



Lost In Translation: The Mars Climate Orbiter Mishap

Leadership ViTS Meeting

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THE MISHAP



The Mars Climate Orbiter (MCO) launched in late December, 1998.

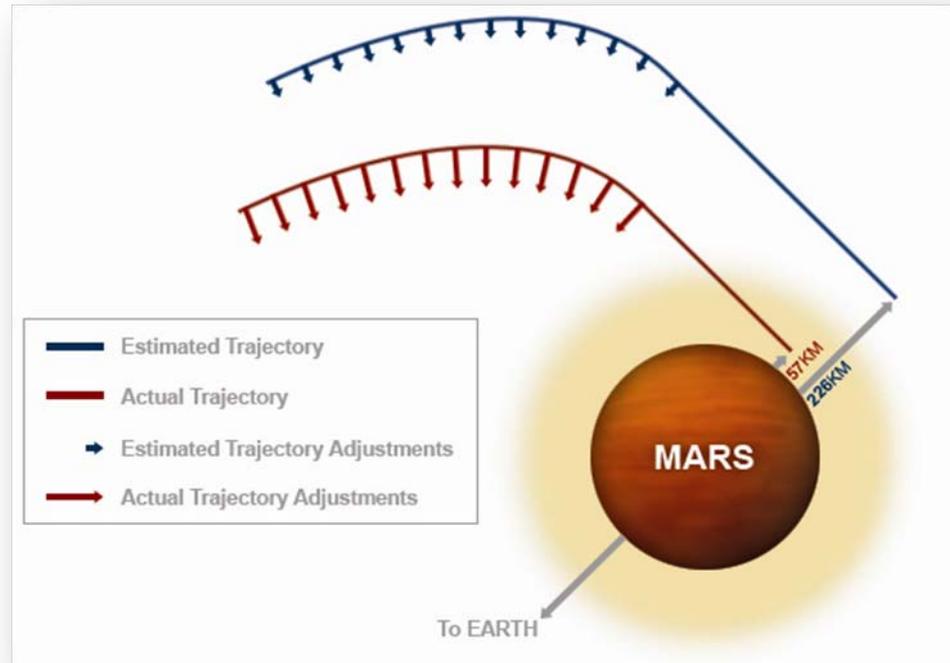
Nine months later, the MCO prepared to move into a circular orbit around Mars.

- The MCO approached Mars at an altitude of approximately 110km above the surface, well-below its target altitude, 226km.
- The mission team considered executing a contingency maneuver but decided to stick to the original plan:
 - The maneuver would shift the timeline, endangering the mission of the MCO's sister spacecraft, the Mars Polar Lander, which would arrive three weeks later.
 - Plans and procedures for the maneuver were not fully developed and the team was not prepared to execute the emergency contingency change.
 - The MCO was still above its estimated minimum safe altitude, 80km.

Four and a half minutes into the MCO's Orbital Insertion Burn, the signal from the MCO disappeared.

WHAT HAPPENED?

The MCO entered the Martian atmosphere at approximately 57km, not at its estimated 110km.



The MCO made minor trajectory changes along its journey to stay on target. The team later discovered that each minor trajectory adjustment along the way had been 4.45 times greater than they realized, because the software tracking the spacecraft was operating in English units rather than the required Metric units. All other calculations were in metric. The discrepancy sent the spacecraft closer to the planet than its calculated trajectory indicated.

Increased atmospheric stress destroyed the spacecraft.



PROXIMATE CAUSE



Ground navigation software used English units, not the required Metric units. This discrepancy biased trajectory calculations and sent the MCO too close to Mars. Increased atmospheric stress destroyed the spacecraft.



ROOT CAUSE / UNDERLYING ISSUES



Verification & Validation:

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- Development and V&V did not rely on the Software Interface Specification (SIS) to ensure the software was compatible.
 - The mishap investigation board found no evidence of complete, end-to-end testing for the trajectory tracking software.



Communication Between Project Teams:

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- Team members relied on informal communication channels.
 - The navigation team did not fully communicate their concerns to the spacecraft operations team or project management.



Preparation and Spacecraft Knowledge:

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- The navigation team came onboard just before launch and never developed an in-depth understanding of the spacecraft and its navigation.
 - The navigation operations team was running three missions simultaneously—the Surveyor, the Orbiter, and the Polar Lander.
 - Even if the team had recognized that the contingency trajectory change maneuver was critical to the MCO's survival, they were not prepared to execute the maneuver.

FOR FUTURE NASA MISSIONS

Managing Risk:

- Define and quantify acceptable risk, then assess and prioritize risks.
- Engage operations personnel early in the project so they understand significant risks.

Critical Tasks & Defining Responsibility:

- Verify and validate technical interfaces between project groups.
- Always include independent reviews for mission critical software in the V&V process.
- In the project plan, identify all critical roles and information, and ensure that they are carried through transitions from development to operations.
- As a part of the team, be aware of others' roles and how they impact the mission.

Communication:

- Encourage open communication and support a policy that empowers all team members to forcefully elevate any issue to the highest priority within the appropriate engineering discipline until it's understood.

From Awareness to Action:

- Simply identifying the problems is not enough; each mission team needs to determine how to implement the lessons learned during previous missions.
- Periodically step back to evaluate the execution of your mission and your role in it.

