



Loss of the Mars Climate Orbiter *Team Engineering Case Study*

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Objective of the Mars Climate Orbiter Mission

The Mars Climate Orbiter's science mission was one Martian year, or approximately two Earth years. In addition to collecting data about the Martian atmosphere, the Orbiter would act as a relay station for five years, assisting in data transmission to and from the Mars Polar Lander mission, as well as the 2001 Lander mission. NASA's Jet Propulsion Laboratory (JPL) was given primary responsibility for the Mars Climate Orbiter (MCO) mission.

History of the Mars Climate Orbiter Mission

December 11, 1998. Mars Climate Orbiter launches from Cape Canaveral aboard a Delta rocket.

September 23, 1999 (11 a.m. PST). After a 9-month space flight, MCO approaches the Martian planet. Communication link fails. Further attempts to communicate with the spacecraft are unsuccessful. At 5 p.m. (PST), Mars Climate Orbiter is declared lost.

September 30, 1999. NASA issues a statement, stating that a likely cause of mission failure is the use of incompatible scientific units among engineering teams (English units versus metric units).

October 6, 1999. NASA Marshall Space Flight Center director, Arthur G. Stephenson, is named chairman of the mission failure investigative board.

October 20, 1999. Investigative board issues first public statement regarding its own scope of work.

November 10, 1999. Investigative board releases its first report.

Assignment

Read the following news release, which is available at the Jet Propulsion Laboratory website:

<http://mars.jpl.nasa.gov/msp98/news/mco991110.html>

After reading the release, consider the following:

1. What are the 8 contributing factors that NASA JPL believes led to the loss of the spacecraft?
2. Which of the factors involve team-engineering issues? What issues are involved?
3. Pick one of the factors, and propose a solution to the problem. Describe how your solution addresses the issue(s) at hand.

Douglas Isbell/Don Savage
Headquarters, Washington, DC
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MARS CLIMATE ORBITER FAILURE BOARD RELEASES REPORT, NUMEROUS NASA ACTIONS UNDERWAY IN RESPONSE

Wide-ranging managerial and technical actions are underway at NASA's Jet Propulsion Laboratory, Pasadena, CA, in response to the loss of the Mars Climate Orbiter and the initial findings of the mission failure investigation board, whose first report was released today.

Focused on the upcoming landing of NASA's Mars Polar Lander, these actions include: a newly assigned senior management leader, freshly reviewed and augmented work plans, detailed fault tree analyses for pending mission events, daily telecons to evaluate technical progress and plan work yet to be done, increased availability of the Deep Space Network for communications with the spacecraft, and independent peer review of all operational and contingency procedures.

The board recognizes that mistakes occur on spacecraft projects, the report said. However, sufficient processes are usually in place on projects to catch these mistakes before they become critical to mission success. Unfortunately for MCO, the root cause was not caught by the processes in place in the MCO project.

"We have mobilized the very best talent at the Jet Propulsion Laboratory (JPL) to respond thoroughly to the specific recommendations in the board's report and the other areas of concern highlighted by the board," said Dr. Edward Stone, director of JPL. "Special attention is being directed at navigation and propulsion issues, and a fully independent 'red team' will review and

approve the closure of all subsequent actions. We are committed to doing whatever it takes to maximize the prospects for a successful landing on Mars on Dec. 3."

The failure board's first report identifies eight contributing factors that led directly or indirectly to the loss of the spacecraft. These contributing causes include inadequate consideration of the entire mission and its post-launch operation as a total system, inconsistent communications and training within the project, and lack of complete end-to-end verification of navigation software and related computer models.

"The 'root cause' of the loss of the spacecraft was the failed translation of English units into metric units in a segment of ground-based, navigation-related mission software, as NASA has previously announced," said Arthur Stephenson, chairman of the Mars Climate Orbiter Mission Failure Investigation Board. "The failure review board has identified other significant factors that allowed this error to be born, and then let it linger and propagate to the point where it resulted in a major error in our understanding of the spacecraft's path as it approached Mars.

"Based on these findings, we have communicated a range of recommendations and associated observations to the team planning the landing of the Polar Lander, and the team has given these recommendations some serious attention," said Stephenson, director of NASA's Marshall Space Flight Center, Huntsville, AL.

The board's report cites the following contributing factors:

- Errors went undetected within ground-based computer models of how small thruster firings on the spacecraft were predicted and then carried out on the spacecraft during its interplanetary trip to Mars
- The operational navigation team was not fully informed on the details of the way that Mars Climate Orbiter was pointed in space, as compared to the earlier Mars Global Surveyor mission
- A final, optional engine firing to raise the spacecraft's path relative to Mars before its arrival was considered but not performed for several interdependent reasons
- The systems engineering function within the project that is supposed to track and double-check all interconnected aspects of the mission was not robust enough, exacerbated by the first-time handover of a Mars-bound spacecraft from a group that constructed it and launched it to a new, multi-mission operations team
- Some communications channels among project engineering groups were too informal
- The small mission navigation team was oversubscribed and its work did not receive peer review by independent experts

- Personnel were not trained sufficiently in areas such as the relationship between the operation of the mission and its detailed navigational characteristics, or the process of filing formal anomaly reports
- The process to verify and validate certain engineering requirements and technical interfaces between some project groups, and between the project and its prime mission contractor, was inadequate

The failure board will now proceed with its work on a second report due by Feb. 1, 2000, which will address broader lessons learned and recommendations to improve NASA processes to reduce the probability of similar incidents in the future.

Mars Climate Orbiter and its sister mission, the Mars Polar Lander, are part of a series of missions in a long-term program of Mars exploration managed by the Jet Propulsion Laboratory for NASA's Office of Space Science, Washington, DC. JPL's industrial partner is Lockheed Martin Astronautics, Denver, CO. JPL is a division of the California Institute of Technology, Pasadena, CA.

The Board's report is available on-line at:

ftp://ftp.hq.nasa.gov/pub/pao/reports/1999/MCO_report.pdf