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SUMMARY

Flight experiments were conducted to evaluate two control concepts for configuration management during the transition to landing approach for a powered-lift STOL aircraft. NASA Ames' Augmentor Wing Research Aircraft was used in the program. Transitions from nominal level-flight configurations at terminal area pattern speeds were conducted along straight and curved descending flightpaths. Stabilization and command augmentation for attitude and airspeed control were used in conjunction with a three-cue flight director that presented commands for pitch, roll, and throttle controls. A prototype microwave system provided landing guidance. Results of these flight experiments indicate that these configuration management concepts permit the successful performance of transitions and approaches along curved paths by powered-lift STOL aircraft. Flight director guidance was essential to accomplish the task.

INTRODUCTION

The transition from cruise flight to the landing approach is likely to be a demanding task for the pilot of a STOL aircraft. Because the approach phase is of shorter duration than that of current transport operations, and because it is desirable to maintain conventional traffic pattern speeds and to delay powered-lift operation until the latter stages of the approach, the pilot will be required to quickly perform the final transition from a flaps-up conventional configuration to flaps-down powered-lift configuration. Furthermore, it is possible that a number of controls will have to be manipulated in order to establish the powered-lift aircraft in the landing configuration and to stabilize it at the final approach condition. In contrast to current jet transports — which require that flaps and thrust be set to a nominal approach configuration early in the approach, and that glide-slope tracking be done primarily with the pitch control with only occasional throttle adjustments — the powered-lift aircraft may require that the landing flaps be set, thrust deflected to a nominal approach configuration, direct-lift or direct-drag controls deployed, and both thrust and pitch control be used continually throughout the approach for glide-slope tracking and speed control.

It is useful to consider procedures or control schemes that would reduce the number of controls required to establish and maintain glide-slope and approach conditions, thereby simplifying the pilot's workload during the transition and approach. The availability of NASA Ames' Augmentor Wing Research Aircraft presented an opportunity for flight evaluation of some control schemes designed to meet these objectives. This report describes the configuration management systems that were evaluated, the flight profiles that were flown, and the results of the experiment.

DESCRIPTION OF THE RESEARCH AIRCRAFT

The Augmentor Wing Research Aircraft is a propulsive-lift jet STOL transport that because of its configuration and operational flight conditions exhibits some of the control characteristics typical of its class that were noted in the foregoing discussion. The aircraft was developed for the purpose of demonstrating the augmented jet flap concept for powered-lift STOL operation and to provide a powered-lift STOL transport aircraft for research in flight dynamics, navigation, guidance and control, and STOL operations. Initial flight experiments were conducted to explore the aircraft's flight envelope and to demonstrate the performance, stability, and control characteristics associated with the augmented jet flap. Following these proof-of-concept flight tests, a versatile digital avionics system and electronic cockpit displays were installed in the aircraft to extend its capability to support the STOL flight research program noted above.

The aircraft (fig. 1) is a de Havilland C-8A Buffalo, modified by The Boeing Company, de Havilland of Canada, and Rolls Royce of Canada to incorporate a propulsive-lift system. The aircraft is described in detail in reference 1. It has a maximum gross weight of 21,792 kg (48,000 lb) and a range of operational wing loadings of 215-272 kg/m^2 (44-55 lb/ft^2). The propulsive-lift system utilizes an augmentor jet flap designed for physical flap deflections up to 72°. Two Rolls Royce Spey 801-SF (Split Flow) engines, each producing 46,280 N (10,400 lb) thrust, power the aircraft. Fan air is distributed through bypass ducts to the flaps to augment the basic wing aerodynamics, with the flow from each engine split to supply air through the inner and outer bypass ducts to both right and left flap to maintain symmetric lift in the event of an engine failure. Hot flow from the engine core passes out of the conical nozzles, which can be rotated through 98° (6° to 104° relative to the fuselage centerline) to deflect the direct thrust component.

The primary flight controls are fully powered hydraulically. They consist of a single-segment elevator; ailerons, spoilers, and outboard augmentor flap chokes; a two-segment rudder; hot thrust exhaust nozzles; and inboard augmentor flap chokes. The elevator is used for both pitch maneuvering and trim and has a total deflection of -15° to +24° at normal landing approach speeds. Ailerons, spoilers, and outboard augmentor chokes are programmed to deflect together for roll control in response to wheel command inputs. The ailerons have boundary-layer control, and droop as a function of flap position. They can be deflected to ±19° about the nominal droop position for the approach flap angle. The spoilers can be deflected up to 48° and outboard chokes can be deflected to reduce the augmentor flap exit area by as much as 55%. Full rudder deflection is ±25° for the forward segment, where the aft panel to forward panel gearing ratio is 2:1. The inboard augmentor chokes are controlled symmetrically to modulate lift in flight and to dump lift when on the ground. Their full deflection is 65% closure of the flap exit area for the approach flap configuration. The pilot's cockpit controls consist of a yoke and wheel, rudder pedals, and overhead throttles and nozzle control levers.

Pitch, roll, and yaw stabilization and command augmentation systems (SCAS) and an airspeed stabilization system have been developed for the aircraft and incorporated in the digital flight control system. These control modes are described in detail in reference 2. The pitch and roll SCAS provides rate command-attitude hold functions for pitch attitude and bank angle stabilization throughout the flight envelope up to 140 knots. The yaw SCAS performs dutch roll damping and turn coordination functions. Airspeed is regulated to a pilot-selected reference once the hot thrust nozzles are deflected beyond approximately 50°. A three-cue flight director can be selected to present commands for the pitch, roll, and throttle controls for longitudinal and lateral path tracking. The flight director is described in detail in reference 2.

The primary instrument displays and system mode controls available to the pilot are shown in figure 2. An electronic attitude director indicator (EADI) presents pitch and roll attitude, aerodynamic flight path, and raw glide-slope and localizer deviation as well as calibrated airspeed, vertical speed, and radar altitude in digital readout. Flight director command bars can be called up on the display if desired. They consist of centrally located column and wheel (pitch and roll) command bars and a throttle command bar positioned on the left wing of the aircraft symbol. An electronic multifunction display provides a moving map presentation of the aircraft's position with respect to the desired flightpath, as well as heading and altitude status information. An electromechanical horizontal situation indicator (HSI) presents aircraft heading and bearing to the navigational aid as well as glide-slope and localizer deviation. A mode-select panel provides switches for engaging SCAS modes and the flight director. The keyboard and status display on the center console permit manual entry and readout of instructions to the digital computer.

An example of a fully manual transition to the approach for the Augmentor Wing Aircraft is shown in the flight records of figure 3. In level flight the deceleration prior to glide-slope capture is managed through flap deployment at or below the flap placard speeds. Altitude is maintained through coordinated pitch and thrust control. The hot thrust vector is not deflected prior to glide-slope capture. Initial glide-slope acquisition is made at 90 knots with a coordinated nozzle deployment and pitch-over. In response, the aircraft begins to descend at the nominal approach sink rate and slows to approach speed. Thrust must be increased to avoid settling below the glide slope. Ordinarily, glide-slope acquisition is not performed at higher speed since little capability is available to simultaneously decelerate and descend along a 7.5° glide slope. Then for glide-slope tracking, the aircraft may require a series of adjustments of three controls (nozzles, throttles, and pitch) throughout the approach.

TRANSITION CONFIGURATION MANAGEMENT CONCEPTS

One way of simplifying the approach control requirement for this particular aircraft is to provide nozzle configuration scheduling as a function of speed during transition in addition to speed stabilization at or about the approach flight condition. This system is illustrated in figure 4 and the nozzle-speed relationship is defined in figure 5 for nominal values of approach thrust and pitch attitude. The open-loop nozzle command is sufficient to establish the nominal nozzle configuration required for the commanded speed; any fluctuations in speed due to off-nominal thrust or attitude or winds and turbulence are substantially suppressed by the closed-loop speed control once the nozzles are deflected beyond 50°. Operational procedures for use of this system require that it be engaged after acquiring the glide slope and prior to initiation of the deceleration to approach speed. Flap deployment is performed manually as described previously for the basic aircraft. With the system engaged, deceleration and glide-slope tracking may be performed using either the throttles or the pitch control to maintain the glide slope. There is little or no requirement for control in the other axis. A flight director may be used with this configuration but must be tailored to the particular glide-slope control technique.

A somewhat more complex transition configuration management system was developed for the Augmentor Wing Research Aircraft under contract by Systems Technology, Inc. That system, which is described in detail in reference 3, is structured to eliminate the need for the pilot to manage either the flap or nozzle controls during level-flight deceleration, glide-slope acquisition, and deceleration during the approach. The system, illustrated in figure 6, requires that both flaps and nozzles be scheduled as a function of speed and that the nozzles also be used for closed-loop speed control during the approach. Flap and nozzle schedules are presented in figure 7. Note that the nozzles are active in level flight (thrust is deflected prior to reaching 90 knots). Continuous flap and nozzle variations occur down to the final approach speed of 60 to 65 knots; they are monitored by either the pilot or copilot by observing the flap and nozzle control levers or the respective position indicators. The pilot then is only required to manage the control of thrust and pitch attitude during the transition. Figure 8 illustrates the nominal trim values for these two controls over the transition profile. Following this profile from cruise to final approach, the decelerations in level flight to the glide-slope capture speed (90 knots) require only two nominal reference values for thrust and pitch attitude; those reference values will, of course, be temperature and altitude dependent. In addition, pitch control is used to hold the desired altitude. At glide-slope capture, a coordinated reduction in thrust and pitch-over is required to establish the 7.5° descent at 90 knots. For the final deceleration to an approach speed of 60 to 65 knots, a gradual increase in thrust is required to maintain the nominal rate of descent associated with the glide slope. Initial glide-slope tracking is accomplished by modulating pitch attitude. After the deceleration to the final approach speed, glide-slope tracking can be accomplished either with pitch attitude or with thrust at essentially a constant pitch attitude. Again, it should be emphasized that the nominal values of thrust and attitude associated with the descent and deceleration on glide-slope are dependent on weight, altitude, temperature, and wind conditions. As indicated in reference 3, this system simplifies the pilot's control task. It maintains adequate control authority to accelerate or decelerate and climb or descend as may be required by modifications to the approach by air traffic control or by variations in winds during the approach. As with the other transition management alternative, this concept may be used in conjunction with a flight director.

DESCRIPTION OF THE FLIGHT RESEARCH PROGRAM

Flight operations were conducted at NASA Ames' experimental flight facility at the Crows Landing Naval Airfield. Transition and approaches were flown to landings on a 30 m × 518 m (100 ft × 1700 ft) STOL runway. Landing approach guidance was provided by a prototype microwave landing system (MODILS). Figure 9 shows the runway and approach guidance arrangement. Straight-in transitions and approaches were initiated at about 450 m (1,500 ft) inbound to runway 35. Curved path transitions and approaches followed a profile that included turns, from the downwind leg to the final approach, with radii of 610-915 m (2,000-3,000 ft). It was desired to avoid a transition from conventional VOR or TACAN to MODILS guidance during the curved-descending portion of the approach. Consequently, for a base-leg turn radius of 760 m (2,500 ft), the downwind segment was started at an altitude of 1,220 m MSL (4,000 ft) and the turn commenced at 1,180 m MSL (3,860 ft) and at 6.1 km (3.3 n. mi.) downrange from the landing zone to stay within the ±20° cone of the MODILS system. The broader area of coverage expected of the forthcoming national MLS system and sophisticated filtering to blend conventional airways guidance with the MLS guidance will permit a final approach profile such as this to be initiated at altitudes of 300 to 450 m (1,000 to 1,500 ft) and within 1.6 km (1 mile) of the runway threshold.

Research pilots from Ames Research Center and from the Canadian Government's National Aeronautical Establishment conducted the flight evaluations in this program. Both VFR and simulated IFR approaches were flown in calm to light wind conditions. Additional evaluations were obtained when possible with surface conditions ranging from strong headwinds to light tailwinds and in light to moderate turbulence.

DISCUSSION OF RESULTS

The transition configuration management concept in which both flap and nozzle controls are automatically scheduled during the transition and the nozzles used for speed control, was evaluated for both straight and curved approaches. In all cases, it was operated in conjunction with the flight director, where the flight director was tailored to the particular control scheme with its associated glide-slope tracking technique. In this regard, two alternative techniques were evaluated: one utilized pitch attitude for glide-slope control throughout the transition and at the final approach condition; the other switched from pitch attitude to thrust for glide-slope control when the aircraft decelerated below 80 knots (the speed at which the aircraft transitions to the backside of the drag curve in the approach configuration).

For the straight-in approaches, the localizer was acquired in level flight at altitudes of about 460 m (1,500 ft). A typical transition and approach is shown in figure 10 for the pitch attitude/glide-slope control technique. Surface winds were less than 10 knots and were essentially down the runway. During level flight, deceleration from 130 to 90 knots was performed in preparation for glide-slope capture. Flap and nozzle deployment proceeded according to the schedule shown in figure 7. At glide-slope capture, a reduction in thrust and a pitch-over were commanded to acquire the glide slope. If the thrust reduction is not accomplished promptly some glide-slope overshoot occurs, and large nose-down pitch attitudes may be commanded (up to the 10° nose-down limit) to acquire the glide slope. At these large nose-down attitudes, speed control is degraded and the aircraft accelerated to about 10 knots above the reference. Once established on the glide slope, tracking is easily accomplished at the higher speeds. For the example shown in figure 10, pitch attitude was used for glide-slope control throughout the transition to the final approach condition. In this case, the deceleration from 90 knots to the approach speed of 72 knots was initiated at 275 m AGL (900 ft) and completed in 13 sec at 180 m AGL (600 ft). Some increase in the nominal thrust setting was required to maintain adequate angle-of-attack margins. Glide-slope tracking was successfully accomplished with pitch control down to the break-out for a visual landing. Attitude excursions for glide-slope tracking were excessive on some occasions when wind and turbulence disturbances were encountered during the approach. The pilots generally appreciated being relieved of the need to manage both flaps and nozzles during transition. It was noted that adjustments to the flap and nozzle schedules with airspeed for various combinations of gross weight, altitude, temperature, and reported winds would be required for a fully operational configuration.

Figure 11 shows a transition and approach with a change of technique for glide-slope tracking from use of the pitch control to the throttle. Control for level flight, glide-slope capture, and initial deceleration proceed much the same as shown in figure 10, although with better glide-slope capture and tracking performance. Below 80 knots, the throttle director and control become active for glide-slope tracking while the pitch director and controls settle down and only small, slow attitude changes are made over the remainder of the approach. In this case, the pilot objected somewhat to the change of control technique during the course of the deceleration and noted some difficulty in establishing good trim conditions. It was felt that a more appropriate time to change control techniques would be at glide-slope capture, with the initial command to reduce thrust. It is anticipated that glide-slope tracking can be performed quite well using thrust for control during the deceleration, thereby avoiding the confusion of changing control technique part way through the approach.

Curved approaches having turn radii ranging from 610-915 m (2,000-3,000 ft) were conducted during the flight program. An example of a 760-m (2,500-ft) radius curved-approach profile is illustrated in the approach plate shown in figure 12. The initial flightpath is acquired on the downwind leg, abeam the runway, at an altitude of 1,220 m MSL (4,000 ft). The approach profile is constructed to confine the curved segment from the downwind to final approach legs within the ±20° cone of coverage of the experimental microwave landing system (MODILS). As a consequence, the downwind leg of the profile is flown at an unusually high altitude and the final approach leg is exceptionally long.

For the initial flights, the radius of the base-leg turn was set at 610 m (2,000 ft). However, to accommodate a variety of wind conditions while maintaining speeds up to 90 knots during the initial part of the descent and restricting bank angles to 30°, turn radii of up to 915 m (3,000 ft) were flown. An illustration of an approach following a 760-m (2,500-ft) radius profile is presented as an example in figure 13. Automatic flaps, speed stabilization, and the flight director were engaged on the downwind leg at 130 knots. Deceleration to 90 knots was initiated in the vicinity of waypoint 2. This deceleration was accomplished prior to initiating the descent at waypoint 3. Just prior to waypoint 3, at a vertical beam offset of 30 m (100 ft), a reduction in thrust was commanded for capture of the descending path. Capture proceeds smoothly without overshoot, and path tracking progresses using the pitch control. Three seconds prior to waypoint 4, the lateral flight director commands the turn entry. To avoid going outside the turn, the pilot must follow the director commands closely. Winds at the pattern altitude were approximately 15 knots from 150° and it was necessary to use bank angles up to 30° in attempting to track the path. On other approaches, with stronger winds and with the turns flown at 90 knots, 30° bank angles were inadequate for tracking curved paths with radii up to 915 m (3,000 ft). Localizer capture was commanded 3 sec prior to reaching waypoint 5 and the localizer was acquired with one overshoot. Deceleration from 90 knots to the final approach speed was commanded after completing the turn. Once on the final approach leg, glide-slope and localizer tracking proceeded smoothly to the break-out for landing. Occasionally, large pitch excursions were required for correcting glide-slope deviations due to wind disturbances.

As with the straight-in transition and approach profiles, the pilots appreciated being relieved of the need to manage both flaps and nozzles during transition along the curved path. Large attitude excursions were objectionable, as noted previously, particularly at glide-slope capture if the throttle commands were not followed promptly. When the attitude maneuvers became large enough to produce angle-of-attack excursions beyond the 10° limits incorporated in the throttle flight director, throttle control activity was commanded. In some instances, this control activity upset glide-slope tracking and induced more activity in the pitch control, which temporarily produced a high workload situation that was not satisfactory to the pilots. Further development of the throttle director logic is needed to effectively isolate the throttle and pitch control axes while still providing angle-of-attack protection. Objections to the excessive pitch excursions can be overcome by augmenting the pitch control authority and response in a manner provided by the flight-path SCAS configuration discussed in reference 2. A few curved approaches were flown with this SCAS mode engaged following deceleration to approach speed and establishment of the final approach. Glide-slope tracking precision and control activity were noticeably improved and the pilots felt that the deficiencies in vertical path control had been corrected. Since this SCAS mode provides quite effective angle-of-attack regulation, the difficulty with the pitch and throttle flight directors for angle-of-attack control would also be resolved.

Lateral flight-path tracking during the turn was generally good except when the 30° bank-angle limit was reached. Under those circumstances, the only recourse for maintaining the path while observing the bank-angle limit is to slow to a lower speed or increase the turn radius. Lateral flight director activity for tracking during the turn was greater than desired and all the pilots felt that relaxing the tight tracking requirement (lowering the director gain) during the turn and the initial stages of the approach would be desirable as a means of reducing their control activity.

The transition configuration management scheme, which scheduled only the nozzle control and required the pilot to deploy the flaps during transition, was evaluated only for straight-in approaches. Again, the flight director was employed throughout the transition and approach to break-out. Only the flight director mode employing pitch control for glide-slope tracking will be discussed here.

Figure 14 presents an example of the transition and approach for this configuration. During level flight, the flaps are deployed to 30° for deceleration to 90 knots. The nozzles remain up, and altitude and speed control are accomplished manually through coordinated use of the pitch and throttle controls. Glide-slope capture was initiated at about 30 m (100 ft) low by selecting landing flaps (65°), lowering the nose, and reducing thrust somewhat. Speed control at the higher speeds after glide-slope capture was not satisfactory. For speeds above 85 knots, the nozzles have still not been deflected sufficiently to provide effective speed regulation. Once established on the glide-slope, the final deceleration to approach speed of 72 knots was selected. After the deceleration to approach speed was in progress, the characteristics of this system are identical to those of the automatic flap-nozzle configuration discussed at the beginning of this section.

CONCLUDING REMARKS

The results of the transition configuration management experiment indicate that it is feasible to perform transitions and approaches along curved paths with a powered-lift STOL aircraft. The pilots appreciated the reduction in the number of controls required to accomplish the complete transition. Guidance provided by the flight director was felt to be essential to permit the task to be accomplished with an acceptable workload, particularly for the curved approach. The control schemes and flight director logic evaluated in this program were primarily conceptual in nature. It will be necessary to extend and refine the control and display systems for actual terminal area operations to accommodate pilot-assist modes in the cruise configuration; to blend those modes with the configuration management system; to account for variations in weight, altitude, temperature, and winds; to better handle control-mode blending and control-limiting conditions in the flight director;

and to present suitable situation information on the display to permit the pilot to monitor system performance and safety margins with respect to an established flight reference. Several control and flight director concepts that incorporate these features were evaluated in flight on the Augmentor Wing Research Aircraft. As reported in reference 4, successful terminal area operations were demonstrated throughout the aircraft's flight envelope, from the flaps-up cruise configuration to the STOL approach and landing. Satisfactory flying qualities and task performance were achieved for curved, decelerating approaches to a final landing configuration stabilized at 125 m AGL (700 ft) on the straight-in approach segment. Those results from reference 4 indicate the feasibility of manual control for such complex approach profiles and, similar to this report, show the potential for instrument operations to minimum decision heights approaching 30 m (100 ft).

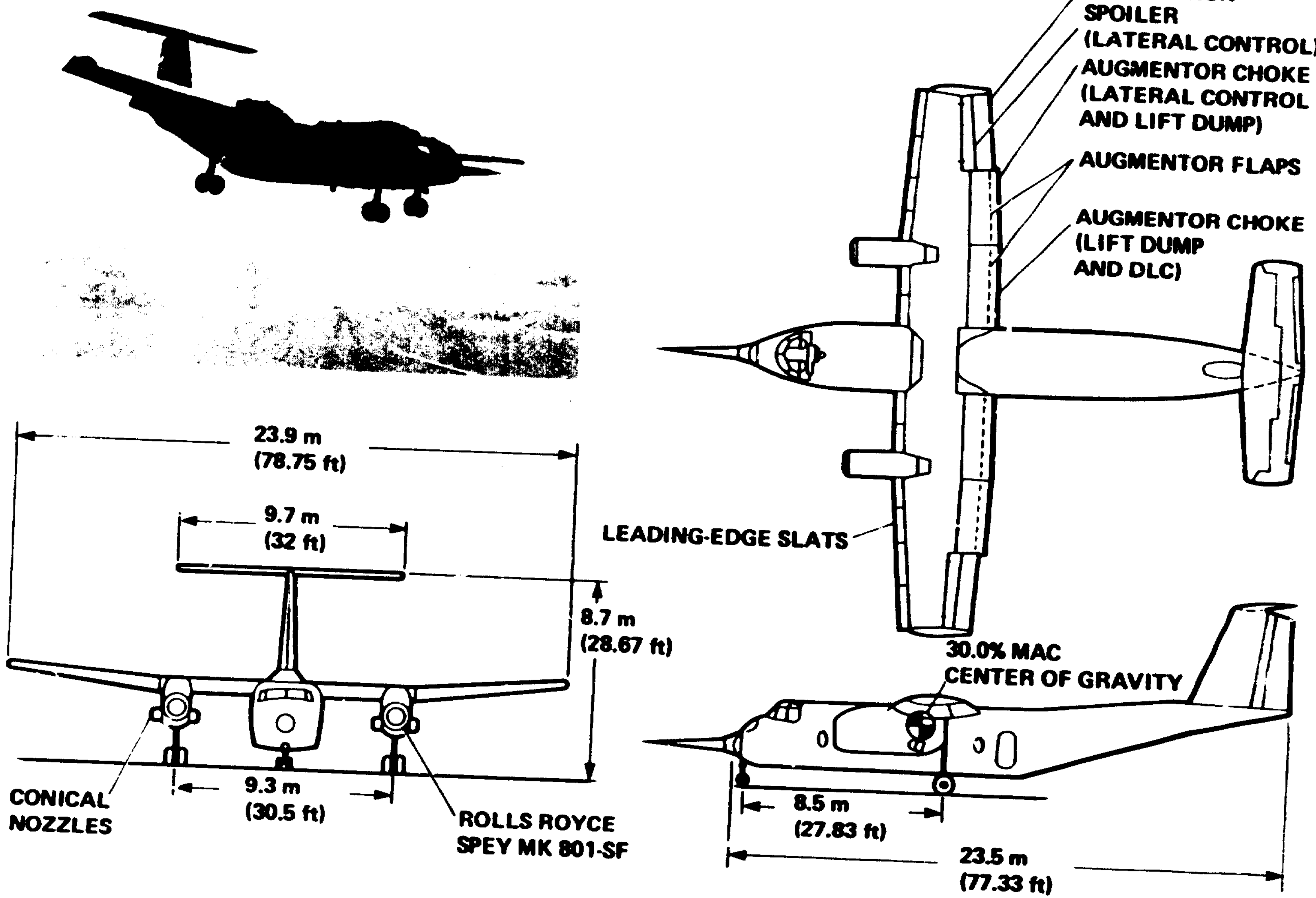
REFERENCES

1. Vomaske, Richard F.; Innis, Robert C.; Swan, Brian E.; and Grossmith, Seth W.: A Flight Investigation of the Stability, Control, and Handling Qualities of an Augmented Jet Flap STOL Airplane. NASA TP-1254, 1978.

2. Franklin, James A.; Innis, Robert C.; and Hardy, Gordon H.: Flight Evaluation of Stabilization and Command Augmentation System Concepts and Cockpit Displays During Approach and Landing of a Powered-Lift STOL Aircraft. NASA TP-1551, 1979.

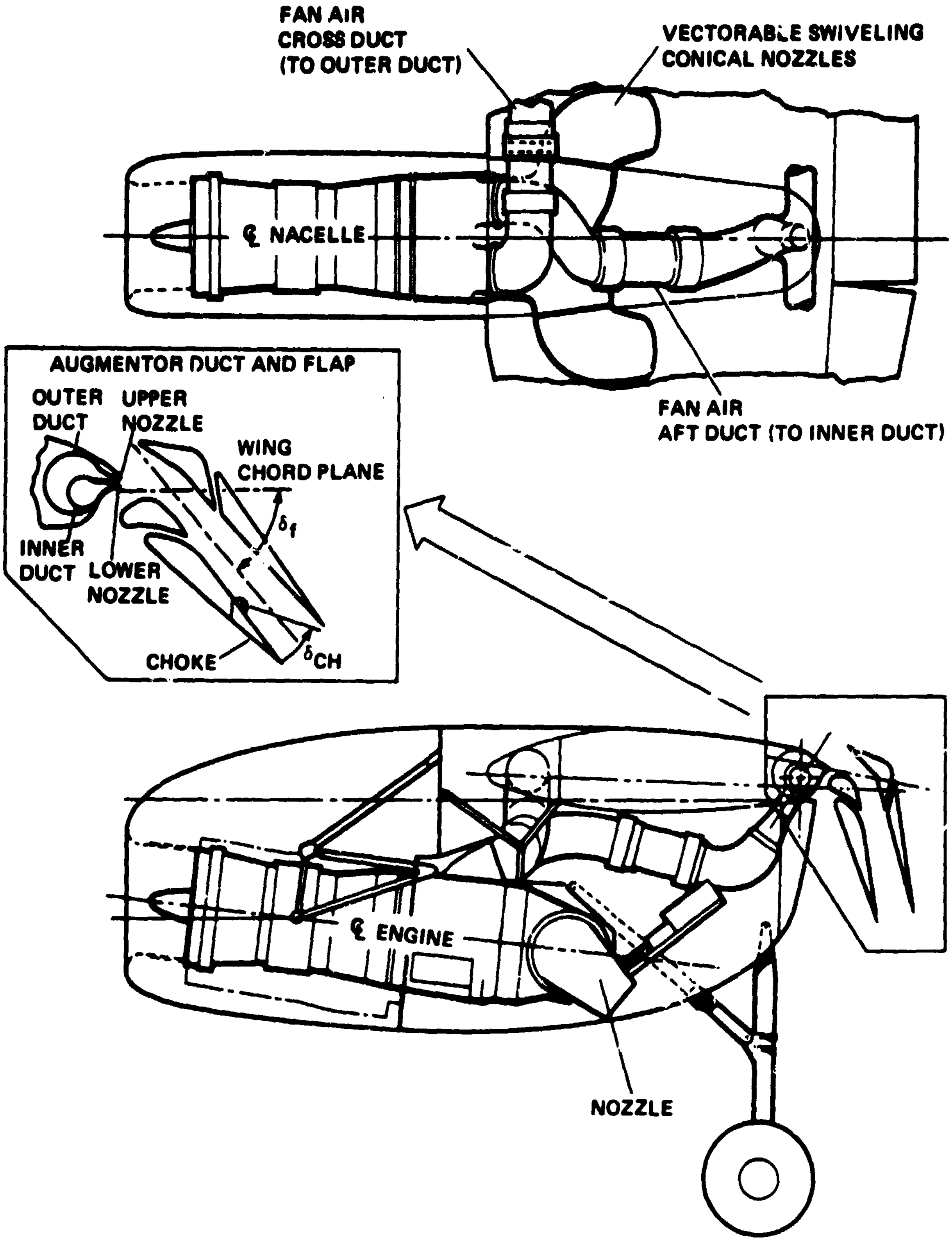
3. Hoh, R. H.; Klein, R. H.; and Johnson, W. A.: Development of an Integrated Configuration Management/Flight Director System for Piloted STOL Approaches. NASA CR-2883, 1977.

4. Hindson, William S.; Hardy, Gordon H.; and Innis, Robert C.: Evaluation of Several STOL Control and Flight Director Concepts From Flight Tests of a Powered-Lift Aircraft Flying Steep, Curved, and Decelerating Approaches. NASA TP-1641, 1980.



(a) Aircraft—three view.

Figure 1.- Augmentor Wing Research Aircraft.



(b) Augmentor jet flap and propulsion system.

Figure 1.- Concluded.

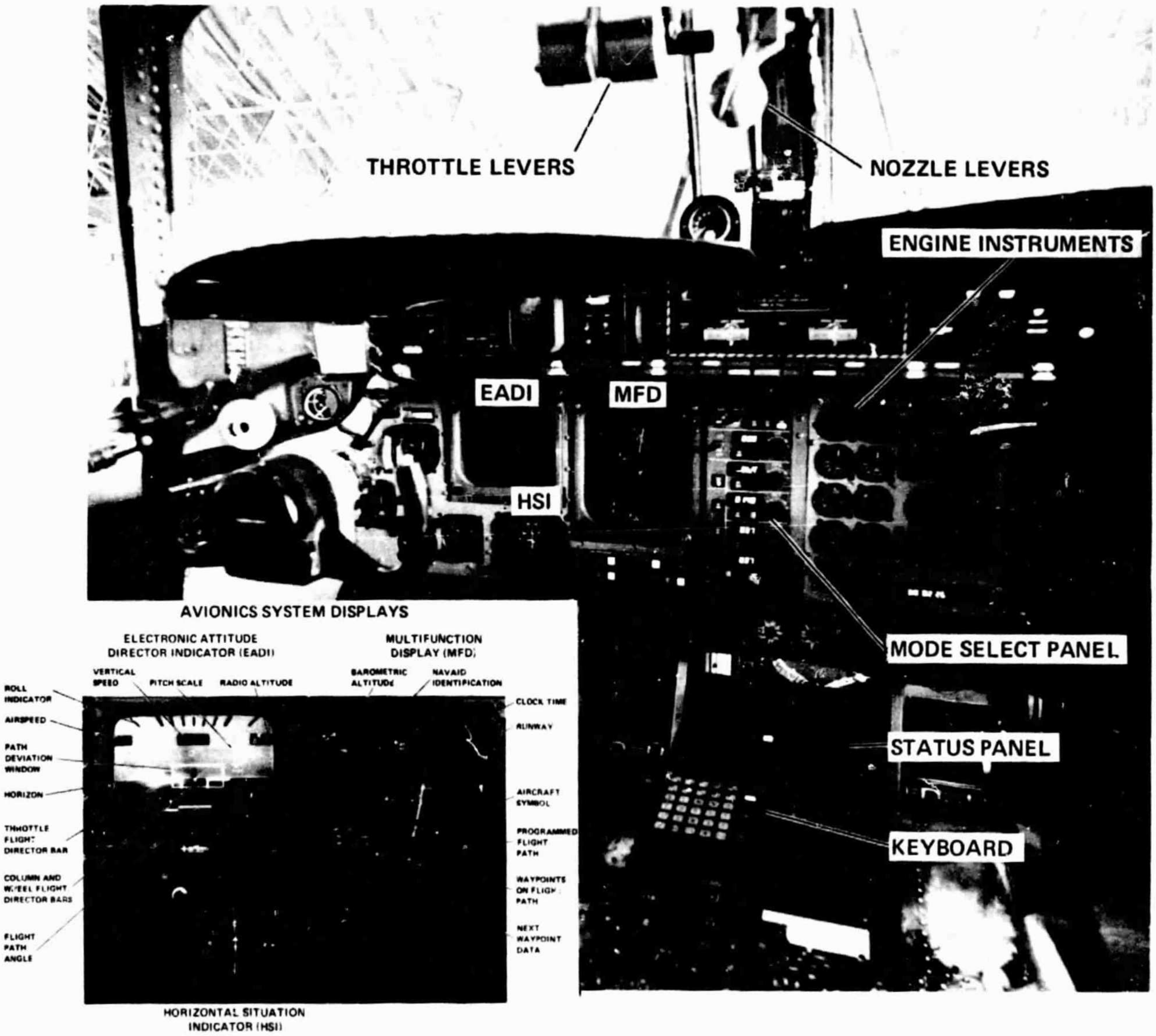


Figure 2.- Cockpit control and instrument arrangement.

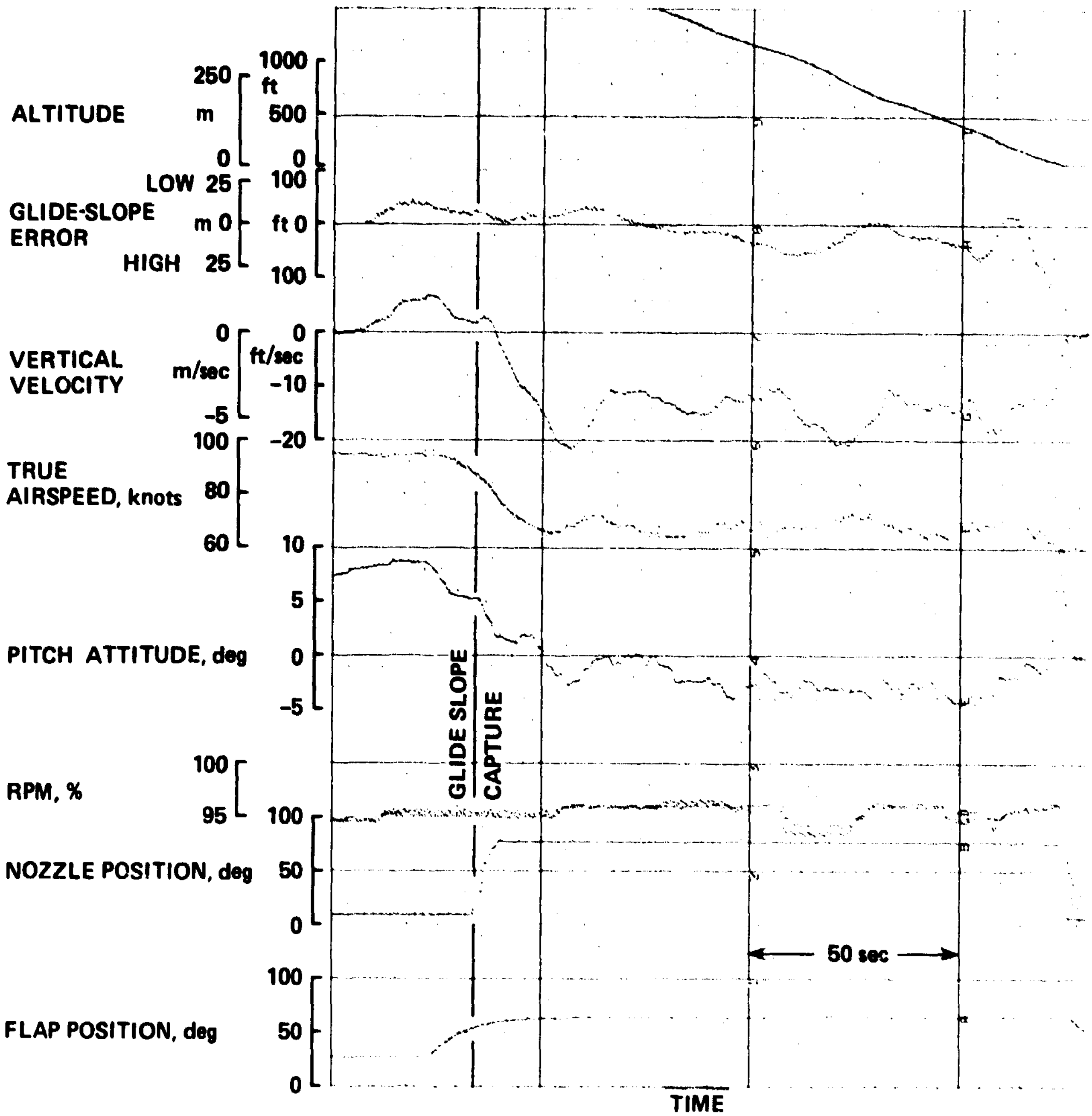


Figure 3.- Transition profile—basic aircraft plus pitch, roll, yaw SCAS.

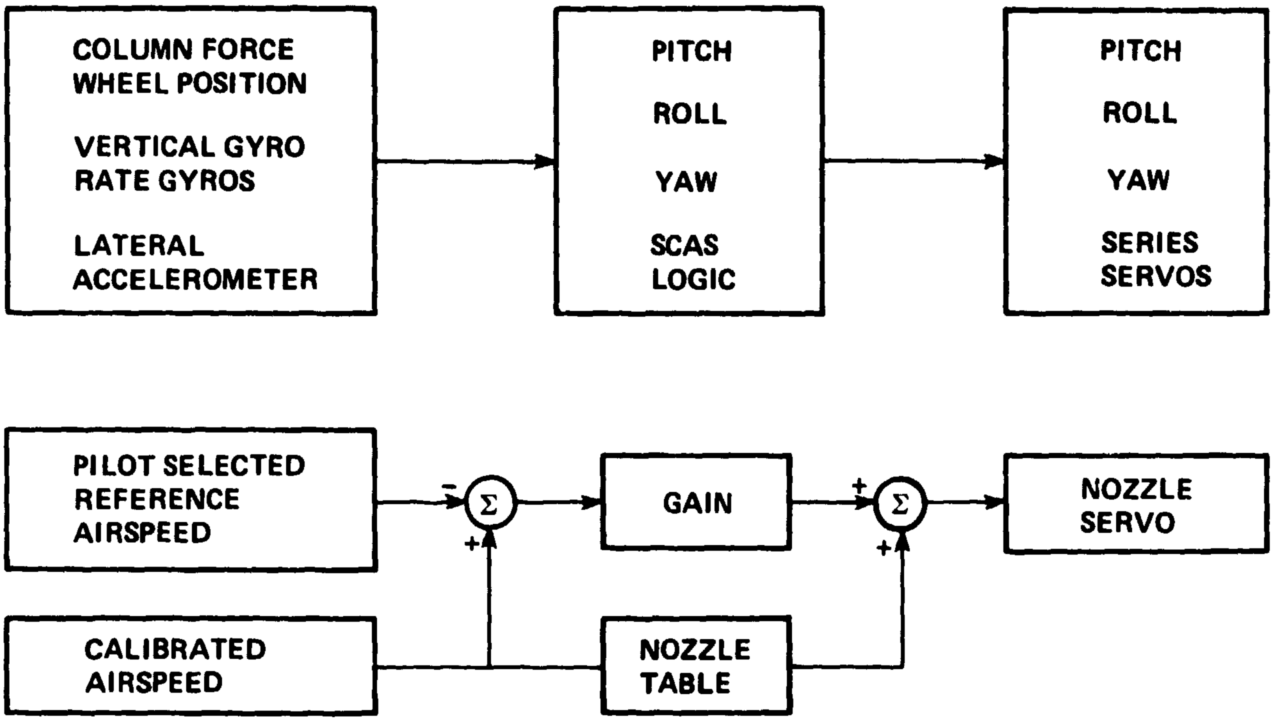


Figure 4.- Automatic nozzle configuration management system.

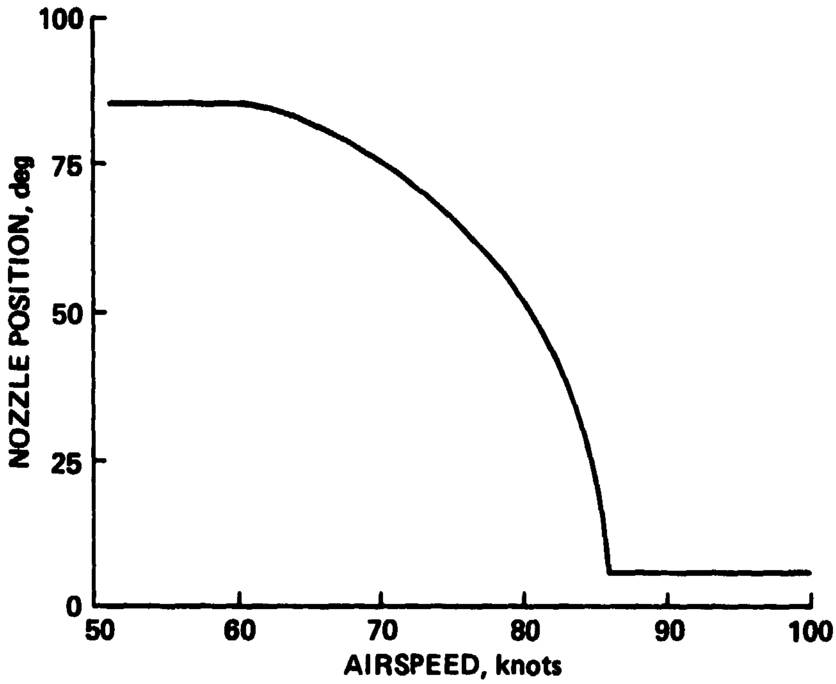


Figure 5.- Nozzle-airspeed relationship for the automatic nozzle system.

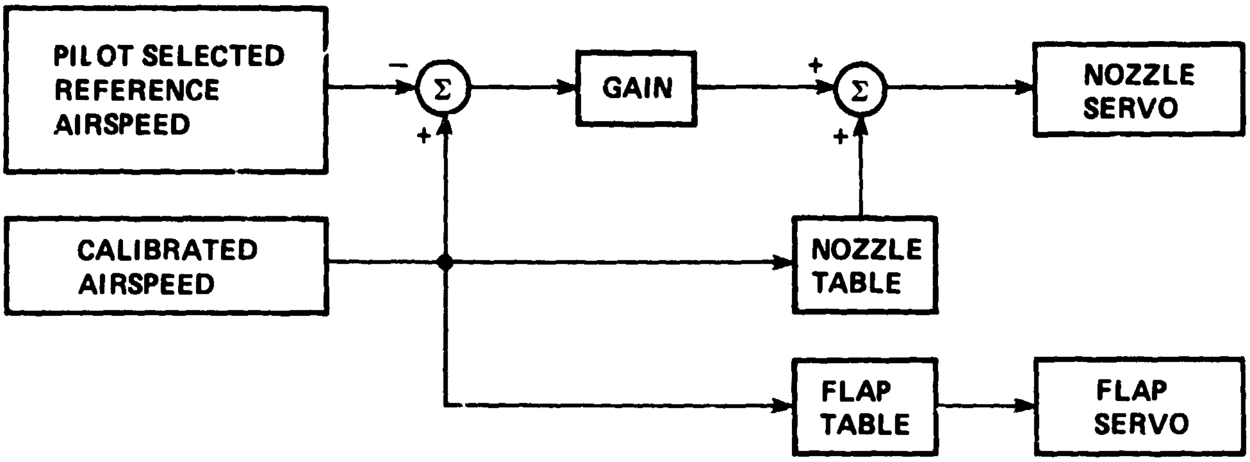


Figure 6.- Automatic flap/nozzle configuration management system.

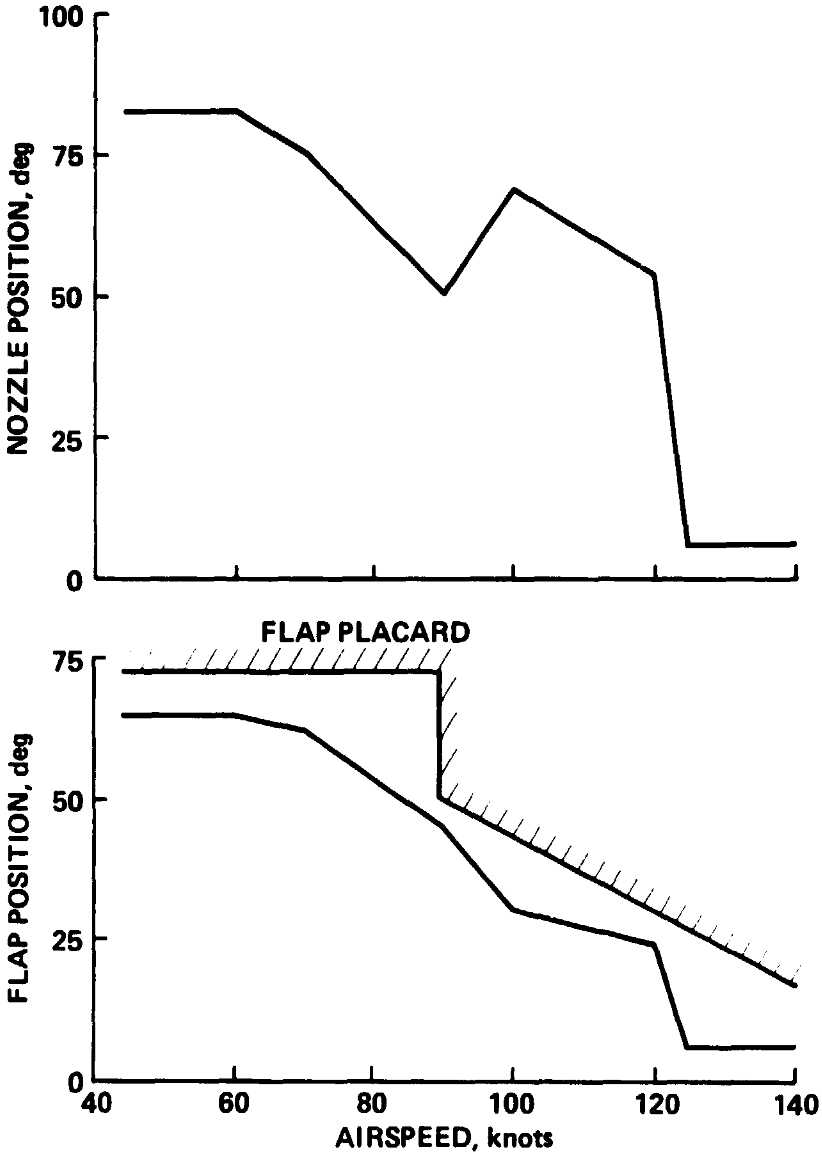


Figure 7.- Flap and nozzle-airspeed relationship for the automatic flap/nozzle system.

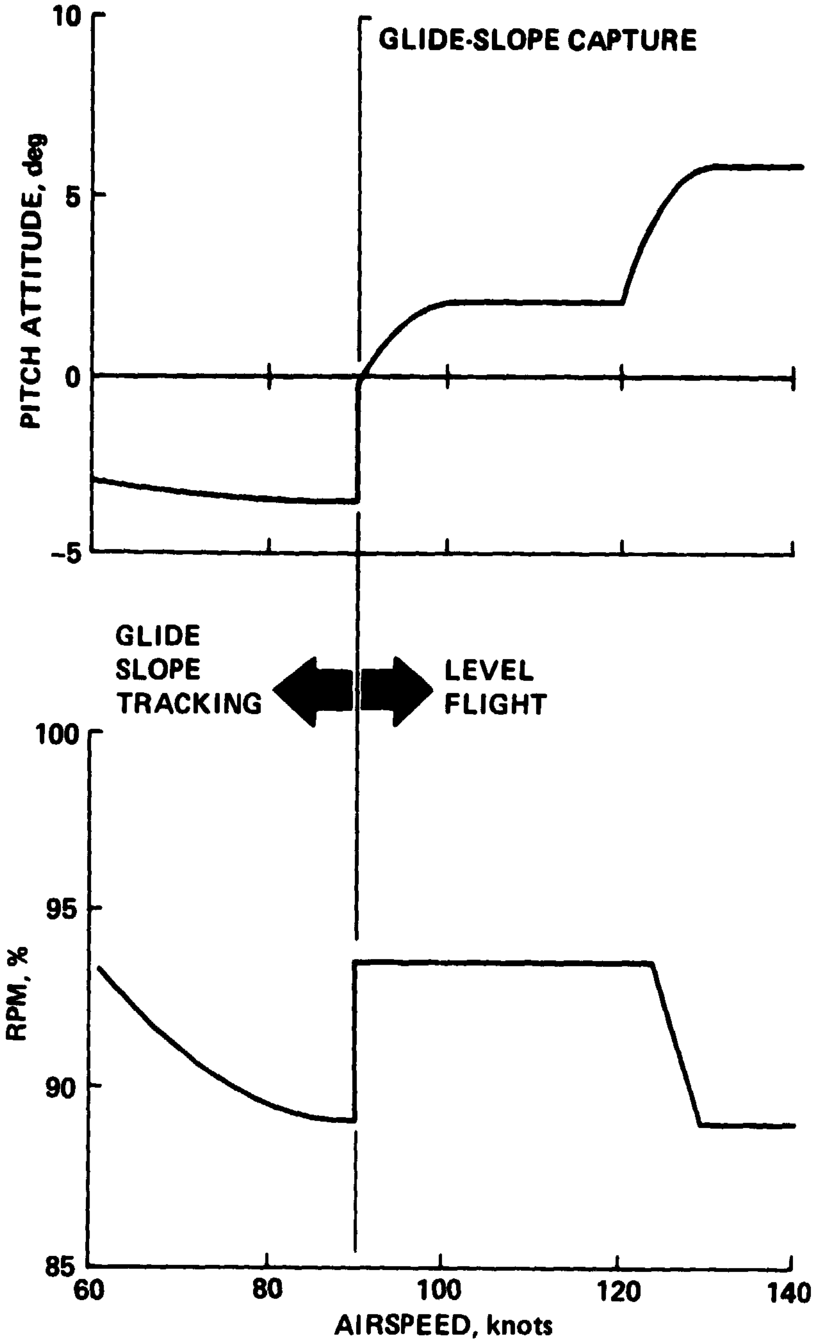
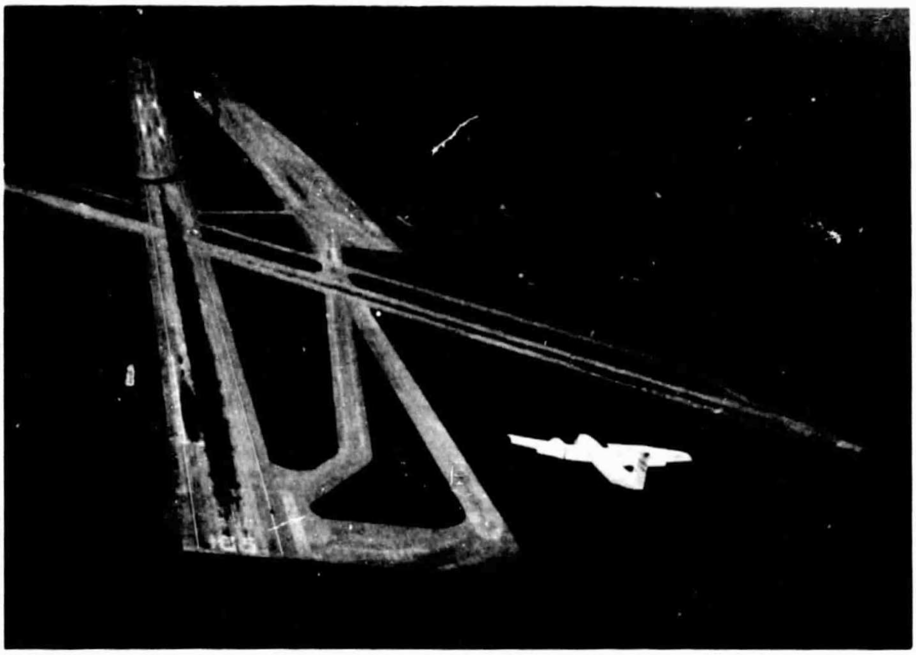


Figure 8.- Pitch and thrust trim requirements for the automatic flap/nozzle system.



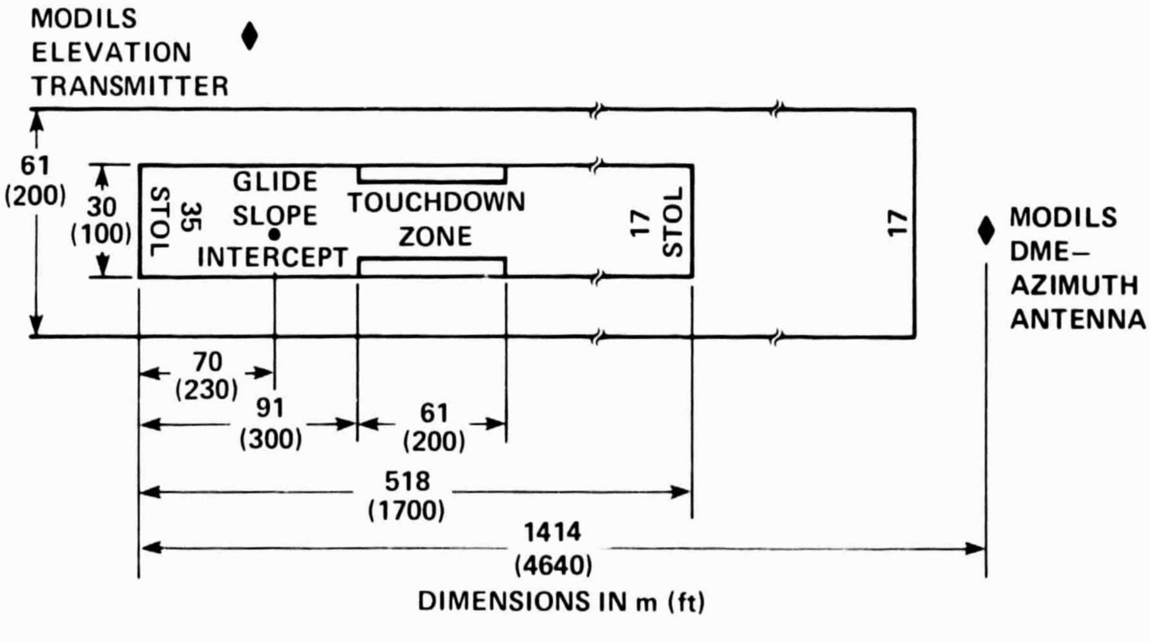


Figure 9.- Crows Landing Flight Research Facility and STOL runway layout.

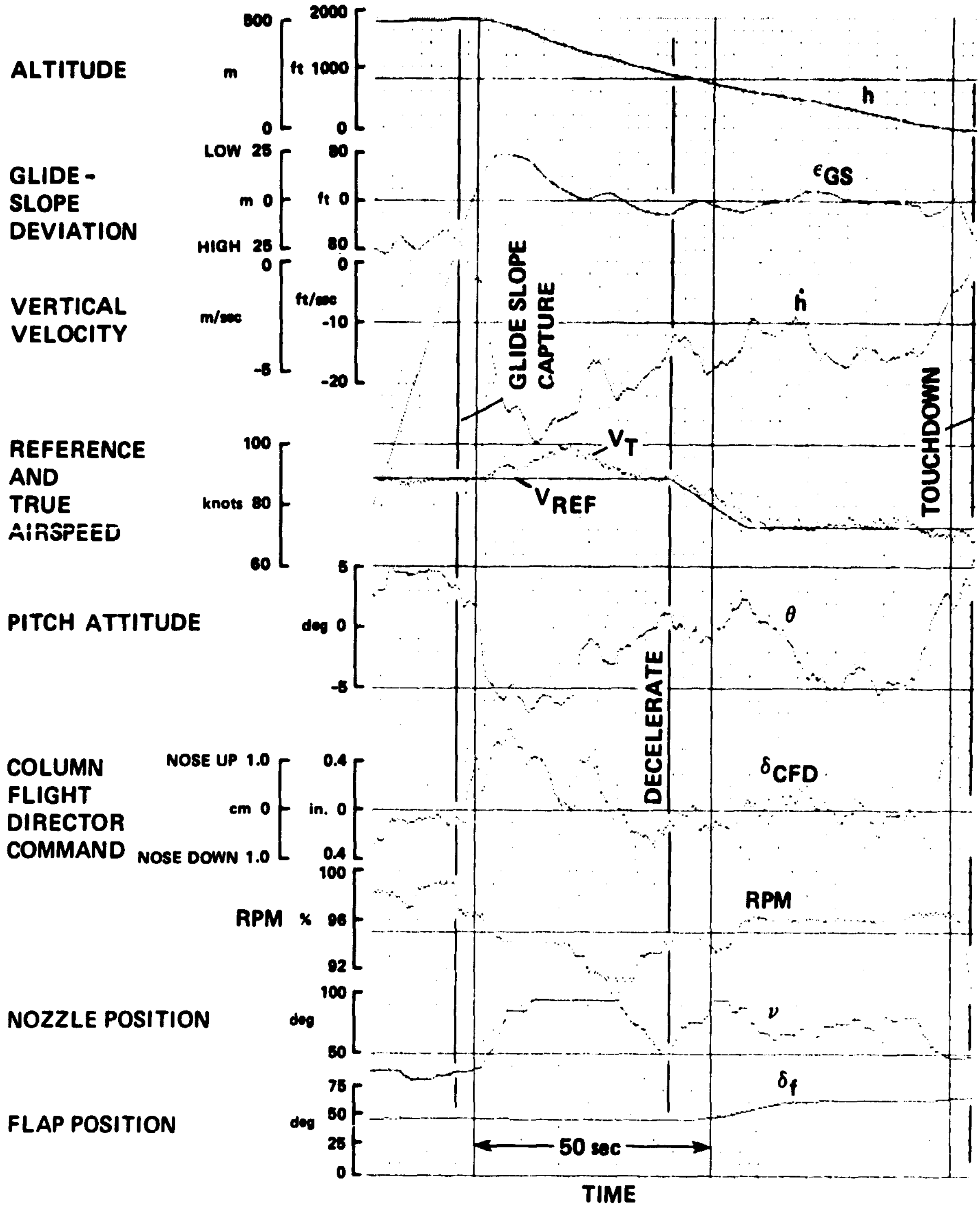


Figure 10.- Transition, approach, and landing—automatic flap/nozzle configuration management system/flight director; frontside control mode.

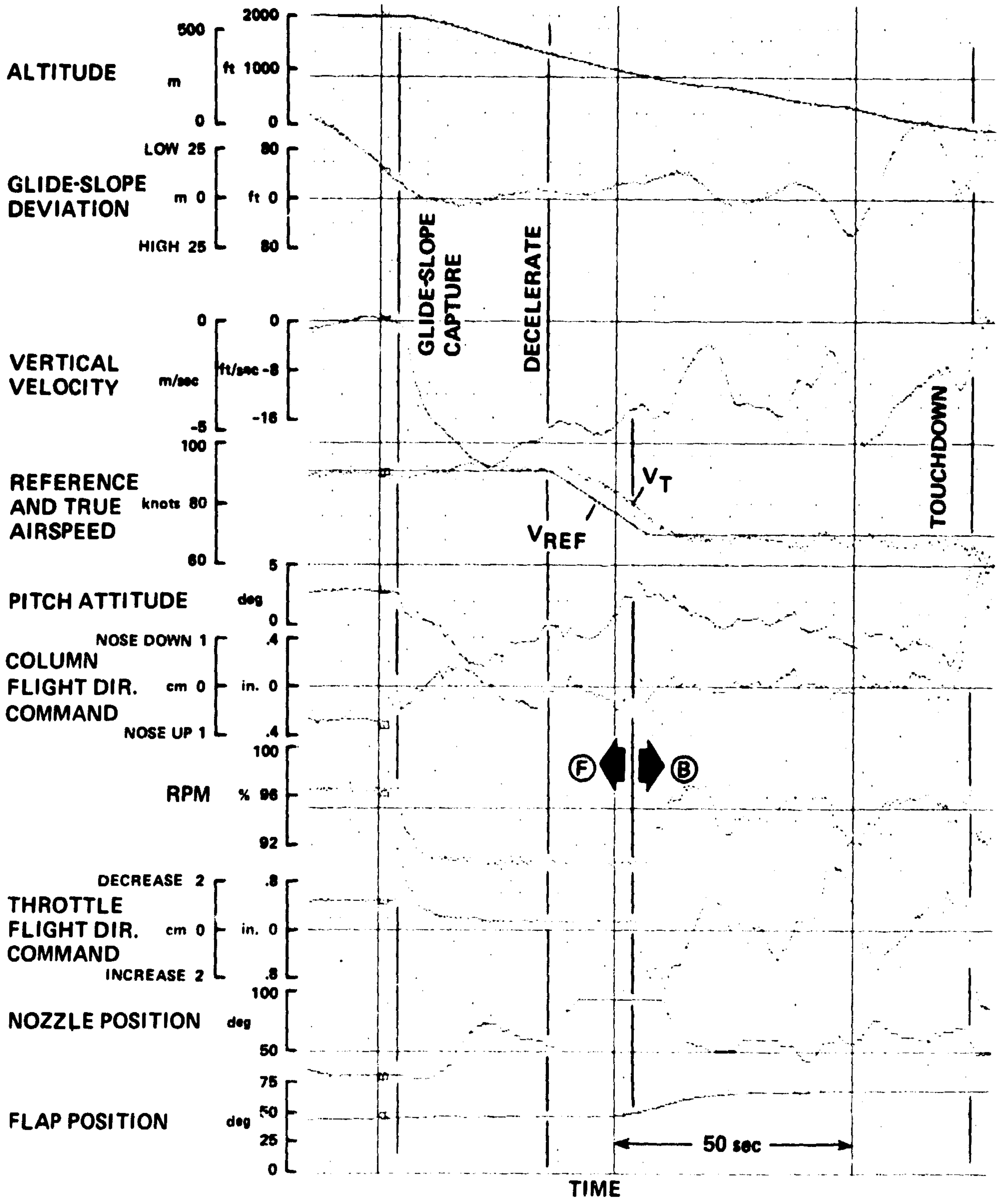


Figure 11.- Transition, approach, and landing—automatic flap/nozzle configuration management system/flight director; blended frontside/backside control mode.

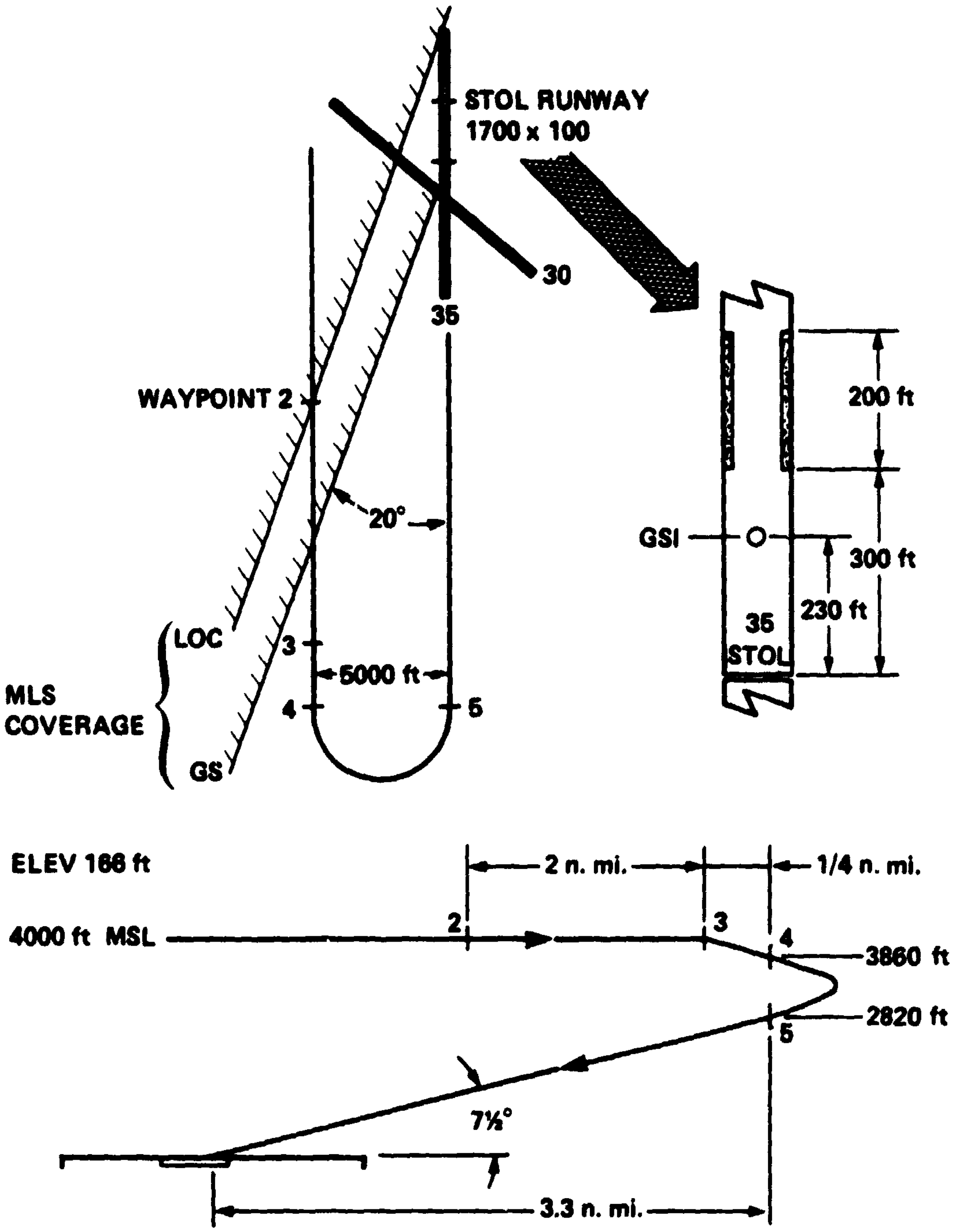
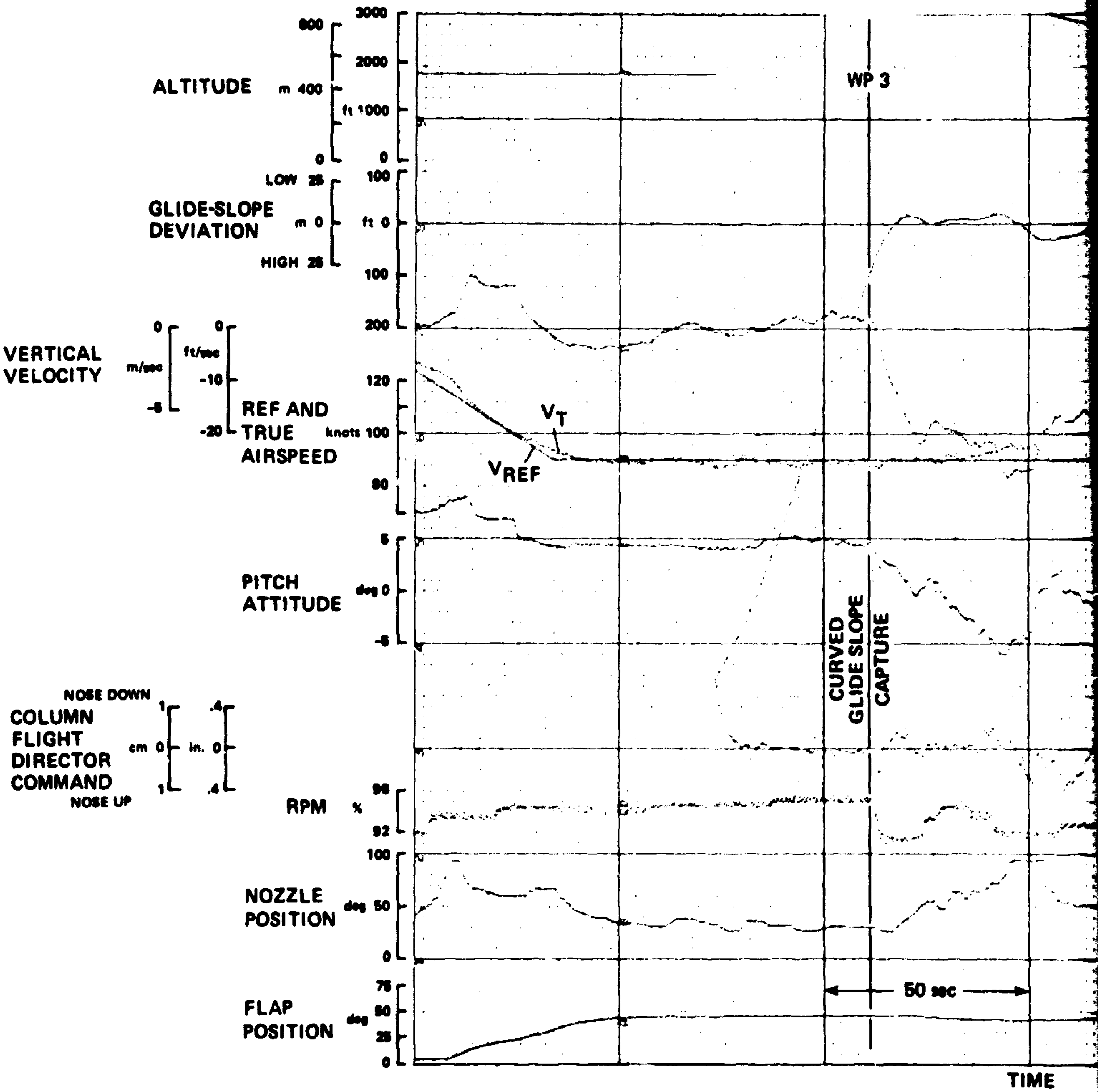


Figure 12.- Flight profile for curved, descending approach.



(a) Automatic flap/nozzle configuration management system/

Figure 13.- Curved, descending, deceleration approach t

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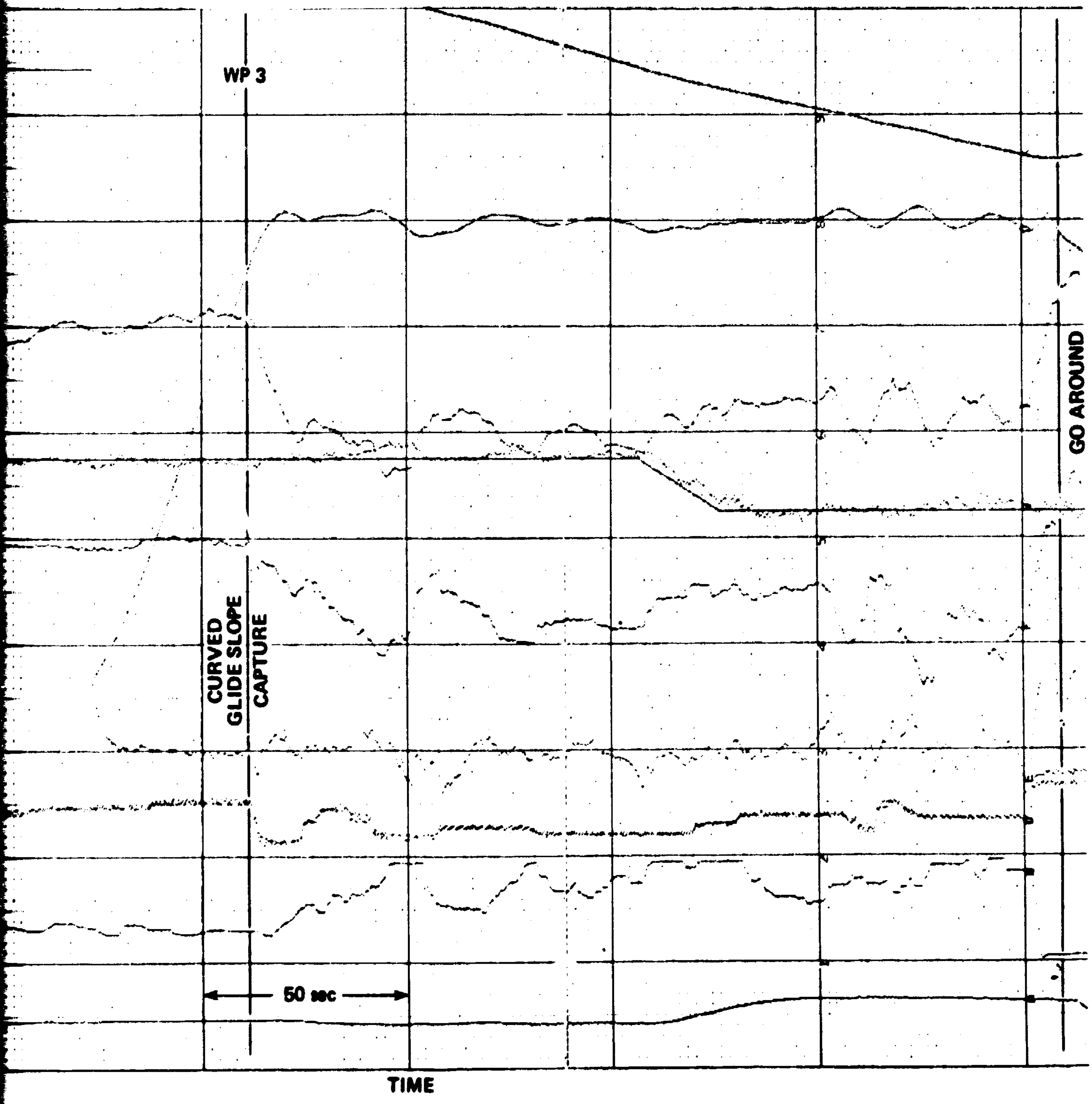

Flap/nozzle configuration management system/flight director.
Curved, descending, deceleration approach time histories.

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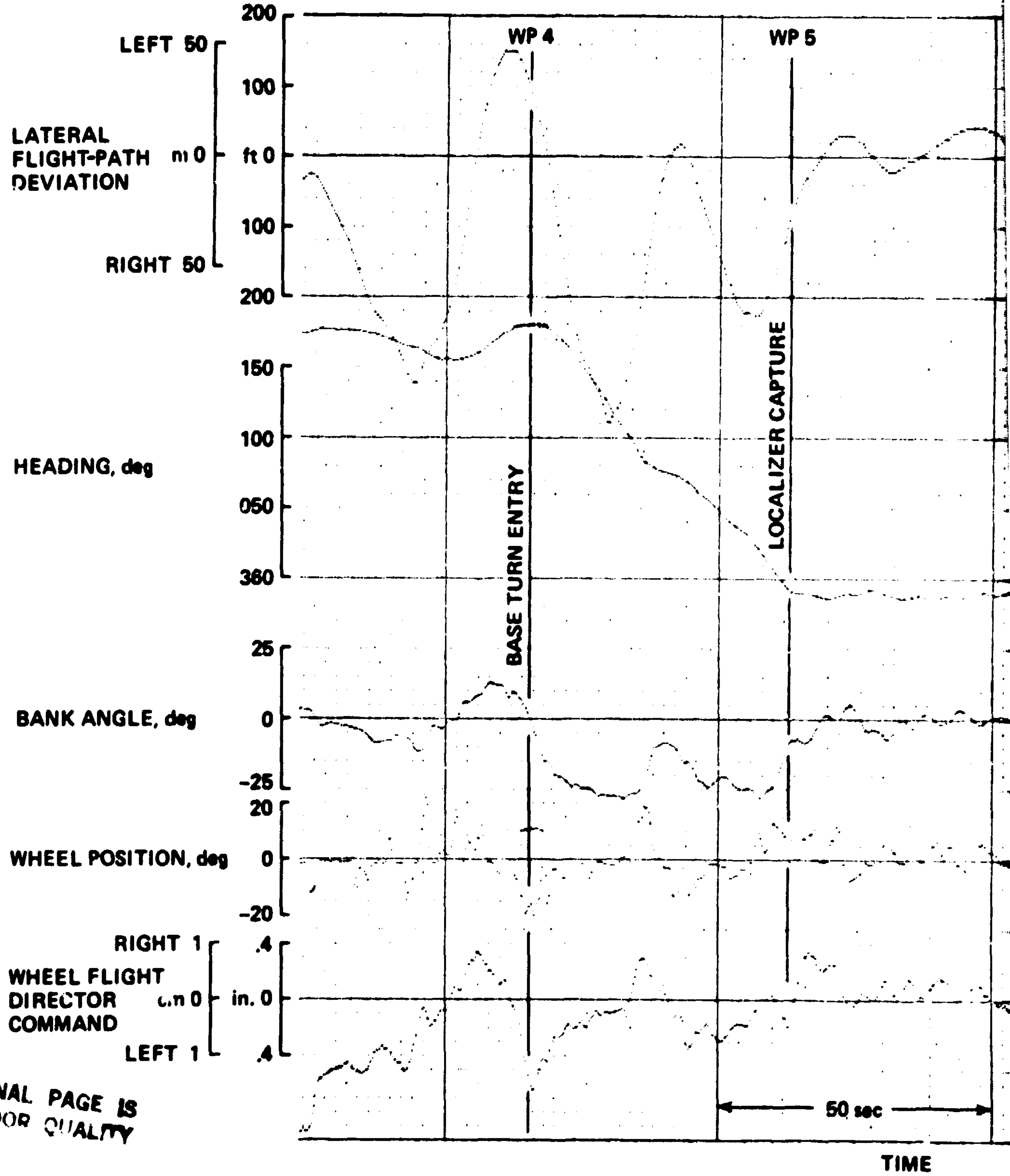

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(b) Lateral flight director.

Figure 13.- Concluded.

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(b) Lateral flight director.

Figure 13.- Concluded.

FOLDOUT FRAME 2

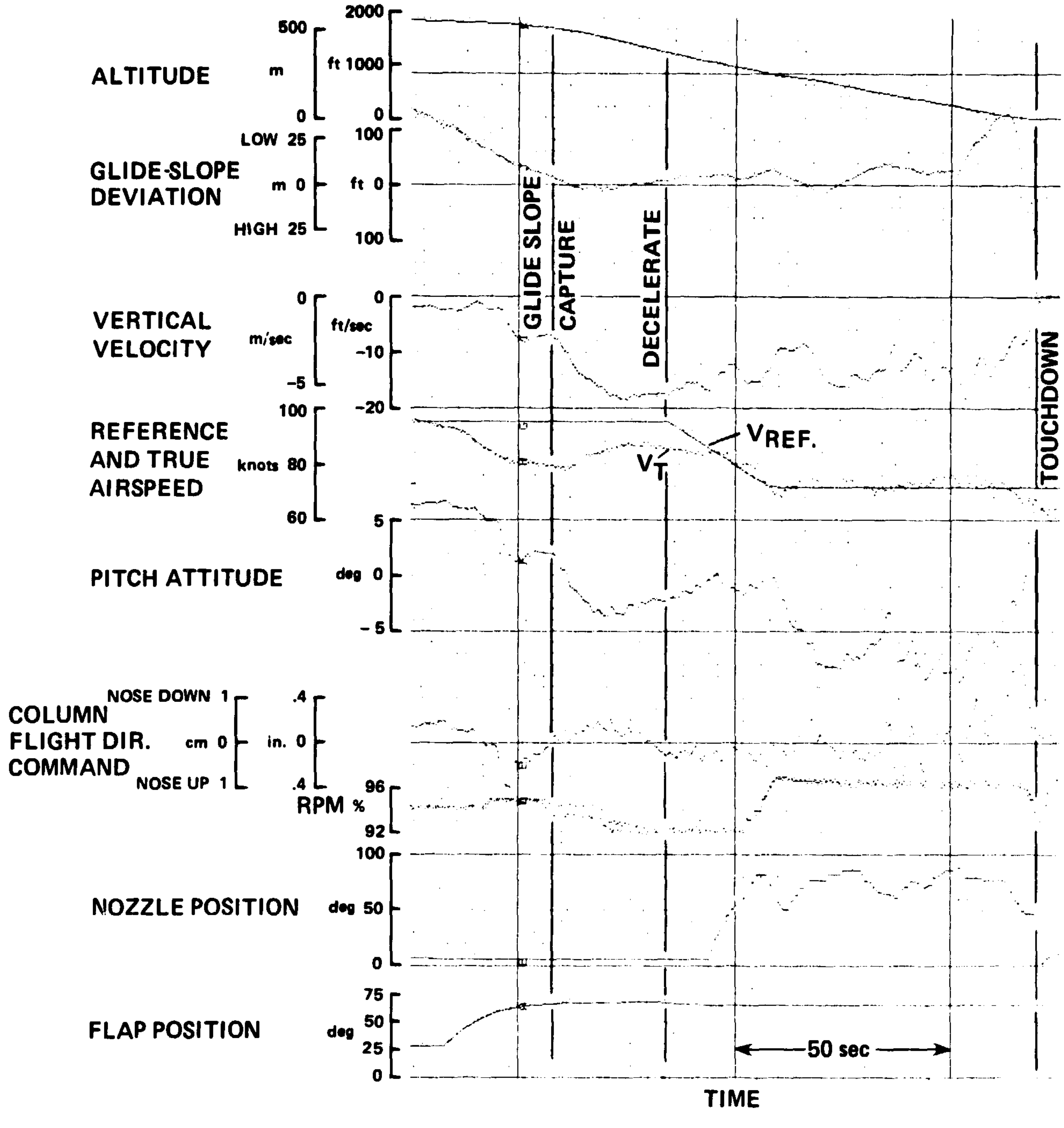

Figure 14.- Straight-in transition, approach, and landing—automatic nozzle airspeed stabilization system/flight director.