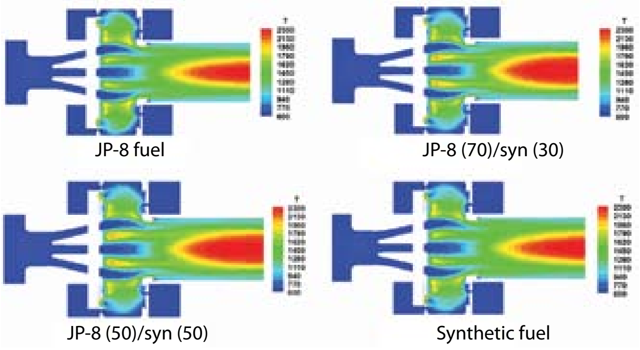
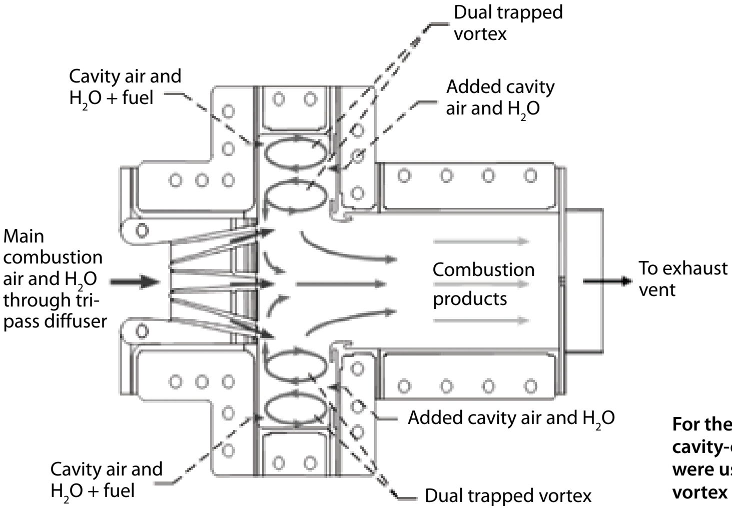
This month's focus previews three of the many papers that will be presented at the SAE AeroTech Congress and Exhibition September 17-20 in Los Angeles.

A step toward CO_2-neutral aviation



Combustor midplane contours showed researchers that the flame structure for all four fuels are "strikingly similar."



For the study in question, cavity-only fuel injectors were used in the trapped vortex combustor.

Realizing that small changes in one area of the planet can make large differences in climatic conditions elsewhere (planetary telekinesis), the aviation industry is diligently seeking alternative fueling and combustion methodologies to mitigate harmful emissions and become CO_2-neutral.

Alternative liquid fuels as derived from coal (CTL) or natural gas (GTL), termed "synfuels" when refined as aviation fuels and combusted, release significant amounts of CO_2, water, and hydrocarbons—but less than Jet-A. Plant-derived fuels, termed "biofuels," depend heavily on currently available food crops such as rice, wheat, corn, and soybeans, yet other forms such as switchgrass, algae, halophytes, palm oil, and similar cellulose or oil plant feedstocks, could become effective fueling feedstock sources. Potentially, biofuels could, through carbon tradeoff, provide a way for the aviation industry to partially achieve a goal of CO_2 neutrality while still using "drop-in" fuels for legacy aircraft.

Synfuels and blends are moving through the certification process.

Understanding combustor design and performance issues using alternative fuels is a step toward understanding aviation impact on climatic change and energy independence. To that end, and using CFD, researchers from **Flow Parametrics**, **NASA - Glenn Research Center**, and the **National Institute of Standards and Technology** (NIST) compared the performance of various fuel types.

Combustor performance was baselined to the trapped vortex combustor (TVC) with cavity-only fueling using Jet-A fuel to simulate the experimentally fueled JP-8+100 TVC. This computationally (with a CFD flow solver) and experimentally established baseline was then compared to that computed using two other fueling methods: synfuel and JP-8 fuel.

The 10-component simulation volume fraction of synfuel is based on the major constituents of a synthetic manufactured fuel supplied to the **U.S. Air Force** Research Laboratory at Wright-Patterson Air Force Base. In the lower-temperature regime, thermophysical properties of the 10 components are derived from the NIST code SUPERTRAPP (STRAPP). In the higher-temperature regime, the properties are derived using a simple Cp^0/R relation based on the McBride-Gordon NASA thermodynamic code. The 12-component JP-8 fuel is simulated in a similar manner. For combustor computations, each multicomponent mixture is simulated as a homogeneous fluid.

Based on this chemical mixture information, this study produced CFD-generated TVC cavity-only fueling performance for four cases.

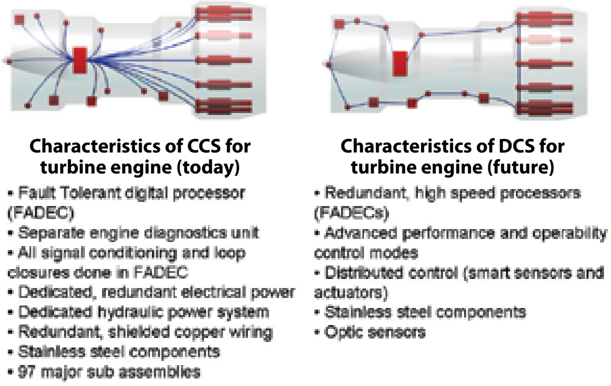
- JP-8 fuel with gaseous JP-8 fuel real gas properties
- Liquid JP-8 50/synthetic 50 fuel with associated real gas properties
- Liquid JP-8 70/synthetic 30 fuel with associated real gas properties
- Liquid Synthetic fuel with gaseous synthetic fuel real gas properties

These fuels and blends were selected to reflect current and projected fuel use. Computed flow structure for the four fuels showed strong similarities; however, inspection of the mass-averaged combustor exit quantities indicates that temperature differences may be sufficient to require reconsideration of turbine fueling schemes. Experimental validation studies using these fuels, over a range of operating conditions, are expected to be carried out.

Information for this article was provided by **Andreja Brankovic** and **Robert C. Ryder** of Flow Parametrics; **Robert C. Hendricks** of NASA - Glenn Research Center; and **Marcia L. Huber** of the National Institute of Standards and Technology.

Envisioning an intelligent distributed engine-control architecture

A Distributed Engine Control Working Group (DECWG) consisting of the **U.S. Department of Defense**, **NASA - Glenn Research Center**, and industry has been formed to examine current and future requirements of propulsion engine systems. The scope of this study includes an assessment of the paradigm shift from centralized engine control architecture to an architecture based on distributed control using open-system standards.



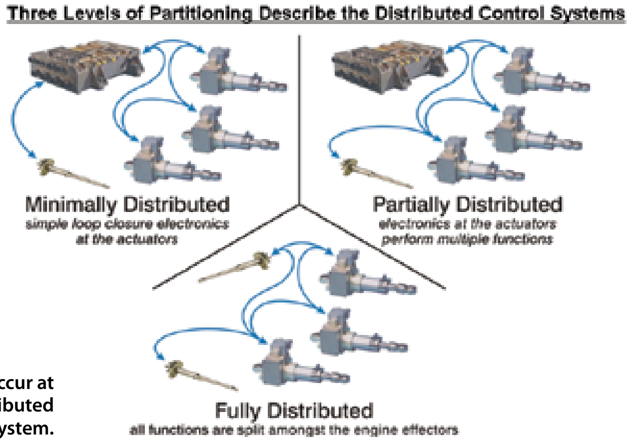
Characteristics of CCS for turbine engine (today)

- Fault Tolerant digital processor (FADEC)
- Separate engine diagnostics unit
- All signal conditioning and loop closures done in FADEC
- Dedicated, redundant electrical power
- Dedicated hydraulic power system
- Redundant, shielded copper wiring
- Stainless steel components
- 97 major sub assemblies

Characteristics of DCS for turbine engine (future)

- Redundant, high speed processors (FADECs)
- Advanced performance and operability control modes
- Distributed control (smart sensors and actuators)
- Stainless steel components
- Optic sensors

A centralized control system in a turbine engine uses point-to-point connections while the digital communications employed in a distributed control system allow for sharing of fewer wires.



Functional partitioning can occur at three different levels in a distributed control system.

The DECWG began work in the 1990s, but technical challenges must be overcome to realize the vision for on-engine distributed control.

The incentives for more advanced engine-control systems are many, including increased performance, wider operability, and reduced life-cycle costs. To address these needs, increasingly sophisticated electronics have been incrementally added to the engine-control system without a full, fundamental reconsideration of the overall architecture. This approach, while successful to some extent, has also exacerbated some inherent weaknesses.

The Working Group structure recommends a process to lay, via a government/industry partnership, a road map for development and assessment of enabling technologies for distributed engine control.

Today, in industry, there is what amounts to a revolution in control-system design methodology and implementation. This revolution is a direct outgrowth of the dramatic progress in electronics and the use of open-system standards in the development of new products and systems. The question of how the new challenges of aero-engine development will be met lies in the ability of control-system engineers to adopt these new technologies.

Distributed control is a mechanism for the proper implementation of systems-engineering processes in engine systems. The distributed control approach is inherently more powerful, flexible, and scalable than a centralized control approach. In the long term, businesses can achieve greater efficiencies and expect higher rates of return on investment by implementing this technology. At the same time, customers can expect greater value because new engine control technology will have fewer barriers hindering its implementation.

New technology also will offer effective strategies for the mitigation of obsolescence issues. Whereas centralized control effectively limits design choice, distributed control is about providing choices that add value to engine-control systems. This includes the use of centralized control strategies where they are most appropriate, such as in small engines.

Distributed control does not imply a specific architecture; instead clustering of different system elements can be arranged in any configuration that best maximizes customer value.

The main perceived benefits of the distributed-engine-control system are largely agreed upon by members of the DECWG:

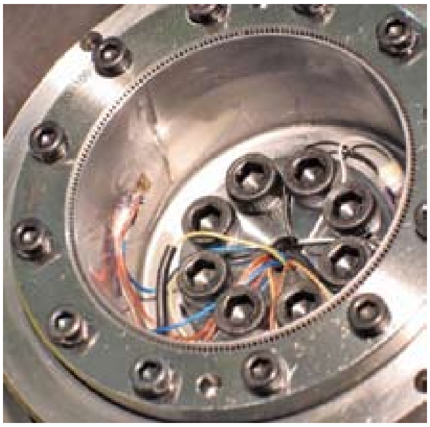
- Reduction in size/weight/cost of wiring harnesses
- Simplified potential for system upgrades
- Distribution of computational burden
- Potential increased robustness of the control system against faults/damage
- Mitigation strategy for obsolescence issues.

Information for this article was provided by U.S. Air Force Research Laboratory; NASA; U.S. Army; U.S. Navy; Pratt & Whitney; GE-Aviation; Honeywell; Rolls-Royce; BAE Systems; Hamilton Sundstrand; and Goodrich.

FE modeling leads to gear advance

Precision gear systems using **Harmonic Drive** gears are known to have a high torque-to-weight ratio. The company claims a new series of gear improves this property and adds new features, including an increased hollow-shaft diameter.

The company says this is an important development given the trend toward more-electric aircraft.



Strain gauges were applied by Harmonic Drive during testing for a new gear.

Stiffness of the gear is a key element for the precision and zero-backlash features of the Harmonic Drive gear. A systematic analysis of the actuator elements and their impact on overall transmission accuracy, performance, and precision was done to identify where reduced cross sections with lower stiffness results in lower weight without compromising performance.

The analysis included FE modeling and deformation values under various loading conditions. Stiffness requirements for the mounting structure were defined. The resulting product allows for transmitting the same torque as the previous design with a weight benefit of 20 to 40%, depending on gear size. One gear analysis saw a potential weight savings of 50%.

Gear inertia was reduced by about 40% (as expected, although under a different scaling law than envisioned), allowing a higher dynamic response of the actuator. The torque/weight ratio reached between 1000 and 1300 N•m/kg for the optimum gear ratio.

Further gear-system improvement is possible by using lightweight materials and by integrating the motor and gear to a higher degree.

Information for this article was provided by **Ingolf Schäfer** of Harmonic Drive.