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STS-51L: Reflecting Upon the Failed Engineering of the Challenger Disaster

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Abstract: The Challenger, a space shuttle capable of carrying people into space, returning them back to Earth safely, and doing the whole thing over again, was made to continue the exploration of the grand unknown. Having a total of nine missions completed, the shuttle was a pioneer of its kind, paving the way for future generations of shuttles to follow in its footsteps and learn from its mistakes. Like every space exploration vehicle, the Challenger had its peaks and its troughs, but it was ultimately a lack of misinformation that caused its and its crew's tragic and heartbreaking end.

Introduction and Background

The Challenger was a space shuttle, which is different than a spacecraft or rocket. Rockets are single-use vehicles and typically carry heavy loads into space mainly to the International Space Station (Dunbar: What Is a Rocket?"). Spacecrafts are also single-use vehicles, but only part of the spacecraft containing the astronauts returning to Earth (Space Craft vs Space Shuttle). Space shuttles on the other hand, are vehicles that launch like a rocket but return safely and wholly back to Earth like gliders or planes (Dunbar: What Is the Space Shuttle?). Their main objective is to orbit around Earth, and many of the space shuttle missions have included various experiments to test the effects of space and microgravity (Gebhardt). Because it returns in its entirety, space shuttles attend processing and are ultimately reusable once they return to Earth (Space Craft vs Space Shuttle).

The Challenger Space Shuttle started its journey as the STA-099 (Structural Test Article-099), a vehicle used to "test and validate the effects of launch and entry stress" on lightweight space vehicles (Gebhardt). This vehicle weight reduction would allow National Aeronautics and Space Administration (NASA) to take more weight in supplies and people into space (Gebhardt). Ideas about making a space shuttle out of the STA-099 came into light, and after running thorough and extensive tests on the it, NASA realized how time-efficient and cost-efficient it was to transform the STA-099 into a worthy exploratory space shuttle (Gebhardt). On January 1, 1979, the decision to convert the STA-099 into the OV-099 (Orbital Vehicle-099) was made, and the makeover started promptly (Gebhardt). The OV-099 was given the title the Challenger, named after a British space vehicle which "served as a command ship for the Challenger Expedition" (Gebhardt). Shortly after, on June 30, 1982, the Challenger was transported to Edwards Air Force Base, located in Southern California, where it then took off for its ferry flight to Kennedy Space Center, located in Florida (Gebhardt). Upon arrival at Kennedy Space Center, the Challenger was sent to OPF (Orbital Processing Facility) for inspections before its maiden flight, and four months later, the Challenger was rolled out to the launch pad for the mandatory FRF (Flight Readiness Firing) and pad processing (Gebhardt).

While running the FRF, it became clear that the Challenger had problems from the start. In preparation for the Challenger's maiden flight, scheduled on January 20, 1983, the FRF done in December 1982 pointed out hydrogen leaks in the Space Shuttle Main Engine-1 (SSME-1), postponing the maiden flight (Gebhardt). Another FRF confirmed this leak, and all SSME's were taken out of the Challenger, marking "the first time in Shuttle Program history that the SSME's were removed at the launch pad" (Gebhardt). NASA removed all three of the SSME's and reinstalled SSME-2 and SSME-3 while replacing SSME-1 altogether (Gebhardt). The launch date was reset but postponed again due to contamination of the Challenger's payload, the Tracking and Data Relay Satellite (TDRS-1), caused by a storm (Gebhardt). Once fixed, the Challenger's maiden flight was rescheduled again for April 4, 1983 (Gebhardt). The Challenger had a total of 10 flights in its career, starting with the maiden flight, and ending with the devastating disaster that left all aboard dead and millions shocked.

On April 4, 1983, the Challenger and its first four astronauts took to the sky, marking many firsts for

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the Space Shuttle Program, such as "the first flight of a space shuttle from the new MLP-2 (Mobile Launch Platform-2), the first shuttle flight to use the Light Weight External Tank…, the first afternoon launch of a space shuttle, and the first time that a second reusable spacecraft flew into space" (Gebhardt). The goal of this flight was not only to test out the Challenger in real space conditions, but also after deploying the TDRS-1, the Challenger crew focused on conducting the first spacewalk, or EVA (Extravehicular Activity), which "allows astronauts to conduct experiments in the shuttle's payload bay, to test new equipment in space and to repair satellites in orbit" (Gebhardt and Dunbar: Extravehicular Activity (EVA): Astronauts Walk In Space). The Challenger ended its maiden flight on April 9, 1983, touching down at Edwards Air Force Base (Gebhardt). From there, the Challenger went back to OPF at Kennedy Space Center, where it was tested and then prepared for its next mission, STS-7 (Gebhardt).

The Challenger's second flight, called the STS-7 (Space Transportation System-7), took off on June 18, 1983, carrying the first American woman into space (Gebhardt). The main testing associated with this flight was to study the effect of space on social behavior of an ant colony, along with other technological and infrastructural studies (Gebhardt). At the end of the STS-7 mission, the Challenger was supposed to be the first shuttle to land at Kennedy Space Center, but due to weather complications, it instead landed at Edwards Air Force Base on June 24, 1983 (Gebhardt). From there, it returned to OPF at the Kennedy Space Center for just under a month, while the crew did processing for its next mission (Gebhardt).

After OPF processing, the Challenger was rolled out to the launch pad for its third mission, STS-8, scheduled for August 30, 1983 (Gebhardt). Launched 17 minutes late due to weather, this mission marked the first night launch, the first time an African American went to space, and the 20th mission sent into space from launch pad 39-A (Gebhardt). The mission deployed an Indian communication satellite, INSAT-1B, as well as tested the effect of extremely cold conditions on the flight deck by pointing the vehicle's nose away from the sun for 14 hours (Gebhardt). Six days later on September 5, 1983, the Challenger glided to a stop at Edwards Air Force Base, marking the first night landing for the Space Shuttle Program (Gebhardt). On September 9, 1983, the Challenger returned to the Kennedy Space Center, where it underwent processing for four months for its next mission, STS-41B (Gebhardt).

On February 3, 1984, the Challenger took off on time for its fourth mission, STS-41B (Gebhardt). In the seven days it was in space, two of the astronauts aboard, Bruce McCandless and Robert L. Stewart, performed the first ever untethered EVA, getting as far away as 320 feet from the Challenger (Gebhardt). On February 11, 1983, the Challenger reentered the Earth's atmosphere and successfully performed the first landing of a space shuttle at the Kennedy Space Center (Gebhardt). Shortly after landing, the Challenger spent just over a month in OPF, preparing for its fifth flight (Gebhardt).

The fifth flight, STS-41C, set out on April 6, 1984, with the mission of finding, getting, repairing, and re-deploying the Solar Max satellite (Gebhardt). Video footage of Mission Specialist George Nelson's EVA towards the satellite was eventually made part of a documentary, "The Dream Is Alive" (Gebhardt). After properly re-deploying the satellite, the crew headed back to Earth, landing at Edwards Air Force Base on April 13, 1984 (Gebhardt). From there, it headed to OPF at Kennedy Space Center, where it spent a total of 5 months getting tested, the longest time it has ever spent at OPF (Gebhardt).

Following its time in OPF, the Challenger took off on its sixth flight, STS-41G, launched on October 5, 1984, marking another series of firsts for the Space Shuttle Program (Gebhardt). It was the first time a shuttle carried a crew of seven, the first time two women flew together, the first time a Canadian flew into space, the first time an Australian born person flew into space, and the first time an EVA involved a woman (Gebhardt). The Challenger's mission this time was to deploy an Earth Radiation Budget Satellite and connect the Components of Orbital Refueling System, "demonstrating that it was possible to refuel a satellite in orbit" (Gebhardt). STS-41G landed at Kennedy Space Center on October 13, 1984, making this operation the Challenger's longest mission in space, lasting "8 days 5 hours 33 minutes and 23 seconds" (Gebhardt). The Challenger then retired to OPF to start processing for her next mission, STS-51E, which had the purpose of deploying the second of the TDRS's, TDRS-B (Gebhardt). The Challenger rolled out to the launch pad, but timing issues surrounding the TDRS-B became severe, and NASA ultimately cancelled the mission (Gebhardt). The Challenger was rolled back into OPF, where it was prepared for its next mission, STS-51B (Gebhardt).

During the launching of the Challenger's next and seventh mission, STS-51B, a "launch processing system failure" produced a two-minute delay but regardless proceeded into the sky on April 29, 1985 (Gebhardt). The STS-51B mission did 15 primary experiments, which were broken down into five categories: materials sciences, life sciences, fluid mechanics, atmospheric physics, and astronomy; and 14 of the 15 experiments were successful (Gebhardt). The Challenger touched down at Edwards Air Force

Base on May 6, 1985 and headed back to the Kennedy Space Center (Gebhardt). During its time in OPF, NASA found out that a small rubber part of the shuttle, called O-rings, were severely charred; further investigations on the O-rings "led to the understanding that the cold temperatures…significantly reduced the sealing power of the O-rings" (Gebhardt). Unfortunately, these serious warnings were ignored, and this issue would again arise in the upcoming year.

After its time in OPF, the Challenger attempted its eighth mission, STS-51F (Gebhardt). On July 12, 1985, pad processing and countdown proceeded as normal, but at T-3 seconds, NASA computers registered a malfunction in the SSME-2's coolant valve, and they immediately triggered a shutdown, postponing the mission (Gebhardt). After the SSME's were replaced, the mission was reset for July 29, 1985, which started roughly with a one-minute delay caused by a minor problem (Gebhardt). Three minutes into the flight, "one of the two high pressure fuel turbopump turbine discharge temperature sensor for SSME-1 failed, leaving only one sensor active on the engine," and then five minutes into the flight, the second sensor failed, which triggered a shutdown of SSME-1 (Gebhardt). Then, around ten minutes into the flight, a similar turbopump failed in SSME-2 (Gebhardt). An engineer in Mission Control Houston acted quickly, telling the crew to prevent any more automatic shutdowns of SSME's after carefully looking at the readings from the remaining sensors, which ultimately "prevented the loss of another engine and possible abort scenario far more risky" (Gebhardt). The abortion of these two SSME's causes a decline in thrust for the Challenger, which caused a "lower-than-planned…orbit" and a revision in the experiments conducted during this mission because of the lower orbit (Gebhardt). Although it didn't go as planned and although we will fortunately never know for sure, it is speculated that the quick thinking by Mission Control Houston to prevent a third shutdown saved the lives of the astronauts aboard. Seven days later, on August 6, 1985, the Challenger landed safely at Edwards Air Force Base and was shortly returned to the Kennedy Space Center's OPF to begin processing for its next mission (Gebhardt).

After two months in OPF, the Challenger rolled out for the ninth time, ready to perform mission STS-61A (Gebhardt). Pad processing proceeded normally, and on October 30, 1985, the takeoff went smoothly, marking the "22nd flight of the Space Shuttle, the 9th flight of Challenger, and the first and only time in history when eight people launched into space at the same time on the same vehicle" (Gebhardt). The STS-61A was completely dedicated to the German Spacelab, which housed 75 different experiments, some of which were conduced more than once (Gebhardt). After a seamless mission, the Challenger glided back to Edwards Air Force Base, touching down on November 9, 1985 (Gebhardt). From there, it went back to the Kennedy Space Center, where it underwent processing for its next and unfortunately final mission, the STS-51L (Gebhardt).

After a quick in-and-out at OPF, the Challenger was rolled out on December 22, 1985 for its January 22nd launch date (Gebhardt). Delays in another mission on a different launch pad caused the due date to slip to January 23rd and then the 24th, and then the 25th due to weather conditions, then the 26th due to the ground teams being unable to meet the proper launch time, then the 27th due to unacceptable weather conditions (Gebhardt). Finally, on the 27th, the crew loaded up into the vehicle, but when the closeout crew went to lock the hatch, they could not remove the locking tool (Gebhardt). Eventually, the tool was sawed off and the attaching bolt was drilled out, but this postponed the mission another 24 hours (Gebhardt). Overnight, temperatures dropped dramatically, and NASA was worried that water pipes would freeze and break, so they opened them, producing icicles on the launch pad structure (Gebhardt). In the morning, with minor delays, the crew of seven re-boarded the Challenger. On the cold morning of January 28, 1986 at 11:38:00 AM EST, the Challenger launched away on mission tenth mission, STS-51L, its 25th Space Shuttle flight, 10th flight, and first Space Shuttle flight from Pad-B (Gebhardt). For the first minute, the aircraft flew into the sky, appearing to be going smoothly from the ground standpoint from which families and friends watched hopefully; unfortunately, this was far from true. At 11:39:13 EST, the Challenger was torn apart by aerodynamic forces, killing all seven of the astronauts aboard (Gebhardt). This tragedy took place on live television with millions of American watching around the nation (Challenger Disaster). Aboard the Challenger that infamous morning was Commander Dick Scobee, pilot Michael Smith, mission specialists, Judy Resnik, Ronald McNair, and Ellison Onizuka, and payload specialist Gregory Jarvis (Challenger Disaster). Also aboard the Challenger that morning was Christina McAuliffe, a teacher from New Hampshire "who was set to become the first teacher and civilian in space," selected to join the mission to pioneer the Teacher In Space Program, which would have taught lessons from space to schoolchildren across the nation (Tate and Challenger Disaster).

Soon after giving a heartbreaking and sorrowful speech, President Ronald Reagan "appointed a special commission" which included former astronaut, Neil Armstrong, "to determine what went wrong with [the] Challenger and to develop future corrective measures" (Challenger Disaster). The information they found was truly tragic, as it had to do with the rubber O-ring failure discovered during

the Challenger's seventh flight, the STS-51B mission. Due to the cold temperatures, the rubber O-ring became brittle, did not seal properly, and ultimately failed, allowing flames to break out of the booster, damaging "the external fuel tank [and] causing the spacecraft to disintegrate," resulting in a true tragedy and a loss of seven courageous lives (Challenger Disaster).

This heartbreak halted all shuttle missions for an extended period of time, during which NASA redesigned a number of the shuttles' features (Challenger Disaster). Finally, in 1988, the revamped Space Shuttle Discovery reappeared into the sky, finishing off the last of the Challenger's mission and signaling the continuation of exploration (Challenger Disaster). Ten years after the tragedy, two large pieces of the Challenger washed ashore the Florida beach; those remains, along with other debris is stored in a missile silo at Cape Canaveral, Florida (Challenger Disaster).

Discussion

It is no question what caused the Challenger to implode, as the rubber O-rings' temperature limitations were made and then subsequently ignored right after the STS-51B mission. The makers of the O-rings, Morton and Thiokol, assembled the rocket boosters vertically at the launch site, which comprised of fuel tanks layered on top of one another with the rubber O-rings in between (Tate). Two of these tanks, separated by rubber O-rings, contained oxygen and hydrogen gas, but during the unusually cold weather on January 28, 1986, the "rubber became stiff, failing to fully seal the joint" (Tate). As the Challenger took to the sky, one of the rubber O-rings was not flexible enough to make its seal and instead opened, allowing a "plume of exhaust" out of the booster, a clear sign of an O-ring burnt through (Tate). Hot gases poured out onto the "cold external tank" full of oxygen and hydrogen, and once enough energy was supplied, the tank imploded, splitting the Challenger and its payload apart and sending the remains hurtling through the sky (Tate).

This disaster is not a matter of assigning blame to one party or the other; instead it was a series of miscommunication, misinformation, and sheer bad luck. Both Morton Thiokol and NASA did not properly test the equipment in all variable temperatures. In addition, both Morton Thiokol and NASA ignored warnings regarding the O-rings, issued after the STS-51B mission. To add insult to injury, the incredibly cold temperatures reached overnight were near impossible to guess, especially in Florida.

That being said, this disaster could have been prevented fairly easily. After the STS-51B mission that left the rubber O-rings charred, all parties decided to ignore the possible impact of the malfunction. Instead, they continued to launch more missions, using the rubber O-rings even though they became stiff in the cold; by then, it was only a matter of time before an unusually cold day in Florida coexisted with a launching date. Unfortunately, this error was overlooked and deemed as unimportant, irrelevant, or too rare to ever occur again, leaving both parties misinformed of the severity of a simple piece of rubber. If either Morton Thiokol or NASA were to have stopped and tested the effectiveness of the rubber O-rings in all possible conditions, then it is quite likely that there would still be a Teacher In Space Program, that the Challenger would still be flying or at least in a museum for generations to awe at, and we would not refer to January 28, 1986 as a tragic day in American history, but as a day to celebrate the exploration of the unknown.

Conclusions

January 28, 1986 was a horrific day in American history, a heartbreaking and tear-filled day, and a day that will truly live in infamy. With millions of hopeful people watching the crew wave goodbye and strap up into the Challenger, no one could have ever guessed what was going to happen in the first 73 seconds after takeoff. Caused by a rubber O-ring malfunction due to the unusually cold temperature that morning and the previous night, the Challenger took off into the sky for its last time, carrying with it seven courageous voyagers who risked and gave their lives for science and for exploration. This malfunction was due to misinformation on both Morton Thiokol and NASA's end, as they didn't realize the impact of an inflexible rubber O-ring the first time it occurred during the STS-51B mission and unfortunately did not learn from their mistakes during the final Challenger mission, STS-51L.

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