N85-33527

MAN-VEHICLE SYSTEMS RESEARCH FACILITY ADVANCED AIRCRAFT FLIGHT SIMULATOR THROTTLE MECHANISM

Seth S. Kurasaki* and Wilbur C. Vallotton**

ABSTRACT

This paper describes the conceptual and detail design as well as some preliminary results of an automatic throttle control system for use in an Advanced Aircraft Flight Simulator at the Ames Research Center. The mechanism simulates an aircraft engine throttle system for a future two-engine jet-transport aircraft.

INTRODUCTION

The Man-Vehicle Systems Research Facility Advanced Aircraft Flight Simulator is an important new facility at the Ames Research Center. This new aircraft simulator features a number of innovative aircraft controls and displays to study advanced cockpit concepts and to investigate pilot-vehicle interactions for the next-generation commercial-transport jet aircraft. The results of human factors research performed on these systems may result in improved safety for future commercial aviation.

Included in these control systems is a dual-throttle, jet-engine control system that can be operated by the Pilot, First Officer, or the aircraft's computer-operated performance-management system. The throttle-control system is located in the Advanced Concepts "Flight Desk" forward of and between the crew seats. The Pilot operates the throttle controls with his right hand and the First Officer operates them with his left hand. The movement of the throttles is conventional with full forward being the maximum thrust condition and full aft being the thrust-reverse condition. A "gate" is used to prevent the accidental movement of the thrust levers into the thrust-reverse condition from the idle position. The simulated aircraft is powered by two advanced, high by pass turbofan engines which contain full-authority electronic engine control both for manual operation and for interface with the aircraft computer-driven performance-management system.

DESIGN REQUIREMENTS

Since existing aircraft simulator throttle systems either could not perform to meet the needed requirements, or be configured for all of the operations necessary for the Advanced Aircraft Flight Simulator, a new throttle control system specific to the simulator was created.

The effort directed to the design of the mechanism was to provide separate engine controls for both pilots within the constraints of the advanced aircraft shell enclosure and crew seating, provide features identified as being critical to aircraft operation, and complete the effort within the project's schedule and cost constraints.

*Research Engineer, NASA Ames Research Center
**Mechanical Engineering Technician, NASA Ames Research Center

In the Advanced Aircraft Simulator, each flightcrew member is 21 inches off the aircraft centerline to provide the correct position for the computer-generated "out-the-window" imagery. The placement of the crew, because of the visual systems and the ergonomic requirements for a 95-percentile pilot, necessitated the installation of dual throttle-control handles so that the pilots could jointly or individually manage the engine-control systems.

The proper arc travels, placements, and heights of the throttle control handles were determined before any design work commenced. The system was configured to conform to the "Flight Desk" Cockpit concept of the Advanced Aircraft.

DESIGN

Various design approaches for the throttle system were considered. Of these, the most promising was a mechanism that combined a mechanical linkage design and separate motor drive systems design. In this manner, separate and simultaneous designs could be worked on without the necessity for constant interfacing to assure that parts would match. The interfacing requirement would be a chain drive where the drive system coupled to the mechanical torque tube. This original design did not work as expected and was replaced later with a mechanical linkage. The new design shown in figure 1 is the system now installed in the simulator.

Figure 1 shows the concept of the throttle system and the relative placement of the components. The system is primarily composed of two sets of four-bar linkages. These four-bar linkages are coupled in sets of two by torque tubes so that operation of one linkage causes the other appropriate linkage to move. In this manner, the throttle system has left and right engine controls that either pilot can operate. All torque tubes are supported on needle bearings, and the pushrods have aircraft spherical rod-ends with both left-and right-hand thread. Alignment of torque tubes and bellcranks with each other during assembly is not critical, and the use of the rod-ends eliminates the requirements for precision tolerances. The thrust levers can be adjusted to reduce free-play and/or increase "binding" in the mechanical system as necessary by twisting the pushrods appropriately. This feature was incorporated into the design to allow the shop fabrication personnel to make a "loose" initial installation and to tighten up the system later to eliminate "slop" by making final adjustments.

Mechanically, the left and right engine controls are independent of each other. However, if it is so desired and because they are motorized, they can be coupled electronically through the simulator computer for any research that may require such configuration. It should be noted that the torque-tube push-rod concept is extendable to three or four engine controls. Each thrust lever, which the pilot operates, has an arc travel limit of 20 degrees. This travel encompases the range of normal operation from idle to the full thrust or the "rated overboost" condition for each engine.

the thrust conditions to instrument displays such as Engine Pressure Ratio, Exhaust Gas Temperature, Revolutions per Minute and fuel flow for each engine.

Two electric switches were incorporated into the handles of the thrust levers. These switches are thumb-operated and represent the "ground spoiler" and "autothrottle disconnect" switches. The switches are located on the left engine handle for the Pilot and on the right engine handle for the First Officer. A separate switch to command the "go-around" mode is located on the throttle panel. All switches are wired into the system computer and function as they would normally in an aircraft. The wires terminate in an electric plug to facilitate ease of removal for any servicing or maintenance.

TESTING AND RESULTS

A chain was originally used to provide power from the motor drive to a sprocket located on the torque tube of each of the two mechanical linkages. An idler wheel was used to take up the slack in the chain to allow the potentiometer to function.

In the initial testing, it became evident that the chain drive system could not provide the accuracy necessary for the potentiometer to resolve the angular position of the thrust levers within the tolerances necessary for correct operations. Consistent repeatability of the thrust lever positions could not be achieved. In addition, friction in the system, due to the idler wheels tensioning the chains, was masking the friction in the magnetic brakes rendering them unusable. The required variable forces could not be achieved if the friction continued. When the chain drive was disconnected, the mechanical linkages freely rotated on their ball bearing rollers and the motor drive mechanism worked properly. The solution to the friction problem, therefore, was to eliminate the chain drive and find an alternative solution to powering the mechanical linkages. This problem was resolved when a direct bell-crank/linkage-arm mechanism was substituted for the chain-drive system. The inherent friction in the chain-drive system disappeared and the brakes could now provide the friction to the thrust levers as originally envisioned without being masked.

Preliminary testing has demonstrated that the drive motors can position the thrust levers to within 0.5 degree of the correct position. The potentiometer feedback system provides sufficient accuracy so that positioning error is negligible. The speed of the thrust levers is approximately 5 - 7 deg/sec. The friction in the system is yet to be measured. The magnetic particle clutches and brakes have been demonstrated to provide variable forces to the thrust levers; however, no accurate measurements have been done on these yet. Because of the demand of the use of the simulator facility to check out other systems, these tests are not planned to be done until after 1985.

The computer that operates the control system is a Digital Equipment Corporation SEL Computer. This computer also operates the B-727 Flight Simulator as well as the rest of the Man-Vehicle Systems Research Facility. Various flight conditions for the Advanced Aircraft Flight Simulator can be

The second four-bar linkage mechanism is "piggy-backed" onto the first mechanism and allows the pilot to engage the thrust reverse of the engines. This part of the thrust lever motion provides an additional 15 degrees of movement aft of the idle position. The engagement of the thrust reverse is accomplished by manually lifting the thrust lever to a different plane before engaging the thrust-reverse features. Figure 2 shows the right engine thrust lever in the full reverse position. When the pilot lifts the thrust lever through the gate to engage the thrust-reverse condition, the second four-bar mechanism mechanically lifts the corresponding thrust lever on the other pilot's side. Movement of the thrust levers in the thrust-reverse condition, however, is still controlled through the first four-bar linkage.

The mechanism provides a cam and follower so that the track of the thrust levers is predetermined. The throttles may be moved through a range from the maximum reverse, through idle, to the rated overboost position. The total arc travel of the thrust levers is, therefore, 35 degrees. Operationally, the computer disengages the drive motors from the system during reverse thrust-operations. Mechanically, whenever the thrust levers are pulled into the reverse condition by either pilot, an electric switch, attached to the thrust lever, is disengaged. When the switch is disengaged, an electrical signal is sent to the systems computer telling it that thrust reverse is to be used and that the drive motors should be disengaged from the mechanism. This is done by deenergizing the magnetic particle clutches. The switch is used since it is very reliable. The potentiometer was not used as it was believed that it would not be a reliable means of detecting the change from normal to thrust-reverse condition.

The motor drive mechanism consists of a globe motor with gear reduction, magnetic particle clutch, and electric brake for each engine. These components are geared to provide the proper angular rotations at the thrust lever handle to the pilot. It also provides proper rotation of a separate shaft connected to a potentiometer. The force at the handle can be varied, by energizing the magnetic clutch and magnetic brake, and hence its friction, from 0 to 7 N (15 lb). The gear-reduction unit of the globe motor, along with the designed gear-reduction system provides some resistance force. The rest of the friction is made up by the brake. The thrust lever forces can, therefore, be configured through software changes by programming the system computer rather than by mechanical design. Although the system does have some mass moment of inertia, the amount is negligible when compared to the friction caused by the brake.

The potentiometer is used to resolve the angular position of the thrust levers and provides the feedback to the system computer to increase or decrease the thrust lever force at various positions. For example, the throttle system requires approximately 3.5 N (7.5 lb) of constant force throughout its normal operating range. In the rated overboost condition at the furthest forward thrust lever position, the system computer, having detected the voltage level from the potentiometer, increases the force required for the maximum thrust condition to 7 N (15 lb) by energizing the magnetic clutch and brake. The pilot operating the thrust levers will then feel the increased force and know that he is operating in this flight condition. The signals from the two potentiometers also are used to supply simulated including IFR and emergency conditions. All signals sent through the throttle system's two potentiomcters are resolved into performance parameters displayed on the flight displays. Similarly, when the aircraft is engaged in the auto throttle mode, the computer provides for correct operation of the throttle system. The system is configured so that, as in a real aircraft, the computer can be overridden by the pilot and the throttle mechanism can be physically overpowered under a simulated emergency condition.

CONCLUSIONS

The Advanced Aircraft Flight Simulator is equipped with a motorized mechanism that simulates a two-engine throttle-control system that can be operated via a computer-driven performance-management system or manually by the pilots. The throttle-control system incorporates features to simulate normal engine operations and thrust reverse and vary the force feel to meet a variety of reserach needs. While additional testing to integrate the mechanism into the facility is required and to verify correct operations, the work required is principally now in software design, since the mechanical aspects function correctly. The mechanism is an important part of the flight-control system and provides the capability to conduct human-factors research of flight crews with advanced aircraft systems under various flight conditions such as go-arounds, coupled IFR approaches, normal and ground operations and emergencies that would or would not normally be experienced in actual flight.

THROTTLE MECHANISM

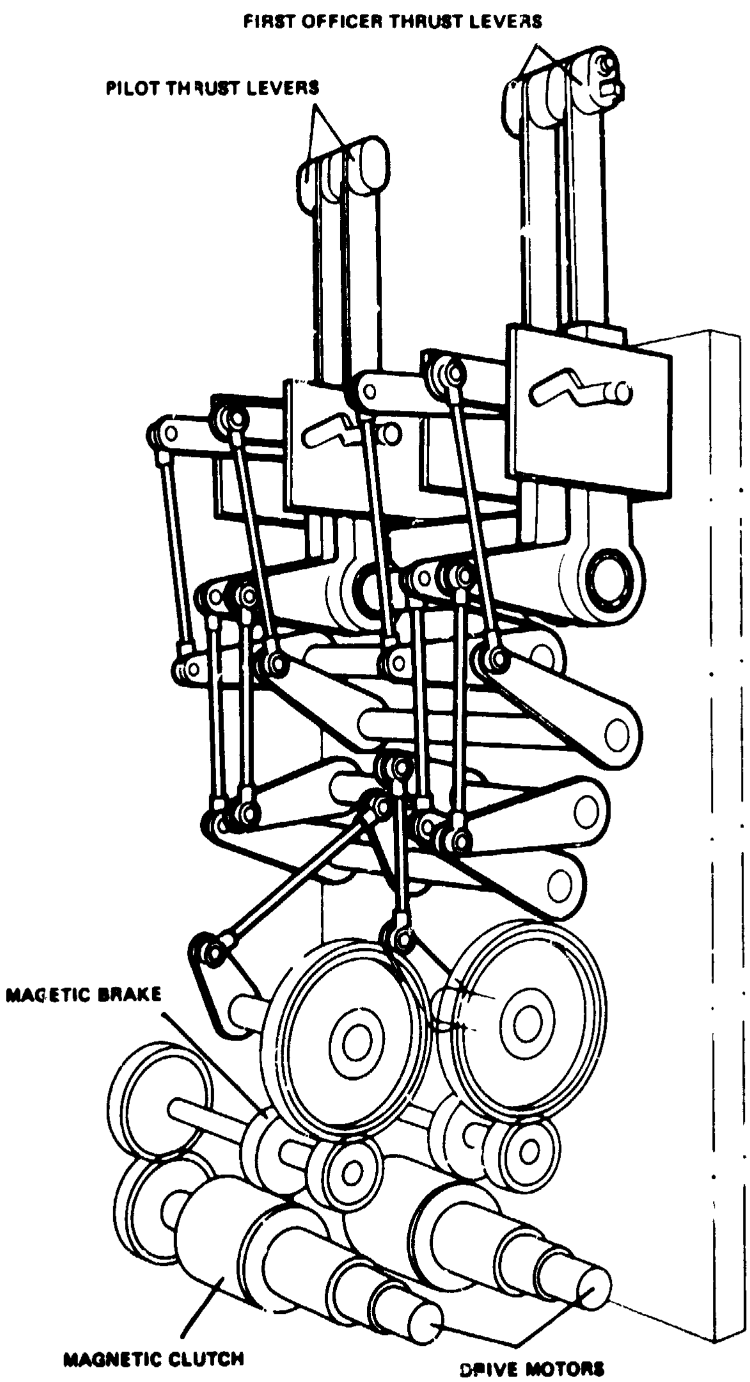

FIG. 1

ORIGINAL PAGE IS
OF POOR QUALITY

RIGHT ENGINE THRUST LEVER IN FULL REVERSE

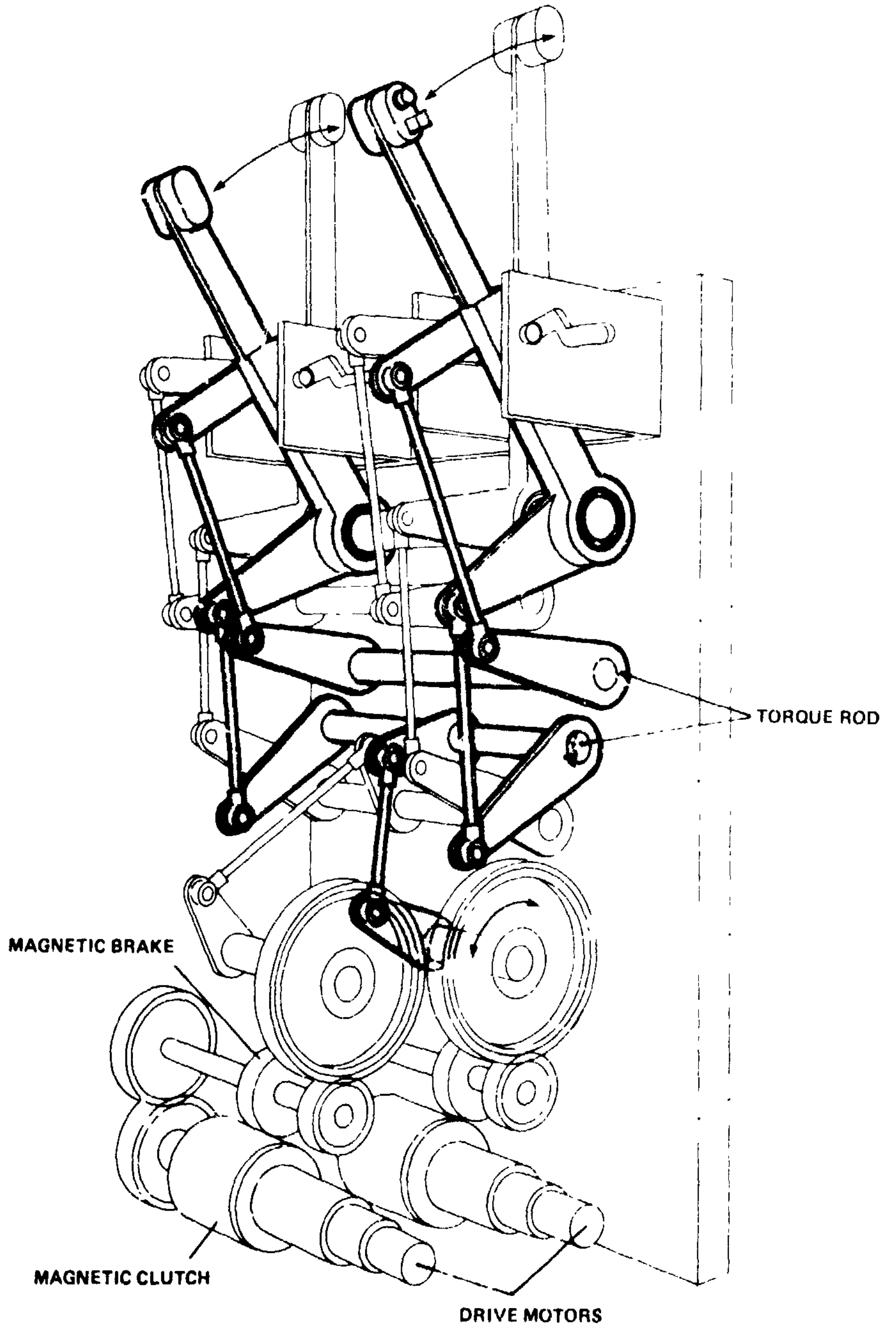

FIG 2