National Aeronautics and Space Administration

EXPLORATION 101

2010 2020 2030 2040 2050

DARE TO EXPLORE.

explore

we dare.

EXPLORATION 101 >>>

we dare to explore.

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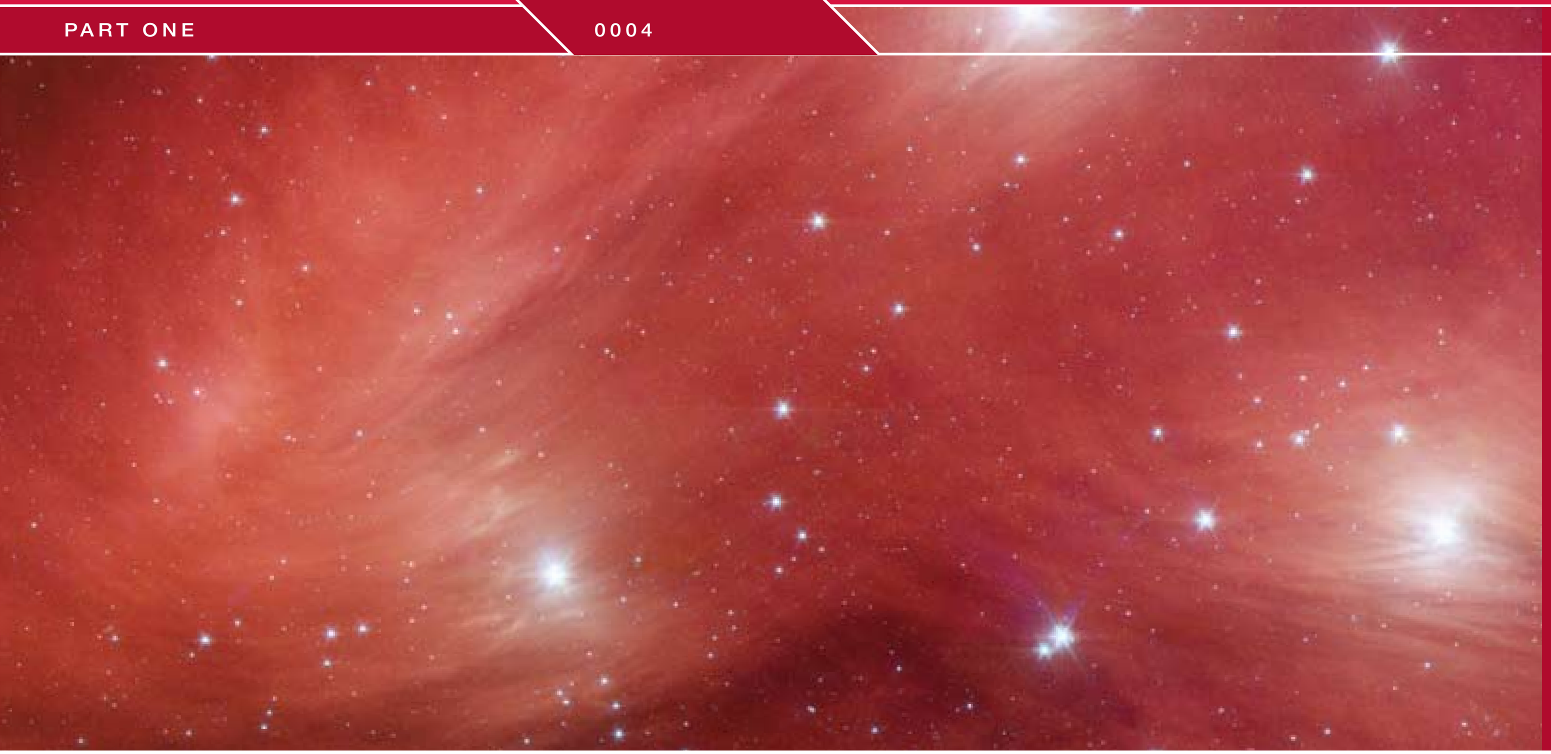


part one

THE CALL TO EXPLORATION

Carl Sagan

"The surface of the Earth is the shore of the cosmic ocean. From it we have learned most of what we know. Recently, we have waded a little out to sea, enough to dampen our toes or, at most, wet our ankles. The water seems inviting. The ocean calls."

—*Cosmos*, 1980

LETTER FROM THE ADMINISTRATOR

Tomorrow's greatest triumphs will stand on the shoulders of yesterday's achievements. NASA's space exploration program is moving forward by building on the proven technologies and successes of Gemini, Mercury, Apollo, Skylab, the Space Shuttle, and the International Space Station. America is now poised to take the next great step of space exploration and human spaceflight.

NASA has made remarkable achievements in space exploration, reaching higher, seeing further, and realizing accomplishments larger than ourselves. Continuing this rich tradition, today NASA looks to the future of human exploration beyond the Space Shuttle and the International Space Station. As we make greater steps forward in spaceflight, we will return to the Moon, where we will eventually establish a lunar outpost that will allow us to voyage to Mars and beyond.

Building on existing Space Shuttle and International Space Station resources, NASA is creating future exploration programs that will shape spaceflight for a new generation. NASA faces the challenge of maintaining our current budget while transitioning the Space Shuttle out of service and developing a new launch system to service the International Space Station and carry us back to the Moon. To ensure a smooth transition to the future without jeopardizing ongoing International Space Station operations, NASA has adopted a balanced risk approach that leverages the current Space Shuttle workforce and infrastructure, develops incremental technology advancements, and reaches back to proven flight hardware whenever possible.

We are explorers. Our curiosity propels us to push the frontiers of human possibility and imagination. This is the core of NASA's mission—we dare to explore.

Michael D. Griffin
NASA Administrator
April 2008

destiny

"We Shall Return"

During the Apollo 17 mission, the last human walked the lunar surface on December 14, 1972. Leaving the Moon, Eugene Cernan said, "America's challenge of today has forged man's destiny of tomorrow. And, as we leave the Moon at Taurus-Littrow, we leave as we came and, God willing, as we shall return, with peace and hope for all mankind." This spirit of innovation, inspiration, and discovery continues to run throughout NASA and our Nation.

Apollo 17 sent two astronauts to the lunar surface for only three days. The next generation of lunar exploration missions will have a larger landing party of four astronauts, who will stay for extended periods on the lunar surface. Initially, the lunar lander will serve as the surface habitat for a new generation of space explorers who will, over time, build a lunar outpost that will allow for even longer stays. Like the International Space Station that is being constructed in space over several missions and an extended period of time, the lunar outpost will be built on the Moon using a modular system that can be linked together to build a growing lunar station.

Crew exploration vehicle and Altair lunar lander orbiting lunar surface *(Artist's conceptual rendering)*

REMEMBERING THE PAST >>>

Remembering the Past, Challenging the Future

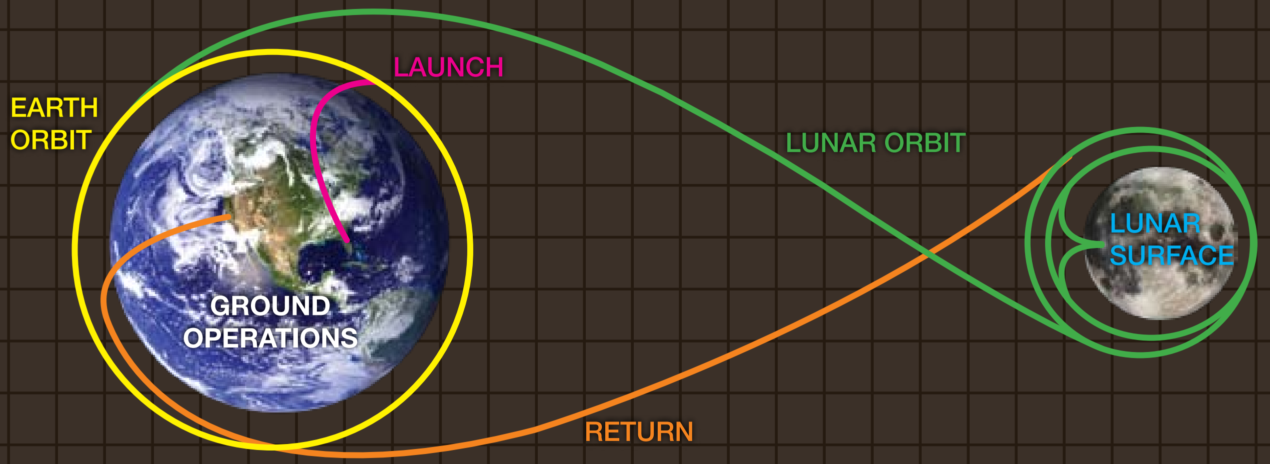
Before October 1957, spaceflight was a thing of fantasy. Today, we are experienced space explorers with unlimited voyages to undertake. Where is spaceflight's next horizon?

For over thirty years, NASA has been successful in advancing both national and scientific goals by focusing on Space Shuttle missions, constructing the International Space Station, and advancing our understanding of the universe through robotic missions such as Voyager, Viking, Mars Exploration Rovers, and the Hubble Space Telescope. NASA is utilizing its regional Centers and resources across the country to take the next step forward and shift to a new human exploration strategy of reaching the Moon, Mars, and beyond.

The Next Steps in Space Exploration

As verified by the history of spaceflight, there is no 100 percent guarantee to risk-free space travel. Indeed, the riskiest moments of space exploration occur within the first hundred miles of both leaving and returning to the Earth. Launching astronauts safely through the Earth's atmosphere and then getting them back safely is difficult business.

The Apollo astronauts used a single rocket to move the crew and cargo from the launch pad to orbit, to the Moon, and then back down to Earth. The new mission represents a long-term effort to sustain human habitation off-planet. As a result, NASA engineers and scientists are looking at new ways to reach the Moon. Keeping in mind the necessity of balancing cost and risk, NASA is evaluating all of the technologies, systems, and architectures required to return to the Moon and, eventually, on to Mars. The current plan splits the job between a rocket for the crew, which has been subjected to extensive ground-based testing in order to be rated for human safety, and a second heavy-lift rocket more suited for large cargo payloads.



Potential pathways for future lunar transportation
(Artist's conceptual rendering)

Beyond Low-Earth Orbit

Today all human exploration in space takes place in low-Earth orbit—near the outer edge of the Earth's atmosphere—with the International Space Station as the focus. Traveling only 220 miles above the surface of the Earth, the Space Shuttle launches and quickly reaches the International Space Station. The Moon, on the other hand, is approximately 240,000 miles away and takes several days to reach. Just as an international voyage requires different resources than a short trip around the corner, the lunar mission will require additional resources and more involved planning than the missions to low-Earth orbit.

focus

A National Mission: The Path to the Future

Like the National Aeronautics and Space Act of 1958, the NASA Authorization Act of 2005 set clear objectives for NASA's path into the future. Congress mandated NASA to promote America's preeminence in space by advancing exploration, science, and commerce in space; developing a program to return to the Moon; and providing a stepping-stone to Mars.

EXPLORATION STRATEGY >>>

A Global Mission: The Global Exploration Strategy

Recognizing that the benefits of space exploration cross national boundaries, NASA is reaching out and participating in international discussions on how countries can work together and combine resources for the advantage of all. Indeed, scientific missions are already emerging from these international collaborations. Given the significant cost and challenges, eventual human exploration of Mars may only be achievable through sustained international cooperation.

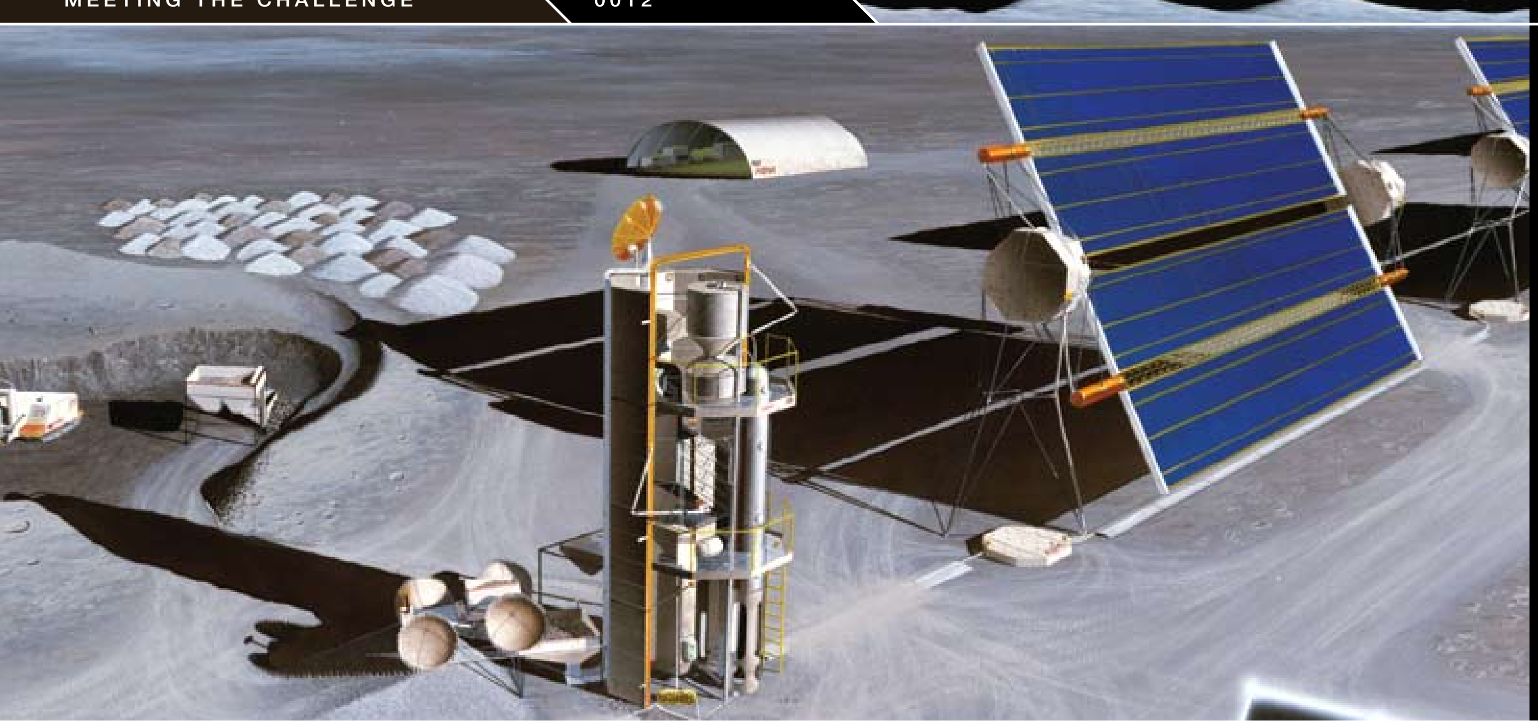
In 2006, NASA began working with representatives of thirteen other space and science agencies from around the world, as well as with non-governmental organizations and commercial interests, to develop a Global Exploration Strategy that addresses the following two issues: why we are returning to the Moon and what we plan to do when we get there. From these discussions came a comprehensive set of themes and objectives for the human and robotic exploration of space: exploration preparation, scientific knowledge, human civilization, economic expansion, global partnerships, and public engagement. The spirit of collaboration envisioned by the Global Exploration Strategy will provide further momentum to NASA's efforts to cooperate with the international community.

Exploration Strategy Focus

The American people continue to support NASA's pursuit of technical knowledge, global economic competitiveness, and leadership in space. History has shown that the cultures and nations who invest in exploration and push both physical and intellectual boundaries are those that reap the benefits of economic growth and technical advancement.

As a part of a collaboration between the United States and international partners, NASA developed a lunar exploration strategy that concentrates on six key areas. These areas—whose priorities may change as the exploration strategy takes shape—include the following:

- **Preparing for future exploration:** Prepare for future human and robotic missions to Mars and other destinations
- **Accumulating scientific knowledge:** Pursue scientific activities addressing fundamental questions about the Earth, the solar system, and the universe, as well as our place in them
- **Expanding human civilization:** Extend civilization beyond Earth
- **Expanding economic opportunities:** Expand Earth's economic sphere and conduct activities with benefits to life on Earth
- **Developing global partnerships:** Strengthen existing global partnerships and create new ones
- **Engaging the public in the mission:** Engage, inspire, and educate the public



solutions

Meeting the Challenge

With a project the size of a lunar mission in which strategic national goals are at stake and human lives are at risk, it is critical to find the solutions to the mission's challenges. As a result, NASA takes a careful engineering approach to all aspects of the mission. Engineers at every level and stage of the process analyze their programmatic decisions by studying the merits and tradeoffs that accompany them. NASA conducts extensive tests and trial runs to improve confidence at every step of the development process.

One such example of Earth-based testing is the Desert Research and Technology Studies (RATS) program in which the Arizona high desert is used as a proving ground to prepare for human-robotic exploration. Here engineers and scientists in spacesuits test hardware and software, identify and establish technical requirements for future planetary exploration, and validate mission operational techniques. Such a systematic engineering approach ensures that the Nation's goals for space exploration will be attained both safely and efficiently.

The Desert RATS program in the Arizona high desert tests prototype spacesuits, field assistant vehicles, communications, and science equipment.

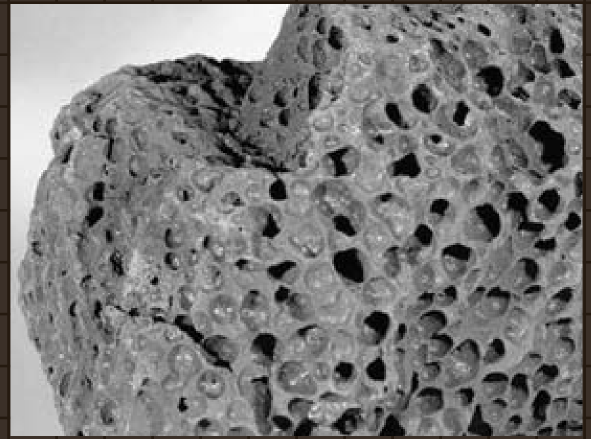
MEETING THE CHALLENGE >>>

Tackling Obstacles

There are many obstacles to returning to the Moon, but the lessons learned from past success in space and the energy NASA has dedicated to this mission prove that the Agency is up to the task. The greatest risks for human spaceflight are associated with launch, lunar ascent and descent, and the return to Earth; however, obstacles will also be present throughout the mission. Once the astronauts arrive at their destination off the home planet, a new set of challenges must be overcome. The astronauts must create a hospitable environment in which to live and work for extended periods of time. In addition, NASA must be able to generate power and meet the basic human needs of the crew, such as oxygen, food, water, and moderate temperature. These difficulties are being addressed through a portfolio of options under development across NASA that draws both from past missions and the many advances made since the early rockets of Robert Goddard and Wernher von Braun.

Generating Power—Providing an adequate energy supply will be critical for operating the lunar outpost. NASA is evaluating a combination of two power elements to provide power: a self-contained, trailer-deployable primary unit that contains power generation, storage, and distribution capabilities, and a secondary unit to provide energy storage capabilities during eclipse periods so that the outpost can be continually operated and maintained.

Natural Lunar Resources—The success of long-term lunar living depends on the ability to extract and use resources from the Moon. For example, scientists believe that some lunar locations have water ice, so these will likely be key destinations of the lunar missions. NASA is engineering the production units, transportation capabilities, and storage facilities necessary for extracting consumables from the Moon's surface.



The vesicular nature of this lunar basaltic sample that was retrieved during the Apollo-15 mission leads scientists to infer the presence of gases or water vapor on the Moon. The possible presence of water is one of the factors that will determine the future location of the lunar outpost.

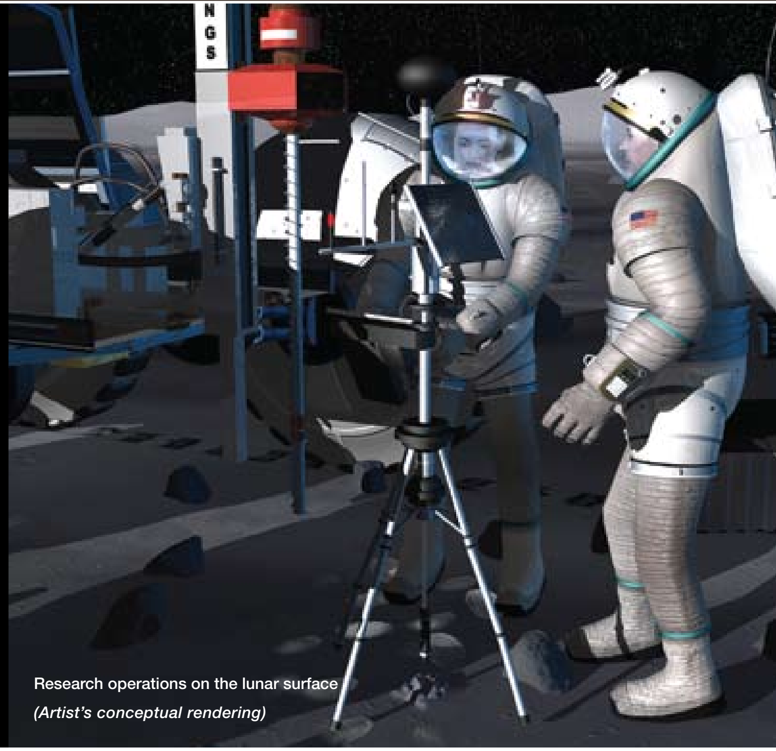
Water and Waste Management—Long-term space habitation requires both the recovery of water and the recycling of human waste. This research for off-planet living currently being conducted on the International Space Station will also impact environmental issues on Earth. A few potential benefits being returned to the Earth from this research include improved water reclamation techniques, new solid waste management technologies, advanced environmental sensors, better contamination control methods, and increased crop productivity.

Surface Mobility—The Apollo missions to the Moon demonstrated that surface mobility is key to improving the efficiency of humans on the lunar surface. NASA is currently developing surface mobility vehicles essential to meeting many lunar science objectives. For example, pressurized rovers are critical for lunar exploration and reaching surface features located at distances that would require human crews to be away from the outpost for days. Long-range traverses would allow for the exploration of surface features such as large impact craters or basins and resource deposits.

imagine

Living on the Moon

Imagine the view as our astronauts wake up in the lunar outpost to see the Earth through the window. They will be living 240,000 miles away from the home planet, further away than humans have ever lived. The day-to-day activities on the lunar outpost will be spent conducting fundamental space research and scientific studies, while maintaining life support systems for breathable air, potable water, stable temperature, waste disposal, and human health.



Research operations on the lunar surface *(Artist's conceptual rendering)*

LIVING ON THE MOON

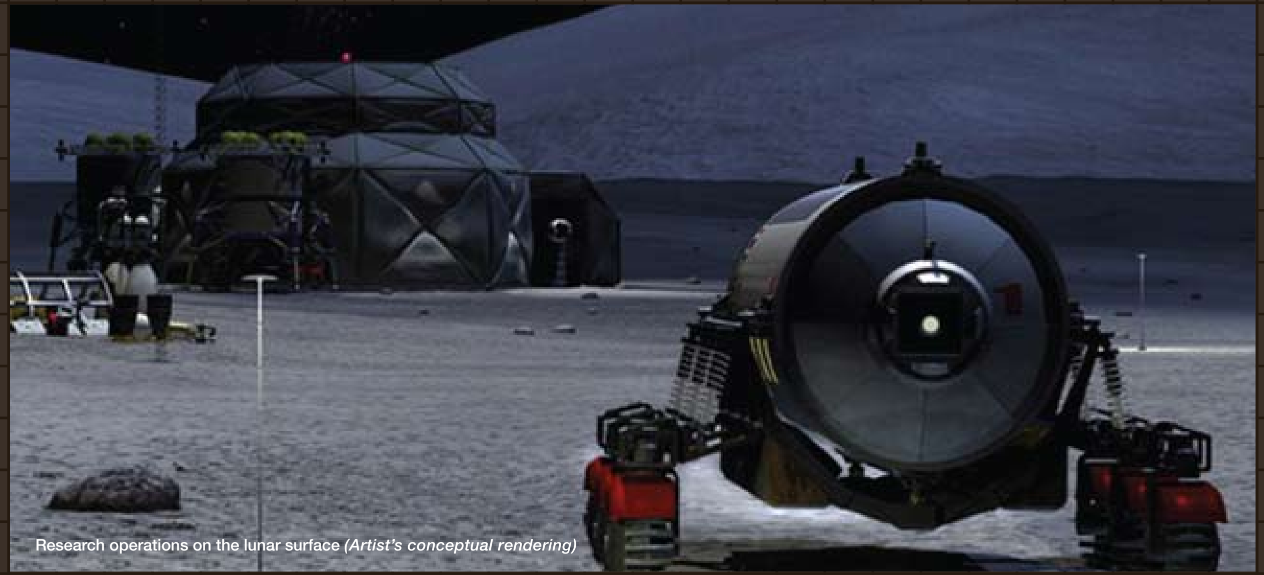
Expanding the Human Environment

Keeping crews both physically and mentally healthy during long-duration missions is of highest concern at NASA. Scientists are developing new technologies and capabilities to counter the negative effects of space by studying and testing how the space environment, close quarters, heavy workloads, and long periods of time away from the home planet contribute to physical and psychological stresses. For example, the NASA Extreme Environment Mission Operations project uses an underwater laboratory called Aquarius near Key Largo, Florida, as an analog to space exploration in which crewmembers can experience some of the same tasks and challenges in a controlled environment as they would in space.

Astronauts will face a myriad of challenges as they travel through space. NASA engineers must consider the risks posed by radiation, technology, the environment, and prolonged exposure to lunar dust. The dangers presented by debris and micrometeoroids while astronauts are on their space journey must also be considered.

As a result, technologies in development include radiation shielding, health monitoring, and other health programs that will ensure the good health and well-being for astronauts on the Moon and during the long-duration spaceflight required to reach Mars.

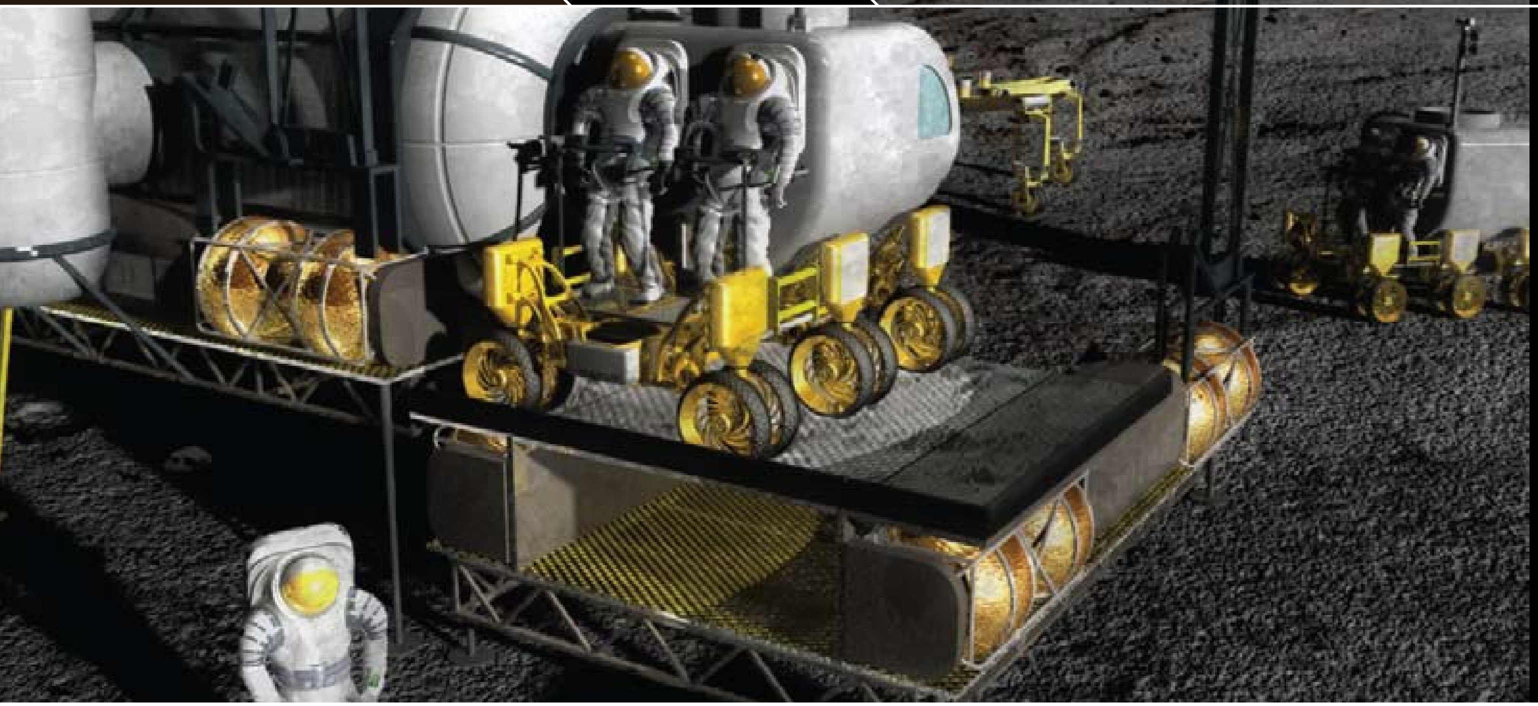
During an undersea session of extravehicular activity, an exploration astronaut/aquanaut climbs a ladder to simulate tasks on the lunar surface.



Research operations on the lunar surface *(Artist's conceptual rendering)*

The Lunar Laboratory

While on the Moon, astronauts will pursue scientific activities addressing fundamental questions about the Earth, the solar system, and the universe. An example of potential onsite activities includes investigating the composition of the lunar surface by collecting geologic samples for analysis in lunar laboratories. The geoscience activities conducted will also test the equipment and techniques required for future geologic exploration of Mars and other destinations in the solar system. In addition to conducting scientific studies, astronauts will also test technologies, systems, flight operations, and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond.

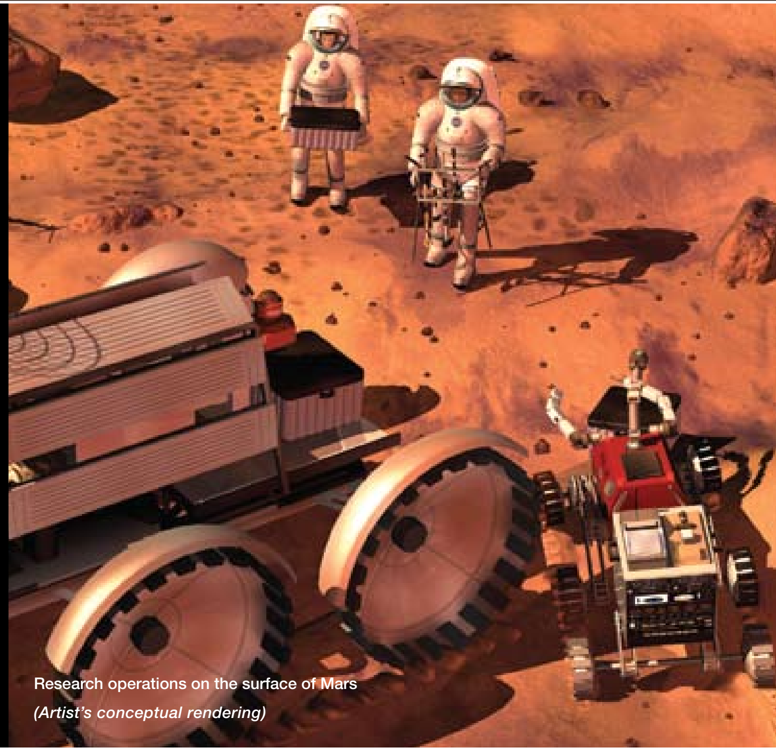


destination

Beyond the Moon to Mars

The first destination of the exploration strategy has been the International Space Station, which will continue to provide support to human spaceflight. Here we have learned how to live and work in space, as well as how to develop hardware that can function for years in this environment. The next exploration destination is the Moon, which will function as a testbed to prepare humans for further exploration to include Mars.

The Red Planet has long been the destination of choice dating back to the first lunar planners—it is most similar to Earth, the surface is partially shielded from harmful radiation, surface temperatures at low latitudes are manageable, and there is the potential presence of ice and water under the Martian surface.



Research operations on the surface of Mars
(Artist's conceptual rendering)

Understanding Mars, Understanding Earth

Understanding the dramatic changes that have taken place on the Martian landscape may help us to better understand our own environmental history. By studying Martian geology, weather, climate, and other natural phenomena, researchers will learn about Mars while also gaining insight into how Earth's environment has evolved, and how it may change in the future.

The possibility of humans visiting, exploring, and living on Mars may be the most challenging and rewarding objectives of space exploration in this century. The day humans step foot on Mars will mark a new milestone for the future and be a moment forever etched in history. Because of this, NASA is studying how to leverage existing resources, while developing the technologies and capabilities to enable future missions to Mars.

Ongoing experiments on the International Space Station evaluate the physiological impact of zero gravity as part of NASA's ongoing preparation for prolonged off-planet human habitation.

Bringing Space Home

As the population on Earth grows and resources become less plentiful, finding innovative solutions for supporting human life in space will lead to applications on Earth. Some of these technologies are already in use today. For example, the gas chromatograph developed by NASA to analyze air during long-duration human spaceflight is being used to detect leaks in underground gas transmission lines. In addition, the studies being conducted by NASA scientists to address a variety of health issues related to space travel are leading to treatments for patients with similar conditions on Earth, such as osteoporosis, muscle wasting, shift-related sleep disorders, balance disorders, and cardiovascular system problems.

However, the impulse to look to the stars for solutions on Earth is not unique to the United States. Europe, Russia, India, China, and Japan are also conducting scientific studies in space. Therefore, NASA is cooperating with space agencies across the globe to utilize assets and extend capabilities while optimizing NASA's resources.

As countries work together exploring the Moon and beyond, NASA spacecraft will continue to send back scientific data from throughout the solar system, laying the groundwork for future space exploration and potential human journeys.

we dare to
explore.

part two

THE PATH TO EXPLORATION

NASA's successes are our Nation's successes. What began with the space race in the 1950s and 60s continues today with the Space Shuttle, the International Space Station, the Hubble Telescope, and the Mars rovers. The new exploration strategy is ushering in yet a new era in this long tradition of American leadership in space.

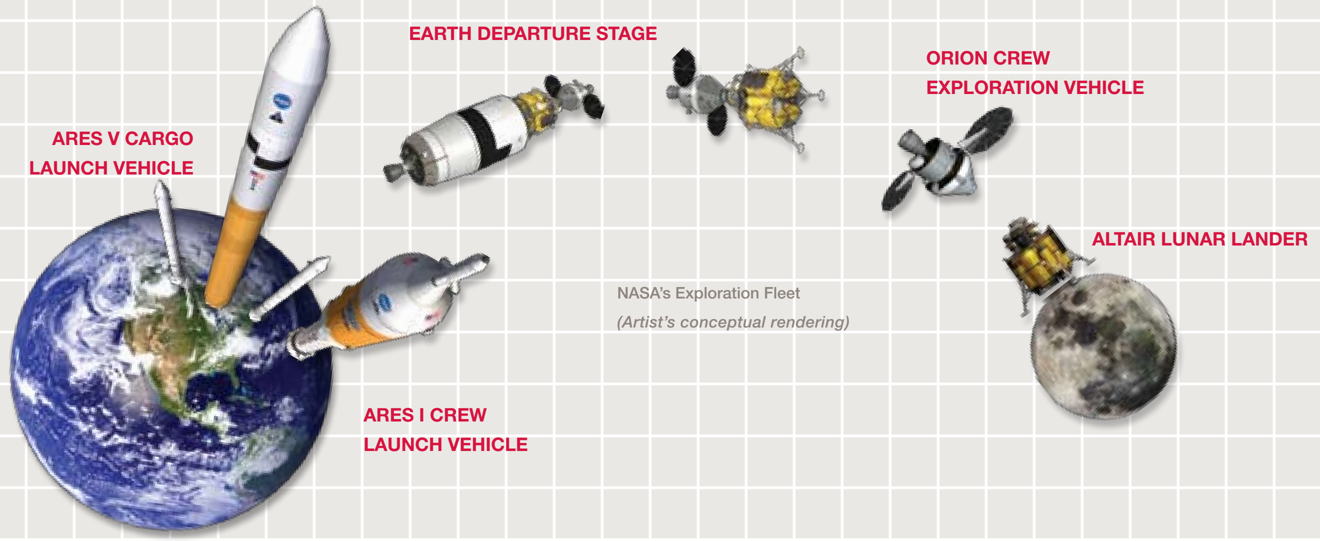
transition

New Mission: Old Design and New Design

The Space Shuttle was designed for transportation to low-Earth orbit. Exploration to the Moon will require a different vehicle design; however, the existing Space Shuttle resources must still be maintained to complete the International Space Station and to ensure a smooth transition to the new vehicle capability. Fortunately, many Space Shuttle components can be reused and leveraged for the next step in human spaceflight. For example, the small rockets that push a booster away from the Space Shuttle during launch will be used to help separate the upper stage of the Ares 1 from the solid rocket after the first part of the flight. Furthermore, legacy engines dating back to the Apollo era will play a role in the new mission architecture. Currently available commercial components will also be part of the overall effort to maximize resources.

Ares I spacecraft inside the Vertical Assembly Building at Kennedy Space Center *(Artist's conceptual rendering)*

SPACE ARCHITECTURES TO THE FUTURE >>>

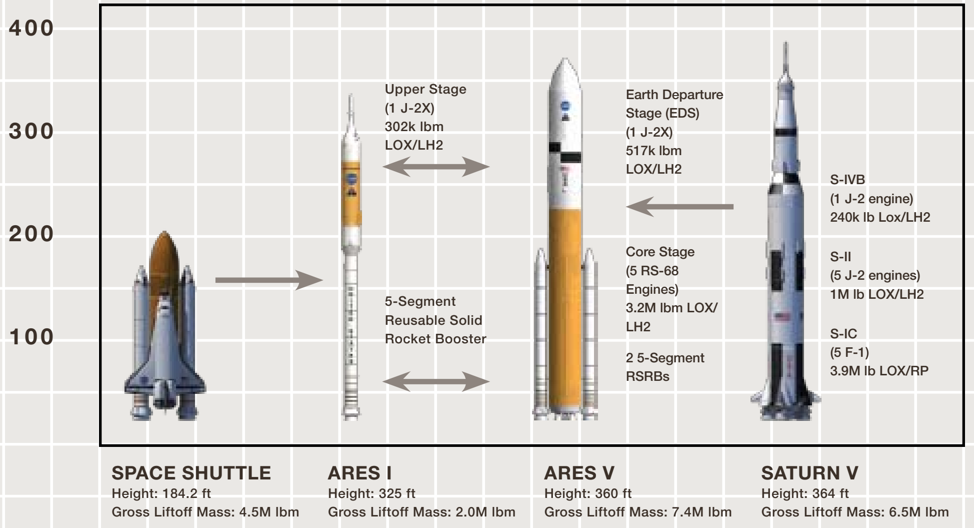


NASA's Exploration Fleet *(Artist's conceptual rendering)*

A New Age of Space Transportation

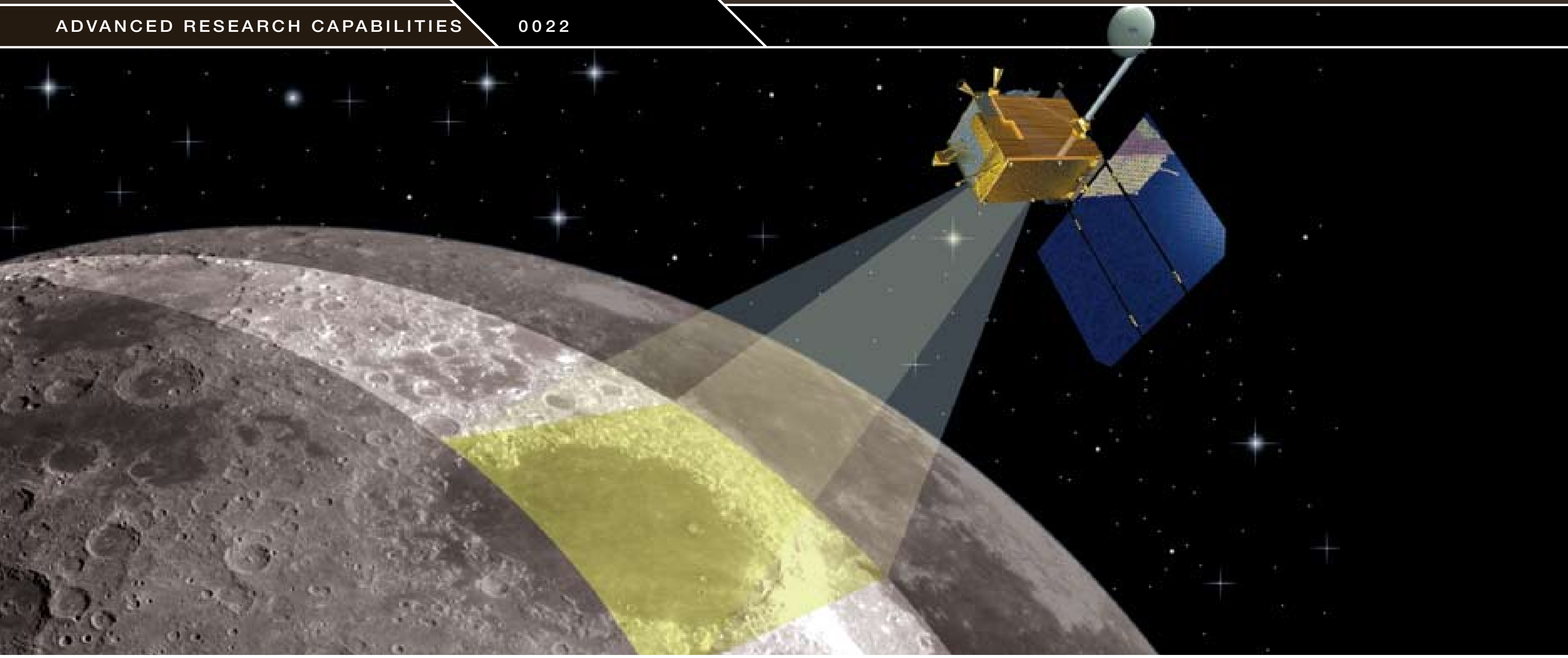
The new age of space transportation will be built upon the lessons learned and the technology developed over the first half century of spaceflight. The Space Shuttle introduced reusability to spaceflight and taught NASA many lessons that are impacting the design of the next generation of spacecraft. Spacecraft of the future will be reusable whenever possible and designed not only for the current mission, but for future missions as well.

NASA'S EXPLORATION LAUNCH ARCHITECTURES



Shuttle-Derived Spacecraft

The Space Shuttle fleet has served America's interests since 1981, constituting a substantial investment in knowledge, infrastructure, and technology. More than 650 facilities, 980,000 equipment line items, and 17,000 civil servants and contractors are engaged by the Space Shuttle program. The success of America's future space exploration depends, in large part, on efficiently utilizing the Space Shuttle's significant assets while continuing to develop new ones.



technology

Advanced Research Capabilities

Exploring the Moon and reaching Mars will require advanced technologies that work together seamlessly. Mission components and systems must be coordinated, integrated, and compatible. Through the research being conducted by NASA and its partners, integrated technologies and systems that will reduce risks and enhance mission performance are being developed. In addition, scientists are also addressing the human component by investigating methods for keeping crews physically and mentally healthy during long-duration missions. The work being performed in advanced capabilities is crucial to providing the knowledge, technology, and innovation that will enable future exploration missions.

The LCROSS mission will help determine if there is water hidden in the permanently dark craters of one of the Moon's poles. Substantial amounts of water ice may be used by astronauts to make rocket fuel when they later visit the Moon. *(Artist's conceptual rendering)*

ADVANCED RESEARCH CAPABILITIES

Technology and System Support

Paving the road to space exploration, NASA is developing the advanced research capabilities necessary to support future space exploration by addressing a wide range of potential advances in technologies and systems that include:

- **Structures, Materials, and Mechanics**
  Lightweight composite structures for Orion and surface habitation
- **Thermal Protection Systems**
  Systems that protect Orion from temperature extremes
- **Non-Toxic Propulsion**
  Options to replace toxic propellants on Orion and booster rockets
- **Energy Storage and Power Systems**
  Lightweight, high-energy density batteries and surface power systems
- **Thermal Control for Surface Systems**
  Materials and processes to manage temperature extremes
- **Avionics and Software**
  Guidance systems and programs for precision control of flight
- **Environmental Control and Life Support**
  Technologies to keep the crew cabin environment safe
- **International Space Station Research Development and Operations**
  The International Space Station as a research facility and as a testbed for exploration technologies
- **Advanced Fission-Based Power Systems**
  Concepts for affordable fission surface power systems
- **In situ Resource Utilization**
  Options for reducing mission resource requirements by using available lunar resources
- **Robotics, Operations, and Supportability**
  Surface mobility and automation of routine tasks

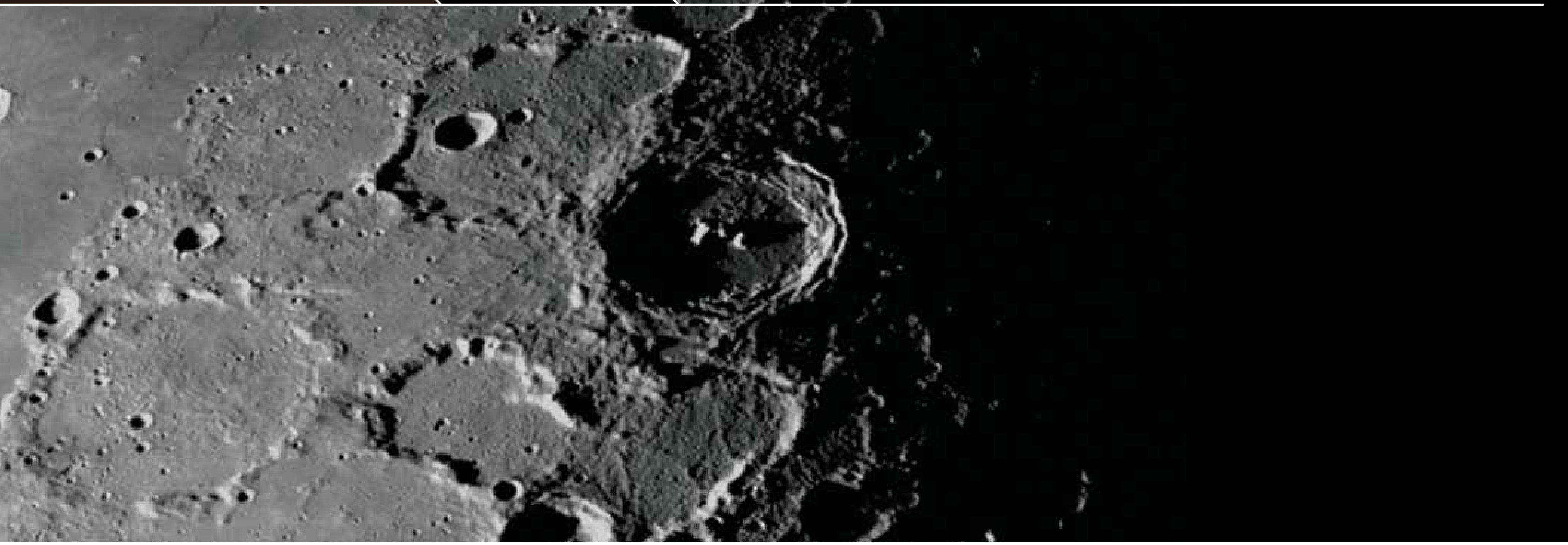
Lunar Robotic Mission

Paving the way for humankind's return to the Moon is the Lunar Precursor Robotic Program. In the near future, the robotic mission will provide information needed by exploration mission planners. In preparation for human missions, robotic missions will provide vital data regarding the lunar radiation environment, surface topography, and other environmental conditions such as temperature and lighting.

The Lunar Reconnaissance Orbiter (LRO) will launch in late 2008. Using an extensive set of instruments to measure the topography of the Moon's surface, the LRO will take high-resolution images of sites of interest, globally assess thermal and radiation environments, and assay potential resources.

The LRO will spend at least one year in low-polar orbit around the Moon, collecting detailed information about the lunar environment. *(Artist's conceptual rendering)*

Also aboard the LRO will be the Lunar Crater Observation and Sensing Satellite (LCROSS), which will begin the search for water on the Moon by determining if there is ice present in a permanently shadowed polar crater. The upper stage of the LRO/LCROSS booster will be crashed into a lunar crater, creating a 1000 metric ton plume of lunar ejecta. This debris will then be tested for water and other compounds.



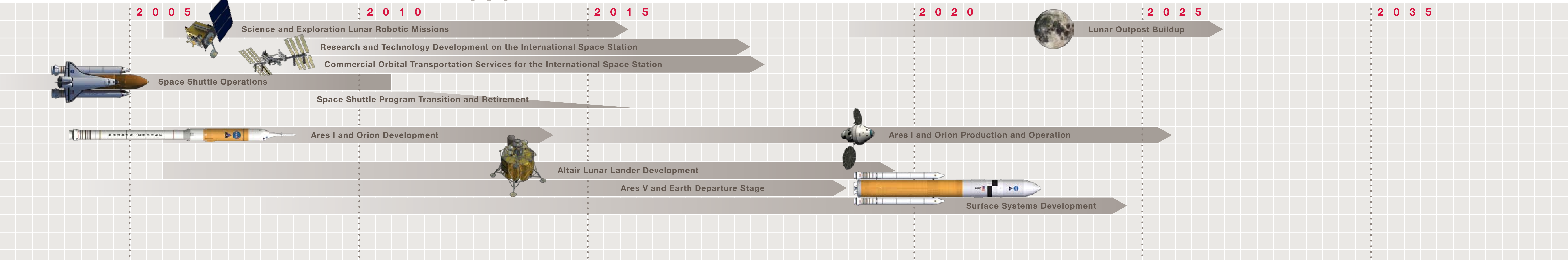
roadmap

NASA's Exploration Timetable

As NASA moves forward, it will maintain Space Shuttle operations and ongoing programs while ramping up the development of future systems on the same budget. NASA's exploration timetable is dictated in large part by the budget resources available and how they must be spread out over time. The Space Shuttle will continue to operate and service the International Space Station until 2010. Ares I and Orion will be developed while the Space Shuttle is still in operation. Specifically, initial Orion operating capabilities—in which the craft flies to the International Space Station and back—will begin by 2015. Robotic lunar missions will begin in 2008, serving as the first steps to returning to the Moon. Furthermore, NASA will develop Ares V, the Altair lunar lander, and lunar surface systems throughout the next decade in preparation for a lunar mission no later than 2020. In the decade that follows, NASA will concentrate its focus on lunar activities and outpost building.

Astronaut working on the lunar surface
(Artist's conceptual rendering)

EXPLORATION ROADMAP >>>



Testing and calibration of a wind tunnel model of the ARES I crew launch vehicle at a NASA center.

systems

The Constellation Program

Safety and mission success—defined as completing mission activities with minimal risk of personnel injury followed by the safe return of all crewmembers after the mission is completed—are Constellation's primary design considerations. Because NASA knows the inherently higher risks associated with launch and landing, the Constellation Program devotes great attention and significant resources to ensuring that the design of hardware and systems, especially those that will carry our astronauts, will be as safe as possible.

Parachute drop tests are being conducted on the Orion recovery system.

The Constellation Program has already begun the design and testing of the Ares I crew launch vehicle that will carry astronauts to the International Space Station and, subsequently, to the Moon. The development teams for the Ares V cargo launch vehicle and the Orion crew exploration vehicle are refining possible designs.

In support of this new era of spaceflight, NASA engineers are testing materials for use in the heat shield that will protect Orion's crew during reentry from the intense heat caused by the friction of entering the Earth's atmosphere. The heat shield will need to be able to withstand temperatures of up to 4,800°F in order to maintain vehicle integrity.

In order to confirm that the heat shield can endure temperatures hot enough to melt metal, testing on the thermal protection system (TPS) occurs inside an apparatus engineers describe as a "room-size blowtorch." In this apparatus, hot hypersonic winds with temperatures that exceed those at the surface of the Sun are created to simulate the heat of reentry.

Partnerships with Industry

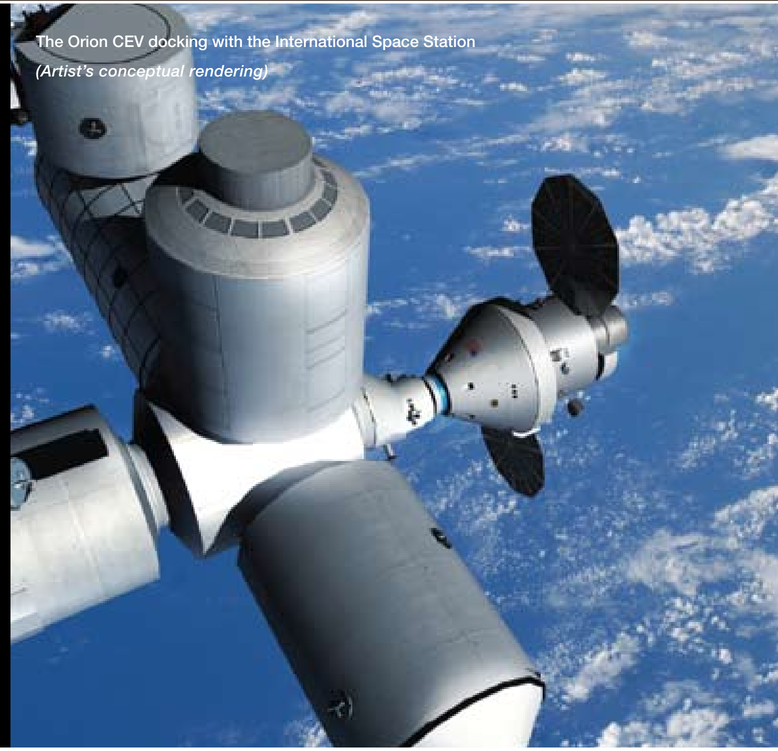
Recognizing the growth of America's commercial space and satellite industry, NASA initiated the Commercial Orbital Transportation Services (COTS) project. COTS addresses the implementation of U.S. space exploration policy through commercial investment in an effort to achieve reliable and cost-effective access to low-Earth orbit. The project will provide for the privatization of various operational aspects of space exploration, including the delivery and return of cargo and crew to the International Space Station. COTS will reach its objectives by incentivizing new launch technologies with seed funding from NASA and by creating a market environment where commercial space transportation services are available to both government and private sector customers. NASA expects use of this model to increase over time as the exploration program unfolds. Of first order, COTS will provide the capability needed to resupply the International Space Station as the Space Shuttle program enters retirement. However, COTS has the potential of extending its services to the provision of power, communications, and habitation facilities, thereby freeing up NASA resources for mission activities.

Capable of lifting over 61,000 pounds to low-Earth orbit and over 26,000 pounds to geostationary transfer orbit, the Falcon 9 Heavy from SpaceX will compete with the largest commercial launchers now available.

capsule

Orion, the Crew Exploration Vehicle (CEV)

The Orion vehicle blends proven design with new capabilities and technology. Orion's design borrows its shape from the capsules of the past, yet its components are comprised of 21st century technology in computers, electronics, life support, propulsion, and heat protection systems. Among the most obvious improvements is the command module's size. Even though Orion is similar in shape to Apollo, its habitable space has significantly more volume, thereby allowing for a larger crew and longer missions to the Moon. Orion will be crucial in developing a sustained human presence on the Moon.



The Orion CEV docking with the International Space Station
(Artist's conceptual rendering)

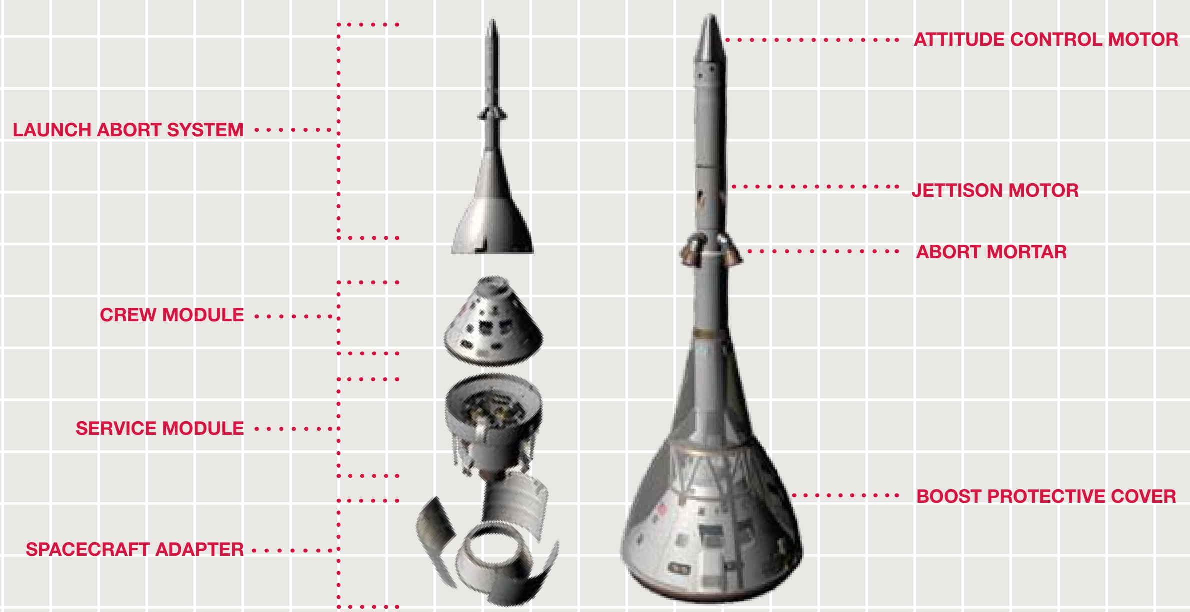
ORION >>>

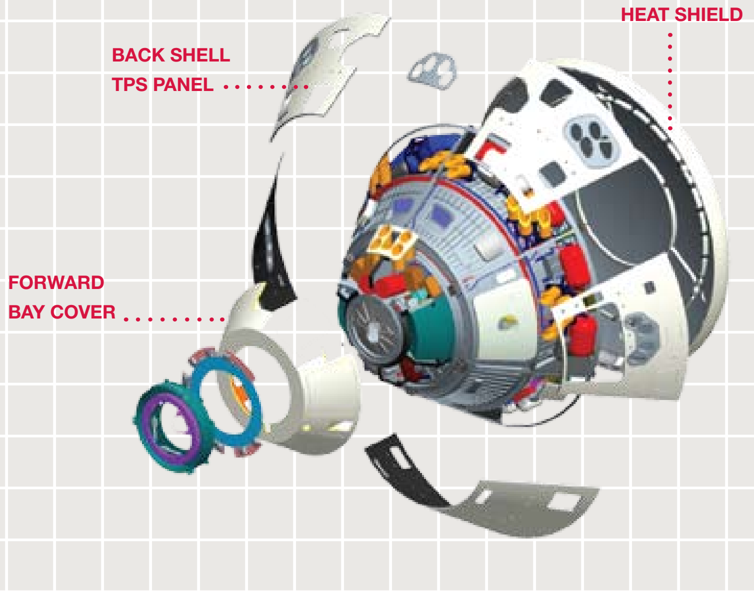
The Orion crew exploration vehicle is the spacecraft module that will carry a human crew of four to six astronauts to the International Space Station, the Moon, and Mars. Another Orion component—the service module—will house Orion's power and propulsion systems. The service module will be mounted directly below the capsule, covering the entry heat shield during launch and in-space activities. Orion's spacecraft adapter component will connect the capsule and service module to the launch systems.

A significant feature of Orion is the launch abort system. Mounted atop the capsule in a vertical configuration, it will pull the spacecraft and its crew to safety in the event of an emergency on the launch pad or at any time during ascent. Orion will be launched into low-Earth orbit by the Ares I crew launch vehicle (see page 30).

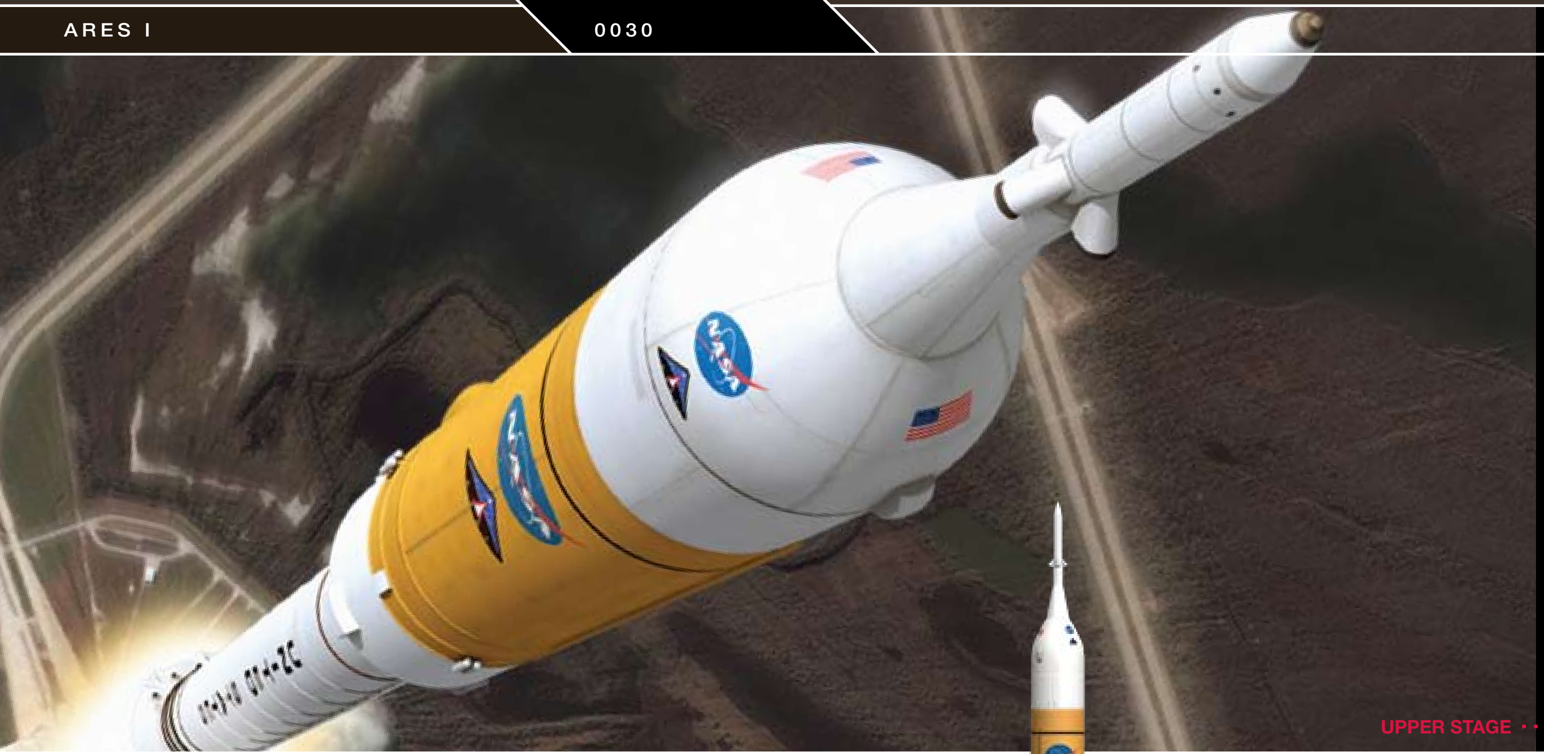
CEV preparing for landing following Earth reentry
(Artist's conceptual rendering)

Conceptual designs of launch abort systems





Expanded view of Orion
(Image Credit: Lockheed Martin Corp.)



transport

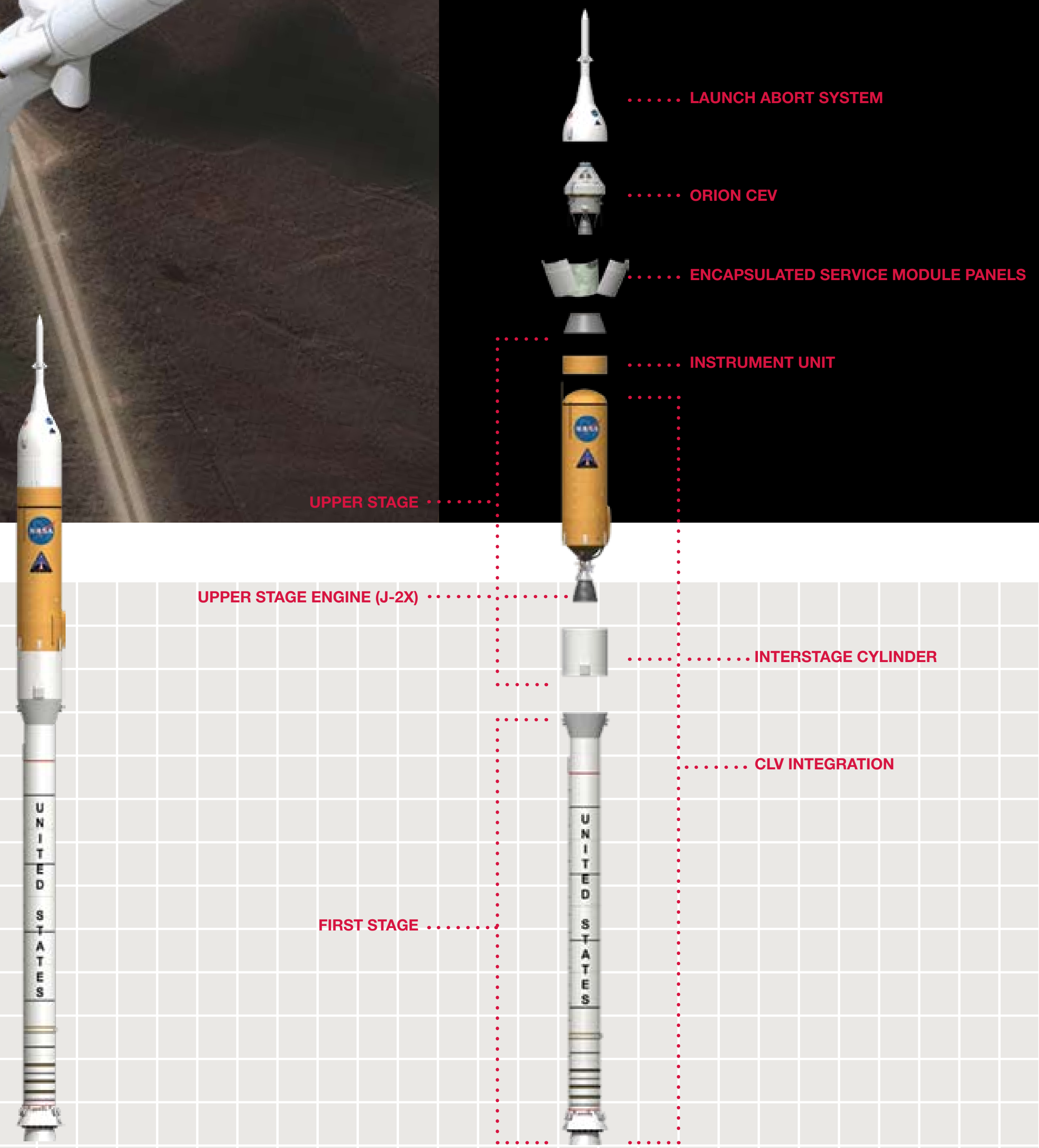
Ares I, the Crew Launch Vehicle (CLV)

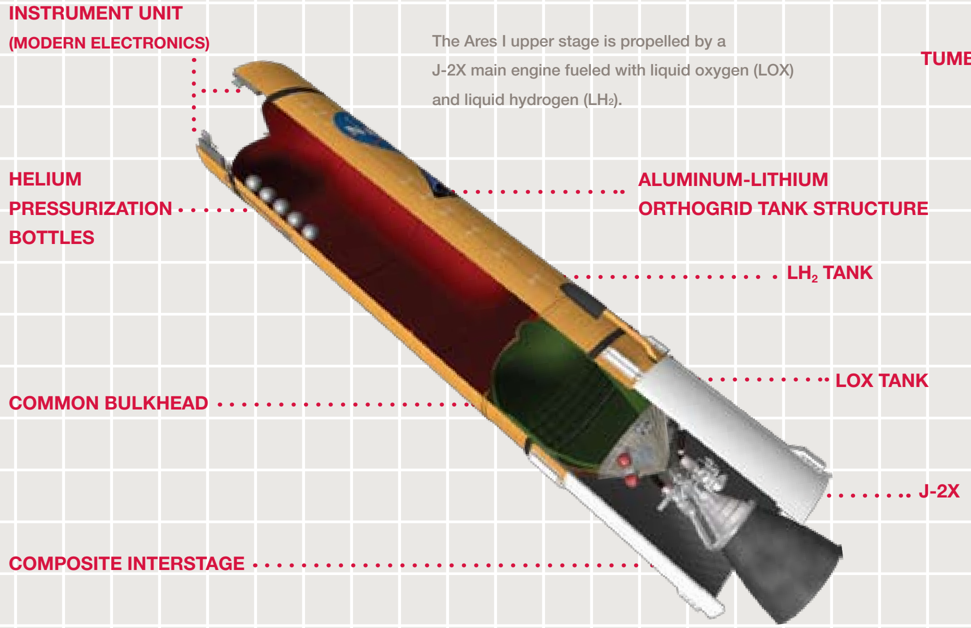
The Ares I crew launch vehicle, or CLV, is the rocket that will lift the crew into low-Earth orbit in the Orion spacecraft. An example of technology transition, the Ares I first stage will modify the Space Shuttle's solid rocket motors for liftoff. While these time-tested, reliable, and reusable engines will undergo some redesign and thorough retesting, for the most part the rocket motor will be reused in its current form. In addition to its primary mission of carrying crew to low-Earth orbit, the 25-ton payload capacity of the Ares I may be used for delivering cargo to space, bringing resources and supplies to the International Space Station, or dropping payloads off in orbit for retrieval and transport to exploration teams on the Moon.

Ares I preparing for launch
(Artist's conceptual rendering)

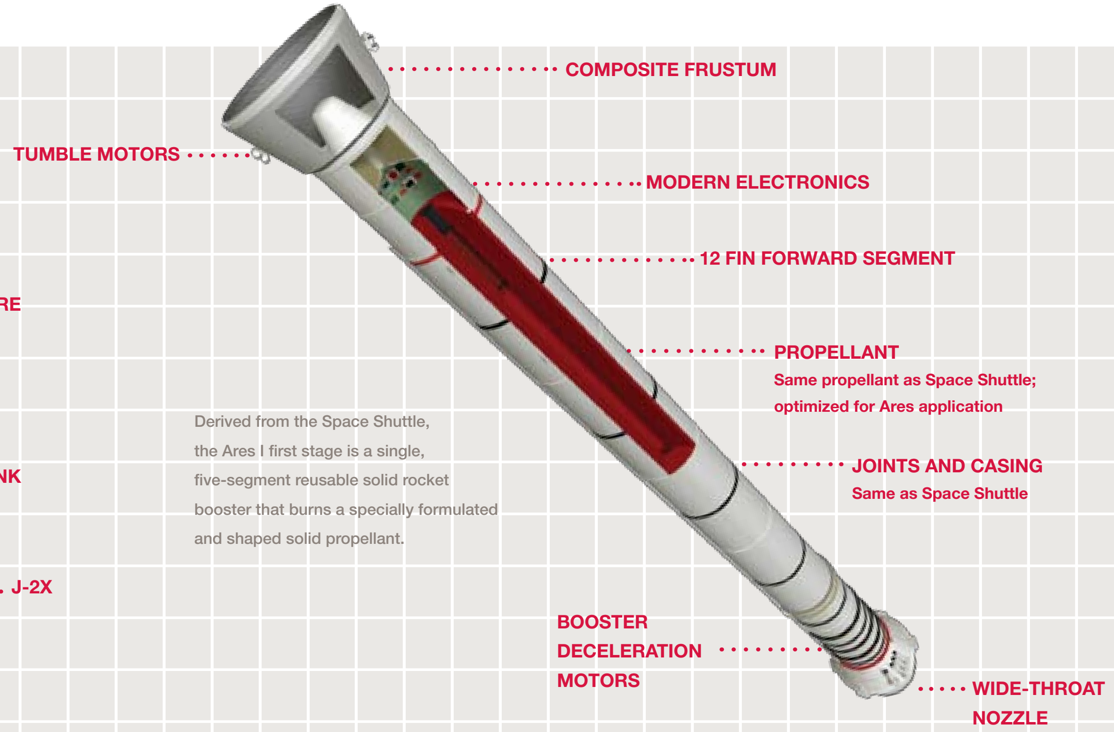
ARES I >>>

The Ares I is an inline, two-stage rocket. The first stage is a single, five-segment reusable solid rocket booster derived from the Space Shuttle's reusable solid rocket motor that burns a specially formulated and shaped solid propellant. A newly designed forward adapter will mate the vehicle's first stage to the second. This second or upper stage—a totally new element—is propelled by a J-2X main engine. In midflight, the reusable booster separates and the upper stage's J-2X engine ignites, putting the vehicle into orbit.





The Ares I upper stage is propelled by a J-2X main engine fueled with liquid oxygen (LOX) and liquid hydrogen (LH_2).



Derived from the Space Shuttle, the Ares I first stage is a single, five-segment reusable solid rocket booster that burns a specially formulated and shaped solid propellant.

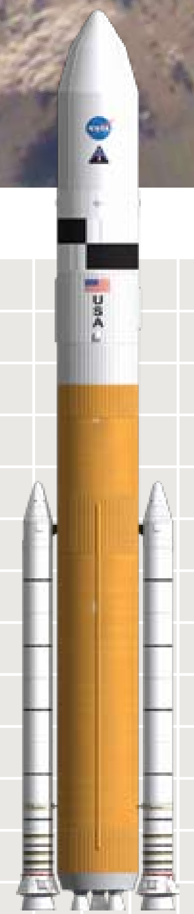
heavy lifter

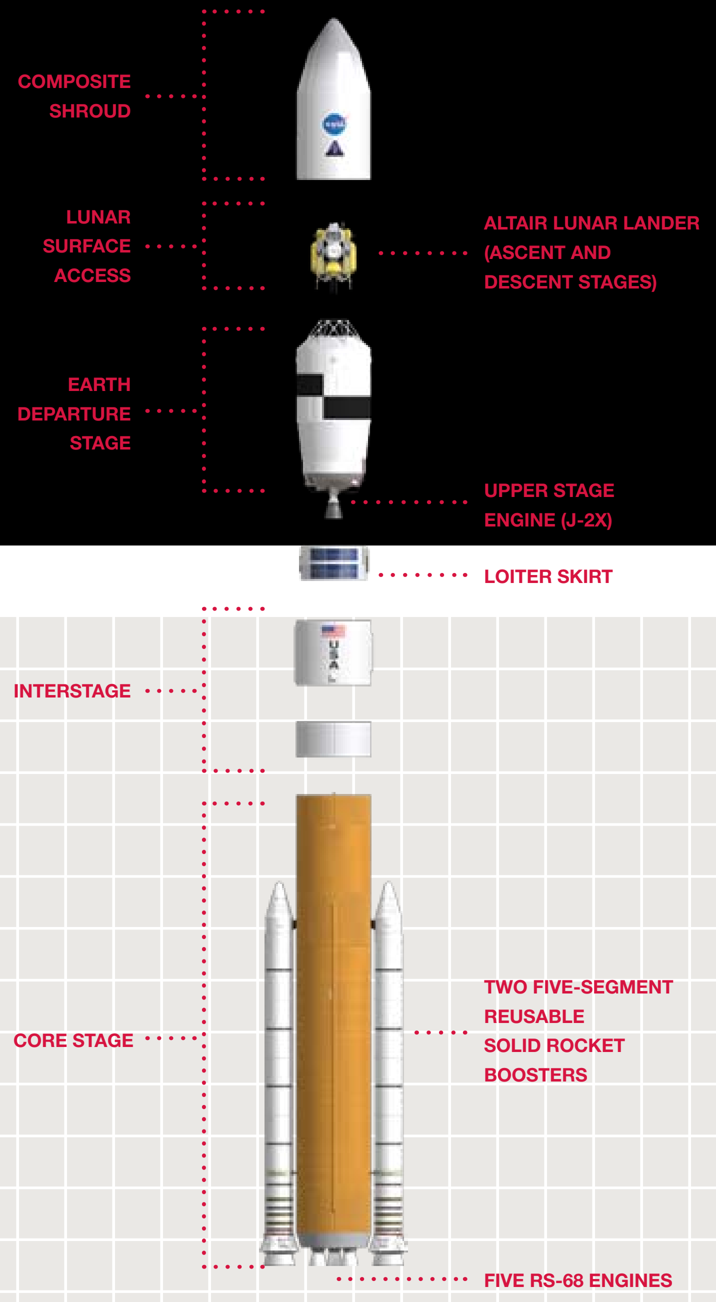
Ares V, the Cargo Launch Vehicle (CaLV)

Planning and early design are underway for the hardware, propulsion systems, and associated technologies for NASA's Ares V cargo launch vehicle—the "heavy lifter" of America's next-generation space fleet. Ares V will serve as NASA's primary workhorse for the safe, reliable delivery of resources to space—from the large-scale hardware and materials for the establishing a permanent moonbase, to the food and water and other staples needed to extend a human presence beyond Earth orbit. Its engines are sized to go to both the Moon and Mars.

The J-2X engine will power the upper stages of the Ares I and Ares V launch vehicles. *(Artist's conceptual rendering)*

ARES V >>>





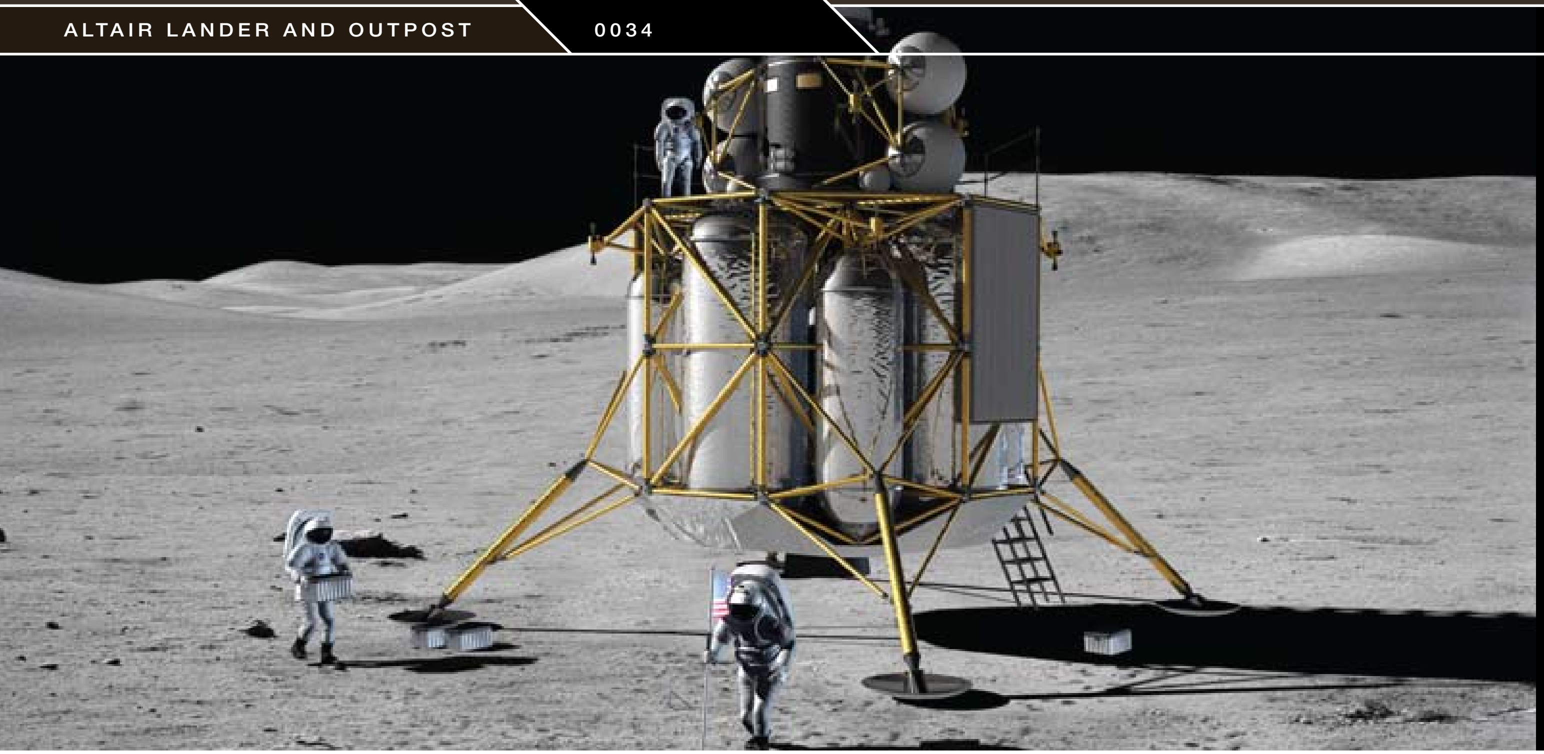
The versatile, heavy-lifting Ares V is a two-stage, vertically stacked launch system. The first stage, which will carry it from Earth into orbit, relies on two five-segment reusable solid rocket boosters derived from the Space Shuttle's solid rocket boosters. These are also similar to the single booster that serves as the first stage for Ares I. The twin reusable solid rocket boosters of the first stage flank a single, liquid-fueled central booster element, known as the core propulsion stage. Atop the central booster element is an interstage cylinder, which includes booster separation motors and a newly designed forward adapter that mates the first stage with the second stage, also known as the Earth departure stage.

NASA engineers have successfully completed testing of subscale main injector hardware, an early step in development of the RS-68 engine that will power the core stage of Ares V.

The Engines: Legacy and Innovation

The J-2X engine will drive the next generation of spaceflight by powering the upper stages of both the Ares I crew launch vehicle and Ares V cargo launch vehicle. The J-2X draws its heritage from the Apollo-Saturn Program and relies on nearly a half-century of NASA spaceflight experience, legacy hardware, and technological advances. It will measure 185 inches long and 120 inches in diameter at the end of its nozzle, and weigh approximately 5,300 pounds with 294,000 pounds of thrust.

Whereas the J-2X engine represents an evolution of technology, the RS-68 engine, which will power the core stage of the Ares V, represents new innovation. From the outset, the RS-68 was designed to be simple and inexpensive to build. The bell-nozzle RS-68 develops 700,000 pounds of sea level thrust—the most powerful liquid oxygen/liquid hydrogen booster in existence—and utilizes a simple design philosophy that has drastically reduced the total part count when compared to engines of equivalent size.



arrival

Altair, the Lunar Lander

Lunar explorers will venture to the Moon's surface in the Altair lunar lander. The Altair will hold cargo and provide a habitable environment for the crew while on the lunar surface. The craft consists of descent and ascent modules connected together. Both modules will undock from Orion while in lunar orbit and descend to the Moon's surface. The descent module will provide access to the surface of the Moon and then remain in place, much like that of the Apollo lunar lander. In addition, it will also have the capability to deliver cargo to the outpost and perform sorties. The ascent module will return the crew from the lunar surface back to orbiting Orion. The design for Altair is undergoing initial studies to evaluate mission flexibility for current and future missions.

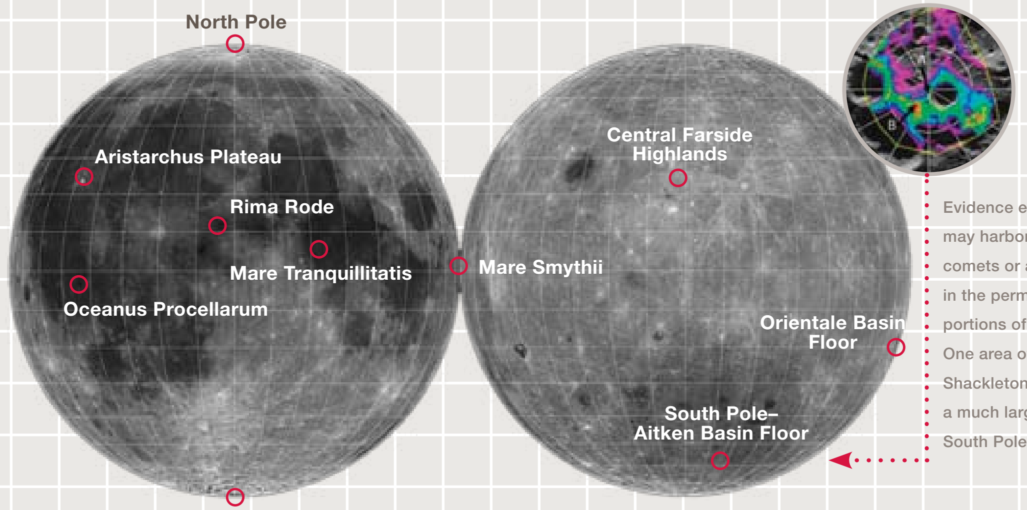
Altair descending to the lunar surface while Orion remains in orbit
(Artist's conceptual rendering)

ALTAIR LANDER AND OUTPOST >>>

Location of the Lunar Outpost

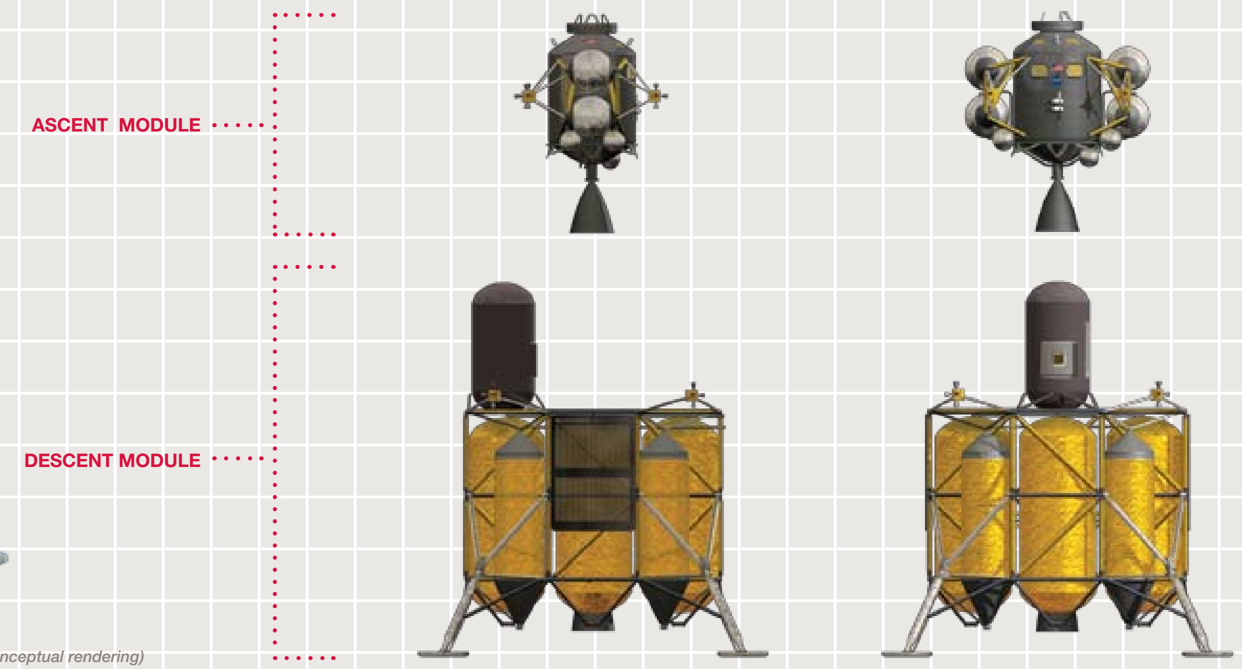
Many factors will influence the site selection for America's lunar outpost, including accessibility, available natural resources, and potential for cutting-edge science. Specifically, sites are being evaluated based upon their likely proximity to ice, sunlight exposure, orientation to the Earth for communications relay, and thermal stability of the region. Robotic missions, beginning in 2008 with the LRO, will provide additional scientific information about local conditions as part of the selection process for humanity's first lunar home.

Surveys are being conducted of possible landing sites for future lunar missions. Some of these sites were previously used during the Apollo era.



Evidence exists that the Moon may harbor water ice deposited by comets or asteroids and preserved in the permanently shadowed portions of certain lunar craters. One area of particular interest is the Shackleton crater, which lies within a much larger crater called the South Pole-Aitken Basin.

The Altair lunar lander *(Artist's conceptual rendering)*



protection

Spacesuits: Personal Spacecraft

An extravehicular activity (EVA) suit, commonly known as a spacesuit, essentially serves as an astronaut's personal spacecraft with many of the same requirements as other spacecraft. For example, the spacesuit must protect the astronaut from environmental hazards while providing oxygen, maintaining proper ventilation, and regulating temperature. EVA suits do not have external propulsion, instead getting their mobility from the astronaut inside; therefore, they must be both flexible enough to allow for a full range of movement and rugged enough to provide effective protection. Because of the complexity of spacesuits and their importance to keeping astronauts both safe and mobile, NASA considers EVA suit development a top priority.

A suited subject is undergoing a CEV seat/suit interface evaluation.

EXTRAVEHICULAR ACTIVITY >>>

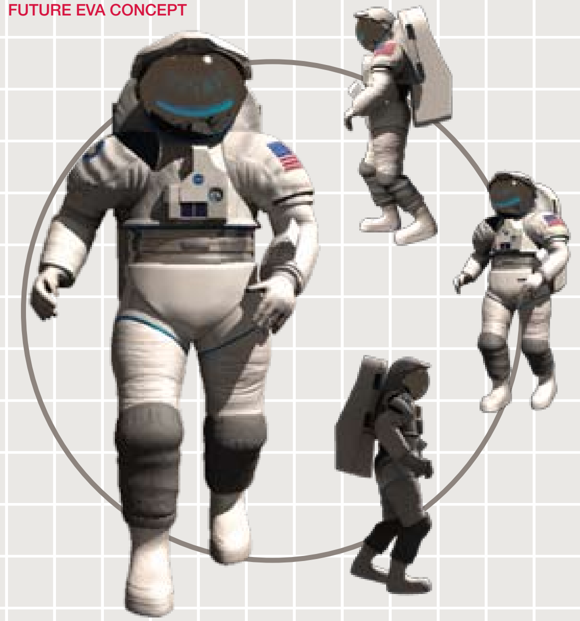
Spacesuit Development

From Gemini to Apollo, from Skylab to the Space Shuttle and the International Space Station, NASA has tailored the extravehicular activity suit and system to meet the needs of each mission. Spacesuits are needed to protect astronauts from the hostile environment of planetary surfaces that lack breathable atmosphere and have significant temperature swings. The spacesuit needed for a lunar EVA is quite different then that needed for an in-space EVA at the International Space Station. The lunar EVA suit must provide superior mobility for astronauts since they must be able to walk and crouch on the lunar surface. Also, the design of the lunar EVA suit must consider the impact of lunar dust and other hazards that are not present while in orbit.

As NASA plans the new exploration mission, EVA suits are being designed to meet the new requirements. NASA's next generation EVA systems and elements include pressure suits; EVA-related life support systems; umbilicals (the tethers through which air and power are transported from the craft to the spacesuit), tools and mobility aids; EVA-specific vehicle interfaces; EVA-servicing equipment; suit avionics; individual crew survival equipment; and ground support systems needed for successful exploration.

EVA SUITS FROM THE PAST TO PRESENT

FUTURE EVA CONCEPT



Field tests on spacesuits conducted in the Arizona desert simulate a "day in the life" for a surface exploration crew: investigating the surrounding landscape, installing and testing science equipment, and excavating and collecting samples.

The PUMA (Portable Unit for Metabolic Analysis) is a portable unit that measures crew fitness levels during long-duration spaceflight.

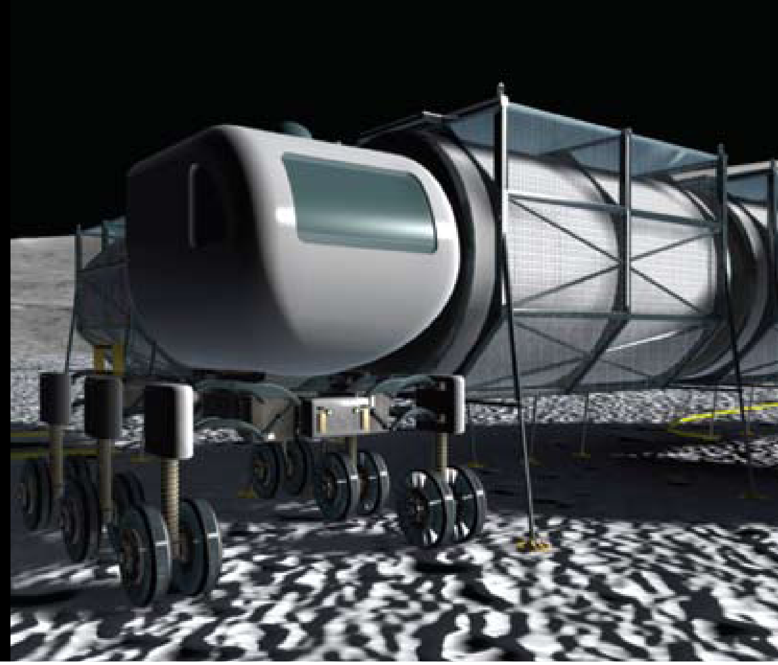
Interior view of lunar habitat
(Artist's conceptual rendering)

surface

The Human Outpost

When the initial missions of astronauts return to the Moon's surface, their landing craft will serve as their first home. Eventually, their lunar home will expand. The outpost will include comprehensive facilities and technologies to assist astronauts in their daily activities and provide for up to four crewmembers during 180-day rotations. Power, communications, and navigation infrastructures will support the outpost in addition to autonomous and remotely operated robotic systems, surface mobility systems, and EVA systems. This foundation will make it possible for humans to explore beyond the outpost, leading to the possible development of sustainable resources on the lunar surface itself.

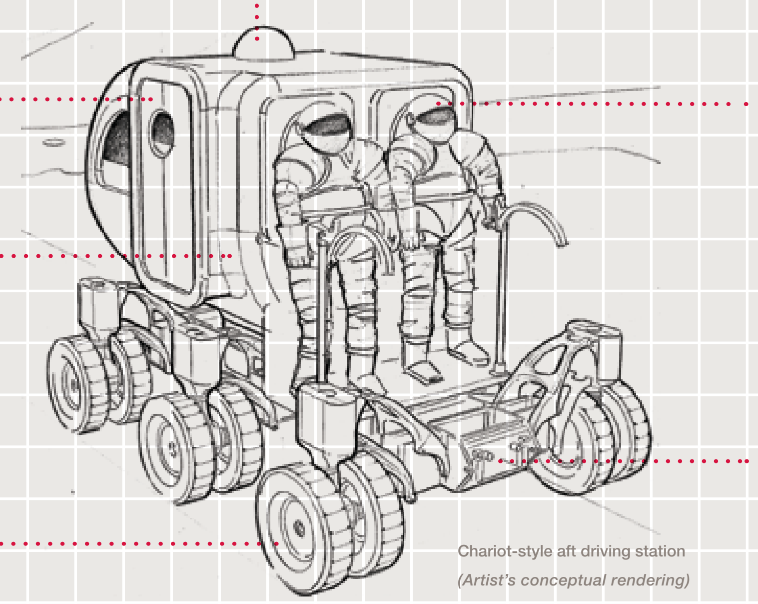
Surface mobility option for the lunar outpost
(Artist's conceptual rendering)



LIFE ON THE SURFACE >>>

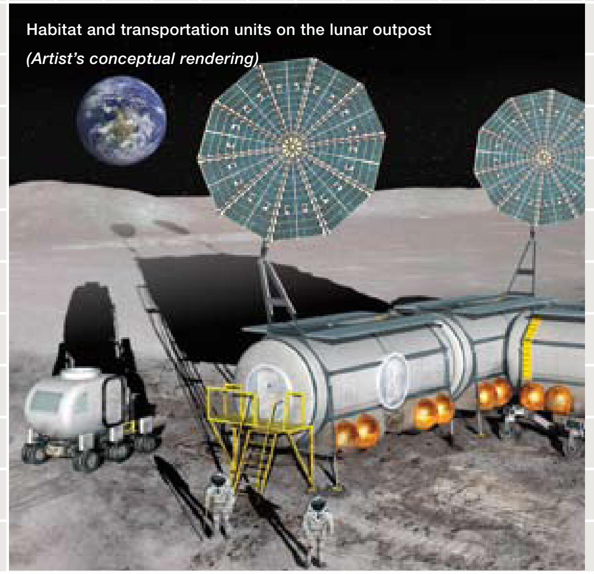
Habitats on Wheels

Pressurized rovers are a mobility option for assisting astronauts in their exploration of the lunar surface, providing them with the relative comfort of not wearing EVA suits. About the same size as the rovers used during the Apollo Moon landings, these two-person rovers would be equipped to handle three-day, seven-day, and two-week excursions on the Moon. Exterior-mounted spacesuits could be donned by climbing through a shared hatchway, taking astronauts only 10 minutes to step into the spacesuits and onto the lunar surface. Short jaunts could range about 25 miles, while longer ones could cover up to 600 miles of the lunar surface during two-week trips.

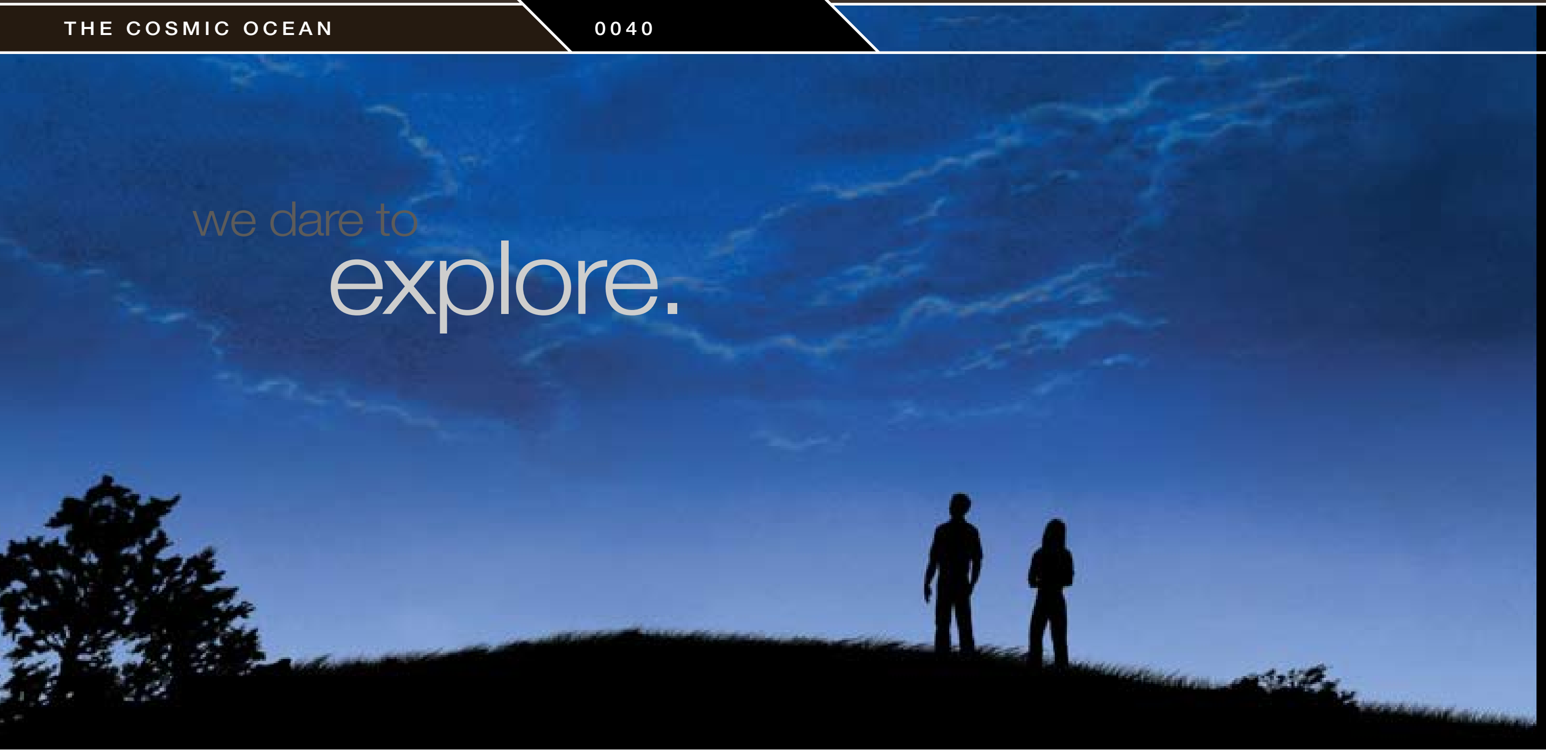


Chariot-style aft driving station
(Artist's conceptual rendering)

Habitat and transportation units on the lunar outpost
(Artist's conceptual rendering)



Pressurized rovers will allow humans to venture away from the outpost. *(Artist's conceptual rendering)*



Johannes Kepler

"As soon as somebody demonstrates the art of flying, settlers from our species of man will not be lacking (on the Moon) . . . Given ships or sails adapted to the breezes of the heavens, there will be those who will not shrink from even that vast expanse."

—From a letter to Galileo, 1610

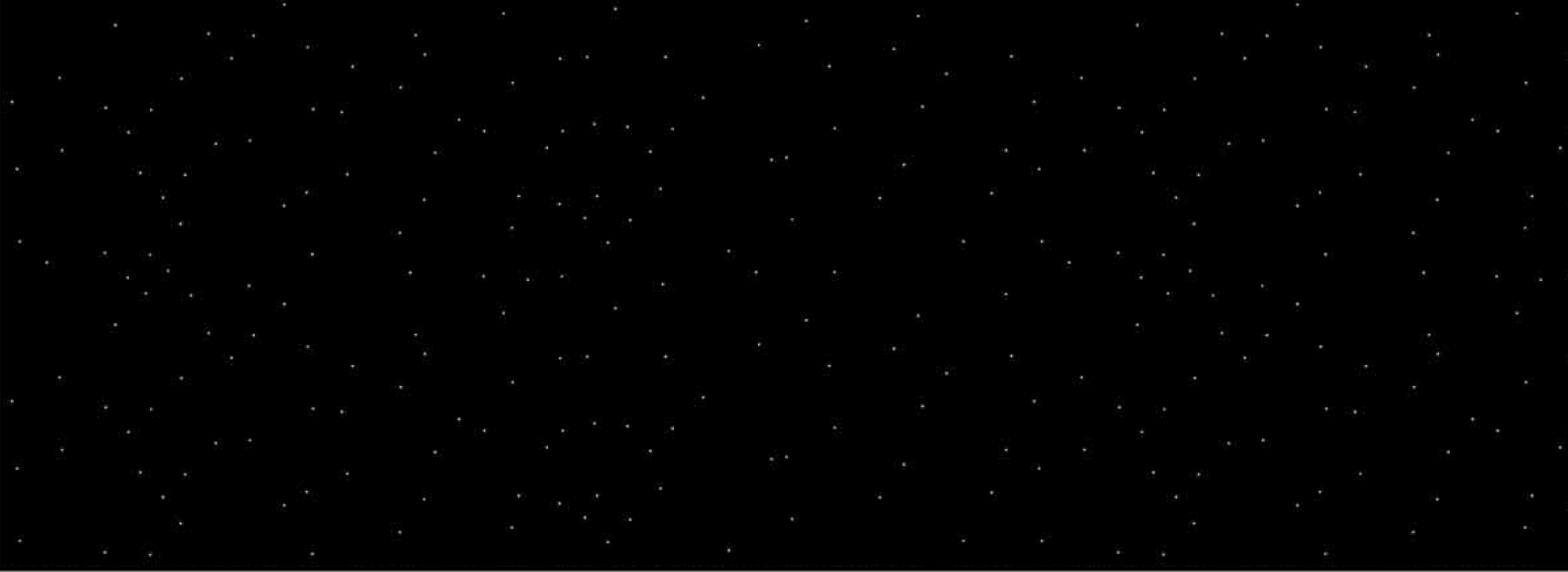
THE COSMIC OCEAN

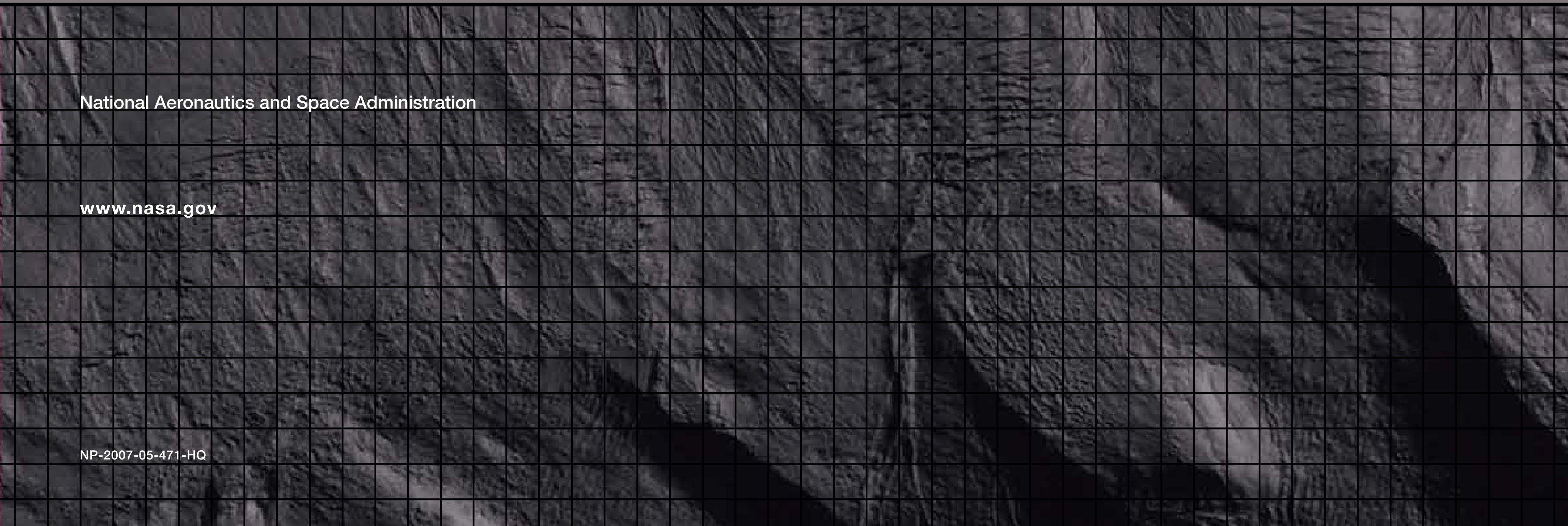
Cosmic Ocean

Just as it was impossible to envision the breadth of benefits to humanity that resulted from the first space age, it is equally difficult to predict all the rewards that the new, upcoming space age has to offer. There is no doubt, however, that exploration will continue to shape the future.

Throughout history, the great nations have been the ones at the frontiers of their time. Early seafaring explorers had to learn to survive in a strange new place across vast oceans. If we are to become a spacefaring Nation, the next generation of explorers will have to survive in other forbidding, faraway places across the vastness of space.

For the United States, NASA continues to chart the course for the next space age and a new era of exploration. Only our imagination can tell what the future of exploration will bring.





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