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Information Summary

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Aerospace Careers:
Controls and Dynamics Engineers

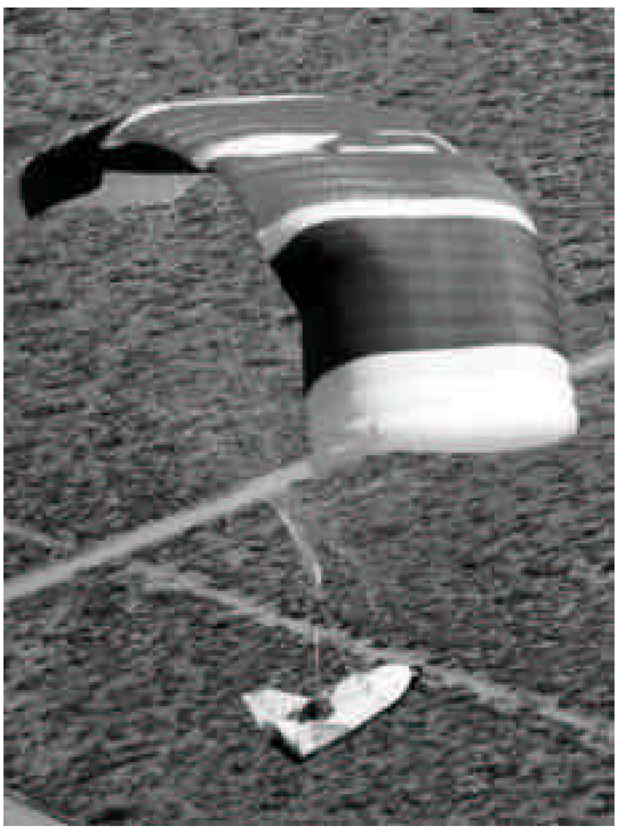
Engineers in the Controls and Dynamics Branch at NASA's Dryden Flight Research Center are concerned with the integrated operations of aerospace vehicles. They design, develop, integrate and test flight control systems for piloted, remotely piloted and autonomously operated research and experimental aircraft and space vehicles.

Flight control systems on many modern aircraft are computerized units that have replaced mechanical linkage — bell cranks, push rods and wire cables — between the cockpit and flight control surfaces such as ailerons on the wings, and rudder and elevator on the tail surfaces. The control system provides the basic stabilization in all three axes — pitch, yaw, and roll, and provides the actuator commands for aircraft maneuvering.

NASA Dryden controls and dynamics engineers were integral to the development of the X-29.

Modern flight controls systems increasingly incorporate additional processing capabilities to perform navigation, guidance, fault identification and control system reconfiguration. Piloted or remotely piloted vehicles can use these capabilities and the controls engineers are required to understand the issues and implications of their use.

The branch is also involved in the development and validation of new methodologies for controlling aircraft; testing and evaluating flying and handling qualities and vehicle stability in a wide range of flight conditions; developing new test and evaluation techniques; and developing and validating simulation models. When designing or modifying aircraft control systems, the controls engineer can also be responsible for identifying required sensor characteristics, processing requirements, and developing actuator specifications.



Engineers working on flight control systems and in the field of flight dynamics have been associated with nearly every aeronautical research project flown at Dryden in the past half century, including the X-38 shown here.

Due to the Controls and Dynamics Branch involvement in the flight testing and flight research of experimental vehicles, flight safety is one of the overall concerns during any activity.

What are Flight Controls?

A modern flight control system incorporates the three disciplines of guidance, navigation and control with the vehicle systems and subsystems to meet the design requirements effectively. The flight controls engineer must understand interaction between sensors, control laws and actuators. The development of simulation models for these systems is often required. The engineers develop the ability to write specifications for hardware to meet overall control and guidance algorithms.

Development and flight test of control systems for modern research vehicles require a sound understanding of classical and modern control methodologies and the ability to apply them prudently. Understanding of linear, nonlinear, and hardware-in-the-loop simulations is required. The flight control engineer has the ability to understand bare airframe dynamics and designs the inner loop stabilization. This includes both stability and robustness analyses through classical stability margins or a variety of more modern methods.

Guidance and navigation have been increasingly integrated with the electronic flight control system. For piloted vehicles, this has usually been done through autopilot modes to reduce pilot workload or to enhance a vehicle’s capabilities. This has become more important in remotely piloted vehicles and is essential for autonomous aircraft. These autonomous vehicles must be programmed to operate in the absence of human intervention with the guidance and control system responsible for all operations from taxi through takeoff and flight.

Flight control engineers can be required to support research vehicle development from inception to the final flight. These duties include simulation development, software specification, hardware specification, flight test development, ground testing and flight test support. These are opportunities to develop new control concepts for unique vehicles, and to develop new analysis and validation methods.

What is Flight Dynamics?

The discipline of flight dynamics tends to deal with the behavior of flight systems — how they perform, how they can be modeled, and how they can be improved to enhance an aircraft's handling and flying qualities. One of the duties required for this aspect of engineering is to develop simulation requirements, models and databases. When the simulation is developed, flight studies are conducted to validate and improve the fidelity.

Simulations are then used to conduct flying qualities, ride qualities, and handling qualities studies. These are used as the basis to develop flight test requirements to conduct a subset of these studies. Flight data are used in conjunction with pilot comments and ratings, when available, to assess the flying qualities and flight characteristics. The combined data are used to compare new aerospace vehicles with existing criteria and to develop new criteria. Many of the flight regimes currently being explored, such as high angle of attack or the hypersonic flight regime, do not have validated criteria.

The Work of Control and Dynamics Engineers

Developing and evaluating a flight control system begins when a Controls and Dynamics Branch customer defines a requirement for a system. The customer can represent an aerospace project at Dryden, another NASA center, or a commercial contractor developing a vehicle.

Flight control system design and development work are tailored to the specific vehicle requirements. The performance required has to be traded against the schedule and funding available to develop the overall system that best meets the customer requirements.

Each project is unique in its requirements and passes through multiple phases before flight testing is finally complete. Initial design phase begins with an assessment of the requirements for a specific vehicle. System specifications begin to be developed along with linear and nonlinear simulation development. As the mature and more complete data are incorporated, such as from wind tunnel tests, the fidelity and confidence in the simulations improve. These simulations will be used throughout the life of the project and will be continuously improved.

As the designs mature, the simulation testing and analysis become more complex and thorough. The engineers begin developing the test plans and hardware specifications that are required for systems integration, verification and validation testing. Even at this early stage of the project, hazard analysis and system safety are critical issues to be addressed. Flight controls engineers work closely with other discipline engineers and pilots to ensure that design requirements are met in an appropriate manner.

Simulation development and complexity continue to grow as flight hardware is integrated into the system. Ultimately this activity will be transferred to the actual flight vehicle. Throughout this process, the branch engineers are actively involved, understanding and assessing control system operation in real-world environments.

At Dryden, this activity culminates in the actual flight testing. Branch engineers continue to be actively involved, supporting the flight readiness review process and preparing for the flight testing that will ultimately validate the control system design. Control engineers are involved in all aspects of the flight: designing maneuvers or techniques to assess performance, monitoring the flight from the control rooms, and conducting post-flight data analysis. As required, this whole process repeats as flight data indicate the need for redesign and testing of the system.

The People and the Projects

Engineers working on flight control systems and in the field of flight dynamics have been associated with nearly every aeronautical research project flown at Dryden in the past half century.

Flight control and dynamics engineers played a big role in NASA's rocket-powered X-15 research aircraft project. Flown from 1959 to 1968, the X-15 is considered among the most productive and successful of all NASA research aircraft. It extended piloted aircraft research to a speed of 4,520 mph and it reached an altitude of over 354,000 feet — records still standing for a winged aircraft. Flying at these speeds and altitudes required an extremely precise and dependable flight control system. One of the X-15's important contributions to the space program was information gained from the use of rocket-thrusters (reaction controls) for attitude control while on the fringes of space. The reaction control system thrusters were located in the nose and on the wings for pitch, yaw and roll control and were a part of the aircraft's central flight control system.

Rugged and dependable flight control systems were also critical to the success of Dryden's lifting body program, flown between 1966 and 1975. The five wingless vehicle designs obtained information about controllable atmospheric reentry. Program results solidified the concept of the space shuttles gliding back into the atmosphere from space and landing, without engines, at a predesignated airfield. The lifting body fleet began with the unpowered plywood M2-F1, followed by the five rocket-powered designs: the M2-F2, M2-F3, HL-10, X-24A and the X-24B.

One far-reaching project at Dryden was the F-8 Digital Fly-By-Wire aircraft. It pioneered the concept of the electronic flight control system now used on the majority of military and commercial aircraft. The testbed was a former United States Navy F-8 Crusader, which used a surplus Apollo spacecraft flight control computer. The project, which demonstrated the feasibility of digital-fly-by-wire control systems, is considered one of the most significant research projects carried out at Dryden.

Several more recent projects have also led to improved performance and maneuverability. These include the X-29, the F-18 High Alpha Research Vehicle (HARV), and the X-31 Enhanced Fighter Maneuverability (EFM) aircraft.

As the designs mature, the simulation testing and analysis become more complex and thorough. This is a photo of the X-31 flight simulator.

The X-29 demonstrated that forward-swept wings, coupled with moveable canards, reduced drag by up to 20 percent at transonic speeds. The statically unstable aircraft required an active control system to maintain control and demonstrated better-than-expected maneuverability at angles of attack of up to 45 degrees.

NASA's participation in the X-31 program helped show the value of thrust vectoring for close-in air combat maneuvering at angles of attack up to 70 degrees. The digital flight control system was also used to drive the rudder in a manner to simulate a tailless aircraft with the thrust vectoring paddles providing the stabilization and yaw control for maneuvering. The five-year program, which ended in July 1995, logged 559 research missions, the most flights ever for an "X" series experimental aircraft.

NASA's High Angle-of-Attack Research Vehicle (HARV), a modified F/A-18, also used thrust-vectoring paddles. This program included research in computational fluid dynamics, in-flight flow visualization, modern control methodologies, evaluation of high angle of attack handling qualities criteria, and advanced control effectors such as active forebody strakes.

The F-15 Advanced Control Technology for Integrated Vehicles (ACTIVE), using axisymmetric thrust vectoring nozzles, has continued the evaluations of modern control methodologies. In the Intelligent Flight Control System (IFCS) project, a neural net used to identify the aerodynamic coefficients was an integral part of the flight control system.

Controls and dynamics engineers have also participated in the Propulsion Controlled Aircraft (PCA) experiments, where modulation of engine thrust on multi-engine aircraft has been used to provide control forces in moments in place of aerodynamic surfaces. This has been successfully demonstrated on F-15 and MD-11 aircraft and could be used as an emergency control system in the event of hydraulic system failure.

Controls and dynamics engineers are involved in projects covering the spectrum of atmospheric flight, from the subsonic regime of current commercial transport, to the supersonic and hypersonic flight regimes of the high performance and Access to Space programs. While maintaining an emphasis on flight safety, the Controls and Dynamics Branch is expanding its expertise in flight control system design, analysis, development and test.

Education and Experience

Flight control and dynamics engineers at Dryden have a bachelor of science degree in physics, aeronautical, mechanical or electrical engineering.

Individuals interested in working in this NASA career field should have a broad working knowledge of aircraft dynamics, stability and controls. Control and dynamics engineers must also have the ability to communicate skillfully. Oral and written communications are essential for fulfilling NASA's mission to disseminate information. Branch engineers are expected to have the ability to communicate with other discipline engineers and all levels of management, not only at the Dryden but also at other NASA centers, government agencies and commercial firms