Apollo 13 Disaster

Introduction

Apollo 13 was the seventh manned mission in the American Apollo space program and the third intended to land on the Moon. But it was not that simple. The craft was launched on April 11, 1970, at 13:13 CST from the Kennedy Space Center, Florida, but the lunar landing was aborted after an oxygen tank exploded two days later, crippling the Service Module (SM) upon which the Command Module (CM) depended. So why it exploded ?

Main motive

The Apollo 13 mission was to explore the Fra Mauro formation, or Fra Mauro highlands, named after the 80-kilometer-diameter Fra Mauro crater located within it. It is a widespread, hilly selenological area thought to be composed of ejecta from the impact that formed Mare Imbrium.

The next Apollo mission, Apollo 14, eventually made a successful flight to Fra Mauro.

Accident

Approaching 56 hours into the mission, Apollo 13 was approximately 205,000 miles (330,000 km) from Earth en route to the Moon. Approximately six and a half minutes after the end of a live TV broadcast from the spacecraft, Haise was in the process of powering down the LM, while Lovell was stowing the TV camera, and Houston flight controllers asked Swigert to turn on the hydrogen and oxygen tank stirring fans in the Service Module, which were designed to destratify the cryogenic contents and increase the accuracy of their quantity readings. Two minutes later, the astronauts heard a "loud bang," accompanied by fluctuations in electrical power and the firing of the attitude control thrusters.[6] The crew initially thought that a meteoroid might have struck the Lunar Module. Communications and telemetry to Earth were lost for 1.8 seconds, until the system automatically corrected by switching the high-gain S-band antenna used for translunar communications from narrow-beam to wide-beam mode

Immediately after the bang, Lovell reported a "main B bus undervolt", a temporary loss of operating voltage on the second of the spacecraft's main electrical circuits. Oxygen tank 2 immediately read quantity zero. About three minutes later, the number 1 and number 3 fuel cells failed. Lovell reported seeing out the window that the craft was venting "a gas of some sort" into space. The number 1 oxygen tank quantity gradually reduced to zero over the next 130 minutes, entirely depleting the SM's oxygen supply.

Because the fuel cells generated the Command/Service Module's electrical power by combining hydrogen and oxygen into water, when oxygen tank 1 ran dry, the remaining fuel cell finally shut down, leaving the craft on the Command Module's limited-duration battery power and water. The crew was forced to shut down the CM completely to save this for re-entry, and to power up the LM to use as a "lifeboat." This situation had been suggested during an earlier training simulation, but had not been considered a likely scenario. Without the LM, the accident would certainly have been fatal.

Analysis

Once the astronauts were safely back on Earth, engineers began working to understand the causes of the accident, to prevent it from happening again. Within weeks, review teams had constructed a clear picture of the events that created this near-disaster.

The series of events that led to Apollo 13’s life-and-death drama began five years earlier with a simple design change to the Apollo spacecraft.

During flight, the systems aboard the command and service modules were designed to operate at 28 volts. In 1965, however, it became clear that during preflight tests at the Kennedy Space Center, 65 volts would be used. That year, engineers at North American directed that the craft's electrical components be redesigned to accept both levels of voltage.

But one crucial participant never got word of the change.

Within the service module were two tanks of liquid oxygen. Oxygen from these tanks was used not only for the astronauts to breathe, but to help run three fuel cells that provided electrical power to run the command ship's many systems.

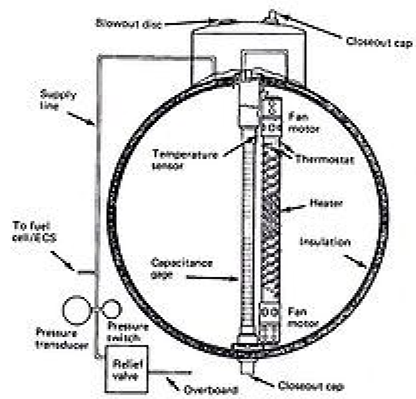
Inside each oxygen tank was a thermostat which, along with a heater, was used to regulate the temperature inside the tank. It was the manufacturer of this thermostat that never learned of the need to accept 65 volts of electricity.

All things being equal, that might not have been a problem. In fact, the oxygen tanks used on all previous Apollo missions had flown without trouble. But the Number 2 oxygen tank aboard Apollo 13 did have a slightly tarnished history.

In October 1968, the Number 2 tank eventually used on Apollo 13 was at the North American Aviation plant in Downey, California. There, technicians who were handling the tank accidentally dropped it about two inches. After testing the tank, they concluded the incident hadn't caused any detectable damage. The dropped tank was eventually cleared for flight and installed in Apollo 13. The tank passed all of its routine prelaunch tests. But at the end of March 1970, after a practice session called the Countdown Demonstration Test, ground crews tried to empty the tank -- and couldn’t.

The small tube used to fill and empty the tank of its super-cold contents had been damaged by the mishandling almost two years earlier.

To get around the problem, workers turned on heaters inside the tank to warm up the remaining liquid oxygen, turning it into gas that could then be vented to the outside. The thermostat inside the tank was supposed to prevent the temperature from exceeding 80 degrees Fahrenheit (25 degrees Centigrade).



But as the temperature inside the tank rose, the thermostat was activated, and the oversight from 1965 came into play. The resulting surge of electricity at 65 volts caused the 28-volt thermostat to weld shut. Technicians failed to notice the situation, and during the procedure to empty the tank, temperatures inside rose to 1,000 degrees Fahrenheit (500 degrees Centigrade). The intense heat damaged some insulation on wiring inside the tank.

No one knew it, but when Apollo 13 lifted off, it carried the makings of a small bomb inside its service module.

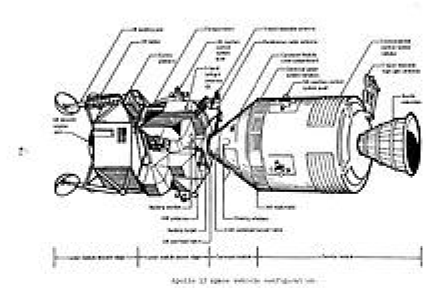
The "bomb" was triggered on the evening of April 13 when ground controllers asked Jack Swigert to turn on the fans inside the service module's two liquid-oxygen tanks, as a way of stirring the contents, to allow more accurate quantity readings.

When the fan inside the Number 2 tank was turned on, the damaged wiring caused a spark, starting a fire inside the oxygen tank.

With pure oxygen feeding the fire, the pressure inside quickly grew to the point where the tank burst open, at the same time damaging much of the other plumbing inside the densely packed service module and crippling the spacecraft.

Theory:

1. **Define the Problem:** Apollo 13 was intended to land on the Moon and to explore Fra Mauro formation.
2. **Collect information:**
   Once Kennedy had defined a goal, the Apollo mission planners were faced with the challenge of designing a spacecraft that could meet it while minimizing risk to human life, cost, and demands on technology and astronaut skill. Four possible mission modes were considered:



Direct Ascent: The spacecraft would be launched as a unit and travel directly to the Moon and land. It would return, leaving its landing stage on the Moon. This design would have required development of the extremely powerful Nova launch vehicle.

Earth Orbit Rendezvous (EOR): Multiple rocket launches (up to 15 in some plans) would carry parts of a Direct Ascent spacecraft and propulsion units for translunar injection (TLI). These would be assembled into a single spacecraft in Earth orbit.

Lunar Orbit Rendezvous (LOR): A single Saturn V could launch a spacecraft that was composed of a mother ship which would remain in orbit around the Moon, while a smaller, two-stage lander would carry two astronauts to the surface, return to dock with the mother ship, and then be discarded. Landing only a small part of the spacecraft on the Moon and returning an even smaller part to lunar orbit minimized the total mass to be launched from the Earth.

Lunar Surface Rendezvous: Two spacecraft would be launched in succession. The first, an automated vehicle carrying propellant for the return to Earth, would land on the Moon, to be followed some time later by the manned vehicle. Propellant would have to be transferred from the automated vehicle to the manned vehicle.

3. **Requirements:**
   In required the location where the spacecraft will be build plus the money was important at that time. Materials were provided by the team.

4. **Brainstorming:**
   Faget's preliminary Apollo design employed a cone-shaped command module, supported by one of several service modules providing propulsion and electrical power, sized appropriately for the space station, cislunar, and lunar landing missions. Once Kennedy's Moon landing goal became official, detailed design began of a Command/Service Module (CSM) in which the crew would spend the entire direct-ascent mission and lift off from the lunar surface for the return trip, after being soft-landed by a larger landing propulsion module. The final choice of lunar orbit rendezvous changed the CSM's role to the translunar ferry used to transport the crew, along with a new spacecraft, the Lunar Excursion Module (LEM, later shortened to Lunar Module, LM) which would take two men to the lunar surface and return them to the CSM.

5. **Choosing best data:**
   The Apollo program has been called the greatest technological achievement in human history. Apollo stimulated many areas of technology, leading to over 1,800 spinoff products as of 2015. The flight computer design used in both the Lunar and Command Modules was, along with the Polaris and Minuteman missile systems, the driving force behind early research into integrated circuits (IC). By 1963, Apollo was using 60 percent of the United States' production of ICs. The crucial difference between the requirements of Apollo and the missile programs was Apollo's much greater need for reliability. While the Navy and Air Force could work around reliability problems by deploying more missiles, the political and financial cost of failure of an Apollo mission was unacceptably high. With all these technology Apollo mission got so many resources that they choose the best one

and always implemented it in their latest launch.

6. **Prototype Little Joe II:** Since Apollo, like Mercury, would require a launch escape system (LES) in case of a launch failure, a relatively small rocket was required for qualification flight testing of this system. A size bigger than the NAA Little Joe would be required, so the Little Joe II was built by General Dynamics/Convair. After an August 1963 qualification test flight,[49] four LES test flights (A-001 through 004) were made at the White Sands Missile Range between May 1964 and January 1966.

7. **Result:** After all the declaration Apollo 13 was launched. But soon after 2 days lunar landing was aborted due to oxygen tank explosion.

Finding problem

The board exhaustively investigated and analyzed the history of the manufacture and testing of the oxygen tank, and its installation and testing in the spacecraft up to the Apollo 13 launch, as documented in detailed records and logs. They visited and consulted with engineers at the contractor's sites and the Kennedy Space Center. Once a theory of the cause was developed, elements of it were tested, including on a test rig simulation in a vacuum chamber, with a damaged tank installed in the fuel cell bay. This test confirmed the theory when a similar explosion was created, which blew off the outer panel exactly as happened in the flight. Cortright sent the final Report of Apollo 13 Review Board to Thomas Paine on June 15, 1970.

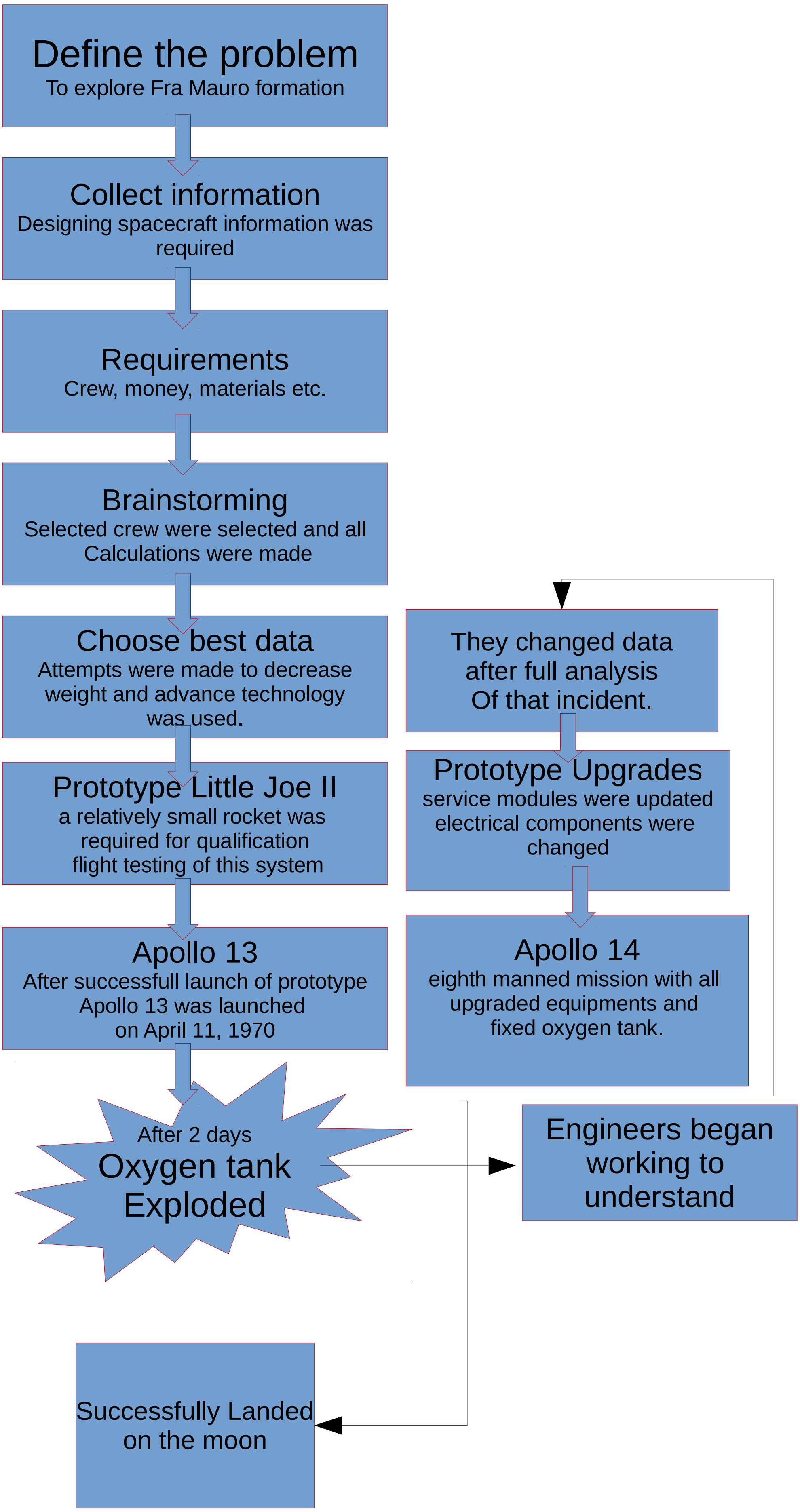
The failure started in the Service Module's number 2 oxygen tank. Damaged Teflon insulation on the wires to the stirring fan inside oxygen tank 2 allowed the wires to short-circuit and ignite this insulation. The resulting fire rapidly increased pressure beyond its 1,000-pound-per-square-inch (6.9 MPa) limit and the tank dome failed, filling the fuel cell bay (Sector 4) with rapidly expanding gaseous oxygen and combustion products. It is also possible some combustion occurred of the Mylar/Kapton thermal insulation material used to line the oxygen shelf compartment in this bay.

Re-design

In the wake of Apollo 13, engineers redesigned the oxygen tanks to prevent similar accidents. Also, a third oxygen tank was added to the service module, as an additional backup. Eight more Apollo spacecraft flew and none of them experienced the same trouble again.

Conclusion

In conclusion it was found that due to different service module installed in a spacecraft, that error caused increase in temperature which in result caused explosion of oxygen tank. So overall the major fault was of Technician who placed 65 volts service modules but didn’t checked its working. The main step which they missed is that after changing the service modules there was no testing/examination.


Define the problem
To explore Fra Mauro formation
Collect information
Designing spacecraft information was required
Requirements
Crew, money, materials etc.
Brainstorming
Selected crew were selected and all Calculations were made
Choose best data
Attempts were made to decrease weight and advance technology was used.
Prototype Little Joe II
a relatively small rocket was required for qualification flight testing of this system
Apollo 13
After successfull launch of prototype Apollo 13 was launched on April 11, 1970
After 2 days
Oxygen tank Exploded
Engineers began working to understand
They changed data after full analysis Of that incident.
Prototype Upgrades
service modules were updated electrical components were changed
Apollo 14
eighth manned mission with all upgraded equipments and fixed oxygen tank.
Successfully Landed on the moon