NASA Dryden Flight Research Center

"Performance Seeking Control Program Overview"

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Abstract

The Performance Seeking Control (PSC) program evolved from a series of integrated propulsion–flight control research programs flown at NASA Dryden Flight Research Center (DFRC) on an F–15. The first of these was the Digital Electronic Engine Control (DEEC) program and provided digital engine controls suitable for integration. The DEEC and digital electronic flight control system of the NASA F–15 were ideally suited for integrated controls research. The Advanced Engine Control System (ADECS) program proved that integrated engine and aircraft control could improve overall system performance.

The objective of the Performance Seeking Control (PSC) Program was to advance the technology for a fully integrated propulsion flight control system. Whereas ADECS provided single variable control for an average engine, PSC controlled multiple propulsion system variables while adapting to the measured engine performance. PSC was developed as a model–based, adaptive control algorithm and included four optimization modes: minimum fuel flow at constant thrust, minimum turbine temperature at constant thrust, maximum thrust, and minimum thrust. Subsonic and supersonic flight testing were conducted at NASA Dryden covering the four PSC optimization modes and over the full throttle range.

Flight testing of the PSC algorithm, conducted in a series of five flight test phases, has been concluded at NASA Dryden covering all four of the PSC optimization modes. Over a three year period and five flight test phases, 72 research flights were conducted. The primary objective of flight testing was to exercise each PSC optimization mode and quantify the resulting performance improvements.

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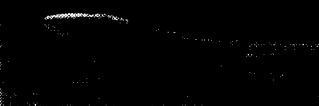
The Performance Seeking Control (PSC) program has evolved from a series of integrated propulsion–flight control research programs flown at NASA Dryden Flight Research Center (DFRC) on an F–15. The first of these was the Digital Electronic Engine Control (DEEC) program which provided digital engine controls suitable for flight control integration. Later, a digital electronic flight control system (DEFCS) was installed and tested. The DEEC and DEFCS enabled propulsion researchers to explore performance gains of an integrated controls approach. For the Advanced Engine Control System (ADECS) program, the DEEC was modified to permit airframe to engine communication and the control software was hosted in the DEFCS computer. Optimum engine pressure ratio (EPR) trims, determined from simulation and scheduled in the DEFCS, were used to demonstrate 5– to 10– percent increases in thrust during ADECS. The ADECS experience proved just how valuable an integrated system testbed was for providing significant performance improvements, but questions remained about applying its scheduled optimum trims to unmatched engines. The next logical step was an adaptive real–time optimization capable of trimming multiple propulsion system elements. Thus, the Performance Seeking Control program concept was proposed, developed, and first flight tested in 1990.

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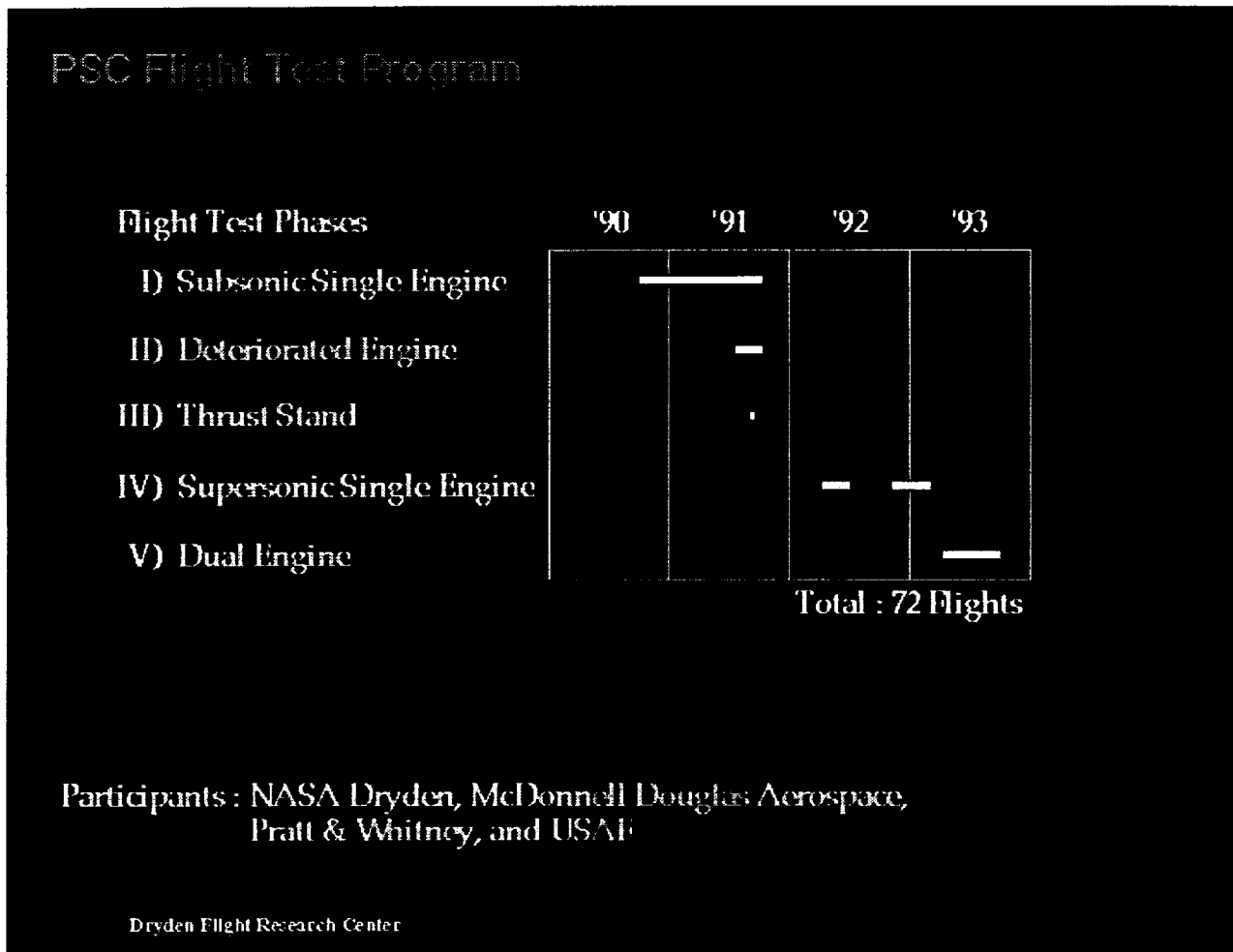
PSC Flight Test Program

The Performance Seeking Control (PSC) program was developed by NASA with McDonnell Douglas Aerospace as the prime PSC contractor and with Pratt and Whitney as subcontractor. The NASA F–15 highly integrated digital electronic control (HIDEC) aircraft and engines were loaned by the U.S. Air Force. The flight test team at NASA Dryden, which is an integrated group composed of Dryden engineering and technical support and on–site engineering support from both McDonnell Douglas Aerospace and Pratt and Whitney, continues to be an effective government and industry team.

The F–15 PSC schedule shows five test phases starting in 1990. Phase I was the implementation and verification of the first flown PSC algorithm. Subsonic testing designed to demonstrate single engine performance benefits was conducted after initial checkout. The ability of the PSC algorithm to adapt to different levels of engine deterioration was tested with an intentionally deteriorated engine during Phase II. Phase III, a two week installed static thrust stand test, was performed in the fall of 1991. Phase IV expanded the single engine envelope of PSC testing out to Mach 2.0 and 45,000 feet. The final flight test phase was a of full envelope demonstration of the dual engine PSC which concluded in October of 1993.

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PSC Objectives

PSC Objectives

Overall: to optimize the steady state performance of the aircraft/propulsion system in real-time

- Adapt to specific aircraft/propulsion systems

- Integrates airframe and propulsion system performance

- Primary modes of operation:

  - Minimize Fuel Consumption in Cruise at Constant Thrust

  - Maximize Thrust During Accelerations

  - Extend Engine Life by Reducing FTIT at Constant Thrust

  - Minimize Thrust and Maximize Drag During Decelerations

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Digital inlet and engine controls and optimal control algorithms enable significant performance improvements of the integrated aircraft-propulsion system. Developing and applying integrated controls technology will contribute to both commercial and military applications by maximizing excess thrust and fuel efficiency and extending engine life. However, conventional scheduled control systems may not recover the full performance potential of the propulsion system because of variations in engine deterioration, engine-to-engine component variations, and non-standard day conditions. The PSC system recovers latent performance from the propulsion system with onboard adaptive engine models.

NASA Dryden, McDonnell Aircraft Company, and Pratt & Whitney have developed and flight tested an adaptive performance seeking control (PSC) system with the objective of demonstrating an onboard adaptive performance optimization. The objective was to optimize the steady state performance of the F-15 propulsion system. The PSC system was developed with the following optimization modes: minimum fuel at constant thrust, maximum thrust, minimum fan turbine temperature at constant thrust, and minimum thrust.

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"F-15 Propulsion System"

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