Space Launch Report: SpaceX Falcon 9 v1.1 Data Sheet

SpaceX Falcon 9 v1.1
Updated September 08, 2017

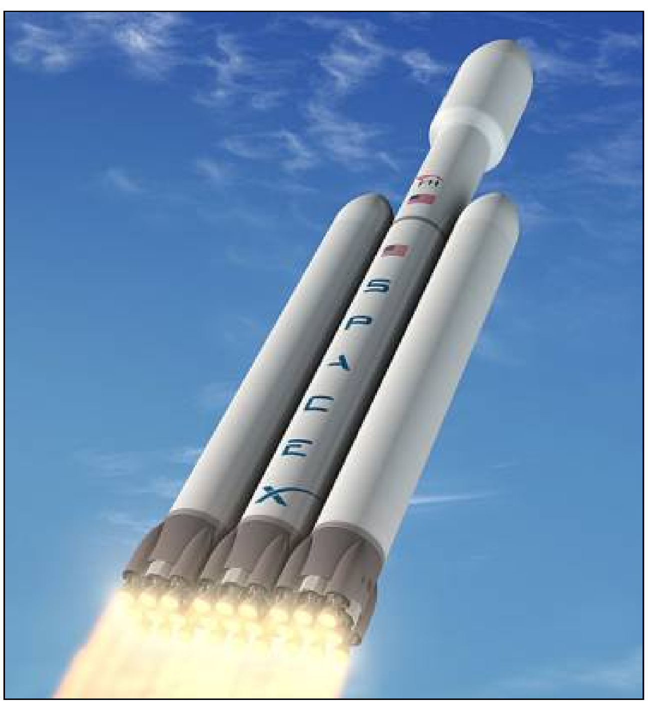
On April 27, 2013, Elon Musk tweeted a photograph showing the base of the first Falcon 9 v1.1 first stage on the big stand at McGregor, though only through a misty cloud of smoke during an ignitor test. The photo confirmed the long-suspected octagonal arrangement of Merlin 1D engines.

Merlin 1D, Falcon Heavy, and Falcon 9 v1.1

By the end of 2010, SpaceX had completed development and two flight tests of its Merlin 1C-powered Falcon 9. For several years the company had discussed a more powerful Falcon 9 version that would be powered by a higher-thrust Merlin engine, but an official effort was not announced until April 5, 2011.

On that date SpaceX announced that it would develop a new rocket. Press attention focused on the triple-body Falcon Heavy rocket shown in press release materials, but the real story was about the new upgraded Merlin 1D engine that would power the rocket, and about a new two-stage core version that would become known as Falcon 9 v1.1.

Each of the Falcon Heavy's 27 Merlin 1D engines would produce 63.5 tonnes thrust at sea level, nearly 1.5 times more than the Merlin 1C engines that powered the first two Falcon 9 rockets. Using the new engines, combined with propellant crossfeeding from the twin boosters to the central core, Falcon Heavy would be able to lift a surprising 53 tonnes to LEO, 19 tonnes to GTO, or 13.6 tonnes toward Mars. Plans called for the first Falcon Heavy to fly a demonstration mission in 2013 from Vandenberg AFB Space Launch Complex 4 East, the former Titan 4 pad.



Falcon Heavy as Originally Presented by SpaceX, April 2011

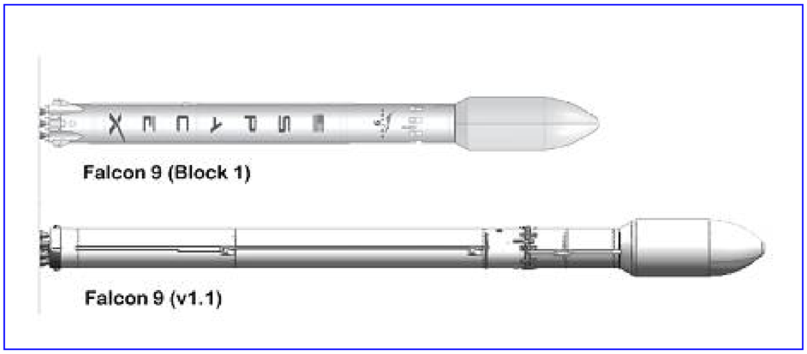
Falcon 9 v1.1 was divulged with much less fanfare. It would be a two-stage rocket powered by nine Merlin 1D engines off the pad. This Falcon 9, substantially more capable than either Falcon 9 or the originally planned Falcon 9 Block 2 version, would, according to a briefly released information sheet that was swiftly withdrawn, would be able to lift 16 tonnes to LEO or 5 tonnes to GTO, would stand 69.2 meters, and would weigh 480 tonnes at liftoff. The company continued to show Falcon 9 Block 2 as the baseline in its Payload Users Guide, but Falcon 9 v1.1 clearly was more than a "block" upgrade.

Weighing 50% more, standing one-third taller, powered by brand new engines, using new tank and thrust structures, and using new launch equipment, Falcon 9 v1.1 was for all practical purposes a brand new rocket.

On April 25, 2011, Elon Musk, in a Space News interview, confirmed that Falcon Heavy would use a "stretched" Falcon 9 stage augmented by two additional "first stages". He stated that Merlin 1D would fly in mid-2012 on a Falcon 9 mission, most likely on the seventh flight of the rocket. (This, of course, turned out to be over-optimistic.) Mr. Musk described how the Merlin 1D combustion chamber was being explosively formed, streamlining the production process. He noted that a fully integrated Merlin 1D was already being test-fired.

Design details of Falcon Heavy, and of Merlin 1D performance, were not provided at the time. In order to achieve the payload capability claimed by SpaceX, the new rocket engine would have to provide improved specific impulse and the stages would have to provide very high, almost unrealistic and certainly unprecedented, propellant mass ratios. SpaceX claimed that the two "first stage" strap-on units would achieve a 30 to 1 gross mass to dry mass ratio, implying an unprecedented propellant mass fraction of better than 0.966.

Beginning in 2012, drawings of Falcon Heavy began to show boosters that were longer than the core first stage, implying a larger propellant loading for the boosters than the core. The drawings showed booster propellant tanks that were about 10 to 15 percent longer than the core tanks.



Falcon 9 v1.1

Falcon 9 Block 1 and Falcon 9 v1.1 Comparison

Falcon 9 v1.1 itself was not named in public until May 14, 2012, when NASA announced that it had modified its Launch Services (NLS) II contract with Space Exploration Technologies (SpaceX) by adding a new "Falcon 9 v1.1" variant to the program. The modification allowed SpaceX to offer "Falcon 9 v1.1" in competition for future launch contracts.

An image of "Falcon 9 v1.1" was provided during a presentation made on March 9, 2012 by Jeffrey White, an Iridium Director.   The image showed a stretched Falcon 9, with both stages stretched. It also showed, compared to Falcon 9 Block 1, shortened interstage and propulsion sections.   The bigger rocket appeared to be outfitted with Merlin 1D engines, possibly in a rearranged configuration. An octagonal arrangement, with a ninth, center engine, was suspected by outside observers.

Nine Merlin 1D Engines Mount to an "Octaweb" Structure at the Base of the Falcon 9 v1.1 First Stage

"Falcon 9 v1.1" represented an improvement over the long-expected "Falcon 9 Block 2" that, originally, was to be powered by improved Merlin 1C engines. The SpaceX user's guide continued to show outmoded "Block 2" performance data as of May 14, 2012, but the SpaceX web site was updated with v1.1 performance numbers on June 6 or 7, 2011. Payload to was shown to be 13.15 tonnes to a 185 km x 28.5 deg low earth orbit, 4.85 tonnes to a 185 x 35,788 km x 28.5 deg geosynchronous transfer orbit, or 2.9 tonnes to escape velocity.

The Merlin 1D powered "Falcon 9 v1.1" was apparently set to be the building block for the company's announced Falcon Heavy, but "v1.1" clearly would be a substantial performer in its own right, pushing deep into EELV payload territory.

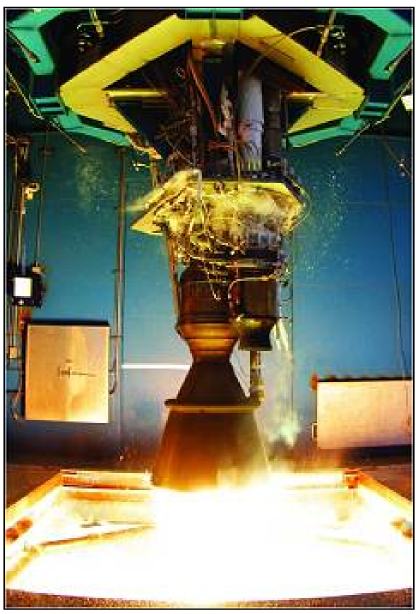
In early August, 2013, SpaceX provided updated performance details for Falcon Heavy and Falcon 9 v1.1. Falcon Heavy still hauled 53 tonnes to LEO. GTO performance was upgraded to 21.2 tonnes while trans-Mars performance fell to 13.2 tonnes. Falcon 9 v1.1 performance was still 13.15 tonnes LEO or 4.85 tonnes GTO, but gross liftoff mass had risen to as much as 505.846 tonnes.   Liftoff thrust was 600.109 tonnes for v1.1 and 1,800.327 tonnes for Heavy.

Erector at Vandenberg AFB SLC 4E with Hangar in background

Falcon 9 v1.1 was expected to premier at Vandenberg AFB Space Launch Complex 4 East during 2013. During a May 18, 2012 interview, Elon Musk said that all Falcon 9 rockets after the first five would be 1.1 versions. He also referred to the original Falcon 9 as "v1.0".

A massive construction effort neared completion at SLC 4E during early 2013. The rebuilt flat pad had a massive fixed launch vehicle erector similar to the type used by Delta IV. It also had a big horizontal hangar connected to the pad by a curved roadway, consistent with use of a wheeled transporter.

An extension of the Cape Canaveral SLC 40 Hangar was noted during May, 2012 to accomodate the longer rocket. Construction of a new transporter/erector system at SLC 40 was being performed during the early months of 2013.



Merlin 1D

Merlin 1D Development Testing During 2012

Merlin 1D development was well underway by the time of the April 2011 announcement. Its explosively formed chamber dispensed with the tube-wall chamber construction of the Merlin 1C. The engine as originally announced would produce 63.5 tonnes thrust at sea level and 70.31 tonnes thrust in vacuum. Its vacuum specific impulse was target to be 310 seconds. The engine had an expansion ratio of 16, a chamber pressure of 1,410 psi, and an ability to throttle down to 70%. It also would have an unprecedented 150:1 vacuum thrust to weight ratio.

During the August 2011 Joint Propulsion Conference, SpaceX VP of Propulsion Tom Mueller said that the Merlin 1D test engine had demonstrated a vacuum thrust to weight ratio greater than 150:1 and a vacuum specific impulse greater than 309 seconds. He also said that the engine had performed a 185 second long burn at up to 66.68 tonnes thrust. Engine data was subsequently updated to show 66.68 tonnes sea level thrust, 73.03 tonnes vacuum thrust, a sea level specific impulse of 282 seconds, and a vacuum specific impulse of 311 seconds. This was believed to be the highest specific impulse ever achieved by a gas-generator cycle first stage kerosene rocket engine.

On March 20, 2013 SpaceX announced that the Merlin 1D engine had completed flight qualification testing. During the 28-test program, Merlin 1D completed 1,970 seconds of total test time, the equivalent of more than 10 full duration missions. The program included four tests at or above the 66.68 tonnes sea-level thrust and 185 second duration needed for a Falcon 9 v1.1 flight. The testing took place at SpaceX's McGregor, Texas facility.

Merlin 1D Vacuum

Merlin 1D Vacuum Testing at McGregor

A single Merlin 1D Vacuum version would power the Falcon 9 v1.1 second stage. In September, 2012, SpaceX provided an image of a Merlin 1D Vacuum engine being tested. The engine will be fitted with an extended nozzle, not shown in its ground test image, to improve specific impulse. The specific impulse has not been announced, but it will likely exceed the 311 seconds listed for the first stage engine.

Grasshopper

Fifth Grasshopper Flight Reached 250 Meter Altitude

In late 2012, SpaceX began test program that at the time seemed to be an expensive research-oriented side show. It later turned out to be a key part of Falcon 9 v1.1 development effort. The effort was called "Grasshopper".

Grasshopper was a vertical takeoff vertical landing test vehicle. It was composed of a Falcon 9 first stage fitted with a single Merlin 1D engine and, at its base, a massive landing leg structure. Four fixed landing legs supported the stage both prior to takeoff and upon landing. Grasshopper took off and landed on a concrete apron at McGregor, using no hold-down arms or other similar launcher equipment. The vehicle flew 2.5 meters off the ground in September, 2012. It rose 5.4 meters in November and 40 meters in December. In March, 2013, it flew to an 80.1 meter height where it hovered briefly before returning to land. In April, 2013, Grasshopper rose to 250 meters. SpaceX provided a dramatic helicoper-based aerial view of that flight. On June 14, 2013, Grasshopper flew for more than one minute and exceeded 300 meters altitude. A dramatic lateral divergence test took place on August 13, 2013 when the stage rose 300 meters while moving 100 meters horizontally during ascent and descent. Liftoff and landing occurred from the same spot during this final flight of this first Grasshopper stage at McGregor. Future testing was planned to take place in a more remote location in New Mexico, near White Sands, using a more advanced test stage.

On March 28, 2013, Elon Musk announced that Falcon 9 v1.1 would perform similar "fly-back" tests during early missions. After separation, the stage would fire its center engine to scrub horizontal velocity, vastly reducing reentry heating. It would then attempt to restart its engine just before it hit the ocean to demonstrate a final vertical velocity reduction.

It became clear that the company planned to eventually develop a "fly back" version of its Falcon 9 v1.1 first stage. Elon Musk began using the "Falcon 9R" name to describe the rocket. Such a stage would actually return to its launch site for a propulsively controlled vertical landing using deployable landing legs that would be much lighter than those fitted to Grasshopper. Musk noted that testing of such a system would take awhile and that a successful reentry was not necessarily expected during the initial tests. A fly-back test would not occur for many months at the earliest.

First Flight Preparations

Falcon 9 v1.1 Payload Fairing Testing Preparations at Plum Brook Station near Sandusky, Ohio in March, 2013.

The big test stand at McGregor was modified to accept the larger, more powerful v1.1 first stage during late 2012. An entirely new ground-level test stand was also under construction during this time. The new stand, which appeared to use a water deluge system to dampen accoustic energy, was likely being constructed for Falcon Heavy testing.

Structural Falcon 9 v1.1 first and second stage structural test articles were seen at McGregor during late 2012 and early 2013. The structural test stands previously built for Falcon 9 v1.0 had to be stretched to handle the longer stages.

On satellite launch missions, Falcon 9 v1.1 would use a large, never-flown payload fairing. During late 2012 and early 2013, SpaceX installed a test version of its new 5.2 meter diameter fairing in NASA's massive Plum Brook Station vacuum test chamber in Sandusky, Ohio. The fairing, with a 13.9 meter usable length, performed separation testing with the chamber pumped down to near-vacuum conditions.

The first Falcon 9 v1.1 flight first stage was shipped from Hawthorne to McGregor during March 2013, where it was erected onto the big test stand. Propellant loading and other tests of the stage occurred during April and May, a process delayed when problems such as LOX leaks had to be resolved. An initial developmental static test attempt on May 31, 2013 was aborted just prior to ignition. A second attempt on June 1 resulted in an abort after 10 seconds due to high gas generator inlet temperature readings.

June 7, 2013 First Stage Development Test Firing

A third attempt on June 7 was more successful, but nonetheless suffered an abort after 112 seconds of a planned 180 second burn. Another high temperature reading was the cause. A video posted by Elon Musk of this test showed small pieces of a burning lightweight material, possibly insulation, falling from the stage after the abort. On June 13, 2013, a fourth attempt resulted in an abort after 70 seconds. The center engine was removed after this test to inspect the engine compartment. Finally, on June 19, the first stage ran for more than 2.5 minutes. SpaceX announced that development testing of the stage was completed at the conclusion of this test. The company announced that the total firing time for the stage now exceeded 6 minutes, implying that the final test lasted for perhaps 170 seconds or more.

With development testing of the stage complete, the company prepared to begin acceptance testing. Test engines were replaced with flight engines, and a long acceptance test firing occurred on July 4, 2013. A full-duration, three-minute mission length firing was performed on July 14, 2013. After the test, Elon Musk tweeted that he was "proud of the boost stage team for overcoming many tough issues". The stage was subsequently delivered to Vandenberg AFB by the end of July.

Meanwhile a development test of the second stage had been attempted on May 21, 2013, but had ended in an abort. No additional news about second stage testing was available one month later. Presumably, the stage completed a development and acceptance test cycle like the first stage, since it was delivered to Vandenberg AFB by mid-July.

Falcon 9 v1.1 (F9-006) at SLC 4E, with September 19, 2013 Hot Fire on Right

The first flight of the Falcon 9 with Merlin 1D engines was expected to launch Canada's Cassiope, a 360 kg weather research and communications satellite into an elliptical low earth orbit from Vandenberg SLC 4E. A second flight would lift 3.6 tonne SES-8 to geosynchronous transfer orbit from Cape Canaveral SLC 40.

The stages for the seventh Falcon 9, also a v1.1, were at McGregor preparing for their acceptance tests by early August, 2013. The first stage fired for 45 seconds as planned on August 13. The second stage subsequently completed its testing and arrived at Cape Canaveral on September 10, 2013. Meanwhile, the Falcon 9-008 stages were being prepared for their acceptance tests.

Falcon 9 No. 6, the first v1.1, was mated to its transporter erector at Vandenberg AFB on August 22, 2013. It rolled out to SLC 4E and, on August 28, performed a wet dress rehearsal (propellant loading) exercise with no payload attached. The rocket returned to its hangar where the payload and payload fairing were attached. Back on the launch pad, an attempted hot fire test was scrubbed on September 11, 2013 before being performed on September 12, following two aborted attempts earlier in the day.

A variety of "bugs" cropped up during the initial hot fire test, including vehicle/pad interface problems and a problem with a liquid oxygen drain valve that prevented rapid detanking after the test. During the ensuring days, the vehicle was rotated back to horizontal to allow some corrective work to be performed. A second hot fire test was performed on September 19, 2013 at 17:51 UTC. This time the rocket and its ground launch equipment passed the test. Falcon 9 No. 006 was prepared for an expected late September launch date, pending completion of at least one Minuteman 3 launch from Vandenberg AFB.

Falcon 9 v1.1 Debut

SpaceX Corporation successfully launched its first Falcon 9 v1.1 launch vehicle from Vandenberg AFB on September 29, 2013. The two-stage kerosene fueled rocket, much longer and heavier and with more powerful engines than its five Falcon 9 predecessors, and equipped for the first time with a payload fairing, lifted off from rebuilt Space Launch Complex 4 East at 16:00 UTC on a demonstration mission with Canada's 500 kg Cassiope and with five small cubesats that together weighed about 100 kg. The second stage and satellites were aimed south toward a planned 300 x 1,500 km x 80 deg orbit.

It was the first SpaceX launch from the Western U.S. launch center, a site typically used for near polar orbital missions. The company extensively rebuilt SLC 4E, previously used for Titan 4, creating a flat pad with a massive wheeled transporter-erector that rolls from a horizontal assembly hanger nearby.

Falcon 9-006 lifted off on 600 tonnes of liftoff thrust produced by nine Merlin 1D engines. This was the first flight test of the new Merlin 1D, a gas generator engine designed from the outset to be mass produced. Falcon 9 v1.1 presented a unique sight as it rose, with the highest "fineness ratio" (length divided by width) of any large rocket currently flying. Two of the first stage engines shut down as planned shortly before the remaining seven cut off some time around the planned 2 minute 43 second mark. The second stage separated and ignited its new Vacuum Merlin 1D, beginning a more than six-minute long burn. The composite payload fairing was jettisonned at about the 3 minute 37 second mark.

Merlin 1D Engines Gleam in the Morning Sunlight Prior to Liftoff

After second stage cutoff, SpaceX ended its launch webcast as the stage flew out of tracking range. About 30 minutes later, word came that Cassiope and the cubesats had separated as planned beginning more than 14 minutes after liftoff.

SpaceX performed a test re-ignition of three of the first stage engines after staging, about 7 minutes 45 seconds after liftoff, in a demonstration of a reentry velocity reduction that might be used for stage recovery in the future. This burn and the reentry went as expected.

A second re-ignition of only the center engine also initiated as planned shortly before impact with the Pacific Ocean, but roll rates on the stage quickly exceeded the control ability of the reaction control system. The roll rate pushed propellant toward the tank edges, causing the engine to shut down. The stage fell, impacted the ocean, and broke into pieces. A recovery ship was able to haul aboard some floating pieces of the stage. SpaceX head Elon Musk was pleased with the results of the experiment, which he said moved SpaceX closer to recovery of stages in the future.

The second stage was also expected to perform a restart after spacecraft separation that would burn to propellant depletion. This planned "disposal burn" failed during engine restart. Elon Musk reported that the cause of the anomaly was understood and would be fixed before the next launch, when a restart would be necessary to insert SES 8 into a geosynchronous transfer orbit.

Propellant Loading for November 21, 2013 Static Test at Cape Canaveral

On November 21, 2013, SpaceX announced the cause of the Flight 6 restart problem. Frozen fluid lines for the Merlin 1D Vacuum engine's hypergolic igniter fuid (triethylaluminum-triethylborane, or TEA-TEB) were responsible for the failed second stage restart. The lines froze when they were exposed to liquid oxygen boiloff. Designers added insulation to the lines and reoriented systems to prevent GOX impingement on the lines in preparation for the next Falcon 9 launch with SES 8.

On the same date, SpaceX performed a wet dress rehearsal and static test firing of second Falcon 9 v1.1 at Cape Canaveral SLC 40 in preparation for a planned November 25 launch of SES 8 into supersynchronous earth orbit.

Falcon 9 Performs First Geosynchronous Transfer Mission

The second SpaceX Falcon 9 v1.1, and the seventh Falcon 9 overall, performed the Hawthorne, California company's first commercial geosynchronous transfer orbit launch from Cape Canaveral, Florida on December 3, 2013. The launch boosted SES 8, a 3,138 kg communications satellite built by Orbital Sciences for SES of Luxembourg, toward a targeted 295 x 80,000 km x 20.75 degree supersynchronous transfer orbit.

Liftoff from Space Launch Complex 40 occurred at 22:41 UTC. The on-time launch took place after two prior scrubbed attempts. A November 25 attempt was halted 3 min. 40 sec before launch by pressure fluctuations in the first stage LOX tank. A last-second abort during engine start ended the launch attempt on Thanksgiving Day, November 28, 2013. SpaceX replaced a gas generator on one Merlin 1D engine after that attempt.

Falcon 9's nine Merlin 1D first stage engines produced about 600 tonnes of liftoff thrust to boost the 69 meter tall, more than 500 tonne rocket slowly off its pad. The first stage burn ended about two minutes 54 seconds after liftoff, with two engines cutting off shortly before the remining seven. The second stage Merlin 1D Vacuum engine peformed two burns, with the first lasting about five minutes 20 seconds and the second about 71 seconds. The stage coasted in a parking orbit for about 18 minutes toward the first equator crossing over the Atlantic Ocean before the restart.

SES separated about 31 minutes 15 seconds after liftoff.

The second stage restart was a critical event. A restart had failed to occur during the inaugural September 29, 2013 Falcon 9 v1.1 flight in a test of the stage after payloads had successfully separated into their planned low earth orbits. SpaceX determined that hypergolic igniter fluid had been frozen by gaseous oxygen impingement during the flight. The company added insulation to prevent a recurrence.

SES 8 became the first satellite boosted to geosynchronous transfer orbit by a two-stage hydrocarbon fueled rocket.

It was the third Falcon 9 launch of 2013, the most in one year to date. The launch was also the 10th of the year by all launch vehicles from Cape Canaveral.

Falcon 9 Launches Thaicom 6

SpaceX Corporation's eighth Falon 9 rocket, and its third upgraded Falcon 9 v1.1 variant, launch Thailand's Thaicom 6 commuication satellite into orbit from Cape Canaveral, Florida on January 6, 2014. Liftoff from Space Launch Complex 40 took place at 22:06 UTC. The Merlin 1D Vacuum powered second stage performed two burns to accelerate the 3.016 tonne Orbital Sciences GEOStar 2 satellite toward a targeted 295 x 90,000 km x 22.5 deg supersynchronous transfer orbit.

After maneuvering itself to geosynchronous orbit, Thaicom 6, equipped with Ku and C-band transponders, will be co-located with Thaicom 5 at 78.5 degrees East.

After a 174 second long first stage burn, the second stage burned for about 350 seconds to place itself and its payload into a 173 x 497 x 27.3 deg parking orbit. Payload fairing separation occurred during the early part of the second stage burn. After an 18 minute coast, the second stage reignited for just over one minute to loft the payload toward its insertion orbit. Spacecraft separation occurred about 31 minutes 13 seconds after liftoff.

SpaceX performed its quickest launch pad turnaround for Thaicom 6, which lifted off just more than one month after Falcon 9 No. 7 orbited SES 8. During the campaign, the Thaicom 6 booster performed a hot fire test at SLC 40 on December 28, 2013.

F9-9 Sports First Landing Leg Assembly in SLC 40 Hangar

The ninth Falcon 9 was the first v1.1 version topped by a Dragon cargo carrier spacecraft. This was the CRS-3 mission, which was expected to carry more than 1.5 tonnes of cargo for ISS.

F9-9 was also the first Falcon 9 v1.1 equipped with landing legs. Plans called for the legs to be deployed shortly before the first stage reached the Atlantic Ocean during a second reentry test. After stage separation, the first stage would turn around and three of the first stage Merlin 1D engines would reignited to eliminate most of the stage horizontal velocity, allowing the stage to fall nearly straight down through the atmosphere at low enough velocity to survive reentry. SpaceX called this a "reentry burn". As the stage approached the Atlantic Ocean off the northern Florida coast, the center Merlin 1D would reignite for a third and final "landing burn" designed to scrub vertical velocity. The four landing legs would deploy 10 seconds after the start of the burn to simulate the process of an actual landing on land. At the conclusion of this test the stage would drop into the ocean. Recovery of the stage is unlikely, and is unnecessary for a successful test.

CRS-3 Dragon is Attached to F9-9. Dragon Adapter Visible on Left.

Future first stage recovery will likely require three post-separation burns. The first would both scrub horizontal velocity and boost the stage back toward the launch site, all while above the atmosphere. The second burn would eliminate the boost back horizontal velocity to allow reentry. A landing burn would land the stage near the launch site. Before SpaceX can attempt a boost back stage recovery, which will involve fly a loaded rocket stage back toward a populated coastline, it will have to demonstrate precise control and operation of the stage using several reentry tests offshore.

F9-9 Static Test Firing

SpaceX assembled the F9-9 vehicle in its Cape Canaveral SLC 40 hangar during February and March, 2014. On March 8, the vehicle performed a combined propellant loading and static test firing.

Falcon 9 v1.1 CRS-3 Launch, Showing Water Plume Kicked up from Flame Trench by Merlin 1D Ignition

Falcon 9 Orbits Dragon Cargo Mission

The ninth SpaceX Falcon 9 - and the fourth upgraded "1.1" version - launched a Dragon spacecraft on the CRS-3 resupply mission for NASA's International Space Station from Cape Canaveral on April 18, 2014. Liftoff from Space Launch Complex 40 took place at 20:25 UTC. The two-stage rocket boosted Dragon into a 313 x 332 km x 51.6 deg low earth orbit during a 9 minute 40 second ascent. Dragon controllers had to bypass a faulty quad thruster helium pressurization system isolation valve during the spacecraft initiation phase, but the problem was quickly solved using a backup system.

Dragon was loaded with either 2.09 or 2.27 tonnes of supplies (sources vary) for ISS - the heaviest Dragon cargo load to date a result of the first use of Falcon 9 v1.1 to launch a cargo mission. The spacecraft weighed as much as 7.76 tonnes at liftoff, including cargo, making it the heaviest Falcon 9 payload to date. It was expected to return to a splashdown off California's coast in several weeks with 1.59 tonnes of returning cargo.

After the first stage separated, it restarted three of its Merlin 1D engines to perform a reentry burn to eliminate most of its horizontal velocity. The stage, the first equipped with landing legs folded against the lower part of the vehicle, then dropped through the atmosphere and restarted a single Merlin 1D as it approached the surface of the Atlantic Ocean to eliminate vertical velocity. During the burn, the stage was expected to extend its legs in a test of future land landing techniques. The stage was unlikely to be recovered, and recovery was not necessary for the purposes of this test.

Landing Legs on F9-9 First Stage Prior to Rollout

Several hours after the flight, Elon Musk tweeted that data from a tracking plane had showed that the final landing phase had been performed successfully, meaning that the stage had remained stable, that the landing burn had fired for its full duration, and presumably that the landing legs had deployed. Several boats were enroute to the landing zone located about 520 km downrange from the Cape and about 400 km east-southeast of Charleston, South Carolina, though heavy seas were reported in the area.

After Dragon separated, the second stage coasted for 35 minutes before performing a brief depletion burn as it flew over the Indian Ocean southwest of Australia. The burn was intended to determine propellant residuals and to lower the orbit of the stage, hastening its

reentry.

Dragon successfully berthed with ISS two days after launch.

CRS-3 Dragon Approaches ISS

On April 21, 2014, SpaceX President and Chief Executive Officer Gwynne Shotwell said that the first stage had landed softly at near zero velocity, but that recovery was unlikely due to rough seas. She said that the stage, or that parts of the stage, had been located. A Coast Guard navigation hazard notice briefly listed a floating stage obstruction at about 31 North, 76 West, but the notice was subsequently canceled.

Four days later, Elon Musk confirmed that the stage had deployed its legs and landed softly, but had subsequently sunk due to wave action. High seas prevented any ships from searching for the stage for two days. Only floating fragments were located, included pieces of the carbon composite interstage and of one of the landing legs. Mr. Musk said that the company would try another first stage ocean landing on the next Falcon 9 flight.

Long Falcon 9 Campaign Ends with Success

The fifth SpaceX Falcon 9 v1.1, and tenth Falcon 9 overall, launched six Orbcomm data relay satellites into low earth orbit following a July 14, 2014 Cape Canaveral launch. Liftoff from SLC 40 took place at 15:15 UTC. The second stage performed a single direct insertion burn to place the Orbcomm OG 2 payload, consisting of an adapter with six 172 kg Orbcomm satellites and two 172 kg mass simulators, into a 614 x 743 km x 47 deg orbit. Sierra Nevada Corporation and Boeing Corporation built the satellites, which will maneuver themselves into 715 km circular operational orbits.

The launch culminated a difficult campaign that endured more than two months of delays. An early May launch date had to be postponed after a May 8, 2014 static test was called off due to ground support equipment issues. A helium leak occurred inside the first stage during propellant loading for a second static test attempt on May 9, 2014. The leak required rollback of the rocket for inspection and replacement of an unspecified part from the stage, along with a review of designs and procedures.

The Orbcomm payload was deencapsulated and removed from the rocket after the leak.   After the rocket was repaired, the launch campaign restarted, leading to a successful static test on June 13, 2014. Then the launch was delayed for five days due to issues that appeared during testing of the Orbcomm satellites after their period of storage at SLC 40.

On June 20, 2014, a launch attempt was scrubbed several minutes before liftoff due to a decay in second stage pressurization, apparently due to an issue with ground support equipment. A June 21 attempt was scrubbed due to weather after the propellant was loaded. Another attempt was scrubbed on June 22 before propellant loading began after a problem with a first stage thrust Vector Control actuator was detected. Once again, Falcon 9 was rolled back into its hangar for repairs.

While repairs were underway, the Cape Canaveral range entered a pre-planned two-week shutdown for maintenance, which prevented launch attempts. The rocket was static tested on July 1, 2014. On the evening of July 10, 2014, Falcon 9 No. 10 rolled out to its pad for the final time.

The Falcon 9 first stage burned for about 2 minutes 38 seconds as the rocket climbed on a steeper than typical trajectory while aiming for a 620 km insertion altitude. The trajectory also allowed the first stage to attempt a landing closer to Cape Canaveral than achieved during the previous flight. The second stage fired for about 6 minutes 46 seconds to reach its insertion orbit. Orbcomm deployment began about 15 minutes after launch.

After staging, the first stage perrformed a reentry burn, followed by reentry and a final landing burn to attempt soft landing in the Atlantic Ocean, in a continuation of a test series evaluating the possibility of recovering the first stage by having it fly back and land near its launch site. SpaceX head Elon Musk tweeted that the burn and leg deployment were successful, but that the stage "lost hull integrity right after splashdown (aka kaboom)". He said that a review of data was needed to determine if the issue was due to splashdown forces or to the tip over and "body slam" after landing.   A few days later, he reported that the "body slam" was likely responsible, suggesting that the landing itself had been successful. SpaceX subsequently released on-board video that showed a successful landing. The released video cut off just before the safely landed stage tipped sideways into the ocean.

The second stage performed a reentry burn after payload separation, a maneuver aided by the substantial excess delta-v for this mission. Total deployed operational mass was only 1.032 tonnes. Total mass including the two mass simulators and deployment adapter was likely only about 1.5 tonnes. Falcon 9 v1.1 capability to the Orbcomm insertion orbit was likely more than 10 tonnes, though some of that capability was likely expended in the steep ascent.

Falcon 9 Launches Asiasat 8

The 11th SpaceX Falcon 9 rocket, and the sixth v1.1 variant, boosted the Asiasat 8 communications satellite into geosynchronous transfer orbit from Cape Canaveral on August 5, 2014. Liftoff from Space Launch Complex 40 took place at 08:00 UTC, only three weeks after the previous Falcon 9 launch from the same pad.

Falcon 9's second stage performed two burns during a 32 minute mission to aim the 4,535 kg Space Systems Loral 1300 series satellite toward a 185 x 35,786 km x 24.3 deg insertion orbit. Asiasat 8 will burn its own propellant to provide roughly 1,750 meters per second delta-v to reach geostationary orbit.

Before the encapsulated Asiasat 8 satellite was attached, the rocket was rolled out to perform a brief static test firing on July 31, 2014. Like recent payloads, Asiasat 8 was processed in the SPIF (Satellite Processing and Integration Facility) at Cape Canaveral. The SPIF, part of the former Titan Integrate Transfer Launch (ITL) launch complex, formerly handled Shuttle, Titan IV, Altas II, and EELV Defense Department payloads.

Asiasat 8 was the heaviest beyond LEO payload carried by a Falcon 9 to date. Falcon 9 flew in expendable mode without landing legs as a result. It was the year's fourth Falcon 9 launch.

Falcon 9 Launches Asiasat 6

A SpaceX Falcon 9 v1.1 boosted Asiasat 6 into geosynchronous transfer orbit (GTO) from Cape Canaveral Air Force Station on September 7, 2014. The 500-plus tonne two stage rocket lifted off from Space Launch Complex 40 at 05:00 UTC to begin a 32 minute long mission that featured two burns of the Merlin 1D Vacuum powered second stage. The first burn placed the vehicle into a 202 x 175 km x 27.7 deg parking orbit about 9 minutes after liftoff. The second, roughly one-minute burn began after a 17 minute coast downrange to the equator. Asiasat 6, a 4.428 tonne Space Systems Loral 1300 series satellite, was targeted toward a 185 x 35,786 km x 25.3 deg GTO.

AsiaSat of Hong Kong owns the satellite, which will use 28 C-band transponders to transmit video and data across China and Southeast Asia. Transponder sharing with Thaicom will give the satellite a second moniker: Thaicom 7. AsiaSat 6's launch came just over one month after the previous Falcon 9 launched similar Asiasat 8.

The first stage restarted three of its Merlin 1D engines after stage separation. The duration of the burn was not announced, but it was likely only a brief ignition test. No landing burn was attempted.

It was the seventh Falcon 9 v1.1 launch, the 12th Falcon 9, and the fifth SpaceX launch of 2014.

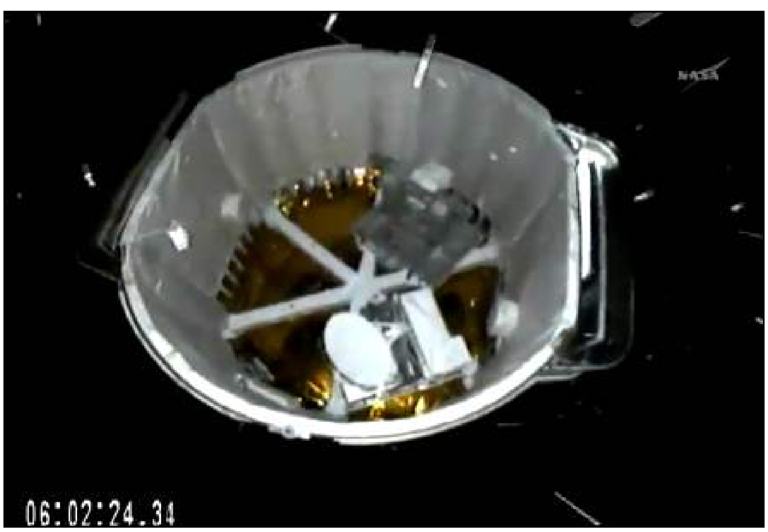
The launch was delayed two weeks to allow SpaceX engineers to review data from an August 22 failure of the company's Falcon 9R Dev 1 landing test rocket stage at the company's McGregor, Texas test site. On that date the test stage lifted off on the thrust of three Merlin 1D engines, but one of the outboard engines suffered a sensor failure at startup, creating conditions that ultimately led to loss of control and the triggering of an automatic destruct sequence after the stage had risen several hundred meters. The review confirmed that Falcon 9 v1.1 would not have encountered the problem because it uses redundant sensors while Falcon 9R Dev 1 used a single string setup.

Falcon 9R Dev 1 failed during its fifth test flight. It first flew on April 17, 2014. On subsequent tests it flew to 1,000 meters, maneuvered, and landed successfully. On its third test on June 17 it used steerable grid fins for the first time to augment control. The August 22 flight was apparently the first to use three engines, with the two outboard engines expected to be throttled and then shut down prior to landing.

Falcon Lofts Dragon

A SpaceX Falcon 9 v1.1 successfully orbited the Dragon CRS-4 spacecraft on a resupply mission for the International Space Station from Cape Canaveral, Florida on September 21, 2014. The more than 500 tonne two-stage rocket lifted off from Space Launch Complex 40 at 05:52 UTC to begin its 9 minute 30 second ascent to a 199 x 359 km x 51.644 deg orbit.

Dragon was loaded with 2.216 tonnes of cargo for ISS. The spacecraft weighed as much as 7.716 tonnes at liftoff, including cargo. Included was the first 3D printer to be launched into space, 20 mice riding in a specially-made habitat, a radar scatterometer to measure ocean winds, and a metal plating experiment flown by a golf club manufacturer. that could improve the design of golf clubs.



Dragon Separation

CRS-4 is slated to return to a splashdown off Southern California's coast with 1.486 tonnes of cargo after a four week stay at the station. It is the fourth of at least 12 missions to ISS that SpaceX is contracted to fly under NASA's Commercial Resupply Services (CRS) contract.

This Falcon 9 was not fitted with landing legs, but the first stage performed reentry and landing burns after separating from the second stage. During the ascent the first stage fired for about 2 minutes 50 seconds and the second stage for about 6 minutes 40 seconds. Dragon separation occurred about 10 minutes 15 seconds after liftoff. Some time after separation, the second stage reignited to perform a brief deorbit burn that targeted a reentry south of New Zealand during the first orbit.

The launch came after a September 17, 2014 static test firing of the Falcon 9 first stage engines on SLC 40. It followed by only 14 days the previous Falcon 9 launch of Asiasat 6 from the same launch pad. A 13 day turnaround might have occurred were it not for a weather scrub on September 20.

It was the 13th Falcon 9, the 8th Falcon 9 v1.1, the 8th Falcon 9 launch during the past 12 months, and the fourth launch during the past two months.

Falcon 9 Orbits Dragon CRS-5

SpaceX's ninth Falcon 9 v1.1 rocket successfully orbited another of the company's Dragon spacecraft on the CRS-5 (Cargo Resupply Services) mission from Cape Canaveral, Florida on January 10, 2015. Rising on nearly 590 tonnes of thrust produced by its nine first stage Merlin 1D engines, the 63.4 meter tall two-stage rocket lifted off at from Space Launch Complex 40 at 09:47 UTC and steered on a northeastward track. The first stage shut down its nine Merlin 1D engines about 157 seconds after liftoff and the second stage Merlin Vacuum engine began a roughly 7 minute burn to boost the vehicle into a 206 x 353 km x 51.64 degree orbit.

Dragon carried 2.317 tonnes of cargo for International Space Station Expeditions 42 and 43. The spacecraft likely weighed as much as 7.807 tonnes at liftoff, including cargo. One unpressurized payload carried in Dragon's trunk was NASA Goddard's Cloud-Aerosol Transport System (CATS), a laser remote sensing experiment designed to measure clouds and aerosols in the atmosphere. It also carried an IMAX camera and tools for future spacewalks to prepare the station for the installation of the new international docking adapters.

After about four weeks at ISS, Dragon will return to a Pacific Ocean splashdown loaded with more than 1.633 tonnes of return cargo, packaging materials, and trash.

It was the second launch attempt for CRS-5. A January 6 attempt was scrubbed 1 minute 21 seconds before the planned liftoff because of a second stage engine thrust vector control actuator issue. SpaceX said that engineers had "observed drift on one of the two thrust vector actuators (Elon Musk identified it as the "Z actuator") on the second stage that would likely have caused an automatic abort". A similar problem had appeared during the rocket's initial hot fire test countdown at SLC 40 on December 17, 2014 but engineers had thought the problem subsequently solved.

That initial hot fire test was itself aborted after ignition due to a valve problem, causing the planned December 20 launch date to slip to January 6. A second hot fire test attempt was successful on December 19, 2014.

After the first stage separated, it performed another in a continuing series of SpaceX stage recovery experiments. This time, for the first time, a landing was attempted on a converted barge, parked more than 320 km downrange, that was equipped with a flat top landing platform and position-holding capabilities. Also, for the first time, four grid-fins attached to the interstage were used to help steer the stage toward a precise landing spot. The stage reignited three of its engines to perform an initial boost-back burn to shorten its range. Then, as it fell through the upper atmosphere, it fired its engines a second time to reduce reentry velocity.

A third single-engine landing burn took place during the final moments of the descent, designed to set the stage safely down on four landing legs that were to deploy just before landing. The stage apparently steered itself to the barge and attempted to land, but it crashed, or landed hard, on the barge and was destroyed. The barge itself remained afloat, but stage recovery equipment aboard the barge was destroyed. SpaceX head Elon Musk announced that the grid fins had worked during the hypersonic to subsonic velocity phase, but that they exhausted their hydraulic fluid supply shortly before the landing, which may have contributed to the crash.

It was the first orbital launch of 2015 and the 14th Falcon 9 launch.

Falcon 9 Launches DSCOVR

SpaceX's tenth Falcon 9 v1.1 rocket, and 15th Falcon 9 overall, launched the NASA/NOAA/USAF Deep Space Climate Observatory (DSCOVR) from Cape Canaveral, Florida on February 11, 2015. The 500+ tonne two-stage rocket lifted off from Space Launch Complex 40 at 22:03 UTC and steered on an eastward track, rising into the light of a setting sun for a spectacular dusk ascent.

The first stage shut down its nine Merlin 1D engines about 164 seconds after liftoff and the second stage Merlin Vacuum engine began a 5 minute 44 second burn to boost the vehicle into a parking orbit. After coasting across the Atlantic Ocean, the second stage reignited at the 30 minute 9 second mark to begin a 58 second burn aimed to boost DSCOVR into a highly elliptical earth orbit. The target orbit was 187 x 1,241,000 km x 37 degrees. The achieved orbit was 187 x 1,371,156 km x 37 degrees.

DSCOVR is a 570 kg satellite that was originally built by Lockheed Martin during the 1990s. It will move itself into a Lissajous orbit around the Sun-Earth L1 Lagrangian point, 1,500,000 km from Earth in line with the Sun. There it will monitor the solar wind and provide images of the fully-illuminated side of the Earth. The spacecraft will take 110 days to reach its final L1 orbit.

It was the third launch attempt for DSCOVR. A February 8 attempt was scrubbed with a little more than 2 minutes remaining in the count due to a range tracking issue. A February 10 attempt was scrubbed due to excessive high altitude winds. The rocket performed its static fire test at SLC 40 on January 31, 2015 during the day's second attempt.

After the first stage separated, it performed a reentry burn followed by a terminal landing burn, but a second attempt to land on a converted barge had to be abandoned due to high seas. The landing attempt would have been more than 400 km downrange. An initial boost-back burn performed during previous recovery missions was not performed due to the need to assign propellant to the DSCOVR ascent.

It was the second Falcon 9 launch of 2015.

Falcon 9 Orbits Ion Engine Satellite Pair

Falcon 9 No. 16 During Final Minutes of Countdown

The 16th SpaceX Falcon 9 launch vehicle, and the 11th Falcon 9 v1.1 variant, launched two landmark communications satellites into orbit from Cape Canaveral on March 2, 2015. Liftoff from Cape Canaveral SLC 40 took place at 03:50 UTC. ABS-3A and Eutelsat 115 West B, the first two all-ion-engine powered Boeing HS-702SP satellites, were stacked atop one another inside the 5.2 meter diameter payload fairing.

The first stage was not equipped with landing legs or grid fins for a landing attempt due to the requirements of the mission. The first stage fired for 2 min 56 seconds before separating. After a 10 second unpowered interval, the second stage started its Merlin 1D Vacuum engine for a 5 min 44 second burn that boosted the vehicle into a 174 x 953 km x 28.19 deg parking orbit. The stage coasted for 16 min 52 seconds before reigniting for a 59 second burn that boosted the stage and payloads toward a targeted supersynchronous transfer orbit of 408 x 63,928 km x 24.83 deg. The satellites separated in sequence during the subsequent nine minutes. The satellites separated in sequence during the subsequent nine minutes and were subsequently tracked in roughly 400 x 63,300 to 63,400 km x 24.8 deg orbits that exceeded customer expectations. They will gradually maneuver themselves to geostationary orbit, a process that will take at least eight months due to the low thrust provided by the ion engines.

ABS-3A stacked atop Eutelsat 115 West B During Payload Processing

By dispensing with standard liquid monomethyl hydrazine propellants in favor of highly efficient xenon-ion propulsion system (XIPS), Boeing developed satellites that could weigh substantially less. Each satellite has at least four 25 cm diameter XIPS, each producing about 8.2 grams thrust at an average ISP of 3,420 seconds.

ABS-3A weighed 1.954 tonnes and Eutelsat 115 West B weighed 2.205 tonnes, about half the weight of a standard satellite of equal capability. The Eutelsat satellite weighed more than ABS-3A because it was the lower of the two satellites and was designed to support the weight of ABS-3A. This arrangement allowed for a standard Falcon 9 payload fairing and payload attach fitting to be used.

The total 4.159 tonne payload mass was the heaviest boosted to a supersynchronous transfer orbit by Falcon 9 to date. The rocket performed a static test firing on the pad on February 25 with no payloads or payload fairing attached.

Falcon 9 Launches Dragon CRS-6

A SpaceX Falcon 9 v1.1 rocket successfully orbited the company's Dragon spacecraft on the CRS-6 (Cargo Resupply Services) mission from Cape Canaveral, Florida on April 14, 2015. The 63.4 meter tall two-stage rocket lifted off from Space Launch Complex 40 at 20:10 UTC and steered on a northeastward track. The first stage shut down its nine Merlin 1D engines about 159 seconds after liftoff and the

second stage Merlin Vacuum engine began a 408 second burn to boost the vehicle into a 199 x 364 km x 51.65 degree orbit.

Dragon carried 2,015 kg of cargo for the International Space Station, a total that included 117 kg of packing material. The spacecraft likely weighed about 7,505 kg at liftoff, including cargo and the weight of two solar array fairings that were jettisonned shortly after reaching orbit.

After about five weeks at ISS, Dragon will return to a Pacific Ocean splashdown loaded with 1,370 kg of return cargo, packaging materials, and trash.

It was the second launch attempt for CRS-6. The first attempt was scrubbed by approaching weather on April 13. The rocket's first stage performed an on-pad hot-fire test on April 11.

The CRS-6 mission, complete with its launch vehicle, had moved ahead of the previously-processed Turkmensat mission when a potential problem was found with that rocket's helium pressurization system a few days before its planned launch on March 21. The CRS-6 launch vehicle was then swapped with the Turkmensat rocket so that CRS-6 was launched by the 18th Falcon 9 launch vehicle although it was the only the 17th Falcon 9 to fly.

After the first stage separated, it performed a three-burn recovery experiment aiming toward a landing on a converted barge floating in the Atlantic Ocean about 330 km downrange. The stage landed on the barge, but apparently landed hard and disentegrated.

Falcon 9 Launches TurkmenAlem 52E

The 13th Falcon 9 v1.1 to fly, and the 12th to be built, successfully boosted the TurkmenAlem 52E communications satellite into geosynchronous transfer orbit from Cape Canaveral, Florida on April 27, 2015. Liftoff from Space Launch Complex 40 took place at 23:03 UTC after a half-hour weather delay.

The 4,500 kg Thales Alenia Space Spacebus 4000 series satellite was released about 32 minutes 15 seconds after liftoff, following a second burn of the Falcon 9 second stage, toward a targeted 180 x 36,600 km x 25.5 deg orbit. The satellite is the first satellite launched for the government of Turkmenistan.

The flight was originally shelved only a few days before its planned March 21, 2015 date when concerns were raised about helium pressurization bottles in the first stage LOX tank after an anomaly was detected in other hardware at the Hawthorne, California Falcon 9 factory. As a result, the F9-17 vehicle (12th Falcon 9 v1.1 and 17th Falcon 9) being prepared for TurkmenAlem 52E was pulled from the SLC 40 hangar back to the SpaceX hangar in the Cape Canaveral industrial area. This allowed the F9-18 vehicle to move ahead in the queue to perform the CRS-6 launch on April 14. F9-17 quickly returned to SLC 40, where it performed a static test firing on April 22.

Falcon 9 CRS-7 Failure

F9-19/CRS-7 Failure

The 19th SpaceX Falcon 9 to fly (production serial number 20) suffered a launch failure about 2 minutes 19 seconds after liftoff from Cape Canaveral SLC 40 on June 28, 2015. The flight, carrying cargo for the International Space Station, lifted off at 14:21 UTC. The Falcon 9 v1.1 steered into clear skies and headed downrange with no obvious problems during the first two minutes of flight, but a cloud of white vapor suddenly expanded from the front of the vehicle at the 2:19 mark, and pieces were visible breaking off of the vehicle, even

as the first stage engines continued thrusting.   The rocket quickly broke up and was enveloped by a larger explosion.

F9-19/CRS-7 Liftoff

An hour or so after launch, SpaceX CEO Elon Musk reported via. Twitter that the second stage liquid oxygen tank had become overpressurized and failed due to "counterintuitive" reasons that were still under investigation. At the time of the failure the second stage was being prepared to begin its portion of the flight, with the Merlin Vacuum engine in a chilldown phase.

It was the first failure of a Falcon 9 v1.1 in 14 flights, the first Falcon 9 to fail to reach orbit, and the second failure of any type of a Falcon 9.

The failure was the third involving an ISS cargo carrier during the last 8 months, placing the station in a potential cargo-shortage danger.   The loss reduced the planned on-board cargo margin by at least one month.

Helium Bottle Support Eyed in Falcon 9 Failure

On July 20, 2015, Elon Musk, head of SpaceX, announced preliminary investigation results of the company's June 28 Falcon 9/CRS-7 launch failure. Musk said that a strut supporting one of the high pressure composite overwrapped pressure vessel (COPV) helium bottles inside the second stage liquid oxygen (LOX) tank is believed to have failed as vehicle acceleration passed 3.2 Gs, allowing the bottle to break free. As a result of the failure, enough helium was released to rapidly overpressurize the tank. The bottles hold helium at 5,500 psi.

Mr. Musk also revealed that the CRS-7 Dragon capsule, which broke away from the disentegrating rocket, transmitted data until it fell below the horizon and could have been saved if a parachute could have been ejected. Flight software did not have a mode for such a contingency, but Musk said that future versions would have such software.

The 2 foot long, one inch thick strut failed at only 20% of its 10,000 pound rated strength. During its investigation, SpaceX tested a large number of the struts and found a few that failed below the rated strength due to metallurgical weaknesses. SpaceX will replace the struts, which are also used in first stages, with stronger struts from a different manufacturer. The company will also improve its quality control processes to assure strut strength.

Musk said that the next launch will not occur until September at the earliest, depending on reviews by NASA, the FAA, the U.S. Air

Force, and commercial customers.

Falcon 9 Orbits Jason 3, Stage Landing Fails

The final SpaceX Falcon 9 v1.1 rocket boosted Jason 3, an ocean monitoring satellite, into low earth orbit from Vandenberg AFB on January 17, 2016. Liftoff from fog-enshrouded Space Launch Complex 4 East (SLC 4E) took place at 18:42 UTC. The first stage burned for about 2 min 34 sec. The second stage then fired for about 6 min 15 sec to place itself into a 175 x 1,321 km orbit. The stage coasted until about 55 minutes after launch, when it fired again while passing northward above the Indian Ocean east of Africa, for 12 seconds, to reach a 1,305 x 1,320 km x 66 deg insertion orbit. Jason 3 separated soon after.

Four international agencies partnered for the Jason 3 mission. They include NOAA, NASA, the French Space Agency CNES (Centre National d'Etudes Spatiales), and EUMETSAT (European Organization for the Exploitation of Meteorological Satellites). Thales Alenia of France built the 553 kg spacecraft. NASA managed the launch service. Jason 3 will perform ocean topography using a microwave radiometer and other instruments.

The second stage performed a deorbit burn after spacecraft separation, targeting a mid-Pacific Ocean impact zone.

After staging, the first stage performed boostback, reentry, and landing burns while aiming for a converted landing barge floating in the Pacific about 280 km downrange, west of San Diego, California. The stage landed, but one of the landing legs did not fully lock in place and the stage fell over. Parts of the destroyed stage remained on the barge.

The first stage performed a static fire at SLC 4E on January 11, 2016 after rolling out the previous day. The stage had completed its testing at McGregor, Texas in May, 2015, but had to wait for flight after the mid-2015 Falcon 9 launch failure. The second stage was tested at McGregor on November 4, 2015 to verify modifications mades after the F9-20 launch failure. It was the 14th success in 15 flights of the Falcon 9 v1.1 variant.

Vehicle Configurations

	LEO Payload (metric tons) 185 km x (1) 28.5 deg (CC) (2) 98 deg (VA) (3) 9.1 deg (KW) (4) 51.6 deg (CC)	**Geosynchronous Transfer Orbit Payload (metric tons) 185x35,788 km x 27 deg ~1,800 m/s from GEO**	**Escape Velocty Payload (5)LEO+3,150 m/s (6)LEO+3,750 m/s**	**Configuration**	**Liftoff Height (meters) [1] Dragon [2] PLF**	**Liftoff Mass (metric tons)**	**Price (2005) $Millions**
Falcon 9 Block 1 (Merlin 1C) 2010	9.0 t (1) 8.5 t (4)	3.4 t	2 t (5)	2 Stage Falcon 9 (Merlin 1C) + 3.6 m or 5.2 m PLF	[1] 48.1 m	318 t	$35-55 m (2007)
Falcon 9 v1.1 (Merlin 1D) >2013?	13.15 t (1)	4.85 t	2.9 t (est)(5)	2 Stage Falcon 9 v1.1 (Merlin 1D) + 3.6 m or 5.2 m PLF	[1] 63.3 m [2] 68.4 m	505.8 t	$54-59.5 m (2013)
Falcon Heavy >2014?	53 t	21.2 t	13.2 t (6)	3 Falcon 9xMerlin 1D cores + 1xMerlinVac Upper Stage + PLF	[2] 68.4 m?	1,462 t	$80-124 m (2013)

Vehicle Components

	Falcon 9 Stage 1 - Block 1 Merlin 1C	**Falcon 9 Stage 2 - Block 1 Merlin 1C**	**Falcon 9 Stage 1 - "v1.1" Merlin 1D**	**Falcon 9 Stage 2 - "v1.1" Merlin 1D**

	Version Estimated	Version Estimated	Version Estimated	Version Estimated
Diameter (m)	3.66 m	3.66 m	3.66 m	3.66 m
Length (m)	~30.1 m (est) not incl I/S	~10.0 m incl I/S	~40.9 m (est) not incl I/S	~14.6 m incl I/S
Empty Mass (tonnes)	~19.24 t? burnout	~3.1 t? burnout	~19 t? burnout	~4-4.5 t? burnout
Propellant Mass (tonnes)	~239.3 t? used	~48.9 t? used	~360-385 t? used	~70-80 t? used
Total Mass (tonnes)	~258.5 t?	~52 t?	~380-405 t?	~74-84 t?
Engine	Merlin 1C	Merlin Vac	Merlin 1D	Merlin 1D Vac
Engine Mfgr	SpaceX	SpaceX	SpaceX	SpaceX
Fuel	RP1	RP1	RP1	RP1
Oxidizer	LOX	LOX	LOX	LOX
Thrust (SL tons)	387.825 t		600.109 t	-
Thrust (Vac tons)	442.938 t	42.18 t	680.396	81.647 t
ISP (SL sec)	266 s	-	282 s	-
ISP (Vac sec)	304 s	336 s	311 s	340s
Burn Time (sec)	180 s	346 s	185 s?	375 s?
No. Engines	9	1	9	1
Comments	-	-	-	-

				Falcon 9 Payload Fairing
Diameter (m)				5.2 m
Length (m)				13.9 m
Empty Mass (tonnes)				~ 2.0 t?

Falcon 9 v1.1 Flight History

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Date    Vehicle        No.   Payload              Mass  Site  Orbit (kmxkmxdeg)
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09/29/13 Falcon 9 v1.1 F9-6  Cassiope/5 Cubesats   0.6   VA 4E 500x1500x80    LEO [8]
12/03/13 Falcon 9 v1.1 F9-7  SES 8                 3.183 CC 40 295x80000x20.8 GTO+[9]
01/06/14 Falcon 9 v1.1 F9-8  Thaicom 6             3.016 CC 40 295x90000x22.5 GTO+[A]
04/18/14 Falcon 9 v1.1 F9-9  CRS-3 Dragon         ~7.76  CC 40 313x332x51.6   LEO/ISS[10]
07/14/14 Falcon 9 v1.1 F9-10 Orbcomm OG2 (6sats)   1.032 CC 40 614x743x47     LEO [11]
08/05/14 Falcon 9 v1.1 F9-11 Asiasat 8             4.535 CC 40 185x35786x24.3 GTO
09/07/14 Falcon 9 v1.1 F9-13 Asiasat 6             4.428 CC 40 184x35762x25.3 GTO
09/21/14 Falcon 9 v1.1 F9-12 CRS-4 Dragon         ~7.716 CC 40 199x359x51.64  LEO/ISS
01/10/15 Falcon 9 v1.1 F9-14 CRS-5 Dragon         ~7.807 CC 40 206x353x51.6   LEO/ISS[12]
02/11/15 Falcon 9 v1.1 F9-15 DSCOR                 0.57  CC 40 187x1371156x37 EEO [13]
03/02/15 Falcon 9 v1.1 F9-16 Eutelsat 115WB/ABS 3A 4.159 CC 40 400x63300x24.8 GTO+
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04/14/15 Falcon 9 v1.1 F9-18 CRS-6 Dragon         ~7.505 CC 40 199x364x51.65  LEO/ISS[14]
04/27/15 Falcon 9 v1.1 F9-17 TurkmenAlem 52E       4.5   CC 40 180x36600x25.5 GTO
06/28/15 Falcon 9 v1.1 F9-20 Dragon CRS-7         ~7.944 CC 40                [FTO][15]
01/17/16 Falcon 9 v1.1 F9-19 Jason 3               0.553 VA 4E 1305x1320x66   LEO [16]
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[8] First Falcon 9 v1.1. First VAFB SLC 4E launch of Falcon 9.
     1st stage performed two reentry burns (3 and 1 engine), but 2nd
     burn cutoff early due high roll rates. 2nd stage restart for
     disposal burn failed.
[9] First Falcon 9 GTO+ launch.  Targeted 295 x 80,000 km x 20.75 degree
      supersynchronous transfer orbit.  Stg 1 briefly restarted post sep.
      Fire reported in Stg1 octaweb during ascent.
[A] Lower than planned fuel reserves reported at end of final Stg2 burn.
      Planned orbit achieved.
[10] First Falcon 9 fitted with extending landing legs.  First stage
      performed two retro burns after separation, lowering itself to a
      simulated landing in the Atlantic off the Georgia/S. Carolina coast.
[11] 2nd Falcon 9 with legs.  First stage performed two retro burns and
      landed in Atlantic but exploded during tip over.
[12] 1st stg attempted landing on converted barge about 320 km downrange,
      but landed hard on barge and was lost.
[13] 187 x 1,371,156 km x 37 degree insertion orbit.  DSCVR bound for Earth-Sun L1.
      Stg 1 barge landing attempt abandoned due high seas.
[14] First stage landed hard on downrange landing platform and was destroyed.
[15] Broke up at about T+2m 19sec, before staging, due Stg2 LOX tank overpress.
[16] First stage landed on downrange landing platform, but one leg failed to
      lock in place.  Stage fell over and was destroyed.
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