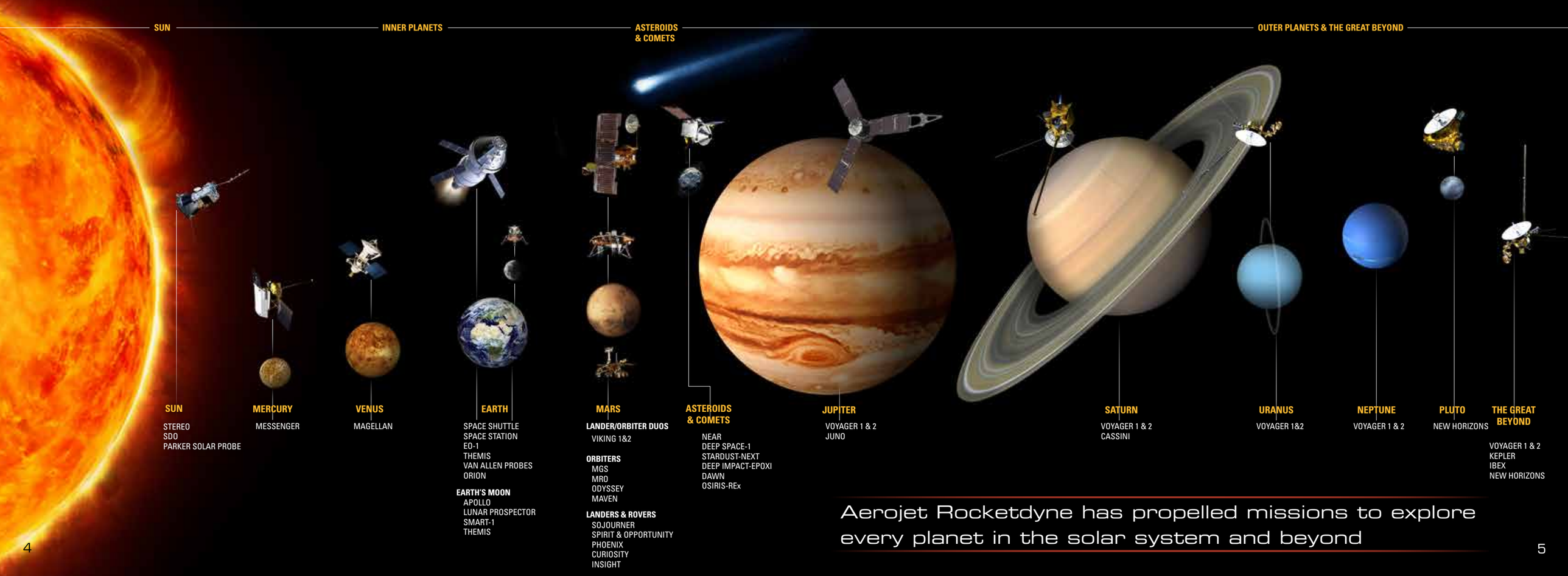

WE ARE
GO FOR
EXPLORATION
AEROJET
ROCKETDYNE

EXPANDING HUMAN PRESENCE

Aerojet Rocketdyne's unparalleled power and propulsion expertise is enabling a new era of exploration. We are developing the systems and technologies to make a new reach possible.

SUN | INNER PLANETS | ASTEROIDS & COMETS | OUTER PLANETS & THE GREAT BEYOND



SUN

STEREO
SDO
PARKER SOLAR PROBE

MERCURY

MESSENGER

VENUS

MAGELLAN

EARTH

SPACE SHUTTLE
SPACE STATION
EO-1
THEMIS
VAN ALLEN PROBES
ORION

EARTH'S MOON

APOLLO
LUNAR PROSPECTOR
SMART-1
THEMIS

MARS

LANDER/ORBITER DUOS

VIKING 1&2

ORBITERS

MGS
MRO
ODYSSEY
MAVEN

LANDERS & ROVERS

SOJOURNER
SPIRIT & OPPORTUNITY
PHOENIX
CURIOSITY
INSIGHT

ASTEROIDS & COMETS

NEAR
DEEP SPACE-1
STARDUST-NEXT
DEEP IMPACT-EPOXI
DAWN
OSIRIS-REx

JUPITER

VOYAGER 1 & 2
JUNO

SATURN

VOYAGER 1 & 2
CASSINI

URANUS

VOYAGER 1&2

NEPTUNE

VOYAGER 1 & 2

PLUTO

NEW HORIZONS

THE GREAT BEYOND

VOYAGER 1 & 2
KEPLER
IBEX
NEW HORIZONS

Aerojet Rocketdyne has propelled missions to explore every planet in the solar system and beyond

Powering the International Space Station

The International Space Station is critical to scientific research and our ability to support future deep space missions. The station's continuous and reliable operation is made possible through Aerojet Rocketdyne's key contributions to its 100 kW Electric Power System (EPS) — including the batteries, and the power conditioning and distribution system.

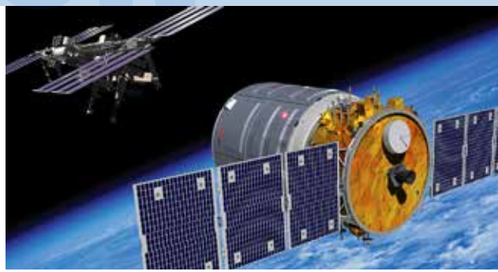
Low-Earth Orbit Operations

Aerojet Rocketdyne supports today's International Space Station cargo resupply missions by providing propulsion and helium tanks on **Northrop Grumman's Cygnus spacecraft**.

Aerojet Rocketdyne is also supporting **Boeing's Starliner** and **Sierra Nevada's *Dream Chaser*©** spacecraft to expand America's access to Low-Earth Orbit (LEO) and the Space Station.

Dream Chaser will have the ability to carry cargo to and from the International Space Station. Aerojet Rocketdyne will supply an electrical power and distribution system to power its avionics, thermal and propulsion systems, and any payloads requiring electrical power.

Starliner is a next generation spacecraft carrying humans to and from LEO destinations, including the Space Station. Aerojet Rocketdyne is providing propulsion to the crew and service modules, and the composite overwrap pressure vessels.



A 21st century system designed to carry a mix of crew and cargo to LEO destinations

Starliner

SPACECRAFT

Aerojet Rocketdyne is helping to bring back the ability to launch U.S. astronauts from U.S. soil to the International Space Station and other Low-Earth Orbit destinations. Boeing's next-generation *Starliner* spacecraft relies upon Aerojet Rocketdyne's proven propulsion expertise to ensure astronauts and commercial passengers have safe, reliable access to Low-Earth Orbit.

12 Reusable Crew Module Engines:
Used to orient the spacecraft during atmospheric re-entry, each providing 100 lbf.

Starliner is powered by 64 Aerojet Rocketdyne Engines

20 Service Module Orbital Maneuvering and Attitude Control Engines:
Each generating 1,500 lbf for low-altitude abort, maneuvering and stage separation, high-altitude direct abort capability and large orbital maneuvers.

4 Launch Abort Engines:
Each providing 40,000 lbf to separate the service module and crew module from the rocket in the event of a launch or ascent anomoly.

28 Service Module Reaction Control System Engines:
Each generating 100 lbf for on-orbit maneuvering and Space Station reboost.

Safe, Reliable Access to Low-Earth Orbit

Opening New Frontiers

Essential Elements

Space Launch System (SLS)

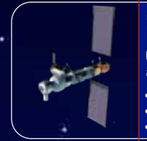
Earth to orbit transportation system

- RS-25 Engine
- RL10 Engine

Orion

Crew vehicle

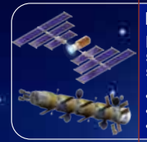
- Reaction Control System - RCS
- Jettison Motor - JM
- Orbital Maneuvering Engine - OME



Gateway Power and Propulsion Element

Outpost for lunar surface access and testbed

- Reaction Control System - RCS
- Solar Electric Propulsion - SEP
- Electrical Power Systems - EPS



In-Space Propulsion

Propulsion to move cargo, systems and astronauts in space

- Solar Electric Propulsion - SEP
- Nuclear Thermal Propulsion - NTP
- Chemical Propulsion

Lander, Transfer and Surface Systems

Retro propulsion for entry, descent and landing on Moon and Mars

- Chemical Propulsion
- Power Systems

Ascent Vehicles

Lift crews and science samples to lunar and Mars orbits

- Chemical Propulsion

Ascent Vehicle

Crew Route

Gateway

NTP or Chemical

Ascent Vehicle

SLS Crew Vehicle

Lander

Commercial Logistics

Orion

Lander

SLS Cargo Vehicle

SEP

Cargo Route

Robotic Exploration

The Space Launch System (SLS) is the rocket that will lift humans and cargo to deep space and will allow greater science return from robotic planetary missions.

Key Features

Greater Mass: Increased payload capacity = fewer launches; less complex operations = lower risk; overall reduced cost

Larger Volume: Larger payloads = additional instruments and greater science return

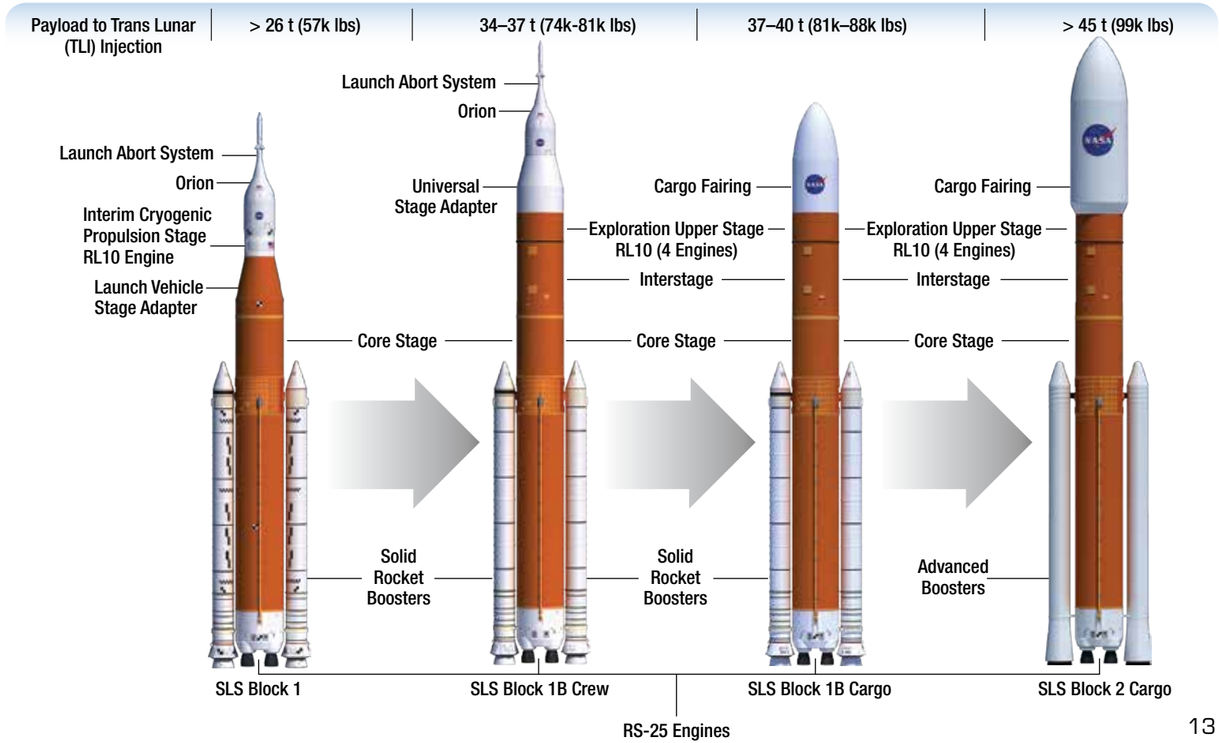
Higher Velocity: Transit to deep space destinations faster = reduced exposure to harsh space environment for crew and cargo

Aerojet Rocketdyne's Role

Four RS-25 main engines power the SLS during its 8 ½ minute trip to orbit.

Four RL10 engines on the Exploration Upper Stage send payloads to deep space destinations.

The Evolvable SLS Rocket



Orion is the world's first interplanetary spacecraft capable of taking crew to multiple deep space destinations and returning them safely to Earth.

Orion

SPACECRAFT

Key Features

1000-Day Mission Capability: Providing maximum radiation protection for a crew of four; advanced life support systems; and a heat shield that withstands the extreme temperatures of reentry

Full Redundancy: Backup capability for all major avionics and crew systems

Safe Emergency Abort Capability: Designed to protect the astronauts in unlikely event of launch vehicle anomoly

Orion reentry

Orion's European Service Module (ESM)

Aerojet Rocketdyne's Role

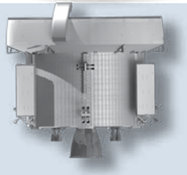
Launch Abort System (LAS)

Jettison Motor (one of three motors on the Launch Abort System) pulls the LAS away from the spacecraft after a safe launch or abort scenario

Crew Module (CM)

Reaction Control System to orient the spacecraft for splashdown

European Service Module Auxiliary Engines maintain trajectory and position in space



European Service Module (ESM)

Orion Main Engine powers the spacecraft

Transportation of Cargo & Crew

Cargo Transportation

Solar Electric Propulsion (SEP) enables efficient transfer of cargo, habitats and payloads to the Moon and Mars in advance of astronaut arrival.

Modular Pre-position: Enables use for multiple missions and destinations

Efficient: More than 50% of the mass required for Mars can be shipped with 25% reduction in launches

Reusable: Tugs designed for multiple orbit refueling and transfers

Affordable: 60% reduction in launch cost over all-chemical solutions

Crew Transportation

Chemical or Nuclear Thermal Propulsion (NTP) will be used to quickly transport astronaut crews to the surface of Mars and safely back to Earth.

Chemical Key Features

Lowest Risk: Mature technology

Commonality: Between in-space, descent and ascent vehicles

NTP Key Features

Fast Transit Time: Minimizing crew exposure to in-space radiation and microgravity

Flexible: Decreasing sensitivity to mission departure and return dates

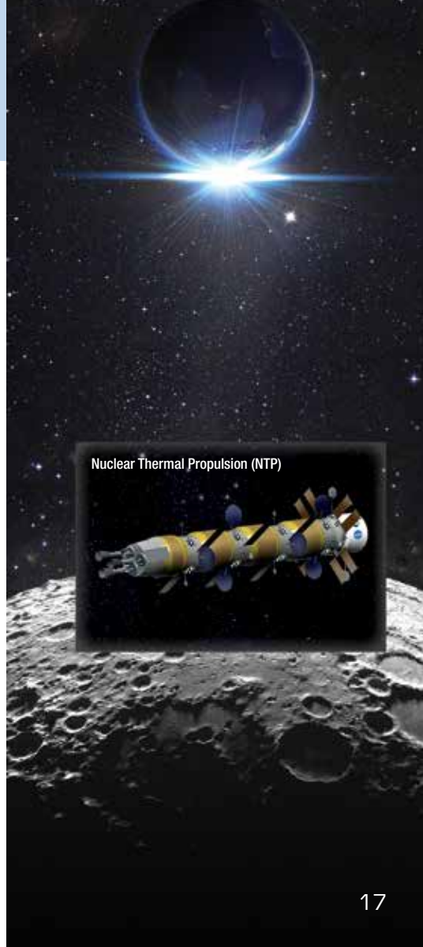
Safer: Increased abort options

Efficient in-space transportation is the key to a sustainable architecture.

Aerojet Rocketdyne's Role for In-Space Transportation

- Development of 50 kW power and propulsion SEP module
- SEP module for habitat power and propulsion capability demonstration
- Advanced approaches for NTP systems for moving crew and habitats from Earth to Mars and back
- Retro propulsion concepts for lander descent
- Surface power generation and management
- In-situ resource utilization approaches for Moon and Mars ascent vehicle propellant production
- Ascent propulsion concepts for crew return

Hall Thruster



Nuclear Thermal Propulsion (NTP)

Returning Humans to the Moon

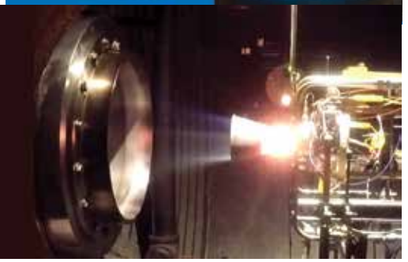
Lunar Orbiting Platform

NASA's Gateway serves as a single stepping off point for human cislunar operations, lunar surface access and missions to Mars.

Together with the Space Launch System (SLS) and Orion, the Gateway is central to advancing and sustaining human space exploration goals, and is the foundational element for human cislunar operations and commerce, lunar surface access and missions to Mars.

Aerojet Rocketdyne is developing for NASA the Advanced Electric Propulsion System thrusters that will power the Power and Propulsion Element of the Gateway, and competing to provide further content in power management and distribution.

Descent and Ascent Propulsion



Aerojet Rocketdyne offers lander propulsion options in support of science and commercial activities on the lunar surface.

RL10

Reliable, high performance 25,000 lbf thrust class engine throttleable over a wide range of thrust levels, making it highly suitable for ascent and descent.

ISE-100

Generating up to 100 lbf, the ISE-100 has successfully demonstrated high-thrust, high-efficiency operation, making it ideal for future lunar lander missions.

MR-107

After successfully landing Phoenix and InSight on Mars, the MR-107 is a proven lander engine with the ability to provide variable thrust up to 70 lbf.

Power and Mobility

As NASA and commercial partners begin to establish a lunar surface presence to explore, prospect, mine and utilize resources, Aerojet Rocketdyne stands ready to provide power and mobility solutions for robotic and human missions.

Kilopower System

1-10 kilowatt small fission reactor to power multiple surface operations.

Multi-Mission Radioisotope Thermoelectric Generator (MMRTG)

Used on the Curiosity and Mars 2020 rovers, the MMRTG offers 200-500 watts of power.

Electrical Power Systems (EPS)

From the Space Station to the Dream Chaser, our heritage in EPS enables efficient power conversion, distribution and energy storage for lunar operations.

Li-Ion Batteries

Our flight-proven battery system meets all NASA safety standards while providing a substantially lighter energy storage capability than traditional batteries.

Unique Aspects of Aerojet Rocketdyne's Deep Space Architecture

- Cislunar Missions
- Human Missions to Lunar Surface
- Power and Propulsion Element for Lunar Gateway
- Entry Ramp for Nuclear Thermal Propulsion
- Modular Power and Propulsion for In-Space Transportation
- U.S. Leadership with Opportunities for International and Commercial Partnerships
- Accelerated Mission Cadence
- Human Missions to Mars Surface


At the Center of Defense and Discovery
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