

# How's the Weather on Mars?

Simulations are critical for calibration of instruments as well as fast and accurate interpretation of data from the Phoenix Mars Lander.

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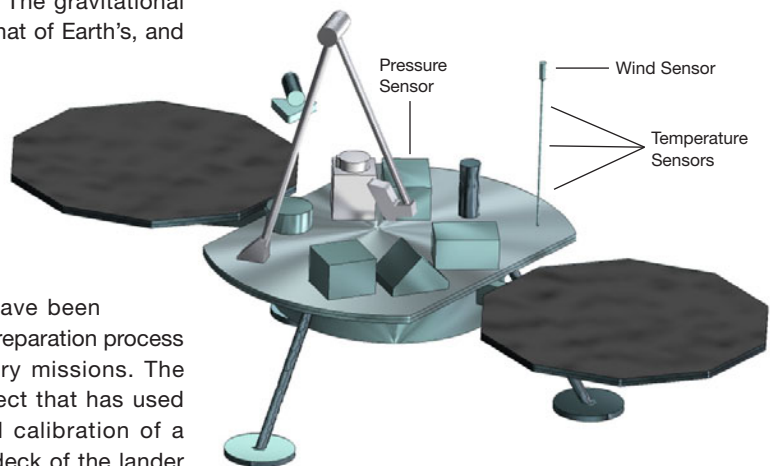
Because Mars is the planet closest to Earth, it has been host to numerous interplanetary missions. The Phoenix Mars mission was designed to study the history of water and habitability potential in Martian arctic ice-rich soil. As the Phoenix Mars spacecraft landed on the Martian surface in May 2008, communications stopped during the switch to orbiter relay. Two hours later, a sigh of relief erupted when data from the lander began streaming in. With space missions, there is only one shot at getting it right. Any minor flaw in the spacecraft or its instruments could result in the instantaneous loss of years of preparation and hundreds of millions of dollars.

Canada's contribution to the Phoenix Mars mission has been to provide the meteorological suite of instruments (MET) that measures the temperature, pressure, velocity and particle content in the planet's atmosphere. Mars has a unique atmosphere composed mainly of carbon dioxide (95.3 percent), nitrogen (2.7 percent) and argon (1.6 percent). The gravitational constant on that planet is 38 percent that of Earth's, and the atmospheric pressure on Mars is 1 percent of ours. As a result, pre-mission design and calibration experiments for the lander and its instruments were difficult and expensive to perform, making numerical simulations the most obvious economically viable solution.

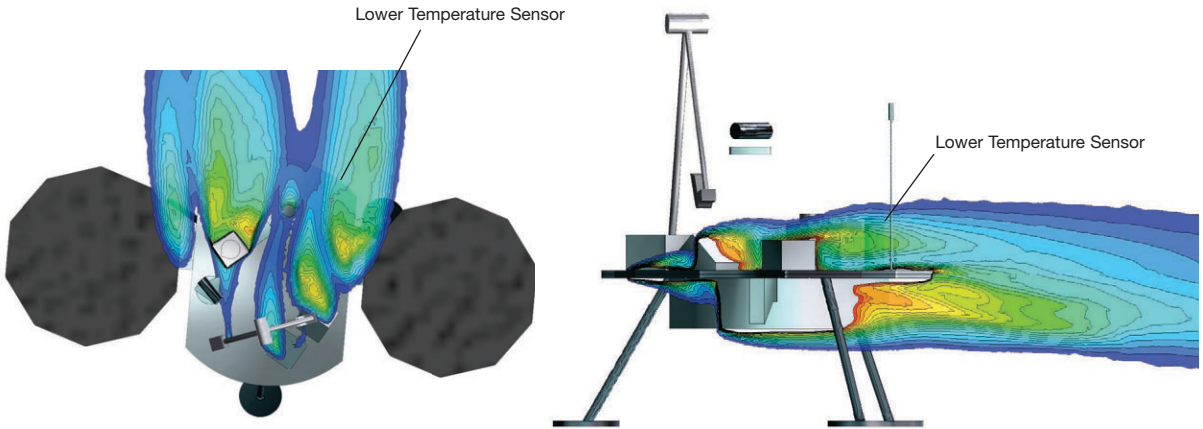
Even so, numerical simulations have been notoriously absent from the extensive preparation process for data collection of earlier planetary missions. The Phoenix Mars Lander is the first project that has used computational fluid dynamics to aid calibration of a planetary mission's instruments. The deck of the lander contains most of the instruments used to collect external

data. Of particular interest are pressure, velocity and temperature sensors [1], whose measurements, under certain conditions, can be influenced by the lander itself. For example, the internal heat generation and emission of radiation from the lander's surface may result in a thermal convective plume, which can increase temperature measurements. Similarly, obstacles upstream from velocity and pressure sensors can alter readings of magnitude and/or direction of Martian winds.

Researchers at the University of Alberta calibrated these instruments pre-flight through a large parametric study using ANSYS CFX fluid dynamics software by virtually varying the environmental conditions and the lander's heat output. Results revealed certain wind directions in which the lander's heat emission caused the lowest of the three temperature sensors to show higher-than-atmospheric values [2]. The University of Alberta team used the results of these fluid dynamic simulations



Model of the Phoenix lander



Temperature contours showing the effect of the lander's heating on the lowest of the three temperature sensors

to evaluate the raw mission data and to find instances when these wind directions occurred. This allowed the team to incorporate an increased measurement uncertainty for these cases. In this manner, simulation was the key to preventing data from being misinterpreted.

A similar study was completed for the pressure sensor, in which the pressure difference was correlated with wind speed. The Telltale wind sensor was a completely new design for the Martian lander, so it required a more in-depth calibration that focused on velocity measurements. The concept for this wind sensor originated at the University of Alberta, and it was designed and built in Denmark. The wind readings from the Telltale played an important part in data interpretation from the Mars lander.

In addition to the model size and number of simulations performed, the duration of each simulation was a factor. During the mission, the lander instrumentation had limited time and power resources. Power and operating time allocations were calculated daily, based on prevailing conditions. In order to decide these allocations, strategic

planners sometimes required input from the simulation data, so it was essential for the University of Alberta team to have rapid simulation turnaround on new cases.

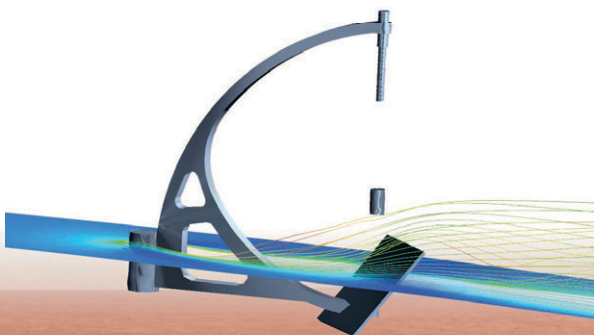
The short time-response requirement was met by running the simulations in parallel. Cases were run on a 64-bit Linux® cluster with each node composed of two quad-core Opteron™ 2350 AMD processors. Benchmarks on the problem resulted in a super-linear speedup of 4.47 on four CPUs and a linear speedup of 8.00 on eight cores, with each simulation running locally on a single node. The efficiency of the parallel processing and multi-domain scheme used in ANSYS CFX software combined with AMD's multi-core architecture enabled new simulations to be completed within the timeframe required for the decision-making process.

Calibration of the Phoenix Mars Lander, using ANSYS CFX technology, was deemed successful in both the pre-mission and operation phases. The success has allowed for additional simulations to be performed to aid in the explanation of certain phenomena found in the raw data. ■

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**References**

- [1] Taylor, P.; et. al. Temperature, Pressure, and Wind Instrumentation on Phoenix MET. *J. Geophys. Res.*, **2008**, v. 113. E00A18 doi:10.1029/2008JE00308.
- [2] Davy, R.; et. al. Initial Analysis of Air Temperature and Related Data from the Phoenix MET Station and Their Use in Estimating Turbulent Heat Fluxes. *J. Geophys. Res.* In press.



Effect of the support on the velocity sensor. Red and yellow streamlines indicate flow direction.