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Surprising findings for thermophysics

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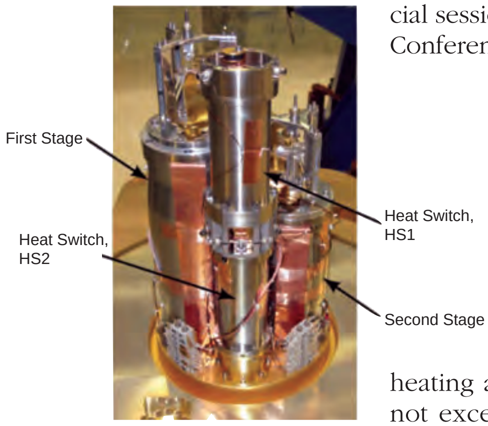
*The **Thermophysics Technical Committee** promotes the study and application of mechanisms involved in thermal energy transfer and storage in gases, liquids, and solids, or combinations.*



This adiabatic demagnetization refrigerator technology enables the NASA/JAXA Soft X-ray Spectrometer's detectors to operate at near-absolute zero and capture extremely high-resolution data. Credit: Mullard Space Science Laboratory.

Following 2012's delivery of the Curiosity rover to the surface of Mars, scientists are studying data from the many instruments embedded in the thermal protection system of the descent craft, called the **Mars Science Lab**. These instruments are collectively known as MEDLI for the Mars Science Lab Entry Descent and Landing Instrumentation. They include seven pressure transducers, 24 thermocouples, and six isotherm sensors. A multidisciplinary team of engineers from NASA Ames, NASA Langley, and the Georgia Institute of Technology are engaged in reconstructing the aerothermal environment and validating computational fluid dynamics and material response tools. The initial findings were presented in a special session at the 44th AIAA Thermophysics Conference in San Diego, Calif., in June.

The MEDLI data demonstrated that the phenolic impregnated carbon ablator thermal protection system, or TPS, on the descent vehicle **performed better** than expected and was adequately sized. The boundary-layer transition to turbulence occurred, as expected, on the leeside of the heat shield. The aerothermal heating and in-depth thermal response did not exceed design margins. The TPS surface recession during entry was found to be lower than model predictions.

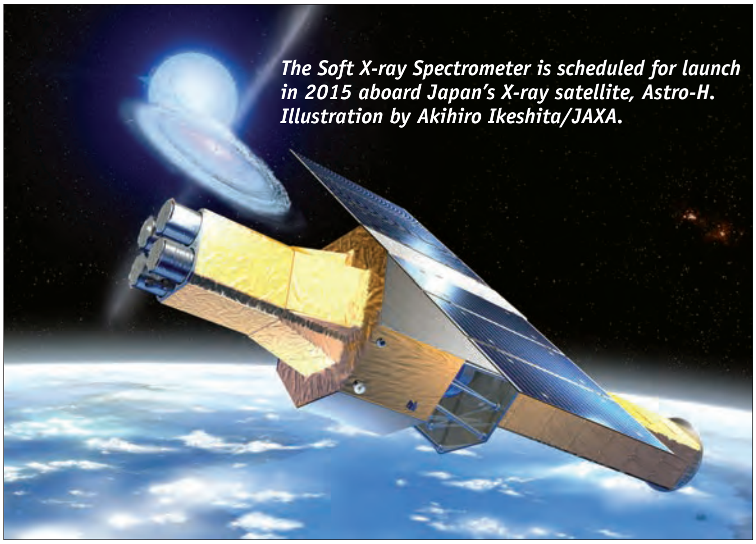
There were some **surprises** as well. The boundary-layer transition occurred earlier than predicted at some locations on the heat shield because of developing surface roughness. Also, maximum temperatures occurred close to the apex of the vehicle, a finding not predicted by the models.

In addition to meeting its science objectives, the MEDLI data are helping engineers reduce model uncertainties and margins in robust and mass-efficient TPS designs for future Mars entries.

This year the Cryogenics and Fluids Branch at NASA Goddard demonstrated an advanced **cryocooling** technology to enable the most sensitive space-based X-ray instrument to date. The Soft X-ray Spectrometer, jointly developed by NASA and the Japanese space agency JAXA will launch in late 2015 aboard Japan's sixth X-ray astronomy satellite, Astro-H. The instrument consists of a 36-pixel array of silicon detectors capable of measuring X-ray energy to better than a part in 1,000. The key to such resolution is detector operation near **absolute zero** (about 50 mK). This is accomplished via a three-stage adiabatic demagnetization refrigerator. ADRs are solid-state heat pumps that acquire and reject heat via the magnetocaloric effect.

Because of the detectors' extreme sensitivity, an engineering model was built to identify potential problems before finalization of the flight model. The overall cryogenic architecture consists of an ADR precooled by superfluid helium (at 1.3 K) and six cryocoolers. NASA had delivered the engineering model ADR and detector array to Japan in early 2012 for integration into the cryogenic system; however, a failed heat switch in the ADR precluded reaching target temperatures. To avoid major schedule impacts that would have resulted from switch replacement, NASA Goddard developed a new heat pump technique that uses **helium** gas inserted into the guard vacuum of the Dewar. At a select pressure, the gas thermally couples the ADR stages to the helium tank, allowing them to be cooled without much heat load on the tank itself or on the cryocoolers.

Afterwards the helium tank is pumped to a lower temperature to adsorb the exchange gas onto its outer surface, thus producing a high vacuum. This unconventional technique has led to over 100 hr of operation at 50 mK, with no signs of He contamination on the detectors.



The Soft X-ray Spectrometer is scheduled for launch in 2015 aboard Japan's X-ray satellite, Astro-H. Illustration by Akihiro Ikeshita/JAXA.