National Aeronautics and Space Administration

Mission to Mars:

Mars Observer

Leadership ViTS Meeting

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THE MISHAP

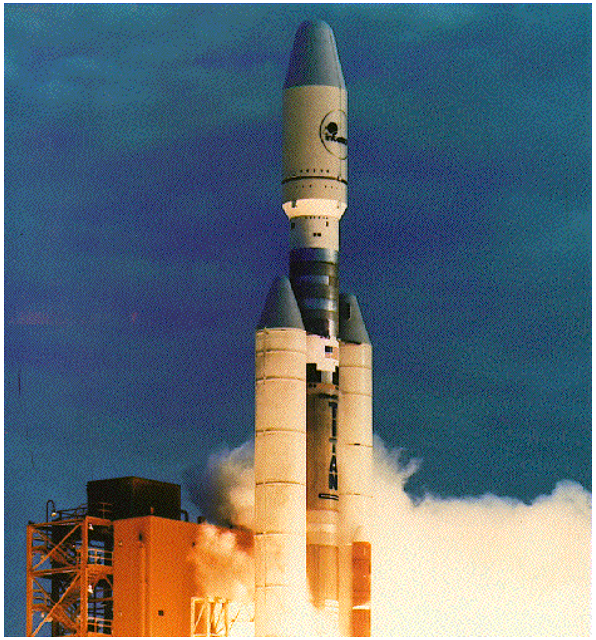
After eleven months in transit, and only three days away from entering the red planet's orbit, Mars Observer dropped from contact with its Earthbound NASA controllers. The project team could not restore communication with the spacecraft; no signals were detected from it in the following months, and NASA was forced to declare Mars Observer permanently lost. NASA Administrator Dan Goldin asked the Naval Research Laboratory to form an investigation board.

Ambitious Vehicle:

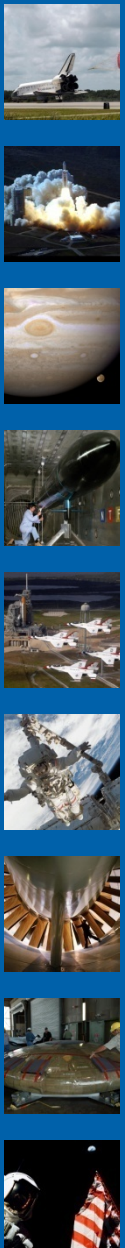
- Mars Observer was the first of the planned Planetary Observer series of missions; the Observer program was envisioned as a series of low-cost missions to the inner solar system
- Mission to map the Martian surface, and collect atmospheric, geologic, and gravitational data
- 4,500 lb vehicle launched from Cape Canaveral, Florida on September 25, 1992 and reached Mars 337 days later
- Scientists anticipated a full Martian year of data collection (about 687 Earth days)

Changing Requirements:

- During its eight-year lifecycle, Mars Observer project weathered significant changes and challenges
- Original schedule was extended by two years and project cost doubled
- Mission crew employed a large number of heritage parts and made tradeoffs in redundancy to reduce spacecraft weight



September 25, 1992 - Mars Observer launch aboard a Titan III rocket.



WHAT HAPPENED?

Orbit Entry Maneuvers:

- After a successful eleven-month journey, the first orbit maneuver into Mars took place on August 21, 1993
- Maneuver called for the firing of two pyrotechnic valves, which would pressurize the fuel tank
- Control Team was concerned that firing the pyro valves would damage the amplifiers in the communication system, so they made the decision to turn spacecraft transmitters off during firing

Loss of Telemetry:

- Transmitters were to remain off for a total of 14 minutes – during this time, something happened which would ultimately prevent communication from being re-established
- JPL Deep Space Network was reconfigured to optimize attempts at gaining communication; efforts during the following year proved futile
- Mission Failure Investigation Board faced a challenge: No physical evidence or telemetry existed to investigate

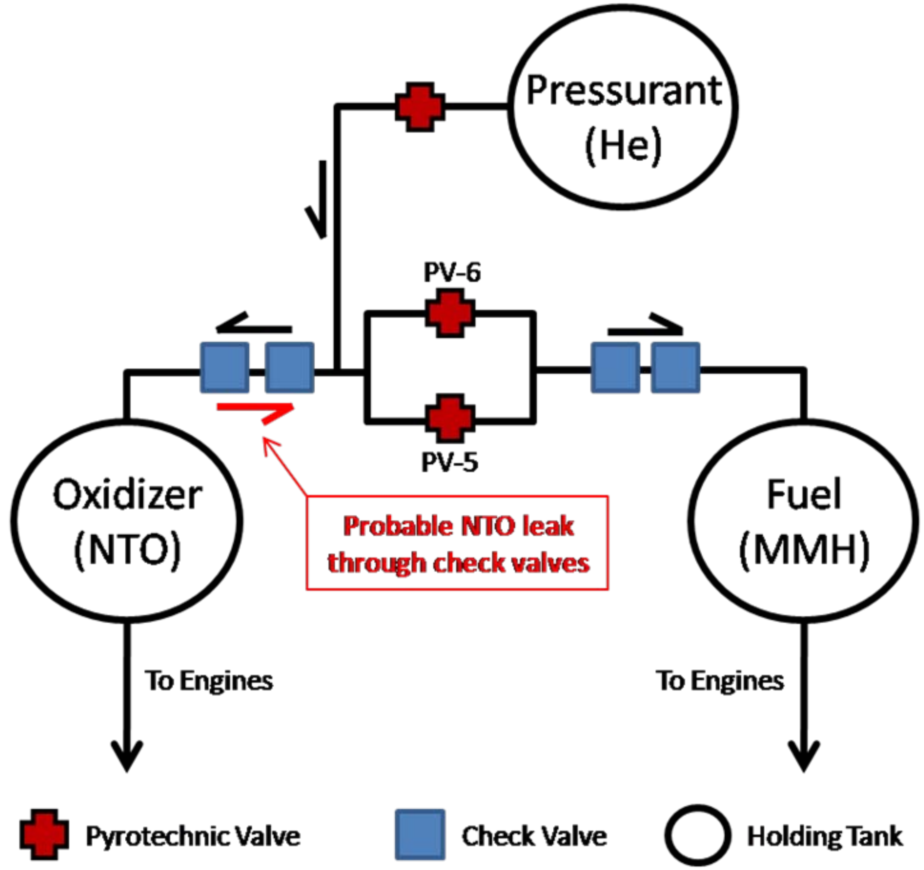
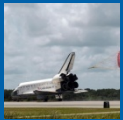
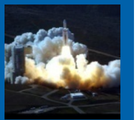
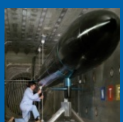
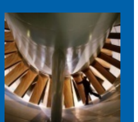


Diagram of section in propulsion system where explosion may have occurred. Investigators believe Oxidizer leaked through check valves (indicated by red arrow) and mixed with fuel when pyro valves 5&6 were opened.



PROXIMATE CAUSE

Probable:

Leak of the oxidizer through a series of check valves during their 11-month exposure to extreme cold. Even a few tenths of a gram of oxidizer mixed with the fuel in the tubing would have become explosive.

Possible:

-Power bus short circuit and power loss
-Propellant tank rupture from regulator failure
-Propellant tank rupture from ejection of initiator

ROOT CAUSE / UNDERLYING ISSUES

Fixed-Price Procurement:

•Fixed-Price acquisition and management strategy intended only minor modifications to a commercial, Earth-orbital production line spacecraft; component heritage was accepted as reliable

Inadequate Testing:

•The board identified the propulsion pressurization system check valves as unfit for an interplanetary mission; valves were tested in Earth-orbiting conditions, but faced significantly more harsh conditions during the journey to Mars

Tradeoff Decisions:

•Mission lacked a solid risk management plan to regulate tradeoffs; Team cut the redundancy of propulsion system to save several pounds of weight – but opened mission to unnecessary risk

Telemetry Priorities in Design:

•Team also made significant mass tradeoff in the telemetry design; ultimately deciding to turn off telemetry during heavy vibration events as opposed to making the system more robust or redundant

AFTERMATH

Board Observations:

- Over-reliance on heritage hardware and software, especially since Mars Observer mission was fundamentally different from previous missions
- Firm-fixed price contract philosophy became too cumbersome when requirements changed; a more flexible approach that took advantage of JPL experience and oversight would have served better
- System integration to sustain actual mission-driven operational and environmental demands fell short of what was needed
- Propulsion and telemetry mass trade-offs done at the cost of redundancy were not appropriate
- Spacecraft autonomy was given too much trust when its execution was not fully tested or understood

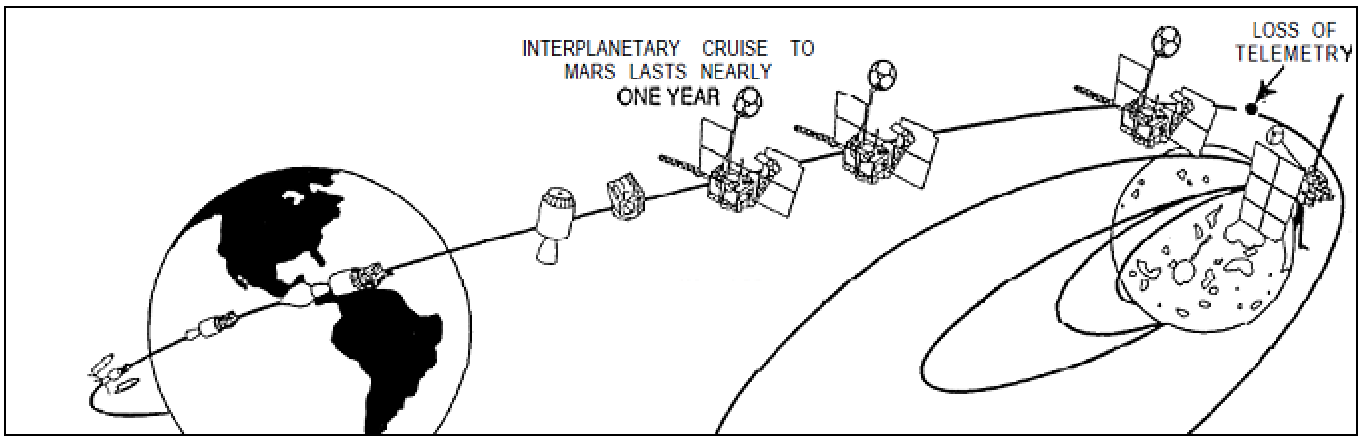


Diagram of the planned journey to Mars. The point where telemetry was turned off is seen in the upper right.

FOR FUTURE NASA MISSIONS

For NASA:

- Unexpected consequences can follow from each design and risk management decision; best defense is a thorough, well-conceived and executed testing plan
- When assessing commercial capability to deliver spacecraft, caution should be exercised – we must take advantage of the best experience and oversight available
- Heritage determination needs to make sure that the heritage experience is consistent with the experience/environment that is expected in the new mission
- Reliable system operation with the ability to adapt to minor failures becomes more important as increasing time and distance interfere with spacecraft control from Earth; **Mars Rover Spirit** and **Opportunity** are excellent examples of this lesson learned
- A comprehensive risk management plan should be established at the start of every project and followed through completion