MEDLI MSL Entry, Descent and Landing Instrumentation

MEDLI — the Mars Science Laboratory Entry, Descent and Landing Instrumentation suite — was embedded in the spacecraft's heatshield to gather data on the aerothermal, thermal protection system, and aerodynamic performance characteristics of the MSL entry vehicle during its entry and descent to the Mars surface, and to help engineers better design future Mars missions.

MEDLI, NASA's first Technology Demonstration Mission to fly, captured a rare and valuable data set. Its innovative Mars Entry Atmospheric Data System (MEADS) pressure sensors gathered information about the aerodynamic characteristics of the entry vehicle as it descended, while also studying the Martian atmosphere itself. The MEDLI Integrated Sensor Plugs (MISP), comprised of thermocouples and isotherm sensors, analyzed the performance of the Mars Science Laboratory's unique tiled thermal protection system.

A challenging mission

Close analysis of the MEDLI flight data is vital to future NASA exploration of the red planet. The Mars Science Laboratory spacecraft entered the Martian atmosphere traveling more than 3.5 miles per second — the second fastest NASA entry to Mars to date, after the Pathfinder mission in 1997. The MSL vehicle's aeroshell also was much larger than Pathfinder's (4.5 meters Vs. 2.65 meters), the craft itself was five times heavier, and its entry included the first-ever guided lifting trajectory attempted at Mars — all conditions expected to result in the highest heat flux and shear stress ever faced by a vehicle's heatshield at Mars. These increases drove MSL to use a heatshield material never before flown to Mars. All of these new vehicle and mission features made MSL's heatshield the perfect one to instrument.

Because the Martian atmosphere is primarily composed of carbon dioxide at about 1/100 the pressure of Earth's atmosphere, design and testing of the entry system to withstand such environments relies primarily on simulation tools. As a consequence, the MSL spacecraft was designed with large safety margins at the cost of payload mass. The results of the MEDLI experiment will help NASA ensure these margins are correctly sized on future missions, enabling more robust robotic studies and, in time, human journeys of discovery on Mars.

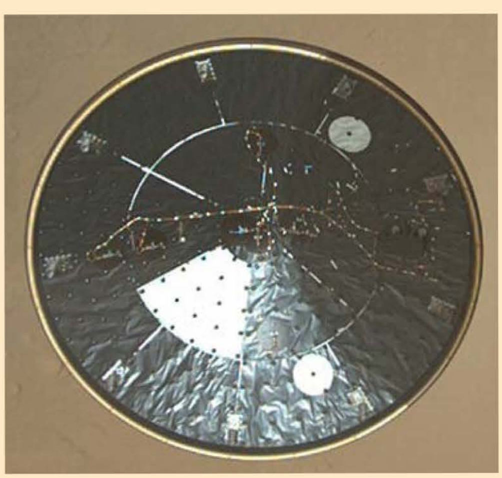
Two types of data

The MEDLI suite included two kinds of instruments, with seven sensors of each kind, in 14 locations on MSL's heat shield. These were all powered by and feeding data to a black box, the Sensor Support Electronics Unit.

One set of sensors, the Mars Entry Atmospheric Data System required seven tenth-inch diameter holes be drilled into the heat shield in a cross pattern. The holes were ports for pressure sensors that measured the atmospheric pressure on the heat shield at the seven MEADS locations during entry and descent.

NASA performed extensive testing in arcjet facilities on Earth to ensure the MEADS pressure ports

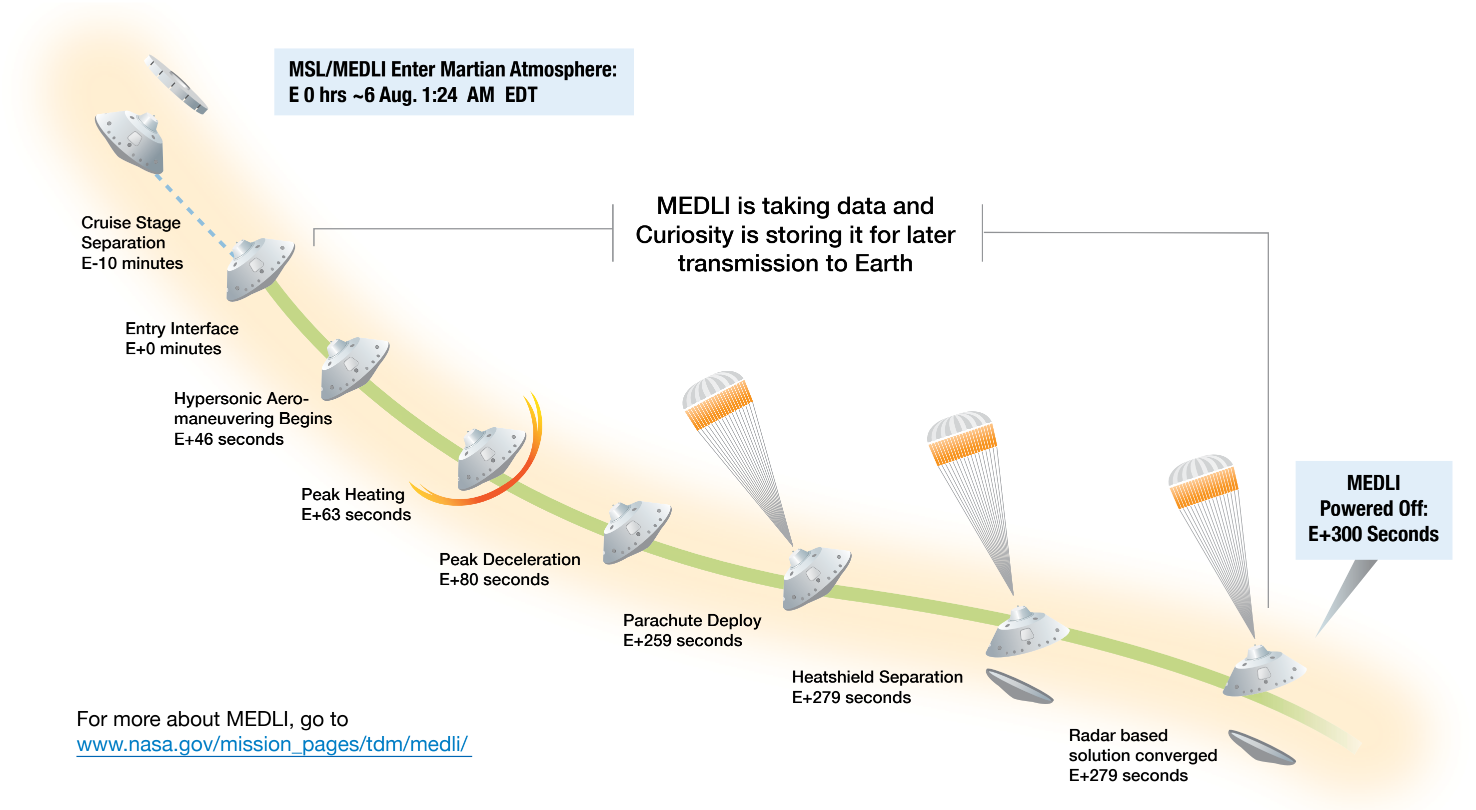
See reverse side



A job well done: The MEDLI instruments and wiring harness are clearly visible as the MSL heatshield falls away from the spacecraft after parachute deployment.

Key MEDLI Facts

- The MSL Entry, Descent & Landing Instrument suite was a first-of-its-kind instrumentation system on the Mars Science Laboratory.
- MEDLI measured the temperature and pressure of the spacecraft heatshield as it flew through the Martian atmosphere, delivering unprecedented data that is helping NASA build more efficient robotic and crewed Mars landers in the future.
- About a tenth of MEDLI's data was transmitted during entry and descent; the remainder was stored on the Curiosity rover, and communicated a few days after landing.
- MEDLI data helped generate the "tones" that told the operations team on Earth how the spacecraft was progressing through the Mars atmosphere. These tones would have provided critical forensic information in the event of an entry failure.



For more about MEDLI, go to
www.nasa.gov/mission_pages/tdm/medli/

could withstand the heat of entry. The cross pattern allowed MEDLI engineers to determine the orientation of the MSL aeroshell and how it changed during the less than 10 minutes MSL took to fly from the top of the atmosphere to the surface. Engineers used this information to see how accurately computer models predicted the spacecraft's path and aerodynamics, as well as to determine the atmospheric density and winds it encountered.

The other set of seven sensors, MEDLI Integrated Sensor Plugs (MISP), measured how hot the heatshield thermal protection system material became at different depths during entry.

Getting warmer

Heating levels on MSL were about three times higher than the levels on space shuttles when they reentered Earth's atmosphere. The heating levels were so high that the spacecraft's thermal protection system was designed to dissipate heat by burning away during entry into the Mars atmosphere. MISP measured the depth of this burning, so researchers could compare flight data to predicted data. MEDLI collected data in the last seven minutes of the flight. That's about how long it took to slow the spacecraft from 13,000 miles per hour (21,000 kilometers per hour) to just under two miles per hour (0.9 meters per second). The instruments recorded the heat and atmospheric pressure experienced during entry and through parachute deploy, then turned off before separation of the heat shield, the Sky Crane maneuver, and soft landing. It marked the first time NASA was able to determine significantly more than the "pass" or "fail" of an atmospheric entry at another planet. Having additional knowledge is important to spacecraft designers — especially when developing future Mars entry systems that are safer, more reliable, and lighter.

What we learned

From less than one megabyte of MEDLI data, researchers now know that the new tiled thermal protection system performed well on this mission, and engineers had designed in sufficient margins to ensure MSL would be safe. Overall, the Mars Science Laboratory heatshield did not get as hot as expected. Predictions of the expected heating were higher in some places on the heatshield, and lower in others. This knowledge is already influencing the design of the next Mars entry vehicle, InSight, scheduled to launch in 2016.

Engineers also determined that predictions of the spacecraft aerodynamics, or how the vehicle will fly through the Mars atmosphere, is very good throughout the high-speed range, but can be improved in the lower speed range near parachute deploy. All of these findings will be applied to future Mars landers, and can provide valuable lessons for entry vehicles at other planetary bodies.

MEDLI was led by NASA's Langley Research Center in Hampton, VA in partnership with NASA's Ames Research Center at Moffett Field, Calif. It is the first Technology Demonstration Mission from NASA's Space Technology Program to return data from space.

NASA's Aeronautics Research Mission Directorate, Science Directorate and Human Exploration and Operations Mission Directorate have also supported the MEDLI system research, development and data analysis.

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