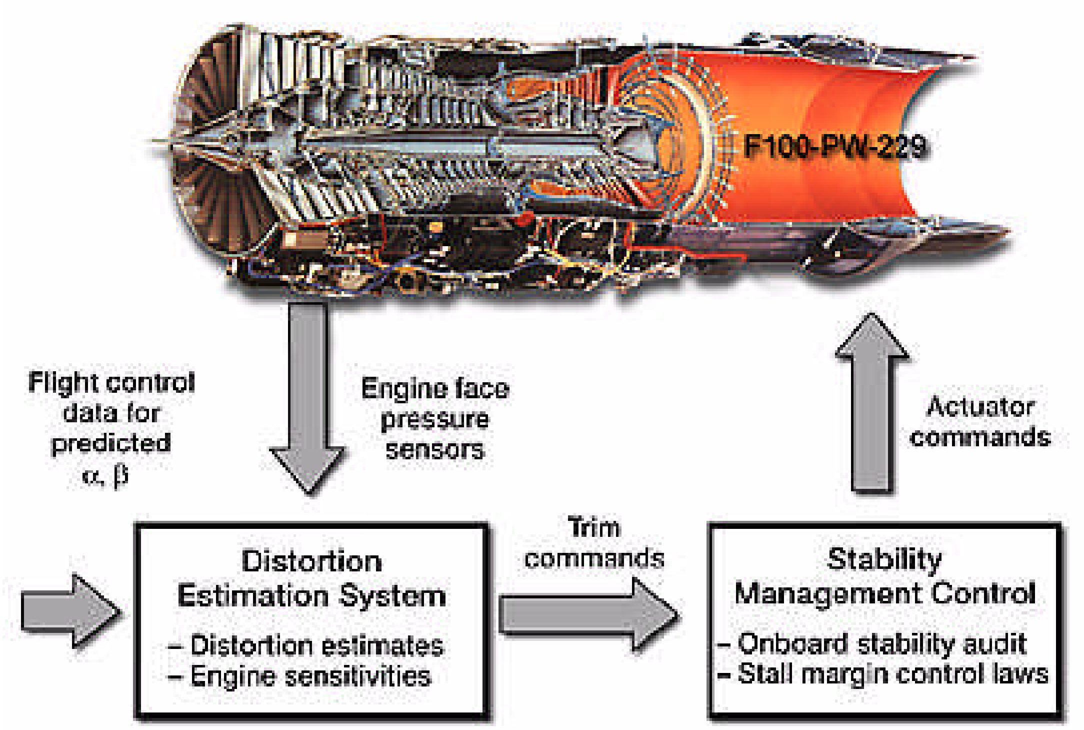
Distortion Tolerant Control Demonstrated in Flight

Future aircraft turbine engines, both commercial and military, will have to 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 for enhanced aircraft maneuverability. As a result, the engines will see more extreme aircraft angle-of-attack α and sideslip β levels than currently encountered with present-day aircraft. Also, the mixed-compression inlets needed for the High Speed Civil Transport (HSCT) 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 sufficient component design stall margin to tolerate these expected levels of distortion would result in significant performance penalties. The objective of NASA's 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 adjusts the stall margin requirement online in real-time. This reduces the design stall margin requirement, with a corresponding increase in performance and decrease in fuel burn.

The HISTEC approach includes two major systems: a Distortion Estimation System (DES) and Stability Management Control (SMC). The 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, the DES determines the effects of the distortion on the propulsion system. In addition, the DES uses maneuver information from the flight control to anticipate high distortion conditions. The DES output consists of fan and compressor pressure ratio trim commands that are passed to the SMC. The SMC performs a stability audit online by using the trims from the DES and then accommodates the distortion through the production engine actuators.



Distortion tolerant control. (Engine cutaway copyright Pratt & Whitney; used with permission.)

This year, the HISTEC distortion tolerant control system was flight tested on the NASA F-15 ACTIVE aircraft at the NASA Dryden Flight Research Center in Edwards, California. The flight demonstration showed closed-loop control operation with the engine fan and compressor stall margins being adjusted on the basis of estimated distortion. Project pilots flew the F-15 ACTIVE aircraft through a variety of maneuvers-such as high angle of attack flight, windup turns, and takeoff-which create distorted airflow conditions at the inlet. Preliminary analysis of the data indicates that both the DES and SMC were performing as designed. The extensive flight test data is currently being analyzed in detail.

F-15 ACTIVE aircraft.

The NASA Lewis Research Center is conducting the HISTEC program in partnership with the NASA Dryden Flight Research Center, Pratt & Whitney, Boeing Phantom Works (formerly McDonnell Douglas), and the U.S. Air Force.

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