# Digital Electronic Engine Control System—F-15 Flight Test

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**Government and industry research programs have repeatedly projected substantial benefits for full authority, digital engine control systems in terms of improved engine efficiency, performance, and operation. A prototype of such a system, the digital electronic engine control (DEEC) system, has been developed by Pratt & Whitney Aircraft for demonstration on the current F100 turbofan engine and potential application on advanced models of the engine. This system exercises full authority control over all the engine controlled variables using digital computation electronics and fault accommodation to control and maintain safe engine operational status. A hydromechanical backup control is provided in the event a major malfunction in the DEEC system is encountered. The DEEC system was flown in an F-15 aircraft at the NASA-Dryden Flight Research Center in 1981. Prior to flight, the engine control system was thoroughly tested at sea level in Florida and at the Arnold Engineering and Development Center (AEDC) altitude facility in Tennessee. This paper will describe the DEEC system design, subsystem development tests, the ground and simulated altitude system tests, and the planned research flights.**

## Nomenclature

| | |
|---|---|
| CIVV | = fan compressor inlet variable vanes |
| RCVV | = core (rear) compressor inlet variable vanes |
| $W_f$ | = main fuel flow in core |
| $W_{fsel}$ | = augmentor sprayring selector signal |
| $W_{fc}$ | = augmentor fuel flow core region |
| $W_{fd}$ | = augmentor fuel flow duct region |
| $Aj$ | = nozzle area |
| Ps2 | = engine inlet static pressure |
| Pb | = main burner pressure |
| PT2 | = engine total inlet pressure |
| PT6 | = engine total exhaust pressure |
| EPR | = engine pressure ratio = PT6/PT2 |
| $W_{at}$ | = total engine airflow |
| $W_{ac}$ | = engine core airflow |
| $W_{ad}$ | = engine duct airflow |
| FA-AB | = fuel air ratio in augmentor |
| PLA | = power lever angle |
| PLA-AB | = rate limited PLA |
| $Mn$ | = Mach number |
| N1 | = engine fan speed |
| N2 | = engine core speed |
| TT2 | = engine inlet temperature |
| FTIT | = fan turbine inlet temperature |

## Introduction

BEGINNING with the first aircraft gas turbine engine, there has been a continuous technology challenge for higher engine performance which has led to today's augmented turbofan engine with compressor variable vane geometry and variable area exhaust nozzle. Continuous engine technology advancements, coupled with higher thrust-to-weight ratios, and aircraft integration have brought greater and greater demands on the control system through increased functions, response, precision and computational requirements. The Pratt & Whitney Aircraft F100 engine, in the F-15 and the F-16 fighters, is the kind of high-performance engine, Fig. 1, which provides the desired thrust in a combat package by utilizing numerous controlled variables. The control system for the F100 engine was started in the late 1960s, and it became quite clear that an all-hydromechanical control type of system used up to this point was inadequate to meet the F100 engine performance requirements. An engine-mounted, fuel-cooled engine electronic control (EEC) system utilizing a digital electronic computer was configured into the control system to supervise or trim the hydromechanical control system. This represents the first operational use of an engine-mounted electronic digital computer on an aircraft gas turbine engine. Additional information on the digital electronic control system is listed in Refs. 1-3.

As a result of the success of the EEC, a team of control engineers was assembled in late 1973 to configure and demonstrate a full authority digital electronic engine control which was projected to improve precision and response of engine control and to reduce both acquisition and operational costs. By mid-1974, a digital electronic engine control (DEEC) system was configured in concert with Air Force control specialists, airframe specialists, propulsion specialists, and control specialists. The DEEC system, Fig. 2, is a relatively low-cost digital full authority control system containing selectively redundant components and fault detection logic with capability for accommodating faults to various levels of operational capability.

The system also contains a hydromechanical backup control, Fig. 3, which provides operational capability in the nonaugmented mode.

A great amount of engine testing and analytical work was required in order to select a control mode(s) for the DEEC system. This work resulted in adapting a full-time fan speed

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(N1) governor and closed-loop control on a nozzle area either with integral trim using engine pressure ratio (EPR) control at intermediate (I/M) power levels and above, or with a fixed nozzle area at part power, see Fig. 4. These modes were selected to maintain a given thrust vs power lever angle (PLA) without the normal requirement of engine trim, providing a truly "no trim" engine control system.

### Control System Description

The approach taken to demonstrate a full authority digital electronic engine control system was to 1) replace the EEC and hydromechanical computation with the new electronic control, and 2) to utilize as much of the proven F100 hydromechanical fuel valves and actuation system as possible. This concept was applied in order to minimize the development risk and time required for the program. The resulting control system is shown in Fig. 5. The DEEC controller receives the following information: 1) the engine status via pressure (Ps2, Pb, PT6) sensors; temperature (TT2, FTIT) sensors, and speed (N1, N2) sensors; 2) the airframe status via power level angle (PLA) and Mach number (*Mn*); and 3) the control system status via actuator feedback (F/B) transducers indicating the fan and rear compressor variable vane position (CIVV, RCVV), the core main and augmentor core-duct fuel metering valves positions, and the augmentor fuel distribution segment sequence position and the nozzle exhaust area position.

The controller then processes the above information by determining the condition of its input signals, selects the proper control algorithm, computes the engine operating status, compares the status with operational requirements, and adjusts actuation variables as required to make the engine operating status equal to the requested operational requirements.

Selective redundancy is found in the input sensors, actuator feedbacks, and the electronic interface components to maintain core operation with the loss of any single input signal. Redundant electrical output lines to dual coil torque motors on actuators are used to ensure reliable operation.

The DEEC digital control system is built around a 16-bit 1.2-$\mu$s cycle time, CMOS processor, microcomputer system with approximately 14K of available memory. The entire computer system is fuel-cooled.

The backup control (BUC) on the DEEC system is a hydromechanical fuel control housed in the same package as the DEEC main engine control valves. A hydraulically operated transfer valve is positioned such that the BUC control components will control fuel flow to the main (core) burner and position the start bleeds and the core compressor variable vanes (RCVV). The BUC receives 1) engine status data via inlet static pressure (Ps2) and temperature (TT2), 2) airframe data via the power lever angle (PLA), and 3) feedback cable indicating RCVV position.

### Control Mode

A major objective of the DEEC program was to operate the engine with a control mode which provided the best operational capability and did not require trimming the control system. This was accomplished by controlling total engine airflow (Wat), via corrected fan speed control, and the engine pressure ratio (EPR), via nozzle area control.

Table 1 lists the DEEC primary control mode operation showing the engine input variables and the required dependent variables to control the actuation systems. Table 2 lists the DEEC backup control mode operation showing the same controlling variables as in Table 1.

## DEEC System Benefits

The DEEC system projects additional improvements in operability, higher reliability and reduced supportability due to available control features. These features include advancements in precision (accuracy and speed) measurement, computation and control, fault detection and accommodation, diagnostics, and an integrated backup control.

Precision measurement, computation, and control features allow precise tailored schedules throughout the engine operational envelope, and make possible accurate engine pressure ratio measurements resulting in a practical engine "no trim" operation which significantly impacts all benefits, i.e., operability, reliability, and supportability. The elimination of engine trim ensures less man-hour support requirements, improves aircraft availability and increases mission life time. DEEC system improves precision and allows the control system to operate closer to engine operational limit lines, which decreases the required tolerance at the limits, thus gaining additional stability margin in both the augmented and nonaugmented operation. Starting is precisely controlled closed loop on acceleration of engine core speed (N2). Thus an expanded airstart envelope is provided with projected capability for airstarts at an airspeed which is from 25 to 50 knots lower than current capability. In addition, accurate control of engine pressure ratio, precise duct, and core fuel air (F/A) ratio scheduling is projected to allow maximum augmentor operation to the limit of combustion.

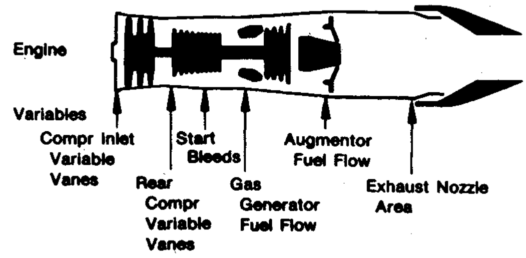

Fig. 1 F100 engine challenges control system.

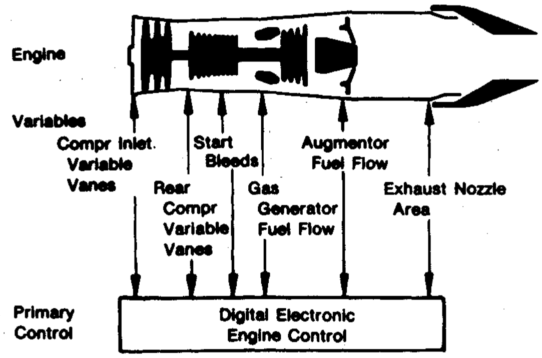

Fig. 2 Precision and response through total electronic controlling is provided.

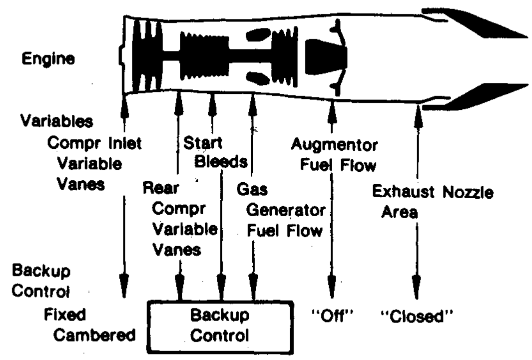

Fig. 3 Critical main engine variable redundancy provided by simple hydromechanical backup control.

Designing for ease of maintenance in the DEEC system was a major goal. The system is modularized, resulting in easy identification, through the DEEC diagnostic computer programs, of 15 line replaceable units (LRU), which when replaced on an engine do not require engine trim runs. An additional 35 modules, 21 hydromechanical and 14 DEEC controller, are replaceable at the base intermediate maintenance level and do not require subsequent component bench testing. Careful consideration has been given in the design to minimize the remove and replace time, which significantly reduces control maintenance man-hour requirements. Many maintenance control items on the current engines have been removed and replaced with DEEC system components. A diagnostic/troubleshooting system has been incorporated within the DEEC system via a readily accessible serial digital output channel to further reduce controls related unscheduled engine removals (UER).

System reliability using the DEEC control system will be improved relative to current operational control systems. The hardware failure rate is projected to be reduced by 50%. Eight hydromechanical components (2167 piece parts) have been eliminated from the control system; DEEC controller vibration isolators show an improvement of 2:1 in attenuation; DEEC controller acoustic protection has a 3:1 improvement; and a 7:1 enhancement in the hydraulic fuel filtration system is achieved with the DEEC system which improves contamination resistance of the control system.

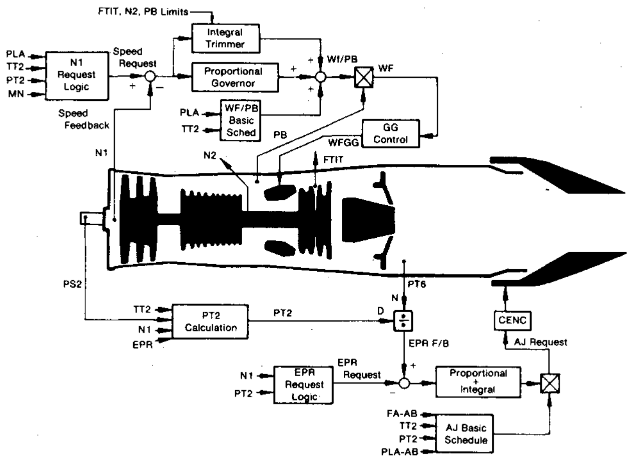

Fig. 4 DEEC basic control modes.

Fault detection and accommodation (FDA) features represent a significant portion (40%) of the control program in the DEEC controller and have been subjected to thorough development and system testing. The fault detection and accommodation illustrated in Fig. 6 shows that when the DEEC system is operating without fault(s), the level of activity of FDA is normal, which is represented at the top of the figure. The next level down occurs when the first system fault is detected and one of two possible fault accommodations can

**Table 1 Prime control variables**

| Engine computed variables | Dependent variables |
|---|---|
| PT2 | EPR, N1, TT2, Ps2 |
| EPR | PT2, PT6 |
| $W_{at}$ | N1, EPR, TT2 |
| $W_{ac}$ | N2, Pb, FTIT |
| $W_{ad}$ | $W_{at}$, $W_{ac}$ |
| FA-AB | $W_{at}$, $W_{fc}$, $W_{fd}$ |
| PLA-AB | Rate-limited PLA |
| **Engine input variables** | **Control dependent variables** |
| Start bleeds | N2, TT2 |
| CIVV | N1, TT2 |
| RCVV | N2, N1, TT2 |
| $W_f$ | PLA, PT2, TT2, Mn, Pb, N1, FTIT, N2 |
| $W_{fsel}$ | PLA-AB |
| $W_{fc}$ | $W_{ac}$, PT2, PT6, PLA-AB |
| $W_{fd}$ | $W_{ad}$, PT2, PT6, TT2, N1, PLA-AB |
| $Aj$ | PLA-AB, FA-AB, PT2, TT2, error (EPR or N1) |

**Table 2 Backup control variables**

| Engine input variables | Backup control dependent variables |
|---|---|
| Start bleeds | PLA, timer |
| CIVV | Fixed position |
| RCVV | PLA, TT2 |
| $W_f$ | PLA, TT2, Ps2 |
| $W_{fsel}$ | Off |
| $W_{fc}$ | Off |
| $W_{fd}$ | Off |
| $Aj$ | Closed position |

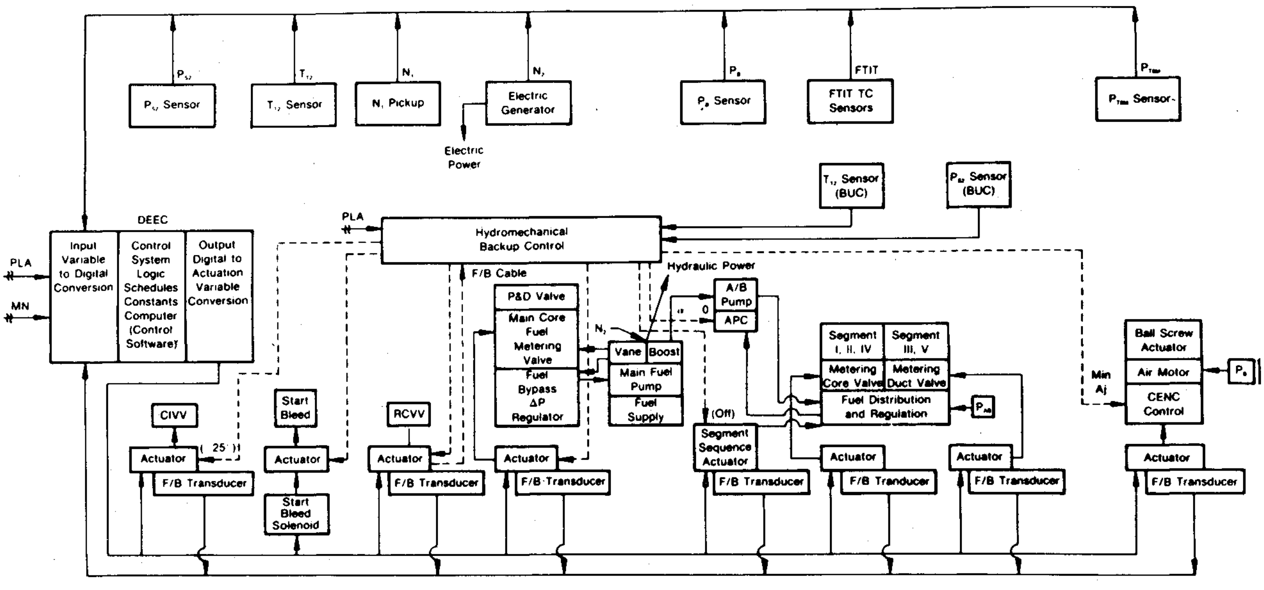

Fig. 5 DEEC engine control system.

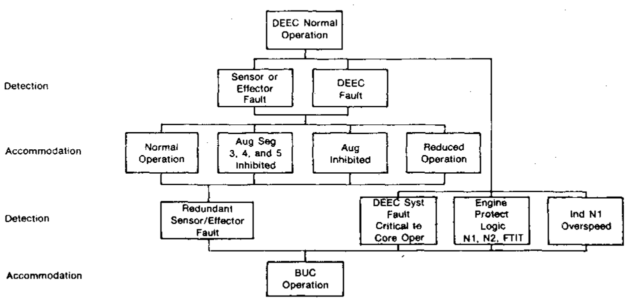


**Fig. 6 DEEC fault detection/accommodation.**

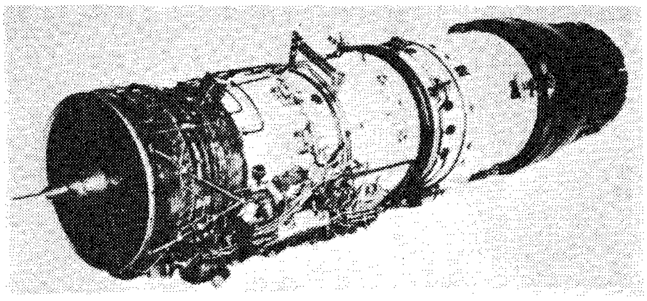

**Fig. 7 DEEC demonstration engine, NASA flight test engine-PO63.**

take place. One possibility is to accommodate the fault internally in the DEEC controller and the second is to transfer to the backup control system. The decision to transfer to BUC is based on one of three possible detected conditions: 1) the DEEC controller has detected a fault which will not allow the controller to be in charge of the main core fuel flow or RCVV position; 2) the engine protection logic has detected a variable (N1, N2, FTIT), is either over the limit condition, or its rate is such that the variable will reach an over-limit condition; or 3) a hardware independent fan speed (N1) circuit built into the DEEC controller detects an overspeed condition.

Other faults at this detection level drop down to the accommodation level (third level down in Fig. 6) where one of four operational conditions is selected depending upon the fault condition. The operational accommodation, which has a one-for-one hardware redundant fault replacement, yields a normal operating system. If the fault lies within the augmentor control of segment III or V (i.e., duct metering valve fault), these elements are inhibited and the control system has an operational degradation. If the fault is more inclusive in the augmentation control, the engine augmentation function is inhibited with further reduction in operational capability. Should the synthesis of a control variable be required (i.e., Pb sensor outage), then additional operational restriction is imposed, as the synthesized variable will be a conservative estimate of the replaced control variable. When operating in this level of accommodation (three levels down) and a second "like" fault occurs, the DEEC control automatically transfers operational control to BUC.

Diagnostics test programs are provided in the DEEC controller to identify incipient anomalies before they can seriously affect the aircraft mission. These tests are separated into two distinct logic groupings: initialization built-in test (BIT) and BIT during normal engine control. The initialization BIT includes; 1) a random access memory (RAM) integrity check; 2) a read only memory (ROM) hash total or check sum; 3) a limited processor instruction check; and 4) selected input interface checks. Items 1 and 3 utilize the watchdog timer hardware. The BIT during normal engine operation includes; 1) ROM check sum test as time permits during the execution of the control algorithm; 2) processor instruction checks as time permits; 3) input range checks; 4)

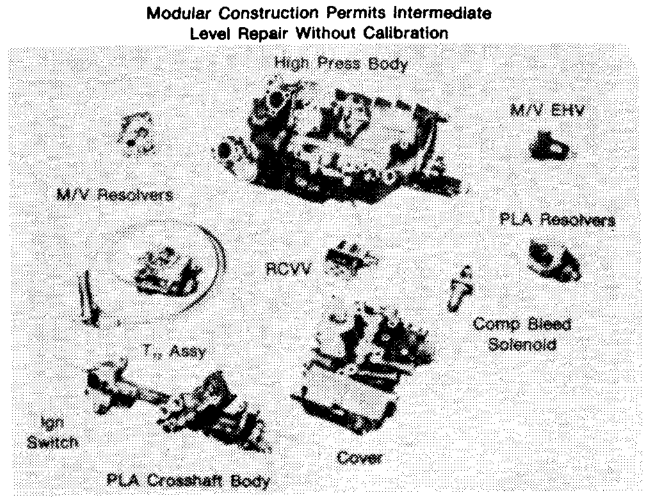


**Fig. 8 DEEC gas generation fuel valve and BUC.**

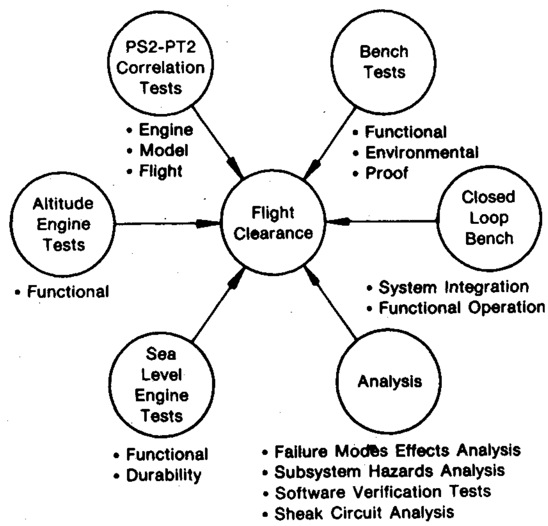


**Fig. 9 DEEC flight clearance process.**

torque motor coil testing to determine if the predescribed amount of current is flowing to each coil; and 5) actuator loop tests for torque motor integrity (as in 4), range checks to identify failed resolver or actuators, and loop dynamic checks for degradation of actuator response.

The integrated backup control (BUC) feature provides a fail-safe operation for the DEEC system prime electronic control. Selection of BUC is made automatically by failure detection in the prime control system or can be selected by the pilot anywhere in the operational envelope. Automatic starting is provided in the BUC mode and is the same pilot procedure as is used in the DEEC system prime control mode.

The DEEC control system mounted on the demonstration engine is shown in Fig. 7, and the modular construction of the DEEC gas generator fuel valve and BUC is illustrated in Fig. 8.

## System Testing

Prototype DEEC hardware was available for testing in July 1978. Vendor acceptance testing, component bench testing, system closed-loop bench testing, sea-level engine testing, PS2-PT2 correlation testing, and altitude engine testing were performed to clear the system for flight test in the NASA F-15 aircraft. A schematic depicting the flight clearance process is shown in Fig. 9.

### Component Bench Testing

Before any full-scale system tests were performed, each of the new control components was subjected to bench tests to

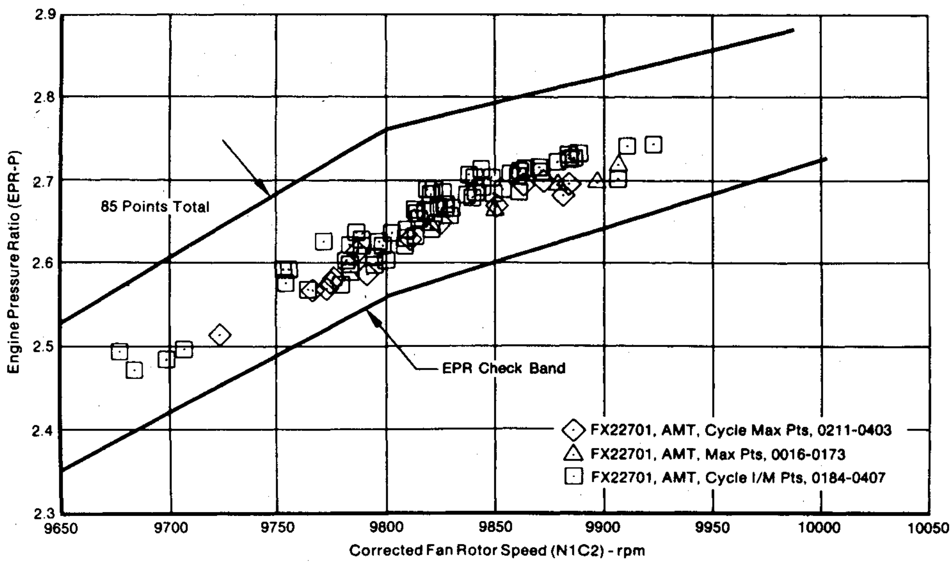


**Fig. 10 EPR was controlled within limits during AMT.**

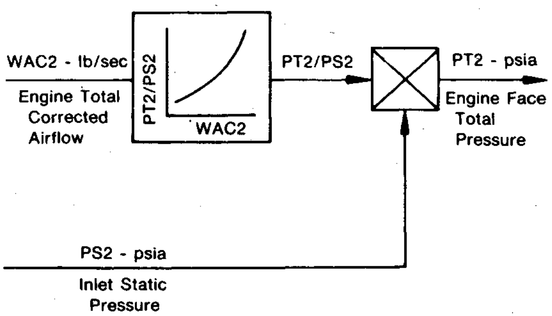


**Fig. 11 PT2 calculation.**

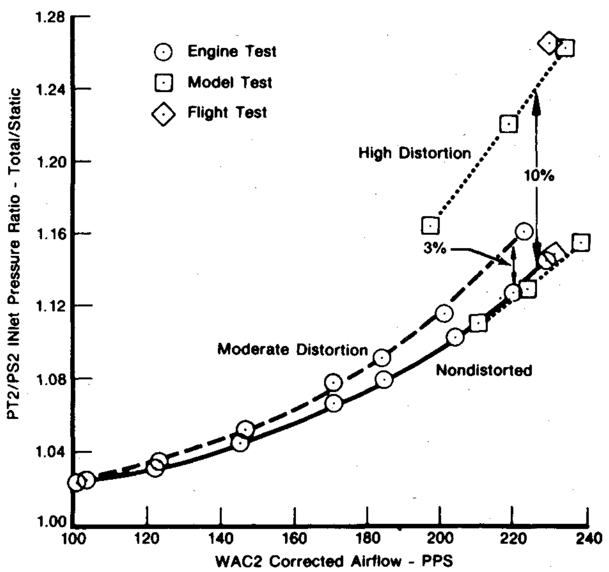


**Fig. 12 PT2-PS2 correlation data.**

verify that they met the criteria specified in purchase specifications. The hydromechanical component tests completed included functional performance, burst tests, and explosion-proof tests. The electronic component tests included cyclic simulated operational tests, environmental (humidity, impact, vibration, acoustical noise) tests, and software verification tests. Software verification was achieved using a multilevel process of visual code verification, software bench test, and hardware bench test to verify that the electronic control met requirements per the purchase specification, the logic documentation, and computer simulations.

### Closed-Loop Bench Testing

The closed-loop bench facility, which allows all the hydromechanical and electronic components to be run simultaneously while operating a computer simulation of an engine, was utilized prior to the first engine tests. The closed-loop bench is useful because problems that can interfere with engine tests can be solved more rapidly and at lower cost than on an engine. In addition, fault detection and failure accommodation tests that would be hazardous to perform on an engine can be performed with no risk.

Approximately 677 h of closed-loop bench testing was performed from November 1978 through March 1979. Two complete control systems were cleared for sea-level engine testing. Simulated sea-level and altitude engine transients were performed with ambient and hot fuel. The effectiveness of the fault detection and failure accommodation logic in the electronic control was verified by intentionally producing faults in the system.

### Analysis

A failure mode and effects analysis (FMEA), which identifies the consequences of failures of subcomponents within the control system, was completed in October 1978 before any engine testing. It was important to perform this effort as early in the program as possible so the results could be incorporated in the hardware, if necessary. The FMEA was periodically updated as hardware or software changes were incorporated.

A subsystem hazard analysis, which identifies the consequences of failures via a fault tree, was completed in August 1979.

Both hardware and software sneak circuit analyses were performed, and this independent audit verified that there were no hardware or software logic paths that produce unwanted control action.

### Sea-Level Engine Testing

Sea-level substantiation tests took place on two Pratt & Whitney Aircraft F100-PW-200 engines, FX225 and FX227, modified to accommodate the DEEC control system. The tests were divided into two categories: first, functional tests to verify the ability of the system to properly control the engine, and second, an accelerated mission test (AMT) to substantiate the durability of the system.

Approximately 200 h of functional testing was performed during 1980 to demonstrate the advantages of a full authority electronic control system. During this time no trims or adjustments were made to the engine trim level or any of the control components. The electronic control schedule engine

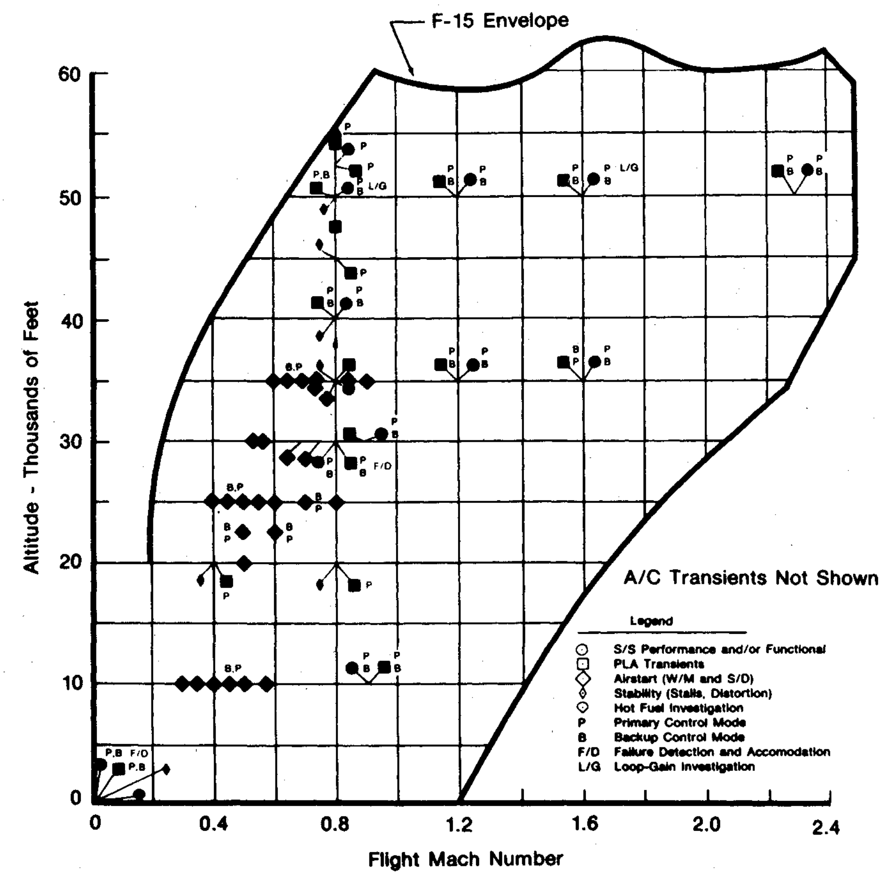


**Fig. 13 Flight clearance points for NASA.**

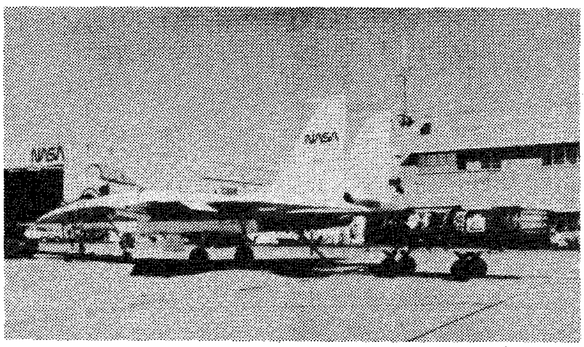

**Fig. 14 DEEC demonstrator engine/F-15 aircraft.**

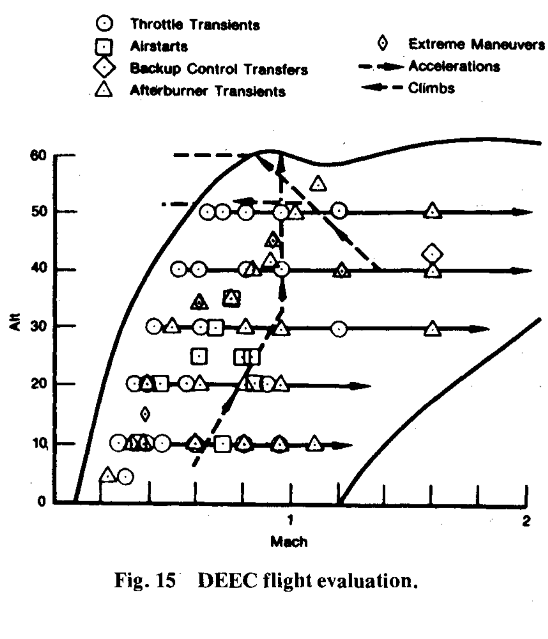


**Fig. 15 DEEC flight evaluation.**

pressure ratio, the engine variable geometry and augmentor fuel-air ratio were within the pretest predicted bands over the entire test period. Gas generator and augmentor transients were successfully performed within the predicted transient times. Engine ground starts, which are accomplished with a closed loop on acceleration rate logic, were performed.

The hydromechanical backup control system operation was verified by performing starts, transients, and transfers to and from the primary control. The transfers were accomplished from idle to maximum afterburning power with no anomalies.

The accelerated mission test (AMT), which required approximately 50 h of engine run time but simulated 163 h of flight time, was performed during July 1979. No trims or adjustments of the system were required and engine parameters remained within check bands. No DEEC control components were changed and no operational or hardware discrepancies which would impact flight test readiness were encountered. The engine pressure ratio check curve, with points taken across the entire AMT, is shown in Fig. 10.

In addition to the AMT, one set of controls hardware was mounted on engine FX225 and subjected to approximately 500 h of run time in conjunction with engine durability testing.

### PS2-PT2 Correlation Testing

As previously described, the DEEC control utilizes an inlet static pressure (PS2) measurement probe forward of the engine face, the output of which is correlated to engine face total pressure (PT2). The calculation of PT2 from PS2 is shown schematically in Fig. 11. Engine corrected airflow (WAC2) is correlated from fan corrected speed (N1C2) and EPR.

One of the most important technical challenges in the initial development of the DEEC control was to verify that a correlation of PT2/PS2 vs WAC2 exists with inlet distortion; any miscalculation of the real PT2 will be in a direction to achieve an engine pressure ratio (EPR) downmatch to achieve

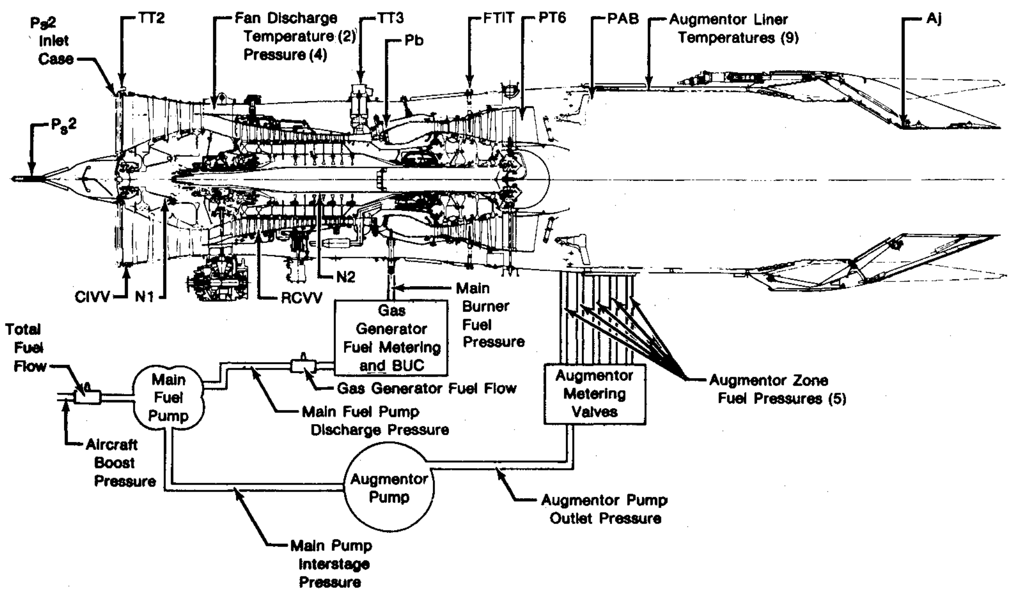


**Fig. 16 Flight test instrumentation on the DEEC engine.**

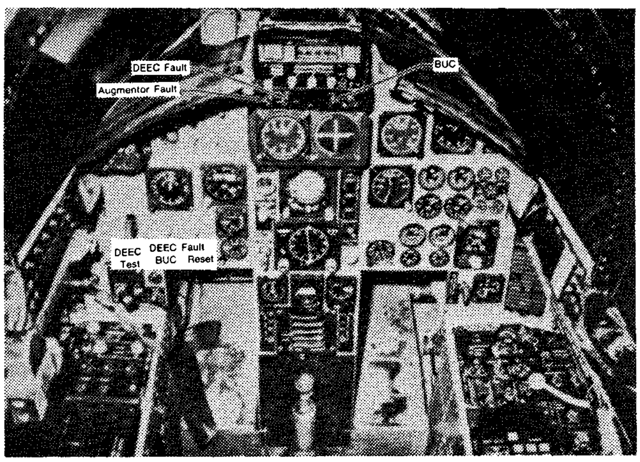


**Fig. 17 F-15 cockpit showing DEEC switches and status lights.**

greater fan stability margin. This will be achieved if the real PT2/PS2 increases when plotted vs WAC2, since the control will use the lower value of PT2/PS2. The resulting calculated PT2 will be lower than real PT2, which results in a lower EPR than the EPR that could result with no distortion.

Extensive sea-level and altitude testing on four F100 engines with classical distortion screens to simulate aircraft inlet pressure distortion was conducted to determine the optimum length and configuration of the PS2 noseboom probe. The results verified that a correlation of PT2 to PS2 existed if the PS2 source was sufficiently forward of the engine face to avoid any engine-induced PS2 profiles. At extremely high levels of distortion, the desired "automatic EPR downmatch with distortion" effect was achieved.

The next step in the verification of the PS2/PT2 correlation was to obtain data behind the aircraft inlet. First, a scale-model test of the F-16 inlet was performed at the Arnold Engineering Development Center at Tullahoma, Tenn. Second, a flight test in the NASA F-15 aircraft at NASA-Dryden Flight Research Center was flown. The results of both tests were as predicted with an excellent correlation of PT2 to PS2 at low distortion and a moderate (~3%) increase in PT2/PS2 vs airflow for distortion levels equivalent to that at maximum aircraft maneuver. Very high levels of distortion, which were equivalent to that obtained with inlet ramp failure or aircraft departure, resulted in up to 5 to 10% increase in PT2/PS2, which would result in a 5 to 10% EPR downmatch from that which would be calculated at low distortion. This automatic downmatch with distortion will reduce the incidence of engine stall. The results are summarized in Fig. 12.

#### Simulated Altitude Engine Testing

Approximately 130 h of testing at the Arnold Engineering Development Center at Tullahoma, Tenn. was conducted from March 1980 to January 1981 on two F100-PW-200 engines. The effort was conducted under a United States Air Force Aeronautical Systems Division F100 EMDP contract in conjunction with testing to evaluate an F100 engine with a DEEC control, an advanced augmentor, a dual augmentor ignition system, and an augmentor light-off detector.

The overall test objective of the altitude testing was to demonstrate the flight suitability of the DEEC with an advanced augmentor and to define initial flight restrictions, if any. Before altitude tests began, sea-level trim checks were performed measuring EPR, variable geometry position, and augmentor fuel-air ratio in the primary mode. N1 rotor speed and variable geometry position were measured in the backup mode. Periodic checks were performed over the test period with the two engines and various sets of control hardware, and all parameters remained within the predicted tolerances. In addition, during the altitude testing, checks were performed to verify that the EPR, variable geometry position and augmentor fuel-air ratio stayed within predicted limits. For example, below 45,000 ft, altitude EPR, as measured by the test facility data system, was maintained with $\pm 1\%$ of that requested by the control. Augmentor fuel-air ratio was maintained within $\pm 5\%$.

The airstart capability of the F100 engine with the DEEC control system was evaluated by performing spooldown and windmill starts at various altitude conditions. Spooldown starts, where the throttle is advanced while the engine is still decelerating and has not reached windmill conditions, were successful down to at least 200 knots airspeed at all altitudes.

The ability to accomplish rapid power excursions to and from idle to maximum power is essential for high-performance military applications. Extensive tests to evaluate the capability to accelerate and decelerate the engine without anomalies were performed at various conditions within the engine operating envelope. Gas generator transients from idle to intermediate power was successful at all conditions tested. Successful augmentor lights and transients were demonstrated at supersonic and subsonic flight conditions, including extreme high altitude, low Mach number conditions.

Since the concept of the DEEC is to have a hydromechanical backup control for operation in the event of a major failure in the electronic control that cannot be accommodated, it is imperative that the backup is capable of safe engine operation over the entire engine operating envelope. Transfers to the backup mode can be made manually or automatically, so they must be successfully accomplished at all engine power settings. Successful steady-state operation, transient operation, and transfers were demonstrated at all conditions tested with no engine anomalies or any engine parameters exceeding safe limits. A flight envelope map with the test points performed for altitude flight clearance is shown in Fig. 13.

### Flight Testing

The DEEC engine was delivered to the NASA-Dryden Flight Research Center and installed in the left side of the F-15 aircraft, Fig. 14. Flight testing continued through December 1981. The flight test verified the system benefits of "no trim" with improved precision in engine parameter control, improved augmentor operation, improved airstarting, improved fault detection and failure accommodation, improved diagnostics, and improved maintainability. The DEEC flight test plan includes gas generator transients, augmentor transients, airstart limits, hydromechanical backup control calibrations/transients/transfers, aircraft accelerations/climbs, and engine power transients during aircraft maneuvers. Figure 15 shows the flight test points flown in the DEEC flight evaluation.

### Data System

The F-15 was equipped with a pulse code modulation data system that recorded approximately 140 parameters, including the 50 digital words from the DEEC. These data were recorded onboard and was also telemetered to the ground for real-time computation and display. Outputs from four high-frequency response pressure sensors were also recorded on wide-band FM tape channels for postflight dynamic analysis. Figure 16 shows the instrumentation on the DEEC engine used in the flight tests. Pressures, temperatures, flow rates, and positions are measured at many locations on the engine and its associated fuel system.

### Cockpit

The lights and switches installed in the F-15 cockpit for the DEEC flight tests are shown in Fig. 17. Three lights advise the pilot of the DEEC status. These include an augmentor fault light to indicate that a fault has occurred requiring augmentation to be inhibited. The DEEC fault light indicates a fault has been detected in the DEEC electronics. The BUC light indicates a transfer to backup control. The switches are a DEEC test switch used on the ground to verify that transfer to backup control is possible. The DEEC/BUC switch is used for flight test points in which it is desired to switch from DEEC to BUC and vice versa. The fault reset switch is used to attempt to clear faults which may have been transient in nature.

### Real-Time Display

During DEEC flight tests, the F-15 and DEEC system is monitored in real time in the Dryden control room. The displays consist of 96 channels of strip chart information, 75 parameters displayed on CRT, lights indicating DEEC status, and a display showing the status of the 160 DEEC faults.

## Summary

The inherent advantages of a full authority digital electronic control system—improved flexibility, accuracy, reliability, cost, maintainability, diagnostics and engine operation—have been conclusively demonstrated during the analysis and testing leading up to the flight clearance of the DEEC control system. In order to meet the requirements dictated by modern high-performance turbofan engines, both military and commercial, future engines will certainly employ the full authority digital electronic control concept. The first flight of DEEC control system was June 4, 1981.

## References

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