Advances in Thrust-Based Emergency Control of an Airplane
It should be possible to land safely after a primary-flight-control failure.

Dryden Flight Research Center, Edwards, California

Engineers at NASA's Dryden Flight Research Center have received a patent on an emergency flight-control method implemented by a propulsion-controlled aircraft (PCA) system. Utilizing the pre-existing auto-throttle and engine-pressure-ratio trim controls of the airplane, the PCA system provides pitch and roll control for landing an airplane safely without using aerodynamic control surfaces that have ceased to function because of a primary-flight-control-system failure. The installation of the PCA does not entail any changes in pre-existing engine hardware or software. [Aspects of the method and system at previous stages of development were reported in "Thrust-Control System for Emergency Control of an Airplane" (DRC-96-07), *NASA Tech Briefs*, Vol. 25, No. 3 (March 2001), page 68 and "Emergency Land-
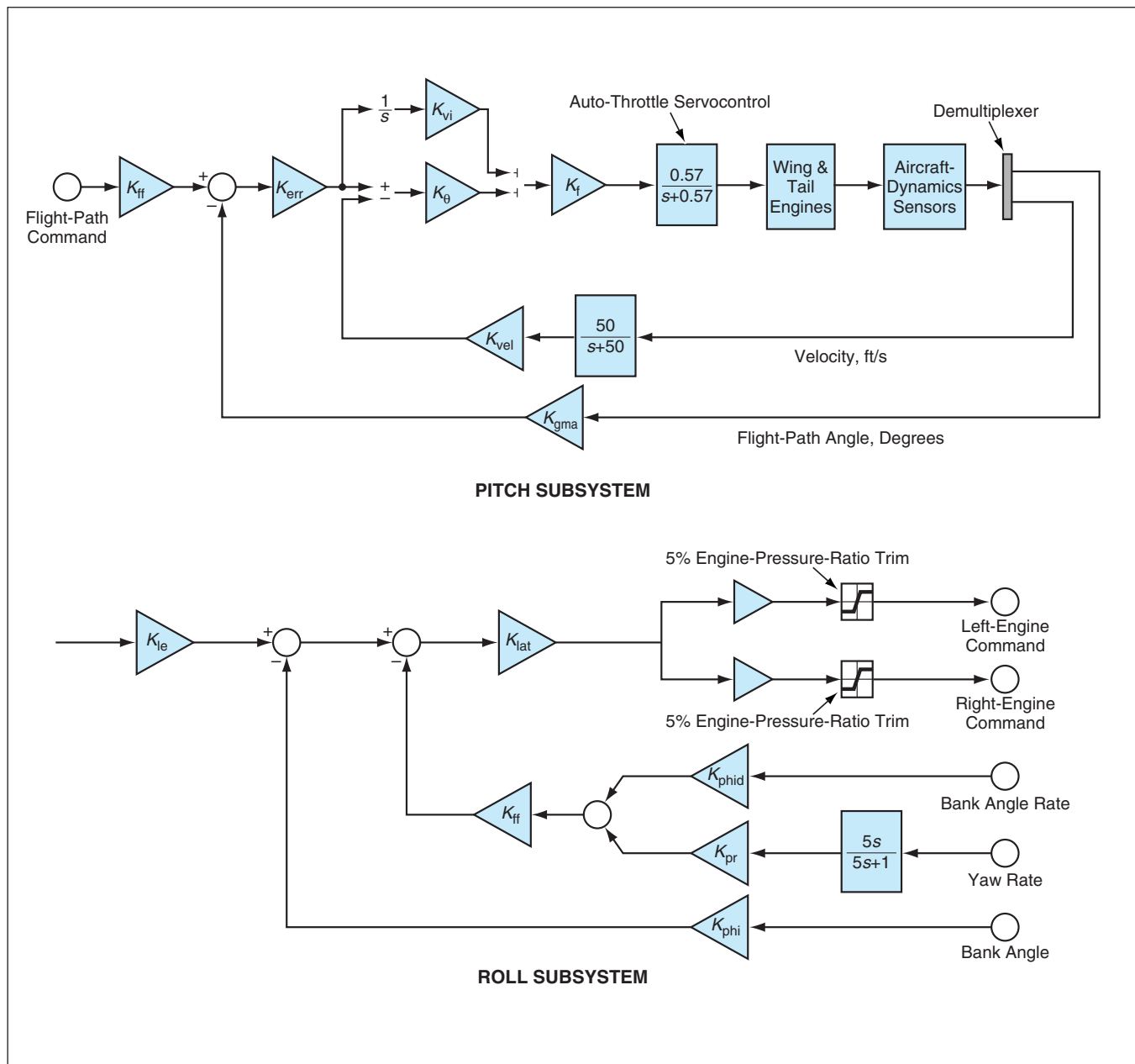

Figure 1. These **Emergency Propulsion Control Subsystems** are combined to obtain the PCA. The pitch subsystem utilizes the auto-throttle to control the pitch or the flight-path angle. The roll subsystem utilizes a five-percent engine trim feature.

ing Using Thrust Control and Shift of Weight" (DRC-96-55), *NASA Tech Briefs*, Vol. 26, No. 5 (May 2002), page 58.]

Aircraft flight-control systems are designed with extensive redundancy to ensure low probabilities of failure. During recent years, however, several airplanes have exhibited major flight-control-system failures, leaving engine thrust as the last mode of flight control. In some of these emergency situations, engine thrusts were successfully modulated by the pilots to maintain flight paths or pitch angles, but in other situations, lateral control was also needed. In the majority of such control-system failures, crashes resulted and over 1,200 people died.

The challenge lay in creating a means of sufficient degree of thrust-modulation control to safely fly and land a stricken airplane. A thrust-modulation control system designed for this purpose was flight-tested in a PCA — an MD-11 airplane. The results of the flight test showed that without any operational control surfaces, a pilot can land a crippled airplane (U.S. Patent 5,330,131). The installation of the origi-

nal PCA system entailed modifications not only of the flight-control computer (FCC) of the airplane but also of each engine-control computer. Inasmuch as engine-manufacturer warranties do not apply to modified engines, the challenge became one of creating a PCA system that does not entail modifications of the engine computers.

The present PCA system, discussed in U.S. Patents 6,102,330 and 6,041,273, provides longitudinal and lateral (pitch and roll) control, effected solely by modifications of the software of pre-existing flight-control computers, and without any changes in the engine controller or any hardware changes in the cockpit. In the event of a failure in the primary-flight-control system, the engines can be used to dampen unwanted motion, enabling a safe landing. This method eliminates the longitudinal- and roll-control tasks. The combination of the teachings of the two patents enables a pilot to align airplane with a runway and land in a normal fashion.

The upper part of Figure 1 shows a pitch- (or flight-path-angle) command subsystem that utilizes feedback from a

velocity sensor and a flight-path angle (g) sensor. The pilot controls an auto-throttle propulsion subsystem by use of a thumbwheel. The signals from this pitch- (or flight-path-angle) command subsystem drive an auto-throttle servo-control forward or backward, thereby causing the engines to increase or decrease thrust, and thereby further controlling the pitch of the airplane. This control action keeps the phugoid mode well damped. Auto-throttle systems are already installed in many multi-engine aircraft, eliminating the need for hardware changes to take advantage of this control action.

The lower part of Figure 1 shows a roll/lateral-axis command subsystem that enables the pilot to turn or roll the airplane down to the runway. The signal that drives the roll-control subsystem comes from a heading knob in the cockpit. By combining the subsystems of Figure 1, one obtains a total PCA system that can be installed and operated without need to modify engine hardware or software. The benefits of utilizing this PCA system include smaller (in comparison to a system that involves engine modifications) development costs and continued viability of the original engine warranties.

The combination of the pitch and roll subsystems of Figure 1 enables a pilot to control a crippled airplane in a manner comparable to that of landing a healthy airplane. Figure 2 shows some expected responses of a wide body airplane flown with engines-only control by use of the PCA system. The auto-throttle emergency PCA system controls the airplane with good damping of pitching motion. The flight-path angle pitches up 1° and tracks the command very well. The thrust is increased and decreased automatically to control the pitching motion. At the same time, the roll angle is commanded to 10° to the right: The roll angle is made to go to 10° in a time of ≈20 s by use of lateral engine pressure-ratio trim control, with an increase in power of the left engine and a decrease in power of the right engine.

This work was done by Gray Creech, John J. Burken, and Bill Burcham of **Dryden Flight Research Center**. *Further information is contained in a TSP (see page 1).*

This invention has been patented by NASA (U.S. Patent No. 6,102,330). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed the Patent Counsel, Dryden Flight Research Center; (805) 258-3720. Refer to DRC-97-21.
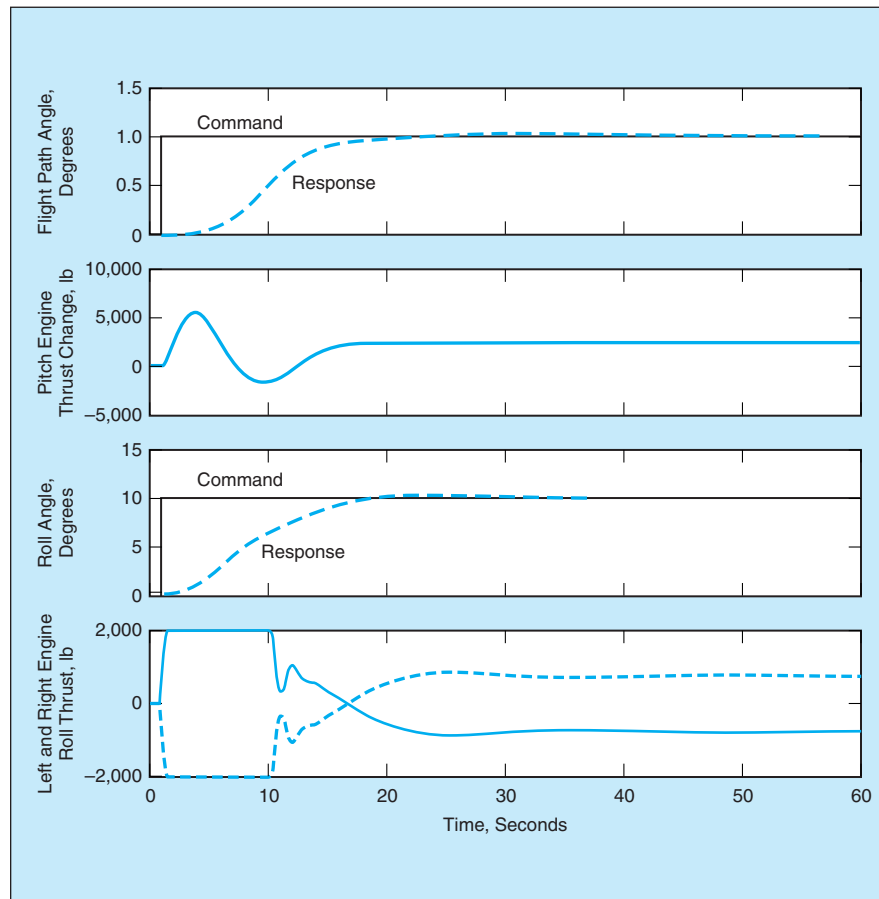

Figure 2. These **Dynamic Responses** to a flight-path angle command of 1° and a simultaneous roll command of 10° were computed for an MD-11 airplane, the weight of each wing-mounted engine of which was considered to be increased by 5,000 lb (≈2.3 tonnes).