LESSON 2 Assembling a Space Mission

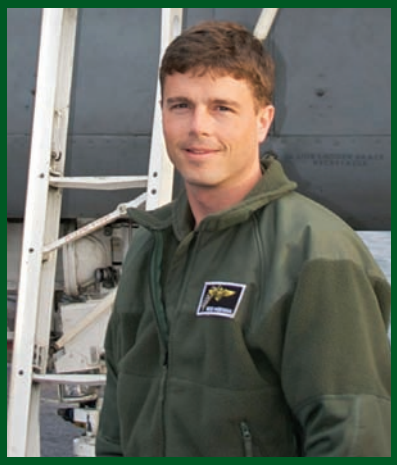
Quick Write

What example can you give from your own experience of having a "click" moment, like Wiseman's, when you realized there was something in particular you wanted to do? What was that like? If you can't think of an example from your own life, give one from the life of someone you know or know about.

"I am not sure there was a definitive moment," Gregory R. Wiseman responded when someone asked him when he first knew he wanted to become an astronaut. NASA chose the Navy flier for its Astronaut Class in the summer of 2009. "I grew up watching space shuttle launches on television and my parents took me to see the Blue Angels perform at Annapolis each spring," he recalled. "These two amazing displays of aviation certainly provided me with the motivation to pursue this path. When I saw my first space shuttle launch from the side of a road in Cocoa Beach in 2001, my ambition was sealed. There is nothing more exhilarating than watching the most complex machine on Earth accelerating downrange."

Learn About

- how NASA plans and implements space missions
- the essential components of a space mission
- the selection and training of astronauts



Lieutenant Commander Gregory R. Wiseman enrolled in Astronaut Class in 2009. "When I saw my first space shuttle launch from the side of a road in Cocoa Beach in 2001, my ambition was sealed," he said.

Courtesy of NASA

How NASA Plans and Implements Space Missions

To put together a space mission, you have to have someone to plan, assemble, and run it. You need money to pay for all the people and equipment that will be involved. And you need public support.

NASA—the National Aeronautics and Space Administration—oversees the US space program. The agency has a broad range of duties. It reaches out into the heavens, but has a strong anchor here on Earth. NASA's Earth-related activities include such things as basic Earth science and efforts to improve the air transport system. For instance, NASA is trying to come up with technology to help airports handle up to three times the number of flights they manage today.

In addition, the types of projects that NASA tackles tend to take a long time to plan and complete. Therefore, when requesting money from the federal government for its annual budget, NASA must look years down the road to predict how much it will require. And as you have probably realized by now, anything involving outer space gets into distances and time frames that are, well, astronomical!

NASA's goals and missions reflect a mix of science, technology, and politics. The agency's plans reflect its relationships with the executive and legislative branches of government, as well as its outreach to the public.

Vocabulary

- aeronautical
- mission directorate
- launch vehicle
- payload
- flight simulator
- cosmonaut

NASA's Mission

Congress established NASA in 1958 with the support of President Dwight Eisenhower. The space agency grew out of the National Advisory Committee for Aeronautics, established in 1915 to conduct and promote aeronautical research. Aeronautical means *anything related to the science, design, or operation of aircraft*.

NASA today conducts cutting-edge research to help transform the nation's air transportation system. It's goals are to:

- improve airspace capacity and mobility
- improve aviation safety
- improve aircraft performance while reducing noise, emissions, and fuel burn.

President Dwight D. Eisenhower (*center*) commissions T. Keith Glennan (*right*) as NASA's first administrator and Hugh L. Dryden (*left*) as deputy administrator in 1958. Congress established NASA the same year with Eisenhower's support.
Courtesy of NASA

NASA plans and carries out many air and space missions. But its overriding mission is to pioneer the future in space exploration, scientific discovery, and aeronautics research. For more than half a century, thousands of people at NASA have been working around the world, and in outer space, to answer some basic questions: What's out there? How do we get there? What will we find? And what can we learn there—or learn just by trying to get there—that will make life better here on Earth?

NASA's Four Principal Directorates

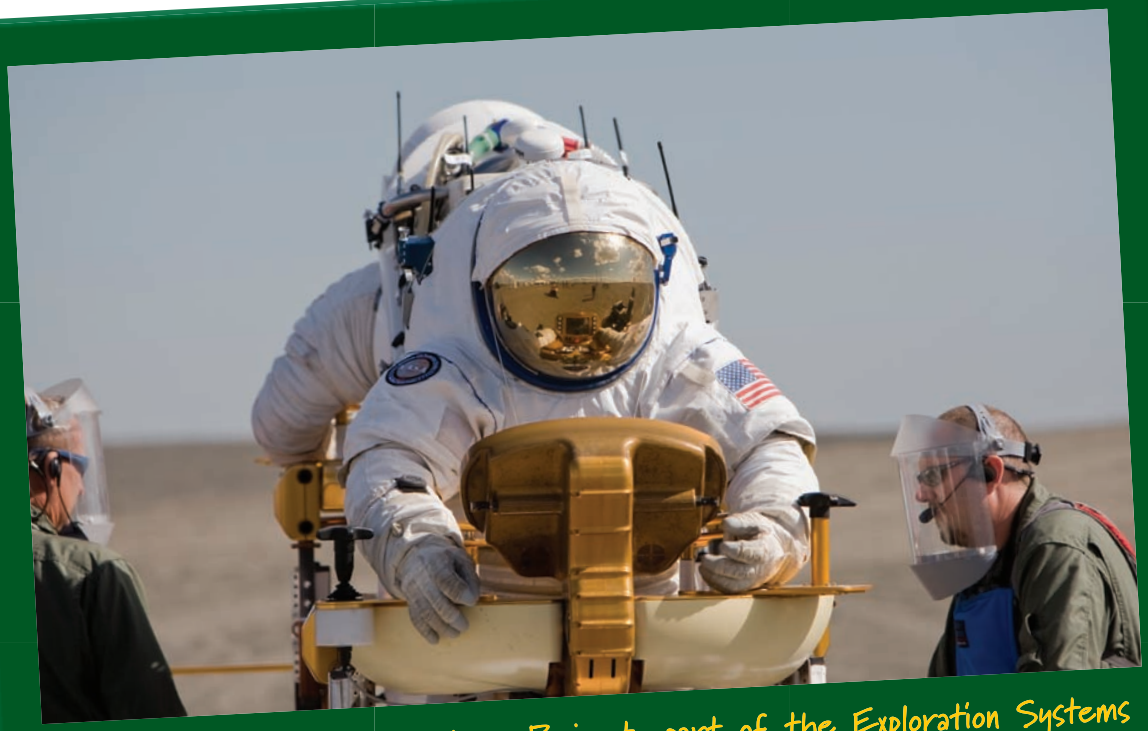
NASA is divided into four mission directorates—*the four main organizations through which NASA carries on its work.*

- ***Aeronautics*** is the directorate that pioneers and proves new flight technologies. These improve human abilities to explore space. But they also have practical applications on Earth.
- ***Exploration Systems*** is the directorate focused on new capabilities and spacecraft for affordable, sustainable exploration. This includes robotic and human missions.
- ***Science*** is the directorate that explores the Earth, the Moon, Mars, and beyond. It charts the routes of space missions. And through its Applied Sciences Program, it helps society at large enjoy the benefits of discoveries in space science.
- ***Space Operations*** is the directorate that provides technical support for the rest of NASA through the space shuttle, the International Space Station, and flight support.

In these early years of the twenty-first century, NASA's reach extends across and beyond the Solar System. The two Mars Exploration Rovers, named *Spirit* and *Opportunity*, arrived on the red planet in 2004 and at this writing are still operating. The *Cassini* orbiter is circling Saturn. The Hubble Space Telescope is transmitting images of the deepest reaches of the cosmos back to Earth. Thirty years after their launch in 1977, Voyagers 1 and 2 were three times farther from the Sun than Pluto.

Closer to home, the International Space Station is extending the human presence in space. NASA satellites are sending back floods of data on Earth's oceans, climate, and other features. NASA's aeronautics team is working with other parts of government and with universities and industry to improve air transport. It's also striving to help maintain American leadership in global aviation.

Among NASA's contributions to aeronautics are improvements in aircraft wings, safer casings for jet turbine fans, better icing detection and deicing fluids, and runway grooves to channel away water. The agency also developed "winglets"—vertical extensions to wingtips that improve airflow and fuel efficiency. And it partnered with the US Army to research and improve rotor designs for helicopters.



NASA's Human Robotic Systems Project—part of the Exploration Systems Mission Directorate—tests spacesuits and lunar robots in the rough, sandy terrain at Moses Lake, Washington.

NASA's four mission directorates provide technical and other support to space missions.

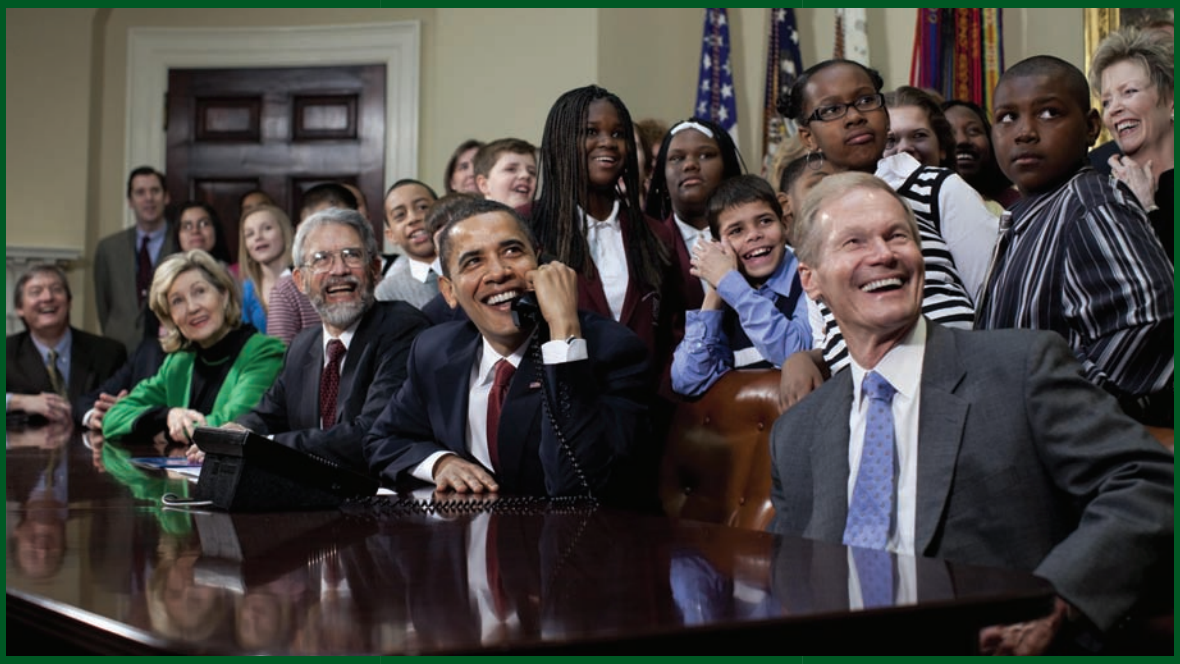
Courtesy of NASA/Sean Smith

How NASA Funds Its Space Missions and Programs

NASA gets the money for all these activities from Congress. As an arm of the federal government, NASA makes a budget request every year. That request goes to the White House, along with similar requests from other parts of the federal government. The president and his staff review and modify these requests. Then they incorporate them into the official White House budget they submit to the Congress. Under the American system, the Congress has the power of the purse—control over government spending. The federal government doesn't spend money, in other words, unless and until Congress appropriates it.

This control means that elected representatives ultimately decide the nation's agenda for space. And members of Congress answer to the public. If public support for space missions appears to be lacking, congressional leaders will hesitate to give NASA the money for them.

But the White House, too, has historically staked out a strong role in setting the national agenda for space. President Kennedy's Cold War call to put a man on the Moon by the end of the 1960s is the best example of this. More recently former President George W. Bush made a bold call to reenergize America's efforts in space. And even more recently, President Barack Obama endorsed an increase in NASA's budget and programming.



President Barack Obama—joined by former astronaut Senator Bill Nelson (in front) of Florida and a group of schoolchildren—places a call to astronauts aboard the International Space Station in March 2009. The president endorsed an increase in NASA's budget and programming that same year.

Courtesy of White House/Pete Souza

NASA's Siblings Around the World

NASA may be the premier space agency in the world. But it's not the only space agency.

The European Space Agency is NASA's counterpart in Europe. It describes itself as "Europe's gateway to space." Its mission is "to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world." Europe consists of a number of affluent but small countries. By pooling its members' resources, the ESA can undertake projects far beyond the scope of any single one of them.

Russia established its Russian Federal Space Agency, known as Roscosmos, in 1992. The Soviet Union's prestigious space program was part of its Cold War effort against the United States. But after the Soviet Union's collapse in the early 1990s, Russia went through hard times and had little money for space exploration. This prompted a push to excel in commercial satellite launches and space tourism. Space science has not been Russia's long suit lately. But Roscosmos has done well with its Mir space station and other space activities. In late 2009 Roscosmos announced a plan to cooperate in space with the Japan Aerospace Exploration Agency.

China also has a space program. Communist leader Mao Zedong became convinced China needed one after the Soviet Union's successful launch of a satellite in 1957. In 1970 China launched its first satellite. In 1984 it sent its first communications satellite aloft. And then in 2003 it sent a man into space—only the third nation on Earth to do so.

The Indian Space Research Organization (ISRO) first launched a satellite into orbit in 1980. It launched the lunar orbiter Chandrayaan-1 in 2008. The orbiter returned data until August 2009. ISRO also builds boosters.

In Japan, the Japan Aerospace Exploration Agency (JAXA) combined three organizations to create a new agency in 2003. It sent several Japanese astronauts on the space shuttle and to the International Space Station. JAXA has launched several research satellites and cargo resupply craft for the space station. It, too, has its own launch vehicles.

The national conversation among Congress, the president, the public (especially professors and scientists), and NASA determines America's role in space. Together these players work out a space program that reflects scientific, technical, and political goals.

One of the challenges in this process is that as political priorities change, NASA projects may also be changed or canceled. This can make it difficult to complete projects that take several years to develop. Sometimes NASA has to cancel projects that show promise simply because it doesn't have the money to finish them.

The Essential Components of a Space Mission

With funding in hand, NASA can turn its attention to specific missions. A space mission—a journey into space—starts with an idea, a goal, or set of goals. Once the mission's goals are in place, NASA must think about what combination of spacecraft plus launch vehicle—or *rocket*—can best accomplish these goals. If a manned mission is called for, the agency must hire and train astronauts. It must prepare them for space travel in general and their own mission in particular. Communications and ground support round out the list of essential components of a mission into space.

The Process of Research and Development for a Mission

NASA's Science Mission Directorate manages a complex list of research goals by means of what's known as the Science Plan. The current plan covers the years 2007 through 2016, although it is likely to change. The plan identifies and prioritizes space missions—whether manned space flight, robotic exploration, or observatories in Earth orbit or deep space. The plan lays out the research program in detail. And it spells out just what's needed to achieve NASA's goals for both space and Earth science. The plan further identifies the research that a given mission will require. It also details exactly what advanced technology, data management, and other related aspects it will involve.

The Task of Building a Launch Vehicle

To get from a Science Mission Directorate concept to actual execution demands lots of work and lots of high-tech parts. One important step when pulling off a space mission is to figure out how to propel a spacecraft into orbit around the Earth, or even beyond Earth's gravity. A spacecraft like the *Apollo 11* capsule that carried Neil Armstrong, Buzz Aldrin, and Michael Collins to the Moon in 1969 can't get into outer space all by itself. It needs a rocket.

Star POINTS

A rocket can produce more power for its size than any other kind of engine.

A rocket is a type of engine that pushes itself forward or upward by producing thrust. Unlike a jet engine, which draws in outside air, a rocket engine uses only the substances carried within it. Because it carries its fuel with it—either liquid or solid—a rocket can operate in outer space, where there is little or no air.

NASA currently uses several different types of rockets. Weight and the mission's objective determine the choice of rocket. The heavier the payload—*the cargo the rocket is to carry aloft*—the bigger the launch vehicle it requires.

From a high perch in the Vehicle Assembly Building at Kennedy Space Center, people watch a crane lift the *Ares I-X* Super Stack 4, which will become part of a solid rocket booster's upper stage. The *Ares I-X* is a test vehicle for the next US mission to the Moon. NASA contracts with different large companies to build its rockets, but a fair bit of actual assembly work is done at Kennedy.

Courtesy of NASA/ Dimitri Gerondidakis

NASA contracts with different large companies to build its rockets under the agency's supervision. These are typically built in pieces at various locations around the country. From there they are shipped by barge or rail to the Kennedy Space Center and assembled on site. A fair bit of actual assembly work is done at Kennedy.

Launch Sites

Despite frequent thunderstorms, it made good sense to establish the site for most US rocket launches on Florida's east coast. It's relatively close to the equator, which helps propel rockets into space because the Earth spins faster the closer it gets to the equator. There's an ocean to the east, so NASA could launch its rockets eastward to take advantage of Earth's spin in that direction and still be over water. And when NASA chose the site, Florida had relatively few people. It did have good roads, however, because of the strong military presence there.

NASA launched its Interstellar Boundary Explorer (IBEX) with an Orbital Sciences Pegasus XL rocket on 19 October 2008 from the Reagan Test Site on the Kwajalein Atoll in the Marshall Islands. IBEX will image and map the Solar System's outer limits.

This bird's-eye view shows the space shuttle *Atlantis* about to be lifted by crane and attached to an external fuel tank and a pair of solid rocket boosters at the Vehicle Assembly Building located at NASA's Kennedy Space Center in Florida. The heavier the payload, the bigger the launch vehicle it requires.

Courtesy of NASA/Jim Grossmann

The Task of Building a Spacecraft

Just as vital as the launch vehicle to any mission is the payload, or spacecraft. The building of a spacecraft and the design of a mission are intimately connected. NASA has to build a craft to do what the mission demands. But sometimes the available technologies can hamper the mission.

The Apollo program illustrated how all this worked. Early on, the plan was for the entire assembly that left Earth's orbit to land on the Moon. Then the assembly's upper stage that landed on the Moon would have to be relaunched from the lunar surface, enter lunar orbit, and return to Earth.

This scenario would require the propellants and associated hardware for the return trip to Earth to be carried to lunar orbit, taken out of orbit, and then soft-landed on the Moon. Propellants and hardware would then have to be brought back up into lunar orbit and burned to send *Apollo* back to Earth.

Under this scenario, the mission would need two *Saturn V* booster rockets to get all this into low Earth orbit. This scenario would also have required an Earth-orbit rendezvous at the beginning of the mission.

The way it all actually worked, though, was much different. NASA mission planners suggested using a lunar orbit rendezvous (LOR) instead. That meant that they

needed only one *Saturn V* booster rocket. Under the LOR scenario, NASA parked the return capsule, with its engine and return propellants, along with one of its astronauts, in lunar orbit.

The spacecraft that actually made it to the Moon's surface was the combined Lunar Descent Module and Lunar Ascent Module. It needed fewer propellants to deorbit and land than the original scenario envisioned. And once the ascent module had done its work of lifting astronauts back off the Moon, the astronauts left it to crash back onto the lunar surface.

Astronaut Training

Another important piece of many space missions is the astronaut. Those chosen to be NASA astronauts are men and women of great accomplishment. (You'll read more later on in this lesson about the requirements to apply for these jobs.) But astronaut candidates typically go through 20 months of additional training. This is on top of all the training and experience that got them into the space program in the first place.

Their training includes sessions in the classroom and in flight simulators—*machines that duplicate what it's like to operate an airplane or a spacecraft*—as well as learning to fly the T-38 high-performance training aircraft. (Mission specialists don't train as pilots.) They learn to use the ejection seat and their parachutes. They practice getting out of an aircraft that is sinking underwater.

They get training in scuba diving. This is useful in preparing them for walking in space.

Astronaut Leroy Chiao trains in a pool. Scuba diving training prepares astronauts for spacewalks.

Courtesy of NASA

As with anything connected with aviation, astronaut training involves lots of checklists. There's a fair bit of memorization involved, so astronauts resort to the use of something you may remember from grade school: flash cards!

Astronaut candidates get training on the computers and software they will use on their missions. They learn about rocket engines. They get to know their spacecraft intimately. They master the radios they will be working with.

The astronauts' training includes wilderness survival skills as well: learning to trap wild animals for food, to find water, to build shelters, and to deal with medical emergencies. It even includes learning to find their way in the woods. But one of the most important outcomes of the training, the astronauts say, is that it teaches each class of candidates to bond as a team.

Star POINTS

Astronaut candidates get some of their first training in a microgravity environment aboard an empty DC-9 jet. The jet's interior is padded so that no one will get hurt. The pilot flies up and down to give trainees that "roller coaster" feeling. They feel it first in the pit of their stomach but eventually get the hang of it and learn to enjoy flying "like Superman," if only for a few seconds.

Preparing Communications

When the European explorers set off on their great voyages, they knew they wouldn't be able to keep in touch with their home ports. Today's astronauts, however, expect more in the way of communication.

NASA relies on the Tracking and Data Relay Satellite System (TDRSS). TDRSS is a communication-signal relay system that provides tracking and data communications between low-Earth-orbiting spacecraft and control facilities on the ground. The system can transmit to and receive data from spacecraft during at least 85 percent of the spacecraft's orbit.

The system relies on six Tracking and Data Relay Satellites (TDRS). Three satellites are available for operational support at any given time. The other TDRSs provide ready backup in the event of a failure.

The TDRSS ground segment is located near Las Cruces, New Mexico, at the White Sands Complex. Forward data is sent up from the ground segment to the TDRS and from the TDRS to the spacecraft. Return data is sent down from the spacecraft via the TDRS to the ground segment and then on to the designated location for collecting data.

Apollo 13 Flight Directors (left to right) Gerald D. Griffin, Eugene F. Kranz, and Glynn S. Lunney cheer Command Module *Odyssey*'s successful splashdown in the South Pacific Ocean on 17 April 1970. Kranz rallied his ground support staff to figure out how to bring the stranded *Apollo 13* astronauts safely home after things went seriously wrong aboard their vulnerable spacecraft thousands of miles from Earth.

Courtesy of NASA

The Importance of Ground Support Operations

Astronauts are at the top of a vast support structure. But they'd be without critical help if not for ground support personnel. Have you ever seen the movie *Apollo 13*? It told the true story of the rescue of three astronauts whose spacecraft suffered an explosion on their way to the Moon.

One of the story's big heroes was Eugene F. Kranz, the mission flight director. He never left Earth. But after things went seriously wrong aboard a vulnerable spacecraft thousands of miles from Earth, he rallied his ground support staff to figure out how to bring the stranded astronauts safely home. Ground support for a NASA mission includes everything from the tracking stations around the globe to the grief counselors on standby at places such as Edwards Air Force Base in case of accident.

The Selection and Training of Astronauts

Before someone gets to sit atop a rocket or even go through training, men and women who dream of soaring into space must endure an extraordinarily tough screening process. Still, it all begins with that desire to navigate the stars. In fact, *astronaut* comes from Greek words meaning "one who sails among the stars." NASA uses the term to refer to all those who have been launched as crew aboard NASA spacecraft bound for orbit and beyond. NASA also identifies as astronauts those selected for the NASA corps of astronauts. These people have made "star sailing" their profession, and they get the designation of "astronaut" even before they launch.

Star POINTS

After astronauts complete their training, they each receive a silver pin. Once they actually go into space, they exchange their silver pin for a gold pin.

The former Soviet Union identified its star sailors as cosmonauts—sailors amid the universe, or the starry firmament. The Soviet Union is no more, but the term cosmonaut is still in use to refer to *astronauts in the space program of the Soviet Union and its successor state, Russia.*

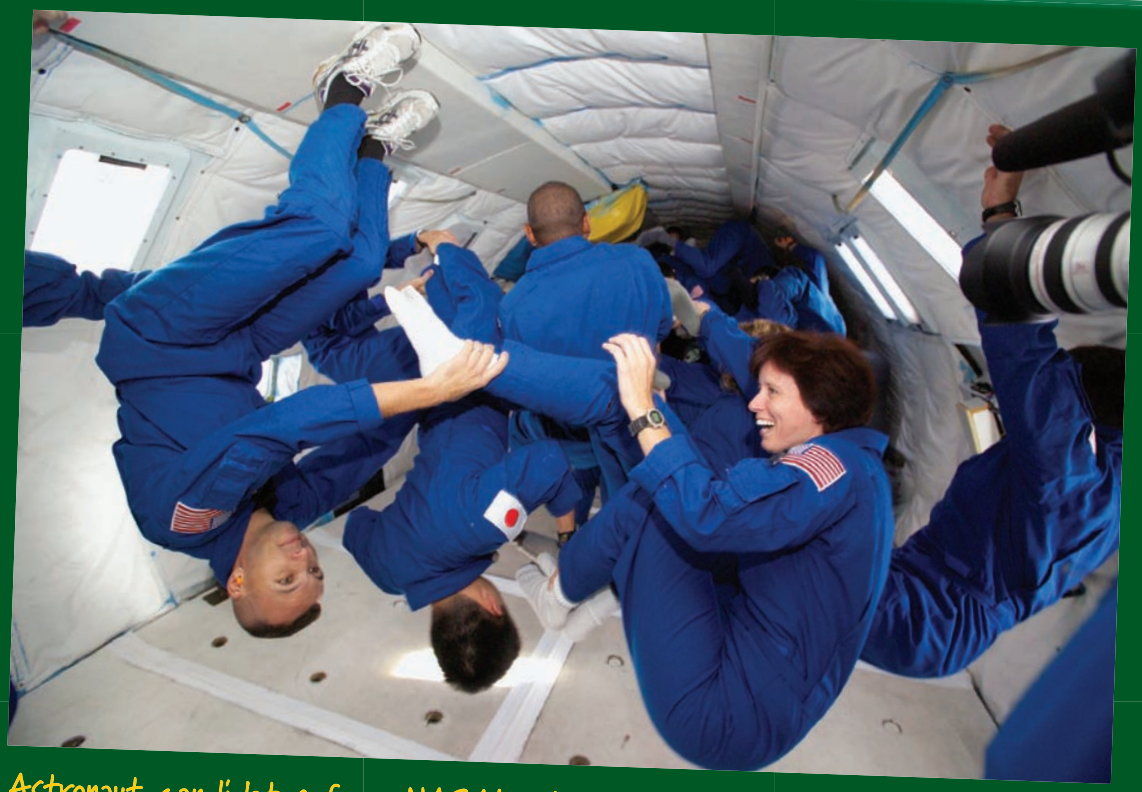
Qualifications Required to Become an Astronaut

Every manned spacecraft that NASA launches carries a crew made up of astronauts from each of four different categories: commanders, pilots, mission specialists, and payload specialists.

Each of these roles has its own basic qualifications. These qualifications may sound relatively simple, but make no mistake. These are extremely competitive positions, and those who win them are remarkably accomplished individuals.

To become an astronaut pilot or commander, someone must have:

- a bachelor's degree in engineering, biological science, physical science, or math. An advanced degree is desirable.
- at least 1,000 hours of pilot-in-command time in jet aircraft. Flight test experience is highly desirable.
- the ability to pass a NASA space physical. This is similar to a military or civilian flight physical. It requires:
  - good distant vision: 20/100 or better uncorrected, correctable to 20/20 in each eye.
  - blood pressure: 140/90 measured in a sitting position.
  - height between 64 and 76 inches.



Astronaut candidates from NASA's class in 2004 experience reduced gravity in a KC-135 flying in parabolas over the Gulf of Mexico.
Pilot candidate Randolph J. "Randy" Breznik and mission specialist candidate Shannon Walker tumble around in the foreground. Astronaut jobs are extremely competitive positions, and those who win them are remarkably accomplished individuals.
Courtesy of NASA

All so-called "mission applicants" for the astronaut candidate program (everyone but the payload specialists, that is) must be US citizens.

Requirements for Mission Specialists

The academic requirements for becoming a mission specialist are like those for becoming an astronaut pilot: a degree in engineering, biological science, physical science, or mathematics. Mission specialists don't face the same requirement for pilot-in-command time in jet aircraft. But they must have either professional experience or an advanced degree. Their vision requirements aren't as strict as the pilots': They can be only 20/200 uncorrected. And they don't have to be as tall as pilots, either. They can qualify at only 58.5 inches.

What Exactly Is a Payload, Anyway?

Payload originally referred to the load of goods on a truck or similar vehicle. It was the load someone paid a trucker to haul. Later *payload* referred to the load a rocket carried into space—a communications satellite, for instance, or even a manned space capsule. This was an extension of the earlier usage. *Payload* also refers to the charge in a guided missile—explosives or chemicals or even biological agents. In NASA lingo, a payload is any "cargo" on a spaceflight. Typically a payload is the equipment related to an experiment or other similar task to be carried out in space. The astronauts in charge of such payloads are known as payload specialists.

Requirements for Payload Specialists

Payload specialists aren't part of the astronaut candidate program. But they must have the appropriate education and training related to the payload or experiment they are responsible for. All applicants must meet certain physical requirements. They must also pass NASA space physical exams, although standards will vary depending on how a given applicant is classified.

How NASA Selects Astronauts

Have you ever wondered whether you have the "right stuff" to become an astronaut? The first astronauts came from the armed services. They were a group of seven military pilots, all men, chosen in 1959. Since these "Original Seven," NASA has chosen 18 more groups of astronauts. They are no longer all male, and their backgrounds are somewhat more diverse. But they are still a pretty exclusive group. Thousands of applicants seek to join the Astronaut Candidate training program. But only 321 have ever been chosen, including the "Original Seven."

NASA developed the process for selecting astronauts to select highly qualified individuals for human space programs. It selects astronaut candidates as they are needed. Both civilian and military personnel may apply for the program. Applicants must meet the minimum requirements mentioned earlier. Once an astronaut candidate's application has survived the screening process, the candidate undergoes a weeklong process of personal interviews, medical screening, and orientation. After NASA makes its final selections from among the finalists, the agency notifies all applicants of the outcome.

Duties of Commanders and Pilots

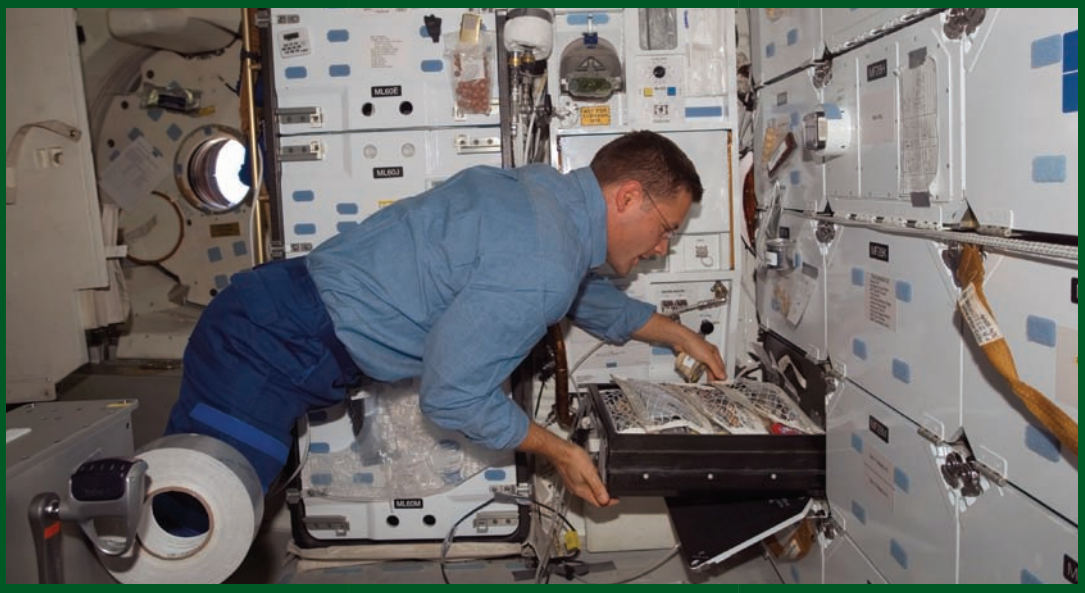
Pilot astronauts serve as both commanders and pilots of the space shuttle and the International Space Station. During flight, the commander is responsible for the vehicle, the crew, the mission's success, and safety. In other words, he or she is in charge of getting everyone back to Earth unharmed. The pilot helps the commander control and operate the spacecraft. The pilot may also help deploy and retrieve satellites. To this end, the pilot uses the remote manipulator system. The pilot also may have a role in spacewalks or in other payload operations.

Duties of Mission Specialists

Mission specialist astronauts, working with the commander and pilot, manage shuttle crew activity planning. They keep track of "consumables"—food, water, oxygen. And they have roles carrying out experiments aboard space missions.

Mission specialists must have detailed knowledge of their spacecraft and its systems. They also have to understand the operational characteristics, mission requirements and objectives, and supporting systems and equipment for each payload element on their assigned missions.

Mission specialists sometimes work outside their spacecraft. NASA calls this "performing extravehicular activities." Most people call this going for a spacewalk. Mission specialists are the ones who use remote manipulators—special tools to handle payloads outside the spacecraft.



Astronaut Doug Wheelock, STS-120 mission specialist, picks out a meal in the space shuttle *Discovery*'s galley. Among many other duties, including spacewalks and conducting experiments, mission specialists keep track of consumables—food, water, oxygen.

Courtesy of NASA

Duties of Payload Specialists

Payload specialists are those other than NASA astronauts who have specialized onboard duties. When foreign nationals take part in NASA missions into space, they do so as payload specialists.

Payload specialists may be added to shuttle crews when the mission's activities require more than the minimum crew of five. Qualified NASA mission specialists are first in line when a place becomes available for an additional crew member on a mission. When payload specialists are required, they are nominated by NASA, the foreign sponsor (in the case of a foreign national), or the designated payload sponsor.

As you can see, putting a space mission together is a complicated and time-consuming task. It's made even more complicated by an unavoidable fact: Space is a dangerous place for spacecraft and human beings alike. The next two lessons will explore those dangers and what is necessary to allow both hardware and people to survive, carry out their missions, and return home.

CHECK POINTS

Lesson 2 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. What is NASA's mission? What are NASA's four mission directorates?
2. List four NASA contributions to aeronautics.
3. What path does NASA's budget request take to get to Congress?
4. What is the Science Plan and what does it do?
5. Why is a rocket able to function in outer space?
6. In the original scenario for the Apollo missions to the Moon, how many booster rockets did it call for and what was the rocket name?
7. Why do astronauts get training in scuba diving?
8. What is TDRSS and where is its ground element located?
9. Who is Eugene F. Kranz and what is he known for?
10. What academic degree must an astronaut pilot have?
11. Who were the "Original Seven"?
12. What is the commander of a space flight responsible for?
13. What are "consumables," and what responsibility does a mission specialist have with regard to them?
14. When foreign nationals take part in a NASA mission, what role do they play?

APPLYING YOUR LEARNING

15. How do the Congress, the president, and the public work with NASA to set the nation's space agenda? Would you change this if you could? Why or why not?