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## Digital Electronic Engine Control "The DEEC"



*NASA's F-15 research aircraft was used to test the Digital Electronic Engine Control (DEEC) unit in a program conducted by the NASA Dryden Flight Research Center between 1981 and 1983.*

*NASA Photo ECN 18899*

The Digital Electronic Engine Control (DEEC) is a highly successful, commercially developed component that integrates a variety of engine functions to improve performance and extend engine life. It was initially tested and evaluated by the NASA Dryden Flight Research Center from 1981 to 1983 in a joint endeavor with engine manufacturer Pratt and Whitney, the U.S. Air Force, and NASA's Lewis Research Center (now the NASA Glenn Research Center).

The DEEC was developed for the Pratt and Whitney F100 turbofan engine, but its technology is now incorporated on other engine models. The DEEC replaced the F100 test engine's standard control system and had full control authority over a variety of engine functions. DEEC performance improvements included faster throttle responses, improved air-start capability, an altitude increase of over 10,000 feet in afterburner

operations, and the ability to provide stall-free operations throughout the aircraft's flight envelope. Aircraft and engine reliability and maintainability were also improved by the integrated actions of the DEEC.

NASA's successful test and evaluation program allowed the U.S. Air Force and Pratt and Whitney to place the DEEC into standard use on F100-PW-220-229 engines that power F-15 and F-16 aircraft of the United States and several foreign nations.

Pratt and Whitney have also incorporated digital engine control technology in its PW 2037 turbofan engines used on 757 commercial jetliners.

The lineage of similar digital engine control units used on other engines, offering comparable operational improvements, can be traced to results of NASA's DEEC test and evaluation program.

## **Inside a DEEC**

The DEEC system tested on the NASA F-15 was an engine mounted, fuel-cooled, single-channel digital controller that received inputs from the airframe and engine to control a wide range of engine functions such as inlet guide vanes, compressor stators, bleeds, main burner fuel flow, afterburner flue flow, and exhaust nozzle vanes.

Engine input measurements that led to these computer-controlled functions included static pressure at the compressor face, fan and core RPM, compressor face temperature, burner pressure, turbine inlet temperature, turbine discharge pressure, throttle position, afterburner fuel flow, fan and compressor speeds, and an ultra violet detector in the afterburner to check for flame presence.

Functions carried out after input data were processed by the DEEC computer included setting

the variable vanes, positioning compressor start bleeds, controlling gas-generator and augmentator fuel flows, adjusting the augmentor segment-sequence valve, and controlling the exhaust nozzle position.

These actions, and others, gave the engine -- and the pilot -- rapid and stable throttle response, protection from fan and compressor stalls, improved thrust, better performance at high altitudes, and they kept the engine operating within its limits over the full flight envelope.

## **DEEC History**

The history of the DEEC can be traced to the integrated flight and engine control system developed by NASA Dryden to improve the performance of the YF-12C Blackbird flown by in the 1970s for high speed and high altitude aeronautical research.

Dryden integrated the engine inlet control, auto-throttle, air data, and navigation functions to improve the overall performance of the Mach 3 aircraft. This "cooperative digital control system" gave the aircraft an increased range of seven percent, improved handling qualities, and also reduced the frequency of inlet "unstarts" which had plagued all Blackbird pilots. With the success of the YF-12C unit, Pratt and Whitney and the Air Force later incorporated the concept on the entire SR-71 fleet in 1983.

Meanwhile, as the control system was beginning to achieve enhanced performance on the YF-12C, Pratt and Whitney began development of a production-quality DEEC for F100 engines used to power F-15 and F-16 fighters.

Participants in the program to fully test and evaluate the DEEC included, in addition to Pratt and

Whitney, the U.S. Air Force, NASA's Lewis Research Center (now the NASA Glenn Research Center) which tested a prototype DEEC on an F100 engine in an altitude facility in 1978, and NASA Dryden, which conducted the DEEC flight test and evaluation program from 1981 to 1983.

The aircraft used in the DEEC tests was an F-15 that NASA Dryden had obtained from the U.S. Air Force in the 1970s for use as a flight research platform.

The DEEC study was completed 1.5 years ahead of schedule and allowed the introduction of the DEEC system on operational engines much sooner than originally anticipated, while also saving millions of dollars.

Early success in the program resulted in the U.S. Air Force approving full production of the F100 control units midway through testing.

## **Testing and Evaluating the DEEC**

The broad objective of the DEEC test program conducted by NASA Dryden between 1981 and 1983 was to demonstrate and evaluate the system as it applied to a modern turbofan engine flown in a high-performance fighter to all corners of the envelope. Within this objective, program officials assessed fault detection, evaluated performance and durability, and compared flight test performance against data generated by design predictions and ground tests activities.

Prior to flight, the F-15 test aircraft was instrumented to collect data typical of most research flights: airspeed, altitude, attitude (pitch, roll, yaw), accelerations, and control surface positions.

The DEEC-equipped engine was installed in the left bay and was extensively instrumented to

record all parameters associated with its performance, including malfunctions. Instrumentation on the right engine displayed its operational status only and it did not produce test data.

The data stream generated by instrumentation on the DEEC engine was recorded on the aircraft and also transmitted to a real-time flight monitoring facility at NASA Dryden where it was then made available for post-flight processing.

NASA's DEEC program logged 30 test flights that accumulated 35.5 flight hours over the two-year period. The entire operational envelope of the F-15 and the F100 engine was covered in a variety of flight conditions, with test points obtained at speeds up to Mach 2.36 and at altitudes up to 60,000 feet.

While the number of flights was relatively low, the evaluation package included nearly 1,300 throttle and afterburner transients, more than 150 air-starts, maximum accelerations and climbs, and the full spectrum of maneuvering flight.

About halfway into the test and evaluation program, several problems were encountered. The most significant was a nozzle instability that occurred during afterburner flight at high altitudes. This instability caused stalls and blowouts and had not been predicted in earlier simulation and altitude facility tests. The problems were eventually eliminated with control system changes after simulation studies at NASA Dryden and additional tests at the Propulsion System Laboratory at NASA Lewis.

By the end of the test and evaluation program, improvements in the DEEC system and improvements in the operational capabilities of the F100 engine had been demonstrated and system performance objectives had been met. These included stall-free operations across the entire F-15

flight envelope, faster throttle responses, improved air-start capability, and an increase of more than 10,000 feet altitude in afterburner without pilot restrictions on throttle use.

After the DEEC program ended at NASA Dryden, the U.S. Air Force successfully evaluated the system for F-16 aircraft.

## **DEEC Benefits**

Following the NASA tests, the DEEC system was installed on several operational Air Force F-15 aircraft. Over a period of time, the DEEC-equipped engines displayed improved reliability and

maintainability, they improved mean-time between failures by a factor of two, and unscheduled engine removals were reduced by a factor of nine.

Improved engine and flight performance in the NASA program and in the F-16 evaluation opened the door for DEEC-equipped engines to be installed in all F-15 and F-16 aircraft.

Development of the DEEC is looked upon as a milestone in propulsion control, and a major transition from hydro mechanical to digital control. Benefits of the system are substantial and include reduced operating and maintenance costs -- plus major boosts in engine performance and extended engine life.