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NASA Technical Memorandum 78474

(NASA-TM-78474) EFFECT OF HIGH LIFT FLAP SYSTEMS ON THE CONCEPTUAL DESIGN OF A 1985 SHORT-HAUL COMMERCIAL STOL TILT ROTOR TRANSPORT (NASA) 29 p HC A03/MF A01 CSCL 01C G3/05
N78-21094
Unclas
14069

Effect of High Lift Flap Systems on the Conceptual Design of a 1985 Short-Haul Commercial STOL Tilt Rotor Transport

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April 1978

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SUMMARY

This study compared two conceptual design 1985 tilt rotor transports for a 370 kilometer (200 nautical mile) short haul mission. The first of these concepts was a derivative of previous designs, while the second had a complex mechanical flap system similar to a short field B737 aircraft. This flap system allowed lift to be shifted from the rotor system to the wing, permitting a 26 percent reduction in dynamic component weight, while also permitting the use of a smaller wing. Although both tilt rotors were designed to cruise at 350 knots, this speed was closer to optimum for the high lift wing concept because its increased wing and disc loadings. The wing and disc loading of this concept were 5746 (120 psf) and 1915 (40 psf) newtons per square meter respectively, while the wing and disc loading of the derivative concept were 4788 (100 psf) and 1197 (25 psf) newtons per square meter respectively.

The high lift wing tilt rotor showed slightly improved fuel usage over its entire operating range and about six to eight percent improvement in direct operating costs, resulting from its improved cruise efficiency, but also partially due to its reduced weight. While both concepts had similar operating costs to conventional jet transports flying a similar mission, each of the tilt rotor concepts used less than half of the fuel required by these conventional transports.

The main advantages of a high lift flap system for a short haul tilt rotor as determined by this study are: improved operating economy; improved reliability with potentially reduced maintenance resulting from the shift of structural weight from dynamic to passive elements; and, improved ride quality resulting from the smaller rotors and higher wing loadings. The main disadvantage of this concept appears to be the loss of VTOL conversion potential and a limitation to short field operations.

INTRODUCTION

The potential of the vertical takeoff and landing (VTOL) tilt rotor concept to provide a fuel conservative aircraft while alleviating the problems of noise and airport congestion led to its consideration as a 1985 civil transport aircraft candidate. Several NASA studies have explored the design requirements of tilt rotor civil transports for the mid 1980's and investigated and identified the technological risk involved in the development of this transport concept (1,2).

Additional gains in fuel conservation and operating economy can usually be made by giving up VTOL capability and operating in a short takeoff and landing (STOL) mode. Two recently completed studies show that substantial improvements can be made in the fuel economy, ride quality and operating costs of the tilt rotor transport by increasing the field length to 610 meters (2000 feet) (1,3). In these studies engine power was reduced to reflect the decreased takeoff requirements, resulting in reduced cruise speed capability. As aircraft productivity is a function of block speed, this cruise speed reduction partially offsets the economic benefits resulting from short field operation (3).

Cruise speed and aircraft productivity can be increased by improving the high speed efficiency of the vehicle. This goal may be accomplished by reducing the rotor size, leading to improved rotor performance at high speed and to significant reductions in rotor and drive system weight. The vehicle wing loading can also be increased, resulting in improved vehicle high speed aerodynamic performance and ride qualities. However, the short field capability of such a transport design rapidly disappears due to the effect of these changes on the static thrust and approach speed of the aircraft. In addition, the transition speed is increased and terminal area maneuvers and safety may be adversely effected.

One solution to this problem is to provide a more efficient wing at low speeds in order to offset the decreased wing area and make up for the reduced rotor lift capability during transition. This increased low speed wing performance can be provided by mechanical flap system similar to those developed for reduced field length operations in recent short haul transport system studies (4,5).

This investigation was conducted to assess the effect of an efficient high lift mechanical flap on the performance, economics and design requirements of a 100 passenger 1985 short haul tilt rotor transport aircraft. The approach used was to develop design point airplanes with and without high lift mechanical flaps and to compare their design characteristics, operating costs and performance. Each aircraft had the same mission and payload requirements, with maximum speed identical to the 350 knot VTOL tilt rotor transport of Reference 2.

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METHOD OF ANALYSIS

Two design point short haul tilt rotor aircraft were developed by "flying" them on a standard mission. The VASCOMP II computer code was used for aircraft performance and sizing.[6] In addition, both aircraft were required to takeoff and land within a balanced field length of 610 meters (2000 feet), and to meet the recommended minimum requirements of Reference 7 in the terminal areas.

In order to provide a consistent basis within this study, the STOL tilt rotor aircraft of Reference 2 was slightly redesigned to be capable of a 350 knot maximum cruise speed. This aircraft, referred to here as the "plain flap tilt rotor" and shown in Figure 1, is modified mainly in its fuselage layout and tail volume coefficients and is equipped with plain trailing edge flaps. The second design point airplane, referred to as the "high lift wing tilt rotor," is significantly different as can be seen in the composite of Figure 2. In this design the wing loading is increased and the rotor diameter decreased in order to provide an efficient high speed cruise and to offset the additional flap weight. This design requires a very high operating lift coefficient during low speed operation because of its high wing loading and higher thrust loading of its rotors. This lift is provided by a fairly sophisticated flap system consisting of triple slotted flaps as shown in Figure 3. A comparison of the characteristics of both design point aircraft is made in Table I.

An assessment of the low speed characteristics of each design was made in order to insure adequate performance margins in terminal area operations. The effectiveness of parametric changes was determined by comparing the changes in vehicle empty weight and mission fuel required. An attempt was made to reduce these weights as much as possible while retaining the best features of the VTOL tilt rotor performance. The fuel economy and economics of each aircraft were determined at the design point and variations are presented for off-design performance.

Mission

The typical mission profile is shown in Figure 4 and is identical to the missions used in the previous studies (1-3). The two design point aircraft were optimized to carry 100 passengers over a 370 kilometer range (200 n.m.), with a maximum cruise speed of 350 knots. The design cruise altitude was chosen as 4267 meters (14000 feet) which is optimum for the plain flap aircraft (2,3), and close to optimum for the high lift wing aircraft.

The reserve fuel allowance used in this study includes: (1) fuel for a 92.6 kilometer (50 n.m.) cruise to an alternate airport at normal cruise altitude and best range speed; and, (2) fuel for a 20 minute hold at 1524 meters (5000 feet) at fuel flow for maximum endurance.

Aerodynamics

The aerodynamic performance used to develop the two design point aircraft in this study is based on data provided in Reference 3. The drag values are representative of current transport designs and are corrected for the effects of Reynold's number and standard day altitude conditions. The VASCOMP II computer program sizes the aircraft components and provides an estimation of the total drag, span-wise lift efficiency and the three dimensional lift curve slope. The lift curve slope is used to determine the angle of attack required during the climb and descent phases of the mission and to calculate the airplane load factors. A summary of the aerodynamics characteristics of each of the design point aircraft is given in Table II.

Low Speed Performance - For short field applications, the balanced field requirements and terminal area manuevers, including engine out performance, can have significant impact on aircraft size, weight and cost. Terminal area performance is not directly determined by VASCOMP II, however, and auxiliary studies were performed to define design input parameters such as the level and duration of takeoff thrust, and tail size required.

The takeoff and landing constraints are summarized in Table III. The stall margin (angle of attack) was established to avoid large rapid control applications resulting from sudden changes of lift.

The takeoff static thrust to weight ratio required to meet the hot day, one engine out case for both design point aircraft was calculated, however, in both cases, a greater installed power was required to enable the design point aircraft to attain a maximum speed of 350 knots at the 4267 meter (14000 foot) cruise altitude than was necessary for takeoff.

The control of tilt rotor aircraft at low speeds is accomplished by differential rotor cyclic and collective pitch adjustment and the minimum control speeds V_{MC}'s have little real meaning in relation to this design concept. At higher speeds, the aerodynamic control surfaces are phased in resulting in a conventional airplane control system during cruise. A detailed discussion of the control system is beyond the scope of this paper, however, it can be assumed that adequate control power can be achieved at or below any minimum flight speed (2,3).

The tilt rotor aircraft considered in this investigation have four engines which are interconnected by cross shafting, resulting in an aleviation of the asymmetric control problem. The main characteristic of an engine failure in this type of aircraft is reduced power operation. Engine out operation for both the high lift wing and plain flap aircraft is typified by small reductions in flight path angle with about a 15 to 20 knot increase in forward speed, resulting in a transference of lift from the rotor to the wing. The effect of engine out operation can be minimized, however, by operating initially at reduced power and by providing for a temporary overspeed capability in the remaining engines.

Airframe-Rotor Interference - The effect of rotor downwash on wing lift was investigated in Reference 8. It was found that the wing contributed to the total lift at forward speeds greater than 35 knots and that rotor and wing were essentially independent at forward velocities greater than 80 knots. It was also determined that at speeds as low as 20 knots the rotor induced a strong upwash on the wing leading edge.

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Based on the results of these studies, it was assumed that neither of the design point airplanes would have any significant wing-rotor aerodynamic interference effects. Although this result has not been varified in the case of a tilt rotor with a high lift wing, the greater circulation strength of the high lift wing could be expected to sweep the rotor wake off the wing at even lower forward airspeeds.

Weights and Dimensions

The weight and structural technology level believed to be representative of a mid 1980's passenger transport was used to develop the two aircraft of this study, thus the use of composite structures was assumed to give a structural weight reduction of 25% over current transport aircraft structures. The aircraft of this study were also assumed to use fly-by-wire control systems contributing to further weight reductions over conventional control systems. The dimension and weight summaries for the design point aircraft are presented in Tables IV and V. It can be noted that the weight of fixed equipment, the useful load, and the payload were constant for both configurations while the structural, propulsion, and flight controls weights were varied. Both aircraft used the same fuselage design which is representative of current DC9/ B737 aircraft.

An examination of Table V shows that the largest weight difference between the two study configurations occurs in the propulsion group. The high lift wing configuration has a higher disc loading rotor, and hence a smaller diameter rotor, yielding a rotor weight reduction of 35 percent. In addition, because the tipspeed increased slightly in cruise, the actual shafting and gear box weight is also reduced because of its higher rotational speed leading to a better power train match. Finally, because of the better cruise match at the design point, the actual engine weight is also slightly reduced, yeilding a total reduction in propulsion group weight of 26 percent over the plain flap wing tilt rotor. The flight controls group is another area where the weight of the high lift wing tilt rotor is reduced, with most of the reduction occurring because of the reduced rotor weight previously mentioned.

Although the structural weight of the high lift wing tilt rotor is slightly reduced, it can be seen that the wing weight of this concept is actually seven percent higher than the plane wing concept even though its wing area is 22 percent less. This weight increase occurs partially because of the higher wing loads, but is principally due to the fact that the high lift wing was penalized for its complex triple-slotted flap system. This flap system with its tracks, complex linkages, and attachment brackets was assumed to weigh 128 percent more than an equivalent area similar flap. In addition, weight was added for the aileron system and for various other control surface differences between this vehicle and the one described in Reference 2. These penality "high lift" factors were input into VASCOMP II and resulted in the structural weight determination described in Table V.

RESULTS AND DISCUSSION

Performance

Performance data are presented for the two short haul tilt rotor configurations, the plain flap and high lift flap wing tilt rotor over a cruise speed range varying from 200 knots to the design point cruise speed of 350 knots. Two intermediate points are also shown, one at the velocity for best range and the other at 99 percent of the best range velocity. Performance for the plain flap tilt rotor was calculated using a wing loading of $4788 N/m^2$ (100 psf) and a disc loading of $1197 N/m^2$ (25 psf) which are identical to the values used for the design point aircraft of Reference 3. High lift wing tilt rotor performance was based on a wing loading of $5746 N/m^2$ (120 psf) and disc loading of $1915 N/m^2$ (40 psf). Although higher values of wing and disc loading were studied, it was felt that the values chosen were at the highest practical limit based on structural, dynamic and other considerations. The cruise performance of the two aircraft configurations is presented in Figure 5. These data are calculated for an altitude of 4267 meters (14000 ft.) on a standard day and with all engines operating. It can be noted that the high lift wing configuration has the better specific range performance of the two aircraft. This may be attributed to its lower gross weight, which is also reflected by the lower fuel consumption of the high lift wing tilt rotor aircraft.

The fuel consumption of the two aircraft concepts is presented in Figure 6 as a function of cruise velocity and is expressed in seat-kilometers per liter (seat-miles per gallon) of fuel. The high lift wing tilt rotor shows improved fuel economy over nearly the entire speed range, from 240 knots to the design point of 350 knots. The design points correspond to a cruise speed obtained with the maximum continuous power setting and rotor speed, and hence do not yield the best fuel consumption. In general, reduced power settings will improve the fuel consumption for both configurations, but would result in higher direct operating costs due to reduced aircraft productivity. At the design point, the plain flap wing tilt rotor gets 27.6 seat-kilometers per liter (65 seat-miles per gallon) while the high lift wing tilt rotor gets a slightly better 28.5 seat-kilometers per liter (67 seat-miles per gallon), however, for comparison, a conventional fan jet transport (DC-9/B737) flown on this same mission gets about 8.5 to 12.8 seat-kilometers per liter (20 to 30 seat-miles per gallon) (10,11).

Operating Economics

A utilization rate of 2500 hours per year was assumed in computing the economics for the two airplanes of this study. The variation of the direct

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operating cost (DOC) with cruise speed for both configurations is shown in Figure 7, plotted in 1976 dollars. These costs were calculated using the standard AIA model (9,6) with cost parameters updated based on current industry costs figures (10,11). At the design point, the plane wing tilt rotor has a direct operating cost of 2.19 cents per available seat kilometer while the high lift wing tilt rotor has a DOC of 2.09 cents per available seat kilometer, a savings of slightly more than six percent. As a comparison the 1976 DOC's of the small jets (DC-9, B737) varied from a low of about 1.94 cents to a high of over 2.5 cents per available seat kilometer (11,12) where the lower cost was generally associated with local service operations and the higher cost with the larger trunk operators. The most representative cost numbers from the stand point of mission, operation, size and block time are spotted on Figure 7 for several DC-9-10 routes and are in the neighborhood of 2.19 cents per available seat kilometer. The air carrier values are spotted as a function of block speed and hence can be compared with the design point tilt rotors. As a further comparison, current turboprop transports have operating costs in the neighborhood of 2.5 cents per available seat kilometer, hence the tilt rotor vehicles compare very favorably with current short-haul transport aircraft in cost and fuel economy.

Noise

Another area where the tilt rotor vehicles show a significant advantage over the current jet transports is in their community noise impact. Based on the data developed in Reference 3, the airport/community area impacted by noise levels of 90 EPNL or greater is on the order of three square kilometers, where as the airport/community area impacted by 90 EPNL or greater noise levels is approximately 11 square kilometers for a DC-9 type aircraft. While the tilt rotor aircraft considered in this study had significantly different disc loadings, the primary rotor effect on noise level is rotor tip speed, with only a small effect due to disc loading. Hence, as both vehicles had about the same tipspeed in terminal operations, it is to be expected that their noise impact areas are approximately the same.

CONCLUDING REMARKS

In several recent NASA studies, relaxing the vertical takeoff and landing requirement for a tilt rotor transport resulted in greatly improved fuel economy but in only slightly improved operating economics. In the present study two derivative tilt rotor transports were considered. The first one was similar to the short field aircraft of the previous studies, and the second one was optimized for high speed cruise, and had a flap system representative of a reduced field B737 aircraft, in order to have similar terminal area operating characteristics.

Both tilt rotor aircraft were designed for a 350 knot cruise speed at a 4267 meter (14000 ft) altitude, with a 100 passenger payload, and made extensive used of an assumed 1985 technology level. The first tilt rotor derivative had wing and disc loadings of 4788 (100 psf) and 1197 (25 psf) newtons per square meter respectively, while the tilt rotor with the high lift wing had its wing and disc loading increased to 5746 (120 psf) and 1915 (40 psf) newtons per square meter respectively which resulted in a 20 knot increase in its best range speed.

Although this second vehicle had slightly better fuel economy and a six to eight percent improvement in direct operating cost, its principal difference is a 26 percent weight reduction in its dynamic components. This weight improvement results from the smaller rotors and the better match of engine and gear box speeds during cruise. However, the wing weight of this high lift tilt rotor increased by seven percent although the wing area decreased by 22 percent indicating a weight shift from dynamic to passive structural elements. The net result was a slightly lower airframe weight for the second tilt rotor concept, which contributed to its lower direct operating costs. These direct operating costs, expressed in 1976 dollars, for the design point plain flap wing and the high lift wing tilt rotors were 2.19 and 2.06 cents per available seat kilometer while costs for the small jet transports (DC-9, B737) on a similar mission were approximately 2.19 cents per available seat kilometer. Although the economics of the two tilt rotor designs are similar to that of the conventional short haul jet transport, the rate of fuel utilization is strikingly different. While the two tilt rotor vehicles have fuel economics of 28 seat-kilometers per liter at the design point, the best jet transports are less than 12 seat-kilometers per liter on a similar mission.

In summary, the principal advantage of the tilt rotor vehicles over conventional short haul jets were their superior fuel economy and their much lower noise impact. The main advantages of the high lift wing tilt rotor over the plain flap wing tilt rotor were: improved operating economy; improved reliability with potentially reduced maintenance resulting from the shift of weight from dynamic to passive structural elements; and improved ride quality and passenger comfort resulting from the higher wing and disc loadings. The main disadvantage of the high lift wing tilt rotor appears reduced VTOL conversion potential limiting it to short field operation.

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REFERENCES

1. DeTore, J. A.; and Sambell, K. W.: Conceptual Design Study of 1985 Commercial Tilt-Rotor Transports. VTOL Design Summary, Volume I, NASA CR-2544; Volume II, NASA CR-137602; STOL Design Summary, Volume III, NASA CR-2690; Volume IV, NASA CR-137765; Bell Helicopter Company, 1975 - 1976.

2. Magee, J. P.; Clark, R. D.; and Alexander, H. R.: Conceptual Design Studies of 1985 Commercial VTOL Transports that Utilize Rotors. Volume I, NASA CR-137599; Volume II, NASA CR-137600; Boeing Vertcl Company, November 1974.

3. Widdison, C. A.; Magee, J. P.; and Alexander, H. R.: Conceptual Design Study of a 1985 Commercial STOL Tilt-Rotor Transport. NASA CR-137601; Boeing Vertol Company, November 1974

4. Douglas Aircraft Company: Study of Quiet Turbofan STOL Aircraft for Short Haul Transportation. Volume I, MDC-J4371; Volume II, NASA CR-114607; Volume III, NASA CR-114608; Volume IV, NASA CR-114609, Volume V, NASA CR-114610; Volume VI, NASA CR-114611, 1973; Summary, NASA CR-2353, 1974.

5. Lockheed-California Company; and Lockheed-Georgia Company: Study of Quiet Turbofan STOL Aircraft for Short-Haul Transportation. Volume I, NASA CR-114612; Volume II, NASA CR-114613, 1973; Summary, NASA CR-2355, 1974.

6. Schven, A. H.: Users Manual for VASCOMP II, The V/STOL Aircraft Sizing and Performance Computer Program. Developed under NAS2-3142 and Revised under NAS2-6107, Boeing Vertol Company, March 1968 and Revised October 1971.

7. Innis, R. C.; Holzhauser, C. A.; and Quigley, H. C.: Airworthiness Considerations for STOL Aircraft. NASA TND-5594, 1970.

8. Gaffey, T. M.; and Maisel, M. D.: Measurement of Tilt Rotor VTOL Rotor Wake Airframe Ground Aerodynamic Interference for Application to Real Time Flight Simulation. AGARD Conference on V/STOL Aerodynamics; AGARD-CPP-143, 1974.

9. Aerospace Industries Association of America, Inc.: Standard Method of Estimating Comparative Direct Operating Cost of Turbine Powered VTOL Transport Aircraft, November 1968

10. Civil Aeronautics Board: Aircraft Operating Cost and Performance Report Financial Analysis and Cost Division, Bureau of Accounts and Statistics; Reports for Fiscal Years 1975 - 1977.

11. Civil Aeronautics Board: Aircraft Operating Cost and Performance Report. Volume XI, 1977.

12. Civil Aeronautics Board: Handbook of Airline Statistics. 1973 - 1975.

TABLE I

Aircraft Characteristics

	Plain Wing A/C		High Lift Wing A/C	
Altitude	4267.2m	(14000 ft)	4267.2m	(14000 ft)
Passengers	100		100	
Maximum Field Length	609.6m	(2000 ft)	609.6m	(2000 ft)
Aspect Ratio	8.5		8.5	
No. Engines	4		4	
Wing Loading	$4788.03 N/m^2$	(100 psf)	$5745.63 N/m^2$	(120 psf)
Disc Loading	$1197.01 n/m^2$	(25 psf)	$1915.21 N/m^2$	(40 psf)
No. of Rotors	2		2	
No. of Blades/Rotor	4		4	
Range	370Km	(200 n.m.)	370K	(200 n.m.)

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TABLE II

AERODYNAMIC SUMMARY

	Plain Flap Wing Aircraft	High Lift Wing Aircraft
C_{D_O}	0.02416	0.02898
$C_{L_{MAX}}$ (Operating)	1.70	2.78
L/D	9.0	9.0
Tail Volume Coefficient	1.43	1.43
Aspect Ratio, Wing	8.5	8.5
Wetted Area	478.8 m^2 (5153.8 ft^2)	431.9 m^2 (4649 ft^2)
Wing Loading	4788 N/m^2 (100 psf)	5745.6 N/m^2 (120 psf)
Disc Loading	1197 N/m^2 (25 psf)	1915.2 N/m^2 (40 psf)

TABLE III

TAKEOFF AND LANDING GROUND RULES FOR SHORT HAUL TILT ROTOR AIRCRAFT

Takeoff - Sea Level 90°F	Landing - Sea Level 90°F
Acceleration: Rolling Friction Coefficient, $\mu = 0.03$. All engines Operating	Approach Speed: (Speed at 10.688 m (35 ft) Obstacle) $V_{AP} \geqslant 1.15\ V_{MCA} \geqslant V_{MCA} + 10$ KT $\alpha \leqslant (\alpha$ Stall - 10°)
Liftoff Speed: $V_{LOF} \geqslant 1.05\ (V_{MCA}$ and $V_{MCG})$	
Rotation: 8 Deg/Sec Maximum	Landing Climbout Gradient:
Climbout Conditions to 10.668 m Obstacle:	
AEO[1]: Climb Gradient $\geqslant$ 6.7% (15:1) (Gear Down)	AEO[1]: Climb Gradient = 3.33% (30:1) (Gear Down)
OEI[2]: Climb Gradient $\geqslant$ 6.7% (15:1) (Gear Up) $\alpha \leqslant (\alpha$ Stall -10°) (Gear Down)	OEI[2]: Climb Gradient = 3.33% (30:1) (Gear Up)
	Flight Path From 10.668 m (35 ft): Maximum Rate of Descent at 10.668 m = 243.84 m/min. (35 ft = 800 ft/min) Maximum Rate of Descent at Touchdown = 91.44 m/min. (300 ft/min)
Speed at Obstacle: $V_2 \geqslant V_{LO} \geqslant 1.15\ V_{MCA} \geqslant V_{MCA} + 10$ KT	Rotation: 8 Deg/Sec Maximum
Factors for Field Length: 1.15 for AEO 1.00 for Engine Cut at Liftoff 1.00 for Accelerated Stop	Deceleration: 1 Sec Time Delay Braking Friction Coefficient, $\mu = 0.35$ 0.4 g Maximum Deceleration on Ground
	Factor for Field Length: Landing Distance from 10.668 m (35 ft) Divided by 0.7

1. AEO = All engines operating
2. OEI = One engine inoperative

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TABLE IV

100 PASSENGER SHORT HAUL TILT ROTOR

DIMENSIONAL SUMMARY

	Plain Wing Aircraft	High Lift Wing Aircraft
Fuselage		
Length	29.63 m (97.2 ft)	29.63 m (97.2 ft)
Width	3.75 m (12.3 ft)	3.75 m (12.3 ft)
Wing		
Span	23.17 m (76 ft)	20.48 m (67.2 ft)
Chord (Geom. Mean)	2.71 m (8.9 ft)	2.41 m (7.9 ft)
Area	63.14 m^2 (679.6 ft^2)	49.34 m^2 (531.1 ft^2)
Aspect Ratio	8.5	8.5
Horizontal Tail		
Span	8.99 m (29.5 ft)	7.47 m (24.5 ft)
Area	17.27 m^2 (185.9 ft^2)	11.93 m (124.1 ft^2)
Volume Coefficient	1.43	1.43
Aspect Ratio	4.67	4.67
Moment Arm	14.26 m (46.8 ft)	14.26 m (46.8 ft)
Rotors		
Diameter	14.05 m (46.1 ft)	9.69 m (31.8 ft)
Number of Blades	4	4
Solidity	0.163	0.163
Disc Loading	1197.01 N/m^2 (25 psf)	1915.21 N/m^2 (40 psf)
Tip Speed, Cruise	200.86 m/sec (659 ft/sec)	236.22 m/sec (775 ft/sec)
Vertical Tail		
Span	4.72 m (15.5 ft)	3.93 m (12.9 ft)
Area	15.90 m^2 (171.1 ft^2)	10.98 m^2 (118.2 ft^2)
Volume Coefficient	0.128	0.128
Aspect Ratio	1.4	1.4
Power		
Number of Engines	4	4
Power/Engine	2.373 MW (3182 hp)	2.127 MW (2853 hp)

TABLE V

100 PASSENGER SHORT HAUL TILT ROTOR

WEIGHT SUMMARY

	Plain Wing Aircraft				High Lift Wing Aircraft			
	Kilograms		(Pounds)		Kilograms		(Pounds)	
Structures Group		7742.8		(17070.0)		7645.8		(16856.1)
Wing	2200.8		(4851.9)		2348.7		(5178.0)	
Horizontal Tail	278.1		(613.1)		220.0		(485.0)	
Vertical Tail	246.8		(544.1)		192.3		(423.9)	
Fuselage	3271.3		(7211.0)		3251.8		(7169.0)	
Landing Gear	1232.9		(2718.1)		1156.2		(2549.0)	
Primary Engine Nacelle	330.2		(728.0)		296.2		(653.0)	
Structure Weight Increment	181.4		(400.0)		181.4		(400.0)	
Propulsion Group		5206.8		(11479.0)		3866.0		(8523.1)
Rotors	1972.7		(4349.1)		1271.4		(2803.0)	
Drive System	1969.5		(4342.0)		1458.3		(3215.0)	
Primary Engines	909.5		(2005.1)		815.6		(1798.1)	
Primary Engine Installation	282.1		(621.9)		252.7		(557.1)	
Fuel System	73.0		(160.9)		67.6		(149.0)	
Flight Controls Group		1634.7		(3603.9)		1270.1		(2800.1)
Cockpit Controls	47.2		(104.1)		45.8		(101.0)	
Upper Controls	591.9		(1304.9)		381.5		(841.1)	
Hydraulics	388.3		(856.1)		268.5		(591.9)	
Fixed Wing Controls	271.2		(597.9)		254.5		(561.1)	
SAS	68.0		(149.9)		68.0		(149.9)	
Tilt Mechanisms	268.1		(591.1)		251.3		(554.0)	
Weight of Fixed Equipment		5601.0		(12348.1)		5601.0		(12348.1)
Weight Empty		20185.3		(44501.0)		18382.9		(40527.4)
Fixed Useful Load		918.5		(2024.9)		918.5		(2024.9)
Operating Weight Empty		21103.8		(46525.9)		19301.4		(42552.3)
Payload		8164.7		(18000.1)		8164.7		(18000.1)
Fuel		1558.1		(3435.1)		1440.6		(3176.0)
Gross Weight		30826.6		(67961.0)		28906.7		(63728.4)

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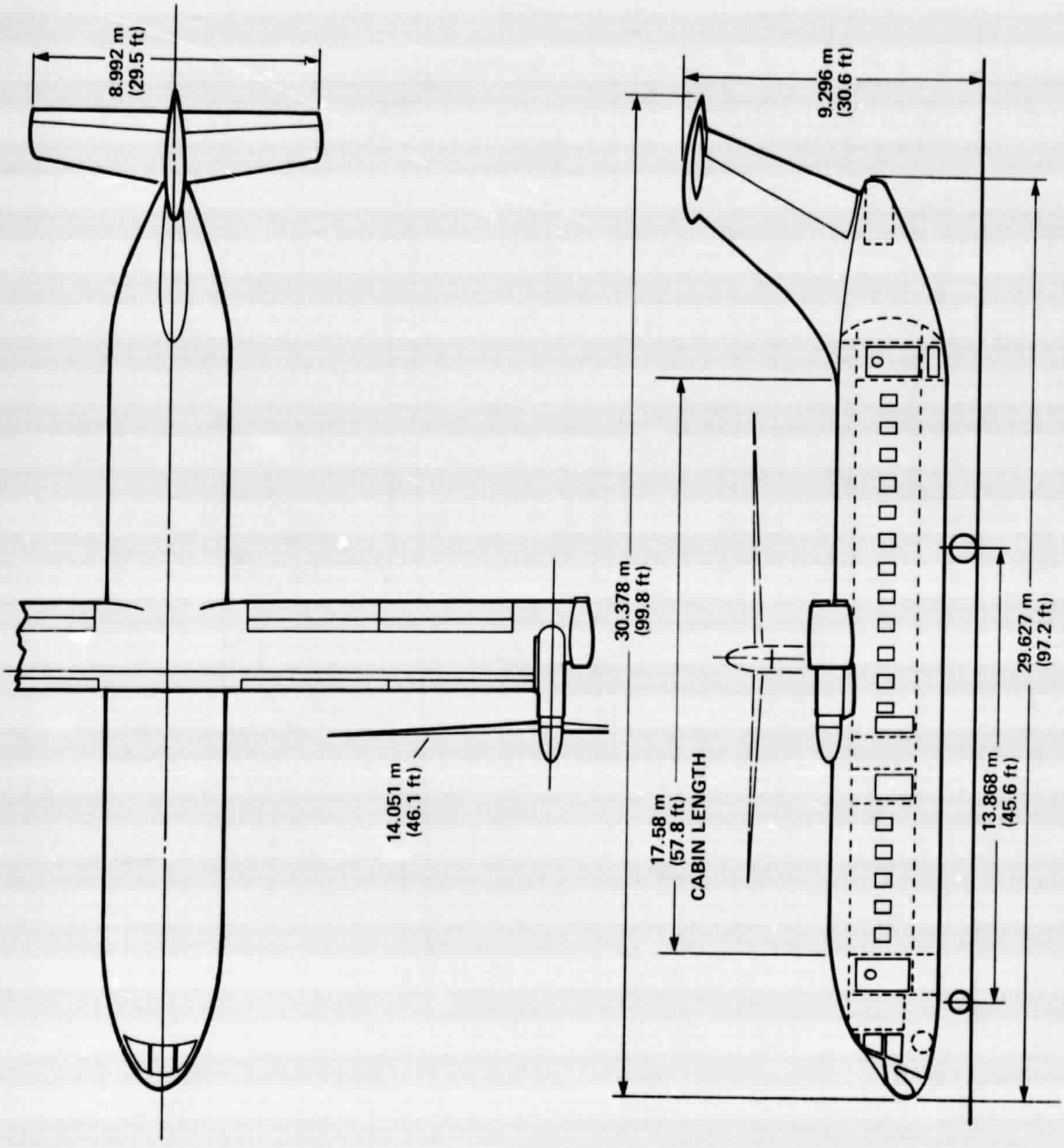

Figure 1.- General arrangement and cabin layout of the plain flap wing STOL tilt rotor aircraft.

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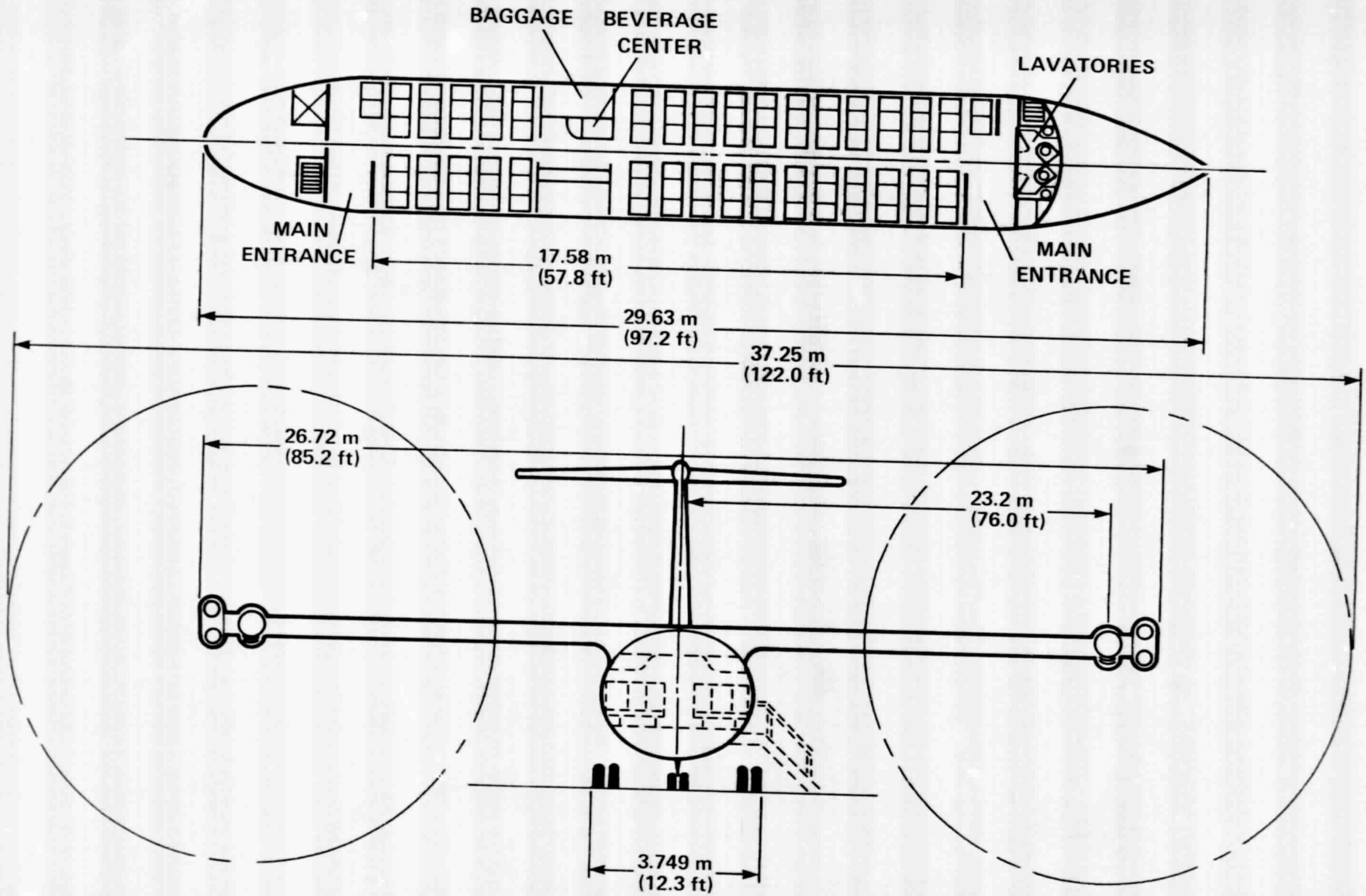

Figure 1.- Concluded.

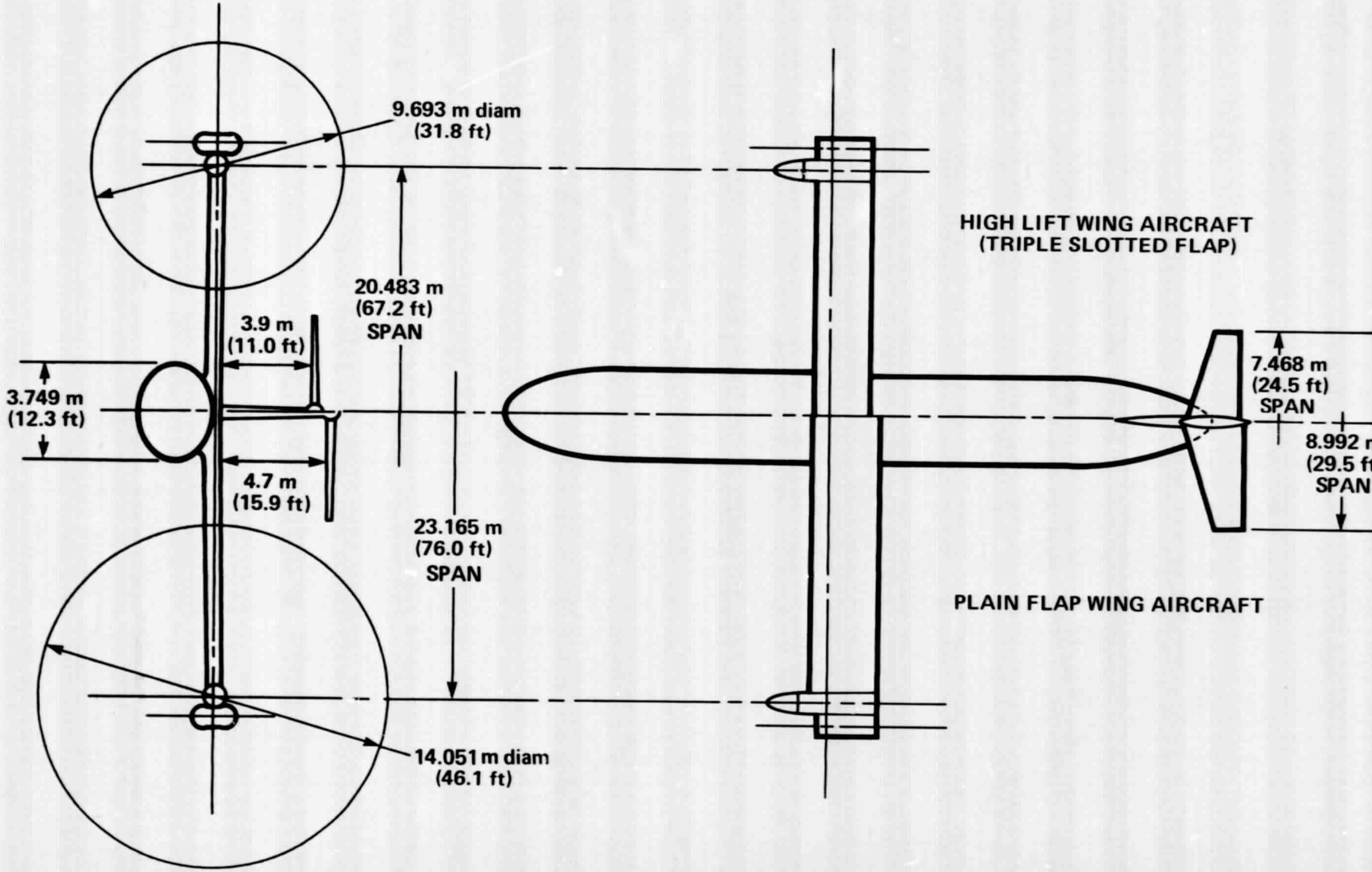

Figure 2.- Composite sketch of the high lift wing and plain flap wing STOL tilt rotor aircraft showing the major external differences in rotor, wing, and tail geometry.

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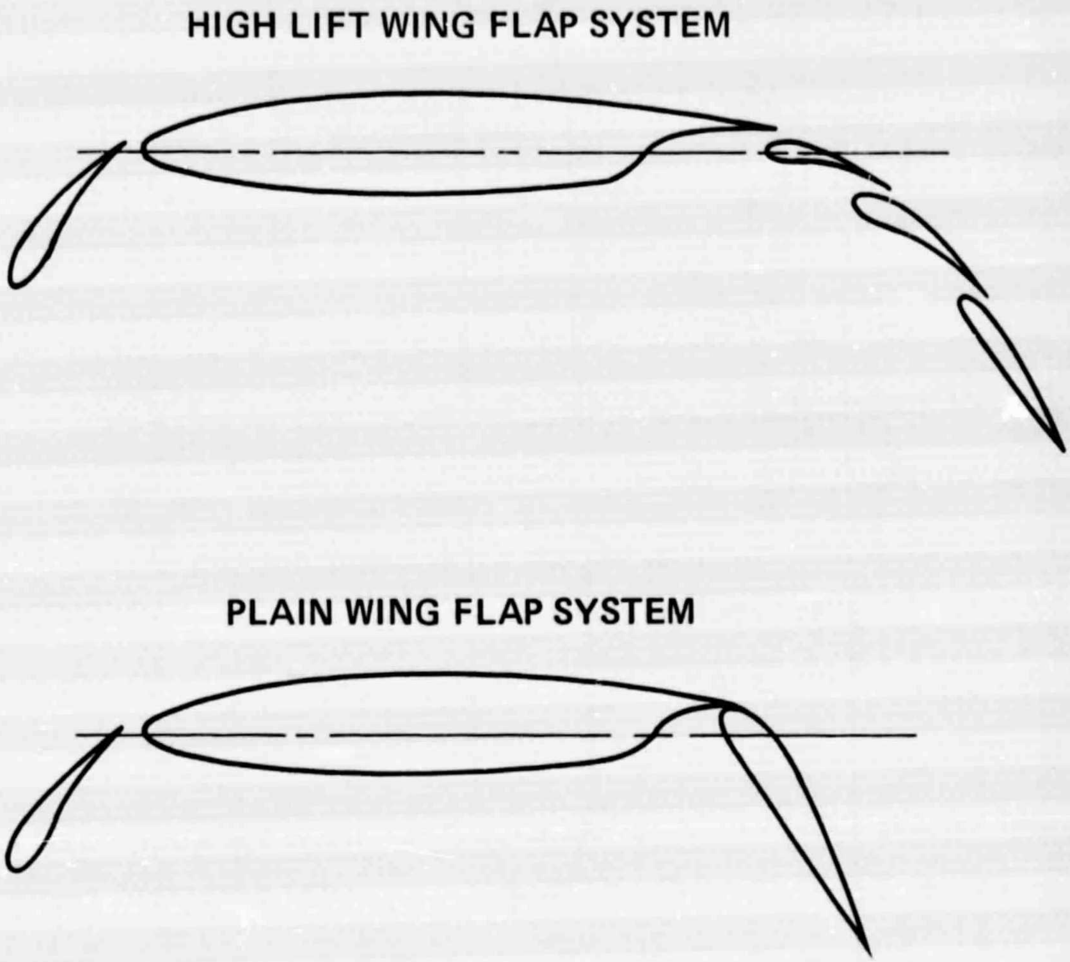

Figure 3.- Comparison of the flap system geometries for the high lift wing and plain flap wing STOL tilt rotors.

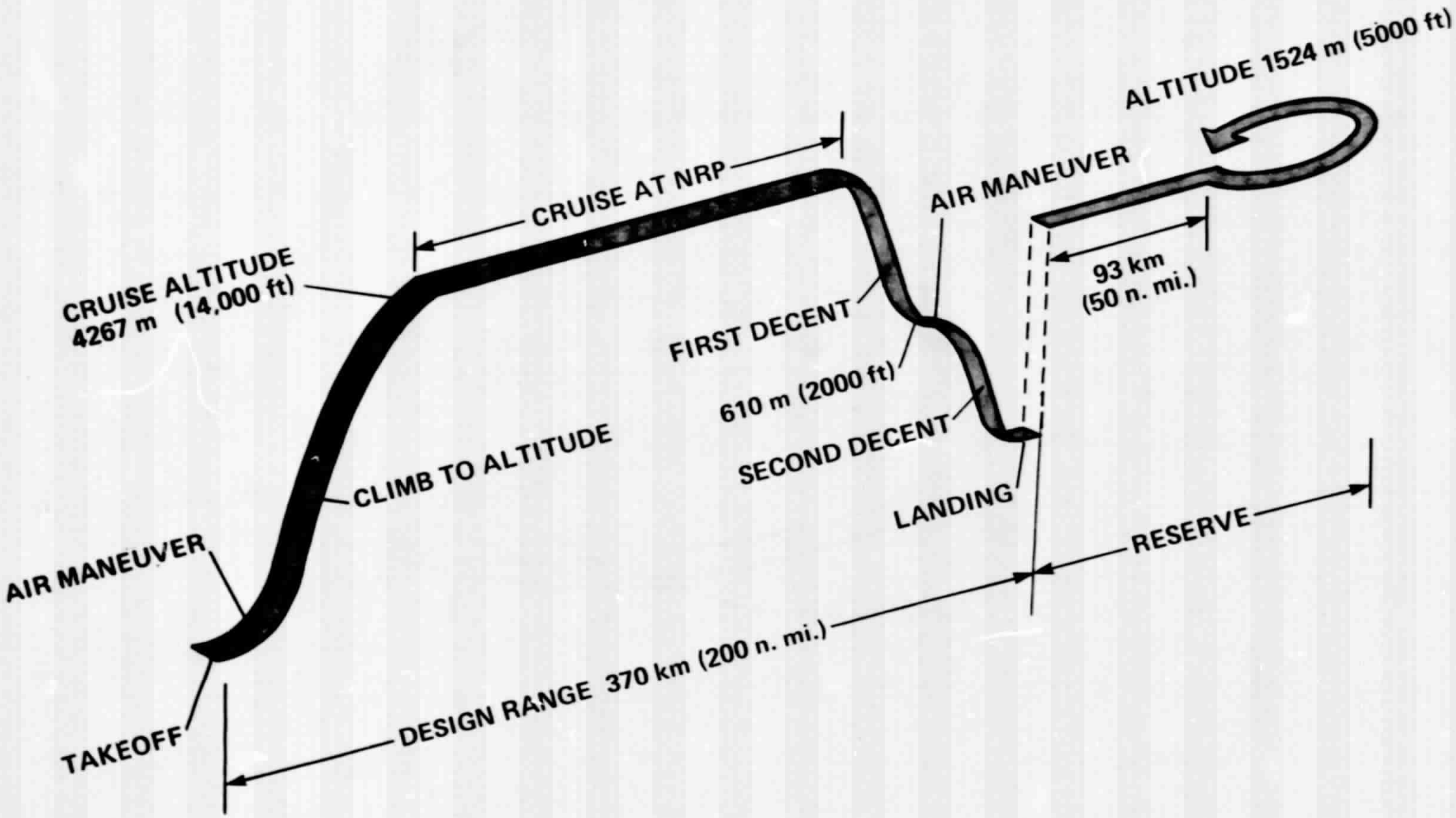

Figure 4.- Design short-haul mission.

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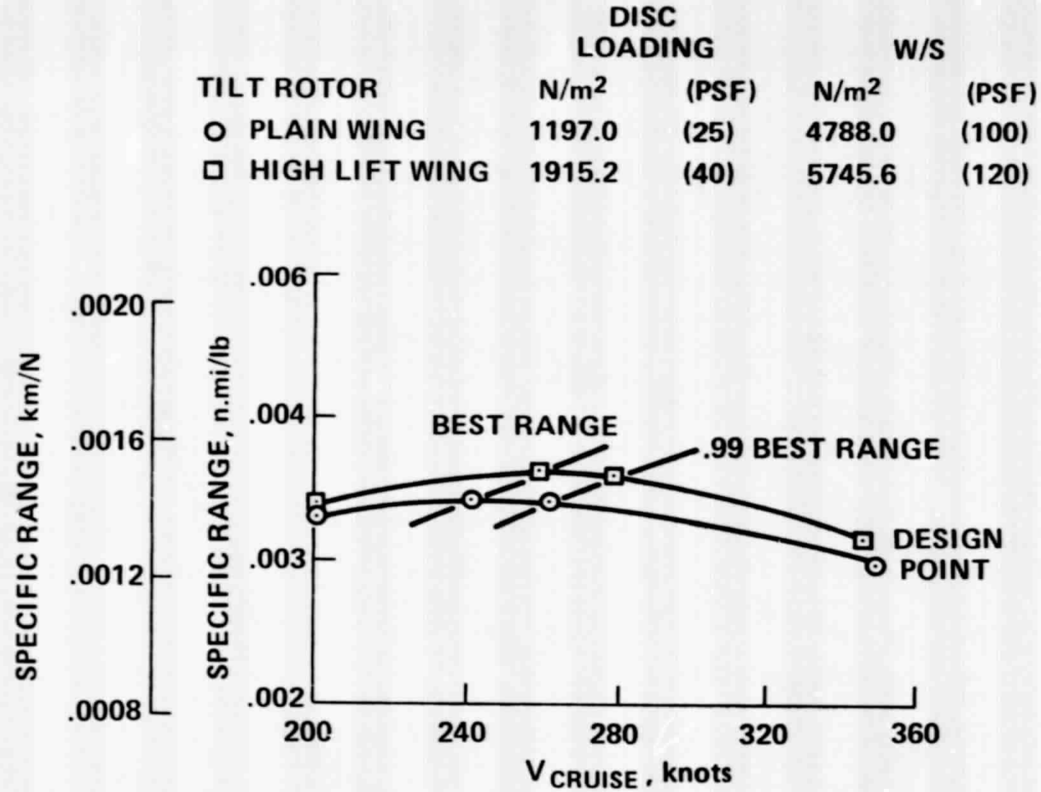

Figure 5.- The variation of specific range with cruise speed for the plain flap wing and high lift wing STOL tilt rotors, at a cruise altitude of 4267 m (14000 ft).

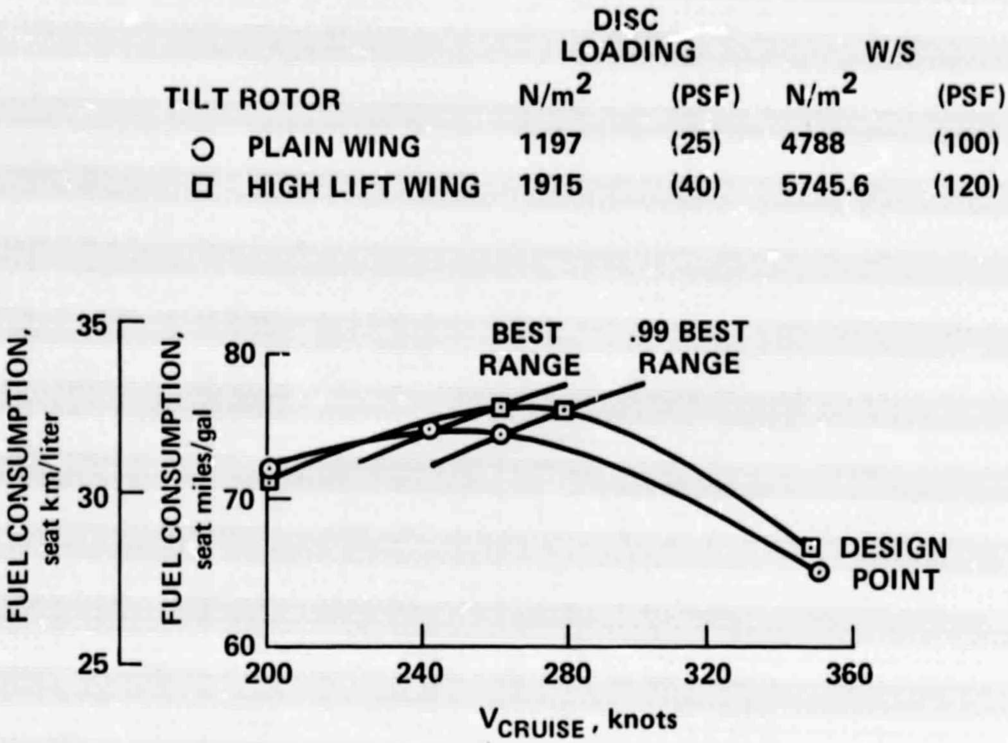

Figure 6.- The variation of specific fuel consumption with cruise velocity for the plain flap wing and the high lift wing STOL tilt rotors, at a cruise altitude of 4267 m (14000 ft).

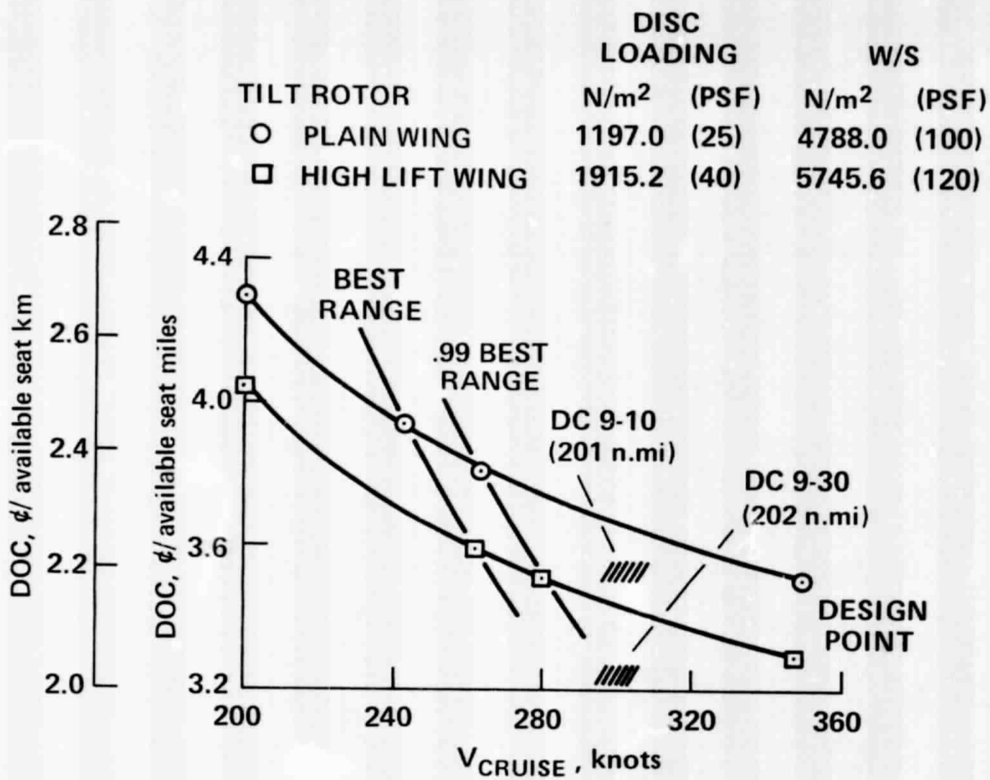

Figure 7.- Variation of direct operating costs with cruise velocity for the plain flap wing and high lift wing STOL tilt rotors, at a cruise altitude of 4267 m (14000 ft), and with cost data in 1976 dollars.

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-78474		

4. Title and Subtitle
EFFECT OF HIGH LIFT FLAP SYSTEMS ON THE CONCEPTUAL DESIGN OF A 1985 SHORT-HAUL COMMERCIAL STOL TILT ROTOR TRANSPORT

5. Report Date

6. Performing Organization Code

7. Author(s)
Michael D. Shovlin and Bruno J. Gambucci

8. Performing Organization Report No.
A-7364

9. Performing Organization Name and Address
NASA Ames Research Center
Moffett Field, Calif. 94035

10. Work Unit No.
791-40-11

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546

13. Type of Report and Period Covered
Technical Memorandum

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This study compared two conceptual design 1985 STOL tilt rotor transports for a 370 kilometer (200 nautical mile) short-haul mission. The first of these concepts was a derivative of previous designs, while the second had a complex mechanical flap system similar to a short field B737 aircraft. The flap system allowed lift to be shifted from the rotor system to the wing, permitting a 26 percent reduction in dynamic component weight, while also permitting the use of a smaller wing. The wing and disc loading of this concept were 5746 (120 psf) and 1915 (40 psf) newtons per square meter, respectively, while the wing and disc loading of the derivative concept were 4788 (100 psf) and 1197 (25 psf) newtons per square meter, respectively.

The high lift wing tilt rotor showed slightly improved fuel usage over its entire operating range and about six to eight percent improvement in direct operating costs, resulting from its improved cruise efficiency and reduced weight.

The main advantage of a high lift flap system for a short-haul tilt rotor as determined by this study are: improved operating economy; improved reliability with potentially reduced maintenance resulting from the shift of structural weight from dynamic to passive elements; and, improved ride quality resulting from the small rotors and higher wing loadings.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Short haul STOL Tilt rotor High lift wing	Unlimited STAR Category - 05

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	28	$4.00

*For sale by the National Technical Information Service, Springfield, Virginia 22161