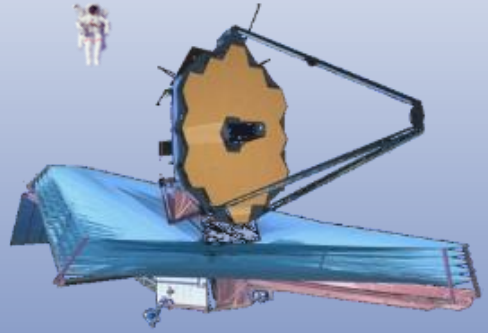
Growth of Primary Mirrors in Space Telescopes

Bigger rockets enable bigger telescopes, and thus bigger science

Value of human assembly and maintenance proven on Hubble Space Telescope



High Definition Space Telescope
12m



James Webb Space Telescope
6.5m

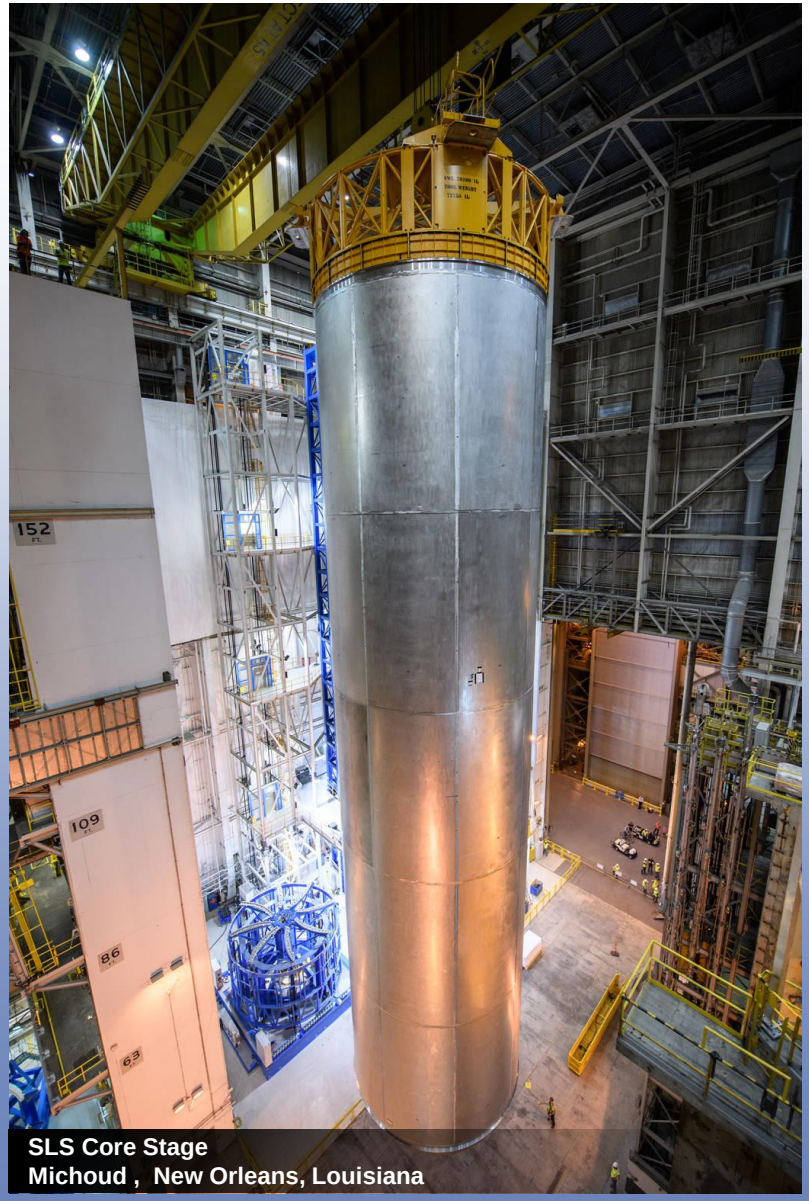
Hubble Space Telescope
2.4m

NOTE: Telescopes shown to scale

Images Courtesy of the Space Telescope Science Institute

The First SLS/Orion Mission - 2018

SLS Preparing for First Launch in 2018

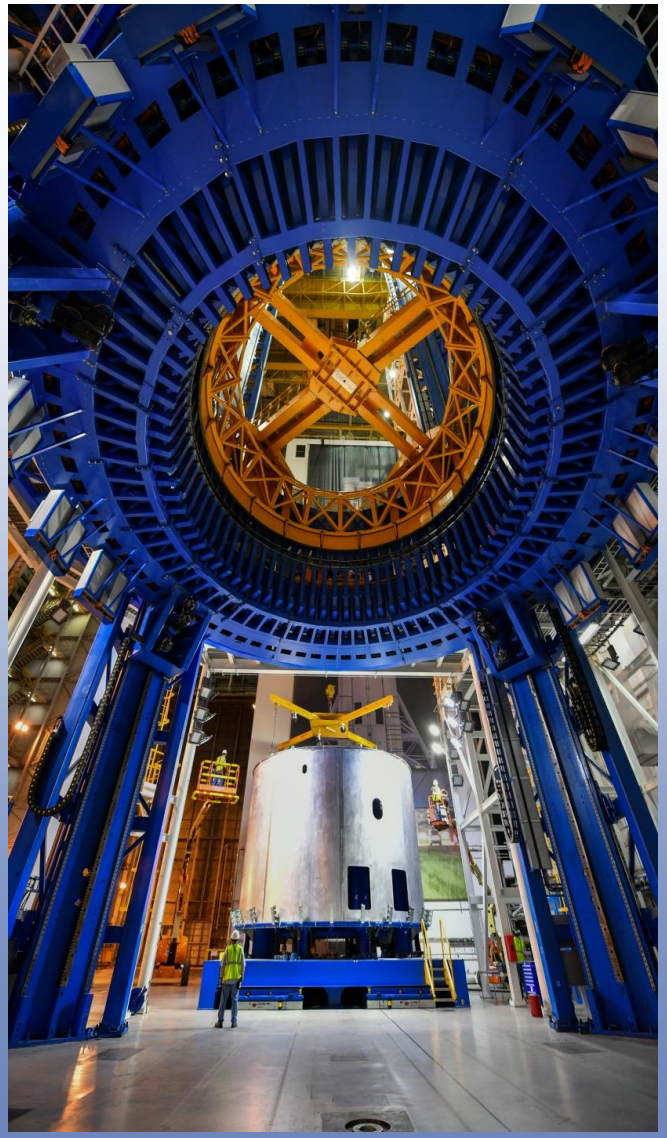


SLS Core Stage
Michoud , New Orleans, Louisiana

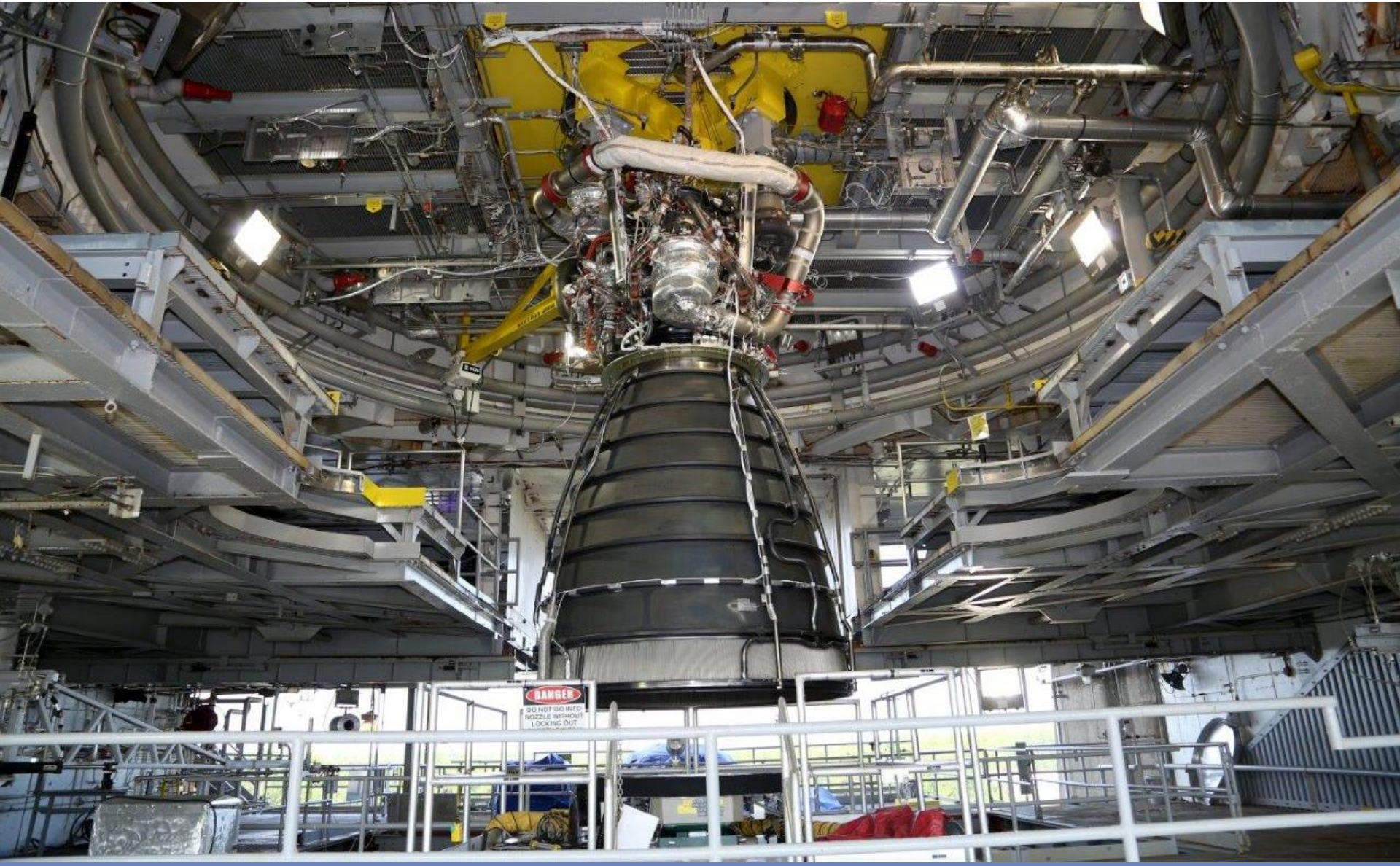

RS-25 Engine
Stennis Space Center, Mississippi


Booster
Orbital ATK, Promontory, Utah

Core Stage



Proven Liquid Main Engines

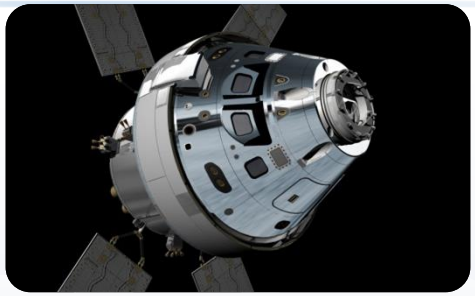


The Most Powerful Operational Booster

Ground Systems Development and Operations (GSDO)

- Successful review of plans for the facilities and ground support systems
- Completed the fifth of 10 levels of work platforms that will surround and provide access to the SLS rocket and Orion spacecraft
- Each platform half is about 62 feet wide and 38 feet long and weigh between 300,000 and 325,000 pounds
- The top platform shown is located about 200 feet above the floor

6 Essential Capabilities for the Journey to Mars



Orion

- ✓ Full scale development underway
- ✓ Successful uncrewed flight test Dec 2014
- • Second flight in 2018 - 1st human-rated spacecraft flight to moon since 1972
- • Human lunar flight in 2021

Habitat

- ✓ ECLSS systems testing underway on ISS
- ✓ Habitat & subsystem studies underway
- • Advanced hab testing during in late 2020s

Mars Ascent Vehicle (MAV)

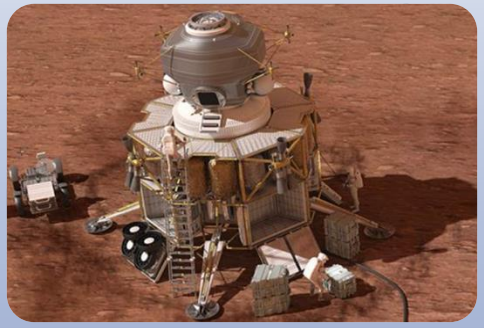
- ✓ Component level testing with LOX /Methane
- • Lunar Lander in mid 2020's
- • Mars precursor mission in late 2020's
- • Mars MAV ready in early 2030s

Space Launch System

- ✓ Full Scale Development Underway
- ✓ Critical Design Review completed
- • 2018 first flight hardware in production
- • Exploration Upper Stage in 2021 increasing SLS capability

Power

- • Next generation array testing underway at ISS
- • Initial 50 kW demonstration - Asteroid Redirect Mission
- • 150 kW - Translunar SEP tug



Mars Lander & Surface Systems

- • Capability testing with lunar landers and habs
- • Precursor EDL testing with robotic missions

The Space Launch System's Path To The Pad

2011	2012	2013	2014	2015	2016	2017	2018
▽✔ Mission Concept Review	▽✔ System Requirements Review/System Definition Review	▽✔ Preliminary Design Review	▽✔ Key Decision Point-C	▽✔ Critical Design Review		▽ Design Certification Review	▽ Launch Availability

With design and development work mostly complete, the SLS Program is now building and testing components of the world's most powerful rocket to be ready for launch in 2018. Each of these steps advance NASA on the Journey to Mars.

Booster Development Test

Engines Delivered to Inventory

RS-25 Development Testing Begins

Booster Qualification Tests

RS-25 Flight Testing Begins

Boosters Fabrication Complete

Booster Assembly at KSC

Manufacturing Tooling Installation

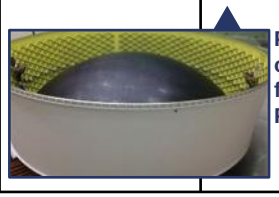
Core Stage Production Begins

Core Stage Assembly Complete

Core Stage Structural Testing

Core Stage Test-Firing

SLS Design Chosen



Production of Adapter for Orion Flight Test

Stage Production Begins

Integrated Upper Stage Structural Testing

SLS Launch Readiness

Concept Studies	Design & Development	Final Design & Fabrication	System Assembly, Integration and Test, Launch Checkout

Summary

- **Human exploration of Mars is ACHIEVABLE by taking the long view**
- **We can pack for the long haul journey to Mars.** SLS provides unprecedented payload capability that can enable human and science deep space missions not previously achievable. We can go farther, faster, carrying more payload, than ever before possible.
- **We can safely carry crew beyond Earth** for deep space mission transfer – and back again. Orion is built for launching – and protecting – our astronauts.
- **We have the orbiting lab** to test technologies and scenarios before deep space launches. In fact, the International Space Station every day models on-orbit challenges and solutions.
- Industry partners are **advancing key capabilities** and technologies, like Solar Electric Propulsion
- Cis-lunar space advancing **habitation systems** and capabilities
- Long term **sustainable** program of human exploration
- **We are building tomorrow's space systems …. Today.**

Want to Learn More

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