02

INTRODUÇÃO À ENGENHARIA

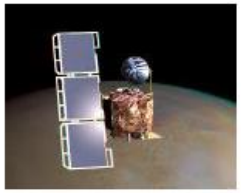
Engenharia
Prof. Luis Fernando

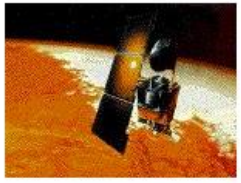
maffeis

Climate Orbiter Fact

mars.nasa.gov/msp98/orbiter/fact.html

Mars Climate Orbiter
Fact Sheet





- **Mission**
  "Volatiles and Climate History"
- **Launch**
  The orbiter was launched from Cape Canaveral Air Force Station (CCAFS) Space Launch Complex 17 (SLC-17) on December 11, 1998.
- **Launch Vehicle**
  Boeing Delta II 7425. The upper stage consists of a spin stabilized Star 48 with a Nutation Control System and a yo-yo despin device.
- **Spacecraft Dimensions**
  - Main bus: 2.1 meters (6.9 feet) tall, 1.6 meters (5.4 feet) wide and 2 meters (6.4 feet) deep.
  - Wingspan of solar array: 5.5 meters (18 feet) tip to tip.
- **Spacecraft Weight**
  629 kg (1,387 pounds) total, consisting of 338 kg (745 pound) spacecraft and 291 kg (642 pounds) fuel.
- **Science Instruments**
  - Mars Colar Imager (MARCI)
  - Press Modulator Infrared Radiometer (PMIRR)
- **Spacecraft Power**
  Solar array providing up to 1,000 watts just after launch, 500 watts at Mars

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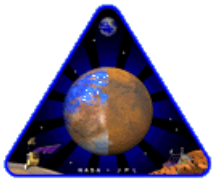
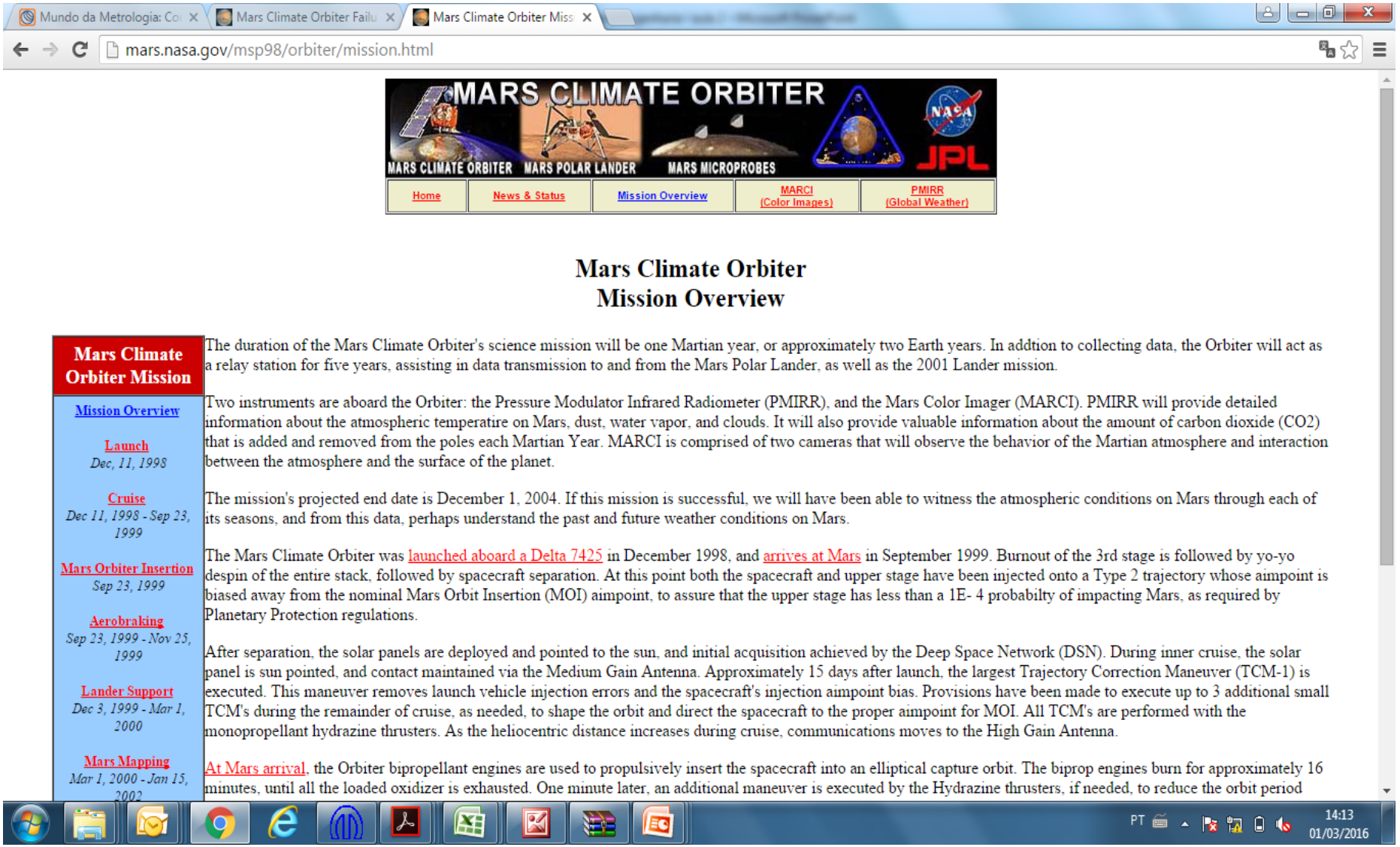
- **Mission Timeline**
  - December 11, 1998: Launch
  - September 23, 1999: Mars Orbiter Insertion
  - September 27, 1999: Mars Aerobraking Begins
  - November 10, 1999: Mars Aerobraking Ends
  - December 1, 1999: Transfer To Mapping Orbit
  - December 3, 1999: Mars Polar Lander Support
  - March 3, 2000: Mars Mapping Begins
  - January 15, 2002: Mars Relay Mission Begins
  - December 1, 2004: End Of Primary Mission

- **Project Cost**
  $327.6 million total for both orbiter and lander (not including Deep Space 2). $193.1 million for spacecraft development, $91.7 million for launch, and $42.8 million for mission operations.

- **Mission Logo**

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mars.nasa.gov/msp98/orbiter/mission.html
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Mars Orbiter Insertion
Sep 23, 1999
Aerobraking
Sep 23, 1999 - Nov 25, 1999
Lander Support
Dec 3, 1999 - Mar 1, 2000
Mars Mapping
Mar 1, 2000 - Jan 15, 2002
The duration of the Mars Climate Orbiter's science mission will be one Martian year, or approximately two Earth years. In addtion to collecting data, the Orbiter will act as a relay station for five years, assisting in data transmission to and from the Mars Polar Lander, as well as the 2001 Lander mission.
Two instruments are aboard the Orbiter: the Pressure Modulator Infrared Radiometer (PMIRR), and the Mars Color Imager (MARCI). PMIRR will provide detailed information about the atmospheric temperatire on Mars, dust, water vapor, and clouds. It will also provide valuable information about the amount of carbon dioxide (CO2) that is added and removed from the poles each Martian Year. MARCI is comprised of two cameras that will observe the behavior of the Martian atmosphere and interaction between the atmosphere and the surface of the planet.
The mission's projected end date is December 1, 2004. If this mission is successful, we will have been able to witness the atmospheric conditions on Mars through each of its seasons, and from this data, perhaps understand the past and future weather conditions on Mars.
The Mars Climate Orbiter was launched aboard a Delta 7425 in December 1998, and arrives at Mars in September 1999. Burnout of the 3rd stage is followed by yo-yo despin of the entire stack, followed by spacecraft separation. At this point both the spacecraft and upper stage have been injected onto a Type 2 trajectory whose aimpoint is biased away from the nominal Mars Orbit Insertion (MOI) aimpoint, to assure that the upper stage has less than a 1E- 4 probabilty of impacting Mars, as required by Planetary Protection regulations.
After separation, the solar panels are deployed and pointed to the sun, and initial acquisition achieved by the Deep Space Network (DSN). During inner cruise, the solar panel is sun pointed, and contact maintained via the Medium Gain Antenna. Approximately 15 days after launch, the largest Trajectory Correction Maneuver (TCM-1) is executed. This maneuver removes launch vehicle injection errors and the spacecraft's injection aimpoint bias. Provisions have been made to execute up to 3 additional small TCM's during the remainder of cruise, as needed, to shape the orbit and direct the spacecraft to the proper aimpoint for MOI. All TCM's are performed with the monopropellant hydrazine thrusters. As the heliocentric distance increases during cruise, communications moves to the High Gain Antenna.
At Mars arrival, the Orbiter bipropellant engines are used to propulsively insert the spacecraft into an elliptical capture orbit. The biprop engines burn for approximately 16 minutes, until all the loaded oxidizer is exhausted. One minute later, an additional maneuver is executed by the Hydrazine thrusters, if needed, to reduce the orbit period
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Mundo da Metrologia: Co | Mars Climate Orbiter Failu | Mars Climate Orbiter Laun

mars.nasa.gov/msp98/orbiter/launch.html

MARS CLIMATE ORBITER

MARS CLIMATE ORBITER MARS POLAR LANDER MARS MICROPROBES

JPL

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Mars Climate Orbiter Launch

Mars Climate Orbiter Mission

Mission Overview

Launch
Dec, 11, 1998

Cruise
Dec 11, 1998 - Sep 23, 1999

Mars Orbiter Insertion
Sep 23, 1999

Aerobraking
Sep 23, 1999 - Nov 25, 1999

Lander Support
Dec 3, 1999 - Mar 1, 2000

Mars Mapping
Mar 1, 2000 - Jan 15, 2002

Relay

The Mars Climate Orbiter was successfully launched on a Delta II launch vehicle from Launch Complex 17A at Cape Canaveral Air Station in Florida on December 11, 1998 at 18:45:51 UTC (13:45:51 EST).

VIEWING THE LAUNCH

In Person
Over NASA TV
Over The Internet

LAUNCH WINDOWS

Launch windows for the Mars Climate Orbiter runs from Dec 10-25, 1998, and there are two launch opportunities per day.

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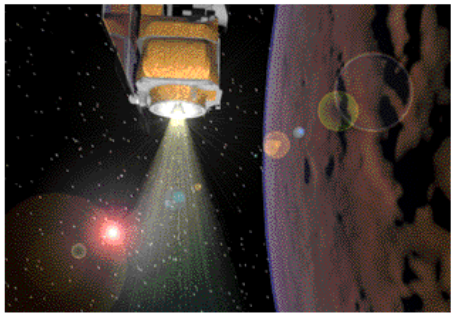
Mars Climate Orbiter Miss

mars.nasa.gov/msp98/orbiter/moi.html

Mars Climate Orbiter - Mars Orbit Insertion

Mars Orbit Insertion Quick Facts
Mars Arrival Date: September 23, 1999
Speed before engine firing (relative to Mars): 12,300 mph (5.5 km/sec) **Speed after engine fireing (relative to Mars):** 9,840 mph (4.4 km/sec) **Change in speed from engine firing:** 3,065 mph (1.37 km/sec)
Earth-Mars distance at arrival: 121.9 million miles (196.2 million km)
One-way speed-of-light time from Mars To Earth: 10 minutes, 49 seconds
Mars season at arrival: Fall in northern hemisphere, spring in southern hemisphere



Mars Climate Orbiter Engine Burn

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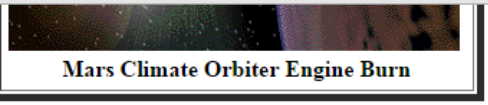
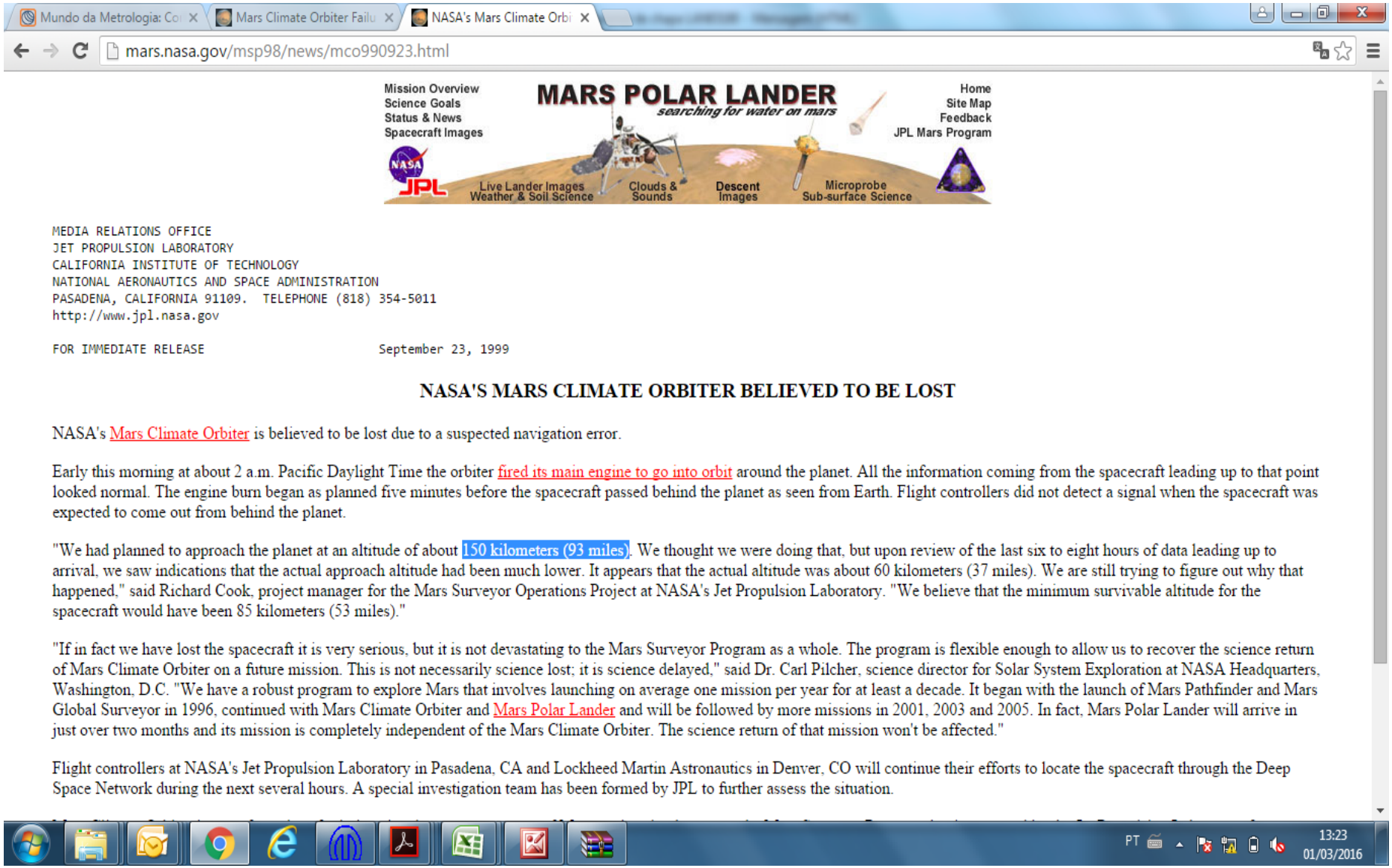


Mars Climate Orbiter Engine Burn

The Mars Climate Orbiter will arrive at Mars on September 23, 1999. As it nears its closest point to the planet coming in over the northern hemisphere, the spacecraft will fire its 640-newton main engine for 16 minutes 23 seconds to brake into an elliptical capture orbit. The spacecraft will loop around Mars roughly once every 12 to 17 hours. The period of the capture orbit will increase if launch takes place on a later date, due to an increasing arrival velocity. If launch takes place at the end of the launch period in late December, the capture orbit period would be approximately 20 hours.

Mars Climate Orbiter MOI Timeline
September 23, 1999
All times in Earth Receive Time (ERT).
One way light time from Mars is 10 minutes 49 seconds.

Event	PDT	EDT	UTC
Orbiter stows solar array	01:41	04:41	08:41
Orbiter turns to correct orientation to begin main engine burn	01:50	04:50	08:50
Orbiter fires pyrotechnic devices which open valves to begin pressurizing the fuel and oxidizer tanks	01:56	04:56	08:56
Main engine burn starts, fires for 16 minutes 23 seconds.	02:01	05:01	09:01
Orbiter passes behind Mars, out of view from Earth	02:06	05:06	09:06
Main engine burn ends	02:17	05:17	09:17
Orbiter turns to orientation which will allow Earth contact	02:19	05:19	09:19
Orbiter comes out from behind Mars, flight controllers regain contact	02:27	05:27	09:27
Solar array unstows	02:30	05:30	09:30



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http://www.jpl.nasa.gov

FOR IMMEDIATE RELEASE September 23, 1999

NASA'S MARS CLIMATE ORBITER BELIEVED TO BE LOST

NASA's Mars Climate Orbiter is believed to be lost due to a suspected navigation error.

Early this morning at about 2 a.m. Pacific Daylight Time the orbiter fired its main engine to go into orbit around the planet. All the information coming from the spacecraft leading up to that point looked normal. The engine burn began as planned five minutes before the spacecraft passed behind the planet as seen from Earth. Flight controllers did not detect a signal when the spacecraft was expected to come out from behind the planet.

"We had planned to approach the planet at an altitude of about 150 kilometers (93 miles). We thought we were doing that, but upon review of the last six to eight hours of data leading up to arrival, we saw indications that the actual approach altitude had been much lower. It appears that the actual altitude was about 60 kilometers (37 miles). We are still trying to figure out why that happened," said Richard Cook, project manager for the Mars Surveyor Operations Project at NASA's Jet Propulsion Laboratory. "We believe that the minimum survivable altitude for the spacecraft would have been 85 kilometers (53 miles)."

"If in fact we have lost the spacecraft it is very serious, but it is not devastating to the Mars Surveyor Program as a whole. The program is flexible enough to allow us to recover the science return of Mars Climate Orbiter on a future mission. This is not necessarily science lost; it is science delayed," said Dr. Carl Pilcher, science director for Solar System Exploration at NASA Headquarters, Washington, D.C. "We have a robust program to explore Mars that involves launching on average one mission per year for at least a decade. It began with the launch of Mars Pathfinder and Mars Global Surveyor in 1996, continued with Mars Climate Orbiter and Mars Polar Lander and will be followed by more missions in 2001, 2003 and 2005. In fact, Mars Polar Lander will arrive in just over two months and its mission is completely independent of the Mars Climate Orbiter. The science return of that mission won't be affected."

Flight controllers at NASA's Jet Propulsion Laboratory in Pasadena, CA and Lockheed Martin Astronautics in Denver, CO will continue their efforts to locate the spacecraft through the Deep Space Network during the next several hours. A special investigation team has been formed by JPL to further assess the situation.

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Mars Climate Orbiter Mission Status

September 24, 1999

Flight controllers for NASA's Mars Climate Orbiter are planning to abandon the search for the spacecraft at 3 p.m. Pacific Daylight Time today. The team has been using the 70-meter-diameter (230-foot) antennas of the Deep Space Network in an attempt to regain contact with the spacecraft.

Engineers now estimate that the altitude of the spacecraft's closest approach to Mars as it was firing its engine to enter orbit around the planet was 57 kilometers (35 miles). The original target altitude had been about 140 kilometers (about 90 miles). The spacecraft team estimates that the minimum survivable altitude for the spacecraft was between 85 and 100 kilometers (about 53 to 62 miles).

The project is moving swiftly to determine the causes of this error, assisted by an internal review team. Expert independent review teams are being formed by JPL and NASA.

Mars Climate Orbiter is one of a series of missions in a long-term program of Mars exploration known as the Mars Surveyor Program that is managed by the Jet Propulsion Laboratory for NASA's Office of Space Science, Washington, DC. JPL is a division of the California Institute of Technology, Pasadena, CA.

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For questions or comments on this website please refer to our list of contacts.

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Lockheed Martin Astronautics, Denver, CO
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Sept. 30, 1999

RELEASE 99-113

MARS CLIMATE ORBITER TEAM FINDS LIKELY CAUSE OF LOSS

A failure to recognize and correct an error in a transfer of information between the Mars Climate Orbiter spacecraft team in Colorado and the mission navigation team in California led to the loss of the spacecraft last week, preliminary findings by NASA's Jet Propulsion Laboratory internal peer review indicate.

"People sometimes make errors," said Dr. Edward Weiler, NASA's Associate Administrator for Space Science. "The problem here was not the error, it was the failure of NASA's systems engineering, and the checks and balances in our processes to detect the error. That's why we lost the spacecraft."

The peer review preliminary findings indicate that one team used English units (e.g., inches, feet and pounds) while the other used metric units for a key spacecraft operation. This information was critical to the maneuvers required to place the spacecraft in the proper Mars orbit.

"Our inability to recognize and correct this simple error has had major implications," said Dr. Edward Stone, director of the Jet Propulsion Laboratory. "We have underway a thorough investigation to understand this issue."

Two separate review committees have already been formed to investigate the loss of Mars Climate Orbiter: an internal JPL peer group and a special review board of JPL and outside experts. An independent NASA failure review board will be formed shortly.

"Our clear short-term goal is to maximize the likelihood of a successful landing of the Mars Polar Lander on December 3," said Weiler. "The lessons from these reviews will be applied across the board in the future."

Mars Climate Orbiter was one 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.

Douglas Isbell/Don Savage
Headquarters, Washington, DC
(Phone: 202/358-1547)

Nov. 10, 1999
Embargoed until 2 p.m. EST

RELEASE: 99-134

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