National Aeronautics and Space Administration

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SPACEX CRS-1 MISSION

First Cargo Resupply Services Mission

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SPACEX

SpaceX CRS-1 Mission Press Kit

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HIGH RESOLUTION PHOTOS AND VIDEO

SpaceX will post photos and video throughout the mission.

High-resolution photographs can be downloaded from: spacexlaunch.zenfolio.com
Broadcast quality video can be downloaded from: vimeo.com/spacexlaunch/videos

MORE RESOURCES ON THE WEB

For SpaceX coverage, visit:

spacex.com
twitter.com/elonmusk
twitter.com/spacex
facebook.com/spacex
plus.google.com/+SpaceX
youtube.com/spacex

For NASA coverage, visit:

www.nasa.gov/station
www.nasa.gov/nasatv
twitter.com/nasa
facebook.com/ISS
plus.google.com/+NASA
youtube.com/nasatelevision

WEBCAST INFORMATION

The launch will be webcast live, with commentary from SpaceX corporate headquarters in Hawthorne, CA, at spacex.com/webcast, and NASA's Kennedy Space Center at www.nasa.gov/nasatv.

NASA TV and web coverage will begin pre-launch coverage at 7:00PM EDT.

The SpaceX webcast will begin approximately 40 minutes before launch.

SpaceX CRS-1 Mission Overview

Overview

On the heels of a successful debut flight to the International Space Station in May, SpaceX is set to launch its next Dragon resupply mission to the orbital outpost. Launch of this first commercial resupply mission (SpaceX CRS-1) to the complex is set for 8:35PM EDT Sunday, October 7 from Launch Complex 40 at the Cape Canaveral Air Force Station, Florida.

If all goes as planned, Dragon will arrive at the station on Wednesday, October 10, when it will be grappled and berthed to the complex for an expected two-week visit. Dragon is scheduled to return to Earth on October 28 for a parachute-assisted splashdown off the coast of southern California. Dragon is the only space station cargo craft capable of returning a significant amount of supplies back to Earth, including experiments.

Dragon will be filled with about 1,000 pounds of supplies, including critical materials to support the 166 investigations planned for the station's Expedition 33 crew, of which 63 will be new. Dragon will return with about 734 pounds of scientific materials, including results from human research, biotechnology, materials and education experiments, as well as about 504 pounds of space station hardware.

Background and Purpose

SpaceX CRS-1 is the first of at least 12 missions to the International Space Station that SpaceX will fly for NASA under the Commercial Resupply Services (CRS) contract. In December 2008, NASA announced that SpaceX's Falcon 9 launch vehicle and Dragon spacecraft had been selected to resupply the space station after the end of the space shuttle program in 2011. Under the CRS contract, SpaceX will restore an American capability to deliver and return significant amounts of cargo, including science experiments, to the orbiting laboratory – a capability not available since the retirement of the space shuttle.

Building on Success

Prior to this flight, SpaceX successfully completed two demonstration flights using Falcon 9 and Dragon under NASA's Commercial Orbital Transportation Services (COTS) program. The second of those missions, from May 22–31, 2012, marked the first time that a private company had launched a spacecraft into orbit, successfully attached to the station, delivered a payload, and returned safely to Earth—a highly challenging technical feat previously accomplished only by governments.

A Challenging Mission

All spaceflight is incredibly complicated, from launch to recovery. Every component of the mission must operate optimally. Hardware, avionics, sensors, software and communications must function together flawlessly. If any aspect of the mission is not successful, SpaceX and NASA will learn from the experience and try again.

Prelaunch

Months before a Falcon 9 launch, both rocket stages and Dragon are transported to SpaceX's development facility in McGregor, Texas for testing, and then trucked individually to SpaceX's hangar at Space Launch Complex 40 at Cape Canaveral, Florida. There, the stages are integrated and Dragon receives its cargo. About a month before launch, SpaceX conducts a wet dress rehearsal of Falcon 9, which simulates the launch countdown and verifies that all ground and launch systems are launch-ready. At that time, a crane/lift system moves Falcon 9 into a transporter-erector system and the vehicle is rolled from hangar to launch pad on fixed rails. The rocket is raised to vertical and both stages fueled as they would be for launch. The final major preflight test is a static fire, when Falcon 9's nine first-stage engines are ignited for a few seconds, with the vehicle held securely to the pad.

Key NASA and SpaceX personnel collaborate on the design of the rendezvous profile, including both the timing and path of Dragon's approach to the space station, and work together to identify, process and pack the NASA and international partner cargo that is to be delivered to and from the station. About two weeks before launch, a formal Stage Operations Readiness Review is conducted, involving representatives from all five of the space station's international partner agencies: NASA, the Canadian Space Agency (CSA), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and the Russian Federal Space Agency (Roscosmos), to ensure the launch vehicle, spacecraft, cargo, space station, and launch and operations teams are ready for the mission.

On launch day, Falcon 9, with Dragon mated, is again transported to the launch pad. All ground personnel leave the pad in preparation for fueling, which proceeds automatically.

Launch Sequence

The launch sequence for Falcon 9 is a process of clockwork precision necessitated by the rocket's instantaneous launch window—that is, everything is timed to the exact second of scheduled liftoff. Because an off-time liftoff would require Dragon to use extra propellant to reach the space station, the launch window must be hit precisely. If not, the mission will be attempted on another day.

Seven and a half hours before launch, Falcon 9 and Dragon are powered up—systems activated and computers turned on. A little less than four hours before launch, the fueling process begins—liquid oxygen first, then RP-1 kerosene propellant. The plume coming off the vehicle during countdown is gaseous oxygen being vented from the tanks, which is why the liquid oxygen is topped off throughout the countdown.

Terminal countdown begins at T-10 minutes and 30 seconds, at which point all systems are autonomous. After polling Mission Control in Houston, Texas, and the launch team in Hawthorne, California, the launch director gives a final go for launch at T-two minutes and 30 seconds. The Air Force range safety officer confirms the physical safety of the launch area and range. One minute before launch, the flight computer is activated. Fifty-five seconds before liftoff, the launch pad's water deluge system, dubbed "Niagara," is activated. Its purpose is to suppress acoustic waves that radiate from the engine plumes, thereby mitigating the effect of vibration on the rocket. Fifty-three water nozzles set low on the launch pad provide a curtain of water flowing at 113,500 liters (30,000 gallons) a minute. The system is deactivated within 20 seconds of T-0.

Three seconds before launch, the nine Merlin engines of the first stage ignite. The rocket computer commands the launch mount to release the vehicle for flight, and at T-0:00 Falcon 9 lifts off, putting out 850,000 pounds of thrust.

Flight

At one minute, 10 seconds after liftoff, Falcon 9 reaches supersonic speed. The vehicle will pass through the area of maximum aerodynamic pressure—max Q—10 seconds later. This is the point when mechanical stress on the rocket peaks due to a combination of the rocket's velocity and resistance created by the Earth's atmosphere.

Around two and a half minutes into the flight, two of the first-stage engines will shut down to reduce the rocket's acceleration. (Its mass, of course, has been continually dropping as its propellants are being used up.) At this point, Falcon 9 is 90 kilometers (56 miles) high, traveling at 10 times the speed of sound. The remaining engines will cut off shortly after—an event known as main-engine cutoff, or MECO. Five seconds after MECO, the first and second stages will separate. Seven seconds later, the second stage's single Merlin vacuum engine ignites to begin a six-minute, 14-second burn that brings Dragon into low-Earth orbit.

Forty seconds after second-stage ignition, Dragon's protective nose cone, which covers Dragon's berthing mechanism, will be jettisoned. At the nine minute, 14 second mark after launch, the second-stage engine cuts off (SECO). Thirty-five seconds later, Dragon separates from Falcon 9's second stage and seconds later, Dragon will reach its preliminary orbit. It then deploys its solar arrays, and begins a carefully choreographed series of Draco thruster firings to reach the space station.

Approach to Station

As Dragon chases the station, the spacecraft will establish UHF communication using its COTS Ultra-high-frequency Communication Unit (CUCU). Also, using the crew command panel (CCP) on board the station, the expedition crew will interact with Dragon to monitor the approach. This ability for the crew to send commands to Dragon will be important during the rendezvous and departure phases of the mission.

During final approach to the station, a go/no-go is performed by Mission Control in Houston and the SpaceX team in Hawthorne to allow Dragon to perform another engine burn that will bring it 250 meters (820 feet) from the station. At this distance, Dragon will begin using its close-range guidance systems, composed of LIDAR and thermal imagers. These systems will confirm that Dragon's position and velocity are accurate by comparing the LIDAR image that Dragon receives against Dragon's thermal imagers. The Dragon flight control team in Hawthorne, with assistance from the NASA flight control team at the Johnson Space Center's International Space Station Flight Control Room, will command the spacecraft to approach the station from its hold position.

After another go/no-go is performed by the Houston and Hawthorne teams, Dragon is permitted to enter the Keep-Out Sphere (KOS), an imaginary circle drawn 200 meters (656 feet) around the station that prevents the risk of collision. Dragon will proceed to a position 30 meters (98 feet) from the station and will automatically hold. Another go/no-go is completed. Then Dragon will proceed to the 10-meter (32 feet) position—the capture point. A final go/no-go is performed, and the Mission Control Houston team will notify the crew they are go to capture Dragon.

Capture and Berthing

At that point, Expedition 33 crew member Akihiko Hoshide of the Japan Aerospace Exploration Agency will use the station's 17.6-meter (57.7-foot) robotic arm to reach for and grapple the Dragon spacecraft. Hoshide, with the help of Expedition 33 Commander Sunita Williams of NASA, will guide Dragon to the Earth-facing side of the station's Harmony module. About two hours after it is grappled, Williams and Hoshide will swap places and Williams will gently install Dragon to Harmony's Common Berthing Mechanism, enabling it to be bolted in place for its stay at the International Space Station.

The next day, crew will pressurize the vestibule between the station and Dragon and will open the hatch that leads to the forward bulkhead of Dragon.

Over the next two and a half weeks, the crew will unload Dragon's payload and reload it with cargo that Dragon will bring back to Earth.

Return Flight

After its mission at the orbital laboratory is completed, newly arrived Expedition 33 Flight Engineer Kevin Ford will use the Canadarm2 robotic arm to detach Dragon from Harmony, maneuver it out to the 15-meter release point, and release the vehicle. Dragon will perform a series of three burns to place it on a trajectory away from the station. Mission Control Houston then will confirm that Dragon is on a safe path away from the complex.

Approximately six hours after Dragon leaves the station, it will conduct its deorbit burn, which lasts up to 10 minutes. It takes about 30 minutes for Dragon to reenter the Earth's atmosphere, allowing it to splash down in the Pacific Ocean, about 450 kilometers (250 miles) off the coast of southern California.

Dragon Recovery

Dragon's landing is controlled by automatic firing of its Draco thrusters during reentry. In a carefully timed sequence of events, dual drogue parachutes deploy at 13,700 meters (45,000 feet) to stabilize and slow the spacecraft.

Full deployment of the drogues triggers the release of the three main parachutes, each 35 meters (116 feet) in diameter, at about 3,000 meters (10,000 feet). While the drogues detach from the spacecraft, these main parachutes further slow the spacecraft's descent to approximately 4.8 to 5.4 meters per second (16 to 18 feet). Even if Dragon were to lose one of its main parachutes, the two remaining chutes would still permit a safe landing.

SpaceX will use a 100-foot boat equipped with an A-frame and an articulating crane, a 90-foot crew boat for telemetry operations, and two 24-foot rigid-hull inflatable boats to perform recovery operations. On board will be approximately a dozen SpaceX engineers and technicians as well as a four-person dive team. Once Dragon splashes down, the team will first secure the vehicle and then place it on deck for the journey back to shore.

SpaceX CRS-1 Mission Timeline

Times and dates are subject to change

Day 1: LAUNCH

COUNTDOWN

Hour/Min/Sec	Events
- 7:30:30	Vehicles are powered on
- 3:50:00	Commence loading liquid oxygen (LOX)
- 3:40:00	Commence loading RP-1 (rocket grade kerosene)
- 3:15:00	LOX and RP-1 loading complete
- 0:10:00	Falcon 9 and Dragon terminal count autosequence started
- 0:02:30	SpaceX Launch Director verifies go for launch
- 0:02:00	Range Control Officer (USAF) verifies range is go for launch
- 0:01:00	Command flight computer to begin final prelaunch checks. Turn on pad deck and Niagara water
- 0:00:40	Pressurize propellant tanks
- 0:00:03	Engine controller commands engine ignition sequence to start
0:00:00	Falcon 9 launch

LAUNCH

Hour/Min/Sec	Events
0:01:25	Max Q (moment of peak mechanical stress on the rocket)
0:03:00	1st stage engine shutdown/main engine cutoff (MECO)
0:03:05	1st and 2nd stages separate
0:03:12	2nd stage engine starts
0:03:52	Dragon nose cone jettisoned
0:09:11	2nd stage engine cutoff (SECO)
0:09:46	Dragon separates from 2nd stage

DRAGON ON-ORBIT OPERATIONS IN THE FAR FIELD

Hour/Min/Sec	Events
0:11:45	Start sequence to deploy solar arrays
2:26:49	Start GNC (guidance and navigation control) bay door deployment—this door holds sensors necessary for rendezvous

Day 2: DRAGON PHASING – DRAGON BEGINS APPROACH TO SPACE STATION

- Coelliptic burn places Dragon in a circular orbit

Day 3: HEIGHT ADJUST MANEUVERS TO R-BAR AND CAPTURE

(R-Bar - Radial Bar - is an imaginary line connecting station to the center of the Earth)

- Height adjust burns start adjusting altitude higher toward station
- COTS Ultra-high Frequency Communication Unit (CUCU) and on-board UHF communication system between Dragon and ISS is configured
- Height adjust burn: Dragon begins burns that bring it within 2.5 km of station (go/no-go)
- Dragon receives and sends information from/to the CUCU unit on station
- Height adjust burn brings Dragon 1.2 km from station (go/no-go)
- Height adjust burn carries Dragon into the station's approach ellipsoid (go/no-go)
- Dragon holds at 250 meters (go/no-go) for confirmation of proximity sensors targeting acquisition
- Dragon begins R-Bar Approach
- Dragon holds at 30 meters (go/no-go)
- Dragon holds at capture point, 10 meters below the station (go/no-go)
- Crew captures Dragon using the station's robotic arm (SSRMS)
- Dragon is attached to the station

Day 4: HATCH OPENING

- Hatch is opened

RETURN DAY -1

- Hatch is closed
- Dragon vestibule de-mate and depressurization

RETURN

- Station's robotic arm uninstalls Dragon
- Robotic arm releases Dragon
- Crew commands the departure
- Dragon starts departure burns
- Dragon closes the guidance, navigation, and control bay door
- Deorbit burn
- Trunk jettisoned
- Drogue chutes deployed
- Main chutes deployed
- Dragon lands in water and is recovered

SpaceX CRS-1 Manifest

USOS (U.S. On-Orbit Segment) Cargo

LAUNCH

Crew Supplies	260 pounds (118 kilograms)
• 8 Bulk Overwrap Bags	• Food, about 29 Bonus food rations
• 5 bags low sodium food kits	• About 22 rations
• Crew clothing	• 8.8 pounds (4 kilograms)
• Pantry items (batteries, etc)	• 8.8 pounds (4 kilograms)
• Official Flight Kit	• 17.6 pounds (8 kilograms)

Utilization Payloads	390 pounds (177 kilograms)
• **US**	**National Aeronautics and Space Agency and U.S. National Laboratory**
o GLACIER	o General Laboratory Active Cryogenic ISS Experiment Refrigerator, ultra-cold freezers that will store samples at temperatures as low as - 301 degrees F (-160 degrees C).
o Fluids and Combustion Facility Hardware	o Fluids Integrated Rack (FIR) is a complementary fluid physics research facility designed to host investigations in areas such as colloids, gels, bubbles, wetting and capillary action, and phase changes, including boiling and cooling.
o CGBA/Micro-6	o Commercial Generic Bioprocessing Apparatus-Micro-6 looks at responses of Candida albicans to spaceflight, studying how microgravity affects the health risk posed by the opportunistic yeast Candida albicans.
o AMS Cables	o Cables for Alpha Magnetic Spectrometer.
o CFE-2	o Capillary Flow Experiments - 2 (CFE-2) is a suite of fluid physics experiments that investigates how fluids move up surfaces in microgravity. The results aim to improve current computer models that are used by designers of low gravity fluid systems and may improve fluid transfer systems for water on future spacecraft.
o MISSE-8 Retrieval Bag	o Materials on International Space Station Experiment - 8 (MISSE-8) is a test bed for materials and computing elements attached to the outside of the station.
o Double Cold Bags	o Two bags, used to refrigerate samples for transport.

Utilization Payloads	390 pounds (177 kilograms)
• **JAXA**	**Japan Aerospace Exploration Agency**
o EPO-10	o Education Payload Operations-10 (Blue Earth Gazing) records video education demonstrations highlighting various fundamental scientific principles performed by crewmembers using hardware already onboard the station.
o Resist Tubule	o Role of Microtubule-Membrane-Cell Wall Continuum in Gravity Resistance in Plants (Resist Wall) investigation was conducted to determine the importance of the structural connections between microtubules, plasma membrane, and the cell wall as the mechanism of gravity resistance.
o Ammonia Test Kit	
• **ESA**	**European Space Agency**
o Biolab	o Biological Experiment Laboratory in Columbus (BioLab) is a multiuser research facility located in the European Columbus laboratory. It will be used to perform space biology experiments on microorganisms, cells, tissue cultures, small plants, and small invertebrates.
o Energy	o Astronaut's Energy Requirements for Long-Term Space Flight (Energy) will measure changes in energy balance in crew members.

Vehicle Hardware	225 pounds (102 kilograms)
• Caution and Data Handling items	Compound Specific Analyzer-Combustion Products
• CHeCS	Crew Health Care System • Compound Specific Analyzer-Combustible Products • Environmental Health System
• ECLSS	Environmental and Closed Loop Life Support Systems • Ion Exchange Bed • Advanced Recycle Filter Tank Assembly filters
• EPS	Electrical Power System
• TCS	Thermal Control System
• ESA	Cabin Filter Automated Transfer Vehicle (ATV) Cabin Fan
• JAXA	Pump package

Computers and Supplies	7 pounds (3.2 kilograms)
• Miscellaneous	Hard drives and CD case

Total Cargo Up Mass	882 pounds (400 kilograms)
Total Mass w/Packaging	1995 pounds (905 kilograms)

RETURN

Crew Supplies	163 pounds (74 kilograms)
	• Crew preference items
	• Official flight kit items
	• ESA PAO items
	• Flight Crew Equipment

Utilization Payloads	866 pounds (393 kilograms)
• **US**	
o Double Cold Bags	o Five cold bags, used to refrigerate samples for transport.
o SPHERES / YouTube Spacelab	o Educational Experiments
o UMS	o Urine Monitoring System (UMS) is designed to collect an individual urine void, gently separate liquid from air, accurately measure the liquid volume of the urine, allow sample packaging, and discharge remaining urine into the Waste and Hygiene Compartment (WHC).
o MELFIEU	o Electronics unit for Minus Eighty-degree Laboratory Freezer for ISS (MELFI), an ultra-cold storage unit for experiment samples.
o GLACIER	o General Laboratory Active Cryogenic ISS Experiment Refrigerator
• **ESA**	
o Biolab	o Biological Experiment Laboratory in Columbus (BioLab) is a multiuser research facility located in the European Columbus laboratory. It will be used to perform space biology experiments on microorganisms, cells, tissue cultures, small plants, and small invertebrates.
o Energy	o Astronaut's Energy Requirements for Long-Term Space Flight (Energy) will measure changes in energy balance in crewmembers.
• **JAXA**	
o CSPINS	o Dynamism of Auxin Efflux Facilitators, CsPINs, Responsible for Gravity-regulated Growth and Development in Cucumber (CsPINs) uses cucumber seedlings to analyze the effect of gravity on gravimorphogenesis (peg formation) in cucumber plants.
o Hicari	o Materials science investigation Growth of Homogeneous SiGe Crystals in Microgravity by the TLZ Method (Hicari) aims to verify crystal-growth by travelling liquidous zone method, and to produce high-quality crystals of silicon-germanium (SiGe) semiconductor using the Japanese Experiment Module-Gradient Heating Furnace (JEM-GHF).
o Marangoni	o Marangoni convection is the flow driven by the

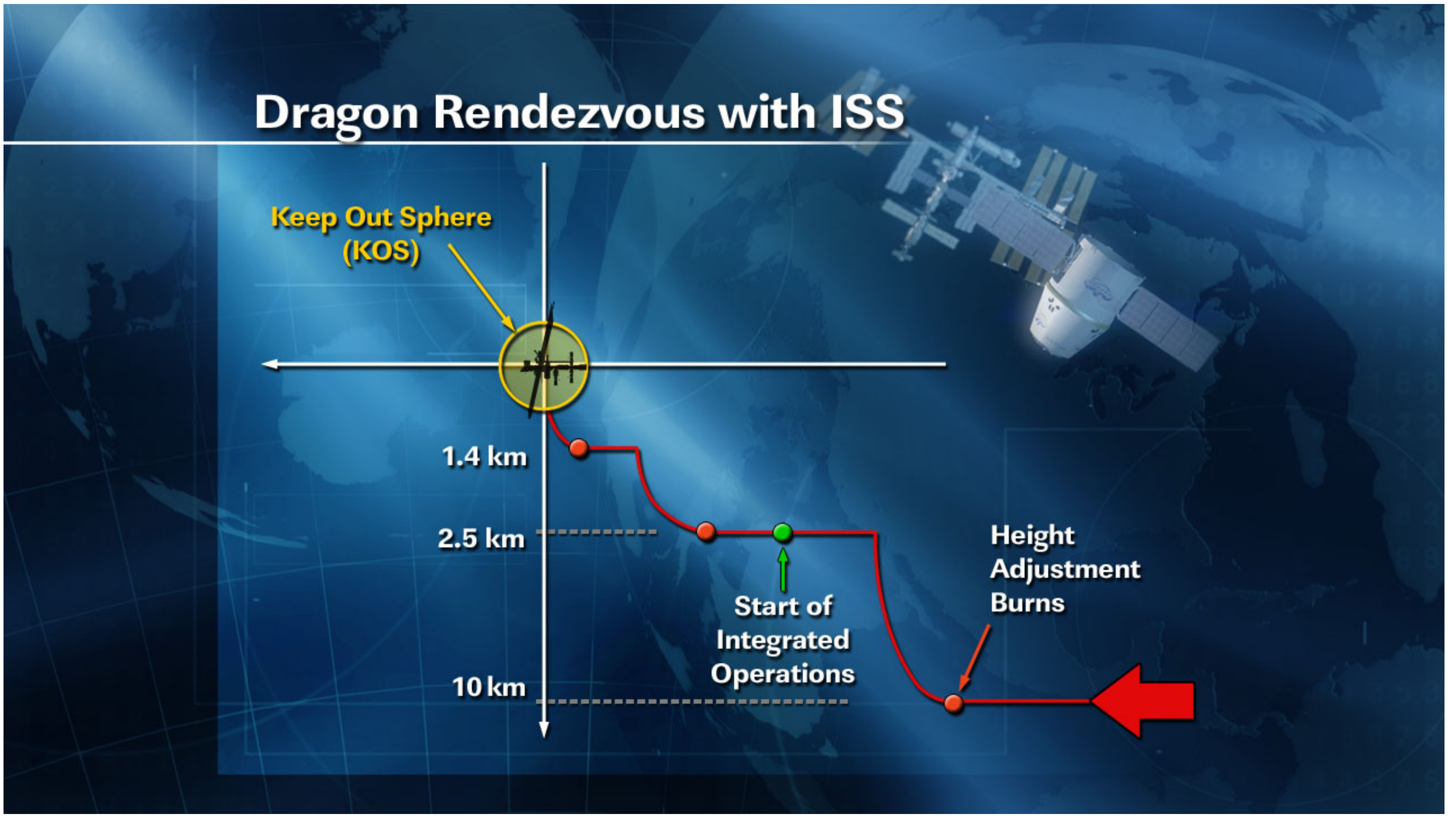
	presence of a surface tension gradient which can be produced by temperature difference at a liquid/gas interface.
o RESIST TUBULE	o Role of Microtubule-Membrane-Cell Wall Continuum in Gravity Resistance in Plants (Resist Wall) investigation was conducted to determine the importance of the structural connections between microtubules, plasma membrane, and the cell wall as the mechanism of gravity resistance.
o MICROBE III	o Microbe-III experiment monitors microbes on board the ISS which may affect the health of crew members.
o MYCO	o Mycological evaluation of crew exposure to ISS ambient air (Myco) evaluates the risk of microorganisms' via inhalation and adhesion to the skin to determine which fungi act as allergens.
o IPU Power Supply Module	o Image Processing Unit (IPU) is a Japan Aerospace Exploration Agency (JAXA) subrack facility that receives, records, and downlinks experiment image data for experiment processing.

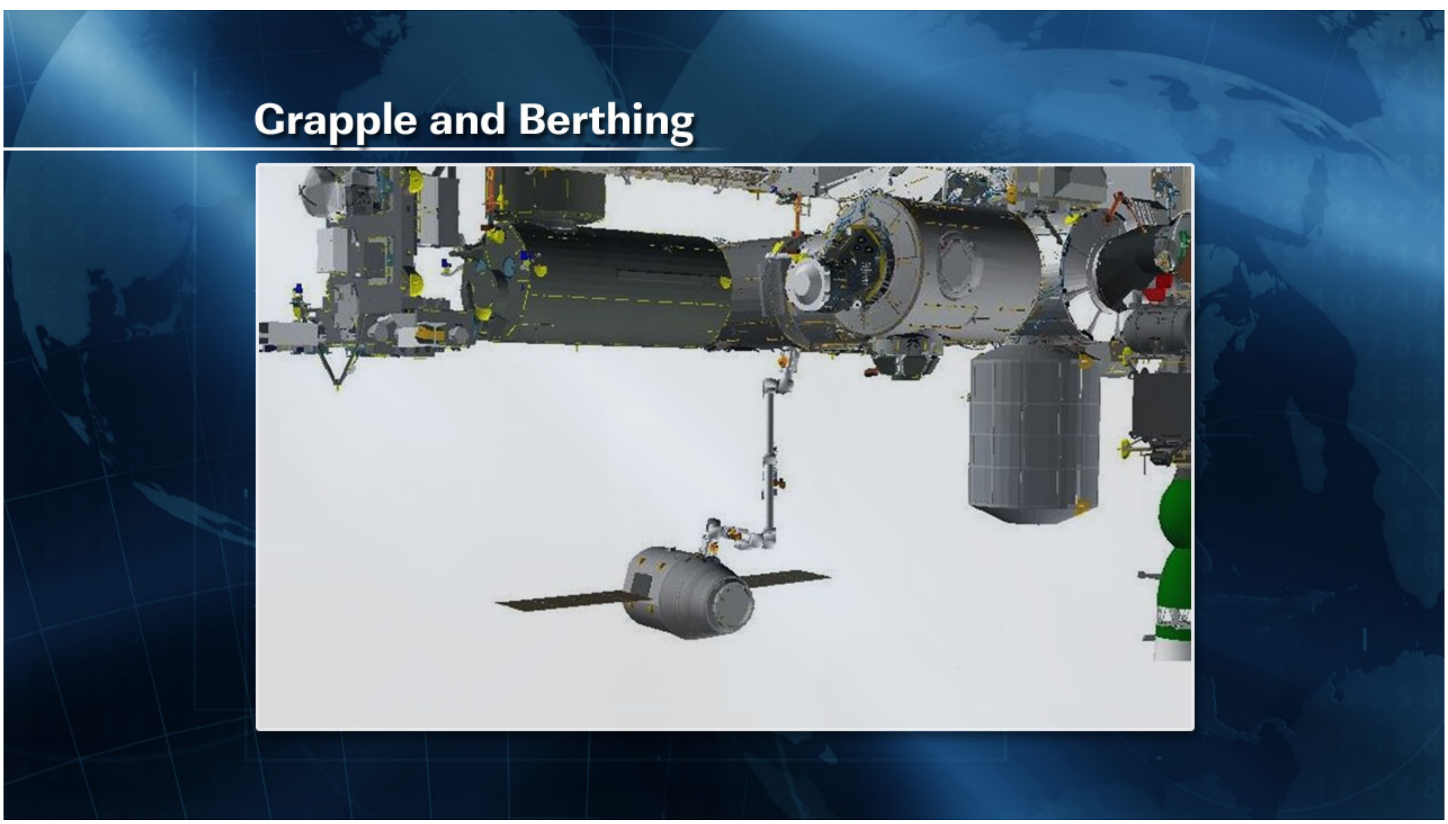
Vehicle Hardware	**518 pounds (235 kilograms)**
• CHeCS	Crew Health Care System – Compound Specific Analyzer-Combustible Products
• ECLSS	Environmental and Closed Loop Life Support Systems • Fluids Control and Pump Assembly • Catalytic reactor • Hydrogen sensor
• CSA-CLPA	CSA-Camera Light Pan Tilt Assembly
• EPS	Electrical Power System
• JAXA	Pump package
• ESA	Cabin Filter ATV Cabin Fan

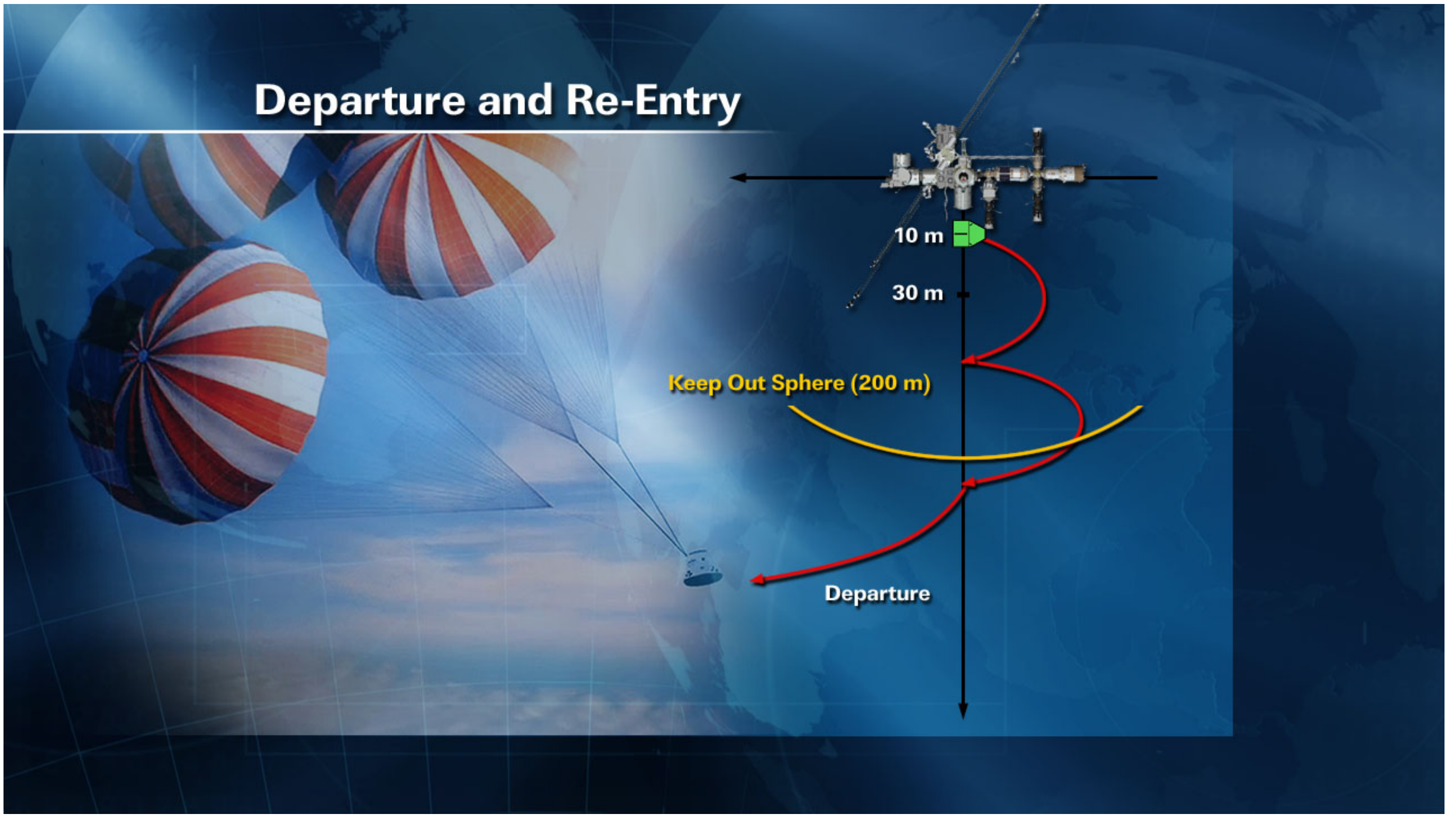
Computers Resources	**11 pounds (5 kilograms)**

Russian Cargo	**44 pounds (20 kilograms)**

Spacewalk Hardware	**68 pounds (33 kilograms)**
	EMU hardware and gloves for previous crew members
Total Down Mass	**1673 pounds (759 kilograms)**
Total Down Mass w/Packaging	1995 pounds (905 kilograms)


Dragon Rendezvous with ISS
Keep Out Sphere
(KOS)
1.4 km
2.5 km
10 km
Start of
Integrated
Operations
Height
Adjustment
Burns


Grapple and Berthing


Departure and Re-Entry
10 m
30 m
Keep Out Sphere (200 m)
Departure

International Space Station Overview

The International Space Station is an unprecedented achievement in global human endeavors to conceive, plan, build, operate and use a research platform in space.

Almost as soon as the space station was habitable, researchers began using it to study the impact of microgravity and other space effects on several aspects of our daily lives. With almost 1,500 experiments completed on the station to date, the unique scientific platform continues to enable researchers from all over the world to put their talents to work on innovative experiments that could not be performed anywhere else.

The space station represents the culmination of more than two decades of dedicated effort by a multinational team of agencies spanning Canada, Europe, Japan, Russia and the United States. While the various space agency partners may emphasize different aspects of research to achieve their goals in the use of space station, they are unified in using the space station to its full potential as a research platform for the betterment of humanity.

The space station provides the first laboratory complex where gravity, a fundamental force on Earth, is virtually eliminated for extended periods. This ability to control the variable of gravity in experiments opens up unimaginable research possibilities. As a research outpost, the station is a test bed for future technologies and a laboratory for new, advanced industrial materials, communications technology, medical research, and more.

In the areas of human health, telemedicine, education and observations from space, the station already has provided numerous benefits to human life on Earth. Vaccine development research, station-generated images that assist with disaster relief and farming, and education programs that inspire future scientists, engineers and space explorers are just some examples of research benefits, which are strengthening economies and enhancing the quality of life on Earth.

Clearly visible with the naked eye in the night sky, the expansive International Space Station is a working laboratory orbiting 240 statute miles (386.24 kilometers) above the Earth traveling at 17,500 miles per hour (32,410 kilometers per hour) and is home to an international crew.

The most complex scientific and technological endeavor ever undertaken, the five supporting agencies represent 15 nations: the U.S., Canada, Japan, Russia, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

On-orbit assembly began in November 1998 with the launch of its first module, Zarya, and was completed with the departure of the Space Shuttle Atlantis on the program's final flight in June 2011. The station is as large as a five-bedroom home with two bathrooms, a gymnasium and a 360-degree bay window, and provides crew members with more than 33,000 cubic feet (935 cubic meters) of habitable volume. The station weighs nearly 1 million pounds (419,600 kilograms) and measures 361 feet (110.03 meters) end to end, which is equivalent to a U.S. football field including the end zones. The station's solar panels exceed the wingspan of a Boeing 777 jetliner and harness enough energy from the sun to provide electrical power to all station components and scientific experiments.

The station now includes the Russian-built Zarya, Zvezda, Pirs, Poisk and Rassvet modules; the U.S.-built Unity, and Harmony connection modules, the Quest airlock module, the Tranquility module and its 360-degree-view cupola, and the Permanent Multipurpose Module. Research facilities populate the U.S. Destiny Laboratory, the European Columbus Laboratory, and the Japanese Kibo laboratory and external experiment platform. The Canadian-provided Canadarm2 robotic arm and its Mobile Servicing System give the station a movable space crane, and the Special Purpose Dexterous Manipulator, or Dextre, provides a smaller two-armed robot capable of handling delicate assembly tasks. This space cherry-picker can move along the Integrated Truss Structure, forms the backbone of the station, and connects the station's solar arrays, cooling radiators and spare part platforms.

The station's first resident crew, Expedition 1, marked the beginning of a permanent international human presence in space, arriving at the station in a Russian Soyuz capsule in November 2000. For almost a dozen years, station crews have provided a continuous human presence in space, with crews averaging six months at a time through the current 33rd expedition.

With the assembly of the space station at its completion and the support of a full-time crew of six, a new era of utilization for research is beginning. During the space station assembly phase, the potential benefits of space-based research and development were demonstrated, including the advancement of scientific knowledge based on experiments conducted in space, development and testing of new technologies, and derivation of Earth applications from new understanding.

The space station also is a vital precursor for future human exploration, where humans are learning how to combat the psychological and physiological effects of being in space for long periods, conducting both fundamental and applied research, testing technologies and decision-making processes.

The 2005 NASA Authorization Act designated the U.S. segment of the space station as a national laboratory. As the Nation's only national laboratory on-orbit, the space station National Lab fosters relationships among NASA, other federal entities, and the private sector, and advances science, technology, engineering and mathematics education through utilization of the space station's unique capabilities as a permanent microgravity platform with exposure to the space environment. NASA's research goals for the space station are driven by the NASA Authorization Act of 2010 and are focused on the following four areas: human health and exploration, technology testing for enabling future exploration, research in basic life and physical sciences, and earth and space science.

The International Space Station Program's greatest accomplishment is as much a human achievement as it is a technological one— how best to plan, coordinate, and monitor the varied activities of the Program's many organizations. The program brings together international flight crews; multiple launch vehicles; globally distributed launch, operations, training, engineering, and development facilities; communications networks; and the international scientific research community.

Elements launched from different countries and continents are not mated together until they reach orbit, and some elements that have been launched later in the assembly sequence were not yet built when the first elements were placed in orbit.

Construction, assembly and operation of the International Space Station requires the support of facilities on the Earth managed by all of the international partner agencies and countries involved in the program. These include construction facilities, launch support and processing facilities, mission operations support facilities, research and technology development facilities and communications facilities.

Operating the space station is even more complicated than other space flight endeavors because it is an international program. Each partner has the primary responsibility to manage and run the hardware it provides. The addition of commercial partners as providers of resupply and, in the future, crew transportation services, adds a new dimension to this complexity.

SpaceX Company Overview

SpaceX designs, manufactures, and launches the world's most advanced rockets and spacecraft. The company was founded in 2002 by Elon Musk to revolutionize space transportation, with the ultimate goal of enabling people to live on other planets. Today, SpaceX is advancing the boundaries of space technology through its Falcon launch vehicles and Dragon spacecraft.

Transforming the Way Rockets Are Made

SpaceX's proven designs are poised to revolutionize access to space. Because SpaceX designs and manufactures its own rockets and spacecraft, the company is able to develop quickly, test rigorously, and maintain tight control over quality and cost. One of SpaceX's founding principles is that simplicity and reliability are closely coupled.

Making History

SpaceX has gained worldwide attention for a series of historic milestones. It is the only private company ever to return a spacecraft from low-Earth orbit, which it first accomplished in December 2010. The company made history again in May 2012 when its Dragon spacecraft attached to the International Space Station (ISS), exchanged cargo payloads, and returned safely to Earth—a technically challenging feat previously accomplished only by governments.

Advancing the Future

Under a $1.6 billion contract with NASA, SpaceX will fly at least 12 more cargo supply missions to the ISS—and in the near future, SpaceX will carry crew as well. Dragon was designed from the outset to carry astronauts and now, under a $440 million agreement with NASA, SpaceX is making modifications to make Dragon crew-ready.

SpaceX is the world's fastest-growing provider of launch services. Profitable and cash-flow positive, the company has nearly 50 launches on its manifest, representing about $4 billion in contracts. These include commercial satellite launches as well as NASA missions.

Currently under development is the Falcon Heavy, which will be the world's most powerful rocket. All the while, SpaceX continues to work toward one of its key goals—developing reusable rockets, a feat that will transform space exploration by radically reducing its cost.

Key SpaceX Milestones

- **March 2002** SpaceX is incorporated
- **March 2006** First flight of SpaceX's Falcon 1 rocket
- **August 2006** NASA awards SpaceX $278 million to demonstrate delivery and return of cargo to ISS
- **September 2008** Falcon 1 becomes first privately developed liquid-fueled rocket to orbit Earth
- **December 2008** NASA awards SpaceX $1.6 billion contract for 12 ISS cargo resupply flights
- **July 2009** Falcon 1 becomes first privately developed liquid-fueled rocket to deliver a commercial satellite into orbit
- **June 2010** First flight of SpaceX's Falcon 9 rocket, which successfully achieves Earth orbit
- **December 2010** On Falcon 9's second flight and the Dragon spacecraft's first, SpaceX becomes the first commercial company to launch a spacecraft into orbit and recover it successfully
- **May 2012** SpaceX's Dragon becomes first commercial spacecraft to attach to the ISS, deliver cargo, and return to Earth
- **August 2012** SpaceX wins $440 million NASA Space Act Agreement to develop Dragon to transport humans into space

Profile

SpaceX is a private company owned by management and employees, with minority investments from Founders Fund, Draper Fisher Jurvetson, and Valor Equity Partners. The company has more than 1,800 employees at its headquarters in Hawthorne, California; launch facilities at Cape Canaveral Air Force Station, Florida, and Vandenberg Air Force Base, California; a rocket-development facility in McGregor, Texas; and offices in Houston, Texas; Chantilly, Virginia; and Washington, DC.

For more information, including SpaceX's Launch Manifest, visit the SpaceX website at www.spacex.com.

SpaceX Leadership

ELON MUSK
Founder and Chief Technical Officer

Elon Musk is the CEO/CTO of Space Exploration Technologies (SpaceX) and CEO and Product Architect of Tesla Motors.

At SpaceX, Elon is the chief designer, overseeing development of rockets and spacecraft for missions to Earth orbit and ultimately to other planets. SpaceX has achieved a succession of historic milestones since its founding in 2002. The SpaceX Falcon 1 was the first privately developed liquid-fuel rocket to reach orbit. In 2008, SpaceX's Falcon 9 rocket and Dragon spacecraft won a NASA contract to provide the commercial replacement for the cargo transport function of the space shuttle, which retired in 2011. In 2010, SpaceX, with its Dragon spacecraft, became the first commercial company to successfully recover a spacecraft from Earth orbit. In 2012, SpaceX became the first commercial company to attach a spacecraft to the International Space Station and return cargo to Earth.

At Tesla, Elon has overseen product development and design from the beginning, including the all-electric Tesla Roadster, Model S, and Model X. Transitioning to a sustainable-energy economy in which electric vehicles play a pivotal role has been one of his central interests for almost two decades, stemming from his time as a physics student working on ultracapacitors in Silicon Valley.

In addition, Elon is the non-executive chairman and principal shareholder of SolarCity, which he helped create. SolarCity is now the leading provider of solar power systems in the United States.

Prior to SpaceX, Elon cofounded PayPal, the world's leading Internet payment system, and served as the company's Chairman and CEO. Before PayPal, he cofounded Zip2, a provider of Internet software to the media industry.

He has a physics degree from the University of Pennsylvania and a business degree from Wharton.

GWYNNE SHOTWELL
President

As President of SpaceX, Gwynne Shotwell is responsible for day-to-day operations and for managing all customer and strategic relations to support company growth. She joined SpaceX in 2002 as Vice President of Business Development and built the Falcon vehicle family manifest to nearly 50 launches, representing about $4 billion in revenue. She is a member of the SpaceX Board of Directors.

Prior to joining SpaceX, Gwynne spent more than 10 years at the Aerospace Corporation. There she held positions in Space Systems Engineering & Technology as well as Project Management. She was promoted to the role of Chief Engineer of an MLV-class satellite program, managed a landmark study for the Federal Aviation Administration on commercial space transportation, and completed an extensive analysis of space policy for NASA's future investment in space transportation. Gwynne was subsequently recruited to be Director of Microcosm's Space Systems Division, where she served on the executive committee and directed corporate business development. She also served as a Chair of the AIAA Space Systems Technical Committee.

Gwynne participates in a variety of STEM (Science, Engineering, Technology, and Mathematics)-related programs, including the Frank J. Redd Student Scholarship Competition. Under her leadership the committee raised more than $350,000 in scholarships in six years. She was named winner of the 2011 World Technology Award for Individual Achievement in Space, and in June 2012 she was inducted into the Women In Technology International Hall of Fame. She is a member of the World Economic Forum's Global Agenda Council on Space Security.

Gwynne received, with honors, her bachelor's and master's degrees from Northwestern University in Mechanical Engineering and Applied Mathematics, and currently serves on the Advisory Council for Northwestern's McCormick School of Engineering. She has authored dozens of papers on a variety of subjects including standardizing spacecraft/payload interfaces, conceptual small spacecraft design, infrared signature target modeling, space shuttle integration, and reentry vehicle operational risks.

SpaceX Facilities

SPACE LAUNCH COMPLEX 40, CAPE CANAVERAL AIR FORCE STATION

Cape Canaveral, Florida

SpaceX's Space Launch Complex 40 at Cape Canaveral Air Force Station is a world-class launch site that builds on strong heritage. The site at the north end of the Cape was used for many years to launch Titan rockets, among the most powerful rockets in the US fleet. SpaceX took over the facility in May 2008.

The center of the complex is composed of the concrete launch pad/apron and flame exhaust duct. Surrounding the pad are four lightning towers, fuel storage tanks, and the integration hangar. Before launch, Falcon 9's stages and the Dragon spacecraft are housed inside the hangar, where Dragon receives its cargo and is integrated with Falcon. A crane/lift system moves Falcon into a transporter-erector system and Dragon is mated to the rocket. The vehicle is rolled from hangar to launch pad on fixed rails shortly before launch to minimize exposure to the elements.

Space X Launch Control, located near the launch complex, is responsible for Falcon 9 all the way to orbit. Mission Control in Hawthorne takes over control of Dragon after it separates from Falcon 9's second stage.

SPACEX HEADQUARTERS

Hawthorne, California

SpaceX's rockets and spacecraft are designed and manufactured at the company's headquarters in Hawthorne, California—a complex that spans nearly one million square feet. It is also home to Mission Control.

ROCKET DEVELOPMENT FACILITY

McGregor, Texas

Engines and structures are tested at a 600-acre state-of-the-art rocket development facility in McGregor, Texas.

SPACE LAUNCH COMPLEX 4E, VANDENBERG AIR FORCE BASE

Lompoc, California

SpaceX is developing a new launch pad at Vandenberg Air Force Base. It is on target for pad activation in late 2012.

Falcon 9 Rocket

Falcon 9 is a two-stage rocket designed from the ground up by SpaceX for the reliable and cost-efficient transport of satellites and SpaceX's Dragon spacecraft.

QUICK FACTS

Made in America. All of Falcon 9's structures, engines, and ground systems were designed, manufactured, and tested in the United States by SpaceX.

21st-century rocket. The first rocket completely designed in the 21st century, Falcon 9 was developed from a blank sheet to first launch in four and a half years (November 2005 to June 2010) for less than $300 million.

Designed for maximum reliability. Falcon 9 features a simple two-stage design to minimize the number of stage separations. (Historically, the main causes of launch failures have been stage separations and engine failures.) With nine engines on the first stage, it can safely complete its mission even in the event of a first-stage engine failure.

Statistics. Falcon 9 topped with a Dragon spacecraft is 48.1 meters (157 feet) tall and 12 feet in diameter. Its nine first-stage Merlin engines generate 855,000 pounds of pounds of thrust at sea level, rising to nearly 1,000,000 pounds of thrust as Falcon 9 climbs out of the Earth's atmosphere.

In demand. SpaceX has nearly 50 Falcon 9 missions on its manifest, with launches scheduled for commercial and government clients.

Designed to safely transport crew. Like the Dragon spacecraft, Falcon 9 was designed from the outset to transport crew to space.

Mission success record. Falcon 9 has achieved 100% of mission objectives on every flight to date, including June 2010 and December 2010 flights to orbit, and its successful mission launching the Dragon spacecraft to the International Space Station in May 2012.

Why "Falcon"? Falcon 9 is named for the Millennium Falcon in the "Star Wars" movies. The number 9 refers to the nine Merlin engines that power Falcon 9's first stage; one Merlin vacuum engine powers the second stage.

ADVANCED TECHNOLOGY

First Stage

Nine SpaceX Merlin engines power the Falcon 9 first stage. After ignition of the first-stage engines, the Falcon 9 is held down and not released for flight until all propulsion and vehicle systems are confirmed to be operational. SpaceX manufactures the rocket's tank walls from an aluminum-lithium alloy using friction-stir welding, the strongest and most reliable welding technique available. The interstage, which connects the first and second stages, is a composite structure made of sheets of carbon fiber and an aluminum honeycomb core. Falcon 9 uses an all-pneumatic stage separation system for low-shock, highly reliable stage separation.

Second Stage

The second-stage tank is a shorter version of the first-stage tank and uses most of the same tooling, materials, and manufacturing techniques. This commonality yields significant design and manufacturing efficiencies. A single Merlin vacuum engine powers the second stage. For added reliability of engine start, the engine has dual redundant pyrophoric igniters using a triethylaluminum-triethylborane (TEA-TEB) igniter system.

Merlin Engine

Falcon 9 is powered by nine Merlin engines in the first stage and one version that operates in vacuum in the second stage. The nine Merlin engines generate 855,000 pounds of thrust at sea level, rising to nearly 1,000,000 pounds of thrust as Falcon 9 climbs out of the Earth's atmosphere. The second-stage engine generates 92,000 pounds of thrust in a vacuum. The Merlin engine was developed internally at SpaceX, but draws upon a long heritage of space-proven engines.

High-pressure liquid oxygen and kerosene propellant are fed to each engine via a single-shaft, dual-impeller turbopump operating on a gas generator cycle. Kerosene from the turbopump also serves as the hydraulic fluid for the thrust vector control actuators on each engine, and is then recycled into the low-pressure inlet. This design eliminates the need for a separate hydraulic power system, and eliminates the risk of hydraulic fluid depletion. Kerosene is also used for regenerative cooling of the thrust chamber and expansion nozzle. On the second-stage engine, the exhaust from the gas generator that drives the turbopump is used to provide roll control via actuation of a turbine exhaust nozzle.

Reliability

This flight represents the fourth flight of the Falcon 9, following three successful missions.

An analysis of launch failure history between 1980 and 1999 by the Aerospace Corporation showed that 91% of known failures can be attributed to three causes: engine failure, stage-separation failure, and, to a much lesser degree, avionics failure. Because Falcon has nine Merlin engines clustered together to power the first stage, the vehicle is capable of sustaining an engine failure and still completing its mission. This is an improved version of the architecture employed by the Saturn I and Saturn V rockets of the Apollo program, which had flawless flight records despite the loss of engines on a number of missions. With only two stages, Falcon 9 limits problems associated with separation events.

SpaceX maximizes design and in-house production of much of Falcon 9’s avionics, helping ensure compatibility among the rocket engines, propellant tanks, and electronics. In addition, SpaceX has a complete hardware simulator of the avionics in its Hawthorne factory. This simulator, utilizing electronics identical to those on the rocket, allows SpaceX to check nominal and off-nominal flight sequences and validate the data that will be used to guide the rocket.

SpaceX uses a hold-before-release system—a capability required by commercial airplanes, but not implemented on many launch vehicles. After the first-stage engines ignite, Falcon 9 is held down and not released for flight until all propulsion and vehicle systems are confirmed to be operating normally. An automatic safe shutdown occurs and propellant is unloaded if any issues are detected.

Dragon Spacecraft

Dragon is a free-flying, reusable spacecraft developed to carry cargo, and eventually astronauts, into space.

QUICK FACTS

Built by SpaceX from the ground up. SpaceX developed Dragon from a blank sheet to its first mission in just over four years.

First privately developed spacecraft to attach to the International Space Station (ISS). In May 2012, Dragon became the first commercial spacecraft to deliver cargo to the ISS and return safely to Earth, a feat previously achieved only by governments.

Payload capability. Dragon carries cargo in a pressurized capsule and an unpressurized trunk. It can carry 3,310 kilograms (7,297 pounds), split between pressurized cargo inside the capsule and unpressurized cargo in the trunk, which also houses Dragon's solar panels.

Dimensions. Dragon is 4.4 meters (14.4 feet) tall and 3.66 meters (12 feet) in diameter. The trunk is 2.8 meters (9.2 feet) tall and 3.66 meters (12 feet) wide. With solar panels fully extended, the vehicle measures 16.5 meters (54 feet) wide.

Advanced heat shield. Dragon has the most effective heat shield in the world. Designed with NASA and fabricated by SpaceX, it is made of PICA-X, a high-performance variant on NASA's original phenolic impregnated carbon ablator (PICA). PICA-X is designed to withstand heat rates from a lunar return mission, which far exceed the requirements for a low-Earth orbit mission.

Smooth, controlled reentry. Dragon's passively stable shape generates lift as it reenters the Earth's atmosphere. Its 18 Draco thrusters provide roll control during reentry to keep it precisely on course toward the landing site before its parachutes deploy.

Designed for astronauts. Although this resupply mission carries only cargo, Dragon was designed from the outset to carry crew. Under a $440 million agreement with NASA, SpaceX is developing refinements for transporting crew, including seating for seven astronauts, the most advanced launch escape system ever developed, a propulsive landing system, environmental controls, and life-support systems.

True rumor. Dragon was named for the fictional Puff the Magic Dragon after critics in 2002 deemed SpaceX's founding goals fantastical.

ADVANCED TECHNOLOGY

Draco Thrusters

Dragon's 18 Draco thrusters permit orbital maneuvering and attitude control. Powered by nitrogen tetroxide/monomethylhydrazine (NTO/MMH) storable propellants; 90 lbf (400 N) thrust is used to control the approach to the ISS, power departure from the ISS, and control Dragon's attitude upon reentry.

Power

Two solar array wings on trunk (eight panels total) produce more than 5 kilowatts of power. Surplus power recharges Dragon's batteries for the periods when it is in darkness. In low-Earth orbit, Dragon is in darkness about 40% of the time.

Avionics

Dual fault-tolerant computing provides seamless real-time backups to all critical avionics components, providing one of the most reliable architectures to fly. The RIOs (remote input/output modules) provide a common computing platform with configurable input and output control cards. This architecture facilitates manufacturing and ensures the components' reliability.

Communications

- Communications between Dragon and the ISS are provided by the COTS UHF communications unit (CUCU). CUCU was delivered to the space station on STS-129.
- ISS crew command Dragon using the crew command panel (CCP).
- Dragon can also communicate on S-band via either tracking and data relay system (TDRSS) or ground stations.

Environmental Control System

Astronauts will enter Dragon to remove cargo.

- Dragon's cabin is habitable: air circulation, lighting, fire detection and suppression.
- Air pressure control, pressure and humidity monitoring.

Thermal Protection System

- Primary heat shield: Tiled phenolic impregnated carbon ablator (PICA-X), fabricated in-house.
- Backshell: SpaceX Proprietary Ablative Material (SPAM).

Transporting Crew

Dragon is currently undergoing modifications that will allow it to transport crew to the International Space Station. To ensure a rapid transition from developing Dragon's cargo configuration to a configuration rated to carry crew, SpaceX has designed the two to be nearly identical. Crew configuration, though, will include life support systems, a crew escape system, and onboard controls that allow the crew to take control from the flight computer when needed. This focus on commonality minimizes the design effort and simplifies the human-rating process, allowing systems critical to Dragon crew safety and ISS safety to be fully tested on unmanned flights.

FACT SHEET

Vision: The World's Premier Gateway to Space

Mission: One Team … Delivering Assured Space Launch, Range and Combat Capabilities for the Nation

Leadership/Organization

Wing Leadership: The 45th Space Wing is commanded by Brig. Gen. Anthony J. Cotton.

Groups: The wing is organized into four groups to accomplish its mission:

- Launch Group: Supports launch vehicle and spacecraft processing from flight hardware arrival through launch.
- Operations Group: Operates and maintains the Eastern Range assets and responsible for airfield operations, weather and communication support.
- Mission Support Group: Provides support through various functions to the people and mission.
- Medical Group: Provides medical, dental, environmental and public health services.

At a Glance

Commander: Brig. Gen. Anthony J. Cotton
Number of Personnel: 9,477
Annual Payroll: $306.3 million
Number of Indirect Jobs Created: 4,797
$ Value of Jobs Created: $204 million
Annual Expenditures: $649.2 million
Total Economic Impact (FY10): $1.142 billion
 # Airmen Deployed: Approximately 100+

Fleet: Atlas V, Delta IV, Falcon 9, Trident II
Satellites Processed: GPS, WGS, MILSTAR
Eastern Range Size: 15 million square miles
Next Scheduled Launch: www.patrick.af.mil

Tenants/Mission Partners

The 45th Space Wing has more than 35 major mission partners and tenants at Patrick AFB and Cape Canaveral AFS, including:

- Defense Equality Opportunity Management Institute
- Air Force Technical Applications Center
- National Aeronautics and Space Administration
- Naval Ordnance Test Unit
- 920th Rescue Wing
- Joint Stars Task Force
- Department of State
- Air Force Office of Special Investigations
- 333rd Recruiting Squadron
- American Red Cross

Control of the Battlefield Begins Here!

(Current as of October 2011)
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