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APPLICATION OF VARIABLE-SWEEP WINGS TO COMMUTER AIRCRAFT

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SUMMARY

A study was conducted of the effects of variable-sweep wings on the ride-quality and mission-performance characteristics of commuter-type aircraft. Accordingly, a pair of aircraft -- a fixed wing baseline and a variable-sweep vehicle -- were configured and evaluated. Both were twin-turboprop, pressurized-cabin, 30-passenger commuter aircraft with identical mission requirements. Mission performance was calculated with and without various ride-quality constraints for cruise altitudes of 5,000 and 10,000 feet at stage lengths of both 100 and 250 nautical miles.

To meet the design-mission requirements, the variable-sweep aircraft commuter required a gross weight almost four percent greater than the fixed-wing baseline. However, a two-mode operation of the variable-sweep configuration -- climb and cruise at minimum sweep in a quiescent atmosphere, and at maximum sweep in turbulence -- provides for less than a three percent fuel-use penalty in smooth-air operation and, depending upon the severity of ride-quality constraint, improvements in both fuel economy and flight times in rough air.

INTRODUCTION

Rapid growth in commuter airlines in recent years has increased the significance of design improvements for the aircraft serving this market. The current fleet of commuter-class aircraft typically operates with short stage lengths and at low altitudes. Records of a commuter airline serving Washington, D.C., Baltimore, Philidelphia and several smaller cities provide an example: a median stage length of 89 nautical miles and a median operating altitude of 5,300 feet are found for the total set of flight profiles. Vehicle design is influenced by the need to use stub runways at larger airports as well as the short runways of the smaller airfields. These operating conditions, and constraints due to cost and maintainability, have led to the commonality seen in commuter aircraft configurations. Beyond being propeller driven, the most notable characteristics are relatively high-aspect-ratio wings and low wing loadings, with newer generations of commuter aircraft differing little in these parameters from earlier designs.

Current commuter aircraft are judged to have ride-quality characteristics significantly inferior to those of the larger commercial aircraft. As shown in figure 3 of reference 1, vertical accelerations of the turboprop commuter aircraft at cruise tend to be two to four times greater than those of the large jet transport at cruise. The dominant contributor is poorer response to the vertical gusts which are much more common and intense at the lower operating altitudes. The common contributing characteristics of the commuter aircraft are high lift-curve slope (aspect-ratio dependent) and low wing loading. Gust response for a given aircraft and operating condition can be shown to be directly proportioned to the former and inversely proportional to the latter.

Two design approaches aimed at alleviating the gust response problem have most commonly been taken. One method utilizes powered lift augmentation for takeoff and landing, allowing for significantly higher wing loading throughout the flight operating envelope. Aircraft which have resulted from this approach have been the propeller-driven Broguet 941S and LTV/Hiller/Ryan XC-142A configurations, and turbofan-powered vehicles such as the NASA/DHC C-8A (modified Buffalo), the Boeing YC-14, and the McDonnell-Douglas YC-15. Beyond complexity, the primary disadvantage of systems with power-dependent lift is the carrying of the weight of the system in all flight modes. The second approach employs an active gust-alleviation system for vehicles with low wing loading. Such systems employ gust sensors and high-rate, trailing-edge flaps which are rapidly positioned to cancel most of the load imposed on the wing by the sensed gust. Although used for years on high-speed, low-altitude strategic bombers, only one commuter aircraft is available with the system - the West German Dornier 228.

A third concept not applied to commercial vehicles, but used by the military services in low altitude, high-speed, penetrator aircraft (such as the F-111 and the B-1), employs the variable-sweep wing. This concept is the subject of this report. In order to examine the effects on both gust response and mission performance of the application of the variable-sweep concept, both a swing-wing and a fixed-wing commuter were designed and evaluated. Both are twin-turboprop, pressurized-cabin, 30-passenger vehicles sized to meet identical reserve requirements and design range (500 n.mi.). Mission performance at altitudes of 5,000 and 10,000 feet over 100 and 250 n.mi. stage lengths are provided for various constraints on incremental gust-response load factor.

SYMBOLS

a	speed of sound
a.c.	aerodynamic center
AR	aspect ratio, b^2/S (if without subscript, refers to wing)
b	span of planform (if without subscript, refers to wing)
c	local chord
c_r	centerline chord, subtended by extension of leading and trailing edges to aircraft plane of symmetry
$\bar{c}$	mean geometric chord (if without subscript, refers to wing)
C_L	lift coefficient, lift/qS
C_{L_α}	slope of lift curve, C_L per radian
h	altitude
L/D	ratio of lift to drag
M	Mach number
q	free-stream dynamic pressure
S	planform reference area (if without subscript, refers to wing)
V	velocity
V_g	gust velocity
W	weight
x	chordwise distance from leading-edge of centerline chord
Δn	incremental gust-response load factor
ρ	density
Λ	leading-edge sweep angle

Subscripts:

H	horizontal tail
max	maximum
V	vertical tail
r	root

Abbreviations:

ktas	true airspeed, knots
kias	indicated airspeed, knots

DEVELOPMENT OF AIRCRAFT

Design Criteria

The fixed-wing and variable-sweep configurations of the study were designed to meet the same mission requirements. Both vehicles carry thirty passengers, two pilots and a flight attendant. The design mission is shown in figure 1. It is unrestricted except that the selected cabin-pressurization system limits the aircraft to an altitude of 25,000 ft and aircraft velocity is limited to 250 knots equivalent airspeed at altitudes of 10,000 ft or less. Required is a range of 500 n.mi., a missed-approach allowance, a subsequent climb to 5,000 ft altitude, a 50 n.mi cruise to alternate, and an allowance equivalent to a 20 minute hold thereafter.

The two configurations were constrained to have as many identical components as practically possible in an attempt to isolate the effects of wing selection. Further, the levels of technology in the underlying disciplines were assumed to be identical.

Configuration Description

Figure 2(a) is a three-view of the variable-sweep commuter configuration. Pertinent geometric characteristics are provided in table I(a). A three-view of the fixed-wing commuter configuration is shown in figure 2(b), and its pertinent-geometry listing appears in table I(b). Common to both configurations are the propulsion systems and fuselages.

Propulsion.- Propulsion is provided by two Pratt and Whitney turbine engines (PT6A-45A) driving four-bladed Hamilton Standard propellers having diameters of 114 in. (These engines are the same as those utilized in the later versions of the

Shorts SD3-30 of ref. 2). Propeller efficiencies at an intermediate altitude of 5,000 ft approach .92 at cruise speeds from 220 to 250 kts. The lowest value of propeller efficiency of .70 occurs at sea level, at 150 kts, and at maximum climb/cruise power.

Fuselage.- The fuselage is configured to provide pressurization of the crew, passenger, and baggage areas. The passenger compartment has a constant fuselage section which permits stand-up headroom in the center aisle, and four-abreast, tourist-type passenger seats spaced at 32-in pitch. Overhead storage racks and under-seat space is provided for carry-on luggage. Space is also provided for a hanging locker as well as a jump seat for the one cabin attendant required.

Wings.- The wing planform of the variable-sweep configuration was strongly influenced by consideration of static longitudinal stability. The airfoil sections selected are the LS(1)-0413 and the LS(1)-0417 of reference 3. These sections exhibit substantially better section maximum lift coefficients and section lift-drag ratios than the airfoils employed in most present-day commuters. As applied to the present configurations, the sections are streamwise when the wing outer-panel leading-edge sweep is at 20 degrees. Outer panel ordinates vary linearly from the LS(1)-0417 at the sides of the nacelles to the LS(1)-0413 at the wing tips. The wing inner panel varies from an LS(1)-0413 section at the nacelles, to a similar airfoil having 10 percent thickness at the fuselage juncture. The fixed-wing configuration has the same airfoil sections and planform shape as the variable-sweep configuration, although, in accordance with the lighter weight of the fixed-wing configuration, its wing is six and one-half percent smaller. Both the fixed-wing and variable-sweep configurations have single-slotted, trailing-edge flaps, mid-semispan spoilers, and fixed-geometry leading edges.

Empennage.- The horizontal-tail sizes for the fixed-wing baseline and variable-sweep configurations are proportional to their wing areas. That for the baseline is, therefore, six and one-half percent smaller. While the two aircraft should have the same payload loadability (center-of-gravity excursions due to payload), the heavier variable-sweep configuration will have a larger takeoff rotation requirement. Vertical tail sizes are identical, since the one-engine-inoperative case appears to be the dominant (and essentially the same) condition for both. All empennage airfoil sections are NACA 0012.

STRUCTURES AND WEIGHTS ANALYSIS

In weighing and balancing the two study configurations, current aluminum-structures technology was assumed. Further, while account was taken of limit maneuver load factor ($\approx$ 2.84), no account was made of limit load factor due to gust. At the most stringent condition -- maximum allowable speed (250 kts equivalent airspeed at altitudes at or below 10,000 ft) and at sea level -- the limit load factor due to gust for the fixed-wing baseline did exceed the maneuver load factor by 6 percent, while that for the variable-sweep configuration at maximum sweep was 26 percent less. This disparity might be used to extend fatigue life or be traded for weight or cost. Account was taken of uncertainties introduced by the unconventional variable-sweep wing through a limited wing-design exercise which revealed a 28-percent penalty in wing weight due to the pivoting requirement.

Table II is a weights summary of the two study configurations, showing the takeoff gross weight of the fixed-wing baseline to be 22,195 lbs and that of the variable-sweep-wing commuter to be 23,000 lbs. Propulsion, payload, and operating items (crew, oil, water, etc.) are identical, while the major differences in weights is in structures for which there is an increment of 760 lbs, due almost entirely to pivot structure. Fuel weight to accomplish the design mission (including reserves) is nearly the same for both, with the larger, variable-sweep vehicle requiring only an additional 15 lbs. The performance of both aircraft over the design mission will be subsequently discussed.

AERODYNAMIC ANALYSIS

Lift and Drag

Lift and drag characteristics were developed using an unpublished method for evaluation of transport-type aircraft based on wind-tunnel/flight-test correlations. As applied, all-turbulent boundary layers are assumed and account is taken of form (supervelocity), interference, pressure, roughness, and excrescences. In lift-dependent drag, correction of the classic induced-drag values are made for effects of sweep, camber, thickness, and nonlinearities in leading and trailing edges.

Figure 3 provides a comparison at Mach number .4 and altitudes of 0 and 10,000 ft of the drag polars for the fixed-wing baseline configuration and the variable-sweep configuration at both minimum (20°) and maximum (66.8°) sweep. Substantially lower drag values are apparent over the moderate and higher lift-coefficient ranges for the configuration at low sweep. The slightly higher drag of the smaller-winged, baseline configuration is due primarily to its higher wetted-to-wing-area ratio. Due to lower camber and form drags, and to slightly higher Reynolds numbers, the drag coefficients in the low-lift-coefficient range are lowest for the variable-sweep configuration in the aft-sweep condition.

Plotted in figure 4 is lift-drag ratio as a function of flight speed at these two altitudes (0 and 10,000 ft) for the variable-sweep configuration at both minimum and maximum sweep. Despite the much higher maximum values in the low sweep mode, there is little difference in lift-drag ratio in the speed range of 250 knots. Thus, at these altitudes, a configuration with the low sweep and high span (typical of commuter aircraft) will have to be operated at low velocities to achieve peak lift-drag ratio.

Lift-Curve Slope

The effect of wing sweep on lift-curve slope is presented in figure 5. The variation is calculated using the methods of references 4 and 5. Reference 4 provides a method for systematically reducing the fixed and movable sections of the wing into equivalent panels and area-weighting the values found for these panels by methods such as those of reference 5. The results show that varying wing sweep from minimum to maximum values essentially halves the lift curve slope. The simple rigid-body equation for determining gust response to an instantaneous, uniform gust,

$$\Delta n = \frac{\rho \; Ma \; V_g \; C_{L_\alpha}}{2 \; W/S}$$

would show incremental gust-response load factor to be reduced proportionately. (Note that the gust velocities used throughout this study are those from the gust profile corresponding to an exceedance probability of one per thousand as presented in reference 6.)

Aerodynamic Center

Aerodynamic-center locations for the configurations of this study were calculated using the methods of references 4 and 5. The variation with wing sweep for the swing-wing configuration is presented in figure 6. At the lower sweep values, aerodynamic center is seen to move aft rapidly as sweep of the wing is increased. A forward shift in aerodynamic center is shown for sweep angles beyond 50 degrees. This is associated with the rapid decrease in lift-curve slope of the movable wing segment as sweep is increased beyond that of the fixed, inboard segment. The final selection of the range of wing sweep (20 to 66.8 degrees in this case) was strongly influenced by the need to minimize the overall change in longitudinal stability or aerodynamic-center location. It should be noted that a corresponding shift in aircraft center of gravity with outer-panel sweep will offset somewhat the effect of this stability change.

FLIGHT PERFORMANCE

Missions

Performance was calculated for the two study configurations flown on the missions shown in table III. Each vehicle flew with a 67-percent passenger load factor (4,000 pounds payload) and took off with its respective design-mission fuel load. Mission performance was computed for stage lengths of 100 and 250 nautical miles at cruise altitudes of 5,000 and 10,000 feet. At each combination of operating range and altitude, mission performance was calculated for three cases: without a constraint on incremental gust-response load factor, and with limits of 1/2 and 1/4 g's. The mission-performance matrix was further expanded by flying the variable-sweep commuter in two operating modes. One mode is aimed at reducing gust-response load factor without reducing flight speed and is most suitable for rough weather operations. The other mode is a fuel-conservation one best suited to operation in a quiescent atmosphere. The schedule of sweep angles for climb, cruise, and descent for each mode is contained in table IV.

Performance

Gust-response limited specific ranges and speeds of the swing-wing commuter in each mode are presented in figure 7. The purpose of this figure is to show the nature of the effect of limiting the gust-response load factor on configurations varying widely in lift-curve slope and sweep. Shown for reference is the gust response point calculated for the Boeing 707-320B at Mach number .85, at a wing loading of 85 pounds per square feet, and at an altitude of 34,000 feet. The marked effect of limiting Δn on the speed of the configuration at minimum sweep is significant, especially at the lower altitude. The configuration at maximum sweep tolerates much more stringent limits in Δn, but once the limiting takes effect, maximum speed falls much more rapidly from the thrust-limited speed values shown. Very apparent also are the advantages in maximum specific range of the configuration at low sweep, especially at the higher altitude. Again, however, the onset of the adverse effect of limiting Δn occurs at much less stringent values than tolerated by the aft-sweep configuration.

As an example, the effects of a specific limit in Δn of .3 is shown. There is no effect at either altitude or the maximum velocity of the aft-sweep configuration. The effect, however, on the minimum-sweep configuration at both altitudes is to limit speeds sufficiently below optimum values as to seriously impact specific range. In fact, at the lower operating alititude, the minimum-sweep configuration, thus limited, operates at much lower speeds and, consequently, at significantly less miles per pound than at aft sweep.

In performing the essentially unrestricted sizing mission of 500 n.mi., both configurations cruise at an altitude of 25,000 ft, with the variable-sweep configuration operating throughout this high-altitude mission at minimum wing sweep. While the larger variable-sweep commuter with its lower power loading requires 24 more pounds of fuel in the climb/cruise/descent portion of the design mission, it requires 9 lbs less in reserves. The better propulsion-system/airframe match of the lower-power-loading, variable-sweep commuter and its ability to descend at maximum wing sweep are particularly beneficial in the low-altitude reserve leg and loiter.

Table IV provides a mission-performance summary for the fixed-wing and variable-sweep commuters over the study missions outlined. As noted earlier, the variable-sweep vehicle is operated in two modes; a ride-quality mode which would be appropriate to rough-weather operation, and a fuel-conservation mode appropriate to quiescent-atmosphere operation. The leading-edge sweep angles of the wing outer panels are noted in descending order for climb, cruise, and descent in each mission for the variable-sweep vehicle. In each case, fuel and time required from lift-off to touchdown are shown.

A comparison of ride-quality-constrained mission performance of the fixed-wing baseline and the variable-sweep configuration in both the ride-quality and fuel-economy modes is shown in figure 8. In this sample case, stage length is 100 n.mi. and altitude is 5,000 ft. Both flight time and fuel used are plotted versus the limit values of incremental gust-response load factor permitted on that flight. For the fixed-wing baseline, the effect on flight time of the ride-quality constraint begins at a value near one-half g and is so severe at one-fourth g that flight time is increased by 62 percent. The speed in this throttle-back mode at the one-fourth g constraint is so far below optimum that the flight fuel required is increased by some 28 percent. In the ride-quality mode, the variable-sweep commuter, which operates at maximum sweep in cruise and descent as well as in climb for Δn limits below .35 g's, total flight time is virtually unaffected by ride-quality constraint. The flight time advantage over the fixed-wing baseline varies from 12 percent to 45 percent, depending upon ride-quality constraint. In total flight fuel, the fixed-wing baseline shows a 7 percent advantage if unconstrained, but imposition of increasingly stringent ride-quality constraints can result in disadvantages approaching 17 percent. For the fixed-wing baseline, as opposed to the variable-sweep commuter in the ride-quality mode of operation, this is a clear advantage in fuel conservation when the ride-quality constraint is above .35 g.

Where the variable-sweep commuter is permitted to operate in the fuel-conservation mode, however, a useful operational flexibility is seen. For incremental gust-response limits above .41 g, the vehicle operates in the minimum-sweep mode at speeds nearly identical to those of the fixed-wing baseline and at fuel use from 2 percent above to slightly below those of the latter. Where the Δn limit is less than .41 g, wings are swept back and the aircraft maintains an increasing speed advantage as ride-quality constraint becomes increasingly stringent. Below this Δn limit of .41 g, fuel use varies from 6 percent greater to 14 percent less than that for the fixed-wing baseline. Thus, the variable-sweep commuter can be tailored to the mission requirement. In smooth air, the low-sweep or fuel-conservation cruise may be used. As the atmosphere becomes more turbulent, a fuel conserving, throttle-back mode or a faster (but less fuel-efficient) wings-back/throttle-forward mode may be selected. A point worth noting, in comparing the fixed-wing baseline with the swing-wing commuter in its fuel-conservation mode, is the effect of being able to descend in the latter at maximum sweep. This ability provides a very slight time and fuel advantage over the fixed wing vehicle as Δn limiting begins to take effect.

The constrained mission-performance summary represented by figure 9 extends the data of figure 8 to cover both altitudes (5,000 ft and 10,000 ft) on the 100 n.mi. mission, and adds the two 250 n.mi. mission at those two altitudes. While the effect of increasing altitude is to reduce the restrictive effect of ride-quality constraint, the effects are qualitatively the same as noted in the discussion of the previous figure. Increasing stage length seems to simply magnify the effects noted for the shorter mission.

A review of the mission-performance results shows that a variable-sweep commuter can, in multi-mode operation, provide a useful flexibility in meeting a variety of mission requirements and flight conditions. Further, it offers the commuter operator a passive solution to the dual problem of avoiding high levels of passenger discomfort and structural fatigue loads without sacrificing the speeds necessary to maintaining schedules and, hence, flight connections. This latter may be important in operations where there are typically a dozen or more flights per aircraft per day.

CONCLUDING REMARKS

A study was conducted of the effects of variable-sweep wings on the ride-quality and mission-performance characteristics of commuter-type aircraft. Accordingly, a pair of aircraft -- a fixed wing baseline and a variable-sweep vehicle -- were configured and evaluated. Both were twin-turboprop, pressurized-cabin, 30-passenger commuters with identical mission requirements. Mission performance was calculated with and without various ride-quality constraints for cruise altitudes of 5,000 and 10,000 feet at stage lengths of both 100 and 250 nautical miles.

To meet the design-mission requirements, the variable-sweep aircraft commuter required a gross weight almost four percent greater than the fixed-wing baseline. However, a two-mode operation of the variable-sweep configuration -- climb and cruise at minimun sweep in a quiescent atmosphere, and at maximum sweep in turbulence -- provides for less than a three percent fuel-use penalty in smooth-air operation and, depending upon the severity of ride-quality constraint, improvements in both fuel economy and flight times in rough air.

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2. "Shorts SD3-30," Aircraft Engineering; October 19, 1974.

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4. Paniszczyn, Thomas F.: "Prediction of Lift and Aerodynamic Center for Variable-Sweep Wings," AIAA Paper No. 67-135. January 23-26, 1967.

5. British Data Sheets: Item 70011 with Amendment C, July 1977.

6. "Low-Wing-Loading STOL Transport Ride-Smoothing Feasibility Study," NASA CR-111819, 1971.

TABLE I. - GEOMETRIC CHARACTERISTICS OF STUDY CONFIGURATIONS

(a) Variable-Sweep Configuration

WING:	
Reference area, sq. ft.	525.7
Mean geometric chord, at min. sweep, ft.	9.87
Tip chord, ft.	3.60
Centerline chord, ft.	18.10
L.E. sweep, fixed panels, deg.	41.2
L.E. sweep, outboard panels, deg.	
at minimum sweep	20.0
at maximum sweep	66.8
Span, ft.	
at minimum sweep	73.70
at maximum sweep*	49.88
Aspect Ratio (ref.):	
at minimum sweep	10.33
at maximum sweep*	4.73
HORIZONTAL TAIL:	
Reference area, sq. ft.	70.00
Mean geometric chord, ft.	4.13
Tip chord, ft.	2.27
Root chord, ft.	5.53
L.E. sweep, deg.	15.9
Span, ft.	17.95
Aspect ratio	4.6
VERTICAL TAIL:	
Reference area, sq. ft.	60.10
Mean geometric chord, ft.	7.16
Tip chord, ft.	3.06
Root chord, ft.	10.03
L.E. sweep, deg.	47.1
Height, root to tip, ft.	9.19

* To intercept of extensions of leading edge and tip chord.

TABLE I. - CONCLUDED

(b) Fixed-Wing Commuter Configuration

WING:	
Reference area, sq. ft.	491.6
Mean geometric chord, ft.	9.54
Tip chord, ft.	3.48
Centerline chord, ft.	17.50
L.E. sweep, inboard panel, deg.	41.2
L.E. sweep, outboard panel, deg.	20.0
Span, ft.	71.27
Aspect ratio (ref.)	10.33
HORIZONTAL TAIL:	
Reference area, sq. ft.	65.50
Mean geometric chord, ft.	3.99
Tip chord, ft.	2.20
Root chord, ft.	5.35
L.E. sweep, deg.	15.9
Span, ft.	17.36
Aspect ratio	4.6
VERTICAL TAIL:	
Reference area, sq. ft.	60.10
Mean geometric chord, ft.	7.16
Tip chord, ft.	3.06
Root chord, ft.	10.03
L.E. sweep, deg.	47.1
Height, root to tip, ft.	9.19

TABLE II. - WEIGHTS SUMMARY
(WEIGHT IN POUNDS)

	VARIABLE-SWEEP COMMUTER		FIXED-WING COMMUTER	
o $W_{STRUCTURE}$	6,390		5,630	
o $W_{PROPULSION}$	1,630		1,630	
o $W_{SYSTEMS}$	5,960		5,930	
W_{EMPTY}		13,980		13,190
o W_{CREW} +	555		555	
o $W_{OIL,\ H_2O,\ ETC.}$	655		655	
O.W.E.		15,190		14,400
o $W_{PAYLOAD}$	6,000		6,000	
ZERO-FUEL WT.		21,190		20,400
o W_{FUEL}	1,810		1,795	
T.O. GROSS WT.		23,000		22,195

TABLE III. - MISSIONS

RANGE, n.mi.	LIMIT ALT., ft	LIMIT Δn, g's
250	5,000	NO LIMIT
↓	↓	1/2
↓	↓	1/4
↓	10,000	NO LIMIT
↓	↓	1/2
↓	↓	1/4
100	5,000	NO LIMIT
↓	↓	1/2
↓	↓	1/4
↓	10,000	NO LIMIT
↓	↓	1/2
↓	↓	1/4

NOTE: 2/3 PASSENGER LOAD FACTOR (4,000 LBS.) : SIZING FUEL.

TABLE IV. - PERFORMANCE SUMMARY

			FIXED-WING COMMUTER		VARIABLE-SWEEP COMMUTER					
	LIMITS:				RIDE-QUALITY-MODE			FUEL-CONSERVATION-MODE		
MISSION DIST., n.mi.	ALT., ft.	Δn, g's	FUEL, lbs.	TIME, min.	Λ_{LE}*	FUEL, lbs.	TIME, min.	Λ_{LE}*	FUEL, lbs.	TIME, min.
250	5,000	NONE	884	77.0	20 67 67	963	66.8	20 20 67	907	77.0
		1/2	884	77.2	20 67 67	963	66.8	20 20 67	907	77.0
		1/4	1,141	125.6	67 67 67	969	67.2	67 67 67	←	
	10,000	NONE	789	78.3	20 67 67	881	68.7	20 20 67	807	78.2
		1/2	790	78.5	20 67 67	881	68.7	20 20 67	807	78.2
		1/4	903	106.3	67 67 67	900	69.5	67 67 67	←	
100	5,000	NONE	365	30.9	20 67 67	393	27.2	20 20 67	372	30.9
		1/2	367	31.1	20 67 67	393	27.2	20 20 67	372	30.9
		1/4	466	50.0	67 67 67	400	27.6	67 67 67	←	
	10,000	NONE	338	31.3	20 67 67	369	28.4	20 20 67	346	31.3
		1/2	340	31.5	20 67 67	369	28.4	20 20 67	346	31.3
		1/4	394	43.9	67 67 67	385	28.9	67 67 67	←	

NOTE: 2/3 PASSENGER LOAD FACTOR (4,000 LBS.) : SIZING MISSION FUEL.

*LEADING-EDGE SWEEP ANGLES SHOWN ARE IN DEGREES AND CORRESPOND IN DESCENDING ORDER TO THOSE FOR CLIMB, CRUISE, AND DESCENT, RESPECTIVELY.

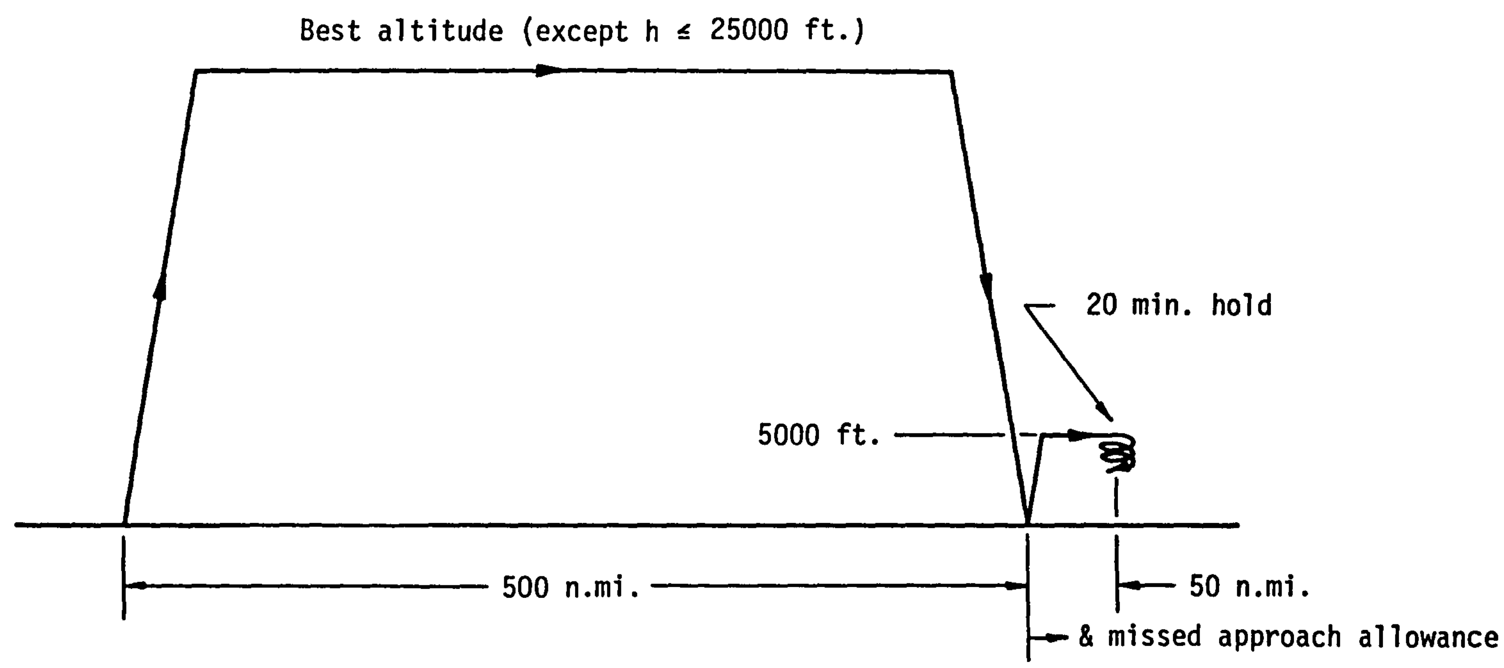
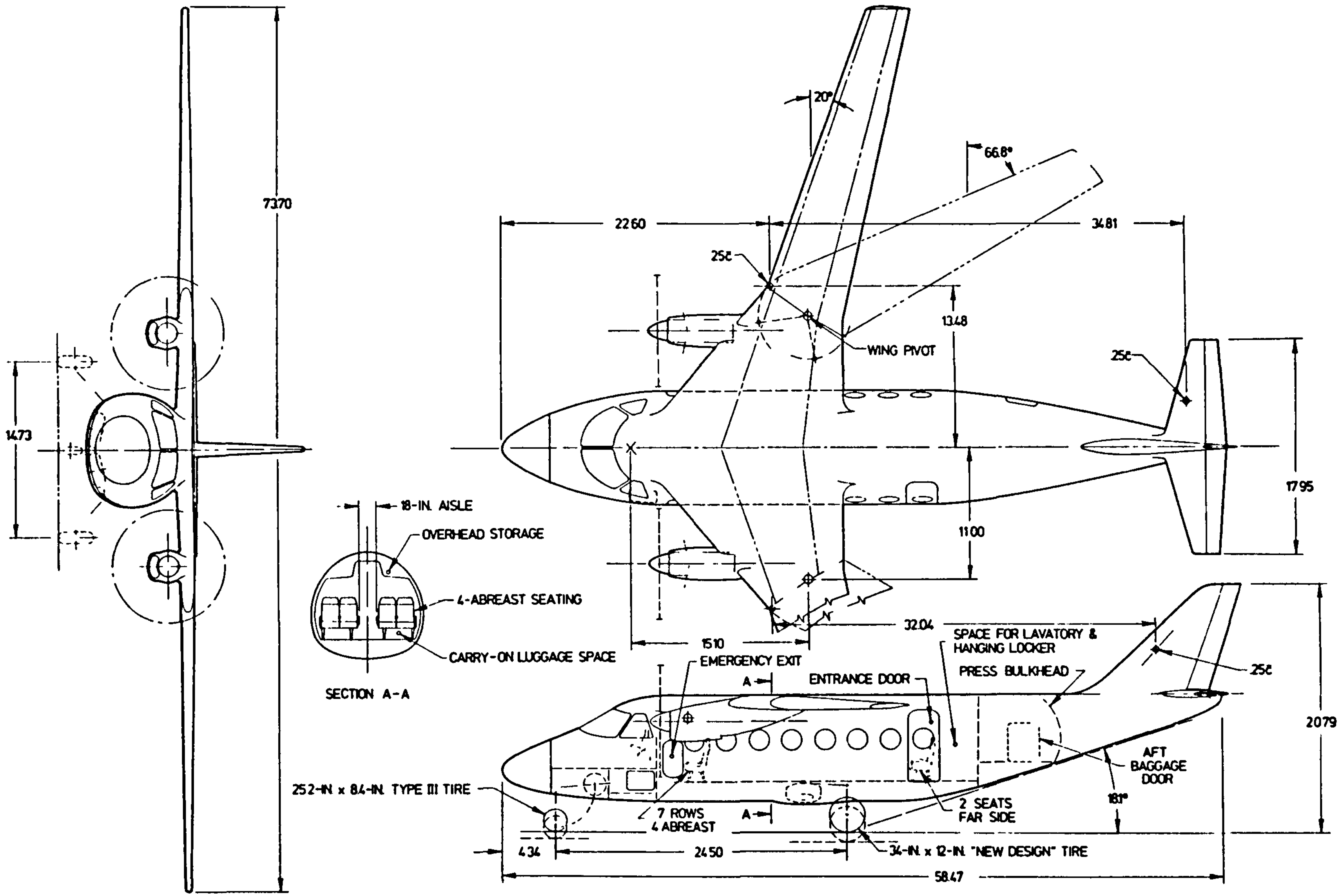
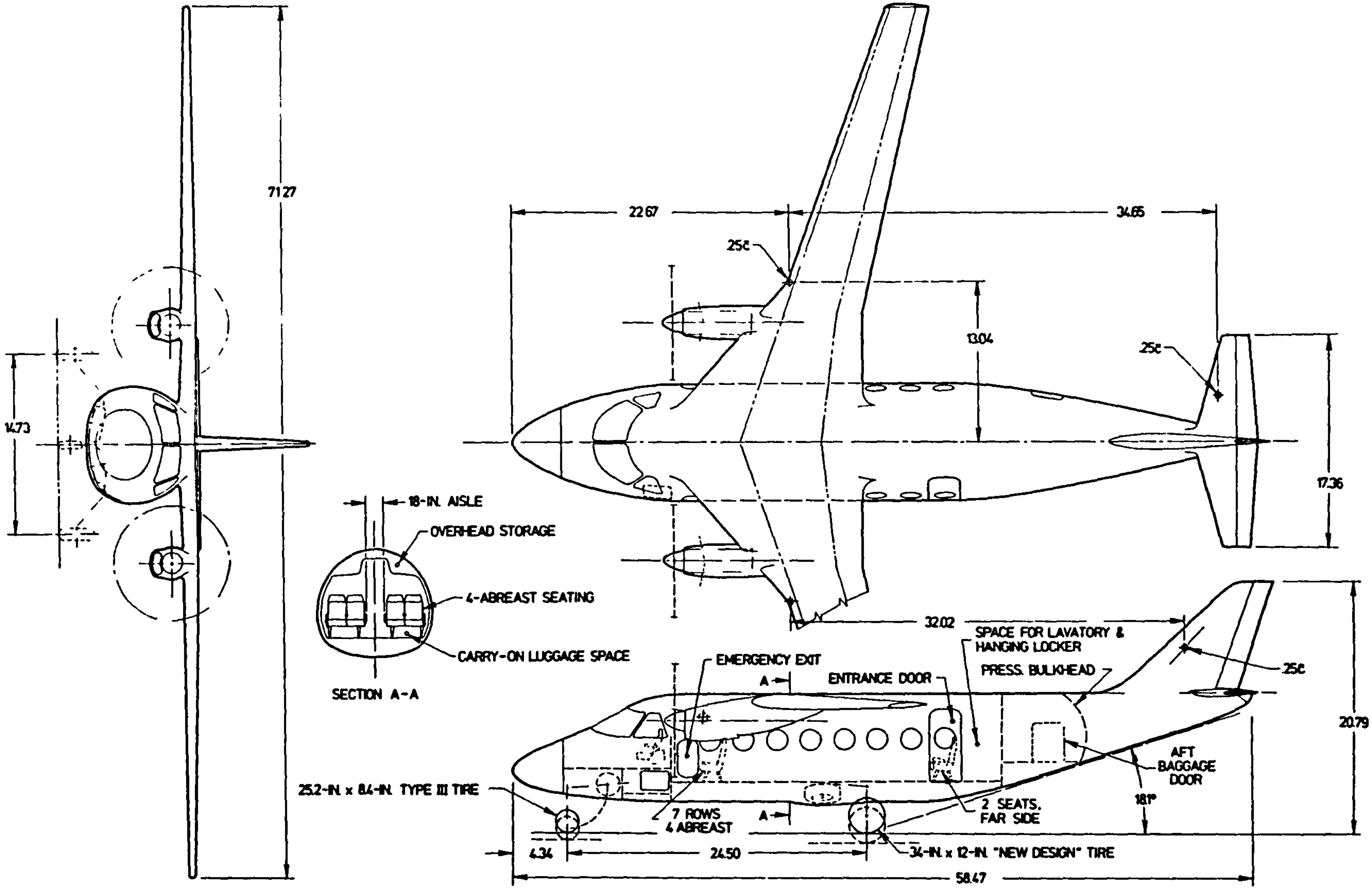


Figure 1.- Sizing mission.



(a) Variable-sweep configuration.

Figure 2.- General arrangement drawings of study aircraft. Dimensions in feet unless otherwise noted.



(b) Fixed-wing configuration.

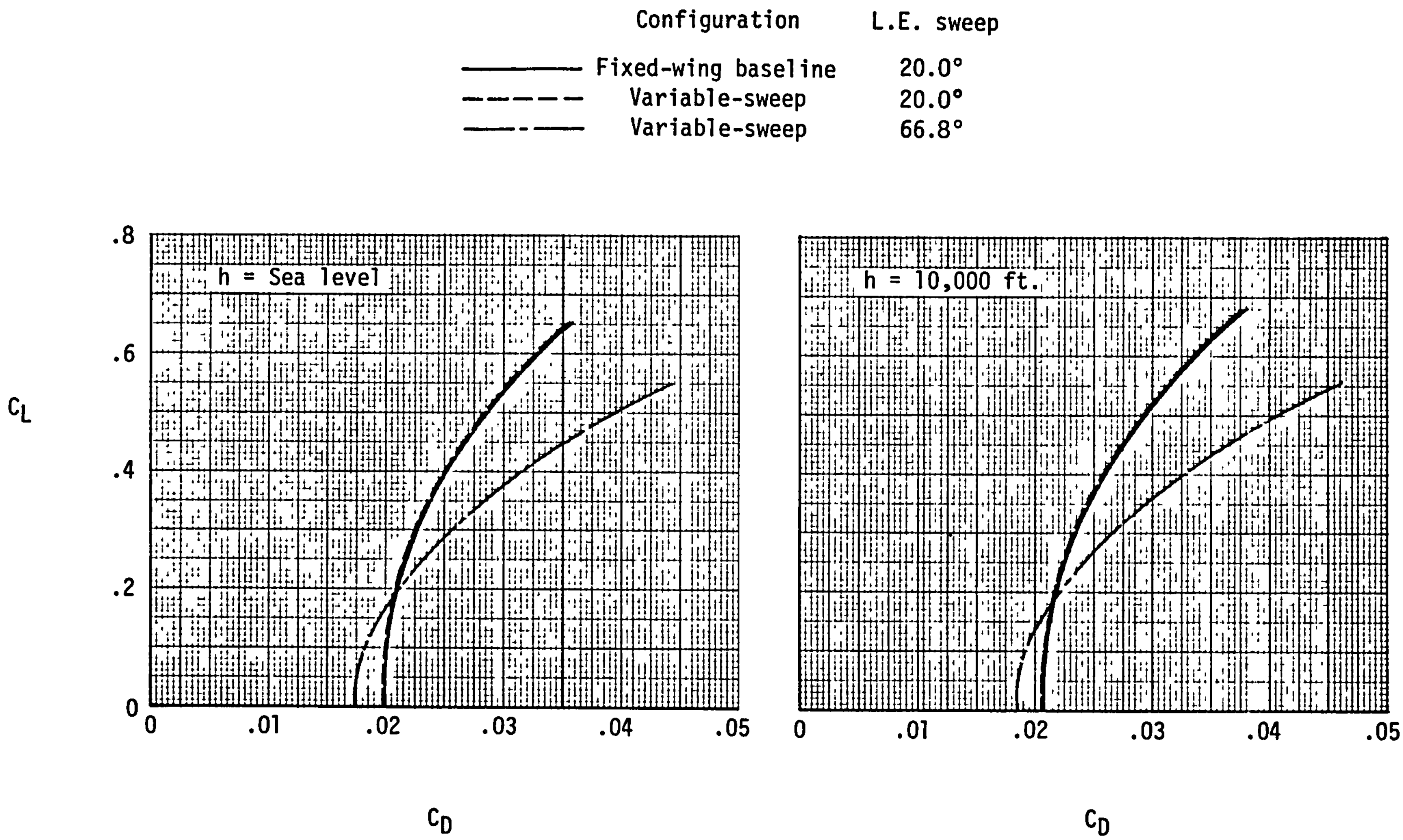


Figure 3.- Drag polars for the fixed-wing baseline and variable-sweep configurations at M = .4.

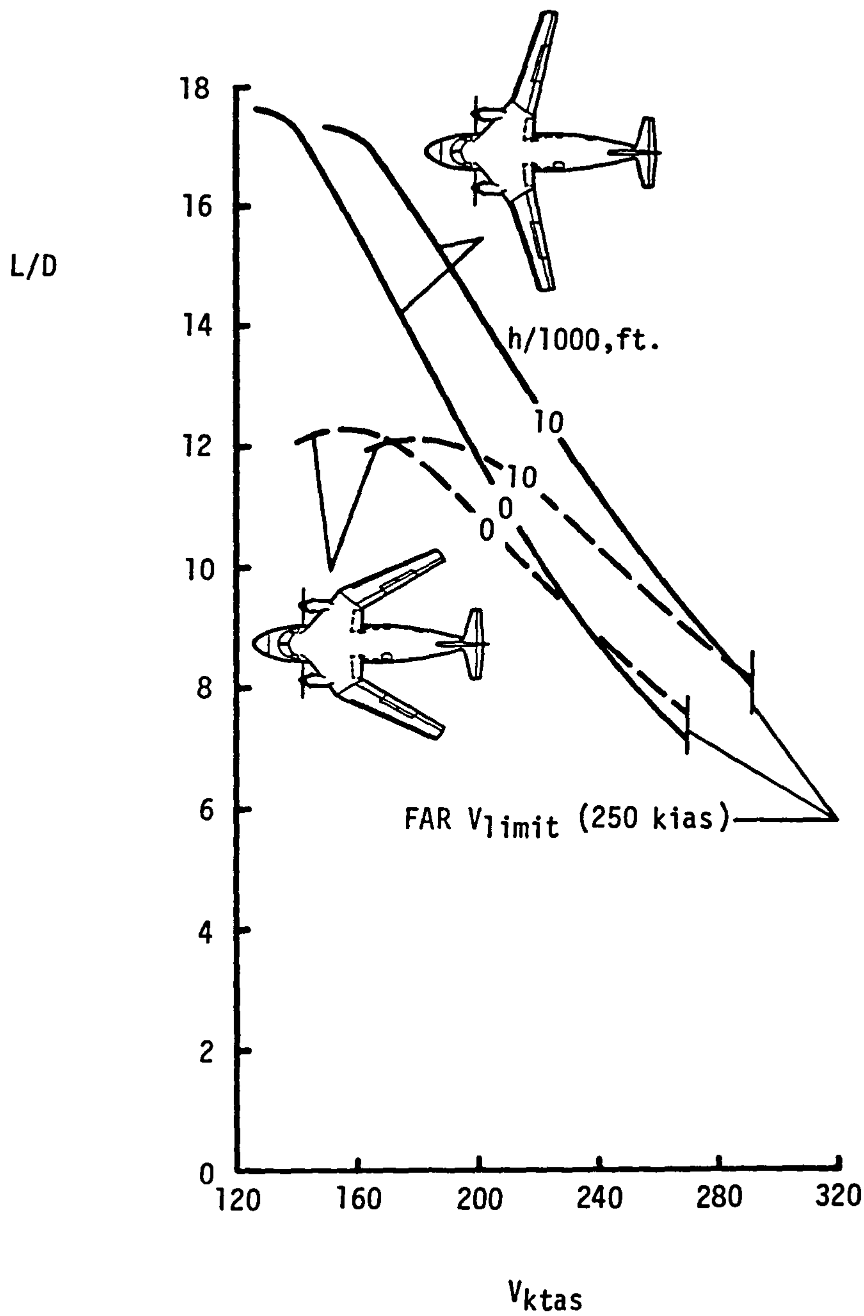


Figure 4.- Lift-drag ratio versus airspeed for the variable-sweep configuration at minimum and maximum wing sweep. W/S = 36.4 psf.

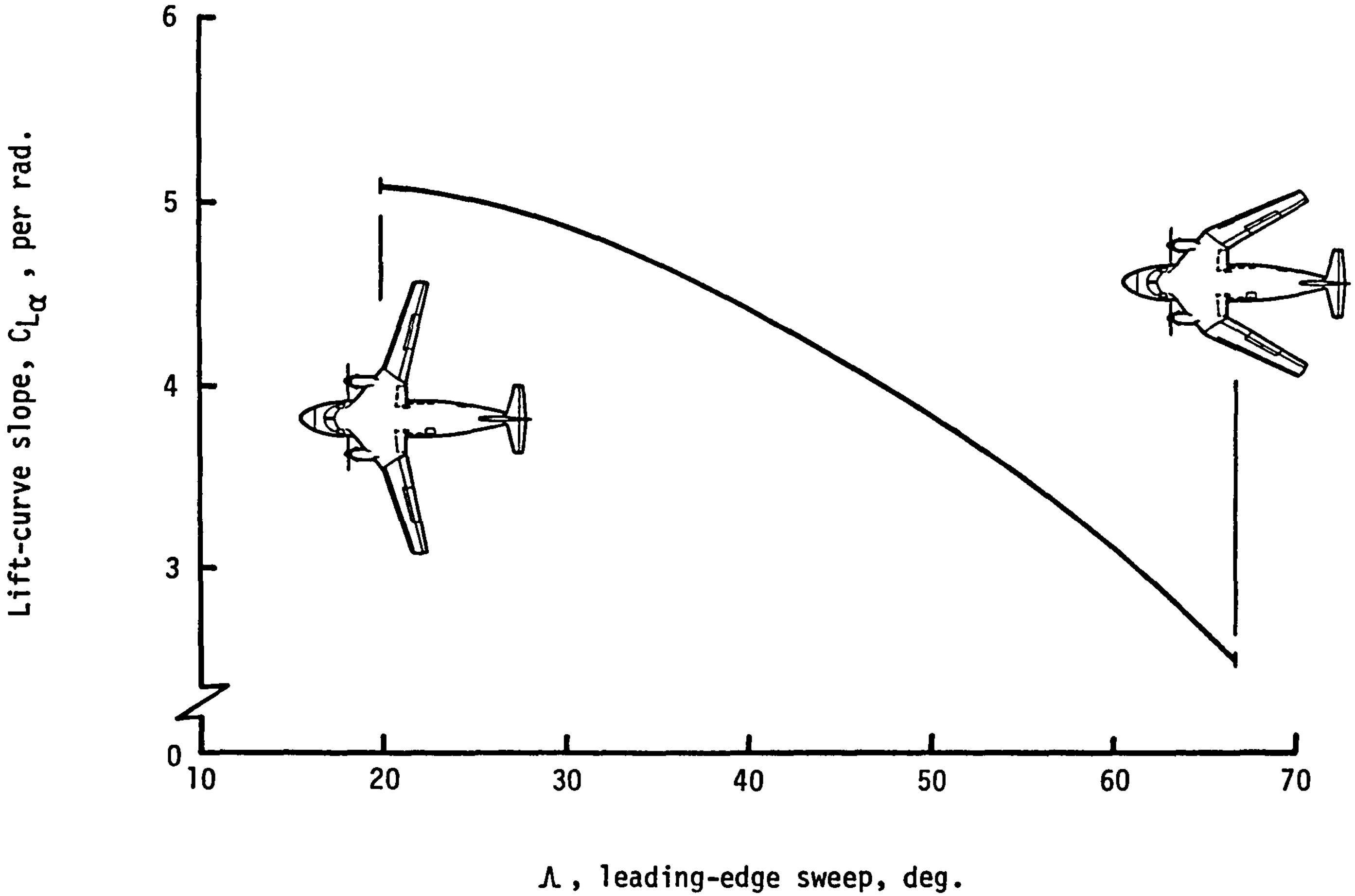


Figure 5.- Variation of lift- curve slope with wing leading-edge sweep.
Variable-sweep configurarion at M = .4.

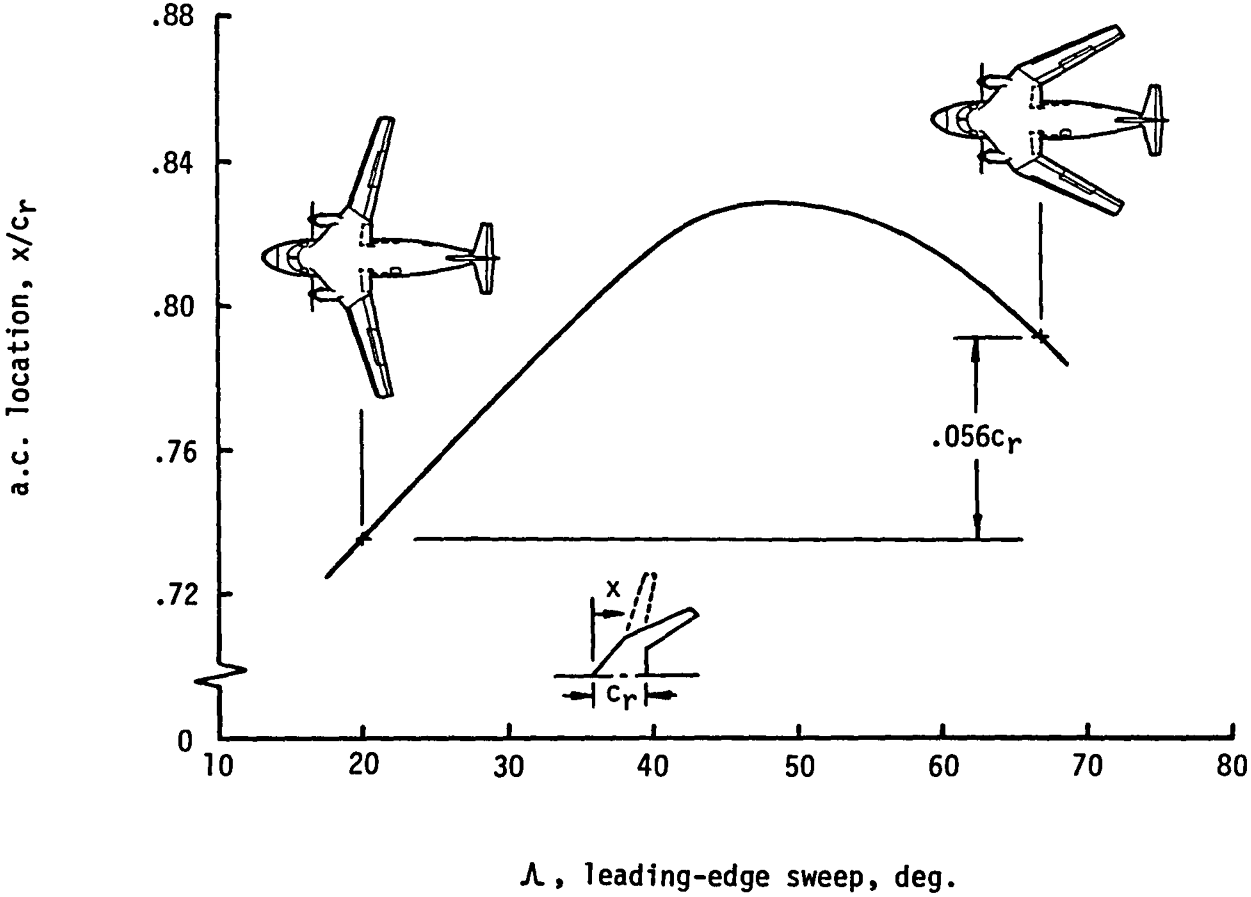


Figure 6.- Variation of aerodynamic center with wing leading-edge sweep. Variable-sweep configuration with horizontal tail off. M = .4.

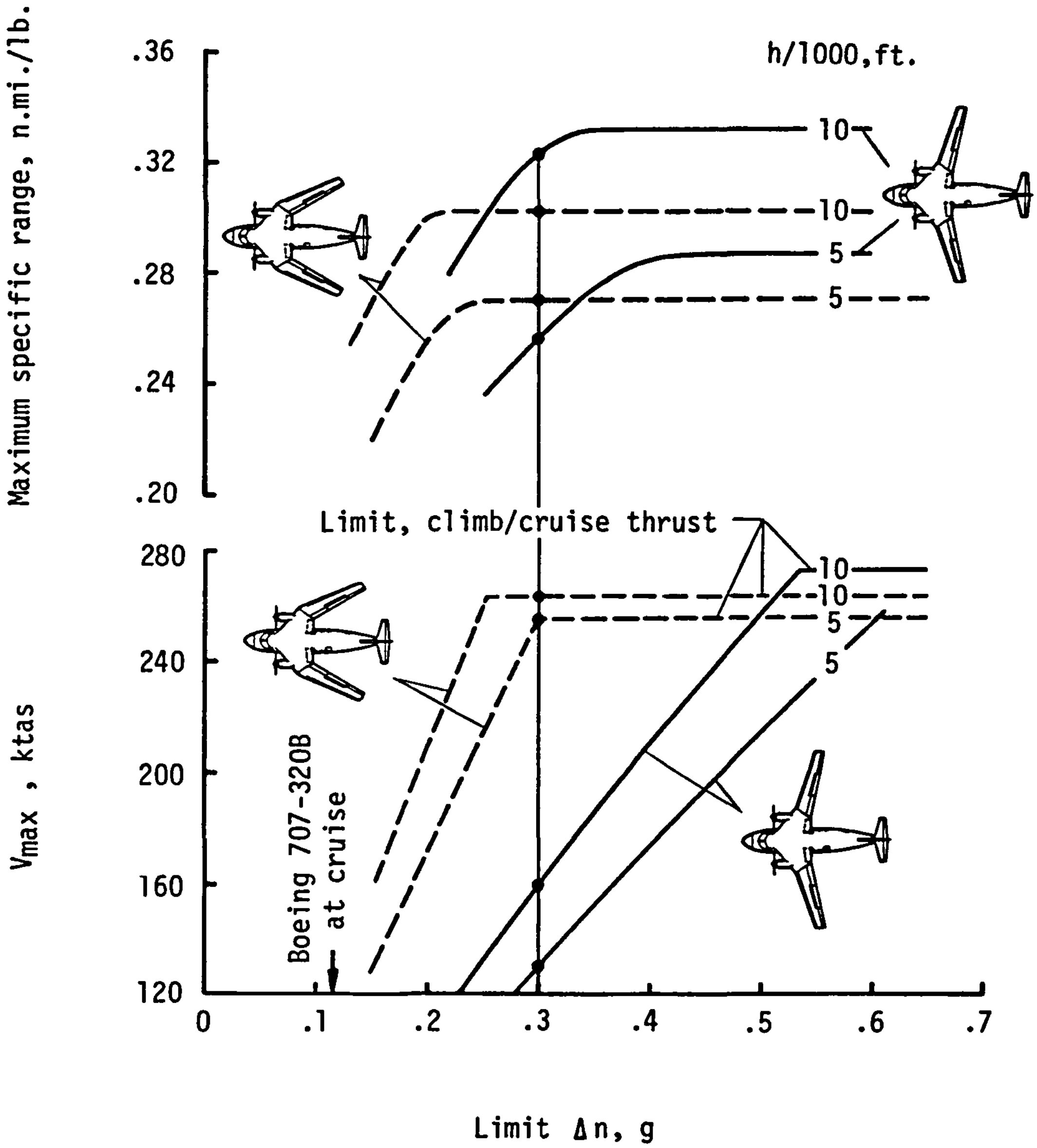


Figure 7.- Effect of limiting incremental gust-response load factor on the speed and specific range of the variable-sweep configuration at minimum and maximum wing sweep. W/S = 36.4 psf.

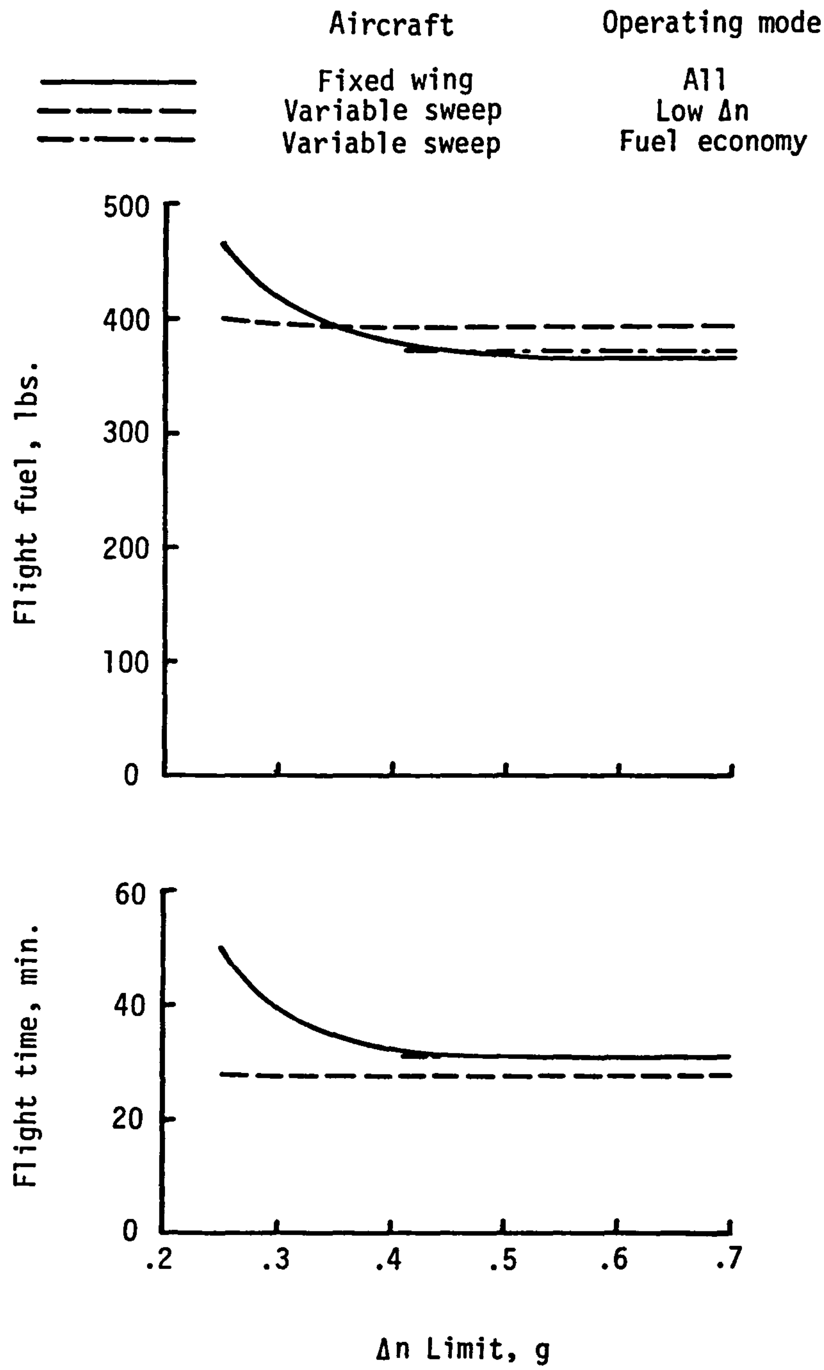


Figure 8.- Comparative gust-response-limited mission performance. Mission length = 100 n. mi. Altitude = 5000 feet.

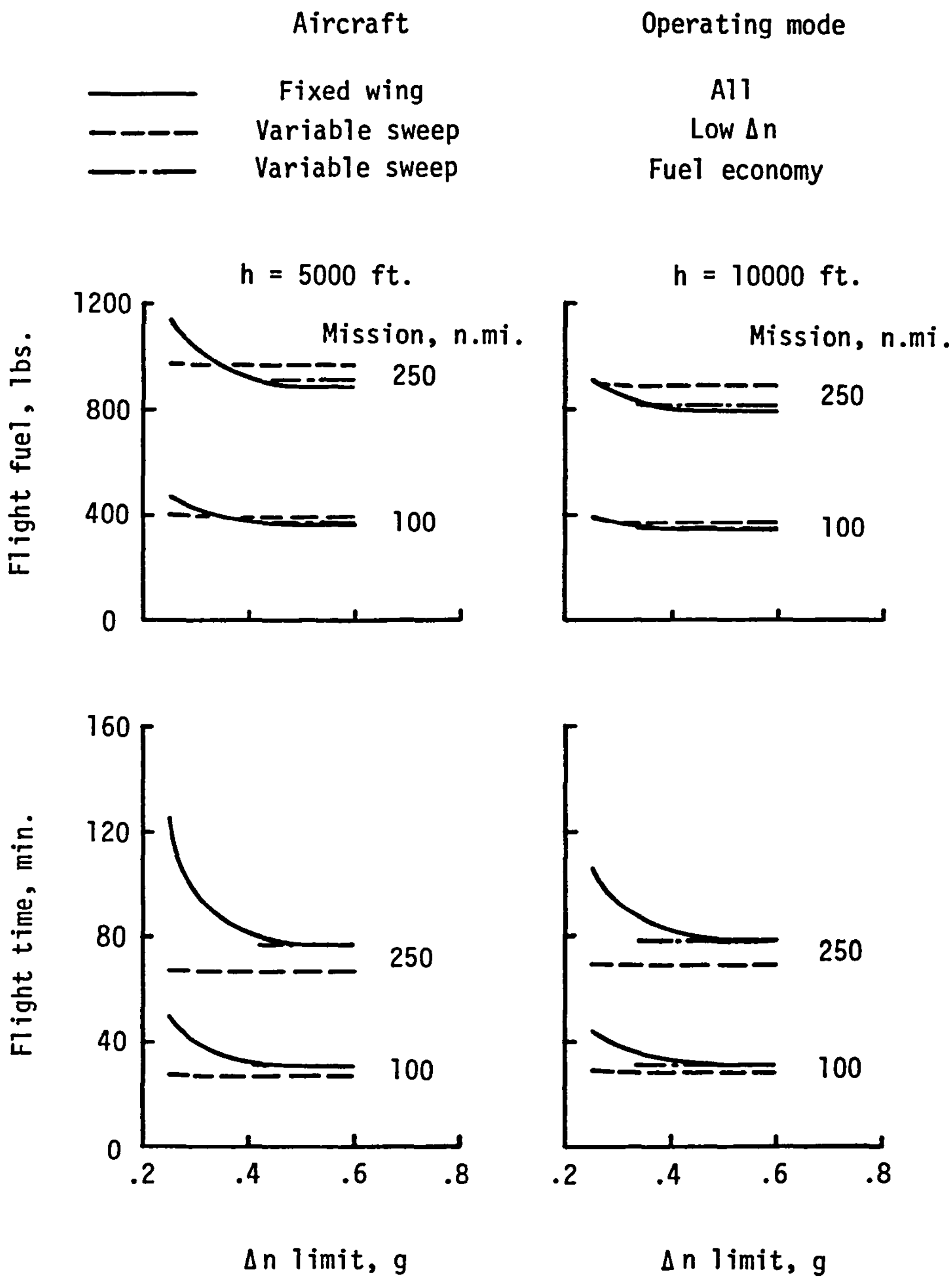


Figure 9 .- Comparative gust-response-limited mission performance.

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15. Supplementary Notes

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16. Abstract

A study was conducted of the effects of using variable-sweep wings on the ride-quality and mission-performance characteristics of commuter-type aircraft. A fixed-wing baseline vehicle and a variable-sweep version of the baseline were designed and evaluated. Both vehicles were twin-turboprop, pressurized-cabin, 30-passenger commuter aircraft with identical mission requirements. Mission performance was calculated with and without various ride-quality constraints for several combinations of cruise altitude and stage lengths.

The variable-sweep aircraft had a gross weight of almost four percent greater than the fixed-wing baseline in order to meet the design-mission requirements. In smooth air, the variable sweep configuration flying with low sweep had a two to three percent fuel-use penalty. However, the imposition of ride-quality constraints in rough air can result in advantages in both fuel economy and flight time for the variable-sweep vehicle flying with high sweep.

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