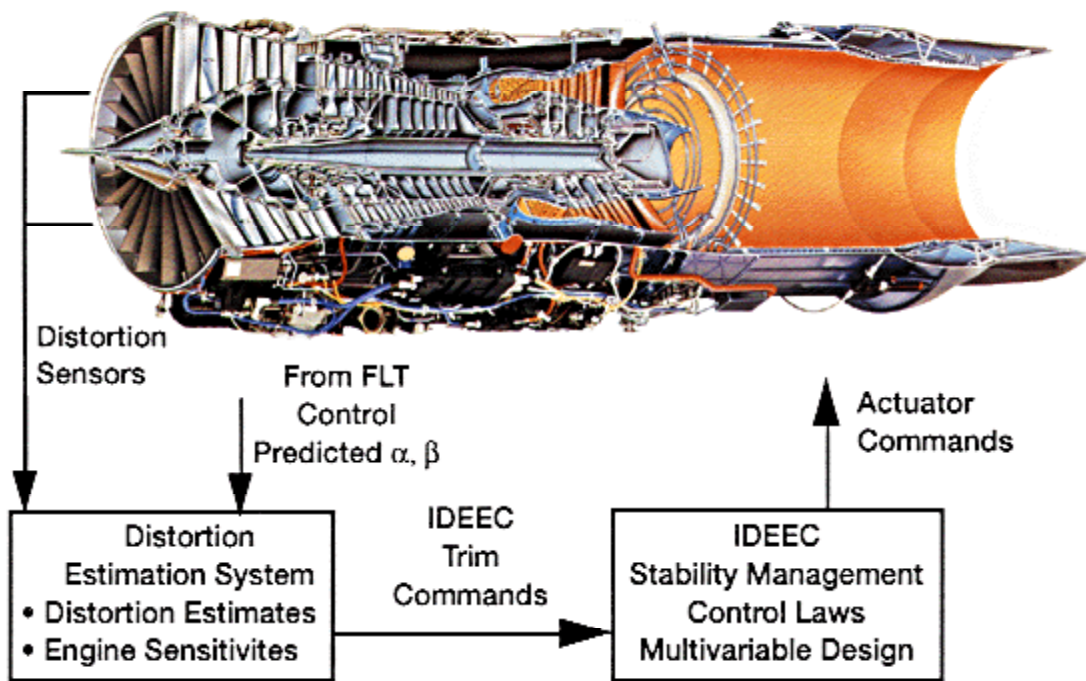# Concept Designed and Developed for Distortion- Tolerant, High-Stability Engine Control

Future aircraft turbine engines, both commercial and military, must be able to successfully accommodate expected increased levels of steady-state and dynamic engine-face distortion. Advanced tactical aircraft are likely to use thrust vectoring to enhance their maneuverability. As a result, the engines will see more extreme aircraft angles-of-attack and sideslip levels than are currently encountered with present-day aircraft. Also, the mixed-compression inlets needed for the High Speed Civil Transport will likely encounter disturbances similar to those seen by tactical aircraft, in addition to planar pulse, inlet buzz, and high distortion levels at low flight speed and off-design operation.

The current approach of incorporating a sufficient component design stall margin to tolerate these increased levels of distortion would significantly reduce performance. The objective of the High Stability Engine Control (HISTEC) program is to design, develop, and flight demonstrate an advanced, high-stability, integrated engine-control system that uses measurement-based, real-time estimates of distortion to enhance engine stability. The resulting distortion-tolerant control reduces the required design stall margin, with a corresponding increase in performance and decrease in fuel burn. The HISTEC concept has been designed and developed, and the software implementing the concept has successfully accommodated time-varying distortion. The NASA Lewis Research Center is currently overseeing the development and validation of the hardware and software necessary to flight test the HISTEC concept. HISTEC is a contracted effort with Pratt & Whitney of West Palm Beach, Florida.

The HISTEC approach includes two major systems: A Distortion Estimation System (DES) and Stability Management Control (SMC) (see figure). DES is an aircraft-mounted, high-speed processor that estimates the amount and type of distortion present and its effect on the engine. It uses high-response pressure measurements at the engine face to calculate indicators of the type and extent of distortion in real time. From these indicators, DES determines the effects of distortion on the propulsion systems and the corresponding engine match point necessary to accommodate it. DES output consists of fan and compressor pressure ratio trim commands that are passed to the SMC. In addition, DES uses maneuver information, consisting of angle-of-attack and sideslip from the flight control, to anticipate high inlet distortion conditions. The SMC, which is contained in the engine-mounted, Improved Digital Electronic Engine Control (IDEEC), includes advanced control laws to directly control the fan and compressor transient operating line (pressure ratio). These advanced control laws, with a multivariable design, have the potential for higher bandwidth and the resulting more precise control of engine match. The ability to measure and assess the distortion effects in real time coupled with a high-response controller improves engine stability at high levels of distortion.

*Distortion Tolerant Control. (Engine illustration copyright Pratt & Whitney, used with permission.)*

The software algorithms implementing DES have been designed, developed, and demonstrated, and integration testing of the DES and SMC software has been completed. The results show that the HISTEC system will be able to sense inlet distortion, determine the effect on engine stability, and accommodate distortion by maintaining an adequate margin for engine surge. The Pratt &Whitney Comprehensive Engine Diagnostic Unit was chosen as the DES processor. An instrumented inlet case for sensing distortion was designed and fabricated. HISTEC is scheduled for flight test on the ACTIVE F-15 aircraft at the NASA Dryden Flight Research Center in Edwards, California, in late 1996.

# Bibliography

Ouzts, P.J.; Lorenzo, C.F.; and Merrill, W.C.: Screening Studies of Advanced Control Concepts for Airbreathing Engines. NASA TM-106042, 1993.

Southwick, R.D., et al.: High Stability Engine Control (HISTEC) Phase I: Algorithm Development, Volume I: Final Report and Appendix A. NASA CR-198399, 1995. (Permission to use this material was granted by Sanjay Garg, February 1996.)