Air Force SBIR STTR IMPACT
FUELING THE ECONOMY
DETECTS TRACE AMOUNTS OF METALLIC ELEMENTS THAT INDICATE WEAR

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AF093-187

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Spectral Measurement System for Health Monitoring of Liquid Rocket Engines

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FA9300-12-C-2002

SBIR COMPANY NAME:
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TECHNICAL PROJECT OFFICE:
AFRL Aerospace Systems
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Space and Missile Systems Center

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Aerojet Rocketdyne completed a series of successful hot-fire tests on a Bantam rocket engine at NASA's Marshall Space Flight Center. The engine contained the Optical Combustion Analysis System, which was developed by a small business in partnership with the Air Force SBIR/STTR Program. (Photo courtesy of Aerojet Rocketdyne)

AIR FORCE PARTNERSHIP

WITH SMALL BUSINESS PROVIDES A BIG BOOST TO THE REUSABLE ROCKET INDUSTRY

Reusable rocket manufacturers are beginning to adopt a new technology that will improve launch safety and reduce maintenance costs.

With support from the Air Force Small Business Innovation Research/Small Business Technology Transfer Program, California-based Opto-Knowledge Systems Inc. developed a system to detect and analyze spectral emissions from the high-temperature combustion of rocket engine propellants. The Optical Combustion Analysis System, also known as OCAS, finds trace amounts of metallic elements that indicate wear or erosion of the engine components, pumps and combustion chamber.

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Two major rocket engine manufacturers – Aerojet Rocketdyne and Blue Origin – have used OCAS in a test program and are exploring opportunities to incorporate the technology into their overall flight engine health management system.

BEHIND THE TECHNOLOGY

There is a big push to reduce the cost of space missions by developing reusable launch vehicles. The issue is that rocket engines operate in a harsh environment, so they can be susceptible to wear and failure. Engine wear typically occurs during start-up and shut-down as well as prolonged engine operation. Over several uses, the cumulative wear may be sufficient to warrant maintenance or replacement. OCAS provides immediate feedback on the level of engine wear and can be used to schedule targeted condition-based maintenance to further reduce costs and help to avoid catastrophic failures.

In the Space Shuttle days, NASA would completely dismantle the shuttle's main engines to inspect all the parts and then rebuild the engine to assure reliability and health. The process of complete refurbishment after each flight is not cost effective and contradictory to achieving true engine reusability.

The engine health management system is an integral component of the launch vehicle, and with OCAS it is able to identify potential wear sources during each launch or test of the engine. By detecting the potential wear source, and relating the wear based on the specific materials to specific components, engine operators can more accurately assess the engine status and schedule proper inspections and maintenance only when needed.

This process is expected to reduce time between launches, eliminate unnecessary and expensive maintenance operations, and mitigate launch failures.

SBIR/STTR SUPPORT WAS CRITICAL

The Air Force SBIR/STTR Program allowed Opto-Knowledge Systems to work with the Air Force Research Laboratory's Rocket Propulsion Division – historically known as the AFRL Rocket Lab – at Edwards Air Force Base. That relationship provided the company an opportunity to test at one of the Rocket Lab's test cells using AFRL's lab-scale rocket engines. The result was a low-cost, rapid testing of concepts.

Opto-Knowledge Systems tested various sensors at Edwards and developed the software for data processing and for extraction of the trace elements in the exhaust plume. As a result of the project, AFRL encouraged the company to connect with domestic developers of rocket engines. That led directly to its work for the two commercial rocket engine manufacturers.

At NASA's Marshall Space Flight Center in 2017, Aerojet Rocketdyne completed a series of successful hot-fire tests on a Bantam liquid-fueled rocket engine built using additive manufacturing, also known as 3-D printing. The OCAS was integrated into the Bantam engine's injector and provided a baseline of useful optical data, according to James Larkin, diagnostics, prognostics and health management discipline lead at Aerojet Rocketdyne.

"In particular, the OCAS identified and quantified metal alloys that were present in the flow path during the combustion process," Larkin said. "Such knowledge enables informed diagnostic, prognostic and health management decisions."

Blue Origin also has been working with Opto-Knowledge Systems to bring the technology into its engine development programs.

"(OCAS) afforded us a new method to evaluate a test article's health with real-time analysis," said Yu Matsutomi, BE-4 engine test lead for Blue Origin. "This has helped us improve our failure detection capability and understanding hardware behavior change through the development process."