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Information Summary

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Aerospace Careers: Propulsion Engineer

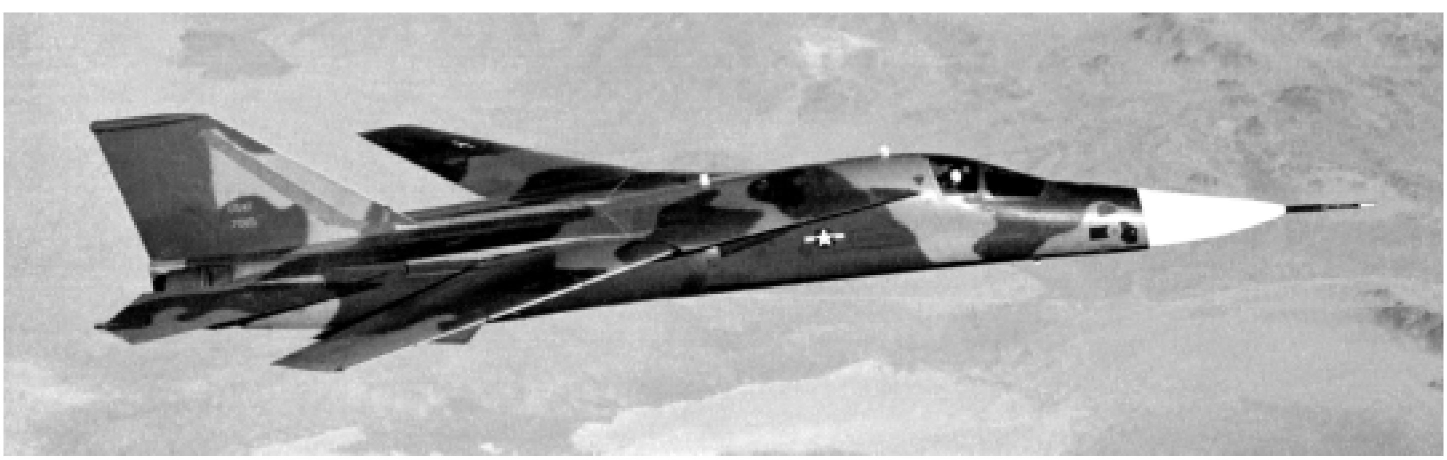
Since the beginning of aviation in the early 1900s, the speed and flight endurance of powered aircraft have been determined by the power and efficiency of their propulsion systems — piston engines at first, and now powerful jet engines.

At NASA's Dryden Flight Research Center, engineers in the Propulsion Branch continually look for ways to improve today's aircraft engines and propulsion control systems so that America's civilian and military aircraft can operate more efficiently and with greater safety and reliability.

The Propulsion Branch is part of the Center's Research Engineering Directorate.

What is Propulsion?

Jet engines are the most widely used form of propulsion on commercial and military aircraft. They generate power when a mixture of compressed air and fuel is ignited and the resulting hot gases escape through an exhaust nozzle. The reaction of the hot expanding gases exiting the exhaust nozzle produces thrust in the opposite direction and moves the aircraft forward.



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Most jet engines today fall into three categories — turbojet, turbofan and turboprop.

Turbojets incorporate a turbine-driven compressor to pull air into the engine and compress it before fuel is injected into the combustion chamber and ignited. The turbine is located in the exhaust section of the engine and is rotated by the hot gases of combustion as they pass across the turbine blades and stream out the exhaust nozzle producing thrust.

Turbofan engines are turbojets in which additional power is generated by compressor blades that extend beyond the exterior of the main engine casing. The extended blades move "bypass air" through a space between the main engine casing and an outer casing. This ducted air is not combusted, but it does produce additional thrust from the propulsive effect produced by the compressor blades. Turbofan engines are also called bypass engines, ducted fans and turbine-driven fan engines.

Turboprop engines are turbojets that have propellers. The propellers are located at the forward end of the same turbine shaft that turns the compressor, giving the powerplant propeller thrust and jet thrust. Turboprop engines are also called propjets and propeller turbine engines.

Aircraft flown by NASA have also been powered by liquid-fueled rocket engines. This form of propulsion has been limited to research vehicles such as the famed X-1, the first aircraft to exceed the speed of sound, and the X-15, which established altitude and speed records that still stand for winged aircraft. Liquid-fueled rocket engines burn a mixture of fuel and an oxidizer and the hot gases of combustion produce thrust similar to a jet engine. While jets burn oxygen existing in the atmosphere, liquid-fueled rocket engines use an oxidizer carried on board the vehicle. This self-contained oxidizer and fuel supply allows rockets to operate at extremely high altitudes and also in space. The three main engines on the space shuttle vehicles are current examples of liquid-fueled rocket engines that operate in space.

Solid fuel is also used on some rocket engines, such as the boosters used on the space shuttle vehicles. Solid fuel rockets generate an enormous amount of power but they cannot be controlled with a throttle. Once ignition occurs they continue to burn until the fuel is exhausted, therefore they are not suitable for the main propulsion systems on aircraft or research vehicles. Small solid-fuel rockets have been used on some aircraft, however, to produce supplemental power and speed during takeoff.

There are several ways propulsion systems are controlled, from a simple throttle mechanism that regulates speed to sophisticated electronic and mechanical systems that manipulate the intake of air, exhaust nozzle positioning, and fuel consumption.

In the early years of turbojet usage, engines were simply bolted into the airframes and the only controls were throttles. Inside the engines, compressor and turbine blades were designed to operate most effectively at a particular speed, altitude and angle of attack. If the engine operated outside of this flight envelope it could experience what is called compressor stall — when compressor blades meet the airflow at such an angle that it causes a reversal of air flow, often leading to an engine flameout.

As turbojet knowledge and experience increased, mechanisms were designed by propulsion researchers and engineers to improve the reliability and operational performance of jet engines.

One of the early improvements to enhance turbojet performance was controlling the shape of the air intake, the duct through which air passes to reach the engine. Many engines now have moveable surfaces called ramps inside and at the front of the intakes. The ramps can be positioned to control the flow and speed of air entering the engine. As the engine operates in conditions requiring less air the ramps can be positioned to reduce the flow. As air requirements increase the ramps are moved to permit an increased flow of air. The ramps significantly reduce the likelihood of a compressor stall by controlling the directional flow of air as it enters the engine.

The exhaust nozzles of many modern turbojets have also been tailored to boost performance. As certain flight and engine performance conditions are reached, the throat of the nozzles will close, much like the pupils of an eye, to increase the thrust. When the added power is no longer needed, the moveable nozzle vanes, called “tail feathers,” expand to create a wider opening and reduce thrust output.

The Work of Propulsion Engineers

Dryden propulsion engineers have carried out far-reaching research in recent years to develop improved engine control systems.

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The IPCS project was the forerunner of digital electronic engine control units, tested on a Dryden F-15A research aircraft and successful in demonstrating the concept of integrating engine controls with the aircraft flight control system. The digital electronic engine controls are now widely used on commercial and military aircraft engines.

Dryden engineers continued to look at ways to improve engine performance even more with projects like the Advanced Digital Engine Control System and Performance Seeking Control. The goal of the research was to create engine performance tailored to all types of flight conditions. The results have been significant: increased engine thrust of almost 11 percent, up to 15 percent reduction in fuel usage, increased climb rates of up to 25 percent, and extended life-cycle of engines by as much as 12 percent.

In the cockpit, pilots flying aircraft that incorporate the results of NASA engine research will see greater thrust and faster throttle response, will use less fuel at a wider range of speeds and altitudes and will eliminate compression stalls.

Much of the propulsion research at Dryden, now and in recent years, has focused on thrust vectoring as a way of improving the performance and maneuverability of high-performance aircraft.

Thrust vectoring occurs when the direction of the exhaust stream of a jet engine is moved up or down or from side to side. The directional change in the exhaust causes a change in the heading of the aircraft, much like water forcefully coming out of a garden hose nozzle.

Research at Dryden with the X-31 aircraft has shown that fighter-type aircraft augmented with thrust vector-

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ing have greater "dogfight" maneuverability than similar aircraft with conventional flight controls.

The X-31 was equipped with three paddle-like vanes that altered the flow of the exhaust stream to achieve thrust vectoring. The F-15 Advanced Control Technology for Integrated Vehicles (ACTIVE) research aircraft was also used to study gimballed exhaust nozzles that can be rotated a full 360 degrees, just like twin garden hoses.

The pioneering work that Dryden propulsion engineers have carried out in the past will show up in the future on military aircraft like the Air Force F-22 Advanced Tactical Fighter and in the Joint Strike Fighter. The thrust vectoring control system on each type of aircraft will be linked to the flight control system and will supplement conventional flight control surfaces, but they will be the primary features giving the aircraft extreme maneuverability.

One of the far-reaching engine performance projects undertaken at Dryden has been to control an aircraft using only engine thrust. The idea came from a senior Dryden propulsion engineer after a series of unrelated commercial airline accidents involving multi-engine aircraft in which part or all of their hydraulic flight control systems had failed and rudders, elevators and ailerons were no longer effective.

The Propulsion Controlled Aircraft (PCA) system gives pilots of multi-engine aircraft the ability to climb, descend and turn using only the engines to provide directional control. PCA computer software links engine throttles with the flight control system. Using asymmetric thrust with just two engines, the aircraft can be yawed left or right to turn, and by decreasing or increasing engine thrust the aircraft can climb, descend and land safely.

The PCA concept was first flight tested on a Dryden F-15A, followed by successful demonstrations on an MD-11. PCA software can be installed on aircraft with digital flight systems.

Education and Experience

Men and women seeking careers as NASA propulsion engineers must have a bachelor of science degree in one of the main engineering disciplines, aeronautical, mechanical or electrical.

A strong background in computer science and computer operations is also desired because much of the work in the propulsion field now, such as developing control laws for engine operations and analyzing flight research data, is accomplished on computers.

Propulsion engineers must also have good communications skills because they are involved in many phases of flight research programs, from planning and implementation of events involving propulsion to postflight critiques and written reports.

All major aerospace companies have flight test branches where there are positions similar to a NASA propulsion engineer. Within the federal government, propulsion engineering positions can be found in the Federal Aviation Administration and also in the flight test branches of the U.S. armed forces.

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