National Aeronautics and Space Administration

NEXT GEN STEM

COMMERCIAL CREW

Rocket Science: Ride to Station Application Educator Guide

For more about Next Gen STEM visit http://www.nasa.gov/stem/ccp.

www.nasa.gov

Introduction

"Ride to Station" is an interactive app designed to be a high-level overview of the complexities involved in getting to and conducting research aboard the International Space Station. It's also designed to be challenging and fun!

On its most basic level, the Commercial Crew Program is focused on working with NASA's two partners, Boeing and SpaceX, to create American commercial capabilities to safely get humans to and from the International Space Station.

What follows in this guide is designed to equip an educator with some simple tools and knowledge to take a fun, interactive app and turn it into a powerful, educational tool for students of all ages! The beginning portion of this guide contains **Classroom Connections**, which includes standards and information to bridge the app to the classroom and **Additional Resources**, containing links to other useful resources for deeper learning and further extensions. The back of this guide contains an **App tutorial** with information related to the actions the user will need to take in addition to the script as it appears in the app itself.

The App can be broken down into six main parts:

Partner selection: Choose between the Boeing/CST-100 Starliner and SpaceX/Crew Dragon

Mission selection: There are a total of nine missions and each time you play you are randomly given a set of three to choose from

Crew selection: You can choose from any of the 39 current NASA astronauts (as of Spring 2019)

Rocket assembly: Identify all of the major components of the rocket and stack the vehicle/spacecraft

Launch: Watch as your commercial rocket and spacecraft make their way to the International Space Station

Rendezvous and Docking: Once the rocket is on its way, you still need to dock to station

Next Generation Science Standards

- 3-5-ETS1-3. Engineering Design- Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved
- 3-5-ETS1-2 Engineering Design- Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem
- MS-PS3-5. Energy- Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object
- MS-ETS1-3 Engineering Design- Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution

Classroom Connections and Additional Resources

Partner Selection:

Classroom Connections

- **Can you name two similarities and two differences between the Boeing Starliner and the SpaceX Crew Dragon?** *Some similarities include the cone shape of the spacecraft, collaboration with NASA, or the rocket and spacecraft configuration. Some differences include the detail in design of the spacecraft, the rocket used to launch, or the launch pad used for liftoff.*

- **Describe how the Engineering Design Process (EDP) is used to solve a problem. Consider each step in your description: Ask, Imagine, Plan, Create, Test, and Improve!** *The EDP includes identifying a problem, imagining a solution, planning to resolve the problem, creating a solution, testing the solution and making improvements based upon testing. After improvements, you share out your solution to others.*

- **In groups, consider the challenge of designing and building a capsule that would transport astronauts to and from the International Space Station. Sketch your designs on paper. Be sure to include measurements such as height, diameter, mass, etc.** *Answers may vary.*

Additional Resources

- **NASA's BEST Engineering Design Process is an iterative process engineers use to guide them in problem solving. NASA Engineers ask questions, imagine solutions, plan designs, create and test models, and then make improvements.**

- **Explore the top five technologies needed for a Spacecraft to Survive Deep Space.**

- **Hear from some of the brightest minds of America's space agency as they discuss topics in engineering, science, technology and more at Houston We Have a Podcast - From American Soil.**

- **Click here to learn more about Boeing's Crew Space Transportation (CST)-100 Starliner spacecraft.**

- **To learn more about SpaceX's Crew Dragon spacecraft, click here.**

Mission Selection:
For Satellite Deployment:

Classroom Connections

- **What are the benefits of deploying small satellites into low-Earth orbit from the International Space Station?** *The benefits of launching satellites from the space station using a robotic arm instead of piggybacking on a larger satellite launched from a rocket include being able to closely control the timing of deploying the small satellite and saving space by limiting the number of small satellites piggybacking on rockets. Small satellites can fit in regularly scheduled cargo resupply flights for deployment once on the station.*

- **If you could test anything in space with a small satellite, what would you test?** *Answers may vary.*

- NASA's CubeSat Launch Initiative provides opportunities for students to conduct research in the areas of science, exploration, technology development, education or operations. Students design and build small satellite payloads to fly on upcoming launches. To learn more, click here.

Additional Resources

- Click here to learn more about how NASA deploys small satellites from the International Space Station.
- Take a look at some of the science experiments conducted from the International Space Station.
- So you want to build a satellite? Click here for a NASA challenge.

For Meteorological Survey:

Classroom Connections

- NASA routinely contributes to the national weather forecasting goals through the development and use of data from space-based sensors. Satellite-based profiles of temperature and moisture have drastically improved forecasting and operational models for weather and extreme-weather events through the collection of data. How does data from science instruments aboard the International Space Station improve life here on Earth? *Examples of how the station improves life on Earth include supporting water purification efforts worldwide, enhancing medical technologies such as ultrasound capabilities, contributing to medical research on preventing bone loss, monitoring weather and changes on Earth, improving vaccinations, etc.*
- What are some benefits to being able to monitor weather from space? *Examples of benefits to weather monitoring from space include the viewpoint of the International Space Station 250 miles above Earth's surface, capability for storm tracking from satellites and ability to monitor dust storms, forest fires and volcanoes from above.*

Additional Resources

- To learn how NASA collects data from clouds to improve weather forecasts, click here.
- The Stratospheric Aerosol and Gas Experiment III, or SAGE III, resides on the International Space Station providing long-term monitoring of ozone vertical profiles of the stratosphere and mesosphere through solar occultation. Occultation involves looking at the light from the Sun or Moon as it passes through Earth's atmosphere. To learn more about the SAGE III instrument, visit: SAGE III-ISS Data and Information.
- Get your students involved in Citizen Science with the Globe program here.

For Personnel Exchange:

Classroom Connections

- **What do all NASA projects have in common? Their success depends on teams of skilled professionals working together to solve problems and deliver results. Why is it important to work collaboratively and effectively as part of a team to accomplish a goal?** *Working collaboratively and effectively as a team allows a group of people to bring a variety of unique skills and viewpoints to the table to help solve a problem. Good communication and trust between team members help to strengthen a team.*

- **Critical thinking, flexibility, communication, productivity, creativity, and leadership are just a few of the essential skills necessary to be successful on NASA missions. Can you name other skills needed to work in the 21st century?** *Additional examples could include collaboration, initiative, self-care, team-care, cultural competency, followership, and teamwork.*

Additional Resources

- **Train Like an Astronaut! The challenge is to investigate and discover how physical activity and nutrition affect the human body in space on the International Space Station through a series of hands-on activities and observations.**

- **Astronauts provide answers to frequently asked questions from students here.**

For Solar Foil Repairs:

Classroom Connections

- **How do you get electricity 250 miles above Earth?** *The International Space Station has Solar Array Wings that use solar energy to keep electricity running on the space station. These arrays are made up of thousands of solar cells.*

- **How do solar cells convert energy to electricity on the space station?** *Solar cells are purified chunks of the element silicon and directly convert sunlight to electricity using a process called photovoltaics.*

Additional Resources

- **Solar arrays that convert energy to electricity on the space station are made of thousands of solar cells. To learn more about the International Space Station's Solar Arrays, click here.**

- **See live views of Earth from the International Space Station here.**

- **Learning Launchers: Robotics - Here you will find "Teacher Toolkits" that focus on research and activities related to the space station. Use these lesson plans, videos, and related resources to bring the International Space Station into your classroom.**

- **To build your own robotic arm to move items around from one location to another, click here. This lesson incorporates the engineering design process to design, build and operate a robotic arm for grade levels K – 8.**

- Solar energy is essential to keeping the International Space Station functional as it provides a working laboratory for astronauts in the unique microgravity environment. Watch Expedition 55/56 Flight Engineer Ricky Arnold explaining the station's solar arrays and the importance of solar energy on the space station here.

- Two NASA astronauts successfully replace nickel-hydrogen batteries with newer, more powerful lithium-ion batteries for the power channel on one pair of the station's solar arrays.

For Exterior Retrofitting:

Classroom Connections

- Discussion: Why is it important to study or train for an upcoming test or athletic event? *Practicing or training for a test or athletic event helps condition our brains to make long-term connections to learn a new skill or expand knowledge. For example, astronauts spend several years learning and training for their upcoming missions. Much like learning a subject in school in school, astronauts must prepare using different mockups, simulators, and instruments.*

- Why must astronauts work out up to three hours per day? *Exercise is an important part of the daily routine for astronauts aboard the station to prevent bone and muscle loss. On average, astronauts exercise two hours per day. The equipment they use is different than what we use on Earth. Lifting 200 pounds on Earth may be a lot of work, but lifting that same object in space would be much easier. Because of microgravity, it would weigh less than 200 pounds there. That means exercise equipment needs to be specially designed for use in space so astronauts will receive the workout needed.*

Additional Resources

- Watch the International Space Station pass overhead from several thousand worldwide locations. It is the third brightest object in the sky and easy to spot if you know when to look up. Sign up here to learn when the space station is flying over your location!

- Astronauts provides answers to frequently asked questions from students - Astronauts Answer Student Questions.

- Spacewalking: Safety, training and a well-equipped spacesuit are essential components for a spacewalk as astronauts work outside of the space station in low-Earth orbit. Watch Expedition 55/56 flight engineer Ricky Arnold in this two-part episode as he explains spacewalk safety and training in addition to the parts of the spacesuit that protects astronauts outside the space station.

For Chemistry Experiments:

Classroom Connections

- **Construct a Venn Diagram that compares and contrasts how fire behaves in space versus here on Earth.** *Sample answers include the following:*

- **Explain the challenges to living in a microgravity environment. For example, how does water behave differently and why? Can you think of anything else that might behave differently in space and how that would pose a challenge to living in space or on another planetary surface?** *The effects of microgravity can be seen when astronauts and objects float in space. Microgravity refers to the condition where gravity seems to be very small. In Microgravity, astronauts can float in their spacecraft – or outside, on a spacewalk where heavy objects move around easily. For example, astronauts can move equipment weighing hundreds of pounds with their fingertips. Some of the challenges astronauts face in a microgravity environment include prolonged exposure to a microgravity environment. Without the effects of gravity on the human body, our bones and muscles are not exposed to loads experienced here on Earth to help counter bone loss and muscle atrophy. Exercise is a critical element to living and working on space in order to maintain the calcium balance of the bones and the muscle contraction needed to support the body.*

Additional Resources

- **If a fire were to break out on a spacecraft in orbit, astronauts would fight the flames in slightly different ways than they would on Earth. Fires in space are not the same as fires on Earth, but the best way to fight any fire is to keep it from starting. To learn more, click here.**

- **Read how NASA Ignites Fire Experiment Aboard Space Cargo Ship here.**

- Spinoff is a publication that highlights NASA technologies that have transformed into commercial products and services. To learn more about NASA spinoffs, visit: https://spinoff.nasa.gov/

For Microgravity Biology:

Classroom Connections

- Discussion: In a microgravity environment, the human skeletal system is no longer subjected to the daily exposure of Earth's gravity. How does microgravity negatively affect the human skeletal system? *The human skeletal system plays an important role as a structure that supports the body and stores calcium. It retains fracture resistance by remodeling through a balance of bone resorption and formation. In a microgravity environment, because of reduced loading stimuli, there is increased bone resorption and no change in or possibly decreased bone formation, leading to bone mass loss at a rate of about ten times that of osteoporosis. The proximal femoral bone loses 1.5 percent of its mass per month, or roughly 10 percent over a six-month stay in space, with the recovery after returning to Earth taking at least three or four years.*

- Discussion: What can astronauts do to slow down the negative effects of microgravity on their muscular and skeletal systems? *To slow down the negative effects of microgravity, astronauts must follow these three key elements: good nutrition, exercise, and some preventative medication. Meals should be nutritionally balanced with calcium-rich foods (milk, small fish, etc.). On average, astronauts must exercise two hours per day to maintain strength and stability while in space. Physical exercise also helps to combat the effects of bone loss and muscle atrophy. Preventative medication, such as vitamin D and calcium help to minimize the effects of microgravity on the human skeletal system.*

Additional Resources

- Train Like an Astronaut! Students are challenged to investigate and discover how physical activity and nutrition affect the human body by conducting a series of hands-on activities and observations.

- Have you ever wondered what it would be like to live and work in space? Check out: A day in the life aboard the International Space Station.

- Bone Density and Muscle Stress in Microgravity: Exercise is an integral part of the astronauts' daily routine aboard the International Space Station. In this STEMonstration, Expedition 53/54 flight engineer Joe Acaba stresses the importance of exercising in orbit and dives into the science behind what happens to bones and muscles in microgravity.

For Plant Growth Experiments:

Classroom Connections

- Do you have what it takes to stay healthy in space? Try developing your own astronaut meal plan! *Eating nutritious food is important to help you grow strong muscles and bones, and to keep you healthy throughout your life. Our bodies need several categories of nutrients. Macronutrients are ones that we need a lot of, like fat, protein, and carbohydrate. Vitamins and minerals are micronutrients which are vital for good health. Consider building your meal plan using MyPlate.*

- **Why do you think it is difficult to grow plants in space? Explain the importance of growing plants in space and for the future of space travel.** *It is difficult to grow plants in space due to microgravity and watering the plants. Plants also take cues from gravity for different aspects of their growth, such as root and stem orientation. Growing plants in space also requires artificial lighting, as opposed to on Earth, where vegetation receives natural lighting. The variety of materials that plants grow in is also different in space. Materials such as clay materials, peat moss and hydroponics are all being experimented with currently on the Space Station. The space to grow plants is also limited on the Station. It is important to learn the best way to grow plants in a microgravity environment as we begin to explore other worlds, such as the moon and Mars, that have lower gravity environments compared to our home planet..*

Additional Resources

- **Nutrition: Watch NASA astronaut Scott Tingle demonstrate the importance of astronaut nutrition on the International Space Station! If you plant it, will it grow in microgravity on the International Space Station? Click here to find out how NASA is using a plant growth system called "Veggie" on the International Space Station to learn how plants respond to microgravity.**

For Adaptive Communications:

Classroom Connections

- **How does sound travel on a string? https://www.nasa.gov/stem-ed-resources/the-astro-not-yets-sound-on- a-string-educator-guide-for-grades-k-2.html**

- **Discuss how the materials affected the sound and ask which combination of materials may create the "best" string cup phone.** *Answers may vary based on the materials provided and your students' exploration of this design challenge.*

Additional Resources

- **The Laser Communications Relay Demonstration, or LCRD, is the next step in optical communications. Optical communications, using infrared lasers to communicate data to and from space, will allow the agency to collect more science data and explore further into the universe than ever before. To learn how, click here.**

Crew Selection:

Classroom Connections

- **What factors contributed to your crew selection?** *Factors include skills that meet the mission requirements, education background, spaceflight experience or military experience.*

- **What type of experience in the biography supports the Astronaut Skills highlighted for each astronaut selected for your mission?** *Answers may vary.*

- **What additional information (beyond what you find in the biography) would you want to consider when assembling an astronaut crew?** *Answers may vary but could include languages spoken, earlier career background, organizations they may volunteer with, team player, etc.*

- **What other types of careers can you find at NASA?** *Each NASA center is like a small city, so any profession that is found in a community, can be found at NASA. Examples include: medical professions, business management, law professionals, engineers, teachers and postal services*.

Additional Resources

- NASA's careers website for students provides information about careers at NASA, astronaut requirements, student internships and more.

- Check out the online astronaut biographies to learn more about each astronaut including a narrative form of the biography, photos, videos, and how to follow them on social media.

- Students can learn more about the Rocket Science: Ride to Station App and careers related to the Commercial Crew Program through the Commercial Crew STEM badge developed by Texas State University for NASA's Educator Professional Development Collaborative.

- Expeditions are journeys made by people who share a definite purpose and specific experiences. To make their expeditions successful, NASA works with astronaut crews on skills that prepare them to live and work together during space missions. Learn more about Expeditionary Skills for Life.

Rocket Assembly:

Classroom Connections

- For more activities related to rocket design, you can explore some classroom activities here: https://www.jpl. nasa.gov/edu/teach/tag/search/Rockets

- Explain the importance of a nose cone and fins on a rocket. Why do you think it is important to test a rocket design in a wind tunnel before constructing the real rocket? *The nose cone and fins on a rocket are designed to minimize air resistance and also make the rocket more stable to prevent it from wobbling as it cuts through the air. A wind tunnel is used in the test of a rocket because it shows how the rocket will behave during flight, and adjustments to the rocket can be made prior to the actual launch.*

Additional Resources

- You can find more on Starliner and the configuration of the Atlas V: https://www/boeing.com/space/starliner/ and https://ulalaunch.com/missions/commercial-crew.

- You can find more on Crew Dragon here: https://www.spacex.com/dragon.

- You can find more on the Falcon 9 here: https://www.spacex.com/falcon9.

Launch:

Classroom Connections

- **Explain why Newton's Laws of Motion are important in the launching of a rocket.** *The first law states that an object at rest will remain at rest or an object in motion will remain in motion, unless it is acted upon by an outside force. A rocket will continue to "rest" on a Launchpad until the engines are fired. The rocket will continue to coast in a straight line through space unless thrusters push the vehicle in one direction or another. The second law states that a force is equal to an object'ss mass multiplied by its acceleration. This law explains how much force will need to be applied to a rocket to launch off of Earth. The third law states that for every action, there is an equal and opposite reaction. A rocket's push against the ground must equal the force needed to get off the ground.*

- **How is the mass of a rocket related to the acceleration needed to escape Earth's gravity?** *Newton's second law states that Force is equal to an objects mass multiplied by its acceleration. In the example of a rocket, you need enough force to accelerate the mass of the entire rocket and spacecraft up into space. You need substantial force because Earth's gravity is constantly pulling everything down. The force to accelerate the rocket needs to be greater than the force of gravity pulling it down.*

Additional Resources

- Explore more about launching and building rockets with the Rocket Educator Guide.

- What is a rocket? Discover rocketry with 5th to 8th grade students in this guide.

- This rocketry educator guide has been developed for students in kindergarten through 4th grade.

- The app doesn't cover the landing process, but it is a critically important part of the process. As part of the broader Commercial Crew Program education effort, a tech heavy twist has been developed for an old classic. In this egg drop challenge, use smart photo and app data to analyze the capabilities of your landing system.

- Several engineering design challenges are contained in this guide about exploring our moon.

- Learn more on engineering design challenges about exploring our Solar System.

- Learn about the importance of thermal protection systems.

- To explore more on parachute design, visit these websites: https://mars.nasa.gov/mer/mission/spacecraft_edl_parachute.html and https://www.nasa.gov/sites/default/files/atoms/files/orion_parachutes.pdf.

Rendezvous and Docking:

Classroom Connections

- **How is moving in space similar to swimming in a pool? What happens when you push off the wall in a pool? Is that similar to how you navigate your crew capsule when docking with the space station?** *In a swimming pool, a person is very close to being neutrally buoyant, like in space. If that person were to push off the side of a pool, they will float away in the opposite direction. The same thing happens in space. If an astronaut pushes off the wall inside the Space Station, they would float in the opposite direction, just like in a swimming pool. When navigating the crew capsule to the space station, the same principle applies. If the capsule needs to move down, thrusters need to fire up. To move left, thrusters fire right. For every action, there must be an equal and opposite reaction.*

- **Explain the motion of the spacecraft using Newton's third law of motion.** *Newton's 3rd law states that for every action (force) there is an equal and opposite reaction. This principle helps explain how the commercial crew spacecraft moves in space. Just like the space station, the commercial crew spacecraft would continue coasting along in orbit if only gravity were acting on it. Using the orbital maneuvering system, which are small rocket engines or thrusters located around the outside of the vehicle, to apply a force, the spacecraft can move in any direction. The space station also uses thrusters occasionally to stay in orbit around the Earth.*

Additional Resources

- **Crew Orbital Docking (CODing) Simulation - Create your own simulation of a commercial crew spacecraft docking with the International Space Station using a block-based programming language like Scratch or Snap! https://www.nasa.gov/stem-ed-resources/crew-orbital-docking-simulation-coding-sim.html**

- **Learn about the history of the first space rendezvous and the importance of autonomy for the future of space travel here.**

- **Learn more about science experiments on the International Space Station here.**

- **Did you know that you can see the Space Station when it moves over your house? Sign up here!**

- **Explore the Humans in Space website here.**

- **Space Station Facts and Figures can be found on this website.**

- **Other NASA apps including Space Station Research and Science Investigations can be found here.**

App Tutorial and Script

To begin, you'll either click "Click/Touch to Start" or the small gear icon in the bottom right hand corner of the screen. The gear icon brings up a menu that allows you to adjust the music volume and FX volume.

Once you click “Click/Touch to Start”, you will be given the option to select the difficulty level. The primary differences between the various levels is when assembling the rocket and docking to the space station.

Partner Selection

App Tutorial

Select a crew capsule to carry astronauts to low-Earth orbit and the International Space Station. There are two choices, Boeing’s CST-100 Starliner or SpaceX’s Crew Dragon. Choosing a capsule requires a diversified approach. Much like Boeing and SpaceX, the user must consider multiple ways to solve a problem. This is the ultimate engineering design challenge! NASA gave a clear end goal and established criteria they would use to judge the ideas and concepts that were submitted by the commercial partners. Each company was responsible for asking questions, imagining solutions, planning designs, creating and testing models, and making improvements to prove they had a realistic, achievable path to success. Boeing’s CST-100 Starliner and SpaceX’s Crew Dragon each have unique characteristics that prioritize crew safety and survival, including launch pad emergency escape and egress systems. Now it’s your turn to choose a capsule for your mission that will successfully launch and dock with the International Space Station!

Boeing

The CST-100 Starliner capsule is Boeing's commercial crew transportation spacecraft. CST stands for Crew Space Transportation and 100 represents the Kármán line, the unofficial line separating Earth and space at an altitude of 100 kilometers. Other characteristics include:

- Seats up to 7 passengers but will carry up to four astronauts and about 220 pounds of cargo and supplies for NASA missions.
- Leverages decades of heritage in human spaceflight and new technologies to make a safe and reliable vehicle.
- The Starliner's main components include the crew module and the service module.
- Is reusable up to 10 times with a six-month processing turnaround time.
- Is equipped with the ability to autonomously fly and dock with the space station.
- It will launch atop a United Launch Alliance (ULA) Atlas V rocket-powered RD-180 main engine from Launch Complex 41 at Cape Canaveral Air Force Station in Florida.
- Contains four launch abort engines which would fire between 3 and 5.5 seconds in the event of an abort scenario, carrying the spacecraft and crew away from the rocket.
- Uses a proven parachute and airbag system for shock absorption in order to land on the ground.

SpaceX

The Crew Dragon capsule is SpaceX's commercial crew transportation spacecraft. The Crew Dragon is designed to deliver cargo and people to orbiting destinations with the capability of autonomously docking with the International Space Station. Featuring three windows, spacious seating and an advanced emergency escape system, the Crew Dragon can be monitored and controlled by on-board astronauts and SpaceX mission control. Other characteristics include:

- Carries up to seven passengers but will carry up to four astronauts and about 220 pounds of cargo and sup-plies for NASA missions.
- Crew Dragon's displays provide real-time information and communication systems to maximize safety and mission success.
- Is composed of two main elements: the capsule and the trunk.
- Is designed with crew and reuse in mind and boasts an innovative achievement worthy of the challenge to advance human spaceflight.
- Is equipped with the ability to autonomously fly and dock with the space station.
- Crew Dragon will fly on top of a SpaceX Falcon 9 rocket and will launch from Launch Complex 39A at Kennedy Space Center in Florida.
- Contains an advanced abort system with eight SuperDraco engines and a series of parachutes that can be activated instantaneously from the moment they are armed on the launch pad through orbital insertion.
- Designed for water landings with the primary splashdown location in the Atlantic Ocean off the coast of Cape Canaveral, Florida and the secondary splashdown location in the Gulf of Mexico.

Script

Capsule Select - "Welcome to Rocket Science: Ride to Station! I'm NASA astronaut Suni Williams and I'm a part of an astronaut team training to fly to the International Space Station. NASA's working with two different commercial companies, Boeing and SpaceX, to develop two new space transportation systems for astronauts to fly to low-Earth orbit. Want to help us get to station? Select a spacecraft to get started."

CST-100 Dossier - "This is the CST-100 Starliner spacecraft. It is built by Boeing to fly astronauts to and from the International Space Station. For NASA, the Starliner will take up to four astronauts and cargo, like scientific research, to the microgravity laboratory in low-Earth orbit. Starliner will fly on top of a United Launch Alliance Atlas V rocket from Space Launch Complex 41 on Cape Canaveral Air Force Station in Florida."

Crew Dragon Dossier - "This is the CST-100 Starliner spacecraft. It is built by Boeing to fly astronauts to and from the International Space Station. For NASA, the Starliner will take up to four astronauts and cargo, like scientific research, to the microgravity laboratory in low-Earth orbit. Starliner will fly on top of a United Launch Alliance Atlas V rocket from Space Launch Complex 41 on Cape Canaveral Air Force Station in Florida."

Mission Selection

App Tutorial

Mission selection follows partner selection. Here you will choose a mission based on topics of interest and the set of requirements shown. Be sure to click the information icon in the top right corner for a Briefing Tutorial to learn more.

Script

Missions to Select From:

- **Satellite Deployment:** Micro-satellites, called CubeSats, are delivered to the space station for a wide array of science activities. You will utilize the Japanese Experiment Module Robotic Manipulator System, a robotic arm, to aim and release the satellites into the correct orbit.

- **Meteorological Survey:** Data from science instruments that have been deployed on the space station needs to be analyzed. Gather temperature and moisture data from these sensors to improve weather forecasts and diagnose severe storms on Earth.

- **Personnel Exchange:** Your six months on station are ending – it's time to make sure station is in top shape for the next crew. The to-do list includes checking equipment and performing necessary maintenance and repairs before the next group arrives.

- **Solar Foil Repairs:** You'll have to strap on to the Canadarm2 and rely on a crewmate to position you to repair a torn solar array. This task requires some creativity as you won't know the extent or type of damage until you get out there.

- **Exterior Retrofitting:** Humanity's most amazing laboratory is fully assembled but still requires maintenance. Conduct repairs and install new hardware outside the International Space Station that are critical to maintaining the orbital outpost.

- **Chemistry Experiments:** Fire behaves differently in space, so proceed carefully! Study interactions of fuel vaporization, radiative heat loss, and other factors to determine how to extinguish flames in space and how to improve combustion on Earth.

- **Microgravity Biology:** Study the science of biology in microgravity to open a world of possibilities! Examine cell growth, bacteria threat level, and strength in human bones. Your work will help scientists translate findings into treatments for a variety of diseases and enable long duration, human exploration missions.

- **Plant Growth Experiments:** Freshly grown food is not easy to come by in space. For humans to survive long duration exploration missions, you need to figure out how to grow healthy, nutritional food on orbit. Use the Advanced Plant Habitat to increase our growing research portfolio.

- **Adaptive Communications:** Use feedback signals to maintain critical communication with Earth and test the technologies needed to communicate from deep space.

Crew Selection

App Tutorial

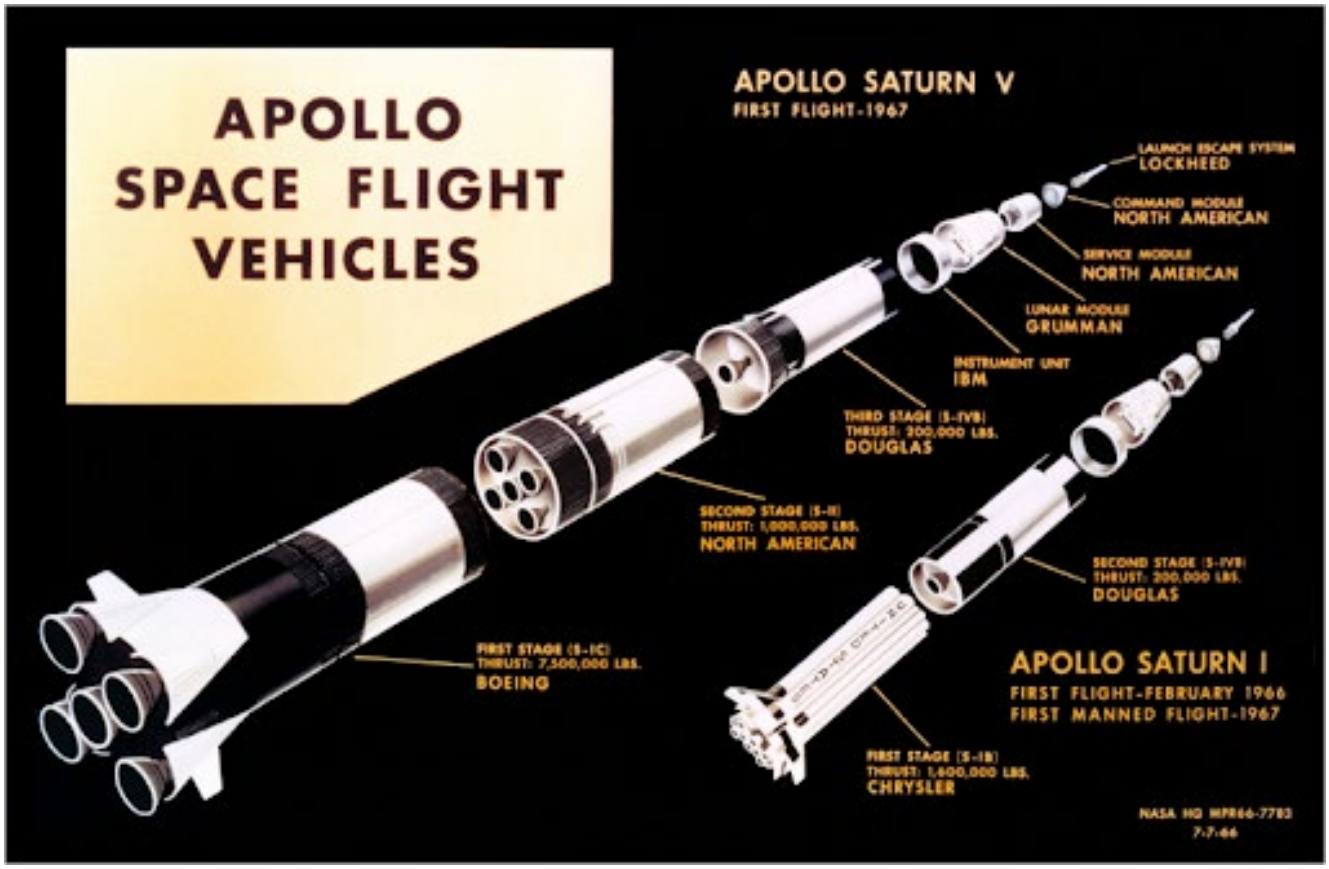
Crew Selection follows Mission Selection. The purpose of Crew Selection is to choose up to four out of the 39 current NASA astronauts (as of Spring 2019) with the combination of skills to meet the mission requirements. Click the green plus sign to add each crew member.

Click “Next Astronaut Group” or “Previous Astronaut Group” to cycle through the 8 sets of astronauts in the As- tronaut Selector. Click on the astronaut headshot in the Astronaut Selector to toggle amongst astronaut biogra- phies within a set. In the biography for each astronaut, you will find background information including education, spaceflight experience, and military experience.

Use the Astronaut Skills icons to quickly identify crew members with skills matching those required by the mission.

Crew members can also be removed by clicking the red minus sign. Not all seats must be filled. You will be able to continue to the next step after meeting all of the Mission Requirements.

Rocket Assembly
App Tutorial



Almost every rocket has multiple “stages”. A stage, in general, is a portion of the rocket that can be separated while still allowing the rest of the rocket to function correctly. For the Saturn V, there were three stages. During liftoff, only the bottom most stage fired its engines. Then once the first stage was empty of fuel, it was released by the rest of the rocket and the second stage would ignite its engines to continue the journey.

That’s important to remember when working through this part of the app. All of the parts of the rockets are either major elements of a stage, connection points between stages, or the spacecraft itself.

Initial instructions: “Drag the highlighted part on the left to its proper position on the rocket.”

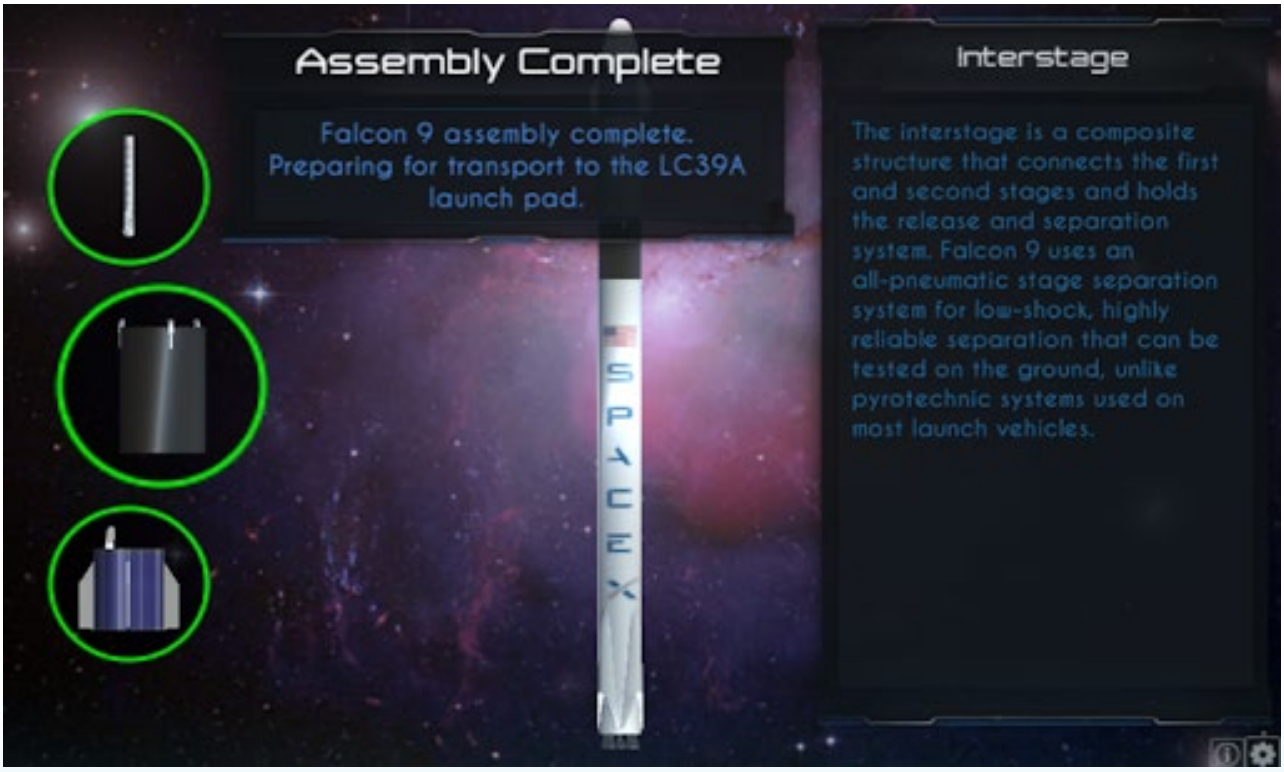
On the left hand side of the screen you will find a series of rocket/spacecraft components that have to be “stacked” (a word often used to discuss the assembling of a rocket) to form the completed rocket with the spacecraft.

Not all components are visible on screen at once. You can cycle through this list to see nine parts for the Atlas V/ Starliner and five parts for the Falcon 9/Crew Dragon.

When a piece appears in the middle on the left side of the screen, it will have a blue highlight on its circle and corresponding data will appear in the text box to the right. Only the piece that is highlighted with the blue circle can be stacked. To rotate through the list, click on either the rocket part at the top or bottom.

In the middle you will see the silhouette of the rocket where the pieces from the left must be dragged to in order to successfully stack the rocket. As each piece is added, it will be highlighted on the left with a green circle.

Once all pieces are correctly placed, you will receive a message that assembly is complete. After a few seconds, the app will reload with the launch pad in the distance, ready to fly!



Script

ATLAS V

Atlas rockets have evolved over four decades to become the Atlas V rocket that is used today. John Glenn became the first U.S. astronaut to orbit the Earth after being launched on a heritage Atlas LV-3B rocket from Cape Canaveral, Florida, in 1962. For Starliner missions to station, Boeing will use the Starliner Configuration of the Atlas V.

Configuration Breakdown:
RD-180: The first stage booster will deliver more than 860,000 pounds of thrust at liftoff and a range of continuous throttling capability. The liquid oxygen/liquid kerosene, two-thrust-chamber RD-180 engine is a complete propulsion unit equipped with hydraulics for control valve actuation and thrust vector gimbaling, pneumatics for valve actuation and system purging, and a thrust frame to distribute loads.

Atlas V Booster: The Atlas V Common Booster Core is the first stage of the Atlas V family of rockets produced and operated by United Launch Alliance. It stands 106 feet tall with a 12.5-foot diameter, and houses the combination liquid oxygen/liquid kerosene fuel to power the RD-180 engine at its base.

Solid Rocket Boosters: A pair of solid rocket boosters, or SRBs, will be used along with the core stage and RD- 180 engine to provide enough thrust to achieve liftoff on the way to orbit. Each SRB is capable of approximately 380,000 pounds of thrust, for a total of over 1.6 million pounds of thrust at liftoff. The Atlas V SRBs are manufactured by Aerojet and use the world's largest monolithic filament-wound carbon composite case.

400 Series Interstage Adapter: The interstage adapter connects the first and second stage while leaving a safe amount of room between the second stage engine and the top of the propellant tanks on the first stage. The adapter is built to be strong enough to manage the forces of launch without buckling, but it also has to be as light as possible. It is jettisoned along with the first stage on the Atlas V.

Dual Engine Centaur: For Starliner missions, the Centaur upper stage will fly with two RL10A-4-2 engines, offering more thrust to accommodate Starliner. The engines also help shape the ascent trajectory to station.

Emergency Detection System: This system monitors various launch vehicle parameters to determine the health of the rocket, and provides a capability to take action by signaling an abort command so the Starliner can escape, if necessary.

Launch Vehicle Adapter and Aeroskirt: The launch vehicle adapter (LVA) provides the structural attachment of the Starliner capsule to the Atlas V rocket. The LVA uses a truss structure and metallic ring to attach the spacecraft to the Centaur upper stage of the Atlas V. ULA also designed a 70-inch-long aeroskirt to extend Starliner's aerodynamic surface, which enhances the aerodynamic characteristics, stability, and loads of the Atlas V for the unique crew configuration.

Stats
- Height: 62.5 meters (205 feet)
- Diameter: 3.81 meters (12.5 feet)
- Mass: 21,173 kilograms (46,678 pounds)
- Stages: Two

FALCON 9

Falcon 9 is a two-stage rocket designed and manufactured by SpaceX for the reliable and safe transport of satellites and the Dragon spacecraft into orbit. Falcon 9 is the first orbital class rocket capable of reflight. Fal- con 9 made history in 2012 when it delivered Dragon into the correct orbit for rendezvous with the International Space Station, making SpaceX the first commercial company to visit the station. Since then, Falcon 9 has made numerous trips to space, delivering satellites to orbit as well as delivering and returning cargo from the space station for NASA. Falcon 9, along with the Dragon spacecraft, was designed from the outset to deliver humans into space, and under an agreement with NASA, SpaceX is actively working toward this goal.

Falcon 9's first stage incorporates nine Merlin engines and aluminum-lithium alloy tanks containing liquid oxygen and rocket-grade kerosene (RP-1) propellant. After ignition, a hold-before-release system ensures that all engines are verified for full-thrust performance before the rocket is released for flight. Then, with thrust greater than five 747s at full power, the Merlin engines launch the rocket to space. Unlike airplanes, a rocket's thrust actually increases with altitude; Falcon 9 generates more than 1.7 million pounds of thrust at sea level and produces over 1.8 million pounds of thrust in the vacuum of space. The first stage engines are gradually throttled near the end of first-stage flight to limit launch vehicle acceleration as the rocket's mass decreases with the burning of fuel.

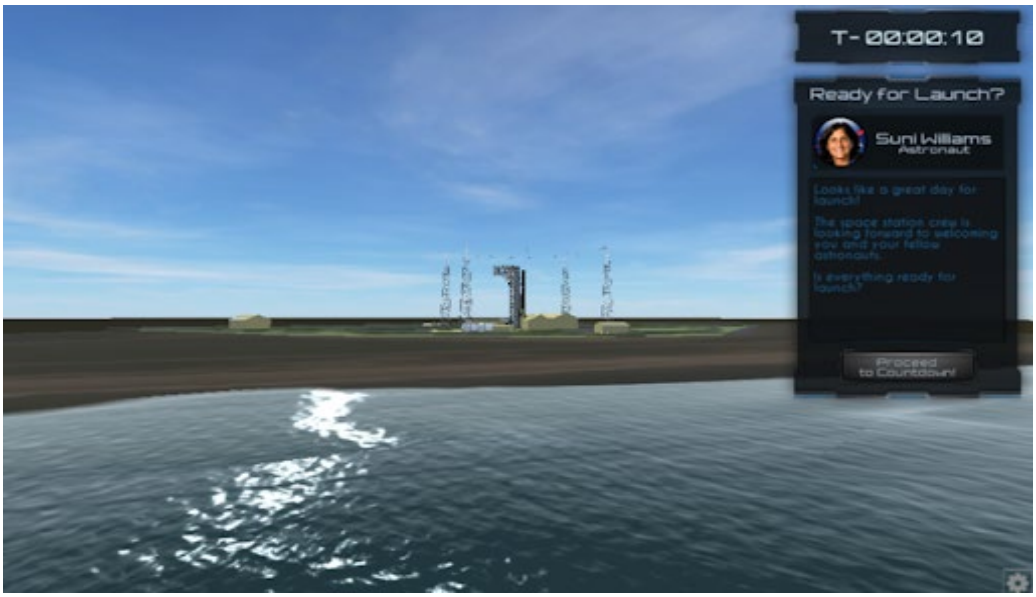
The interstage is a composite structure that connects the first and second stages and holds the release and separation system. Falcon 9 uses an all-pneumatic stage separation system for low-shock, highly reliable separation that can be tested on the ground, unlike pyrotechnic systems used on most launch vehicles. Falcon 9 is equipped with an Autonomous Flight Termination System to be used in the unlikely event that the rocket drifts off course or becomes unresponsive. Carbon fiber landing legs and hypersonic grid fins, all stowed during ascent, are two of the critical elements essential to ensure safe and successful landing of the Falcon 9 first stage.

Technical Overview

- Height: 70 meters or 229.6 feet
- Mass: 549,054 kilograms or 1,207,920 pounds
- Payload to LEO: 22,800 kilograms or 50,265 pounds
- Diameter: 3.7 meters or 12 feet

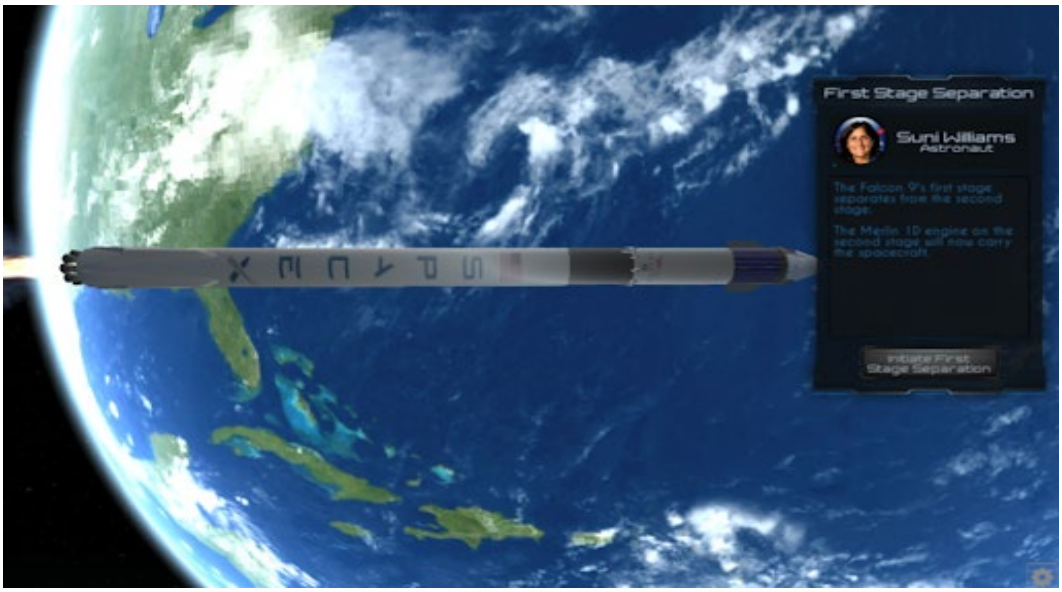
Launch
App Tutorial

Once the application finishes loading, there is a message from Suni Williams on the right with only a single option of what to do next: click “Proceed to Countdown.”



You’ll then zoom up on the launch pad and have to click “Go for Launch!” to start the countdown. At T-0 (pronounced tee minus zero) the engines ignite and the rocket launches on its way to the International Space Station.

Once on orbit around the Earth, you will see the rocket and a series of instructions provided by Suni. This next series of events is sometimes referred to as “staging”. What transpires is that the first stage of the rocket will be empty of fuel (meaning its usefulness is over) and that portion will be released by the upper stage of the rocket. Releasing that extra mass helps the rocket to be more efficient in space.



Click the buttons in the window on the right and watch the rocket change from its original configuration to only the spacecraft that will dock with the space station.

Rendezvous and Docking

App Tutorial

A rendezvous is a meeting time and place. The commercial crew spacecraft will rendezvous with the International Space Station in orbit approximately 400 km (250 miles) above Earth traveling over 7600 m/s (17000 mph). Then a series of orbital maneuvers is required to adjust horizontal and vertical alignment, maintain relative speed, and safely approach the space station for docking. Both commercial crew spacecraft were designed to be fully autonomous (automatic) but have controls for manual override in case of contingencies. The docking system allows you to select either manual or automatic mode for docking or toggle between them to make adjustments. Use the Information Panel on the left to monitor speed, distance, pitch, yaw, and roll. Use the Capsule Controller on the right to engage the thrusters which move the spacecraft with six degrees of freedom. First, align the capsule with the docking port using the outermost arrows to adjust the pitch, yaw, and roll. They must be as close to zero as possible for successful alignment which will turn the sensors green on the Information Panel. Then move forward with an acceptable speed to slowly approach the space station for docking. If you are not successful, the crew will abort and try again. You are also able to view different angles of the docking procedure by clicking the windows in the upper right (Side View) or the upper left (Top Down View).

Script

You have successfully docked with the International Space Station! Your mission is complete. Thank you for playing!