

Chapter 2

Game Changer: SpaceX

The commercial space business is often one of faceless corporate management. This is not the case with SpaceX and its founder Elon Musk. The boldness of Musk's corporate vision, travails of launch vehicle development and the ultimate success of the Falcon rockets and Dragon capsules harkens back to the days of aircraft builders William Boeing, Donald Douglas, and Jack Northrop in the 20th century.

Born and raised in South Africa, Musk was the first in his family to move to Canada and then to the United States to attend college there. He received bachelor degrees in physics from the University of Pennsylvania and economics from the Wharton School. Musk abandoned his plans to get his doctorate in physics at Stamford University to pursue business opportunities in corporate e-commerce. In rapid succession he founded or was involved with Zip2, then X.com, which later became PayPal. Musk sold his share in PayPal in 2002 to eBay for \$165 million.

The seeds of Space Exploration Technologies—SpaceX—were planted in 2001. Musk started informally discussing commercial space ventures with fellow entrepreneur Adeo Ressi. The subject of Mars came up and the possibility of mounting a mission of some kind to the Red Planet. Musk checked the NASA website to see what Mars missions the space agency was conducting and was shocked to learn there were none—at the time. NASA had successfully sent its Martian spacecraft Pathfinder with its small robotic rover Sojourner to Mars in 1997. In 2001, NASA's Jet Propulsion Laboratory was engineering identical exploratory robotic rovers, identified as Mars Exploration Rovers (MERs). These would be launched to Mars in 2003 (Fig. 2.1).

Musk believed the United States should have pressed on to the exploration of Mars after the Apollo lunar program ended in 1972. Upon learning there was no high profile mission to Mars, Musk decided he should be the one to get things started. Initially the plan was to obtain a launch vehicle of sufficient power to send a living payload to land safely on the surface of Mars. Musk and Ressi called their new company Life to Mars. In June of 2001, Musk contacted Jim Cantrell, president of Strategic Space Development. Cantrell's company specialized in business growth strategies for aerospace firms. He agreed to take on Musk as a client and help find the launch vehicle and services the startup would need.

Musk, Ressi and Cantrell dismissed the Atlas with Centaur upper stage as too expensive. They chose instead to go to Arianespace. The cost of using this agency's



Fig. 2.1 SpaceX Falcon 9 boosters being assembled at the company's headquarters in Hawthorne, California (image courtesy of SpaceX, used with permission)

launch vehicle and services were also prohibitive. They then turned to the Russians, with which Cantrell had experience. Several trips to Russia proved demoralizing, as negotiations broke down. The team returned to the United States with no rocket or prospects of one. On the flight back, Musk made a decision. He told Cantrell he believed they should build the rocket themselves. Cantrell had given Musk every book on rocket propulsion and guidance he had, and Musk had been working out a possible design in his head for weeks.

At this point, Musk's vision expanded dramatically. He spoke to Ressi about starting a company that would challenge the status quo in launch vehicles and services. Ressi became alarmed, foreseeing the formidable challenges of such a venture and the staggering attendant costs. He brought in experts to speak with Musk of the daunting engineering involved, notwithstanding the small size of what his prospective company might be. Design and development could run into the hundreds of millions of dollars.

Musk dismissed all the arguments and objections. Musk fully embraced Dr. Wernher von Braun's most famous quote, "I have learned to use the word impossible with the greatest of caution." He planned to move ahead with his ambitious goals of dramatically lowering the cost of getting payloads to orbit, while holding on to the dream of Martian exploration and even colonization. It should be stated here that Musk had no experience in large-scale manufacturing at all; he had only been involved in online commerce. Ressi did not join Musk in his vision, and chose instead to pursue venture capitalism.

The first order of business was to find an experienced propulsion engineer who could design an engine from a clean sheet of paper. Musk believed there could be design and manufacturing efficiencies realized in this area as well. Instead of trying to recruit from Rocketdyne or Aerojet, he went looking for a maverick like himself. Musk found him in a propulsion engineer by the name of Tom Mueller. A fourteen-year veteran of TRW, Mueller was working on advanced propulsion concepts of his own design, manufacture and testing when Musk tracked him down. Impressed with Mueller's working knowledge, proven success in rocket engine design and the successful manufacture of actual flight hardware, Musk hired him away from TRW.

Musk founded Space Exploration Technologies, Inc., in June 2002 in Hawthorne, California. A large commercial building formerly used by Boeing was acquired adjacent to the Hawthorne Municipal Airport as the company's headquarters. Musk was ready to commit \$100 million of his personal wealth to get SpaceX into the launch services industry. He became his own chief engineer and headhunter to recruit the talent and experience he needed for SpaceX. He lured Dr. Hans Konigsmann away from Microcosm, Inc., in El Segundo, California, to act as vice president of Guidance, Navigation and Control.

He next hired Gwynne Shotwell. She held degrees in mechanical engineering and applied mathematics. Shotwell had worked ten years at Aerospace Corporation in El Segundo, California, with responsibility in space systems engineering and technology, and in project management. She left in 1998 to work at Microcosm, Inc., as manager of the Space Systems Division with the added duties of corporate business development [1]. Through Dr. Konigsmann Musk met Shotwell and hired her to be vice president of business development.

"You could characterize all the early leaders at SpaceX as being very knowledgeable about the industry but wanting to change things dramatically and get the industry moving at a much faster pace," Shotwell recalled in an interview [2].

The Falcon 1

Musk wanted to develop a two-stage rocket with the capability of launching 1400 lbs. (635 kg) to low Earth orbit. It would be called the Falcon 1. Mueller worked on the design of the Merlin first-stage single engine; this was a turbo-pumped engine using liquid oxygen (LOX) and RP-1 kerosene as propellants. The smaller second-stage engine would be of a pressure-fed LOX/RP-1 design and was given the name Kestrel [3]. Musk handpicked the remainder of his team who would be responsible for rocket structure, software, manufacturing, and testing.

Through her previous contacts she had established with the U. S. Air Force, Shotwell succeeded in securing a Defense Advanced Research Projects Agency (DARPA) contract for two Falcon 1 launches. DARPA was interested in developing lower cost and reliable launch capability for small payloads [4].

SpaceX spent the remainder of 2002 and all of 2003 and 2004 in the design and development of the Falcon 1. The completed design measured 22.3 m in length and 1.7 m in diameter. Originally the first launch was scheduled to take place from Launch Complex 3W at Vandenberg Air Force Base. Due to concerns of this unproved launch vehicle and the proximity to the Titan launch complex, SpaceX was forced to move the launch to the small island of Omelek in the Kwajalein Atoll in the Marshall Islands. In June 2005, SpaceX shipped the launch equipment to Omelek, followed by the Falcon 1 the following month.

In November of that year the first launch attempt was made. Due to failures of the launch vehicle structure or systems over several launch attempts, SpaceX did not launch its first Falcon 1 until March 24, 2006. At roughly thirty seconds into the flight, the engine shut down abruptly due to a fuel leak fire, and the rocket and its payload were lost.

It would be a year before the second launch of a Falcon 1 took place, on March 21, 2007. This launch was more successful, completing first-stage burn, stage separation and ignition of the second stage's Kestrel engine. The payload fairing separated from the second stage precisely on time. However, the Kestrel engine shut down before the payload reached the required orbit. On August 3, 2008, the third launch of the Falcon 1 took place. During staging, the booster collided with the Kestrel engine, and this mission also failed. Musk and his team were discouraged, but they nevertheless felt confident that success with the Falcon 1 was near.

The fourth launch of the Falcon 1 was in fact less than two months away. The U. S. Air Force provided a C-17 transport for the first and second stage, payload and fairing and the launch team to Kwajalein. On Omelek Island the Falcon 1 was prepared and sitting on the pad for a September 28, 2008, launch. There were no delays of any kind, and at 4:15 PDT the Falcon 1, with its 165-kg mass simulator payload lifted off. Booster cutoff, staging and second stage ignition performed nominally. The second stage placed the payload in the desired orbit. There was also a test of the Kestrel to restart with a burn of several seconds to modify the orbit perigee. The final, near circular orbit was 621.55 km by 643.21 km. This mission became the first privately developed liquid propellant rocket to achieve Earth orbit. All mission milestones were achieved [5].

The last mission on the Falcon 1 launch manifest was for orbiting an Earth observation imaging satellite for the Malaysian government. This was successfully launched and deployed in its correct orbit on July 14, 2009. Although all mission objectives were achieved, this flight of the Falcon 1 was its last. SpaceX had, in fact, been at work on a larger and much more powerful launch vehicle. Although SpaceX had plans for a follow-on rocket, the Falcon 1e, it was never built. The company had, in fact, decided to quietly cease production of the Falcon 1 and not pursue any more customers for it [6].

The Falcon 9

In December of 2003, Musk displayed a Falcon 1 in front of the National Air and Space Museum, even though the first flight was several years away. At a reception within the museum he informed congressional staffers, members of the FAA and other government entities the progress SpaceX had made since its founding. Later, he also announced a new rocket under development: Falcon 5. This was significantly larger with the booster powered by five Merlin engines. It would be capable of lifting 4200 kg to low-Earth orbit, or 1250 kg to geostationary orbit. In addition, it would have engine-out capability not seen since the Saturn V. The price tag for a Falcon 5 was targeted at \$12 million. This rocket was designed to compete for payloads with the Boeing Delta 2 rocket [7] (Fig. 2.2).

Sometime during 2004, Musk changed his mind regarding the Falcon 5, opting for an even larger and more powerful rocket. Called the Falcon 9, the first stage of this rocket was to be powered by nine Merlin engines. This may have come about as a result of talks with management at NASA and with members of the Air Force Evolved Expendable Launch Vehicle (EELV) program office. Musk announced the Falcon 9 in the fall of 2005 while still not having launched a single Falcon 1. There had been some difficulties in the early development of the Merlin engine. Musk and Muller had initially chosen an ablative engine chamber and exhaust nozzle instead of a regenerative cooling design in an effort to simplify the engine and increase reliability. SpaceX finally reverted to a regenerative cooling design. By November



Fig. 2.2 The upgraded Falcon 9 booster features longer propellant tanks and deployable landing legs to permit reusability of the booster (image courtesy of SpaceX, used with permission)

2005, the total workforce at SpaceX numbered 160 employees. There were 40 engineers working on propulsion, 30 working on avionics, 30 devoted to structures and 50 involved in manufacturing [8].

During early development of the Falcon 9, Musk also planned to develop a capsule to ride atop the rocket. Consequently, the Falcon 9 and the capsule, to be called Dragon, would be developed concurrently. Development of the capsule outpaced development of the rocket to the point that work on the capsule was temporarily curtailed. Musk wanted to secure contracts with NASA after the space agency's announcement of the Commercial Orbital Transportation Services (COTS) program in January 2006. NASA would eventually award contracts for the resupply of cargo (to the International Space Station under the Commercial Resupply Services (CRS) program. SpaceX responded to the January request for proposals (RFP) with its recommendation of the Falcon 9 and Dragon capsule to fulfill NASA's needs. In May of that year, awards were given to six aerospace firms. SpaceX won an impressive \$278 million [9].

The Falcon 9 that took shape in the SpaceX Hawthorne, California, plant had a first and second stage fabricated from a lithium aluminum alloy with a diameter of 3.6 m. At the base of the first stage was the thrust frame with mounting locations and required plumbing for nine Merlin 1C engines, each having regenerative cooling. The second stage was powered by a single Merlin 1C engine. Between the first and second stage was a passive aluminum and carbon fiber composite inter-stage. The Falcon 9 was designed to accept either a 5-m payload fairing or the Dragon capsule. With the Dragon capsule the launch vehicle had an overall length of 47 m. It would have a thrust at sea level of 3.8 MN, or 854,000 lbs. It would be capable of launching up to 9800 kg to the orbit of the ISS [10] (Fig. 2.3).

SpaceX acquired 300 acres of property in McGregor, Texas, to build test facilities for the first and second stages of the Falcon 9. The deactivated Launch Complex 40 the U.S. Air Force used for its Titan III and IV launches was designated the launch complex for the Falcon 9 in November of 2007. Existing Titan launch structures were demolished and removed in 2008 and the launch pad reconfigured for launch of the new rocket. For the first time in its history, Launch Complex 40 would now be a commercial launch complex.

On March 8, 2008, a test was conducted of the first stage with three Merlin engines running. In a manner similar to the staged development Dr. Wernher von Braun and his Saturn I and V managers employed, SpaceX employed methodical but rapid development testing. The first full duration 177-second test firing with nine Merlin engines on the first stage took place on November 22, 2008, at the McGregor site. Second-stage tests were also conducted.

During 2008, SpaceX started a new recruiting drive in anticipation of ramping up the Falcon 9 and Dragon capsule development and manufacture. Dolly Singh was brought into be head of talent acquisition. She personally recruited new company officers, program managers and senior engineers. Musk had told her the kind of people he was looking for to work at SpaceX.

"We searched for candidates with a proven history of building and breaking things...candidates who had been tinkering with hardware systems for years," she



Fig. 2.3 This SpaceX Dragon cargo resupply capsule was photographed from the International Space Station prior to docking on April 20, 2014 (image courtesy of SpaceX, used with permission)

said in an interview. “Building some of the world’s most remarkable machines is not for everyone; it requires just the right level of neurosis. If you didn’t have a history of enjoying the high pressure situations and daunting technical challenges, you would be unlikely to fit in. I knew the people who filled my open positions would be put to the test every day and would be asked to meet heretofore impossible targets. We looked for people with a history of defeating the odds, who had made careers of overcoming obstacles” [11] (Fig. 2.4).

In December 2008 SpaceX won a coveted Cargo Resupply Services (CRS) contract from NASA totaling \$1.6 billion for twelve missions to the ISS [12]. This was a very strong vote of confidence from NASA after only one successful launch of the Falcon 1 and the first launch of the Falcon 9 two years into the future. Orbital Sciences Corporation was the other winner of a CRS contract and would use its Antares rocket and Cygnus capsule for its missions to the ISS.

The Dragon Capsule

Integral to the development to the Falcon 9 was the design and development of the cargo and eventual crew capsule, which SpaceX named Dragon. This would be the first new capsule design in the United States since the Apollo era. The last flight of

Fig. 2.4 Falcon 9 lifts off on February 11, 2015, with NASA's Deep Space Climate Observatory (DSCOVR) satellite (image courtesy of SpaceX, used with permission)



the Apollo capsule was the during the Apollo-Soyuz mission; the Apollo capsule returned to Earth with its American crew on July 24, 1975. The Dragon capsule was designed as a blunt cone design as opposed to the Apollo capsule, which was more conical in shape. From the outset, SpaceX designed the Dragon capsule to be human rated several years before the company would have to have its spacecraft meet NASA's stringent standards to accept astronauts, as stipulated in the Commercial Crew Program.

The complete Dragon spacecraft is comprised of the main pressurized section made primarily from machined, formed and welded high-strength aluminum alloy. Integrated below the pressurized section is the unpressurized service section, which contains the eighteen Draco thrusters, their propellant tanks and requisite plumbing and controls. These thrusters are oriented at several different angles and locations relative to the centerline of the capsule. They permit complete movement of the capsule once in orbit, and are used to deorbit the capsule for return to Earth. The heat shield is a SpaceX refinement of NASA's Phenolic-Impregnated Carbon Ablator (PICA-X) developed in four years at far less cost than the space agency had

budgeted for. At the base of the capsule is the unpressured trunk capable of carrying additional cargo and deployable small satellites. On opposite sides of the trunk are stowed solar panels to provide power to the capsule; these are protected by covers that are ejected once the spacecraft is in orbit. The capsule also has a nosecone to protect the forward section with the hatch and the passive common berthing mechanism. Dragon is equipped with autonomous rendezvous and docking electronics for mating to the ISS [13].

Dragon was designed to transport up to 6000 kg to low Earth orbit and is capable of returning 2500 kg from the ISS. The cargo version of the capsule is fitted with three descent parachutes. It is retrieved after its ocean landing, and delivered to the Port of Los Angeles. Capsules returned to Earth from cargo missions can be refurbished and configured as free-flying DragonLab™ capsules for microgravity research and other technology demonstration missions.

Ushering in a New Era

The first Falcon 9 with a 5-m payload fairing was erected at Space Launch Complex 40 in January 2009 to undergo months of vehicle checkout and tests of SLC-40. The goal was to launch the rocket by the end of the year, but construction and flight qualification testing of the Dragon capsule pushed the maiden flight into 2010. The Dragon Spacecraft Qualification Unit would not have the reentry heat shield, thrusters or recovery system. Other systems of the spacecraft would be tested during flight and orbit. The Falcon 9 and Dragon would be monitored for performance milestones throughout the mission.

SpaceX scheduled the inaugural flight for June 4, 2010. It stated that the mission success would be measured by the percentage of mission milestones that were achieved, but cautionary statements were included in press materials. The tone of the statements made by SpaceX was a lack of confidence that the company would have a totally successful mission. The memories of the first three failed launches of the Falcon 1 were still fresh in everyone's minds. Mission control of the flight was not in Houston, Texas, or Kennedy Space Center, but in the SpaceX headquarters in Hawthorne, California.

After several launch delays, the Falcon 9 finally lifted off at 2:45 PM. All nine Merlin engines operated perfectly with main engine cut off at 2:54 after launch. The stages separated and seconds later the single Merlin Vacuum engine fired. It performed nominally until second engine cut off at 9:38 into the mission. The first privately designed and manufactured multistage launch vehicle and its payload reached its 155-mile high orbit within one percent of the designate perigee and apogee [14]. Musk and his SpaceX employees were jubilant, and NASA was relieved. Prospective commercial customers of satellite payloads also took notice. SpaceX, in fact, already had customers lined up on the Falcon 9 launch manifest.

The next launch of the Falcon 9 with complete Dragon spacecraft occurred on December 8, 2010. This was the first demonstration flight by SpaceX under

NASA's Commercial Orbital Transportation Services (COTS) contract. In addition, two cubesats for the National Reconnaissance Office would be deployed in orbit. This flight was a complete test of the Falcon 9 and Dragon capsule to perform orbital maneuvers and to deploy the satellites. The launch and orbit of the capsule was a success. After nearly two orbits, the Draco thrusters fired to slow the spacecraft and initiate reentry. The heat shield performed as designed, the three parachutes deployed and the capsule landed in the Gulf of Mexico.

The third launch of the Falcon 9 and Dragon capsule occurred almost eighteen months later. The initial mission was to have the capsule rendezvous with the ISS but only perform a fly-by in order to test numerous critical mission goals, including communication between the ISS and capsule, docking radar tests and other mission milestones. The follow-on mission to this would have the Dragon dock with the ISS, and its crew would transfer cargo from the capsule. In July of 2011, the possibility of combining the two missions was discussed if all the milestones of the first mission were accomplished. NASA agreed to this in December, and SpaceX modified the mission manifest to accomplish this.

On May 22, 2012, the Falcon 9 lifted off and had a nominal ascent to orbit. All initial milestones were achieved by day two in orbit. NASA gave SpaceX approval to initiate orbit adjustment burns to get the capsule within several kilometers of the ISS. On the third day of the mission, SpaceX controllers started the rendezvous maneuvers. The capsule orbited around the ISS in further tests of its control thrusters and communications with ground and crew on the ISS. On the fourth day of the mission, with all COTS-2 mission requirements achieved. NASA Mission Control in Houston approved the docking of Dragon with the ISS. In a series of precise movements by the capsule, slowly it was brought to within proximity of the Canadarm-2 less than 10 m from the ISS and then stopped. Expedition 31 ISS crew member, U.S. astronaut Don Petit, captured the capsule. Petit, with another crew member assisting, moved the capsule to the common berthing mechanism (CBM) of the Harmony module. The capsule docked and was secured to the CBM. This was the first time a privately manufactured spacecraft docked with the International Space Station [15].

The success of this mission, as well as the success of the capsule's return to Earth with return cargo, bode well for the CRS missions NASA contracted with SpaceX. These resupply missions would be shared with Orbital Sciences Corporation.

Dragon v2 Crew Capsule

SpaceX built on the knowledge gleaned from the cargo configuration of the Dragon to design the crewed version known as Dragon v2. Visually it is a completely new spacecraft, while employing both proven technology from Dragon and many new systems throughout. SpaceX chose a pusher-type propulsion design for capsule emergency crew escape from the Falcon 9 booster. New engines have been

developed to achieve this, and given the name SuperDraco. The engine uses storable non-cryogenic hypergolic propellants. The SuperDraco has a thrust of 73,000 N (16,400 lbs.). The engine is grouped in redundant pairs on four sides of the capsule.

Dragon v2 has been designed to accept up to seven passengers or crew members, or a combination of four crew members and cargo for missions to the ISS. The capsule is designed for autonomous docking to the ISS, with manual override of capsule control if it is ever needed. SpaceX has also partnered with Bigelow Aerospace for access to the Bigelow Commercial Space Station in Earth orbit. The full seven-seat capacity of the Dragon 2 will be used for these missions. The SuperDraco propulsion system was originally conceived to be employed for the entire return to Earth. SpaceX has modified the capsule return profile so that the capsule will reenter the atmosphere, descend via three parachutes and initially land at a designated ocean landing site, much as the Dragon cargo capsule has done. The goal for Dragon v2 is to have the SuperDraco thrusters initiate deorbit and partial reentry whereupon three parachutes will be deployed. The capsule will descend to a specified altitude, and the SuperDraco thrusters will again be fired to allow a soft landing on deployed landing legs at one of various chosen landing sites. This will permit reusability of the capsule, which is not achievable with a water landing.

On September 16, 2014, NASA awarded two Commercial Crew Transportation Capability (CCtCap) contracts. The awards were given to Boeing Space Systems, which won \$4.6 billion, and SpaceX, which was awarded \$2.6 billion [16]. The award will permit SpaceX to proceed with full development of the Dragon v2. The CCtCap phase entails building flight test articles and proving all systems are safe for crew transportation to and from the ISS. Once this is achieved SpaceX (and Boeing) will receive contracts from NASA for crew transportation services to the space station. The crew capsules to be built by Boeing and SpaceX will allow the United States to once again launch NASA crews from Kennedy Space Center, or Cape Canaveral Air Force Station, eliminating dependence on the Russian space agency to do so. Those capsules will also permit the possibility of launching other commercial passengers to the ISS or other low-Earth orbit destinations.

Falcon Heavy

For over a quarter of a century, the space shuttle was America's heavy lift launch and crew transportation system. The maximum payload capability of the shuttle was 24,000 kg to low-Earth orbit. It was used for a variety of NASA, military and commercial payloads. It also carried the majority of the modules and structures for the International Space Station. With the retirement of the shuttle, the United States could only rely on the ULA Delta IV Heavy, capable of launching just over 22,500 kg to LEO [17]. Currently, this vehicle is launched from Cape Canaveral Air Force Station, Florida, and Vandenberg AFB in California.



Fig. 2.5 A Falcon Heavy launching from Launch Complex 39-A at Kennedy Space Center (image courtesy of SpaceX, used with permission)

The Falcon Heavy employs three of the upgraded Falcon 9 v1.1 boosters. The v1.1 booster is longer, carries more propellant, and features more powerful Merlin 1D engines. The cluster of nine 1D engines in each booster produces 5880 kN (1,323,000 lbs.) of thrust. The Falcon Heavy will have a liftoff thrust of 17,615 kN. The second stage is powered by a single Merlin 1D engine designed for vacuum operation (Fig. 2.5).

The Falcon Heavy is capable of lofting 53,000 kg (nearly 117,000 lbs.) to low-Earth orbit, making it by far the most powerful rocket in the world. The v1.1 configuration has booster return and powered descent soft-landing capability for reusability, which will further lower launch costs. The Falcon Heavy will employ complete reusability of these boosters.

Early in the Falcon Heavy's development, SpaceX determined a significant enough potential market for there to be more than one launch complex for it. The first launch site selected was Vandenberg AFB, at Space Launch Complex (SLC) 4. This was in anticipation of winning contracts from the U. S. Air Force and other government agencies for particularly large satellite payloads that exceed the capabilities of the Falcon 9. The company then contracted with NASA to lease the former Apollo and space shuttle Launch Complex 39A at Kennedy Space Center. This is the launch complex for the Falcon Heavy on the East Coast. Most of the existing service structures have been removed, and the pad area reconfigured to support the Falcon Heavy. SpaceX has issued statements that the company anticipates also launching crewed missions from 39A.

Finally, SpaceX will have a third Falcon Heavy launch complex in Brownsville, Texas, near the state's coastline and adjacent to the Mexican border. The test stand for the Falcon Heavy is at the company's test complex in McGregor, Texas.

SpaceX has an extraordinary business plan and aggressive pricing structure that has and will continue to shake up the launch services industry. It has responded to the need of the United States to provide commercial crew capabilities to the International Space Station. Its range of launch vehicles built at surprisingly low cost relative to its competitors is radically bringing down the cost of getting payloads to low-Earth orbit. The company has made no secret of its other ambitious plans to send payloads and even its crewed Dragon capsules further into space. The company's vision and launch capability may make other missions long considered out of the question now within the realm of possibility.

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