Purdue method to help engineers design systems for Mars, Moon missions

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Purdue University researchers, in the culmination of a four-year NASA-funded project, have created a method that will enable engineers to design more efficient systems for heating, cooling and other applications in spacecraft for missions to Mars and the moon.

The new method uses a model that was recently shown to be highly accurate in experiments onboard a NASA KC-135 aircraft that creates reduced gravity conditions such as those in earth orbit, on the moon and Mars. The aircraft flies in steep maneuvers, causing brief periods of microgravity in which to test theories for the design of space hardware, said Issam Mudawar, a Purdue professor of mechanical engineering, director of Purdue's Boiling and Two-Phase Flow Laboratory and the university's International Electronic Cooling Alliance.

"Our model can predict how these systems behave in reduced gravity based on operating conditions, how much fluid is flowing in a tube, how fast it is flowing, what the tube diameter and tube length are, and so on," Mudawar said. "What's neat about the flight experiments is that not only did we get data about the microgravity of space travel, but we also simulated the reduced gravity of the moon and Mars."

Lunar gravity is one-sixth that of Earth's, and Martian gravity is three-eighths as strong.

Using the same principle behind ordinary air conditioners and refrigerators, scientists want to use so-called "two-phase systems" for future spacecraft and space stations on the moon and Mars. The systems will work by using a closed loop in which liquid comes to a boil as it absorbs heat, turns into a vapor and is then returned by pumps so that it condenses back into a liquid and, in the process, cools down to begin the cycle over again.

"Boiling the liquid makes these systems at least 10 times more effective at transferring heat than systems that merely heat liquid, like the cooling system in your car, in which water absorbs heat from the engine and then circulates through a radiator to release the heat," Mudawar said. "The problem is that little has been known about the behavior of boiling and condensing liquids in space.

"Our work with NASA has led to a fundamental understanding of this two-phase fluid behavior in the microgravity of space and a method to provide guidelines for the design of space hardware."

Findings were presented in Cleveland in June during the Workshop on Strategic Research to Enable NASA's Exploration Missions. The study was conducted by Mudawar; Hui Zhang, a Purdue doctoral student in mechanical engineering; and Mohammad M. Hasan, a research engineer at the NASA Glenn Research Center in Cleveland.

The Purdue researchers first created a model in experiments on earth that simulated low gravity. Then, flight experiments on the NASA aircraft proved the model to be highly accurate, Mudawar said.

Engineers designed the flight experiment so that fluid flowed through a transparent plastic window. The researchers then took high-speed photographs and video of the flowing fluid during the flights, enabling the engineers to study its behavior in minute detail.

Zhang operated the experiment on the NASA KC-135 aircraft.

Data recorded during the experiments show how a given system would function in space, on the moon and on Mars.

Because boiling, vaporizing and condensing a fluid is far more effective at dissipating heat than just using liquid, such systems can be significantly more compact and lightweight, which is ideal for space travel.

"Weight is at a premium for any space mission, and this model will help engineers create smaller and lighter systems," NASA researcher Hasan said.

The transfer of heat is critical for cooling and heating systems, as well as the operation of power plants that use nuclear fission reactions. NASA researchers are exploring the possible use of nuclear fission reactors – the type of nuclear power used on earth – for future space applications.

President George W. Bush has launched an initiative establishing human missions to the moon and Mars as priorities, which means better life-support and power-generation systems will be needed.

The next step in the Purdue research will be testing the model with various fluids to broaden the tool's range of applications.

Source: Purdue University