Reports on the loss of Mars Observer

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MISSION ADVISORY

MARS OBSERVER SPACECRAFT LOSES COMMUNICATIONS WITH EARTH

On Saturday evening, August 21st, communications were lost with the Mars Observer spacecraft as it neared to within 3 days of the planet Mars. Engineers and mission controllers at NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif., responded with a series of backup commands to turn on the spacecraft's transmitter and to point the spacecraft's antennas toward Earth. As of 11:00 a.m. EDT on Sunday, August 22nd, no signal from the spacecraft had been received by tracking stations around the world.

Mars Observer has an on-board sequence that will issue the proper commands to execute the critical Mars orbit insertion events on Tuesday afternoon, August 24th, assuming that the spacecraft is operating properly. This on-board sequence is designed to assure that the spacecraft is captured into Mars orbit even if ground controllers cannot communicate with the craft.

Communications were lost during an activity in which the tanks in the propulsion system were being pressurized. This system will be used to slow the spacecraft's speed and allow it to be captured into Mars orbit. Controllers have no reason to believe that the propulsion system has not been properly pressurized.

Engineers and mission controllers are continuing with additional attempts to re-establish communication. Commands are being issued every 20 minutes instructing the spacecraft to switch to a wider beam low-gain antenna and radio its status back to JPL.

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MARS OBSERVER MISSION STATUS
August 22, 1993
8 p.m. Pacific Daylight Time

Engineers are continuing to attempt to reestablish communication with the Mars Observer spacecraft, after losing contact with the spacecraft at 6 p.m. Pacific Daylight Time on Saturday, Aug. 21, three days before the craft's capture in orbit around Mars.

The spacecraft's on-board sequence to begin preparing for orbit insertion was uplinked on Friday, Aug. 20. Controllers have no reason to believe that the spacecraft is not carrying out those instructions even though communication has been interrupted. The spacecraft is set to enter orbit around Mars at approximately 1:30 p.m. PDT on Tuesday, Aug. 24.

The Jet Propulsion Laboratory Public Information Office will be closed until 8 a.m. PDT on Monday, Aug. 23.

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MARS OBSERVER orbital elements — 1 Mar 1993, rev 6 Oct 93

The following are orbital elements for the Mars Observer spacecraft. Element sets are given for (1) the interplanetary cruise from Earth to Mars; (2) for its its initial capture orbit at Mars and (3) its final mapping orbit at Mars if the mission had been successful; and (4) for its orbit around the Sun if the spacecraft did not enter Mars orbit but instead flew by the planet.

These orbital elements are predicts generated by the Mars Observer Navigation Team. The actual set of orbital elements achieved by the spacecraft will deviate somewhat.

INTERPLANETARY CRUISE

Semi-major axis	197163351.177	km
Eccentricity	0.23885397	deg
Inclination	1.294	deg
Argument of periapsis	-173.656	deg
Ascending node	-177.619	deg
Mean anomaly of epoch	110.042	deg

Epoch of elements: March 18, 1993 18:53:38.38 Ephemeris Time
Coordinate system: Sun-centered, Earth Mean Orbit and Equinox of Epoch J2000

MARS CAPTURE ORBIT

Semi-major axis	42923.941	km
Eccentricity	0.907977	deg
Inclination	89.000	deg

Argument of periapsis	112.990	deg
Ascending node	-106.453	deg
Mean anomaly of epoch	-180.000	deg

Epoch of elements: August 26, 1993 10:10:52.78 Ephemeris Time
Coordinate system: Mars-centered, Mars Mean Equator and IAU Vector of Epoch

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MARS MAPPING ORBIT

Semi-major axis	3766.159	km
Eccentricity	0.004049	deg
Inclination	92.869	deg
Argument of periapsis	-90.0	deg
Ascending node	261.590	deg
Mean anomaly of epoch	0.000	deg

Epoch of elements: December 6, 1993 00:00:00.00 Ephemeris Time
Coordinate system: Mars-centered, Mars Mean Equator and IAU Vector of Epoch

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MARS FLYBY (i.e. spacecraft in solar orbit)

Semi-major axis	204968597.	km
Eccentricity	0.174563502	deg
Period	585.789	days
True anomaly	-161.326456	deg
Mean anomaly	-154.029206	deg
Inclination	6.670063	deg
Longitude of ascending node	35.511309	deg
Argument of perihelion	-20.363033	deg

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FOR IMMEDIATE RELEASE January 5, 1994

Several potential causes that may have been responsible for the loss of the Mars Observer spacecraft last August have been identified by a special review board at the Jet Propulsion Laboratory.

The panel, chaired by JPL Deputy Assistant Laboratory Director Dr. R. Rhoads Stephenson, was appointed by JPL Deputy Director Larry N. Dumas as required by JPL management procedures after contact was lost with Mars Observer on August 21 three days before it was to enter orbit around the red planet.

According to Stephenson, the board's findings are generally consistent with those of an independent mission failure review board appointed by NASA Administrator Daniel Goldin and chaired by Dr. Timothy Coffey of the Naval Research Laboratory.

NASA is formulating a corrective action plan based on the independent review board's recommendations.

"Each of the review teams weighted the various hypotheses slightly differently, but we came to the same general conclusions about the loss," said Stephenson.

The JPL board's report says one of several potential causes was most likely to have caused the loss:

-- A breach of the spacecraft's propulsion system, due to one of three possible scenarios;

-- Electrical power loss due to a massive short in the power subsystem;

-- Loss of function that prevented both the spacecraft's main and backup computers from controlling the spacecraft;

-- Loss of both the main and backup transmitters due to failure of an electronic part.

Stephenson added that determining the cause of the loss was especially difficult because the spacecraft was purposely not transmitting data to Earth at the time of the failure.

Mars Observer had turned off its transmitter as a precautionary measure to protect the transmitter tubes from shock just before it pressurized its onboard propellant tanks on August 21. Three days later the spacecraft was due to fire its main engines to place it in orbit around Mars.

At the end of the tank pressurization, Mars Observer was supposed to turn its transmitter back on. Ground controllers, however, never received a signal.

The possibility of a propulsion subsystem breach actually includes three different possible scenarios, the JPL board said:

-- Liquid oxidizer (nitrogen tetroxide) may have migrated past a check valve in the pressurization lines; during the tank pressurization, the oxidizer could have been forced into lines containing the fuel, liquid monomethylhydrazine, causing the line to burst;

-- The pressure regulator could have failed, causing the oxidizer tank to overpressurize and burst;

-- A small pyrotechnic device, or squib, that was fired to open a valve in one of the pressurization system's lines could have been ejected from the pyro valve like a bullet and damaged the fuel tank.

Among the other main categories of failure hypotheses, a massive power subsystem failure could have been caused by a short at one of the main bus power diodes.

Loss of function in the spacecraft's computers could have occurred at the time the pyrotechnic devices, or squibs, were fired in the propulsion subsystem. Under this hypothesis, the squib firing could have generated an electromagnetic pulse that caused the spacecraft's main command processor to "hang" in a state in which neither the main or backup computer was able to control the spacecraft.

Loss of both the spacecraft's transmitters could have resulted if a component failed in a control unit which prevented either of the transmitters from being powered on.

In addition to its findings on direct causes of the Mars Observer failure, the JPL board's report also made general observations and recommendations to improve spacecraft design and implementation in the future.

JPL managed the Mars Observer mission for NASA's Office of Space Science.

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January 5, 1994
EMBARGOED UNTIL 1PM EST

James Gately
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RELEASE: 94-1

MARS OBSERVER INVESTIGATION REPORT RELEASED

The final report by the independent investigation board on the failure of the Mars Observer spacecraft was delivered today to NASA Administrator Daniel S. Goldin by Dr. Timothy Coffey, Chairman of the board. Dr. Coffey is Director of Research at the Naval Research Laboratory, Washington, D.C.

The Mars Observer spacecraft was to be the first U.S. spacecraft to study Mars since the Viking missions 18 years ago. The Mars Observer spacecraft fell silent just 3 days prior to entering orbit around Mars, following the pressurization of the rocket thruster fuel tanks.

Because the telemetry transmitted from the Observer had been commanded off and subsequent efforts to locate or communicate with the spacecraft failed, the board was unable to find conclusive evidence pointing to a particular event that caused the loss of the Observer.

However, after conducting extensive analyses, the board reported that the most probable cause of the loss of communications with the spacecraft on Aug. 21, 1993, was a rupture of the fuel (monomethyl hydrazine (MMH)) pressurization side of the spacecraft's propulsion system, resulting in a pressurized leak of both helium gas and liquid MMH under the spacecraft's thermal blanket. The gas and liquid would most likely have leaked out from under the blanket in an unsymmetrical manner, resulting in a net spin rate. This high spin rate would cause the spacecraft to enter into the "contingency mode," which interrupted the stored command sequence and thus, did not turn the transmitter on.

Additionally, this high spin rate precluded proper orientation of the solar arrays, resulting in discharge of the batteries. However, the spin effect may be academic, because the released MMH would likely attack and damage critical electrical circuits within the spacecraft.

The board's study concluded that the propulsion system failure most probably was caused by the inadvertent mixing and the reaction of nitrogen tetroxide (NTO) and MMH within titanium pressurization tubing, during the helium pressurization of the fuel tanks. This reaction caused the tubing to rupture, resulting in helium and MMH being released from the tubing, thus forcing the spacecraft into a catastrophic spin and also damaging critical electrical circuits.

Based on tests performed at the Jet Propulsion Laboratory (JPL) Pasadena, Calif., the board concludes that an energetically significant amount of NTO had gradually leaked through check valves and accumulated in the tubing during the spacecraft's 11-month flight to Mars.

In addition, the report listed other possible causes of the loss of the spacecraft as:

* failure of the electrical power system, due to a regulated power bus short circuit;

* NTO tank over-pressurization and rupture due to pressurization regulator failure;

* the accidental high-speed ejection of a NASA standard initiator from a pyro valve into the MMH tank or other spacecraft system.

Other concerns noted by the board included:

* a need to establish a policy to provide adequate telemetry data of all mission-critical events;

* the lack of post-assembly procedures for verifying the cleanliness and proper functioning of the propellant pressurization system;

* a current lack of understanding of the differences between the characteristics of European Space Agency and NASA pyro-initiators;

* the potential for power bus short circuits, due to single component or insulation failure;

* the potential for command and data handling control systems to be disabled by single-part failure;

* the lack of fault protection external to the redundant crystal oscillator (RXO) should one of its two outputs fail;

* the absence of information, in the telemetry, on the actual state of the RXO's backup oscillator;

* deficiencies in systems engineering/flight rules;

* too much reliance placed on the heritage of spacecraft hardware, software and procedures for near-Earth missions, which were fundamentally different from the interplanetary Mars Observer mission; and

* the use of a firm fixed-price contract restricted the cost-effective and timely development of the unique and highly specialized Mars Observer Spacecraft.

Dr. Coffey notes, "We were challenged to conduct an extraordinarily complex investigation in which we had no hard evidence to examine nor communications with the spacecraft. However, after an extensive analysis covering every facet of the mission, operations and hardware, I believe that we are justified in arriving at the conclusions we have. If our findings will help to ensure that future missions won't suffer a similar fate, we feel we will have achieved our purpose."

Dr. Coffey also expressed his appreciation for the support provided to the investigation board by the six technical teams, other NRL and Air Force Phillips Laboratory contributors, NASA representatives, the JPL Project Team and Investigation Board, and the Martin Marietta Astro Space technical teams.

"I commend Dr. Coffey and his team for the thoughtful and thorough research into the tragic loss of the Mars Observer," said Dr. Wesley Huntress, Jr., Associate Administrator for NASA's Office of Space Science, Washington, D.C. "Their work will help and guide us in formulating a corrective action plan to help ensure future success as we plan for recovering our Mars science exploration objectives."

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EDITOR'S NOTE: The Mars Observer Investigation Board Report is available to news media representatives by calling the NASA Headquarters Newsroom at 202/358-1600