

Purdue research helps advance new rocket technology

August 8 2006

Purdue University engineers are conducting research to help the United States develop a type of advanced rocket technology that uses kerosene and would not require the foam insulation now used on the space shuttle's external fuel tank.

The NASA-funded research at Purdue focuses on liquid-fueled rockets. Specifically, the work deals with understanding how fuel and a component called the oxidizer interact inside the rocket engine's fuel injectors to cause unstable combustion. The instability results in extreme bursts of heat and pressure fluctuations that could lead to accidents and hardware damage.

Purdue engineers involved in the research earned a best paper award in July from the American Institute of Aeronautics and Astronautics.

"Combustion instability is a complex phenomenon that has hindered rocket development since the beginning of the Space Age," said Nicholas Nugent, a doctoral student in Purdue's School of Aeronautics and Astronautics. "We have to learn more about instability before future engines can be developed and used for space flight. Predicting combustion instability is one of the most difficult aspects of developing a rocket engine."

The paper's findings demonstrate that an experiment can be specifically designed to study instabilities occurring spontaneously, as they do in real engines.

"There haven't been many, if any, experiments in the past that have been able to achieve an instability without actually forcing it by introducing artificial influences not ordinarily seen in the operation of a rocket engine," said doctoral student James Sisco.

The paper was written by Nugent, Sisco, former student Kevin J. Miller and William Anderson, an assistant professor in the School of Aeronautics and Astronautics. Miller now works for Space Exploration Technologies Inc., or SpaceX, in El Segundo, Calif.

The Purdue engineers have completed further research and presented new findings in July during the American Institute of Aeronautics and Astronautics' joint propulsion conference in Sacramento, Calif. Findings for which the best paper award was received were presented at last year's joint propulsion conference in Tucson, Ariz.

"The main purpose of the work is to generate combustion and instability data so that other researchers can develop better computational models for designing rocket engines," Nugent said. "We are generating benchmark data that will improve the design analysis of all types of rocket engines."

Charles Merkle, the Reilly Professor of Engineering, is leading a research group at Purdue focusing on creating such models.

Without effective simulations, engineers must rely on trial and error, which is costly, time consuming and potentially dangerous.

"Without good models, you have to do a lot of testing, and you increase the chances of accidents," Nugent said. "If you do more computational modeling up front, you have less risk of damaging very expensive hardware, reducing the amount of testing needed and getting more out of each test."

Heat from combustion naturally fluctuates inside the combustion chamber. At the same time, the combustion chamber generates resonant sound waves that cause "acoustic pressure," which also fluctuates. When heat and pressure fluctuations coincide, the combined result can be devastating, causing accidents and damage to rocket engines.

"The interactions between combustion and chamber acoustics are very complex," Nugent said. "We are trying to measure and understand the dynamic characteristics of the phenomena. What mechanisms and physical processes occurring after you inject the propellants are causing heat release?"

Data are collected using pressure and heat sensors inside the chamber, and the researchers also take high-speed video of the combustion process to analyze instability.

In the earlier experiments detailed in the first paper, the engineers used a carefully designed injector and varied the length of the combustion chamber to see how changing acoustics affected the heat-driven pressure fluctuations. Findings in the new research paper indicate that simulations from a model created by researchers led by Merkle matched experimental results from laboratory experiments.

Future work will use optical sensors to measure more precisely the dynamic interactions between combustion fluctuations and fluctuations in acoustic pressure.

"Now that we have an experiment that can spontaneously produce instabilities, we will take the research to the next level by adding more instrumentation and looking at specific areas that we think are the root causes of the instability," Nugent said.

The U.S. Air Force also may benefit from the research results because

the experiment used an injector similar to those employed in advanced, high-performance rockets that use kerosene fuel. These rockets require less time to prepare for launch than conventional rockets, meaning they could be quickly sent on military missions. Unlike the space shuttle engines, which require a foam-insulated tank for the cryogenically cooled liquid hydrogen propellant, the "oxidizer-rich stage-combustion cycle" engines on which the experiment is based use a kerosene fuel that can be stored at room temperature. Using kerosene would enable engineers to create sleeker, more compact and lighter rockets that pack the same power as liquid hydrogen rockets.

"Liquid kerosene is about 100 times more dense than hydrogen, so you use much smaller tanks," Anderson said. "With kerosene, the diameter of the rocket is smaller, causing the weight and aerodynamic drag to go down, so it makes a really nice fuel for lifting rockets off the ground. Furthermore, ground operations are greatly simplified because kerosene is much easier to handle than liquid hydrogen."

The work is based at the High Pressure Laboratory, one of six facilities at Purdue's Maurice J. Zucrow Laboratories. The lab is operated jointly by the School of Aeronautics and Astronautics and the School of Mechanical Engineering. Researchers are using the facility for work sponsored by NASA, the Air Force, U.S. Army, other federal agencies and aerospace companies.

The rocket-testing facility within the High Pressure Lab, built in 1965, was upgraded in 2001 and became fully operational in 2003.

The Zucrow labs are named after Maurice J. Zucrow, a Purdue mechanical engineering alumnus who, in 1928, earned the first doctoral degree in an engineering field granted by Purdue. His research in rocket propulsion inspired the construction of the first facility at Zucrow Labs in 1948. Since then, the Zucrow labs have evolved into a complex of six

facilities on a 24-acre site west of campus where engineers perform a wide range of propulsion-related research in rockets, jet engines and other internal combustion engines.

Source: Purdue University

Citation: Purdue research helps advance new rocket technology (2006, August 8) retrieved 10 April 2024 from <https://phys.org/news/2006-08-purdue-advance-rocket-technology.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.