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MULTIPLE APPLICATION PROPFAN STUDY (MAPS) ADVANCED TACTICAL TRANSPORT

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Douglas Aircraft Company
McDonnell Douglas Corporation

Prepared for
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

Contract NAS 3-24348

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PREFACE

This final report was prepared by Douglas Aircraft Company, McDonnell Douglas Corporation, documenting the tasks performed during the period of August 1984 through April 1985 under NASA contract NAS3-24348 for the Lewis Research Center. Susan Johnson was the NASA Project Manager, and Floyd Newton was the Douglas Study Manager.

The support given by Pratt & Whitney and Hamilton Standard for their contributions in the areas of advanced technology propfan and turbofan engine characteristics is gratefully acknowledged.

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SUMMARY

This study was conducted to ascertain the potential benefits of a propfan propulsion system applied to a blended wing/body military tactical transport. The results indicate a significant advantage in figures of merit for the propfan over those of a comparable technology turbofan.

The study assumes a 1992 technology readiness level. This date was selected to permit the development of propfan propulsion systems to be fully competitive with turbofan systems. Counterrotating propfans are used in the study since they are significantly more efficient than single-rotation propfans.

The study is based on a design mission with a cruise Mach number of 0.75, a mission radius of 400 n mi, a 50,000-pound payload on the outbound leg, and a 2,000-foot field length at the off-load base.

A number of design concepts were explored before the concept was selected for both the propfan and the turbofan aircraft. The initial design concept was tailless, but the study showed that excessive wing area was required to meet the field length goals. Therefore, a retractable canard was added to serve as an additional lifting surface and to balance the nose-down moment created by the wing high-lift system. The canard enabled the wing area to be greatly reduced, but the complexity and added weight of the retractable feature proved to be no better than a fixed canard configuration, which was then adopted. The wing areas were reduced further by specifying a maximum negative static longitudinal stability margin of 15 percent. This margin was selected as the maximum that will allow acceptable, short-period flying qualities in the event that the stability augmentation system is disabled. Conventional aft tail configurations were also considered briefly, but the tail downloads needed for trim at takeoff and landing appeared to be too costly for further consideration. All the designs make use of a unique blended wing/body configuration previously developed by Douglas Aircraft Company for application to a tactical transport. This configuration uses a relatively low-aspect-ratio wing blended into the fuselage to enhance survivability and short-field capability, and to enable some of the U.S. Army's outside equipment to be transported.

The effect of wing aspect ratio was studied by developing three propfan configurations with aspect ratios of 2.5, 4.0, and 8.0. In terms of takeoff gross weight and wing area, the 4.0 case was only slightly inferior to the 8.0 case, and the 2.5 case was a poor third. Furthermore, consideration of aircraft survivability favored the 4.0 case. Consequently, an aspect ratio of 4.0 was chosen for both the propfan and the turbofan aircraft.

Two engines were used for all the configuration studies. The resulting turbofan design was such that the engines fit well under the wing and close to the fuselage. In the propfan case, the engines fit well in a pusher configuration behind and above the wing.

The configurations were evaluated both by figures of merit for the design mission and by their performance on three alternate mission types — ferry missions, assault missions, and tactical command and control missions.

In general, the propfan was found to be superior to the turbofan. While the most significant improvement for the propfan is the 27 percent saving in fuel for the design mission, significant advantages are indicated for alternate missions in which the cruise efficiency (fuel saved) is converted into more tangible parameters — an increase in sea level penetration distance, time on station, or payload. For the design mission, the propfan productivity efficiency, identified as ton-miles of cargo per hour per pound of fuel, is larger than for the turbofan, reflecting the better fuel economy of the propfan. The propfan has lower

life-cycle costs in spite of its slightly larger takeoff gross weight. The weight difference is the net result of the higher propulsion system weight for the propfan being nearly offset by the higher fuel load of the turbofan.

The propfan engine size in this study is in the 20,000-shp class, whereas current studies of potential commercial propfan applications are in the 10,000-shp to 15,000-shp class. Future studies may indicate an engine size which is more compatible in both applications. However, if not, it is questionable whether the DoD would participate in the development of a new engine for the tactical transport mission unless other military applications can also be identified; e.g., a maritime patrol aircraft.

SECTION 1
INTRODUCTION

Since NASA-Lewis initiated a research program approximately 10 years ago to address high-speed propeller technology, achievement of propeller efficiencies on the order of 88 percent has been verified by both analyses and tests at flight speeds approaching a Mach number of 0.8. To achieve this efficiency level, counterrotating propellers are required, as single-rotation systems are significantly less efficient. Application studies of the resulting propeller configurations, known as the "propfan," have indicated fuel savings of 15 to 27 percent compared to similarly configured turbofan-powered aircraft.

The purpose of this study is to evaluate the potential application of a propfan propulsion system to a unique blended wing/body configuration previously developed by Douglas Aircraft Company for application as a tactical transport. (See Figure 1.) The frame of reference is a comparable turbofan configuration. (See Figure 2.) These configurations use a relatively low-aspect-ratio wing, blended into the fuselage to enhance survivability and short-field capability, and to enable some of the U.S. Army's outsize equipment to be transported.

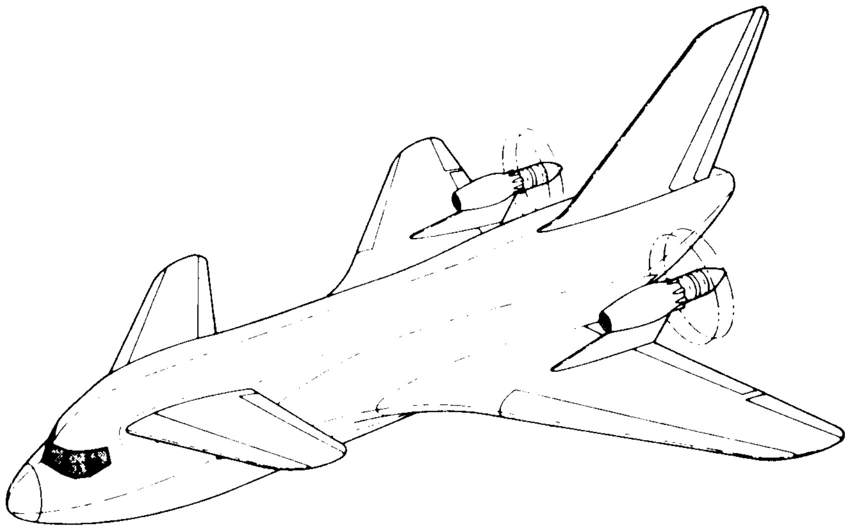


FIGURE 1. PROPFAN CONFIGURATION

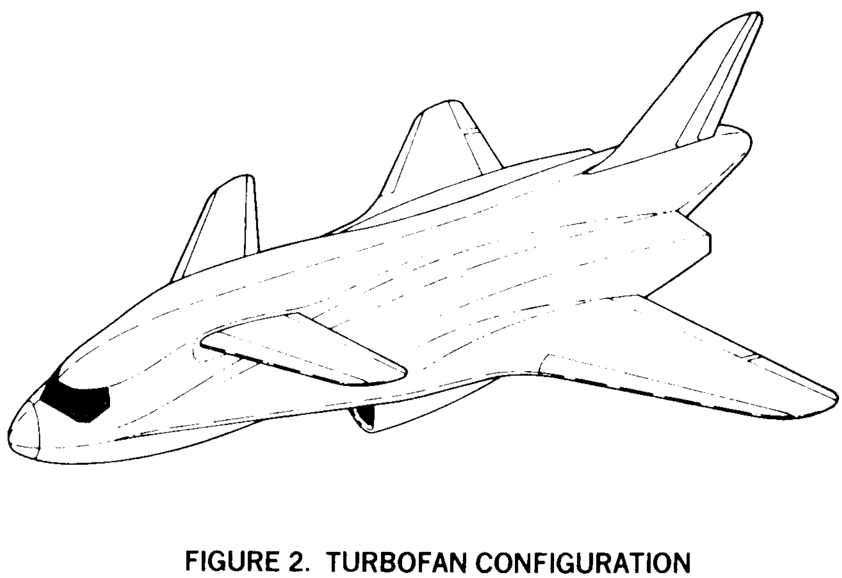


FIGURE 2. TURBOFAN CONFIGURATION

Successful completion of research propfan configurations on a test bed aircraft by the year 1992 is compatible with the time frame for program initiation of an advanced tactical transport. A 1992 technology base is also applied to propulsion, materials, and aircraft subsystems for both the propfan and turbofan configurations.

The design of the two configurations is based on a mission requirement for the delivery of a 50,000-pound outsize load to a forward operating base and a return to the main base without refueling using a cruise Mach number of 0.75. Landing and takeoff distances at the forward base were limited to 2,000 feet. The initial airframe concept was tailless, but the study showed that aircraft with canard surfaces would be smaller because of the capability of the canard to balance the aircraft, with the wing high-lift system needed to accomplish the short field landing and takeoff requirements. With those objectives and the blended wing/body airframe concept, design studies were undertaken for one aircraft with an advanced propfan propulsive system and a second aircraft with an advanced turbofan propulsive system.

As part of the design process, a study was performed using three different wing aspect ratios and a negative longitudinal stability margin. The margin is consistent with the canard design and adequate flying qualities for the worst case, assuming the failure of the stability augmentation system. The study showed the effect of aspect ratio on the aircraft size and weight. This effect was used along with aircraft survivability considerations to select a suitable aspect ratio for both configurations.

The two aircraft are compared on the basis of the following figures of merit: life-cycle costs, design mission fuel, takeoff gross weight, and productivity efficiency. The aircraft are also evaluated on their performance in three alternate mission types: several ferry missions, assault missions, and tactical and control missions. The evaluations are summarized in Table 1.

TABLE 1
FIGURES OF MERIT

			PROPFAN	TURBOFAN
DESIGN MISSION	LIFE-CYCLE COST	($ BILLION)	44.6	47.1
	MISSION FUEL	(LB)	14,220	19,500
	TAKEOFF GROSS WEIGHT	(LB)	149,500	147,100
	PRODUCTIVITY EFFICIENCY (TON-MI PER HR PER LB OF FUEL)		0.77	0.56
ALTERNATE MISSIONS	DEPLOYMENT PAYLOAD (3,000-N-MI RANGE)	(LB)	25,500	18,500
	TIME ON STATION (38,000-LB PAYLOAD, 100-N-MI RADIUS)	(HR)	4.2	3.4
	SEA LEVEL PENETRATION (25,000-LB PAYLOAD, 1,000-N-MI RADIUS)	(N MI)	340	145

SECTION 2
CONCEPTUAL DEVELOPMENT

One of the primary inputs to the aircraft conceptual development was a number of tactical transport configurations selected from ongoing independent research and development (IRAD) studies at Douglas as representative of this class of aircraft (Figure 3). These concepts qualify as "unique" in the sense that short-range (low fuel-fraction) design requirements for a tactical transport lead inevitably to flying wing or delta planform configurations that blend smoothly into noncylindrical fuselage forms to minimize the structural weight fraction.

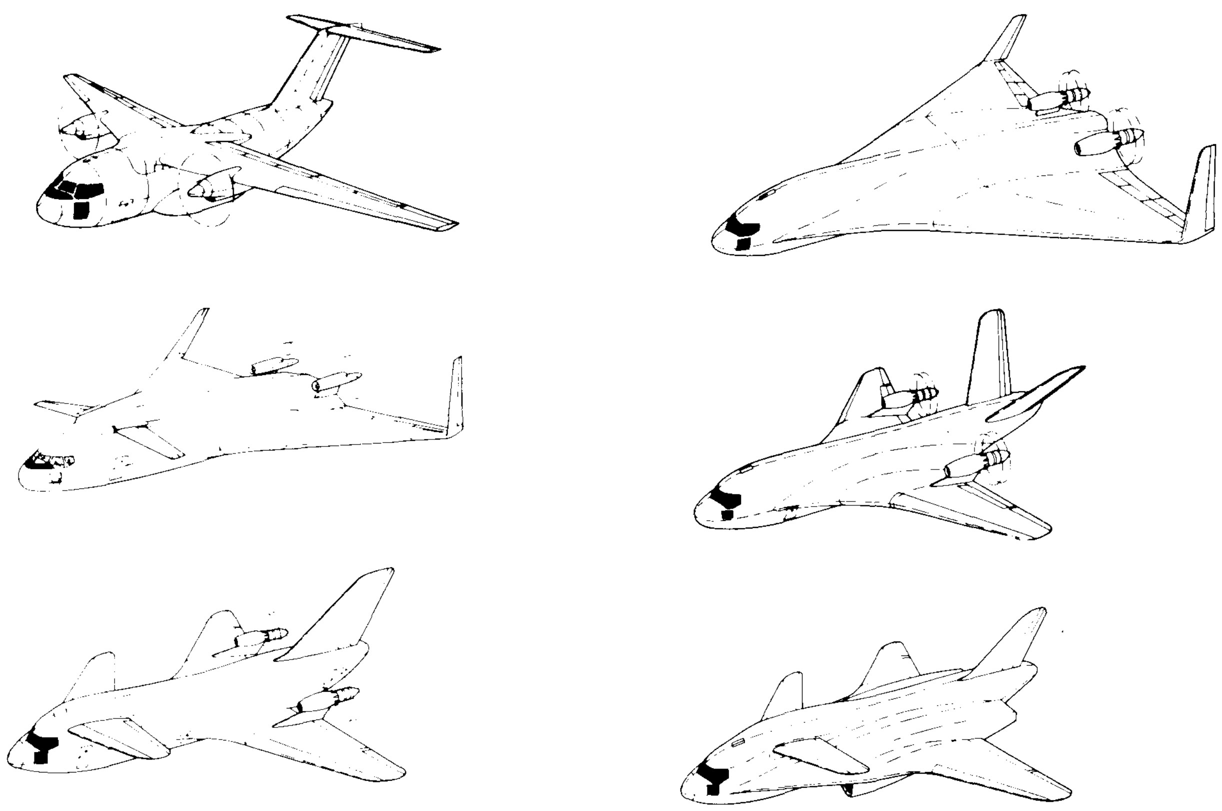


FIGURE 3. CONCEPTUAL ALTERNATIVES

Design concept development had to include, as a primary element, the adaptation of the design of all candidate configurations to consistent mission requirements. The size and shape of the payload volume within the airframe and the operational philosophy must be accommodated. Central to the tactical airlift mission, for example, is the size of the cargo clearance box (e.g., whether or not "outsize" cargo will be carried) and the capability for conducting such operations as paratroop drops, cargo airdrops, and low-altitude parachute extractions (LAPES), in addition to carrying loads into and out of short, unimproved fields.

In addition, the operational environment for a tactical transport can vary from a short-range mission with a completely benign environment to a long-range mission with a very active threat. Airfield facilities can vary from short, austere fields to those available for large commercial transports. Mission flexibility and survivability are paramount considerations for tactical transport operations.

2.1 BACKGROUND

In the interest of achieving the minimum size aircraft, Douglas considered the design of delta wing configurations with an aspect ratio of 2.0 for the short-range MAPS mission. Recent advanced concept studies at Douglas had shown that such delta configurations were consistent with long-range cruise at Mach numbers of 0.7 to 0.8. Since short-range cruise configurations are known to favor a lower aspect ratio than long-range configurations, Douglas concluded that the aspect ratio of 2.0 delta planform could be applied to the short-range MAPS mission as well as long-range missions. At the start of the advanced concept studies very low aspect ratios did not appear consistent with long range; however, the wing thickness (15 percent and possibly larger) coupled with a relatively long root chord enables power plants, fuel, and cargo to be packaged in the wing itself, and this yielded a low structural weight fraction. Aerodynamically, this class of vehicle had a relatively low wing loading due to the entire projected planform being usable wing area. This resulted in cruise lift coefficients on the order of 0.2, with a consequent moderate level of induced drag. Profile drag was also moderate due to the overall wetted area being on the same order as conventional airplanes and to a reduction in interference drag as a result of eliminating the wing-fuselage and horizontal tail-fuselage intersections. Consequently, the lift-to-drag ratio appeared competitive with conventional designs.

Blended delta planform concepts shown in Figure 4 (propfan) and Figure 5 (turbofan) were initial conceptual configurations which preliminary analyses indicated would meet the projected requirements.

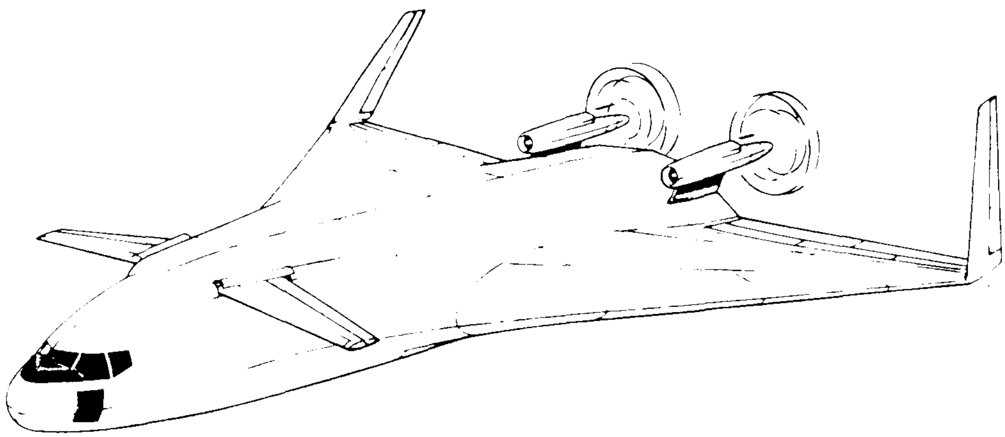


FIGURE 4. PROPFAN-POWERED LOW ASPECT RATIO CONCEPT

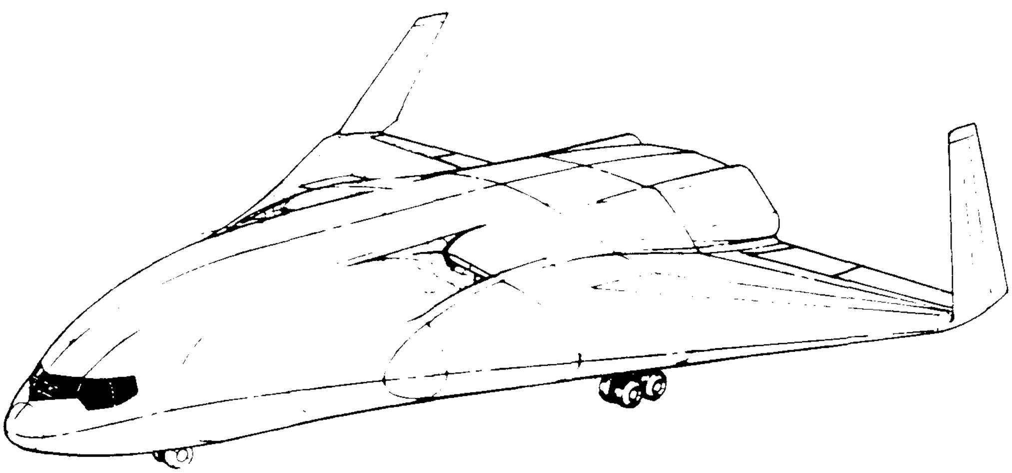


FIGURE 5. TURBOFAN-POWERED LOW ASPECT RATIO CONCEPT

The cargo volume is the same as in the YC-15 (13 by 13 by 45 feet), a McDonnell Douglas prototype aircraft which accommodates many of the outsize weapons and equipment in current and projected U.S. Army inventory. The approach adopted was to utilize a conventional nose faired back into the required cargo envelope, which then terminated in an unswept faired tail section to provide for the aft loading ramp and loading/airdrop clearance envelope. A 15-percent thickness airfoil wing of delta planform (0.10 taper ratio, 2.0 aspect ratio) was fitted to this basic center section, fairing spanwise from the airfoil section to the center body with minimum discontinuities.

These initial concepts were developed without high-lift devices. However, the wing loading requirements necessary to accommodate the unaugmented lift of the wing resulted in extremely large wing areas. Therefore, the airfoil thickness and positioning were adjusted to accommodate deflection of the elevons to a 20-degree flap position in order to enable the aircraft to achieve the desired landing and takeoff field performance without an inordinately low wing loading. The flaps in the deflected position constrain the maximum rotation angle. Incorporation of trailing-edge high-lift devices introduced pitching moments on takeoff and landing which were not present in the cruise configuration. As a result, a retractable canard was added which was to be used only during flight regimes where the flaps were operative.

Some compromises were necessary with application of the propfan. A pusher propfan configuration was required to retain the blending of the forebody into the highly swept leading edge of the wing. The aft location of the propfans, however, placed limits on the propeller diameter due to airframe and cargo loading clearances for ground clearance during rotation. The compromise adopted, as shown in Figure 4, was to place the propfans in nacelles mounted above the afterbody on pylons, suitably angled to reduce thrust-induced pitching moments and to achieve acceptable engine-out control. The capacity of the propfan to operate efficiently at relatively high power-loading (shp/d^2) appears essential to this concept; it would be extremely difficult to install conventional propellers on the delta wing concept in a pusher configuration because of the relatively large diameter required for reasonable loadings.

Preliminary analyses of these and similar configurations indicated performance capabilities which exceed those of conventional high-aspect-ratio configurations. There appeared to be no fundamental problems associated with the low-aspect-ratio delta wing configurations which would preclude the assumption that they could be made competitive with existing designs. Thus, a preliminary investigation into the design problem of a tactical transport airplane yielded the result that there appeared to be no substantive penalties as a consequence of the unique configuration. These very encouraging initial results provided the starting point for the present study.

As discussed above, the propfan configuration shown in Figure 4 might at first appear more amenable to a turbofan propulsion system installation than either a propfan or turboprop; Figure 5 illustrates a similar configuration with buried turbofan engines, as an alternative. A more conventional $AR = 8$ configuration appears ideal for either a propfan or turboprop installation. Consequently, a potentially enlightening trade study emerged with a comparison of aspect ratio versus class of power plant. Figures 6 and 7 show early example concepts incorporating propfans and fuselages blended into moderate-aspect-ratio wings.

This array of aspect ratios and propulsion systems formed a concept matrix. The matrix was screened to define a limited subset of potential designs — i.e., preliminary baseline concepts — for further detailed study. Initially, a matrix of six potential aircraft designs was considered. This consisted of design at the three aspect ratios, 2, 4, and 8, with the two distinct classes of power plants, propfan and turbofan.

The aspect ratio range from 2 to 8 may at first appear rather broad; however, such a coarse grid was felt to be useful in identifying fundamental tradeoffs. Subsequent studies could be conducted to expand the detail about any of those design points which appeared promising as a consequence of the current effort.

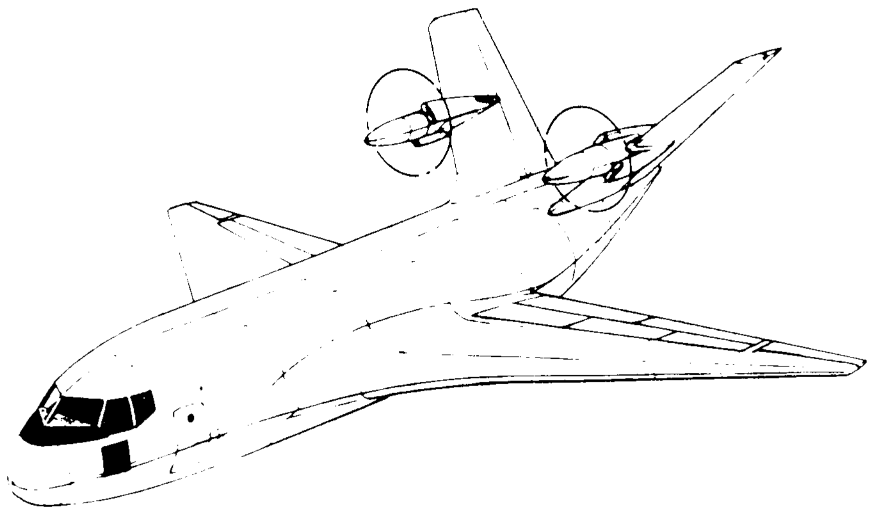


FIGURE 6. MODERATE ASPECT RATIO PROPFAN CONCEPT I

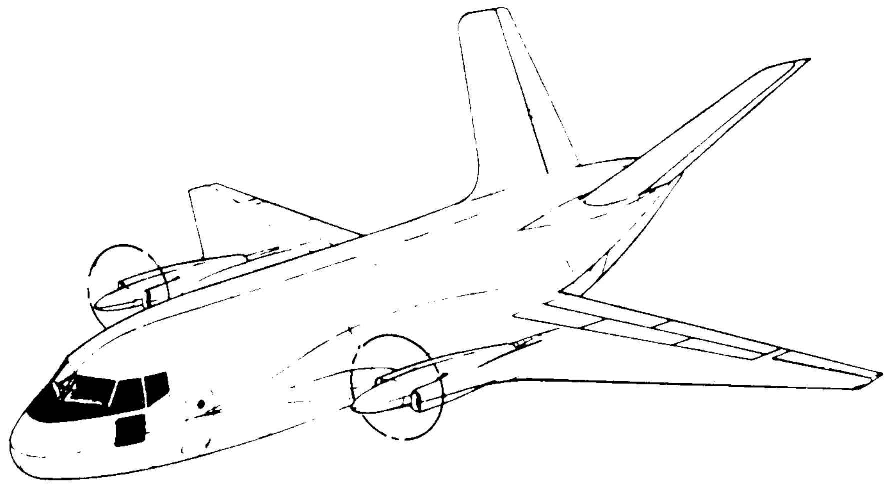


FIGURE 7. MODERATE ASPECT RATIO PROPFAN CONCEPT II

The obvious present-day comparison aircraft for this study is the Lockheed C-130 together with its cargo mission capabilities. All candidate designs were expected to exceed the C-130 performance in payload-range, takeoff, and landing field length, cruise Mach number and altitude, and cargo handling capability. Requiring all of the candidate designs to specifically meet the C-130 performance would have been an impractical constraint. For example, a cruise Mach number of 0.6 would probably show large penalties of fuel burned for a turbofan airplane. Alternatively, fixing the cruise Mach number at 0.8 would complement any of the turbofan-powered designs. Therefore, at each design point (i.e., power plant class and aspect ratio), performance was set to best utilize the features and assets of that particular airplane while meeting the payload-range and cargo handling specification. Takeoff gross weight (the canonical figure-of-merit) was minimized in each case for the specified mission. All of these baseline configurations utilized the 1992-level propulsion and airframe systems technology so as to be comparable.

2.2 TECHNOLOGY READINESS

This study requires application of advanced technologies which are consistent with the expected need date for an Advanced Technology Transport for the USAF. The technology readiness date is generally identified with that point in time at which technology levels for each technical discipline are "frozen" for application to aircraft design, whether it be for a prototype or for FSED.

Equally important for this study is the need to use technology levels consistently between the propfan and turbofan configurations, so that realistic differences and constraints between the two propulsion system technologies are reflected. This is particularly true in the areas of aerodynamics and materials, as well as for the propulsion systems.

2.2.1 Program Timing

The timing for an USAF advanced tactical transport (generically, a replacement for the current C-130) is somewhat nebulous. However, it is possible to identify potential windows of significant program milestones for purposes of establishing technology readiness requirements.

It is generally accepted that the operational need date (initial operational capability, or IOC) for this system is shortly after the turn of the century. Based on this IOC, previous similar development programs and funding profiles, and recent system requirements analyses initiated at ASD, AFWAL, and MAC, the overall program windows have been developed and are summarized in Figure 8. The bars represent the range of probable dates for authority to proceed on the contract (ATP). For example, the propulsion system ATP may be anywhere between 1990 and 1995, depending on the uncertainties of the program priority and funding levels. The prototype ATP will follow the propulsion system ATP by 2 to 3 years, depending on whether a short or a longer time is assumed. The full-scale engineering development may start anywhere between 3 and 7 years after the prototype ATP. The first flight and IOC were added to show how the timing could work out for an IOC date shortly after the year 2000.

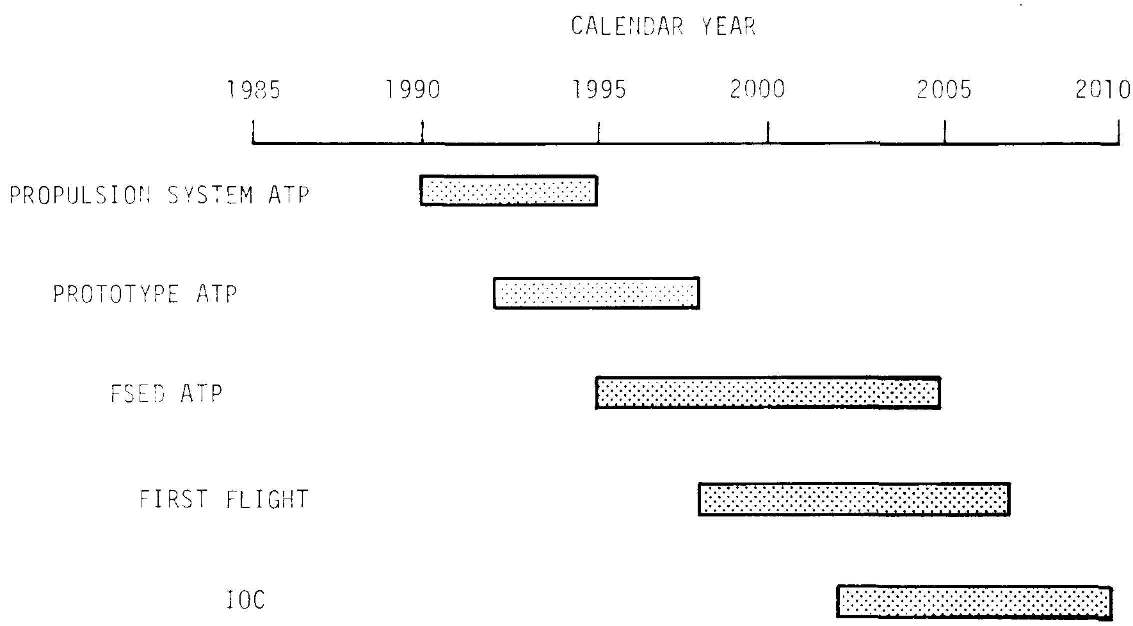


FIGURE 8. ADVANCED TACTICAL TRANSPORT PROGRAM TIMING

Three areas will have a significant impact on the overall schedule: (1) whether a new engine will be developed, (2) whether a prototype will be required, and (3) the importance of the program in light of continuing pressure on the DoD budget. If the engine size for this program is not compatible with a commercial engine size, it is doubtful that the DoD would fund development of a new engine because of a limited production base of approximately 300 aircraft. One requirement which could emerge is the need for VTOL or STOL capability, which will require a development prototype, not otherwise required. Transport systems have historically been low on the procurement priority list, which could mean a delay in program initiation and/or a stretch-out in the system procurement.

With these considerations in mind, it appears that the early 1990s is an appropriate target for consideration of technology readiness.

2.2.2 Technology Assessment

Douglas continuously participates in the advancement of aircraft-related technologies through IRAD and contract research and development (CRAD) programs. Based on this participation and the state of the art in each area, technology readiness dates are reasonably predictable, as summarized in Figure 9.

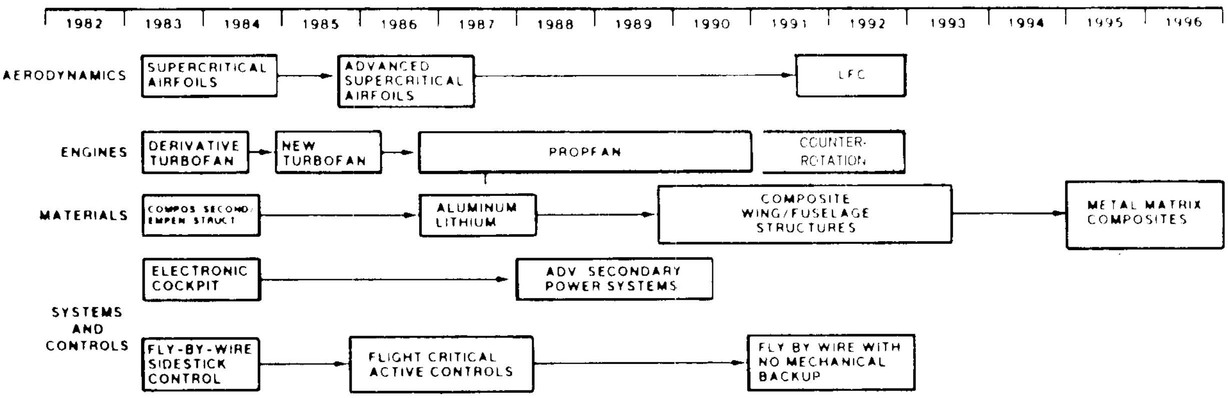


FIGURE 9. TECHNOLOGY READINESS

Foreseeable advancements in each area are expected to be available in time for application to an advanced tactical transport. The counterrotation propfan technology is consistent with current NASA projections. For the MAPS program, it has been assumed that even a limited application of metal matrix composites is apropos. Laminar flow control, however, has not been considered for this mission.

2.2.2.1 Propulsion Systems — Consistent with the technology need date, the results of the NASA-sponsored Advanced Propfan Engine Technology (APET) study are considered representative. Engine data furnished by Pratt & Whitney Aircraft from that study were used and scaled to meet the power requirements of the conceptual designs considered in this study. Propfan propeller data from Hamilton Standard were scaled and used in conjunction with the turboshaft engine for the propfan propulsion system weight and performance characteristics.

Some of the major characteristics of the propulsion systems are summarized in Table 2.

TABLE 2
ADVANCED PROPULSION SYSTEM TECHNOLOGY

ENGINE TYPE	TURBOSHAFT	TURBOFAN
DESIGNATION	P&W STS679	P&W STF686
NOMINAL RATING (S.L., STATIC)	12,000 SHP	19,350 LB
BYPASS RATIO	-	7.0
FAN PRESSURE RATIO	-	1.7
OVERALL PRESSURE RATIO	34	37
TURBINE INLET TEMPERATURE	2600°F	2660°F
SFC (TYPICAL CRUISE)	0.43 LB/HR/LB	0.55 LB/HR/LB
BARE WEIGHT	2400 LB	3800 LB

PROPELLER TYPE	PROPFAN
DESIGNATION	H.S. F252
BLADE CHARACTERISTIC	THIN, SWEPT TIP
TIP SPEED	750 FT/SEC
NOMINAL POWER LOADING (S.L., STATIC)	100 SHP/FT^2
EFFICIENCY (TYPICAL CRUISE)	0.877

2.2.2.2 Aerodynamics — Improvements in aerodynamic technology are expected to be evolutionary, with primary emphasis on airfoil technologies to improve thickness ratios without degradation in cruise lift-to-drag ratios or buffet margins. This is particularly important in attaining the benefits from the blended wing/body configuration being investigated in this study.

The low-aspect-ratio blended wing/fuselage class of configurations considered in the present study are challenging from the aerodynamic design point of view. The wing and fuselage cannot be viewed as separate design problems; instead, the combination must be analyzed as a unit. Fortunately, aerodynamic design and analysis methods now exist which are capable of accurately predicting the complete flow characteristics about such configurations. These procedures coupled with color computer graphics make it possible to design, analyze, and predict the performance of blended wing/fuselage airplanes with confidence.

Negative stability margins are employed in all configurations to minimize the tail size. In operation, a stability augmentation system would be used to provide proper flying qualities. The level of negative static margin is set so that adequate unaugmented, short-period flying qualities will be maintained in case of failure of the system.

2.2.2.3 Structural Materials — Advanced materials and processes promise reduced weights and costs for future aircraft structures. These include metallic structural materials that are improved through alloying, powdering, and heat-treating; composite materials, both metal matrix and resin/epoxy matrix; and new manufacturing processes for transforming raw materials into finished structural components.

A survey of the advanced materials was conducted and the results are presented in Table 3 for the major structural groups. The actual weight saved is a function of the group component and the specific material used. The weight reduction percentage shown relates to aircraft in the current inventory. In the table, it is assumed that almost all of the airplane primary structure is made of composite materials. It is possible that this may never occur. The new aluminum alloys probably will not yield the same weight savings, but they may be more cost-effective. This list is a very optimistic one. However, even if the absolute levels of weight savings are incorrect, the same error will appear in all the configurations in this study. This means that there will be no relative error between the configurations and the error will not affect the configuration comparisons.

TABLE 3
ADVANCED MATERIALS TECHNOLOGY

APPLICATION*	% WEIGHT REDUCTION
WING	16-33
TAIL	16-30
FUSELAGE	16-30
LANDING GEAR	25
NACELLE & PYLON	30

*CARBON/EPOXY, KEVLAR/EPOXY, AL/LI ALLOY, METAL MATRIX

2.2.2.4 Subsystems — Based on an analysis of Douglas IRAD and CRAD studies, vendor offerings, and various technical publications, significant weight reductions in the various subsystem areas can be anticipated. However, one area belies that statement — cockpit displays, wherein CRTs are expected to replace dial and tape gages because of improved performance and effectiveness. Table 4 summarizes the weight changes anticipated for each of the major subsystems.

As in the case of advanced materials, even if the estimates are misjudged to some extent, they will be used consistently for each aircraft configuration and thus will have no impact on the comparisons between propulsion systems.

2.3 MISSION REQUIREMENTS

Design requirements for the advanced tactical transport are currently being formulated by the USAF and will be based on various scenarios, including different theaters of operation, threats, operational and support concepts, and army equipment movement requirements. Mobility and survivability will be the keys for future tactical transport operations.

TABLE 4
ADVANCED SUBSYSTEMS TECHNOLOGY

SUBSYSTEM	% WEIGHT REDUCTION
FLIGHT CONTROLS AND HYDRAULICS (FLY-BY-WIRE, HIGH PRESSURE HYDRAULIC SYSTEM, INTEGRATED ACTUATORS)	20
PROPULSION (LIMITED USE OF COMPOSITES AND ADVANCED METALS FOR DUCTS AND SUPPORT)	4
INSTRUMENTS (CRT DISPLAYS)	(+20)
AIR CONDITIONING AND PNEUMATICS (ADVANCED METALS AND COMPOSITES FOR DUCTS AND SUPPORT)	9
ELECTRICAL SYSTEM (INTEGRATED DRIVE GENERATORS, DOUBLE VOLTAGE AC POWER)	26
AVIONICS (INTEGRATED BOXES, FIBER OPTICS/ LIGHTWEIGHT WIRING)	18
DE-ICE SYSTEM (ELECTRICAL IMPULSE DE-ICE)	10
AUXILIARY GEAR (ADVANCED METALS FOR ROLLER TRAYS, RAILS, AND JACKING PROVISIONS)	9

A tactical transport can be used for a short-range mission with a completely benign threat or a long-range mission with a very active threat. Operational missions will include airlift and/or resupply of Army equipment to a forward operating base (FOB) from a main operating base (MOB), extension of airlift missions to include paradrops, low-altitude parachute extraction (LAPE), and even excursions into hostile territory beyond the forward line of troops (FLOT) or forward edge of the battle area (FEBA) for support of indigenous supporters and/or special operations (see Figure 10).

The mission requirements selected for this study are representative, but are not the most demanding nor the least demanding. They are based on Douglas IRAD and CRAD effort in this area over the past 20 years. They are valid for the propfan/turbofan comparison in this study.

2.3.1 Design Tactical Airlift Mission

The basic tactical airlift mission (Figure 11) is a simple radius mission, in which the aircraft carries the design payload from the MOB to an FOB. The payload is off-loaded at the FOB and the aircraft returns to the primary base empty without refueling. The FOB may be an austere base with short runways, requiring a short-field landing capability with full payload, and a short-field takeoff capability, without a payload. En route between bases, the aircraft flies at the most efficient cruise altitude at the design cruise speed.

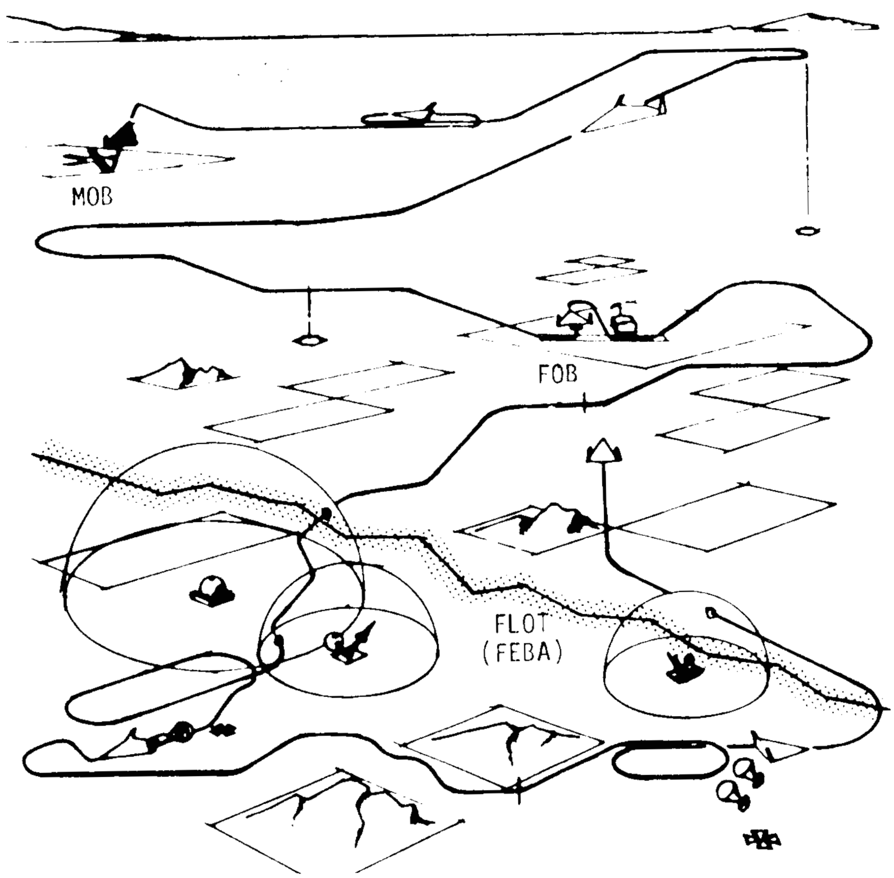
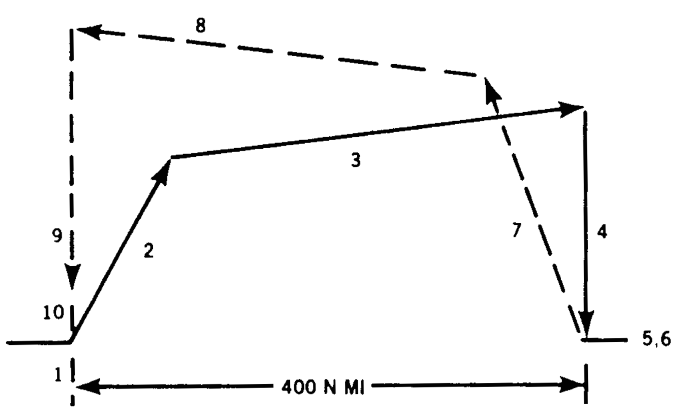


FIGURE 10. TACTICAL TRANSPORT OPERATIONAL ENVIRONMENT



1, 6 TAKEOFF - 5 MINUTES AT MAXIMUM CONTINUOUS POWER

2, 7 CLIMB CLIMB TO CRUISE ALTITUDE AT MAXIMUM CONTINUOUS POWER

3, 8 CRUISE CRUISE AT SPEED FOR LONG RANGE OR AT DESIGN MACH NUMBER, WHICHEVER IS GREATER, AND ALTITUDE FOR LONG RANGE

4, 9 DESCENT AND LANDING NO FUEL OR DISTANCE

5 OFF-LOAD PAYLOAD

10 FUEL RESERVES

30 MINUTES AT MAXIMUM ENDURANCE AT SEA LEVEL

PLUS 5 PERCENT OF INITIAL FUEL

FIGURE 11. DESIGN TACTICAL AIRLIFT MISSION

The mission radius selected for this study is 400 n mi. This is based on Douglas studies for a NATO non-nuclear scenario and provides a capability for complete coverage of the NATO countries from NATO MOBs and FOBs.

2.3.2 Cargo Compartment Size

The cargo compartment cross section size, and consequently the fuselage size, is determined by the largest pieces of equipment expected to be transported. Army planners have determined a need in the next-generation tactical transport to carry components of the Light Infantry Brigade (LIB).

A review of the planned elements of the LIB indicates that the Infantry Fighting Vehicle (IFV), which is tracked, is the single widest unit, and the 2½-ton van is the single highest unit. Standard containers are not critical in either dimension.

With a 6-in. allowance for clearance from any aircraft structure with these vehicles, a nominal fuselage diameter of about 194 in. is required (Figure 12). If the clearance is reduced to 4 in., this fuselage size could accommodate some 5-ton vans. As is the case with the cross section, the cargo floor length is sized to carry the longest van in the LIB inventory. This floor length will also accommodate five standard 463L pallets, and an additional pallet can be carried on the ramp.

Figure 13 presents a summary of the cargo compartment dimensional characteristics used in the MAPS study.

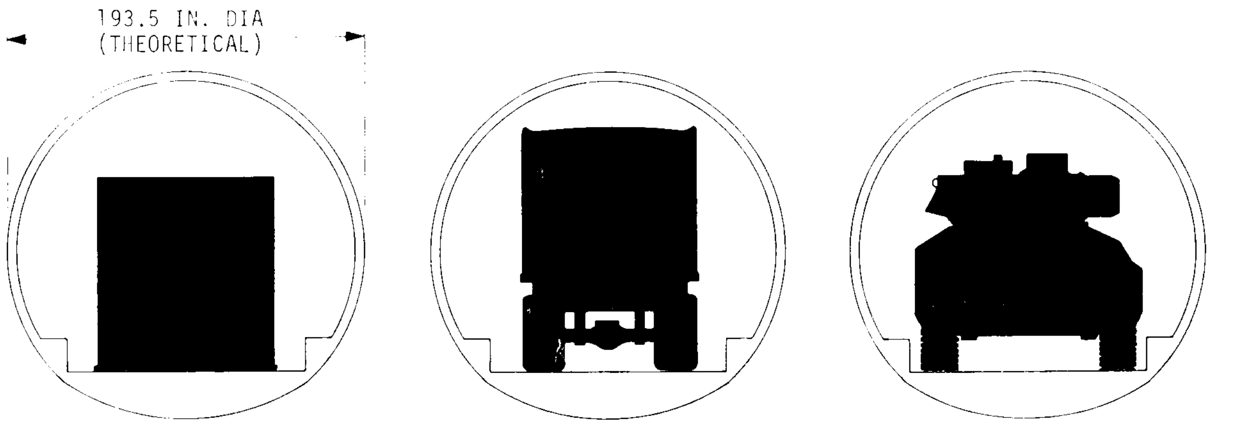


FIGURE 12. CROSS SECTION REQUIREMENTS

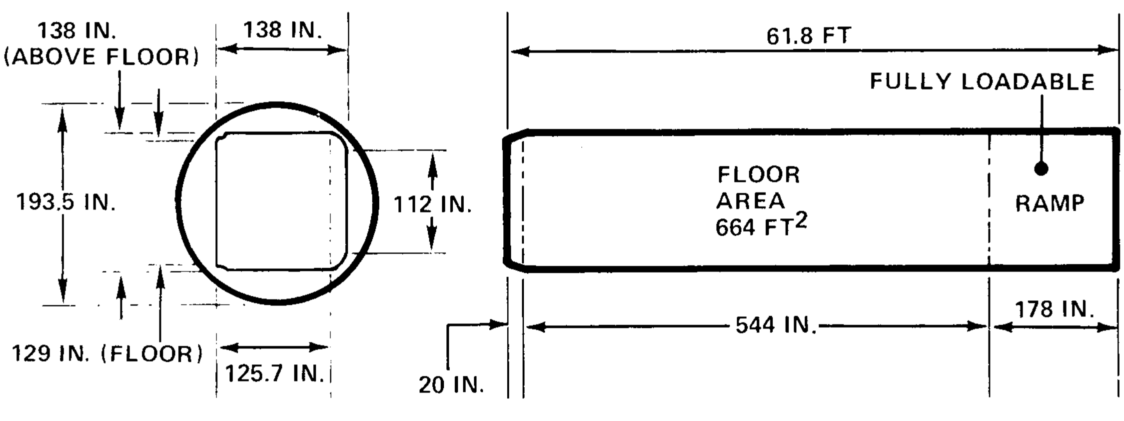


FIGURE 13. CARGO COMPARTMENT DIMENSIONS

2.3.3 Design Payload

The selected design payload is 50,000 lb, which is sufficient capacity to carry the IFV (49,000 lb) or the various 2½- and 5-ton van weights (24,000 lb to 37,000 lb), with some margin. This payload also provides some margin for carrying combined loads of different equipment.

2.3.4 Field Length

The shorter the field length, the larger the number of airfields from which the tactical transport can operate. In addition, a capability to operate from longer, craterized airfields is possible. However, as field length requirement is reduced below the 2,000-ft range, a significant penalty results in a larger, heavier, more costly aircraft. For the MAPS study, a 2,000-ft field length at the payload off-load field is considered a reasonable value.

2.3.5 Cruise Speed

While no design cruise speed was initially specified based on operational requirements, a Mach number of 0.75 was selected for this study. With a relatively low-aspect ratio, high-sweep planform used for the blended wing/body configurations, no advantage would be anticipated with a lower speed, and higher speeds would be compromised by propeller efficiency.

2.3.6 Miscellaneous

The following items are included to clarify other requirements and assumptions used in the study:

- Cruise Altitude — Minimum of 25,000 ft to clear most adverse weather.
- Load Factor — 2.5 at design takeoff weight per military specification.
- Sonic and Acoustic Fatigue — A weight allowance of 400 lb for pusher propeller installations based on previous Douglas studies.
- Survivability — A weight allowance of approximately 1,300 lb for radar-absorbent material and structure based on previous Douglas studies.

2.4 CONCEPT SELECTION

The array of conceptual designs, as described in a preceding section, was modified as expected as the study progressed. Initially, the configurations were set with retractable canard surfaces which were to be deployed in the high-lift mode. These surfaces allowed a significant reduction in wing area over a pure tailless configuration since the wing could be equipped with a high-lift system and in turn trimmed by the canards. A next step was to examine the case of fixed canards which would also be used for trim in cruise. This provided an additional decrease in wing area along with a substantial reduction in structural weight due to the reduced wing area and the elimination of the extension/retraction mechanism. A limited detectability analysis showed that the trade between the fixed and retractable canards was at worst even, and possibly in favor of the fixed canards. Consequently, all of the configurations considered in this study were set with fixed canards. This is not to say that a canard is preferable to a conventionally tailed configuration. In fact, an interesting future study would involve a comparison of a set of conventionally tailed configurations with the canard configurations developed in the present study.

A second modification to the initial array of conceptual designs involved an aspect ratio study, initially considering wing aspect ratios of 2.0, 4.0, and 8.0 for the propfan. Here, the intent was to examine the results of the initial set of configurations and expand the matrix if these studies indicated the designs with an aspect ratio of 4.0 were not realistic. However, the design aspect ratio of 2.0 turned out to be unrealistic, inasmuch as the wide chord of the wing caused interference with the canard. An aspect ratio of 2.5 was workable, as shown in Figure 14, and the study plan was changed to aspect ratios of 2.5, 4.0, and 8.0. Fortuitously, the airplanes with an aspect ratio of 4.0 offered a good compromise between overall performance for the design mission and achieving wing/body blending for visibility concerns; therefore, the set of airplanes in the reduced matrix formed the basis of the study. No evaluation of turbofan aircraft with an aspect ratio of 2.5 and 8.0 was conducted.

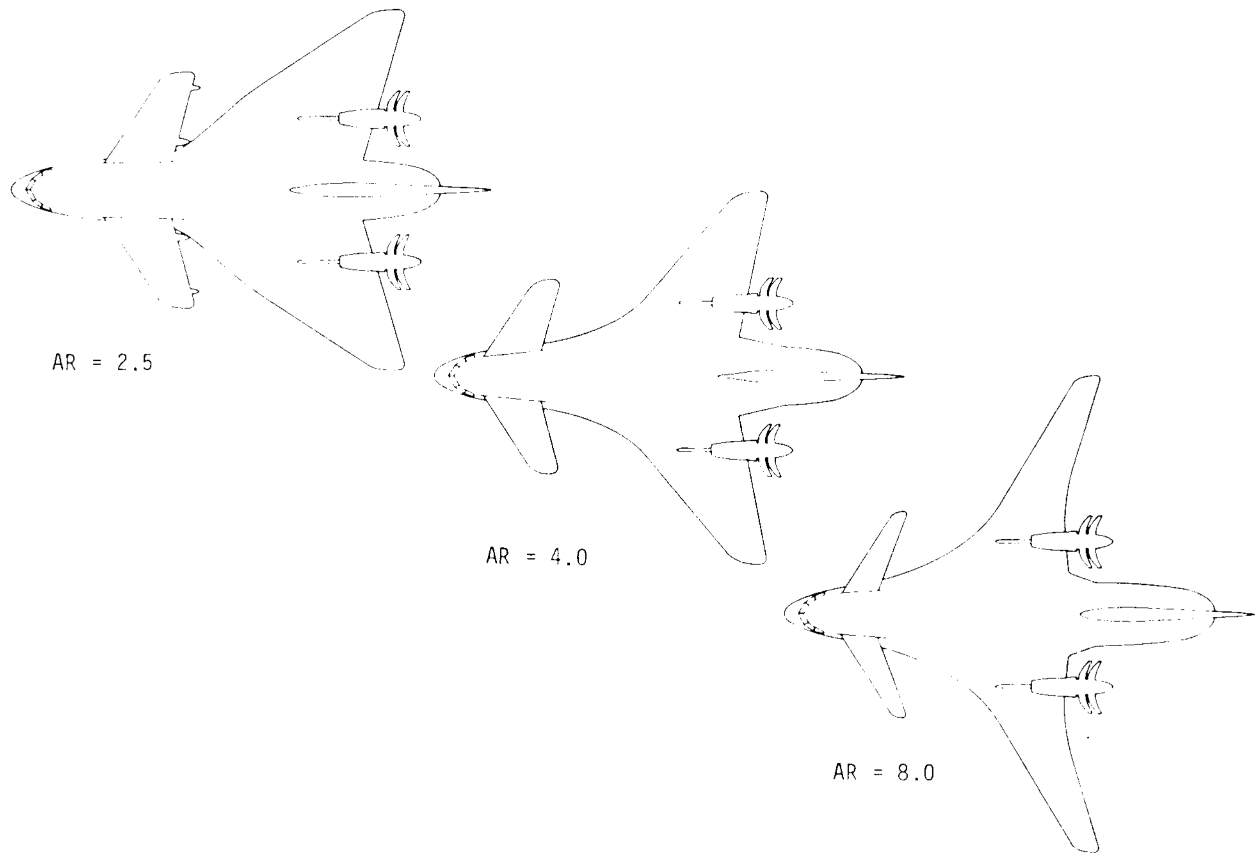


FIGURE 14. PLANFORMS FOR ASPECT RATIO STUDY

The three wing aspect ratio configurations with propfans were investigated thoroughly to assure consistency in meeting mission and design requirements and application of advanced technologies. For example, a negative stability margin of 15 percent was used in each case, and sufficient layout work was completed to validate compatibility among the major structural components. For the aspect ratio 2.5 configuration, this required that the canard surface be located closer to the wing than for the other configurations, with the consequence that the inboard wing section has somewhat lesser sweep than the outboard wing section. On the other hand, higher aspect ratios make complete wing/body blending more difficult to achieve (smaller root chord and thickness).

Table 5 and Figure 15 summarize some of the major characteristics for the three different aspect ratio configurations, where each is sized to meet the design mission requirements. Indeed, the higher aspect ratio configurations result in reduced mission fuel required and reduced wing and engine sizes, as well as reduced takeoff gross weight. However, since the primary purpose of the study is to compare the two different propulsion systems on a consistent basis, and since the higher aspect ratios indicate a diminishing reduction in fuel saved and essentially no reduction in weight empty or takeoff weight, the aspect ratio 4 configuration was selected for the propulsion system comparison.

TABLE 5
CHARACTERISTICS COMPARISON — ASPECT RATIO

ASPECT RATIO			2.5	4.0	8.0
ENGINE	- TYPE		STS679	STS679	STS679
	- RATING (S.L., M = .3)	(SHP)	21,850	19,790	18,610
	- NUMBER		2	2	2
PROPELLER	- TYPE		SWEPT BLADE	SWEPT BLADE	SWEPT BLADE
	- DIAMETER	(FT)	14.0	13.4	12.9
	- NO. OF BLADES		6 X 6	6 X 6	6 X 6
TAKEOFF WEIGHT		(LB)	165,275	149,500	147,500
MISSION FUEL		(LB)	16,550	14,220	12,940
OPERATING EMPTY WEIGHT		(LB)	98,725	85,280	84,560
CRUISE MACH NO.			.75	.75	.75
INITIAL CRUISE ALTITUDE		(FT)	29,200	29,750	33,500
MISSION RADIUS		(N MI)	400	400	400
FIELD LENGTH (MIDPOINT)		(FT)	2,000	2,000	2,000
WING AREA		(FT^2)	3,379	2,230	1,770
ASPECT RATIO			2.5	4.0	8.0
LOADING (INITIAL TAKEOFF)		(LB/FT^2)	48.9	67.0	83.3
LOADING (MIDPOINT LANDING)		(LB/FT^2)	46.4	63.8	79.6
LOADING (MIDPOINT TAKEOFF)		(LB/FT^2)	31.7	41.4	51.4
MAX LIFT COEFFICIENT (LANDING)			1.55	2.13	2.65

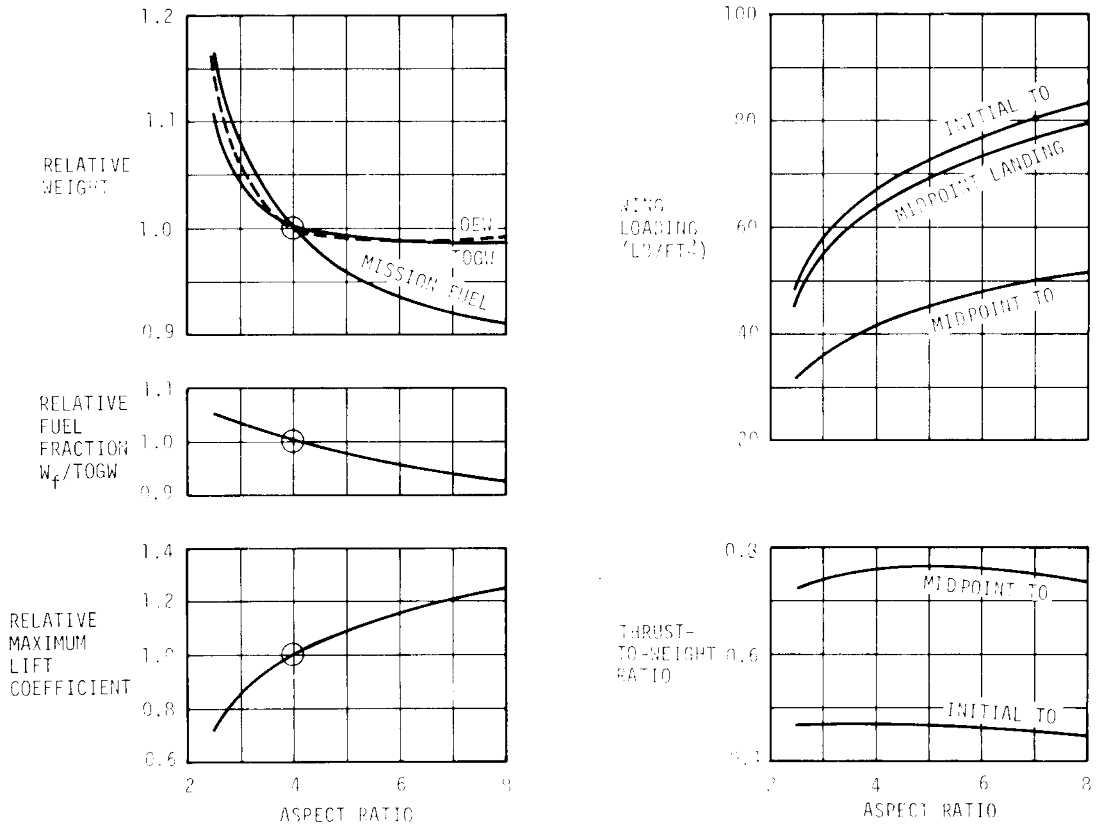


FIGURE 15. SENSITIVITY TO ASPECT RATIO

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SECTION 3
CONFIGURATION CHARACTERISTICS

The major characteristics of the final concept developed in the previous section included:

- Blended wing/body
- Fixed canard (nonretractable)
- Wing aspect ratio of 4
- Two engines
- Counterrotation, high-speed, pusher propellers
- Advanced technology in every area
- Outsize cargo compartment.

Based on these overall characteristics, two configurations were sized to meet the mission requirements — one propfan configuration and one turbofan configuration. The general arrangement three-views and major characteristics of these two configurations are summarized in Figures 16 and 17 and Table 6.

PROPFAN

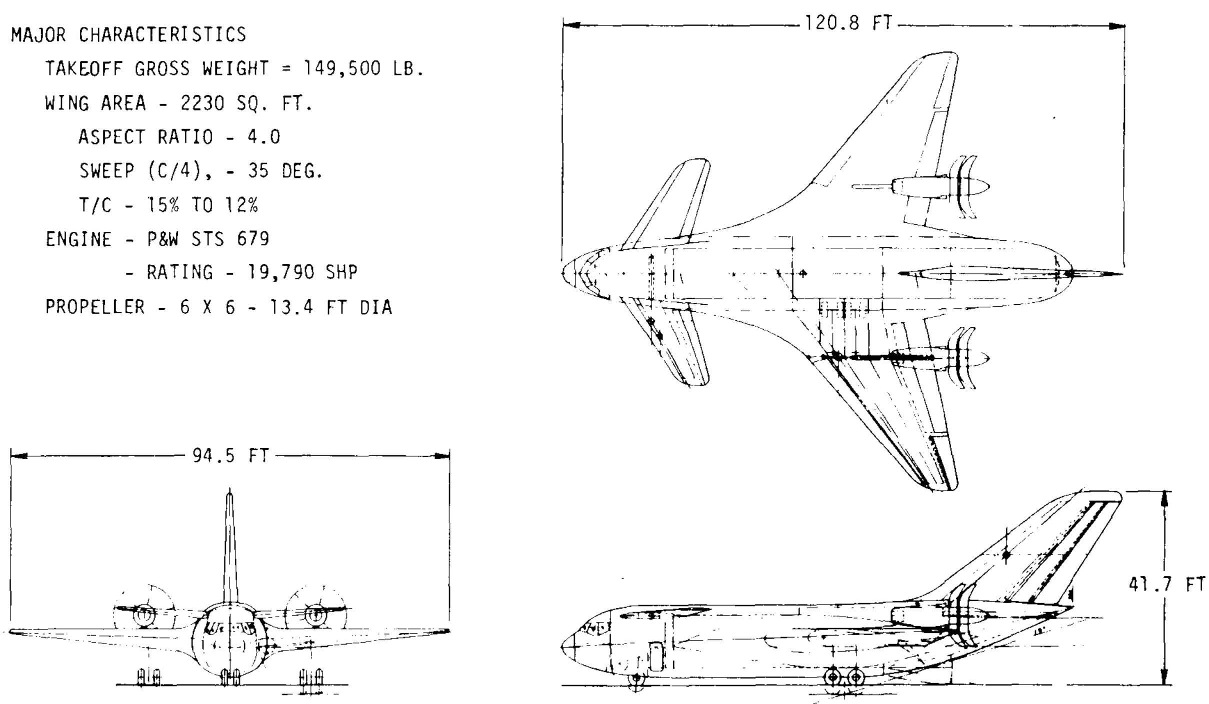


FIGURE 16. GENERAL ARRANGEMENT — PROPFAN

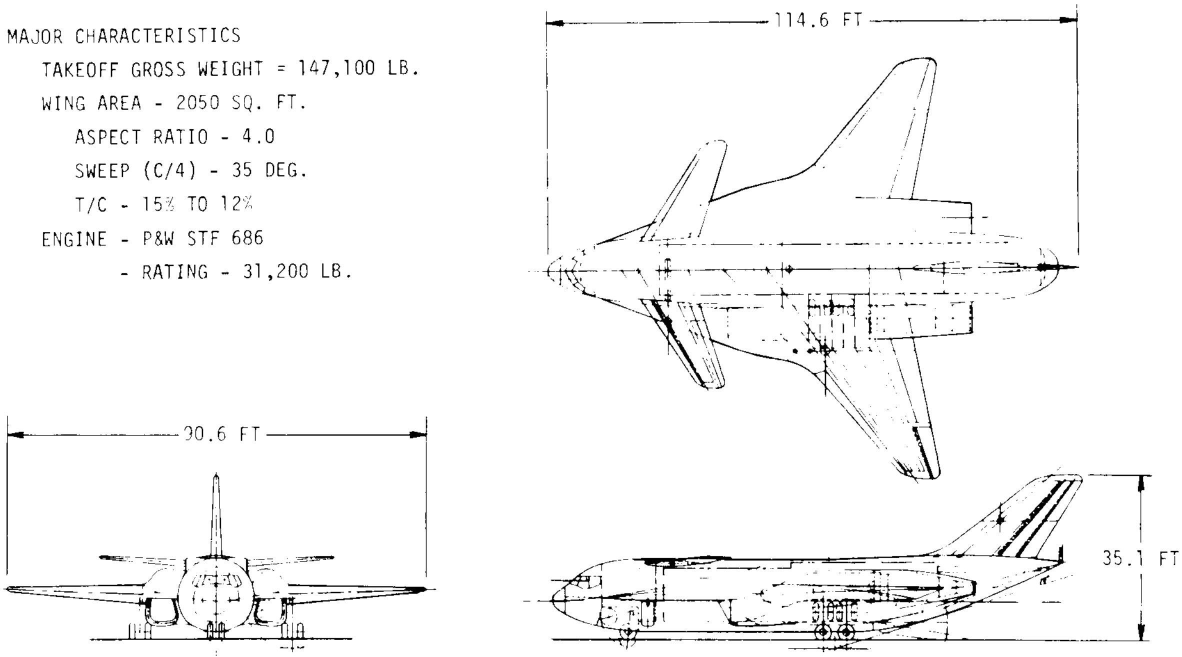


FIGURE 17. GENERAL ARRANGEMENT — TURBOFAN

TABLE 6
CHARACTERISTICS COMPARISON — DESIGN MISSION

PROPULSION SYSTEM			PROPFAN	TURBOFAN
ENGINE	- TYPE		STS679	STF686
	- RATING (S.L., M = .3)	(SHP OR LB)	19,790	31,175
	- NUMBER		2	2
PROPELLER	- TYPE		SWEPT BLADE	-
	- DIAMETER	(FT)	13.4	-
	- NO. OF BLADES		6 X 6	-
TAKEOFF WEIGHT		(LB)	149,500	147,100
MISSION FUEL		(LB)	14,220	19,500
OPERATING EMPTY WEIGHT		(LB)	85,280	77,600
CRUISE MACH NO.			.75	.75
INITIAL CRUISE ALTITUDE		(FT)	29,750	30,900
MISSION RADIUS		(N MI)	400	400
FIELD LENGTH (MIDPOINT)		(FT)	2,000	2,000
WING AREA		(FT^2)	2,230	2,053
ASPECT RATIO			4.0	4.0
LOADING (INITIAL TAKEOFF)		(LB/FT^2)	67.0	71.7
LOADING (MIDPOINT LANDING)		(LB/FT^2)	63.8	66.8
LOADING (MIDPOINT TAKEOFF)		(LB/FT^2)	41.4	42.5
MAX LIFT COEFFICIENT (LANDING)			2.13	2.23

3.1 CONFIGURATION SIZING

The Douglas Computer-Aided Sizing and Evaluation (CASE) program was used to size each of the configurations. This program can be loaded with basic parametric data in all areas affecting mission performance, including variations in mission profiles. Printouts are available in both graphic and tabular form.

Figure 18 shows the graphic printout for the propfan sizing solution based on minimum takeoff gross weight. Once the critical parameters of wing area and engine size were identified, the extraneous parameters (e.g., minimum cruise altitude) were removed from the illustration for clarity. The critical sizing requirements for minimum takeoff gross weight are the landing field length at the payload off-load field (LFL = 2,000 feet) and the engine size required to fly at a given maximum weight using maximum cruise thrust and the design cruise speed of M = 0.75. The latter is represented by W/WMAX1 = 1.000, the ratio of takeoff gross weight to the maximum weight for which the engines could sustain cruise at design Mach number (WMAX1). The minimum takeoff gross weight to meet the requirements is 149,500 pounds; the wing area is 2,230 ft^2, and the engine size is 19,790 shp.

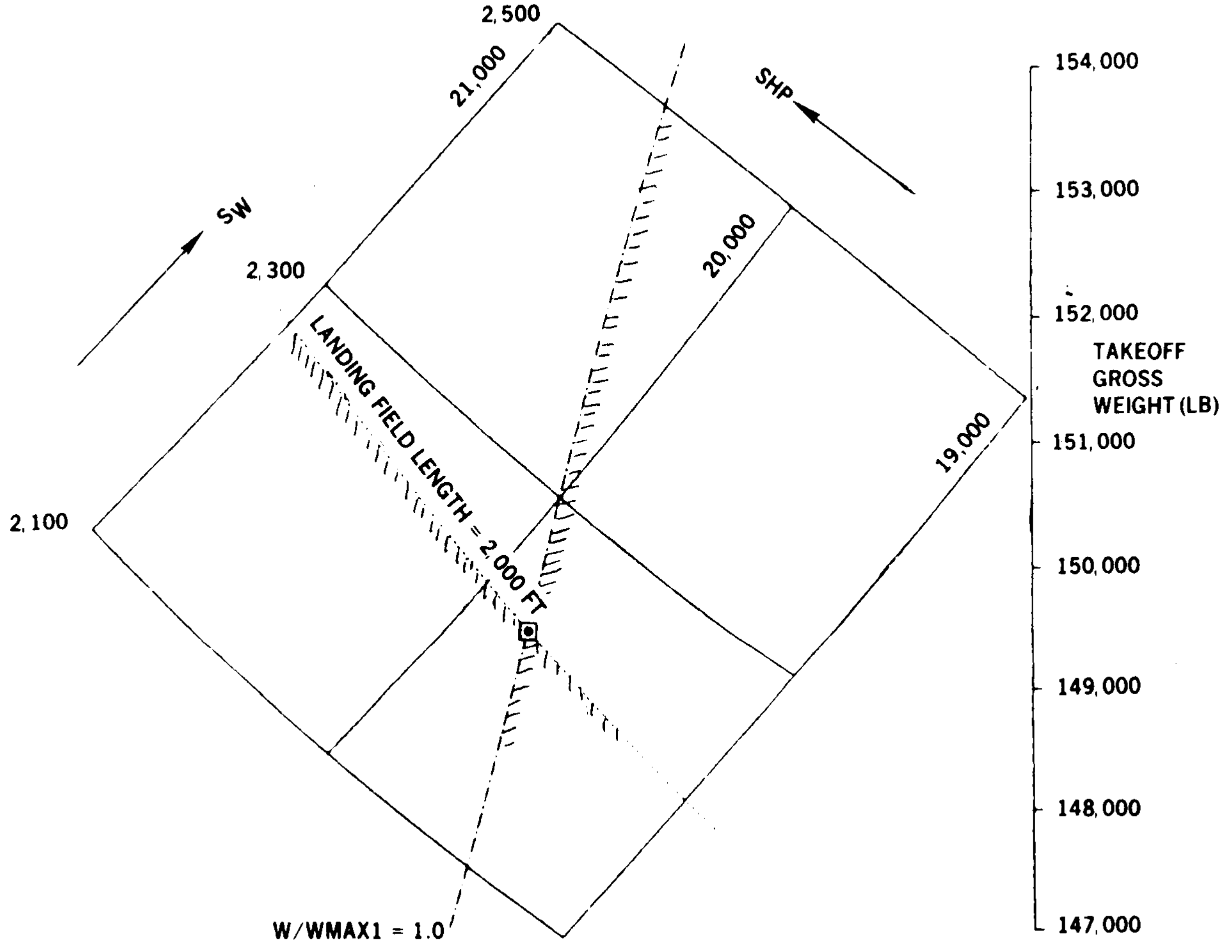


FIGURE 18. PARAMETRIC SIZING SUMMARY — PROPFAN (TAKEOFF GROSS WEIGHT)

Similar graphic solutions (Figures 19 and 20) with minimum operating empty weight and fuel burned as the selection criteria essentially confirmed the selection of engine and wing sizes based on minimum takeoff gross weight. Similar results were obtained for the turbofan. Consequently, only the minimum takeoff gross weight solution was used for the turbofan (Figure 21), which results in a minimum takeoff gross weight of 147,100 lb, an engine rating of 31,175 lb, and a wing area of 2,053 ft^2.

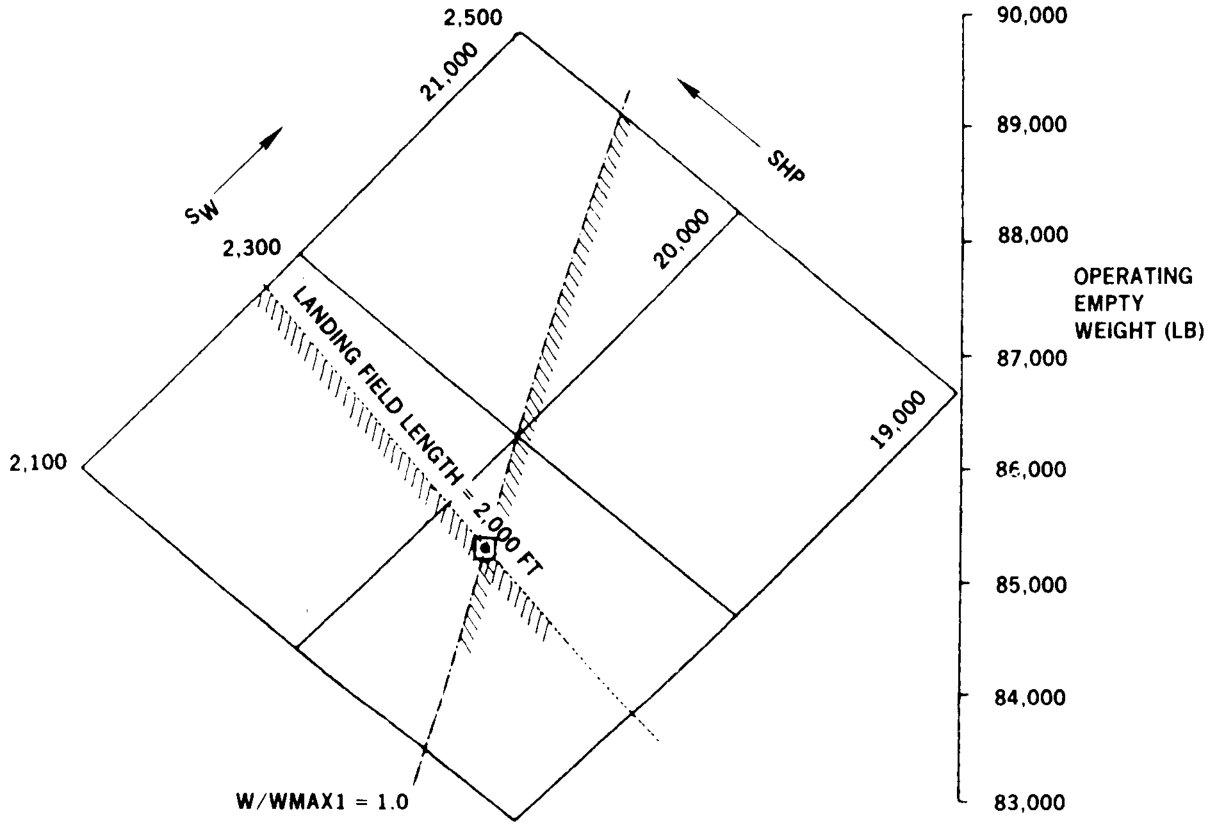


FIGURE 19. PARAMETRIC SIZING SUMMARY — PROPFAN (OPERATING EMPTY WEIGHT)

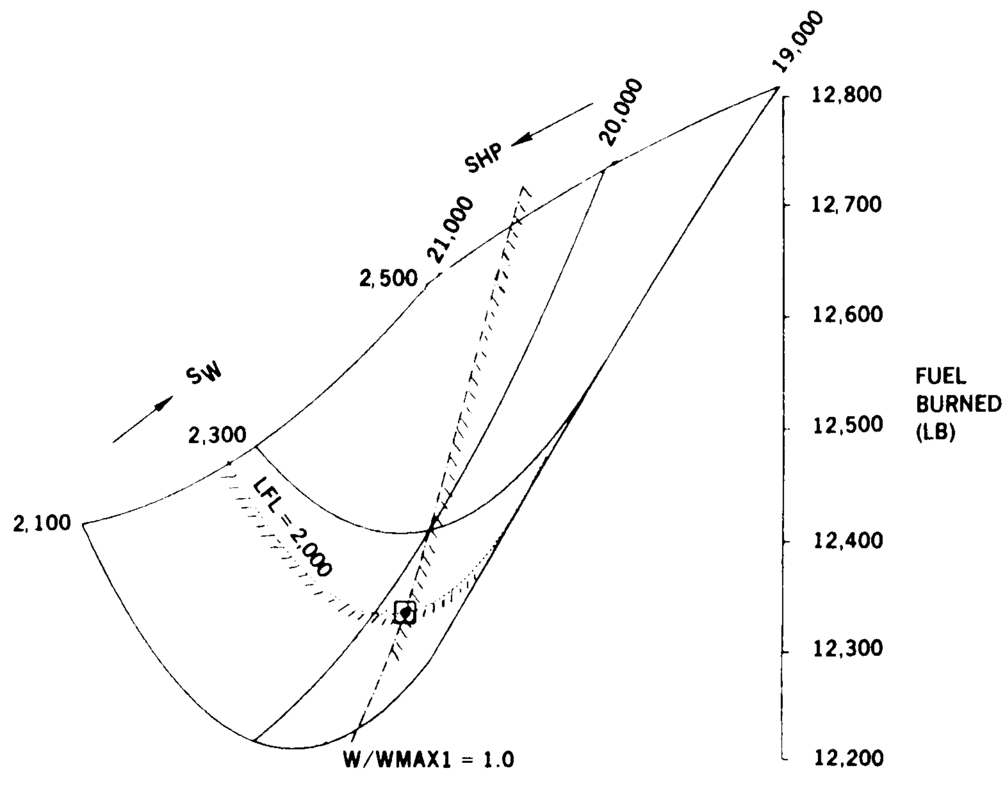


FIGURE 20. PARAMETRIC SIZING SUMMARY — PROPFAN (FUEL BURNED)

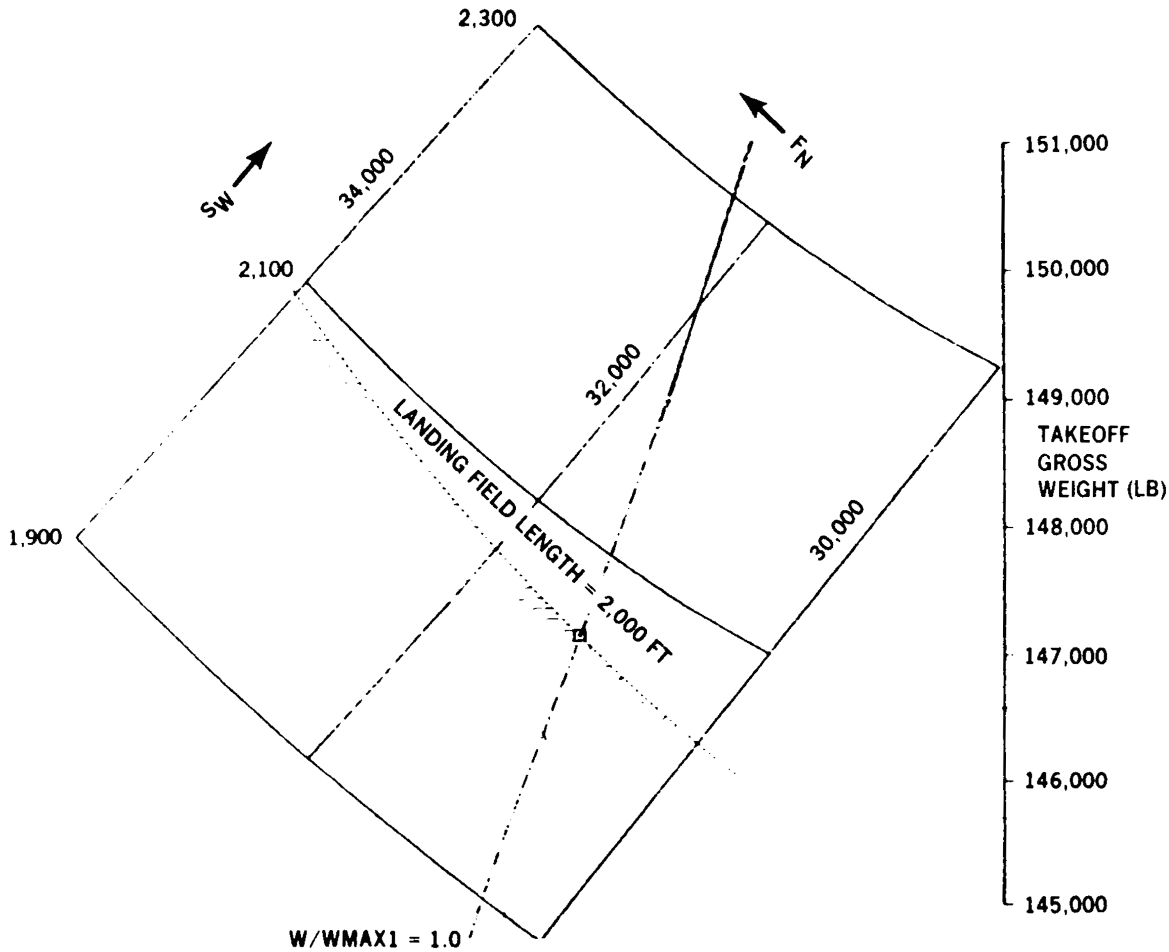


FIGURE 21. PARAMETRIC SIZING SUMMARY — TURBOFAN (TAKEOFF GROSS WEIGHT)

3.2 MISSION PERFORMANCE

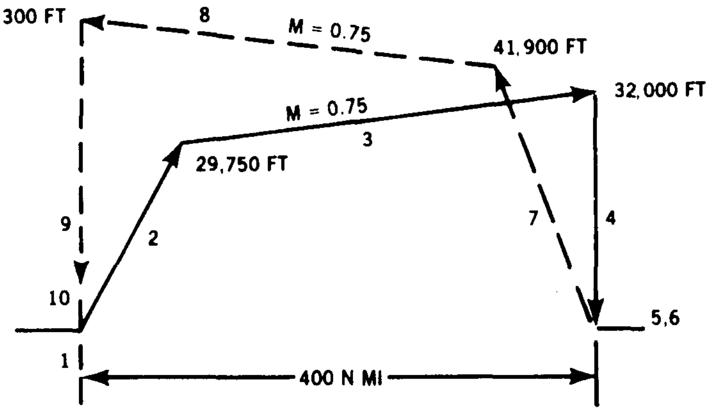
Once the propfan and turbofan configurations were sized for the design mission, additional mission performance characteristics were determined for the design mission and alternate missions. The ability to perform other missions is singularly important in that it demonstrates desired mission flexibility and can influence the total program procurement.

3.2.1 Design Mission

3.2.1.1 Mission Profile — The design mission profile, defined in Section 2.3, is shown in Figures 22 and 23 for the selected propfan and turbofan configurations, along with the cruise altitudes and speeds. Table 7 summarizes the fuel used and distances covered for the same missions.

3.2.1.2 Cruise Characteristics — Some of the more interesting results of the cruise analysis were the basic cruise characteristics of the two configurations. Figure 24 summarizes the variation of the range factor and its components with Mach number for the propfan configuration, and Figure 25 summarizes similar data for the turbofan configuration. For a constant specific fuel consumption (SFC), the maximum value of Mach number times lift-to-drag ratio yields the Mach number for the maximum range factor.

The range factors vary somewhat with altitude and aircraft weight. Figures 24 and 25 represent conditions near the start of cruise on the design mission.



1, 6 TAKEOFF - 5 MINUTES AT MAXIMUM CONTINUOUS POWER

2, 7 CLIMB CLIMB TO CRUISE ALTITUDE AT MAXIMUM CONTINUOUS POWER

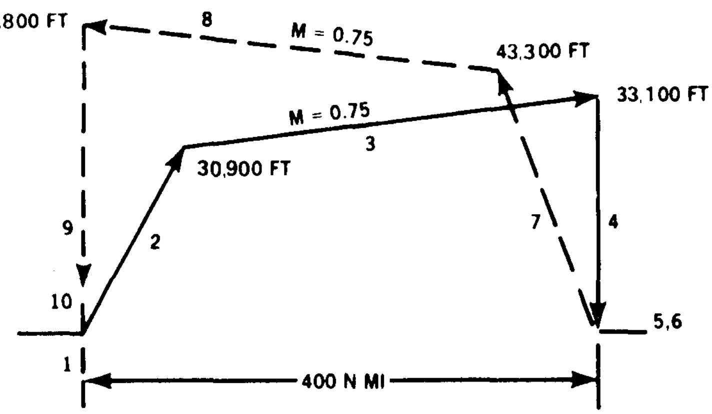
3, 8 CRUISE - CRUISE AT SPEED FOR LONG RANGE OR AT DESIGN MACH NUMBER, WHICHEVER IS GREATER, AND ALTITUDE FOR LONG RANGE

4, 9 DESCENT AND LANDING - NO FUEL OR DISTANCE

5 OFF-LOAD PAYLOAD

10 - FUEL RESERVES
30 MINUTES AT MAXIMUM ENDURANCE AT SEA LEVEL
PLUS 5 PERCENT OF INITIAL FUEL

FIGURE 22. DESIGN TACTICAL AIRLIFT MISSION — PROPFAN



1, 6 TAKEOFF 5 MINUTES AT MAXIMUM CONTINUOUS POWER

2, 7 CLIMB CLIMB TO CRUISE ALTITUDE AT MAXIMUM CONTINUOUS POWER

3, 8 CRUISE CRUISE AT SPEED FOR LONG RANGE OR AT DESIGN MACH NUMBER, WHICHEVER IS GREATER, AND ALTITUDE FOR LONG RANGE

4, 9 DESCENT AND LANDING - NO FUEL OR DISTANCE

5 OFF-LOAD PAYLOAD

10 - FUEL RESERVES
30 MINUTES AT MAXIMUM ENDURANCE AT SEA LEVEL
PLUS 5 PERCENT OF INITIAL FUEL

FIGURE 23. DESIGN TACTICAL AIRLIFT MISSION — TURBOFAN

TABLE 7
FUEL AND DISTANCE SUMMARY — DESIGN MISSION

MISSION SEGMENT	PROPFAN		TURBOFAN	
	FUEL (LB)	DISTANCE (N.MI.)	FUEL (LB)	DISTANCE (N.MI.)
T. O. ALLOWANCE	992	--	1,555	--
CLIMB & ACCELERATE	2,122	80	3,359	108
CRUISE OUT	4,111	312	4,966	292
DESCENT & LANDING	--	--	--	--
T. O. ALLOWANCE	992	--	1,555	--
CLIMB & ACCELERATE	1,555	90	2,232	100
CRUISE BACK	2,555	310	3,130	300
DESCENT & LANDING	--	--	--	--
RESERVE	1,893	--	2,703	--
TOTAL	14,220	800	19,500	800

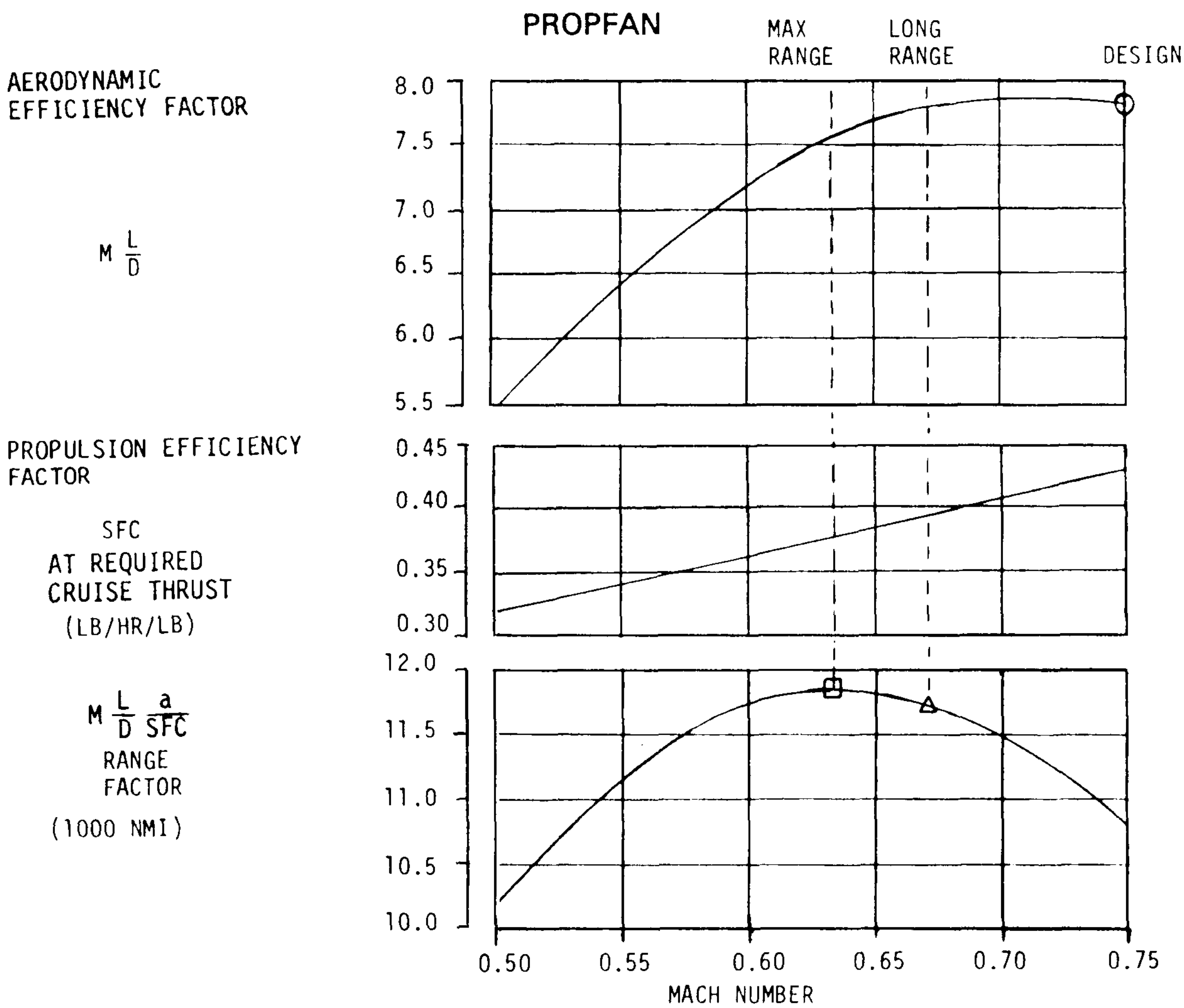


FIGURE 24. CRUISE CHARACTERTICS — PROPFAN

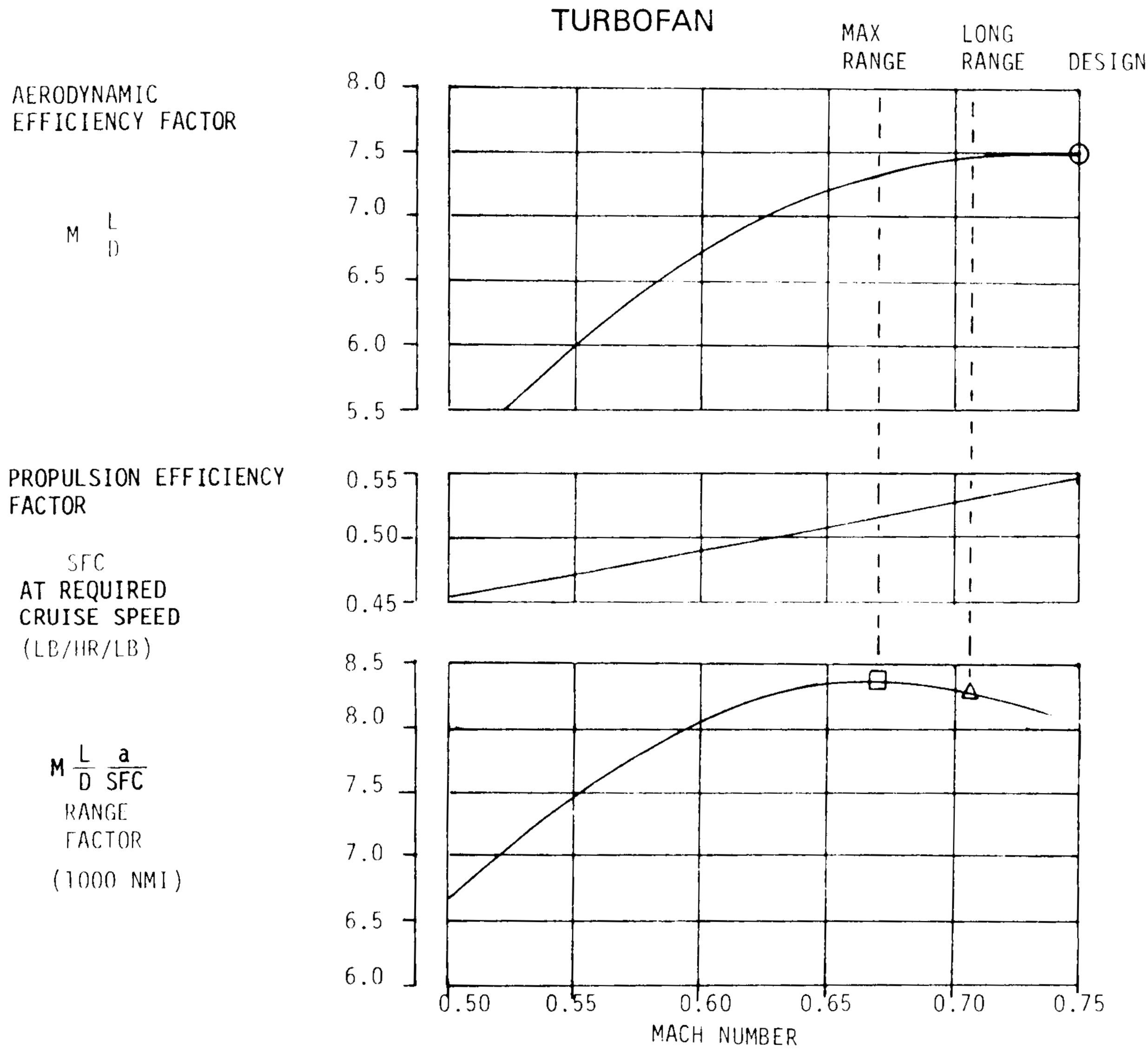


FIGURE 25. CRUISE CHARACTERISTICS — TURBOFAN

However, since the SFC increases with Mach number, the Mach number for the maximum range factor is less than that; and because the slope of the propfan SFC is greater than that of the turbofan, the Mach number of the propfan for the maximum range factor is somewhat less than that of the turbofan, both being less than the design cruise Mach number.

A comparison of the range factors versus Mach number is shown in Figure 26 for the two propulsion systems. At a cruise Mach number of 0.75, which was used for the design mission, the results indicate an improvement of approximately 35 percent for the propfan. At their respective Mach numbers for maximum range factors, 0.63 for the propfan and 0.67 for the turbofan, the propfan improvement increases to 41 percent. Although this would result in a more favorable impact on sizing for the propfan configuration, it would be small, and the lower cruise speeds would be less than attractive.

3.2.1.3 Takeoff Performance — The takeoff performance, while not critical in the sense of sizing the engine or wing area, still must be adequate to meet the 2,000-ft field length at the forward operating base. Figures 27 and 28 summarize the takeoff performance for the propfan and turbofan configurations.

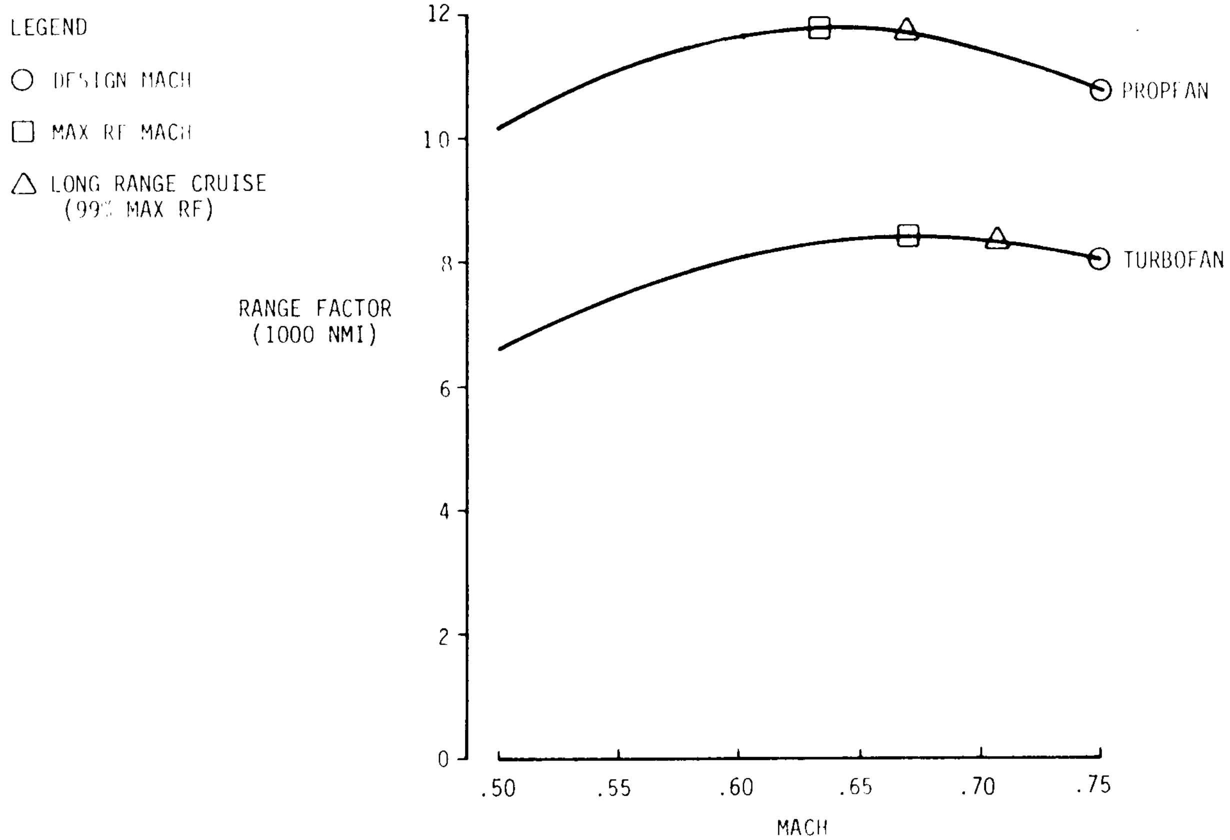


FIGURE 26. RANGE FACTOR COMPARISON

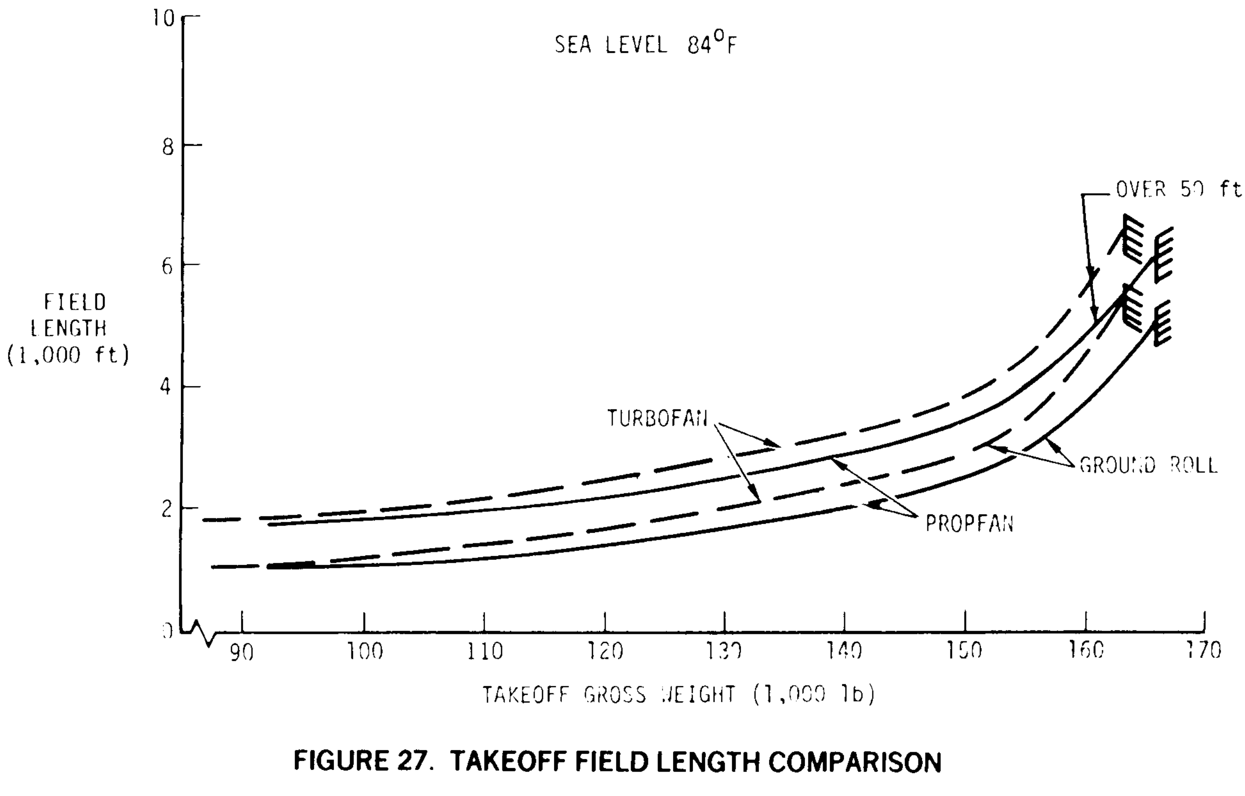


FIGURE 27. TAKEOFF FIELD LENGTH COMPARISON

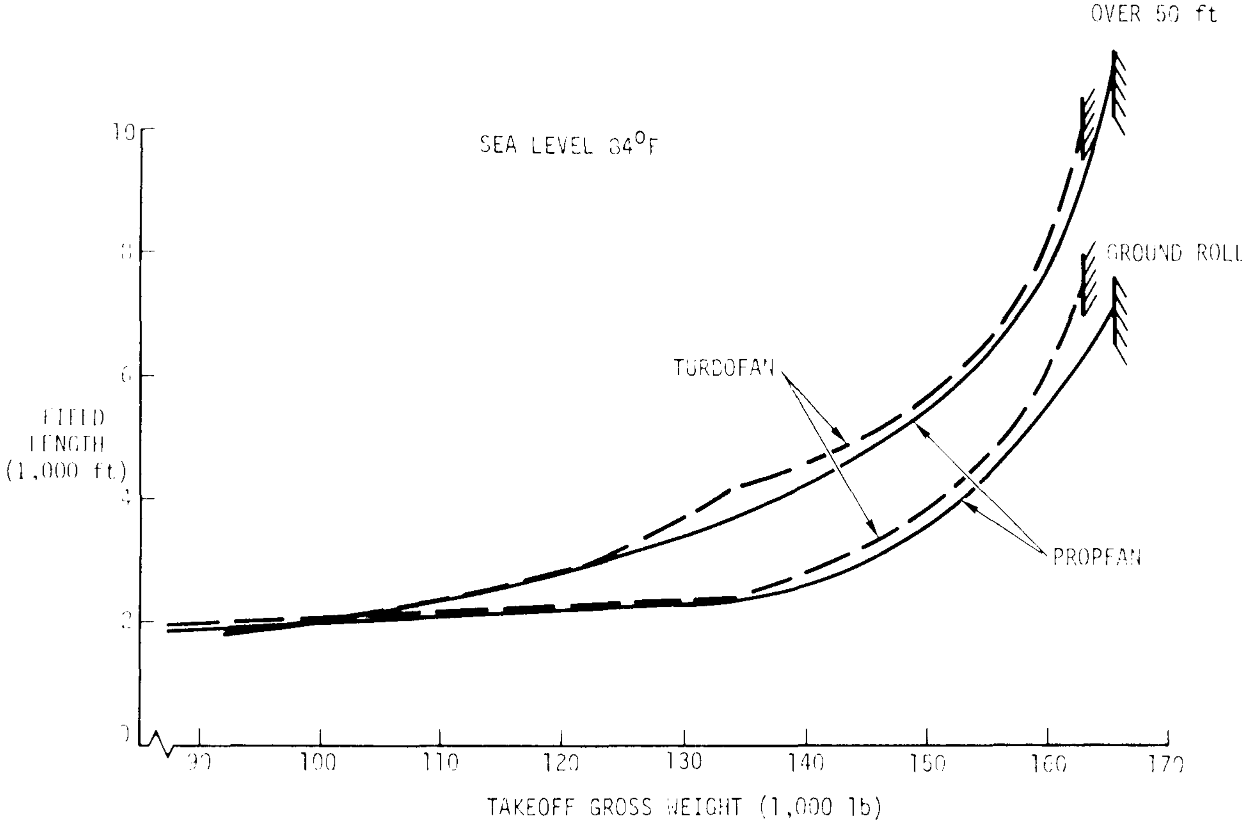


FIGURE 28. CRITICAL FIELD LENGTH COMPARISON

With all engines operating (Figure 27), at the gross weight at the forward operating base of approximately 90,000 lb, the standard military field length over a 50-ft obstacle on a hot day is about 100 ft less than the required 2,000 ft. The corresponding ground roll is approximately 1,200 ft. At the initial takeoff weight, the distance over a 50-ft obstacle is still only about 3,500 ft. The propfan configuration has slightly better performance at all takeoff gross weights.

The critical field length (engine-out) at the midpoint gross weight is still slightly less than 2,000 ft. The critical field length is the distance required to lift off after engine failure or to stop. The continued takeoff in case of an engine failure at the critical engine failure speed results in the distances required to clear 50 ft. At takeoff gross weights below approximately 135,000 lb, the minimum directional ground control speed limits the critical engine failure speed, so that the aborted distance is the critical distance.

3.2.2 Alternate Missions

The alternate missions considered here are regarded as complementary missions which the tactical transport would normally perform in the deployment or employment in the theater of operations. In the context of this study, they are indicative of "off-design" mission capability and provide an additional basis for comparison between the two propulsion system configurations.

3.2.2.1 Ferry Mission — This is a pure range mission (Figure 29) descriptive of the capability for initial deployment of the aircraft from CONUS to a theater of operations or from one theater to another. Payload is a variable depending upon the stage of the conflict, number of aircraft deployed, and, of course, whether en route in-flight refueling or ground refueling is available.

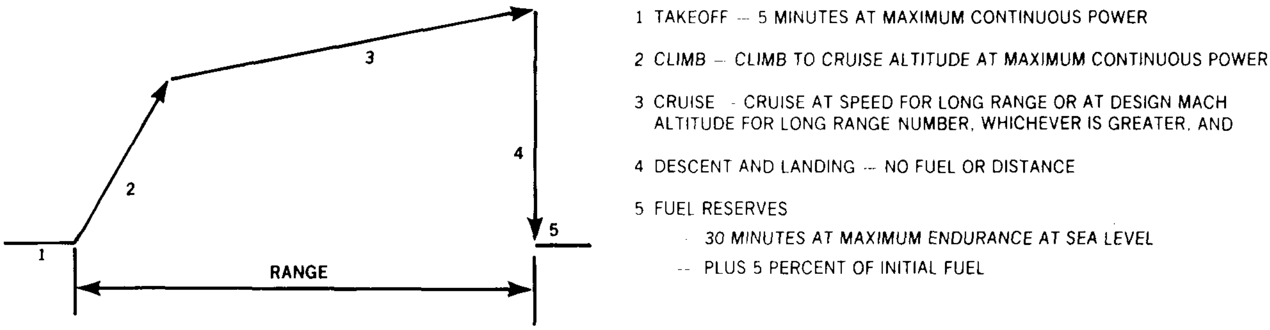


FIGURE 29. FERRY MISSION

Figure 30 summarizes the payload-range capability for the propfan-powered and turbofan-powered aircraft at gross weights for the limit load factor of 2.5 and for an overload load factor of 2.25. At a load factor of 2.5, the total aerodynamic lift is 2.5 times the total weight of the aircraft. The airplane and components are designed to strength levels established by the limit load factor. The limit load factor is the maximum load factor normally authorized for operations. By reducing the load factor to 2.25, the same structure is allowed to carry an increased total weight, resulting in a substantial increase in payload. Because of more efficient fuel usage, the propfan configuration offers some 1,000-n-mi more range capability at reduced payloads. Fuel and distance summaries for a load factor of 2.5 and for each of three payloads are shown in Table 8. Table 9 shows the corresponding cruise altitudes and speeds.

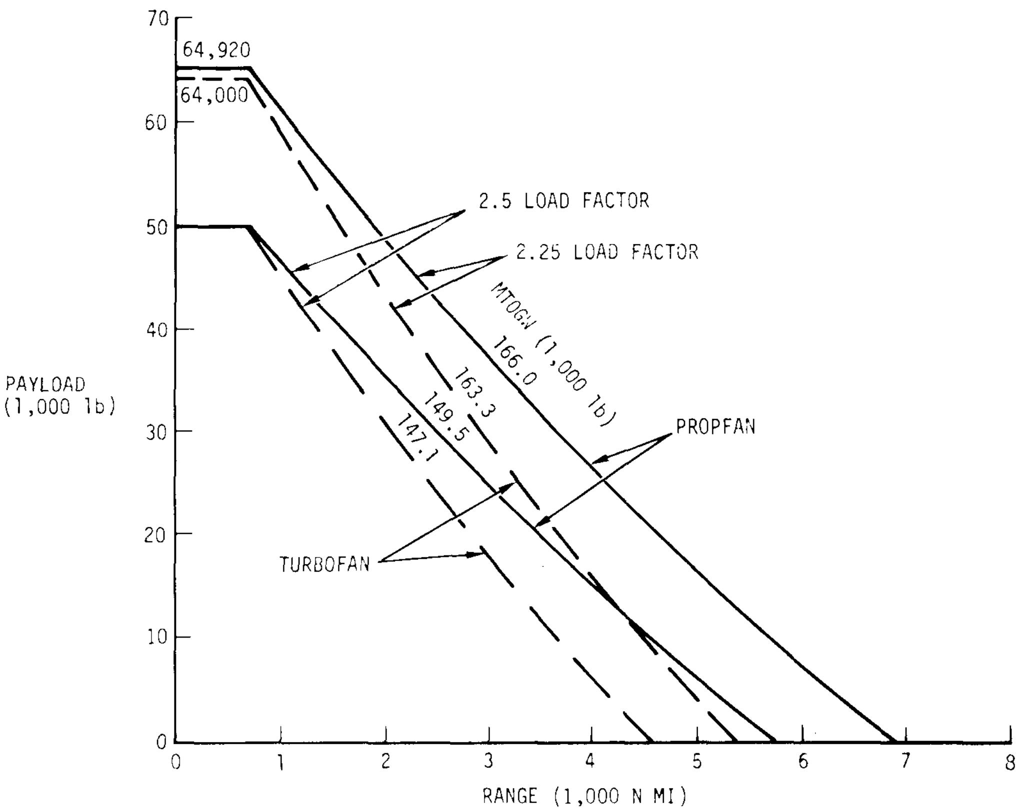


FIGURE 30. PAYLOAD-RANGE COMPARISON

TABLE 8
FUEL AND DISTANCE SUMMARY – FERRY MISSION
LOAD FACTOR = 2.5 LONG-RANGE CRUISE SPEED

a. 50,000-POUND PAYLOAD

	PROPFAN		TURBOFAN	
	FUEL (LB)	DISTANCE (N MI)	FUEL (LB)	DISTANCE (N MI)
TAKEOFF ALLOWANCE	992	--	1,555	--
CLIMB AND ACCELERATE	2,717	129	3,814	131
CRUISE	7,987	664	10,453	647
RESERVE	2,516	--	3,678	--
TOTALS	14,212	793	19,500	778

b. 25,000-POUND PAYLOAD

	PROPFAN		TURBOFAN	
	FUEL (LB)	DISTANCE (N MI)	FUEL (LB)	DISTANCE (N MI)
TAKEOFF ALLOWANCE	992	--	1,555	--
CLIMB AND ACCELERATE	2,717	129	3,814	131
CRUISE	32,042	2,914	34,674	2,357
RESERVE	3,461	--	4,457	--
TOTALS	39,212	3,043	44,500	2,488

c. ZERO PAYLOAD

	PROPFAN		TURBOFAN	
	FUEL (LB)	DISTANCE (N MI)	FUEL (LB)	DISTANCE (N MI)
TAKEOFF ALLOWANCE	992	–	1,555	–
CLIMB AND ACCELERATE	2,717	129	3,814	131
CRUISE	56,080	5,635	58,881	4,445
RESERVE	4,423	–	5,250	–
TOTALS	64,212	5,764	69,500	4,576

TABLE 9
CRUISE ALTITUDE AND SPEED SUMMARY — FERRY MISSION

LOAD FACTOR = 2.5, LONG RANGE CRUISE SPEED, CRUISE CEILING ALTITUDE

		START CRUISE		END CRUISE	
PROPULSION SYSTEM TYPE	PAYLOAD (LB)	ALTITUDE (FT)	MACH NO.	ALTITUDE (FT)	MACH NO.
PROPFAN	50,000	34,190	0.721	35,800	0.725
	25,000	34,190	0.721	36,850	0.694
	0	34,190	0.721	42,030	0.698
TURBOFAN	50,000	33,200	0.735	35,750	0.743
	25,000	33,200	0.735	38,550	0.729
	0	33,200	0.735	43,430	0.725

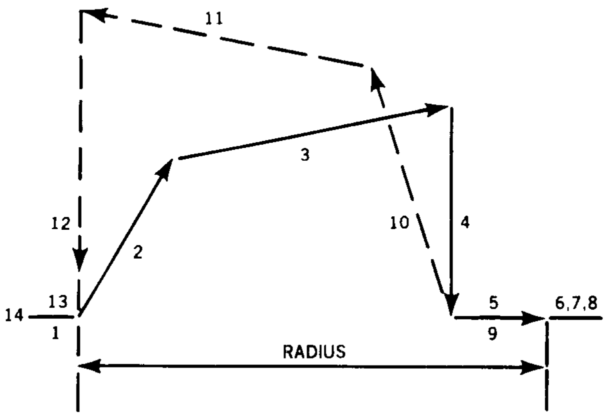
3.2.2.2 Assault Mission — The assault mission (Figure 31) is identical to the design mission except that the last leg into and the first leg from the forward operating base are accomplished at low altitude and high speed to enhance survivability. This low-altitude penetration would require terrain avoidance/following profiles.

Figure 32 summarizes the penetration capability as a function of the overall radius and payload. The overall operational flexibility shown in the figure is further enhanced with the propfan configuration compared to the turbofan configuration. Table 10 presents the fuel used and distance breakdown for two different payloads. Table 11 shows the corresponding cruise altitudes.

As reflected in Figure 33, the maximum level flight speed at low altitudes with both propulsion systems is approximately M = 0.65, the propulsion systems having been sized by the initial high-altitude cruise conditions. As may be noted, the aircraft weight has little impact on the maximum level flight speed at any altitude.

3.2.2.3 Tactical Command and Control Mission — In the tactical command and control mission (Figure 34), a force commander has his command post in the theater of operations. This post controls both air and ground operations, either as an airborne platform or deployable as a ground station. As an airborne platform, one of the requirements is to maintain that station as long as practicable. With no speed requirement on-station, this mission exercises the long-endurance characteristics of the propfan and turbofan aircraft.

Figure 35 summarizes the time-on-station as a function of the distance to the station (radius) for several different payloads and for each of the two propulsion systems. For a given payload and distance to the station, the propfan configuration offers up to 40 percent improvement in time-on-station. A breakdown of the fuel used and distance is summarized in Table 12 for a payload of 30,000 lb and two different radii for each of the propulsion system configurations.



1, 8 TAKEOFF - 5 MINUTES AT MAXIMUM CONTINUOUS POWER

2, 10 CLIMB CLIMB TO CRUISE ALTITUDE AT MAXIMUM CONTINUOUS POWER

3, 11 CRUISE CRUISE AT DESIGN MACH NUMBER, AND CRUISE CEILING ALTITUDE

4, 12 DESCENT - NO FUEL OR DISTANCE

5, 9 PENETRATION AT MAXIMUM SPEED (FIGURE 33) AND AT ALTITUDE OF 100 FEET

6, 13 LANDING NO FUEL

7 OFF-LOAD PAYLOAD

14 FUEL RESERVES
-- 30 MINUTES AT MAXIMUM ENDURANCE AT SEA LEVEL
- PLUS 5 PERCENT OF INITIAL FUEL

FIGURE 31. ASSAULT AIRLIFT MISSION

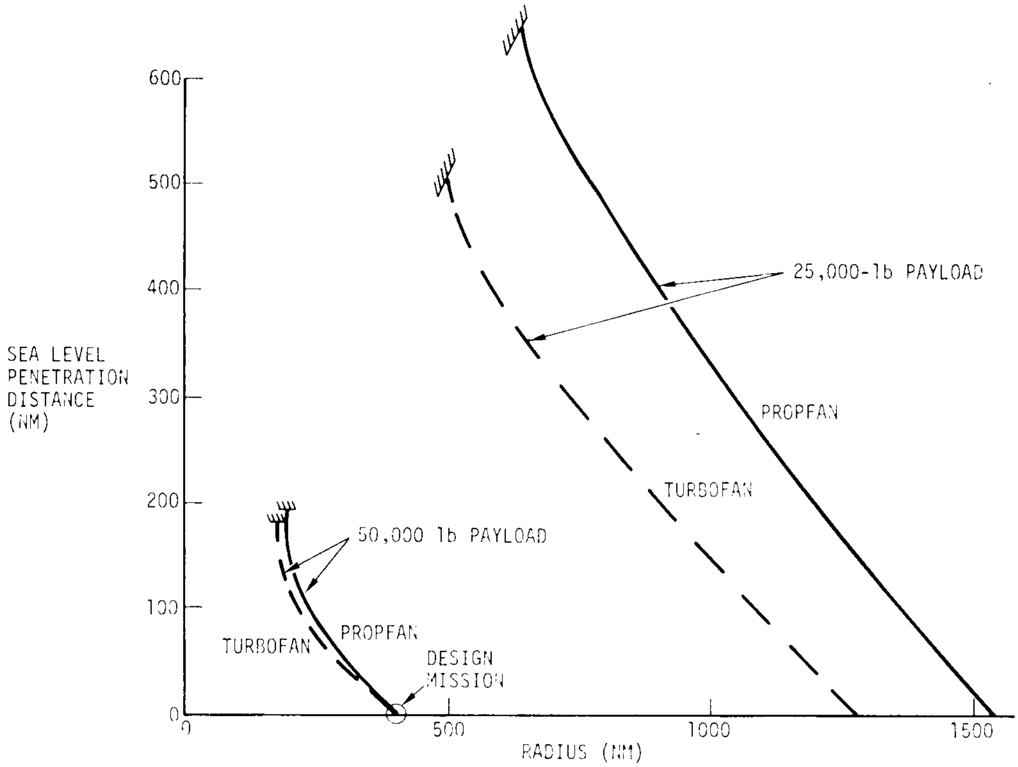


FIGURE 32. SEA LEVEL PENETRATION COMPARISON (ASSAULT AIRLIFT MISSION)

TABLE 10a
ASSAULT MISSION FUEL AND DISTANCE 25,000-LB PAYLOAD

PENETRATION DIST (N MI)	100				300			
PROPULSION SYSTEM	PROPFAN		TURBOFAN		PROPFAN		TURBOFAN	
	FUEL (LB)	DIST (N MI)	FUEL (LB)	DIST (N MI)	FUEL (LB)	DIST (N MI)	FUEL (LB)	DIST (N MI)
TAKEOFF ALLOWANCE	992	--	1,555	--	992	--	1,555	--
CLIMB & ACCELERATE	2,124	88	3,359	108	2,124	88	3,359	108
CRUISE OUT	14,526	1,172	14,194	873	8,549	668	5,617	331
PENETRATE IN	2,628	100	3,684	100	7,890	300	11,065	300
TAKEOFF ALLOWANCE & ACCELERATE	1,312	9	2,023	9	1,314	9	2,030	9
PENETRATE BACK	2,387	91	3,329	91	7,608	291	10,642	291
CLIMB & ACCELERATE	2,385	131	3,196	135	2,271	127	2,974	129
CRUISE BACK	9,699	1,129	9,180	847	5,305	629	3,278	311
RESERVES	3,157	--	3,977	--	3,157	--	3,977	--
TOTALS	39,210	2,720	44,497	2,163	39,210	2,112	44,497	1,479

TABLE 10b
ASSAULT MISSION FUEL AND DISTANCE 50,000-LB PAYLOAD

PENETRATION DIST (N MI)	50				100			
PROPULSION SYSTEM	PROPFAN		TURBOFAN		PROPFAN		TURBOFAN	
	FUEL (LB)	DIST (N MI)	FUEL (LB)	DIST (N MI)	FUEL (LB)	DIST (N MI)	FUEL (LB)	DIST (N MI)
TAKEOFF ALLOWANCE	992	--	1,555	--	992	--	1,555	--
CLIMB & ACCELERATE	2,124	88	3,359	108	2,124	88	3,359	108
CRUISE OUT	2,260	170	2,415	140	649	49	121	7
PENETRATE IN	1,318	50	1,848	50	2,637	100	3,697	100
TAKEOFF ALLOWANCE & ACCELERATE	1,274	8	1,965	8	1,275	8	1,967	8
PENETRATE BACK	1,104	42	1,536	42	2,408	92	3,361	92
CLIMB & ACCELERATE	2,130	122	2,848	125	2,106	121	2,633	105
CRUISE BACK	1,117	136	1,268	123	129	16	101	10
RESERVES	1,893	--	2,703	--	1,893	--	2,703	--
TOTALS	14,212	616	19,497	596	14,212	474	19,497	430

TABLE 11
ASSAULT MISSION CRUISE ALTITUDE SUMMARY

M = 0.75, CRUISE CEILING, ALTITUDE

			CRUISE OUT		CRUISE BACK	
PROPULSION SYSTEM TYPE	PENETRATION DISTANCE (N.MI.)	PAYLOAD (LB)	START CRUISE ALTITUDE (FT)	END CRUISE ALTITUDE (FT)	START CRUISE ALTITUDE (FT)	END CRUISE ALTITUDE (FT)
PROPFAN	100	25,000	29,750	35,570	40,540	42,140
	300	25,000	29,750	33,710	41,270	42,140
	50	50,000	29,750	31,200	42,130	42,330
	100	50,000	29,750	30,250	42,300	42,330
TURBOFAN	100	25,000	30,870	36,000	41,910	43,550
	300	25,000	30,870	33,400	42,970	43,550
	50	50,000	30,870	32,220	43,600	43,800
	100	50,000	30,870	30,940	43,780	43,800

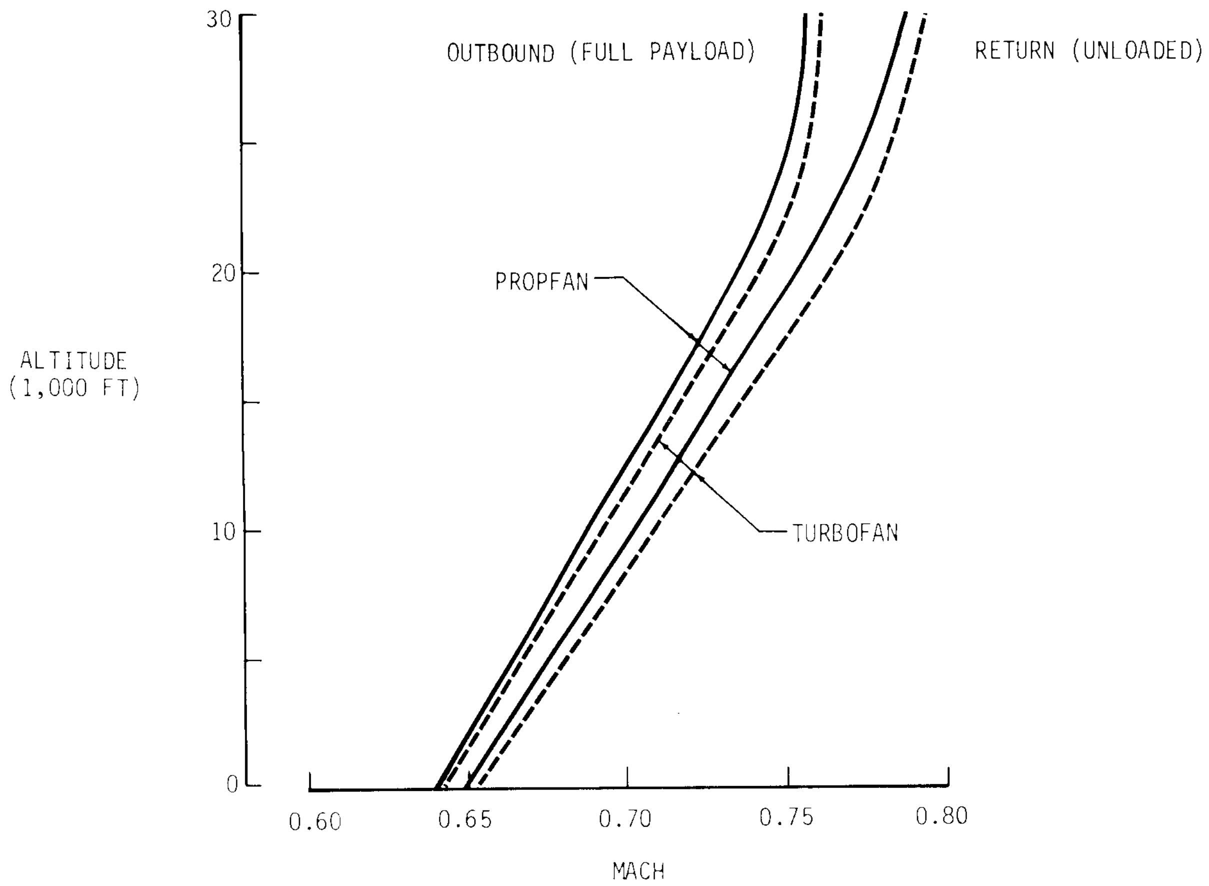
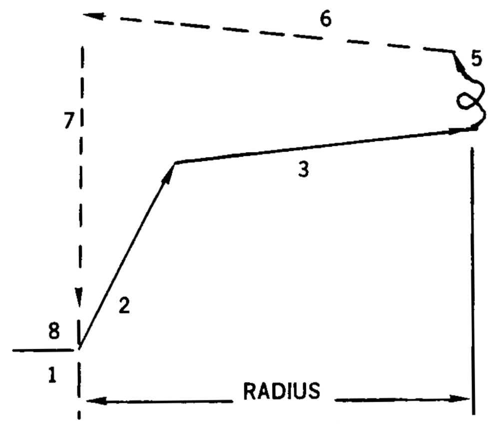


FIGURE 33. MAXIMUM LEVEL FLIGHT SPEED CAPACITY



1 TAKEOFF — 5 MINUTES AT MAXIMUM CONTINUOUS POWER

2, 5 CLIMB — CLIMB TO CRUISE ALTITUDE AT MAXIMUM CONTINUOUS POWER

3, 6 CRUISE — CRUISE AT DESIGN MACH NUMBER, AND CRUISE CEILING ALTITUDE

4 LOITER AT SPEED AND ALTITUDE FOR MAXIMUM ENDURANCE
(M = 0.60 FOR PROPFAN, M = 0.64 TURBOFAN)

7 DESCENT AND LANDING — NO FUEL OR DISTANCE

14 FUEL RESERVES

— 30 MINUTES AT MAXIMUM ENDURANCE AT SEA LEVEL

— PLUS 5 PERCENT OF INITIAL FUEL

FIGURE 34. TACTICAL COMMAND AND CONTROL MISSION

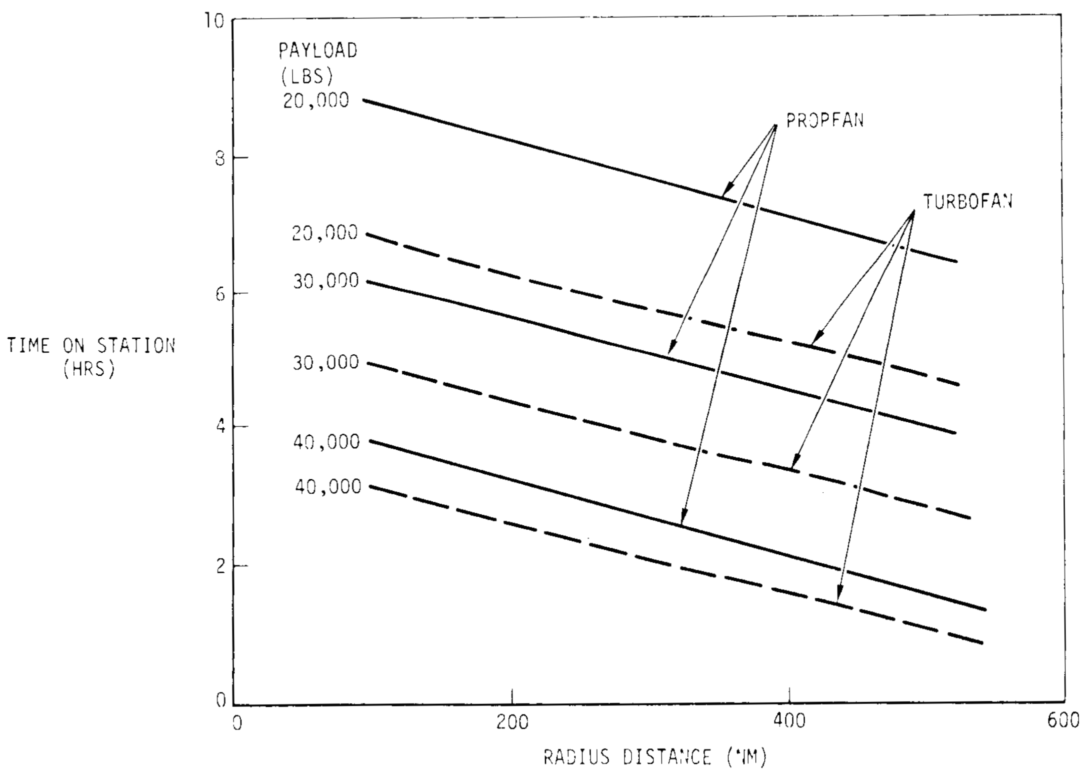


FIGURE 35. TIME-ON-STATION COMPARISON (TACTICAL COMMAND AND CONTROL MISSION)

TABLE 12
COMMAND AND CONTROL MISSION 30,000-LB PAYLOAD

	RADIUS = 200 N MI						RADIUS = 400 N MI					
	PROPFAN, TOS = 5.66 HR			TURBOFAN, TOS = 4.39 HR			PROPFAN, TOS = 4.55 HR			TURBOFAN, TOS = 3.40 HR		
	FUEL	DIST	FIN ALT	FUEL	DIST	FIN ALT	FUEL	DIST	FIN ALT	FUEL	DIST	FIN ALT
TAKEOFF ALLOWANCE	992	--	50	1,555	--	50	992	--	50	1,555	--	50
CLIMB & ACCELERATION	2,124	88	29,750	3,359	108	30,866	2,124	88	29,750	3,359	108	30,900
CRUISE OUT*	1,492	112	30,866	1,592	92	31,791	4,101	312	31,988	4,964	292	33,100
CLIMB & LOITER	24,170	1,951	39,109	25,897	1,621	39,335	19,418	1,569	38,807	19,735	1,237	38,900
ACCELERATION & CRUISE*	2,166	200	37,723	2,794	200	38,544	4,308	400	37,723	5,584	400	38,500
RESERVES	3,271	--	--	4,300	--	--	3,271	--	--	4,300	--	--
TOTALS	34,215	2,351		39,497	2,021		34,214	2,369		39,497	2,037	

*CRUISE IS AT DESIGN MACH NUMBER, 0.75

3.3 POWER PLANT CHARACTERISTICS

3.3.1 Description

The data for the engines used in MAPS were developed from the NASA Advanced Propfan Engine Technology (APET) study. These data were used because they provide a consistent advanced technology level. A characteristic comparison is shown in Table 13.

TABLE 13
TURBOFAN AND PROPFAN ENGINE CHARACTERISTICS COMPARISON

	Turbofan	Propfan
Bypass Ratio	7.0	---
Overall Pressure Ratio at Max Climb, 35,000 ft Altitude	40.8	38.3
Combustor Exit Temperature (°F)		
Growth	2660	2600
Initial	2590	2530
Takeoff Thrust/Power at Sea Level Standard Day Plus 25°F	16,600 LB (Static Thrust)	11,600 shp (Mach = 0.3)
Engine Sizing Condition	Takeoff	Max Climb

3.3.1.1 Propfan Engine — The propfan is powered by the Pratt & Whitney STS 679 three-spool shaft engine. This study engine was designed by Pratt & Whitney under NASA Contract NAS3-23045 for an "Advanced Propfan Engine Technology Definition Study." The high spool is an axial/centrifugal compression system driven by a single-stage high-pressure turbine. The high-pressure compressor system features two axial compression stages followed by a single centrifugal compression stage. A pipe diffuser is used and a single-stage aerating burner is canted to mate with the centrifugal compressor.

The low-presure spool has a four-stage, low-pressure compressor driven by a single-stage low-pressure turbine. The rotor speed was limited by the low-pressure compressor corrected tip speed of 1,440 ft/sec which was considered a reasonable trade between efficiency, weight, and cost. This tip speed, coupled with the requirement to provide sufficient radial space for the bearing compartments, led to selection of the intermediate turbine rotor speed limit.

The three-stage power turbine configuration is used to achieve the velocity ratio required for high efficiency in a close coupled mechanical arrangement in which the speed is set by the maximum turbine blade attachment stress in the last stage.

The propellers are driven by an in-line differential planetary gearbox with counterrotating output shafts.

The STS 679 drives the Hamilton Standard F252 propellers, which are thin, swept, highly loaded advanced designs providing high efficiency at high flight speeds. The 6-by-6 propeller was selected based on results from related in-house studies being conducted at Douglas. The 6-by-6 has the smallest diameter and lowest weight of propellers for which data were available.

The control system for the propfan propulsion system is an advanced design incorporating electronic circuitry, fiber optics, and dual redundancy in the vital control paths.

Electronic computation makes it possible to tailor propulsion system operation to the power setting regime, thus achieving maximum thrust at takeoff, low noise during approach, maximum thrust reversal effectiveness, and optimum fuel consumption during cruise. Integrating gas generator performance and propfan blade pitch setting offers additional flexibility in controlling transient operation during takeoff and landing. Electronic computation also provides great flexibility in dealing with fault accommodation, leading to improved safety of flight. Major control mode features are: (1) independent control of propeller (e.g., synchrophasing) and engine speed/power setting, (2) automatic control in steady state and transient operation for forward and reverse thrust, and (3) protective measures for limiting torque, temperature, overspeed, and possible system fault (e.g., propfan feathering and windmilling).

3.3.1.2 Turbofan Engine — The STS 686 is a twin-spool turbofan engine with a bypass ratio of 7, fan pressure ratio of 1.66, and takeoff overall pressure ratio of 37.

The STF 686 incorporates a single-stage shroudless fan with an aspect ratio of 2.8 with increased flow capacity and higher aerodynamic loading. An improved airfoil contour will reduce shock losses, and manufacture of the airfoil contour with closer tolerances and consistency will improve fan performance.

The high-pressure spool is made up of an 11-stage high-pressure compressor, a low-emissions combustor, and a two-stage high-pressure turbine. The low-pressure spool consists of a single-stage shroudless fan, a three-stage low-pressure compressor, and a five-stage low-pressure turbine. The low- and high-pressure compressors incorporate aerodynamic improvements including new airfoil contours and reduced end wall losses. Advances in airfoil contour design will come from better understanding of both the two-dimensional and three-dimensional loss mechanisms. The introduction of controlled diffusion airfoils (CDAs) in the early 1980s will be followed by a second generation of CDAs in the late 1980s. Improved three-dimensional modeling of end wall flow interactions will result in airfoil designs that enhance aerodynamic efficiency. Also, improvements in materials and mechanical configurations will allow better tip clearance management, with active clearance control and new stator cavity designs resulting in improved compressor performance.

The STF 686 incorporates an advanced technology MARK V combustion system that is now under evaluation and development at Pratt & Whitney. It is an outgrowth of the combustor concepts developed under the NASA/Pratt & Whitney Experimental Clean Combustor Program and the NASA/Pratt & Whitney Energy Efficient Engine Program. The MARK V combustion system uses high-mixing-rate technology to produce rapid burning and dilute combustion products with an integrated low-pressure loss diffuser system.

The major technology features in the turbine are improved single-crystal airfoil materials and increased cooling effectiveness. These advances result in increased high-pressure turbine efficiency and reduced turbine cooling requirements.

Improved single-crystal airfoil materials permit higher stress turbine blade root designs. This will, in turn, permit a better selection of aerodynamic parameters for improved performance.

Improved single-crystal airfoil materials, addition of thermal barrier coating on the blades and vanes, and increased cooling effectiveness will result in lower cooling airflow requirements and higher allowable compressor discharge temperature. Greater cooling effectiveness is attained by multipass designs that use impingement leading and trailing edges. Leading edge impingement air is reused as film through showerhead holes and trailing edge impingement air is used for convective cooling through the trailing edge holes. Skewed trip strips augment the heat transfer. Film cooling is provided in the blade trailing edge tip regions.

3.3.2 Installation

Installation studies were conducted to establish a realistic basis for evaluations and identify technology development needs.

3.3.2.1 Propfan Installation — The propfan installation is shown in Figure 36. The engine is supported from below with thrust and torque loads taken through the aft mounts which are attached to the gearbox. The forward mount takes vertical and side loads. An overhead crane is used for engine removal and replacement.

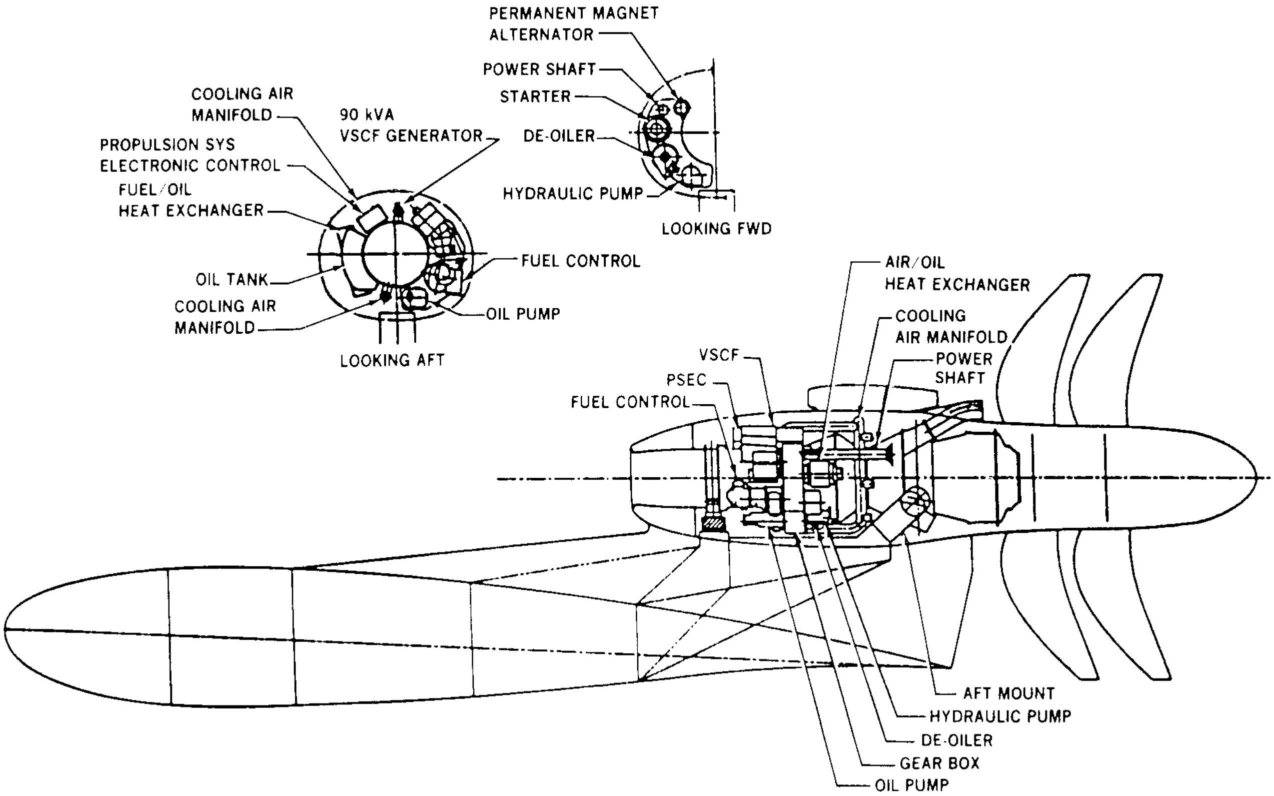


FIGURE 36. PROPFAN INSTALLATION

The gas generator exhaust discharges through a multilobe mixer nozzle forward of the propellers.

The engine and airframe accessories are located on the gas generator gearbox. This arrangement is used to preclude increasing the flow-path diameter around the gearbox, which is forward of the propellers and avoids the hot environment near the exhaust flow.

The air/oil heat exchanger used to cool the gearbox oil is located on top of the nacelle.

3.3.2.2 Turbofan Installation — The installation for the turbofan engine in a blended wing/body configuration is shown in Figure 37. The installation is designed to allow removal and replacement of the engine by opening the lower cowling and dropping the engine straight down with built-in hoist points. The inlet is part of the airframe structure with the engine supported by side mounts. Fan case mounts are used to take thrust and torque loads. Turbine case mounts are used to react vertical and side loads. The relative motion between the engine and inlet is accommodated using a movable butterfly similar to that used in the DC-10 tail engine installation.

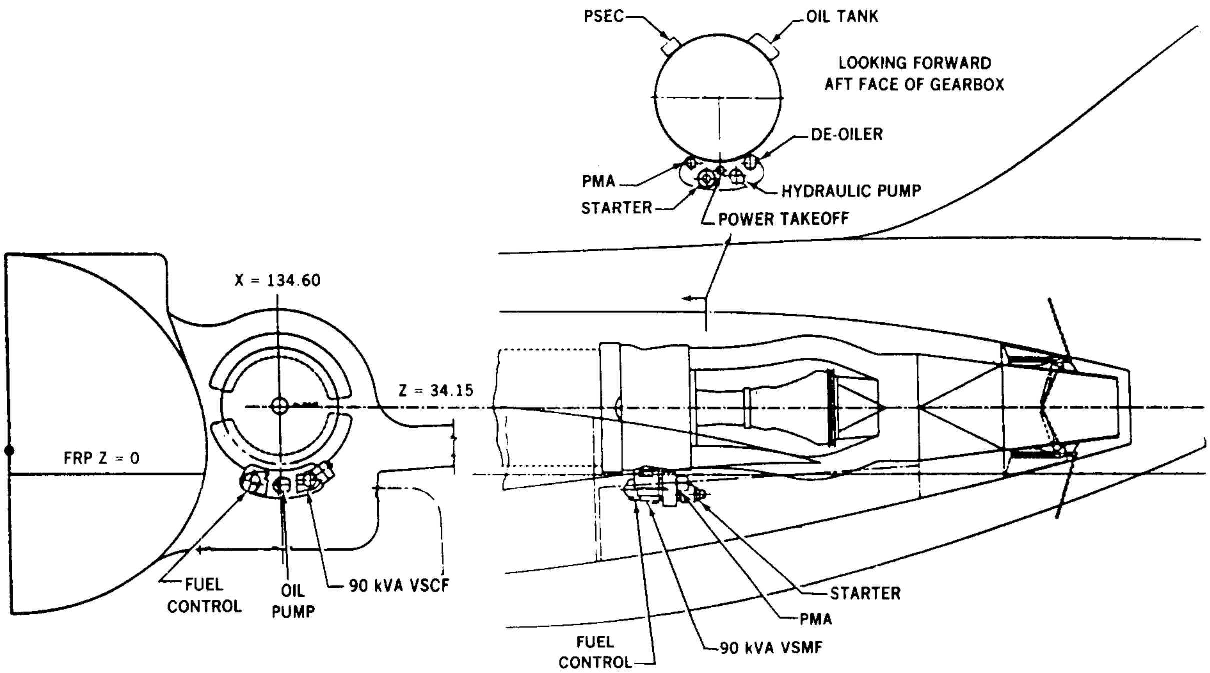


FIGURE 37. TURBOFAN INSTALLATION

The exhaust nozzle is a concentric flow long duct. A two-door thrust reverser is used to discharge flow during reverse thrust in the upward and downward directions.

The airframe accessories are located on the lower fan case for accessibility.

3.3.3 Propulsion System Data

Propulsion system performance and weight data from Pratt & Whitney Aircraft were used for engines, and Hamilton Standard supplied data for propellers. These data are described in References 1 through 3 which are users manuals for computer decks and include performance, weight, and dimensional scaling data for varying engine size.

3.3.3.1 Propfan Installation Losses — The inlet losses used for the propfan are shown in Figure 38 for a typical wing-mounted turbofan engine with a short inlet.

The reference nozzle in the performance deck was used since this mixer nozzle will be part of the basic turboshaft engine.

The power extraction losses were estimated by using representative requirements from the C-17, adjusted for the MAPS study airplane size. The shaft power was estimated to be 50 hp per engine and the bleed flow to be 0.42 lb/sec per engine. Additional losses for nacelle venting, cooling, and leakage were assumed to be equal to 50 percent of the bleed flow and were included in the performance deck by increasing bleed flow to 0.63 lb/sec per engine.

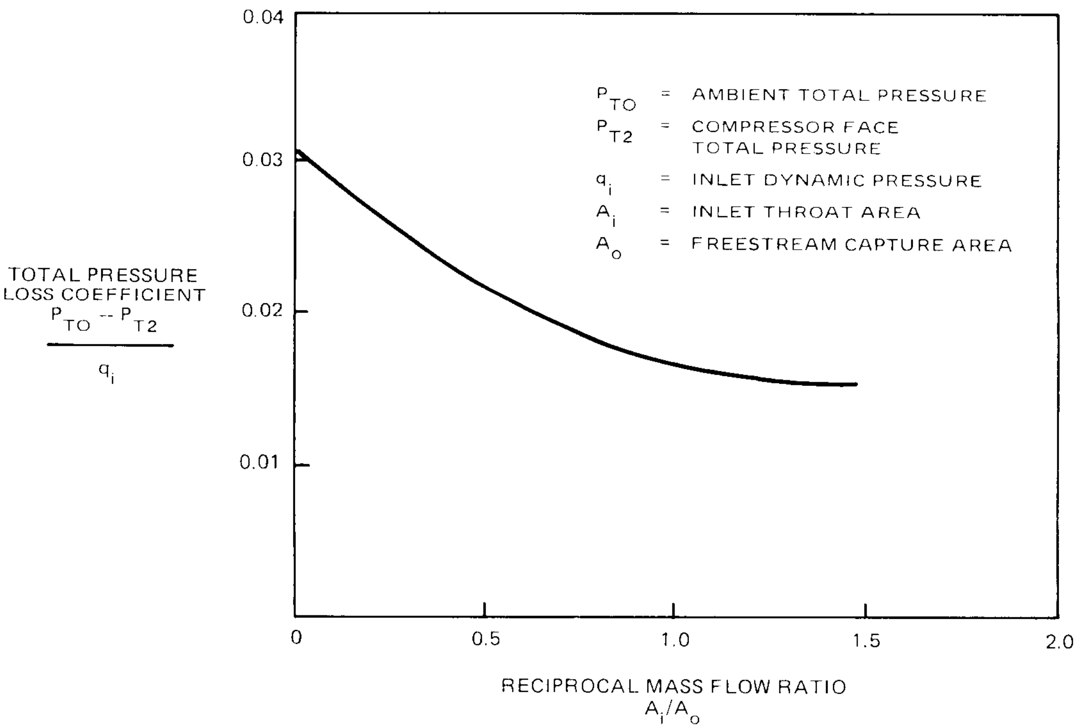


FIGURE 38. PROPFAN INLET TOTAL PRESSURE LOSS

3.3.3.2 Turbofan Installation Losses — The inlet pressure recovery was estimated by using the DC-10 tail engine inlet losses because it has a long inlet, and was analytically corrected for the turning loss and the difference in length. The resultant pressure recovery is shown in Figure 39.

The reference nozzle performance provided by Pratt & Whitney Aircraft was used for the exhaust nozzle performance in the engine performance computer deck. This performance is for a separate flow nozzle. Past studies have shown that the engine cycle can be matched at a design point, but will result in some differences at other conditions. It was beyond the scope of this study to conduct engine cycle studies and the small differences that would occur are not expected to affect the basic comparison of propfans and turbofans.

Similarly, the effect of nozzle length on performance of a confluent-flow nozzle in the length-to-diameter ratio range of interest is relatively small.

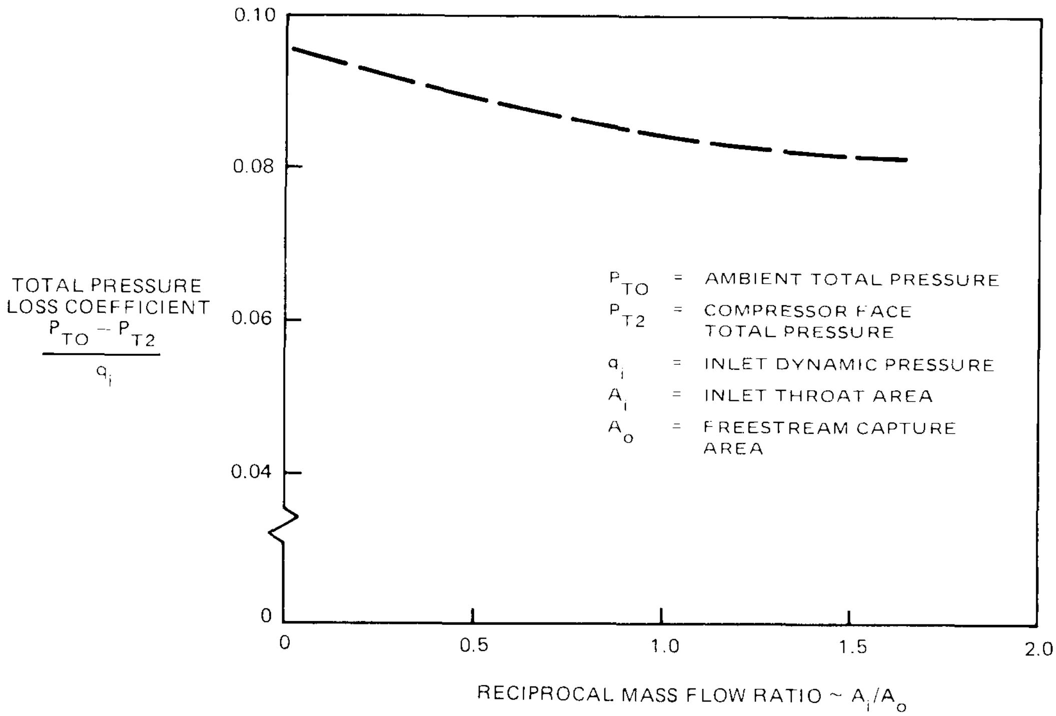


FIGURE 39. TURBOFAN INLET TOTAL PRESSURE LOSS

Figure 40 shows this effect using data from Reference 4. As the nozzle length increases, the mixing gain increases, while the skin friction losses cause decreasing performance. The net effect is close to zero.

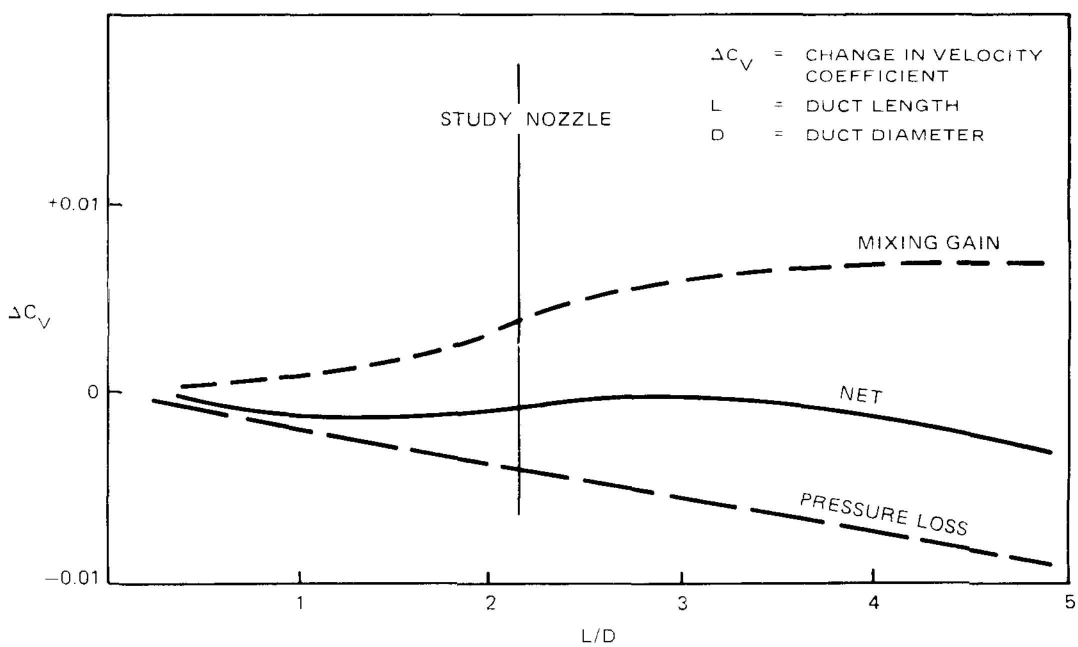


FIGURE 40. EFFECT OF NOZZLE LENGTH ON PERFORMANCE (CONCENTRIC FLOW NOZZLE)

The same power extraction losses used for the propfan which were derived from the C-17 requirements were used for the turbofan. The shaft power extraction was 50 hp per engine with 0.42 lb/sec bleed flow per engine. Additional losses for cooling and leakage were assumed to be equal to 50 percent of the bleed flow and included in the performance analysis by increasing flow to 0.63 lb/sec per engine.

3.4 AERODYNAMIC DESIGN DATA

The low-aspect-ratio blended wing/fuselage class of configurations considered in the present study is challenging from the aerodynamic design point of view. The wing and fuselage cannot be viewed as separate components but must be analyzed as a unit. Aerodynamic computer modeling methods now exist which accurately predict the flow fields about such configurations. These methods, coupled with color computer graphics, make it possible to design, analyze, and predict the performance of blended wing/fuselage airplanes with confidence.

3.4.1 Tail Sizing

The mission requirements made it necessary to design the wings with a high-lift system which incorporates a single-segment flap and leading-edge slats. The first configuration designs were tailless; however, trimming with the high-lift system deployed required the addition of a trim surface. Canard trim surfaces were chosen in order to permit trimming with a positive lift vector. This is not to say that a canard is preferred over a conventional tailed configuration. In fact, future studies should evaluate aspect ratio 4.0 turbofan and propfan conventional configurations.

The canard was sized using a parametric approach as opposed to conventional aft-tail scissors plot. The primary design variables for the parametric sizing are: longitudinal location of wing MAC/4, longitudinal location of canard MAC/4, static stability, canard C_{LMAX}, and canard area.

Figures 41 and 42 present the parametric sizing plot for the propfan and turbofan. (Note that the canard C_{LMAX} is on the vertical axis while the canard-to-wing area ratio is on the horizontal axis.) The following assumptions and constraints were considered in establishing the parameteric values:

1. The canard can trim the aircraft with maximum C_L available.
2. A 40-inch cg range can be accommodated.
3. Adequate unaugmented short period flying qualities exist.
4. Variable incidence canard with flaps for trim and control.
5. The canard is located at the most forward position.

Longitudinal flying qualities of the unaugmented aircraft are represented by lines of constant static margin. Advanced design methods were used to select the minimum static margin required to maintain adequate short period flying qualities. A primary advantage of designing configurations with reduced static stability is the ability to minimize the canard area and/or C_{LMAX} requirement.

For all configurations, a canard to wing area ratio was selected based on: (1) the maximum aft location of the wing, (2) the minimum acceptable static margin with the stability augmentation inoperative, and (3) the minimum complexity/ maximum reliability of the canard high-lift system. This design methodology provides a systematic approach to size canards based on adequate flying qualities following stability augmentation system failures and on relatively simple, easily maintained canard high-lift systems.

Vertical tail sizing was based on ground minimum control speed requirements. A double-hinged rudder is employed to minimize vertical tail areas in view of the relatively high engine-out yawing moments.

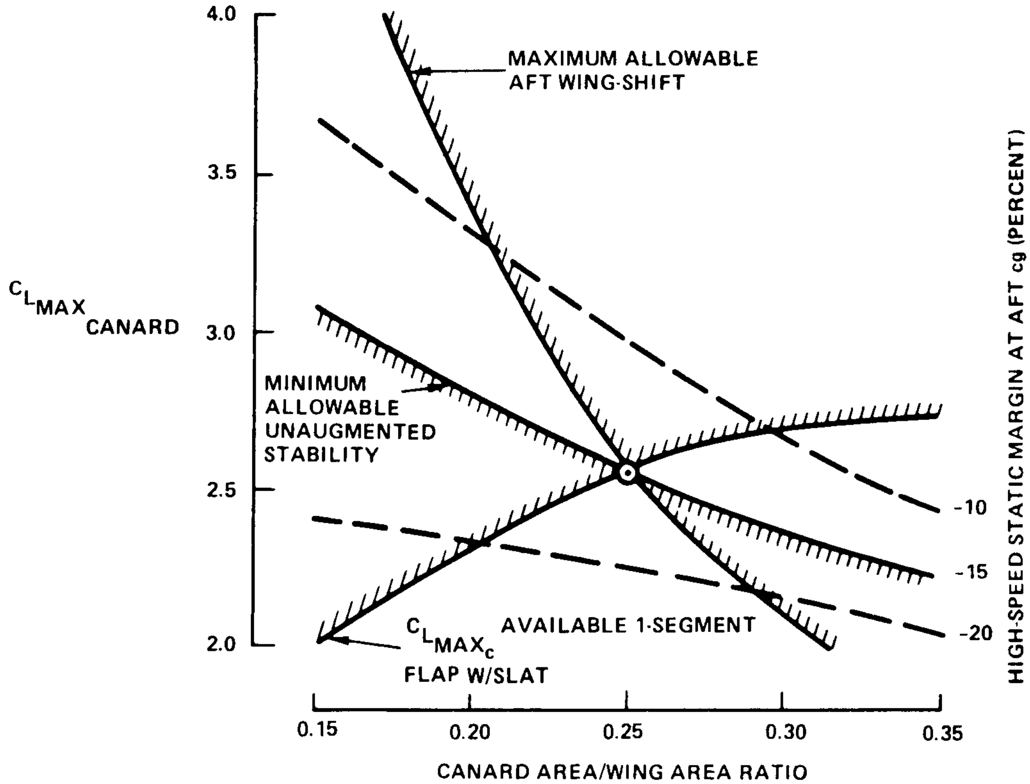


FIGURE 41. CANARD SIZING — PROPFAN

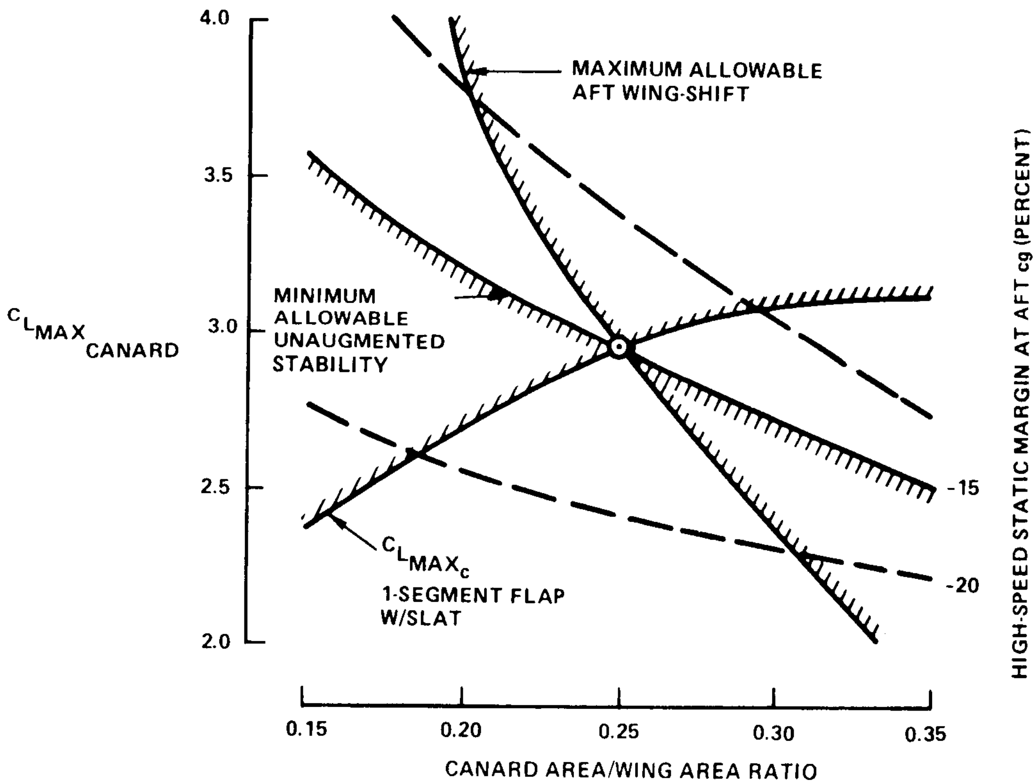


FIGURE 42. CANARD SIZING — TURBOFAN

3.4.2 Lift and Drag Data

Standard Douglas methods were used to generate the aerodynamic data for the canard configurations. The canard loading and its close coupling with respect to the wing affects the wing loading enough to prevent the standard airplane trimming method from being applied directly. The entire configuration was modeled by computer to account for the canard effect on the wing loading. The modeling also made it possible to trim the configurations accurately. In order to trim the airplane with its high-lift system deployed, a high-lift system was also required for the canard. Table 14 presents a parasite drag breakdown for the propfan and turbofan aircraft. Sized wing areas and the airplane efficiency factor, *e*, are also included in the table. As the wing area becomes greater, the wing equivalent parasite drag area, *f*, also increases; and since the canard area changes proportionally with wing area, a larger canard *f* results. Since the fuselage does not change, the fuselage, canopy, and upsweep *f* remain unchanged for all the aircraft. Excrescent drag is the drag of the miscellaneous components such as antennas, rivets, and surface gaps. The interaction of various components with one another (e.g., wing and fuselage) usually causes additional drag and is referred to as interference drag.

TABLE 14
DRAG SUMMARY

ENGINE	PROPFAN	TURBOFAN
COMPONENT	PARASITE DRAG (FT^2)	
FUSELAGE	11.2800	11.2800
WING	12.4245	12.9326
HORIZONTAL (CANARD)	2.4140	2.3064
VERTICAL	2.8016	1.3545
NACELLES AND PYLONS	1.6000	3.1300
CANOPY	0.0613	0.0613
SUBTOTAL	(30.5814)	(31.2648)
EXCRESENCES	1.5291	1.5632
INTERFERENCE	1.2233	1.2506
FUSELAGE UPSWEEP	5.3490	5.3490
TOTAL	38.8827	39.4276
WING AREA (FT^2)	2230.0000	2053.0000
C_{D_0}	0.0173	0.0192
CRUISE "e"	0.8239	0.8466

The low-speed lift curves and drag polars for the aspect ratio 4 propfan and turbofan are presented in Figures 43 to 46. The lift-curve slopes and maximum lift coefficients are slightly larger for the turbofan aircraft. The drag increases as the flap deflections become larger due to larger profile drags. The high-speed drag characteristics are summarized in Figures 47 and 48 for the two aircraft mentioned above and reflect the typical trend of increasing drag with the increase in lift (induced drag) and Mach number (shock wave drag).

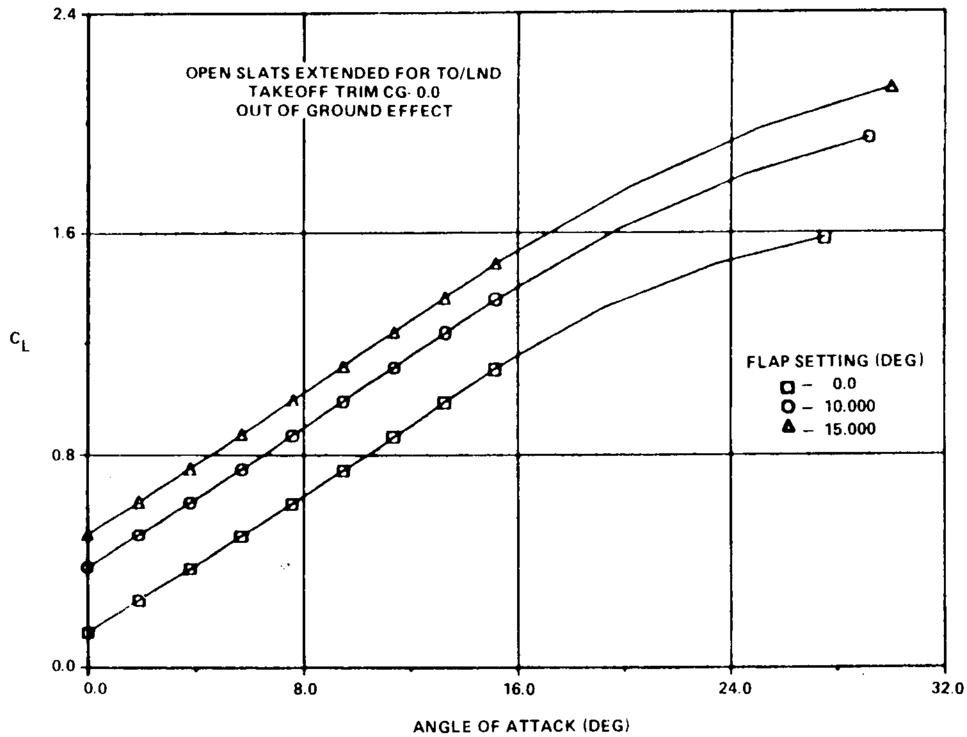


FIGURE 43. LOW-SPEED LIFT CURVE — PROPFAN

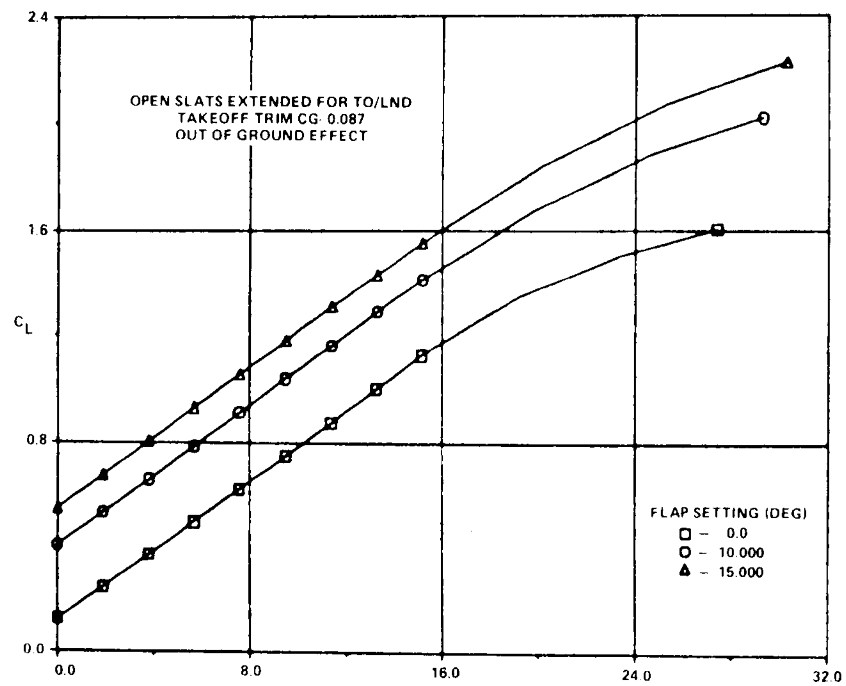


FIGURE 44. LOW-SPEED LIFT CURVE — TURBOFAN

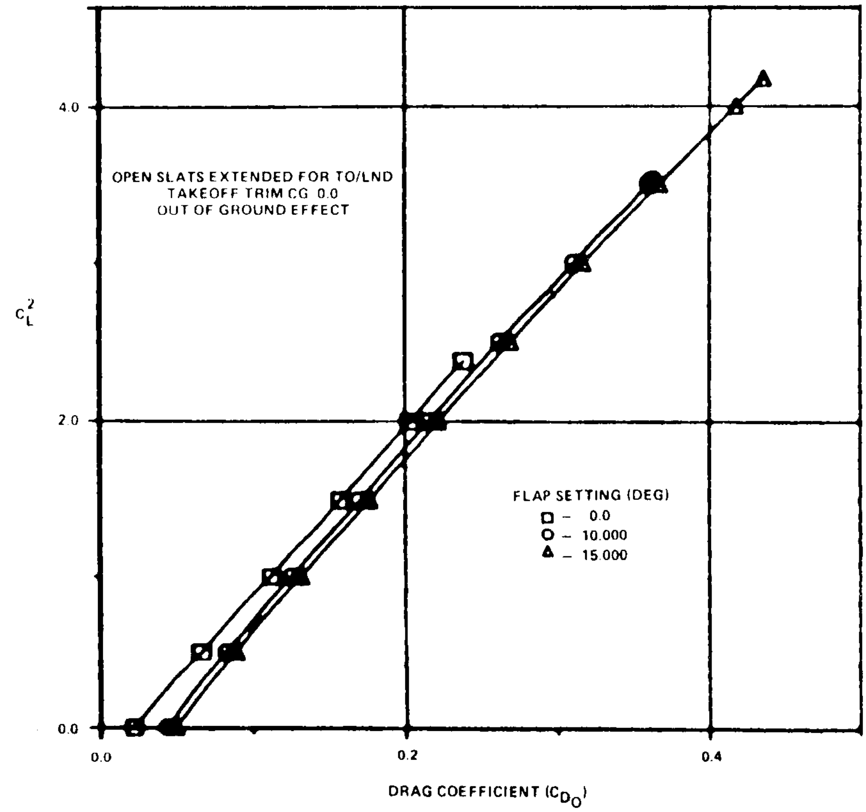


FIGURE 45. DRAG POLAR — PROPFAN

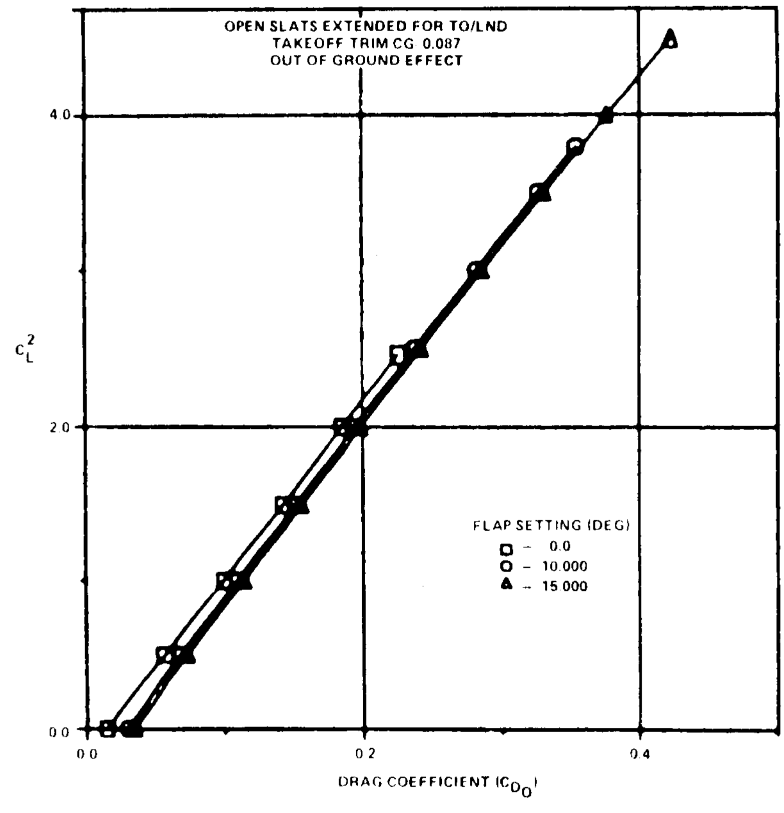


FIGURE 46. DRAG POLAR — TURBOFAN

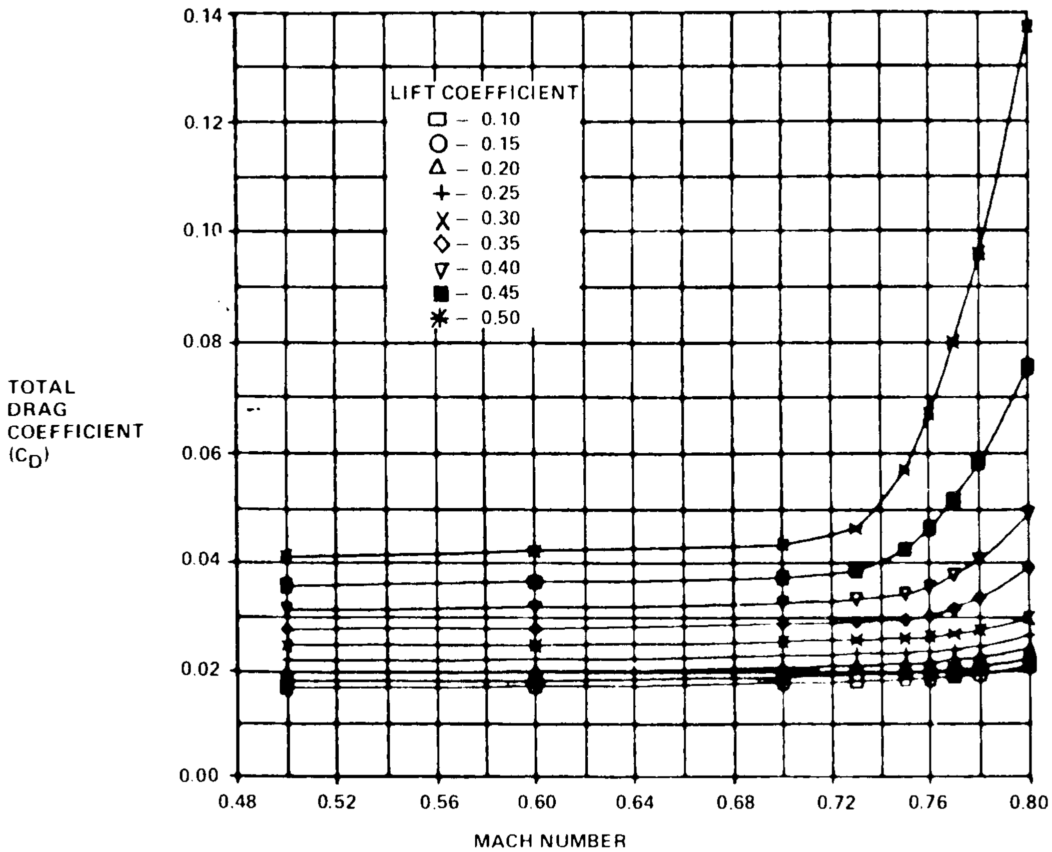


FIGURE 47. DRAG CHARACTERISTICS — PROPFAN

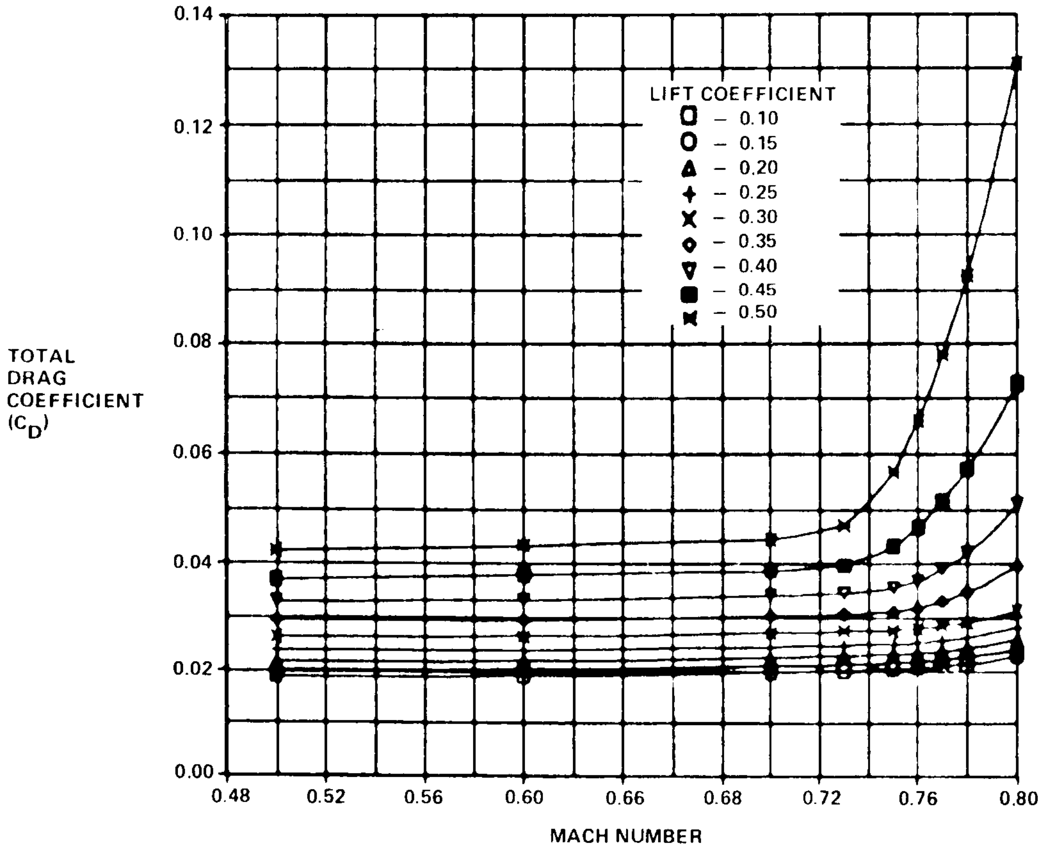


FIGURE 48. DRAG CHARACTERISTICS — TURBOFAN

3.5 WEIGHT DATA

The weights for the MAPS propfan and turbofan aircraft were derived by using the Douglas Computer-Aided Sizing and Evaluation (CASE) programs and from detail analysis and statistical data. The CASE system has the capability to analyze the aerodynamic characteristics and performance, and to derive parametric and point design aircraft weights for specific mission requirements.

The weight module of the CASE system uses inputs from Aerodynamics, Propulsion, Structural Mechanics, aircraft configurations, and weights. With these data, the following characteristics were defined: airloads, sizes of structural members, weight of wing and tail/canard, propulsion system weights, landing gear weights, and total aircraft weight.

Propeller, engine, and gear box weights were scaled from data provided by Pratt & Whitney and Hamilton Standard. The CASE system provides a means of inputting these scaling factors and varies the propulsion system weights as a function of static sea level thrust/shaft horsepower. The weights for the rest of the systems and furnishings for the propulsion system were input as constants, derived from detail or statistical data.

3.5.1 Aircraft Weight Comparison

The breakdown of the takeoff gross weight for propfan and turbofan configurations by major component is summarized in Table 15. Of the 7,680-lb difference in operating weight empty, 58 percent is due to the propulsion system, 38 percent to differences in structure, and 4 percent to changes in the major subsystems. The differences in the structure and major subsystems are primarily due to the larger size and higher takeoff gross weight of the propfan, designed to meet the mission requirements. The structure includes the wing, tail, fuselage, and gear. The major subsystems include the flight controls, APU, and instruments, and the air conditioning, electrical, avionics, furnishings, fuel, and anti-ice systems.

TABLE 15
AIRPLANE WEIGHT COMPARISON

PROPULSION SYSTEMS	PROPFAN (LB)	TURBOFAN (LB)
STRUCTURE	42,324	39,384
PROPULSION	22,704	18,288
SUBSYSTEMS	17,696	17,372
OPERATOR'S ITEMS	2,556	2,556
OPERATING WEIGHT EMPTY	85,280	77,600
MISSION FUEL	14,220	19,500
PAYLOAD	50,000	50,000
TAKEOFF GROSS WEIGHT	149,500	147,100

With the significant reduction in mission fuel required (27 percent) for the propfan configuration, and with a constant payload, the propfan results in only a 1.6-percent increase in takeoff gross weight. (With a longer mission radius, or a change in the mission profile, or both, this difference would likely disappear and possibly show a reduction in takeoff gross weight compared to a turbofan configuration.) A complete weight breakdown in MIL-STD-1374 format is presented in Appendix A for the propfan and Appendix B for the turbofan.

3.5.2 Propulsion System Weight Comparison

Table 16 summarizes the elements of the total propulsion systems. Engine data are from Pratt & Whitney, propeller data from Hamilton Standard, and systems, nacelles, engine mounts, and other assemblies are based on Douglas preliminary design data.

TABLE 16
INSTALLED PROPULSION SYSTEM WEIGHT COMPARISON

(IN POUNDS)

	PROPFAN	TURBOFAN
ENGINE	7,900 (1)	12,200 (2)
PROPELLERS	5,750 (3)	--
GEAR BOX	3,592 (4)	--
NACELLE AND PYLON	3,116	2,776
ENGINE MOUNTS	1,418	718
ENGINE SYSTEMS	928	2,594
GEAR BOX OIL COOLERS	(247)	--
GEAR BOX COOLING DUCTS	(82)	--
GEAR BOX OIL	(148)	--
EXHAUST		(1,010)
THRUST REVERSER		(1,180)
ALLOWANCE FOR CONTROLS, STARTERS, ETC.	(451)	(404)
TOTAL PROPULSION	22,704	18,288

1) SCALED STS-679 ENGINE WEIGHT
2) SCALED STF-636 ENGINE WEIGHT
3) 6-BLADED SPAR & SHELL CONSTRUCTION: COUNTERROTATING
4) SCALED DIFFERENTIAL PLANETARY GEAR BOX WEIGHT

While bare engine weight for the turbofan is 66 percent of the total propulsion system weight, it is only 35 percent for the propfan engine. However, when the gear box and propellers are added to the bare engine, the total is 75 percent of the total propulsion system weight. It is also interesting to note that if mission fuel is added, the propfan total is 31,462 lb and the turbofan total is 31,700 lb, with the turbofan total being higher by 238 lb or less than 1 percent.

3.5.3 Operator's Items Summary

Table 17 identifies the operator's items for both the propfan and turbofan configurations. These weights are based on Douglas preliminary design data, updated to reflect the current design approach on the C-17.

TABLE 17
OPERATOR'S ITEMS SUMMARY

ITEM	WEIGHT (LB)
CREW – 3 AT 215 LB EA	645
UNUSABLE FUEL	400
OIL	190
EMERGENCY EQUIPMENT	170
AERO-MED CONVERSION	38
FOOD, LIQUID, AND CONTAINERS	180
CARGO HANDLING EQUIPMENT	726
MAINTENANCE AND TIE-DOWN EQUIPMENT	138
MISCELLANEOUS SUPPLIES	69
TOTAL USEFUL LOAD	2,556

SECTION 4
CONFIGURATION EVALUATION

4.1 LIFE-CYCLE COST

This section contains the cost data that were generated for the two final concepts and the approach followed to derive these costs. Estimates were developed based on a predetermined life-cycle cost (LCC) framework and approach — i.e., that a Government agency or its branch of service considers a systematic and organized approach to the development of LCC and its components. Therefore, the intent was to comply with generally accepted requirements for accomplishing LCC analyses and in particular, conform to the methodology used by the Government for developing operating and support (O&S) costs.

Specific categories of cost were identified, quantified, and evaluated. Flexibility in estimating systems and designs of the type generated in this study was essential, and total adherence to a conventional cost model was not considered appropriate. In a conventional cost model, the estimating process is driven toward a procedure of extrapolating from an historical base to achieve the estimates for the advanced systems. However, the unique characteristics of the designs in the MAP study mandated the use of greater amounts of discrete estimating and examination of specific characteristics, materials, and concepts.

A life-cycle cost structure was formulated to establish the significant functional elements that would have to be quantified and then provide an input to the concept evaluation process. Emphasis was placed on development of reasonable and relative costs of the two concepts instead of absolute values. A fair degree of imprecision and uncertainty should be expected when attempting to estimate advanced concepts and the application of technological advancements.

Cost data were generated consistent with the technical depth of the study, which was limited to top-level configuration and system characteristics. Therefore, the cost data were generated consistent with these technical definitions and characteristics. Costs were developed by using a combination of techniques — i.e., analogous, trend analyses, and discrete methods — and from historical data.

4.1.1 Approach

A traditional approach was taken to generate and report LCC for the "weapon" system provided in this submittal. This methodology is consistent with the time and information constraints surrounding the program and placed on the contractor. Therefore, data regarding LCC conform in general to USAF and DoD guidelines. There are some exceptions due to the constraints, but these exceptions do not degrade the quality of the data or the methodology.

The values for certain O&S resource elements such as manpower for weapon system security and wing/base staff would essentially remain constant for each configuration. These values are established by the command and are dictated by role, mission, location, and other items assigned to the "weapon" system. Therefore, any significant error made in the estimates for these resource elements can be discounted. On the other hand, any such error does impact and compound the effects on the support and indirect resources. It was concluded that the overriding effects of the fuel savings minimized any problem in this area of manpower costs.

There is evidence that new and projected systems incorporating advanced technologies are particularly vulnerable to the pressure of scrutiny because of a lack of confidence in the estimates of future costs. Experience also shows that operating and support costs have escalated beyond expectation. The uncertainties associated with the costs of new systems and technologies in future years are for the most part due to the inaccuracies of assessing the maturing aspects of advanced technologies, their performance, and their implementation, particularly from a manufacturing standpoint.

Recognizing the current emphasis on cost as one of the primary design/decision tools, costs were developed to provide reasonable estimates, consistent with the level of definition and the budgetary and time constraints of the study. Specific cost categories and cost elements were identified and areas of emphasis were selected to adequately assess the impact on the costs by the various concepts and incorporated technologies.

A life-cycle cost structure was formulated with the objective of identifying significant cost elements and functional areas of emphasis that would have to be considered in deriving cost estimates, regardless of concept or configuration. The LCC structure is not a cost generator, but rather is an accounting structure. It was used to discretely evaluate the different configuration options and the postulated technologies. The cost structure contains more elements than are exhibited. For example, reliability is not separately displayed, but is contained within the engineering function and considered independently for each configuration. As another example, tooling costs were considered as separate entities for the major airframe components where new materials and manufacturing techniques were postulated.

With the incorporation of advanced technologies, vehicle size became a significant factor from the standpoint of determining if economies of size continue in the usual trend. The impact of size on plant equipment (some of which could be considered as tooling) was considered significant.

The acquisition cost elements comprise the development and production resource categories. In turn, these resource categories account for the prime mission equipment hardware and the logistics support system. Development and production costs were derived separately as direct inputs to the life-cycle cost structure. Costs for these categories were estimated from a systematic and organized approach about cost behavior in the future, on the basis of what is known and the state of the technology. Current and historical costs provide a benchmark of those costs that lie ahead. The cost data base included material from Douglas in-house studies and results of work accomplished under contract with the USAF, USN, and NASA on studies of transport/cargo aircraft systems that incorporate advanced technologies for the three major subsystems of an aircraft — airframe, engines, and avionics. These studies also included the ground facilities and logistic support system, which spans equipment for training to factory tools and test equipment at the depot level.

A discrete estimating approach allowed the application of complexity factors to adjust conventional cost accounts and estimating relationships. Conventional design and construction were estimated but adjusted for the new manufacturing process and material substitutions.

Technologies incorporated in the MAP configurations were assumed available and off-the-shelf. This means that the costs did not reflect any basic research and development expenditures for the advanced technologies.

4.1.2 Ground Rules, Assumptions, and Guidelines

This section explains the framework under which LCC and its major resource categories were generated.

All resource elements contained in the LCC estimate are to be considered as rough-order-of-magnitude (ROM) values used primarily for sizing and downstream budgetary and planning purposes. They do not represent a commitment on the part of MDC to furnish products and sevices in the amounts stipulated at this time.

All costs are expressed in constant FY 1985 dollars.

Operating and support costs are based on peacetime operations and a utilization of 1,000 hours per program authorized aircraft (PAA) per year.

The total buy of aircraft was assumed to be 300, with one full-up FSD aircraft and 299 production units. However, the FSD program includes all of the required ground test articles — e.g., fatigue and static test.

The life-cycle cost summary is presented in Table 18, and program cost by phases is given in Table 19. Tables 20 and 21 present life-cycle cost breakdowns.

Of the 299 production units, 240 are designated as PAA, the operational aircraft designated for O&S costing. The remainder are pipeline (maintenance) and attrition systems. The O&S cost estimates were summarized at the Level 2 cost element; e.g., items in Table 18 (Level 1 cost elements) are broken down as shown in Table 20 (Level 2 cost elements).

A crew ratio of 2.0 was applied to a crew complement of two pilot officers, one nonpilot officer, and two enlisted men.

No O&S costs were considered for any aircraft used in training squadrons or for overhead functions.

A basic assumption was made that the concept of maintenance is USAF organic with normal existing depot capabilities.

TABLE 18
LIFE-CYCLE COST SUMMARY — CONSTANT 1985 DOLLARS (MILLIONS)

RESOURCE	TURBOFAN CONFIGURATION	PROPFAN CONFIGURATION
FULL-SCALE DEVELOPMENT	$2,454.5	$2,702.8
PRODUCTION (299 UNITS)	$12,055.8	$12,229.3
ACQUISITION	$14,510.3	$14,932.1
O&S (20 YEARS - 240 PROGRAM-AUTHORIZED AIRCRAFT	$32,232.3	$29,471.5
LIFE-CYCLE COST	$46,742.6	$44,403.6
FLYAWAY UNIT COST*	$34.9	$35.4
AVERAGE UNIT WEAPON SYSTEM UNIT COST**	$48.3	$49.9

*CUMULATIVE AVERAGE UNIT COST OF 299 PRODUCTION UNITS. EXCLUDE LOGISTIC ELEMENTS AND SUPPORT EQUIPMENT.

**ACQUISITION COST DIVIDED BY TOTAL BUY OF 300 UNITS (1 FSD AND 299 PRODUCTION).

TABLE 19
PROGRAM COST BY PHASES

RESOURCE CATEGORY	TURBOFAN CONFIGURATION	PROPFAN CONFIGURATION
	(Percent)	(Percent)
FSD	5.2	6.1
PRODUCTION	25.8	27.5
ACQUISITION (299 UNITS)	31.0	33.6
O&S (20 YR - 240 PAA)	69.0	66.4
LIFE-CYCLE COST	100.0	100.0

TABLE 20
LIFE-CYCLE COST BREAKDOWN TO MAJOR RESOURCE ELEMENTS — CONSTANT 1985 DOLLARS (MILLION)

RESOURCE CATEGORY	TURBOFAN	PERCENT OF LCC	PROPFAN	PERCENT OF LCC	PROPFAN/ TURBOFAN DELTA
FULL-SCALE DEVELOPMENT					
MANUFACTURING	209.610	0.448%	233.412	0.526%	23.802
TOOLING	623.261	1.333%	649.956	1.464%	26.695
ENGINEERING	917.116	1.962%	1,047.528	2.359%	130.412
MATERIALS	19.424	0.042%	18.474	0.042%	(0.950)
SYSTEM INTEGRATION	78.191	0.167%	86.143	0.194%	7.952
PROGRAM MANAGEMENT	48.128	0.103%	52.997	0.119%	4.869
ECO/ECP'S	176.942	0.379%	194.936	0.439%	17.994
LOGISTICS	381.828	0.817%	419.389	0.944%	37.561
SUBTOTAL	2,454.500	5.251%	2,702.835	6.087%	248.335
PRODUCTION (299 UNITS)					
MANUFACTURING	3,579.177	7.657%	3,854.078	8.680%	274.901
TOOLING	471.034	1.008%	491.209	1.106%	20.175
ENGINEERING	942.446	2.016%	1,093.537	2.463%	151.091
MATERIALS	4,420.556	9.457%	4,105.834	9.247%	(314.722)
SYSTEM INTEGRATION	415.970	0.890%	421.779	0.950%	5.809
PROGRAM MANAGEMENT	236.388	0.506%	239.790	0.540%	3.402
ECO/ECP'S	376.528	0.806%	381.786	0.860%	5.258
LOGISTICS	1,613.674	3.452%	1,641.264	3.696%	27.590
SUBTOTAL	12,055.773	25.792%	12,229.277	27.541%	173.504

TABLE 20
LIFE-CYCLE COST BREAKDOWN TO MAJOR RESOURCE ELEMENTS —
CONSTANT 1985 DOLLARS (MILLION) (CONTINUED)

RESOURCE CATEGORY	TURBOFAN	PERCENT OF LCC	PROPFAN	PERCENT OF LCC	PROPFAN/ TURBOFAN DELTA
ACQUISTION (300 UNITS)					
MANUFACTURING	3,788.787	8.106%	4,087.490	9.205%	298.703
TOOLING	1,094.295	2.341%	1,141.165	2.570%	46.870
ENGINEERING	1,859.561	3.978%	2,141.065	4.822%	281.504
MATERIALS	4,439.980	9.499%	4,124.307	9.288%	(315.673)
SYSTEM INTEGRATION	494.161	1.057%	507.922	1.144%	13.761
PROGRAM MANAGEMENT	284.516	0.609%	292.787	0.659%	8.271
ECO/ECP'S	553.471	1.184%	576.723	1.299%	23.252
LOGISTICS	1,995.502	4.269%	2,060.653	4.641%	65.151
SUBTOTAL	14,510.273	31.043%	14,932.112	33.628%	421.839
O&S (20 YEARS-240 A/C)					
UNIT MISSION PERSONNEL	7,158.636	15.315%	7,315.159	16.474%	156.523
UNIT LEVEL CONSUMPTION	11,822.245	25.292%	8,727.867	19.656%	(3,094.378)
DEPOT MAINTENANCE	7,773.144	16.630%	7,835.544	17.646%	62.400
SUSTAINING INVESTMENT	2,068.572	4.425%	2,104.828	4.740%	36.256
INSTALLATION SUPPORT PERSONNEL	832.024	1.780%	857.923	1.932%	25.899
INDIRECT PERSONNEL SUPPORT	1,666.853	3.566%	1,708.635	3.848%	41.781
DEPOT NON-MAINTENANCE	0.000	0.000%	0.000	0.000%	0.000
ACQUISITION AND TRAINING	911.000	1.949%	921.507	2.075%	10.507
SUBTOTAL	32,232.474	68.957%	29,471.463	66.372%	(2,761.011)
ACQUISITION TOTAL (CARRY OVER)	14,510.273	31.043%	14,932.112	33.628%	421.839
LIFE-CYCLE COST	46,742.747	100.000%	44,403.575	100.000%	(2,339.172)

TABLE 21
BREAKDOWN OF INDIVIDUAL RESOURCE ELEMENTS BY MAJOR RESOURCE CATEGORY —
CONSTANT 1985 DOLLARS (MILLION)

RESOURCE CATEGORY	TURBOFAN	PERCENT OF LCC	PROPFAN	PERCENT OF LCC	PROPFAN/ TURBOFAN DELTA
FULL-SCALE DEVELOPMENT					
MANUFACTURING	209.610	8.540%	233.412	8.636%	23.802
TOOLING	623.261	25.393%	649.956	24.047%	26.695
ENGINEERING	917.116	37.365%	1,047.528	38.757%	130.412
MATERIALS	19.424	0.791%	18.474	0.684%	(0.950)
SYSTEM INTEGRATION	78.191	3.186%	86.143	3.187%	7.952
PROGRAM MANAGEMENT	48.128	1.961%	52.997	1.961%	4.869
ECO/ECP'S	176.942	7.209%	194.936	7.212%	17.994
LOGISTICS	381.828	15.556%	419.389	15.517%	37.561
SUBTOTAL	2,454.500	100.000%	2,702.835	100.000%	248.335

TABLE 21
BREAKDOWN OF INDIVIDUAL RESOURCE ELEMENTS BY MAJOR RESOURCE CATEGORY — CONSTANT 1985 DOLLARS (MILLION) (CONTINUED)

RESOURCE CATEGORY	TURBOFAN	PERCENT OF LCC	PROPFAN	PERCENT OF LCC	PROPFAN/ TURBOFAN DELTA
PRODUCTION (299 UNITS)					
MANUFACTURING	3,579.177	29.688%	3,854.078	31.515%	274.901
TOOLING	471.034	3.907%	491.209	4.017%	20.175
ENGINEERING	942.446	7.817%	1,093.537	8.942%	151.091
MATERIALS	4,420.556	36.668%	4,105.834	33.574%	(314.722)
SYSTEM INTEGRATION	415.970	3.450%	421.779	3.449%	5.809
PROGRAM MANAGEMENT	236.388	1.961%	239.790	1.961%	3.402
ECO/ECP'S	376.528	3.123%	381.786	3.122%	5.258
LOGISTICS	1,613.674	13.385%	1,641.264	13.421%	27.590
SUBTOTAL	12,055.773	100.000%	12,229.277	100.000%	173.504
ACQUISTION (300 UNITS)					
MANUFACTURING	3,788.787	26.111%	4,087.490	27.374%	298.703
TOOLING	1,094.295	7.542%	1,141.165	7.642%	46.870
ENGINEERING	1,859.561	12.815%	2,141.065	14.339%	281.504
MATERIALS	4,439.980	30.599%	4,124.307	27.620%	(315.673)
SYSTEM INTEGRATION	494.161	3.406%	507.922	3.402%	13.761
PROGRAM MANAGEMENT	284.516	1.961%	292.787	1.961%	8.271
ECO/ECP'S	553.471	3.814%	576.723	3.862%	23.252
LOGISTICS	1,995.502	13.752%	2,060.653	13.800%	65.151
SUBTOTAL	14,510.273	100.000%	14,932.112	100.000%	421.839
O&S (20 YEARS-240 A/C)					
UNIT MISSION PERSONNEL	7,158.636	22.209%	7,315.159	24.821%	156.523
UNIT LEVEL CONSUMPTION	11,822.245	36.678%	8,727.867	29.615%	(3,094.378)
DEPOT MAINTENANCE	7,773.144	24.116%	7,835.544	26.587%	62.400
SUSTAINING INVESTMENT	2,068.572	6.418%	2,104.828	7.142%	36.256
INSTALLATION SUPPORT PERSONNEL	832.024	2.581%	857.923	2.911%	25.899
INDIRECT PERSONNEL SUPPORT	1,666.853	5.171%	1,708.635	5.798%	41.781
DEPOT NON MAINTENANCE	0.000	0.000%	0.000	0.000%	0.000
ACQUISITION AND TRAINING	911.000	2.826%	921.507	3.127%	10.507
SUBTOTAL	32,232.474	100.000%	29,471.463	100.000%	(2,761.011)
ACQUISITION TOTAL (CARRY OVER)	14,510.273	100.000%	14,932.112	100.000%	421.839
LIFE CYCLE COST	46,742.747	100.000%	44,403.575	100.000%	(2,339.172)

The basic model used to derive the O&S costs was the Cost-Oriented Resource Estimating (CORE) model identified as AFR173-13.

The O&S costs were assumed to commence on the same day for all 240 PAA and proceed for a period of 20 years. This simplifies the computation of phase-in and phase-out of the aircraft and still considers a 20 year O&S period for each PAA.

A basic 1985 JP4 composite fuel price of $0.94 per U.S. gallon was used in this study.

The system is considered to be based so that it is a tenant and not a host at each location, which results in a different approach to manpower estimates for support.

4.1.3 Results

The LCC estimates for the configurations evaluated are summarized in Table 18 by the major program phases of full-scale development (FSD), production, and O&S. The acquisition resource category includes both FSD and production and represents the near-term or front-end exposure expected with this program. A breakdown by percentage of the major resource categories is given in Table 19 to highlight the primary cost drivers.

Based on the ground rules used to derive LCC for this program, O&S is clearly the dominant driver, and production is second. If the most recent concept that cargo/transport aircraft should be estimated for a 25-year O&S is followed, then it can be concluded that the O&S percentage would increase. However, the FSD values as a percentage of LCC are slightly low because the engine development costs have been excluded from each configuration and prorated over the unit price of the production units. This was done because the engine was treated as a commercial development program, which appears to be a common practice in current cargo/transport applications.

Figure 49 shows a bar chart with an LCC comparison of the two configurations. It is readily apparent that the propfan configuration has lower costs than the turbofan configuration during the O&S phase,

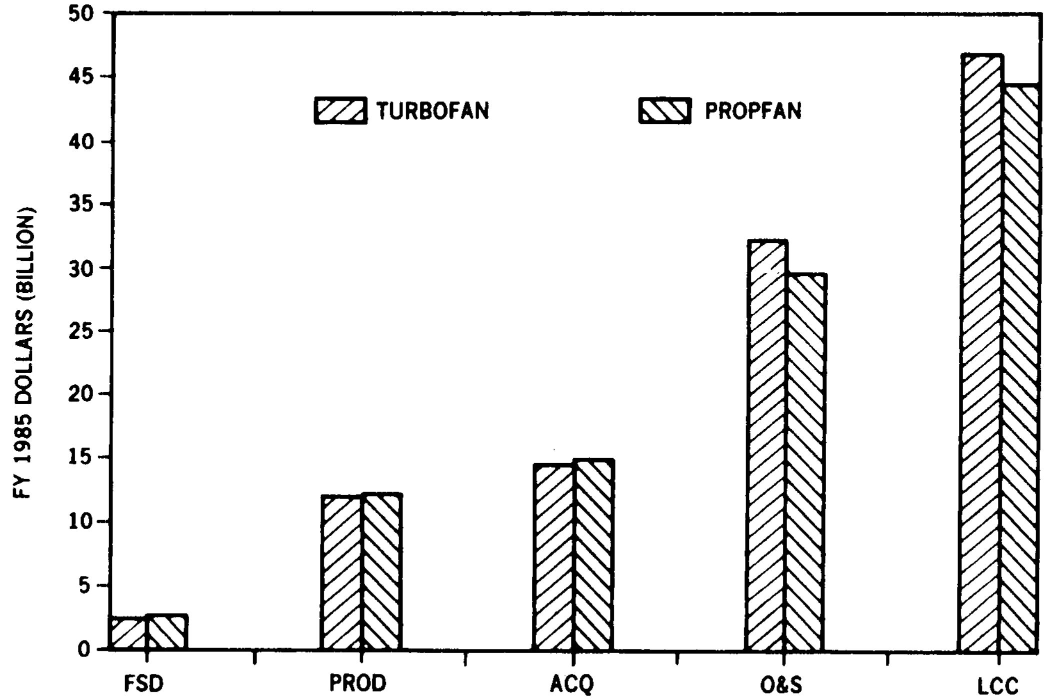


FIGURE 49. LIFE-CYCLE COST COMPARISON

which significantly overrides the higher acquisition cost. The total LCC difference of $2,339.2 million between the two configurations is sufficiently significant to warrant serious consideration of the propfan configuration. The difference is almost entirely a result of savings in fuel. The price of fuel, $0.94 per U.S. gallon, is quite realistic.

Figure 50 exhibits the cost drivers associated with the O&S phase for each configuration. It is evident that while fuel dominates in the turbofan case, this driver is the least in the propfan case — i.e., 36.2 percent versus 29.4 percent. The propfan savings from fuel alone amount to $3,108.8 million or 3,307.2 million gallons. This savings is offset partially by increases in other elements of the O&S phases.

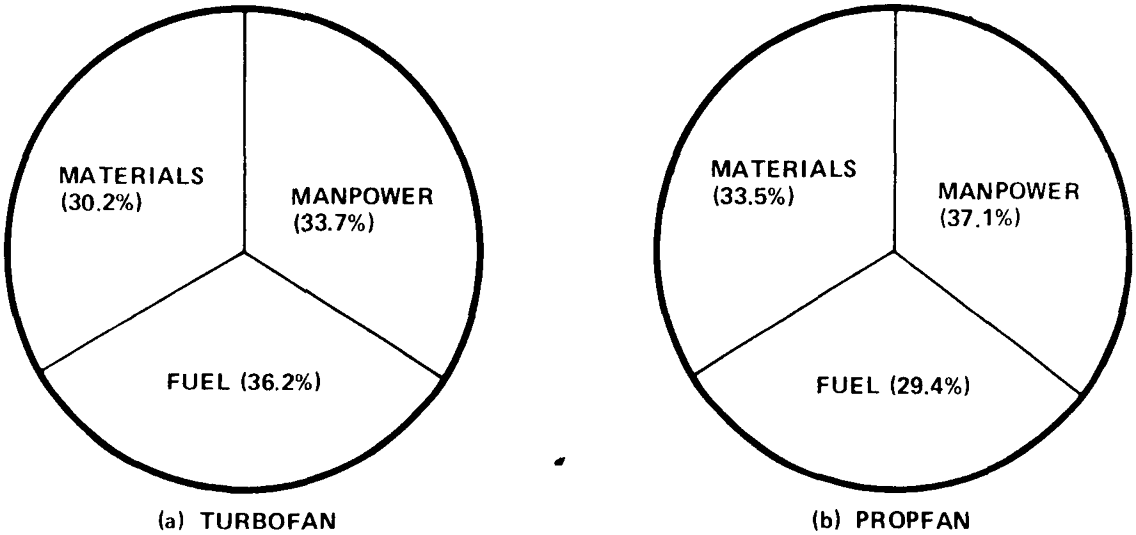


FIGURE 50. OPERATING AND SUPPORT COSTS

4.2 FIGURES OF MERIT

The figures of merit shown in Table 22 are generally accepted as transport aircraft measures of relative value and are used selectively throughout the study. The most encompassing, life cycle cost, is probably the best evaluation tool in that it is not only sensitive to the other figures of merit, but it is also sensitive to the maintainability and reliability characteristics of the different systems and to changes in system effectiveness, which is influenced by availability, survivability, and productivity. However, due to the limited scope of the study and to the minimal depth of definition during a conceptual selection phase, the life-cycle cost was established only for the final propfan and turbofan configurations. During the conceptual selection phase, all of the figures of merit were used to varying extents, with primary emphasis on takeoff gross weight.

4.2.1 Design Mission

The final figures of merit used to evaluate the propfan for the design mission are summarized in Table 23 in order of importance. It is clear that the propfan has superior capability, except for the small change in takeoff gross weight. If the figures of merit were weighted for their importance, the differences would be even larger in favor of the propfan.

4.2.2 Alternate Missions

The figures of merit for the alternate missions are different for each mission, reflecting the unique characteristics of each mission. Table 24 summarizes the figure of merit for each of the alternate missions.

TABLE 22
FIGURES OF MERIT

CONCEPTUAL DEVELOPMENT	SFC	- PROPULSION SYSTEM EFFICIENCY
	$[M\ (L/D)]_{MAX}$	- AERODYNAMIC CRUISE EFFICIENCY
	W_F/W_{TO}	- SYSTEM FUEL EFFICIENCY
	W_E/W_{TO}	- AIRFRAME/SUBSYSTEMS EFFICIENCY
	TON-NMI/HR	- PRODUCTIVITY
FINAL CONFIGURATION	TON-NMI/HR/LB FUEL	- PRODUCTIVITY EFFICIENCY
	TAKEOFF GROSS WEIGHT	- OVERALL SYSTEM EFFICIENCY
	MISSION FUEL	- PEACETIME COST/AVAILABILITY
	LIFE CYCLE COST	- COST OF OWNERSHIP
	(VARIOUS PARAMETERS)	- ALTERNATE MISSION CAPABILITY

TABLE 23
FIGURES OF MERIT — DESIGN MISSION

		PROPFAN	TURBOFAN
LIFE-CYCLE COST	(BIL $)	44.6	47.1
MISSION FUEL	(lb)	14,220	19,500
TAKEOFF GROSS WEIGHT	(lb)	149,500	147,100
PRODUCTIVITY EFFICIENCY (TON-MI PER HR PER LB OF FUEL)		0.77	0.56

While the payload for initial and subsequent deployment movements varies considerably, the larger the payload, the more efficient the configuration. The deployment ranges will also vary considerably. With a deployment range of 3,000 n mi, the aircraft is self-deployable without in-flight refueling; i.e., only en route stops for fueling. The difference in allowable payload in favor of the propfan is almost 40 percent. As a point of reference, payloads on the order of 20,000 lb to 30,000 lb are desirable for an initial deployment.

TABLE 24
FIGURES OF MERIT — ALTERNATE MISSIONS

			PROPFAN	TURBOFAN
FERRY	DEPLOYMENT PAYLOAD (3,000-N-MI RANGE)	(LB)	25,500	18,500
COMMAND AND CONTROL	TIME ON STATION (38,000-LB PAYLOAD, 100-N-MI RADIUS)	(HR)	4.2	3.4
ASSAULT	SEA LEVEL PENETRATION (25,000-LB PAYLOAD, 1,000-N-MI RADIUS)	(N MI)	340	145

For the command and control mission, the longer the capability to remain on station, the more significant the capability. Command and control payloads can vary from 20,000 lb to 40,000 lb, depending upon mission requirements, with a typical, fairly sophisticated system at 38,000 lb. For a typical radius of operation of 100 n mi, the propfan provides just under a 25 percent improvement in time-on-station.

In a hostile environment in which a low-altitude penetration might be used, the deeper that penetration the more likely the mission completion. For an arbitrary overall radius of 1,000 n mi with an outbound payload of 25,000 lb, the propfan configuration offers an overwhelming increase of more than 100 percent in the penetration radius.

Based on these figures of merit, the propfan configuration is clearly superior to the turbofan configuration for these alternate missions.

4.3 AIRLIFTER COMPARISON

To give some perspective of how the MAPS advanced tactical transport compares with other airlifters with a tactical role, a comparison is presented with the C-130 and the C-17. However, it must be kept in mind that each aircraft is designed to meet different design and operational requirements. Moreover, the C-130 is based on 30-year-old technology, the C-17 uses current technology, and the MAPS uses currently foreseeable advanced technology.

4.3.1 General Characteristics

Figure 51 presents a two-view overlay of the three aircraft being considered and Table 25 summarizes the propulsion system and geometric characteristics. It is obvious that the C-17 is considerably larger than either of the other two. The shorter span of the MAPS propfan means less turning and spotting area will be required than for the others.

As illustrated in Figure 52, no single element of the cargo compartment is similar, reflecting changing Army equipment, the changing composition of Army organizations, and a need to double-row some vehicles in massive strategic deployments. The C-17 floor area is almost 2.5 times the area of the MAPS floor and almost 3 times the area of the C-130.

4.3.2 Performance

Table 26 and Figure 53 summarize some of the major performance characteristics of the three aircraft. Weights and performance are based on the design load factor of 2.5. There are no real similarities among the three in any performance characteristic except in general terms. For example, the MAPS propfan has the general cruise speed and altitude characteristics of the C-17, whereas the payload capability of the

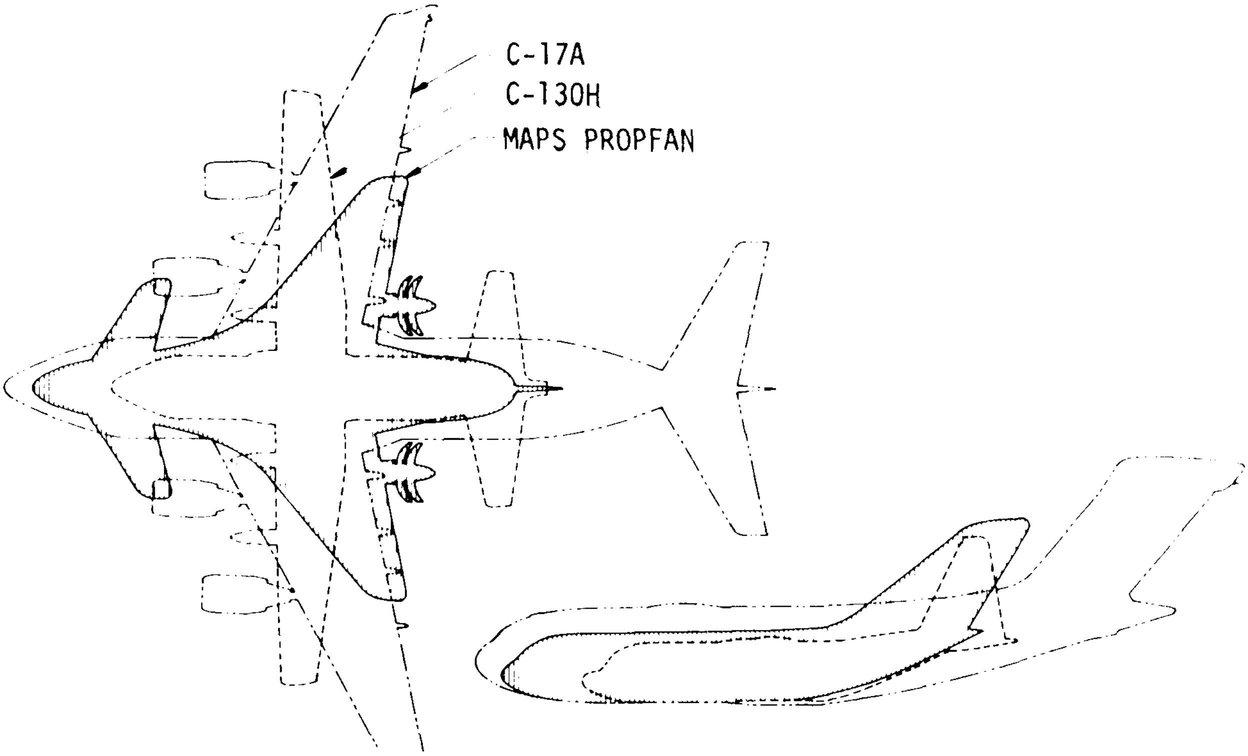


FIGURE 51. AIRLIFTER COMPARISON

TABLE 25
CHARACTERISTICS SUMMARY

*INCLUDES LOADING RAMP		C-130H	MAPS PROPFAN	C-17
ENGINE TYPE		TURBOSHAFT	TURBOSHAFT	TURBOFAN
DESIGNATION		T56-A-15	P&W STS-679	P&W 2037
NO.		4	2	4
RATING		4590 SHP	19,790SHP	37,000 LB.
PROPELLER TYPE		SINGLE ROT.	DUAL ROT.	—
NO. OF BLADES		4	12	—
BLADE DESIGN		STRAIGHT	SWEPT	—
DIAMETER	FT.	13.6	13.4	—
OVERALL HEIGHT	FT.	38	41.7	55.1
LENGTH		98	120.8	175.2
SPAN		132.5	94.5	165
CARGO COMPARTMENT				
HEIGHT	FT.	9.1	11.5	13.5
LENGTH	FT.	41.0	45.3	62.9
WIDTH	FT.	10.25	11.5	18.0
FLOOR AREA*	SQ. FT.	533	664	1554
WING AREA	SQ. FT.	1745	2230	3800
SWEEP	DEG.	0 (18%C)	35 (25%C)	25 (25%C)
ASPECT RATIO		10.1	4.0	7.2

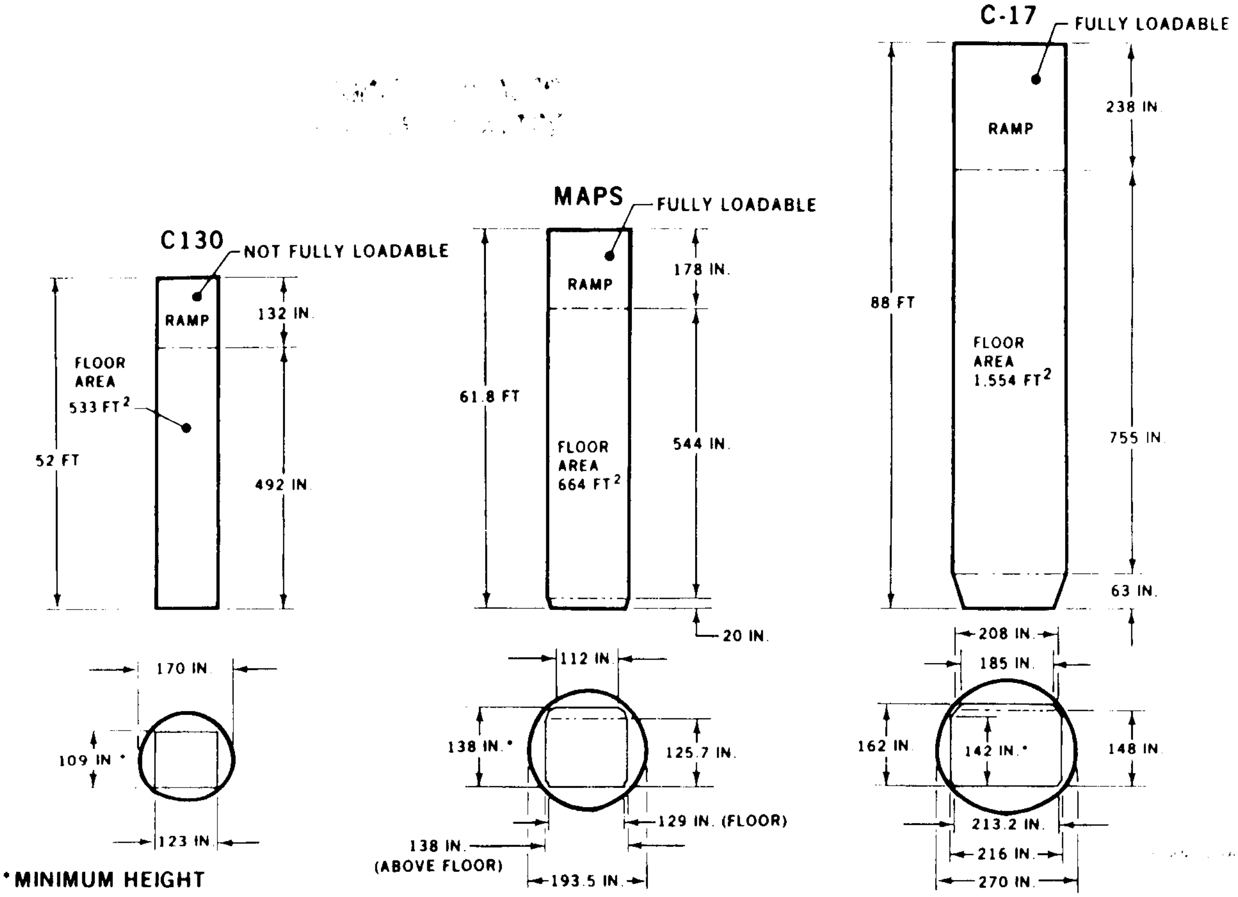


FIGURE 52. CARGO ENVELOPE AND FLOOR AREA COMPARISON

TABLE 26
PERFORMANCE SUMMARY

		C-130H	MAPS PROPFAN	C-17
MAX TAKEOFF WEIGHT	LB	155,000	149,500	523,000
WING LOADING	LB/FT^2	89	67	138
THRUST LOADING	LB/LB	0.24	0.43	0.28
OPERATING WEIGHT EMPTY	LB	76,470	82,550	236,630
MAX PAYLOAD	LB	38,000	50,000	140,800
CRITICAL FIELD LENGTH	FT	4,200	3,500	5,800
RANGE	N MI	2,260	793	3,205
INITIAL CRUISE ALT	FT	26,200	34,200	30,000
CRUISE SPEED	MACH	0.51	0.72	0.77

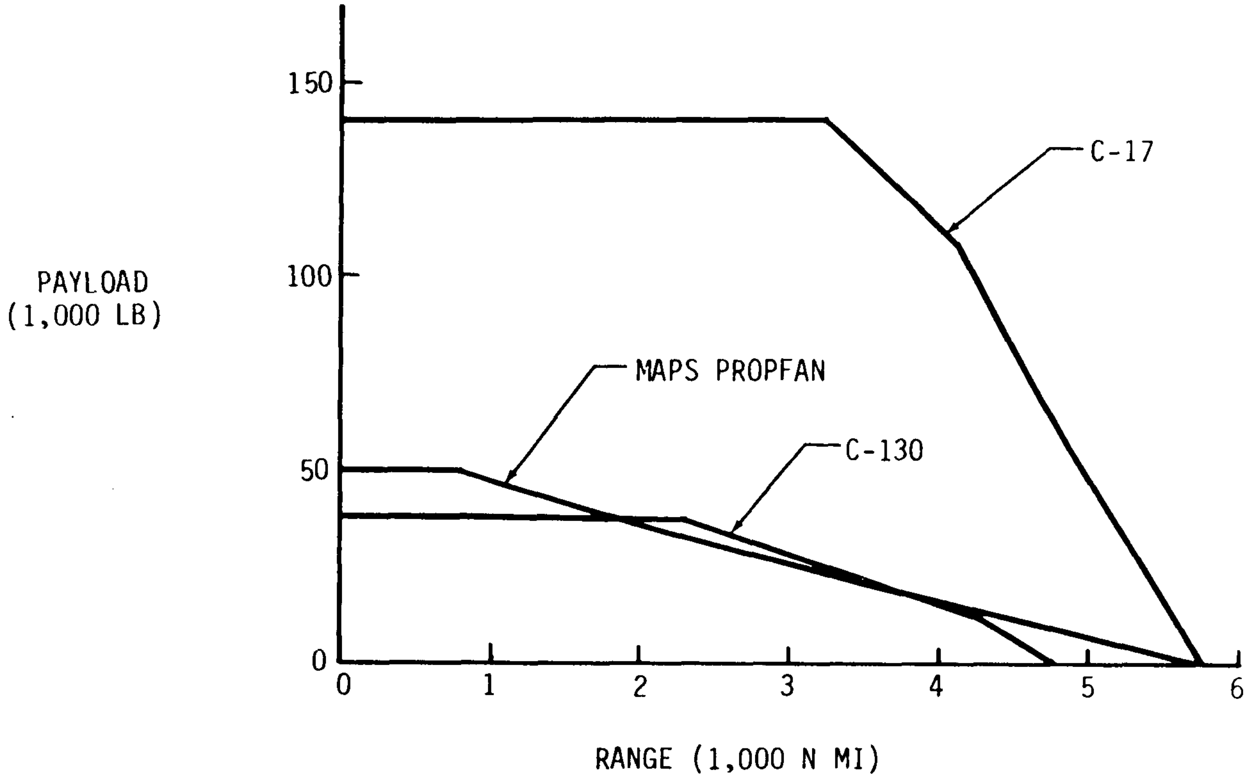


FIGURE 53. PAYLOAD-RANGE COMPARISON (FERRY MISSION)

MAPS propfan is more akin to the C-130. (Note: The cruise speed and altitude of the MAPS propfan are based on the speed for long-range cruise to be consistent with the other two.) The field length capability of the MAPS propfan is superior to either of the other two.

SECTION 5
ADVANCED TECHNOLOGY RESEARCH RECOMMENDATIONS

While the Air Force is developing an advanced transport in the C-17, it is not conducting any significant advanced technology research programs; new transport developments will depend on technology research from industry and NASA. Further, the military is not currently conducting technology research on subsonic transport engines, nor does it plan to do so. It is expected that new military transports will use engines or derivatives thereof developed for commercial transports. The C-17 exemplifies this approach and will have a mature engine when the date for initial operating capability is reached. This will minimize reliability and maintainability problems and allow the Air Force to benefit from the continuing product improvement effort conducted for commercial transports.

The military and commercial transport propulsion technology needs have been in consonance for long-range transports. Current studies being conducted at Douglas Aircraft indicate that future requirements may result in a divergence of technology needs. This divergence is being driven by the commercial desire for fuel efficiency, while a new tactical military transport will need to be highly survivable. Current commercial transport engine technology activities in the U.S. are focused on the use of advanced propellers as the means to dramatically improve propulsive efficiency. Allison, General Electric, and Pratt & Whitney Aircraft are aggressively working toward a 1990s availability for very high-bypass-ratio engines employing variable-pitch blades. The study conducted herein uses engine performance representative of that which could be technologically available in the 1990s.

However, based on current development planning, only the advanced propeller engines are expected to be available. A new turbofan in the 20,000- to 30,000-lb thrust class is not expected to be developed. Consequently, the critical issue is determination of the suitability of a new commercial engine or derivative of the engine for a military transport. The counterrotating pusher propeller, either geared or nongeared, is the leading candidate for commercial development. The most suitable means of adapting a commercial counterrotating pusher to a highly survivable military tactical transport is believed to be a primary current need.

In order to assess the adaptability, the aerodynamic and mechanical integration considerations need to be investigated, and the survivability characteristics achievable need to be determined. Four specific areas have been identified in which in-depth studies are needed to identify solutions to specific technology program needs.

5.1 PROPFAN CONFIGURATION SURVIVABILITY

There are many facets to the survivability issue, of which the airframe/propulsion system configuration is one. However, to evaluate and understand the impact of differences in this one area require an analysis in the total content of what survivability really means. (See Table 27.) However, there is virtually no data base to evaluate the survivability characteristics of a propfan configuration or design alternatives to improve the propfan characteristics. This has been confirmed in discussions with Hamilton Standard.

This recommended study, summarized in Table 28, will define a scenario including the threat, and present an analysis to determine requirements. Following this, the extent to which requirements are met will be determined, and an analysis of design alternatives will be conducted. Some design alternatives may require compromises in the performance capability of a propfan configuration. An extensive evaluation of the tradeoffs involved is required and will involve some model tests to validate existing analytical programs.

TABLE 27
SURVIVABILITY ENHANCEMENT

<table>
<tr><th colspan="3">SUSCEPTIBILITY REDUCTION</th><th rowspan="2">VULNERABILITY REDUCTION</th></tr>
<tr><th>THREAT SUPPRESSION</th><th>DETECTION AVOIDANCE</th><th>DAMAGE MECHANISM AVOIDANCE</th></tr>
<tr><td rowspan="2">• ANTIRADIATION MISSILES
• ARMAMENT
• FLASH BLINDING</td><td>• MINIMUM EXPOSURE WEAPON DELIVERY (STAND-OFF WEAPONS, ADVERSE WEATHER CAPABILITY)</td><td>• RADAR ACQUISITION AND SAM/AAA WARNING RECEIVER
• IR MISSILE LAUNCH WARNING SENSORS
• AIRCRAFT PERFORMANCE</td><td rowspan="2">• COMPONENT REDUNDANCY AND SEPARATION
• COMPONENT LOCATION
• COMPONENT SHIELDING
• ACTIVE DAMAGE SUPPRESSION (FIRE DETECTION/EXTINGUISHING)
• PASSIVE DAMAGE SUPPRESSION (DAMAGE TOLERANCE, DELAYED FAILURE, LEAKAGE SUPPRESSION, FIRE AND EXPLOSION SUPPRESSION, FAIL-SAFE RESPONSE)
• ELIMINATION OF VULNERABLE COMPONENTS</td></tr>
<tr><td colspan="2">• ELECTRONIC NOISE JAMMERS AND DECEIVERS
• SIGNATURE REDUCTION (RADAR, IR, VISUAL, AURAL, UV)
• EXPENDABLES (CHAFF, DECOYS, FLARES)
• TACTICS
• OPTICAL/ELECTRO-OPTICAL COUNTERMEASURES
• CREW SKILL AND EXPERIENCE</td></tr>
</table>

TABLE 28
PROPFAN CONFIGURATION SURVIVABILITY

OBJECTIVE: DETERMINE SURVIVABILITY CHARACTERISTICS OF A BLENDED WING/BODY WITH A PROPFAN PROPULSION SYSTEM.

SCOPE: IDENTIFY AND EVALUATE THE INFLUENCE OF A PROPFAN PROPULSION SYSTEM ON THE RADAR CROSS-SECTIONAL CHARACTERISTICS AND DESIGN ALTERNATIVES TO MEET SPECIFIED LEVELS OF REQUIREMENTS.

SCHEDULE: 2 YEARS.

COST: $500,000 PLUS MODEL TESTS.

5.2 BLENDED WING/BODY PROPFAN INTEGRATION

As discussed earlier, the blended wing/fuselage configurations considered in this study offer a challenging aerodynamic design problem. The propfan airplane designer is confronted with aerodynamic interference problems which can severely impact the airplane performance if proper attention is not paid to them. High disk-loading of propfans intensifies the interference as compared with conventional propellers, and consequently, traditional methods of separating thrust and drag are not adequate. Historically, isolated nacelle plus propeller tests have been used to identify installed thrust, and this has effectively accounted for most of the interference. In the case of the propfan, the propeller's effect on the flow field about the airplane and vice versa is not limited to the nacelle region, and the combined flow field is sufficiently nonlinear that simple addition or subtraction of various thrust/drag components is not valid.

This effort is summarized in Table 29.

TABLE 29
BLENDED WING/BODY PROPFAN INTEGRATION

OBJECTIVE:	ESTABLISH GUIDELINES FOR EFFICIENT INSTALLATION OF PROPFANS ON A BLENDED WING/BODY CONFIGURATION.
SCOPE:	DEVELOP ANALYTICAL MODELS TO PREDICT AERODYNAMIC CHARACTERISTICS AND VALIDATE WITH WIND TUNNEL MODEL TESTS.
SCHEDULE:	3 TO 5 YEARS.
COST:	$300,000 PLUS MODELS.

5.3 PROPFAN/AIRFRAME SUBSYSTEMS INTEGRATION

Top-mounted pusher propfans introduce some unique installation problems associated with secondary power, mounting, maintainability, and safety, as well as aerodynamic interference problems. An evaluation of alternative airframe integration approaches is needed. The study propfan installation incorporated airframe accessories driven from the gas generator gearbox. In a Douglas in-house study, a comparison was made between extracting shaft power from the gas generator versus the propeller gearbox. The result showed the specific fuel consumption penalty to be the same; however, the effect on thrust loss was different. Power extraction from the gas generator results in twice the decrease in thrust as when power is extracted from the propeller gearbox.

Since readiness and supportability are viewed as critical emphasis areas by the Air Force, it is mandatory that these areas be addressed. The overwing installation results in poor accessibility for servicing and maintenance. The need for visual inspections, checking oil levels, changing filters, replacing accessories, and the like can be more difficult. Advanced concepts are needed to provide remote checking and servicing or possible airframe accessories located in a readily accessible location. The accessories could be powered by an energy-efficient auxiliary power unit, with engine bleed used as a backup.

Air/oil exchanger concepts are needed to minimize losses, including avoidance of potential adverse effects on the propeller. Also, provisions have to be included in the design to account for adverse effects from exhaust gas impingement on the propfans, and for engine cooling during ground static operation.

While changing an engine at a main maintenance base may be acceptable, on a remote base this can be difficult. Since a turboprop pod weighs about 9,000 lb and another engine may be required to fly the airplane out, a method of accomplishing this with readily available equipment needs to be identified.

Safety considerations include the consequences of all engine flame-outs, pitch-control failures, blade failures, crash loads, and fires. The military considers the ability to complete a mission with any single failure to be very important.

This study, summarized in Table 30, will address and evaluate design alternatives to minimize and/or eliminate these integration problems.

TABLE 30
PROPFAN/AIRFRAME SUBSYSTEMS INTEGRATION

OBJECTIVE:	DETERMINE SUITABLE APPROACHES FOR AIRFRAME INTEGRATION OF TOP-MOUNTED COUNTERROTATING PUSHERS.
SCOPE:	IDENTIFY AND EVALUATE APPROACHES TO ESTABLISH SUITABLE INTEGRATION FOR SECONDARY POWER, MOUNTING, MAINTAINABILITY, AND SAFETY.
SCHEDULE:	18 MONTHS.
COST:	$500,000.

5.4 PROPFAN ANALYSIS AND DESIGN METHODS

The state of the art for conventional propellers allows for the analysis and design of optimum propellers using the simple, straightforward Glauert/Prandtl/Goldstein theoretical method. Performance predictions made with this method are accurate and reliable. An equivalent capability for propfans does not appear to exist at this time.

From a theoretical design and analysis point of view, propfans are distinguished from conventional propellers by three primary features: high disk-loading, counterrotation, and supersonic helical tip Mach number. In addition, propfans typically have high hub/tip diameter ratios, and in some cases the blades themselves are highly swept.

This effort, summarized in Table 31, will develop a propfan design and analysis code which will predict propfan performance with the same accuracy and reliability as currently exists for conventional propellers.

TABLE 31
PROPFAN ANALYSIS AND DESIGN METHODS

OBJECTIVE:	DEVELOP A PROPFAN DESIGN AND ANALYSIS CODE TO RELIABLY PREDICT PROPELLER PERFORMANCE FOR USE BY THE AIRCRAFT DESIGNER.
SCOPE:	A. UPDATE LIFTING-LINE THEORY FOR COUNTERROTATING PROPELLERS TO MINIMIZE TURNAROUND TIME AND RELIABLY PREDICT PROPFAN PERFORMANCE. B. EXTEND THE RESULTS OF A. TO HANDLE MODERATE-TO-HIGH DISK LOADINGS. C. MODIFY THE RESULTS OF A. AND B. TO ACCOUNT FOR SUPERSONIC HELICAL TIP MACH NUMBERS.
SCHEDULE:	18 TO 24 MONTHS.
COST:	$300,000.

SECTION 6
CONCLUSIONS

Based on the results of this study, the conclusions are not unlike those for comparable studies of commercial airliners and more conventional military transports. The propfan offers fuel economy near that of a conventional propeller, but at speeds comparable to a turbofan. Application of a propfan to an advanced military tactical transport indicates that all of the significant figures of merit investigated in this study are in favor of the propfan configuration as compared to the turbofan configuration.

Based on the design cruise Mach number of 0.75 for the design mission, the propfan has a 1.6 percent greater takeoff gross weight, but its life-cycle cost is 5.3 percent lower, partly because of a 27 percent smaller specific fuel consumption.

For the three alternate missions studied, the propfan showed an increase in sea level penetration distance of more than 100 percent, or an increase in time-on-station of 24 percent, or an increase in deployment payload of 38 percent.

The propfan engine size in this study is in the 20,000-shp class, whereas current studies of potential commercial propfan applications are in the 10,000-shp to 15,000-shp class. Future studies may indicate an engine size which is more compatible for both applications. However, if not, it is questionable whether the DoD would participate in the development of a new engine for the tactical transport mission unless other military applications can also be identified; e.g., a maritime patrol aircraft.

It is considered that some additional analytical effort and possibly model tests would be worthwhile in the areas of improved propfan performance prediction codes, propfan/airframe integration, and survivability. The blended wing/body concept presents some unique aerodynamic interfaces which are further influenced by aft-mounted pusher propellers: techniques need to be developed to better predict the aerodynamic characteristics of this type of configuration. In addition, a key to the acceptability of a propfan configuration for a tactical mission is survivability, which requires that a survivability analysis be pursued with an investigation of propfan design trade studies to assure acceptable characteristics.

APPENDIX A

PROPFAN GROUP WEIGHT STATEMENT

The detailed weight breakdown for the propfan configuration is presented in the MIL-STD-1374 format in this appendix. However, for preliminary design and comparative purposes, it is more convenient to use the major group weight elements presented in the basic report, Table 15. Derivation of those weights that cannot be read directly from the data in this appendix is summarized in Table A-1.

Table A-1
Reconciliation of Table 15 Propfan Weights and Appendix A Weights

MAJOR WEIGHT GROUP	APPENDIX A WEIGHT*, LB	ADJUSTMENTS*	LB		TABLE 15 WEIGHT, LB
STRUCTURE	46,858 (57)	DELETE ENGINE SECTION	1,418	(45)	42,324
		DELETE AIR INDUCT GROUP	3,116	(51)	
PROPULSION	19,759 (59)	ADD ENGINE SECTION	1,418	(45)	22,704
		ADD AIR INDUCT GROUP	3,116	(51)	
		DELETE FUEL SYSTEM	1,589	(71)	
SUBSYSTEMS	(NO SUBSYSTEMS GROUP GIVEN)	ADD FUEL SYSTEM	1,589	(71)	17,696
		ADD FLIGHT CONTROLS GROUP	1,922	(81)	
		ADD AUX POWER PLANT GROUP	618	(86)	
		ADD INSTRUMENTS GROUP	756	(87)	
		ADD ELECTRICAL GROUP	1,703	(90)	
		ADD AVIONICS GROUP	2,460	(92)	
		ADD FURNISHINGS AND EQUIP.	6,697	(97)	
		ADD AIR CONDITIONING GROUP	1,529	(103)	
		ADD ANTI-ICING GROUP	422	(104)	
FUEL	14,620 (118)	DELETE UNUSABLE FUEL	400	(120)	14,220

*THE NUMBERS ENCLOSED BY THE PARENTHESES ARE THE LINE NUMBERS IN THE GROUP WEIGHT STATEMENTS CORRESPONDING TO THE WEIGHTS LISTED ABOVE.

GROUP WEIGHT STATEMENT

MULTIPLE APPLICATION PROPFAN STUDY
AIRCRAFT

(INCLUDING ROTORCRAFT)

ESTIMATED - CALCULATED X - ACTUAL X

(CROSS OUT THOSE NOT APPLICABLE)

CONTRACT NO. NASA NO. NAS3-24348

AIRCRAFT, GOVERNMENT NO.

AIRCRAFT, CONTRACTOR NO.

MANUFACTURED BY DOUGLAS AIRCRAFT CO.

	MAIN	AUX
ENGINE MANUFACTURED BY	P&W	
ENGINE MODEL	STS 679	
ENGINE NO.	2	
ENGINE TYPE	TURBO SHAFT	
PROPELLER MANUFACTURED BY	H.S.	
PROPELLER MODEL	F252	
PROPELLER NUMBER	2	

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	7

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

1	WING GROUP					15848
2	BASIC STRUCTURE-CENTER SECTION					
3	-INTERMEDIATE PANEL				11033	
4	-OUTER PANEL					
5	-GLOVE				475	
6	SECONDARY STRUCTURE-INCL.WING FOLD WEIGHT			LBS.	2009	
7	AILERONS - INCL. BALANCE WEIGHT	LBS.			271	
8	FLAPS - TRAILING EDGE				1283	
9	- LEADING EDGE					
10	SLATS				777	
11	SPOILERS					
12						
13						
14	ROTOR GROUP					
15	BLADE ASSEMBLY					
16	HUB & HINGE - INCL. BLADE FOLD WEIGHT		LBS.			
17						
18						
19	TAIL GROUP					4072
20	STRUCT. - STABILIZER (INCL. LBS.SEC. STRUCT.)					
21	- FIN-INCL.DORSAL (INCL. 52 LBS.SEC.STRUCT.)				755	
22	VENTRAL					
23	ELEVATOR - INCL.BALANCE WEIGHT	LBS.				
24	RUDDERS - INCL.BALANCE WEIGHT	LBS.			1073	
25	TAIL ROTOR - BLADES					
26	- HUB & HINGE					
27	CANARD				2244	
28	BODY GROUP					16527
29	BASIC STRUCTURE - FUSELAGE OR HULL				8911	
30	- BOOMS					
31	SECONDARY STRUCTURE - FUSELAGE OR HULL				1997	
32	- BOOMS					
33	- SPEEDBRAKERS					
34	- DOORS, RAMPS, PANELS & MISC.				5619	
35						
36						
37	ALIGHTING GEAR GROUP - TYPE **	TRICYCLE				5877
38	LOCATION	RUNNING	*STRUCT.	CONTROLS		
39	MAIN	1600	2450	283	4333	
40	NOSE/TAIL	500	944	100	1544	
41	ARRESTING GEAR					
42	CATAPULTING GEAR					
43						
44						
45	ENGINE SECTION OR NACELLE GROUP					1418
46	BODY - INTERNAL					
47	- EXTERNAL					
48	WING - INBOARD				1418	
49	- OUTBOARD					
50						
51	AIR INDUCTION GROUP					3116
52	- DUCTS				3116	
53	- RAMPS, PLUGS, SPIKES					
54	- DOORS, PANELS & MISC.					
55						
56						
57	TOTAL STRUCTURE					46858

* CHANGE TO FLOATS AND STRUTS FOR WATER TYPE GEAR.

**LANDING GEAR "TYPE": INSERT "TRICYCLE", "TAIL WHEEL", "BICYCLE", "QUADRICYCLE", OR SIMILAR DESCRIPTIVE NOMENCLATURE.

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

		X	AUXILIARY	XX		MAIN	X
58	PROPULSION GROUP						
59	ENGINE INSTALLATION				7900		19759
60							
61							
62	ACCESSORY GEAR BOXES & DRIVE						
63	EXHAUST SYSTEM						
64	ENGINE COOLING						
65	WATER INJECTION						
66	ENGINE CONTROL					471	
67	STARTING SYSTEM						
68	PROPELLER INSTALLATION				5730		
69	SMOKE ABATEMENT						
70	LUBRICATING SYSTEM						
71	FUEL SYSTEM					1589	
72	TANKS - PROTECTED						
73	- UNPROTECTED						
74	PLUMBING, ETC.						
75	GEAR BOX				4069		
76	DRIVE SYSTEM						
77	GEAR BOXES, LUB SY & ROTOR BRK						
78	TRANSMISSION DRIVE						
79	ROTOR SHAFTS						
80							
81	FLIGHT CONTROLS GROUP						1922
82	COCKPIT CTLS. (AUTOPILOT	LBS.)					
83	SYSTEMS CONTROLS					1922	
84							
85							
86	AUXILIARY POWER PLANT GROUP			618			618
87	INSTRUMENTS GROUP					756	756
88	HYDRAULIC & PNEUMATIC GROUP						
89							
90	ELECTRICAL GROUP					1703	1703
91							
92	AVIONICS GROUP						2460
93	EQUIPMENT				1900		
94	INSTALLATION					560	
95							
96	ARMAMENT GROUP (INCL.PASSIVE PROT.		LBS.)				
97	FURNISHINGS & EQUIPMENT GROUP						6697
98	ACCOMMODATION FOR PERSONNEL					2012	
99	MISCELLANEOUS EQUIPMENT					2825	
100	FURNISHINGS					1623	
101	EMERGENCY EQUIPMENT					237	
102							
103	AIR CONDITIONING GROUP					1529	1529
104	ANTI-ICING GROUP					422	422
105							
106	PHOTOGRAPHIC GROUP						
107	LOAD & HANDLING GROUP						
108	AIRCRAFT HANDLING						
109	LOADING HANDLING						
110	BALLAST						
111	MANUFACTURING VARIATION						
112	TOTAL CONTRACTOR CONTROLLED			618		15649	16267
113	TOTAL GFAE				19599		19599
114	TOTAL WEIGHT EMPTY - PG 2-3						82724

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GROUP WEIGHT STATEMENT
USEFUL LOAD AND GROSS WEIGHT

115	LOAD CONDITION						
116							
117	CREW (NO. 3)						645
118	PASSENGERS (NO.)						
119	FUEL LOCATION TYPE JP4	GALS.					14620
120	UNUSABLE					400	
121	INTERNAL					14220	
122							
123							
124							
125	EXTERNAL						
126							
127							
128	OIL						190
129	TRAPPED					50	
130	ENGINE					110	
131	APU					30	
132	FUEL TANKS (LOCATION)						
133	WATER INJECTION FLUID (	GALS.)					
134							
135	BAGGAGE						
136	CARGO						50000
137							
138	GUN INSTALLATIONS						
139	GUNS LOCAT.FIX.OR FLEX.QUANTITY CALIBER						
140							
141							
142	AMMO.						
143							
144							
145	SUPP'TS *						
146	WEAPONS INSTALL. **						
147							
148							
149	CARGO HANDLING						726
150							
151	GROUND HANDLING						138
152							
153	AERO-MED CONVERSION						38
154							
155	GALLEY SUPPLIES & FOOD						180
156							
157							
158							
159							
160							
161							
162	SURVIVAL KITS						124
163	LIFE RAFTS						46
164	OXYGEN						
165	MISC.						69
166							
167							
168							
169	TOTAL USEFUL LOAD						66776
170	WEIGHT EMPTY						82724
171	GROSS WEIGHT						149,500

IF REMOVABLE AND SPECIFIED AS USEFUL LOAD.
*LIST STORES, MISSILES, SONOBUOYS, ETC. FOLLOWED BY RACKS, LAUNCHERS, CHUTES, ETC. THAT ARE N PART OF WEIGHT EMPTY. LIST IDENTIFICATION, LOCATION, AND QUANTITY FOR ALL ITEMS SHOWN INCLUDING INSTALLATION.

GROUP WEIGHT STATEMENT
DIMENSIONAL AND STRUCTURAL DATA

1	WING, ROTOR + TAIL GROUPS	WING	H TAIL	V TAIL	CANARD	ROTOR (BLADS/RTR	
2				*	*		
3	RADIUS OR SPAN(FT)	94.5	N/A	21.8	41.0		
4	*SPAN AT .25 CHORD						
5	**ROOT CHORD(IN) - THEO.	472.2	N/A	327.1	156.9		
6	- MAX THICKNESS	71.4	N/A	36.0			
7	**PLANFORM BREAK-CORD (IN)						
8	- MAX THICKNESS						
9	**TIP CHORD (IN) - THEO.	94.4	N/A	150.4	72.1		
10	- MAX THICKNESS	11.3		15.0	17.2		
11	SWEEP ANGLE AT .25 CHORD	35°		49°	30°		
12	ASPECT RATIO	4.0		1.2	4.3		
13	TAPER RATIO	.2		.46	.46		
14	MEAN AERODYNAMIC CHORD	325.3		249.7			
15	AREAS ***	2230	N/A	475.0	391.5		
16							
17	AREAS WING	SPD.BRK.	LE FLAPS	TE FLAPS	SLATS	SPOILERS	AIL
18	(SQ.FT.PER AIRCRAFT)	N/A	N/A	262.7	129.1	N/A	69.7
19	FUS	SPD.BRK.	ELEV.	RUDDER	DORSAL		
20		N/A	N/A	134.6	N/A		
21							
22	ROTOR DISK AREAS - FWD		AFT		FOLDED	WING SPAN	.
23	WING .25MAC TO H TAIL .25MAC(IN)		-488	NOSE	TO WING	.25 MAC	717.0
24	WING .25MAC TO V TAIL .25MAC(IN)		438			LEMAC	
25	WING BOX SPAN AT FUS.INTERSECTION		N/A	WING BOX	LENGTH AT	C.L.	
26							
27		CAPTURE	BLOW-IN	DUCT	MAX.DES.	CIRCUM-	
28	ENGINE INLETS	AREA	AREA	LENGTH	PRESSURE	FERENCE	
29	-MAIN						
30	AUXILIARY						
31		LENGTH	DEPTH	WIDTH	WET.AREA	VOLUME	VOL.PRES
32	BODY + NACELLE GROUPS	IN	IN	IN	FT^2		7.5
33	FUSELAGE OR HULL****	1321.0	193.5	193.5	4686		
34	BOOMS						
35	NACELLES (INBD.B.L.	) 150	50	55			
36	(OUTBD.B.L.	)					
37	ALIGHTING GEAR GROUP	LENGTH-OLEO EXT.		OLEO TRAVEL		LENGTH ARREST	
38		AXLE-CL.	TRUNNION	EXT.TO COLLAPSED		HOOK TRUNNION	
39	- LOCATION	NOSE	WING	NOSE	WING	TO POINT	
40	- DIMENSION(INCHES)	80.0	125.0	40.0	40.0		
41							
42	PROPULSION GROUP	(S.L.S.	UNINSTALLED THRUST	IN LBS./ENGINE)			
43			MAXIMUM	INTERMEDIATE		MAX SLS	SHAFT R
44	ENGINES		RATING	RATING		SHAFT HP	AT MAX
45	MAIN (NO. 2)					19770	
46	AUXILIARY (NO.)						
47							
48				OUTPUT	INTER	NUMBER	
49	ROTOR DRIVE SYSTEM	DESIGN	INPUT	RPM AT	ROTOR	GEAR	TORQUE
50		H.P.	R.P.M.	ROTOR	R.P.M.	BOXES	FACTOR
51	1/2 HOUR RATINGS - MAIN						
52	- TAIL						
53	- INTERMEDIATE						
54	CONT.RATINGS - MAIN						
55	- TAIL						
56	- INTERMEDIATE						
57							

THE NOTES FOR THIS PAGE MAY BE FOUND ON PAGE 8 OF PART I UNDERNEATH "AIRFRAME UNIT WEIGHT".

* EXPOSED

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MIL-STD-1374 - TAB
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GROUP WEIGHT STATEMENT
DIMENSIONAL AND STRUCTURAL DATA
(CONTINUED)

PAGE
MODEL
REPORT

1	FUEL SYSTEM	X PROTECTED		XX UNPROTECTED		XX INTEGRAL	
2	- INTERNAL * LOCATION	NO.TANKS	GALLONS	NO.TANKS	GALLONS	NO.TANKS	GALLONS
3	WING					4	2200
4	FUSELAGE						
5							
6	- EXTERNAL *						
7							
8	OIL ENGINE					2	16
9	APU					1	4
10							
11		QUANTITY	GENERATOR		BATTERY RATING		EMERG
12		MAIN	OUTPUT		(TYPE	)	GENERAT
13	ELECTRICAL GENERATING	GENERATRS	D.C.	A.C.	AMP-HOURS		(KVA)
14	SYSTEMS						
15							
16							
17		BODY					
18		PLUS INT	EXTERNAL	FUEL IN		DESIGN	ULTIMATE
19		CONTENTS	WEIGHT	WINGS		GROSS	LOAD
20	STRUCTURAL DATA - CONDITION	-LBS.	ON BODY	-LBS.		WEIGHT	FACTOR
21	FLIGHT - MANEUVER	68500	0	14220		149500	2.5
22	- GUST						
23	LANDING						
24	MAXIMUM GROSS WEIGHT WITH	ZERO	WING FUEL			135280	2.5
25	CATAPULTING						
26							
27	CRASH LIMIT LOAD FACTOR -	AXIAL		LATERAL		VERTICAL	
28	ULTIMATE LANDING SINK SPEED(FT/SEC)						
29	WING OR ROTOR LIFT ASSUMED FOR LDNG DSGN COND.						
30	STALL SPEED LDNG. CONFIGURATION-POWER OFF (KNOTS)						
31	APPROACH SPEED POWER ON (V-P KNOTS)						
32	ENGAGING SPEED (KNOTS)						
33	PRESSURIZED CABIN - ULTIMATE DESIGN						
34	PRESSURE DIFFERENTIAL FLIGHT (PSI)						
35	CARGO FLOOR AREA (DESIGN LOAD LBS/SQ.FT.)				504.5**	159.5***	664
36	HYDRAULIC SYSTEM OIL CAPACITY (GALLONS)						
37	TAIL ROTOR CANT ANGLE (DEGREES)						
38							
39							
40	ROTOR TIP SPEED AT DESIGN LIMIT		R.P.M.	POWER	FT/SEC		
41	- MAIN						
42	- TAIL						
43							
44	DESIGN THRUST OR LIFT ON	WING		M ROTOR		T ROTOR	
45	ULTIMATE L.F. FOR THE ABOVE LOADS						
46							
47	MATERIAL BREAKDOWN IN PERCENT		STEEL	ALUM	TI	COMPOSITE	OTHER
48	OF STRUCT.WEIGHT(PAGE 2, LINE 57)		10	40	10	25	15
49							
50	DESIGN SPEEDS AT S.L. (KNOTS)	LEVEL			DIVE		
51							
52	DESIGN SPEED AT BEST CRUISE		SPEED		ALTITUDE		
53	MAX. SPEED AND ALTITUDE		SPEED		ALTITUDE		
54							
55							
56	MODEL FIRST FLIGHT DATE						
57	AIRFRAME UNIT WEIGHT						60000

*TOTAL USABLE CAPACITY.

THE AIRFRAME UNIT WEIGHT TO BE ENTERED ON LINE 56 OF PAGE 6 OF THE GROUP WEIGHT STATEMENT SHOULD BE DERIVED BELOW IN DETAIL SHOWING THOSE ITEMS DEDUCTED FROM WEIGHT EMPTY. THE ITEMS BELOW FOLLOW THE DEFINITION OF AIRFRAME UNIT WEIGHT CARRIED IN THE DOCUMENT "CONTRACTOR COST DATA REPORTING SYSTEM" DATED 5 NOVEMBER 1973. AIRFRAME UNIT WEIGHT IS THE SAME AS PREVIOUSLY CALLED AMPR AND DCPR AND IS NOT TO BE CONFUSED WITH WORK BREAKDOWN STRUCTURE (WBS) AIRFRAME COST DEFINITION.

	WEIGHT EMPTY	82724
	DEDUCT THE FOLLOWING ITEMS DESCRIBED IN PART II	
1	WHEELS BRAKES, TIRES & TUBES	2108
2	ENGINES - MAIN AND AUXILIARY	7900
3	RUBBER OR NYLON FUEL CELLS	
4	STARTERS - MAIN AND AUXILIARY	
5	PROPELLERS & GEAR BOXES	9442
6	AUXILIARY POWER PLANT UNIT	618
7	INSTRUMENTS	300
8	BATTERIES & ELECTRICAL POWER SUPPLY & CONVERSION	306
9	AVIONICS	1900
10	TURRETS & POWER OPERATED MOUNTS	
11	AIR CONDITIONING, ANTI-ICING AND PRESSURIZATION UNITS & FLUIDS	150
12	CAMERAS & OPTICAL VIEWFINDERS	
	AIRFRAME UNIT WEIGHT	6000

NOTES FOR PAGE 5:

* INSERT INCHES FROM CENTER LINE OF THE ROTOR TO THE ELASTIC AXIS OF THE BLADE ATTACHMENT FOR THE ROTORS.

** PARALLEL TO THE CENTER LINE OF THE VEHICLE FOR WING AND TAIL.

*** THEORETICAL FOR ROTORS AND CONTINUOUS WING, EXPOSED FOR NON CONTINUOUS WING AND ALL OTHERS.

****NOSE TO AFT TIP OF FUSELAGE EXCLUDING EQUIPMENT PROTUBERENCES.

APPENDIX B

TURBOFAN GROUP WEIGHT STATEMENT

The detailed weight breakdown for the turbofan configuration is presented in the MIL-STD-1374 format in this appendix. However, for preliminary design and comparative purposes, it is more convenient to use the major group weight elements presented in the basic report, Table 15. Derivation of weights that cannot be read directly from the data in this appendix is summarized in Table B-1.

Table B-1
Reconciliation of Table 15 Turbofan Weights and Appendix B Weights

MAJOR WEIGHT GROUP	APPENDIX B WEIGHT*, LB	ADJUSTMENTS*	LB		TABLE 15 WEIGHT, LB
STRUCTURE	42,878 (57)	DELETE ENGINE SECTION	718	(45)	39,384
		DELETE AIR INDUCT GROUP	2,776	(51)	
PROPULSION	16,312 (59)	ADD ENGINE SECTION	718	(45)	18,288
		ADD AIR INDUCT GROUP	2,776	(71)	
		DELETE FUEL SYSTEM	1,518	(71)	
SUBSYSTEMS	(NO SUBSYSTEMS GROUP GIVEN)	ADD FUEL SYSTEM	1,518	(71)	17,372
		ADD FLIGHT CONTROLS GROUP	1,625	(81)	
		ADD AUX POWER PLANT GROUP	618	(86)	
		ADD INSTRUMENTS GROUP	756	(87)	
		ADD ELECTRICAL GROUP	1,703	(90)	
		ADD AVIONICS GROUP	2,460	(92)	
		ADD FURNISHINGS AND EQUIP.	6,697	(97)	
		ADD AIR CONDITIONING GROUP	1,529	(103)	
		ADD ANTI-ICING GROUP	466	(104)	
FUEL	19,900 (118)	DELETE UNUSABLE FUEL	400	(120)	19,500

*THE NUMBERS ENCLOSED BY THE PARENTHESES ARE THE LINE NUMBERS IN THE GROUP WEIGHT STATEMENTS CORRESPONDING TO THE WEIGHTS LISTED ABOVE.

GROUP WEIGHT STATEMENT

MULTIPLE APPLICATION PROPFAN STUDY
AIRCRAFT

(INCLUDING ROTORCRAFT)

ESTIMATED - ~~CALCULATED~~ - ~~ACTUAL~~

(CROSS OUT THOSE NOT APPLICABLE)

CONTRACT NO. NASA NO. NAS3-24348

AIRCRAFT, GOVERNMENT NO.

AIRCRAFT, CONTRACTOR NO.

MANUFACTURED BY Douglas Aircraft Co.

	MAIN	AUX
ENGINE MANUFACTURED BY	P&W	
ENGINE MODEL	STF 686	
ENGINE NO.	2	
ENGINE TYPE	Turbo Fan	
PROPELLER MANUFACTURED BY		
PROPELLER MODEL		
PROPELLER NUMBER		

PAGES REMOVED	PAGE NO.
	7

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

1	WING GROUP						14110
2	BASIC STRUCTURE-CENTER SECTION						
3	-INTERMEDIATE PANEL					9240	
4	-OUTER PANEL						
5	-GLOVE					925	
6	SECONDARY STRUCTURE-INCL.WING FOLD WEIGHT LBS.					2154	
7	AILERONS - INCL. BALANCE WEIGHT LBS.					250	
8	FLAPS - TRAILING EDGE					825	
9	- LEADING EDGE						
10	SLATS					716	
11	SPOILERS						
12							
13							
14	ROTOR GROUP						
15	BLADE ASSEMBLY						
16	HUB & HINGE - INCL. BLADE FOLD WEIGHT LBS.						
17							
18							
19	TAIL GROUP						3426
20	STRUCT. - STABILIZER (INCL. LBS.SEC. STRUCT.)						
21	- FIN-INCL.DORSAL (INCL. 52 LBS.SEC.STRUCT.)					418	
22	VENTRAL						
23	ELEVATOR - INCL.BALANCE WEIGHT LBS.						
24	RUDDERS - INCL.BALANCE WEIGHT 188 LBS.					605	
25	TAIL ROTOR - BLADES						
26	- HUB & HINGE						
27	CANARD					2403	
28	BODY GROUP						16065
29	BASIC STRUCTURE - FUSELAGE OR HULL					8449	
30	- BOOMS						
31	SECONDARY STRUCTURE - FUSELAGE OR HULL					1997	
32	- BOOMS						
33	- SPEEDBRAKERS						
34	- DOORS, RAMPS, PANELS & MISC.					5619	
35							
36							
37	ALIGHTING GEAR GROUP - TYPE **						5783
38	LOCATION		RUNNING	*STRUCT.	CONTROLS		
39	MAIN		1575	2411	278	4264	
40	NOSE/TAIL		490	929	100	1519	
41	ARRESTING GEAR						
42	CATAPULTING GEAR						
43							
44							
45	ENGINE SECTION OR NACELLE GROUP						718
46	BODY - INTERNAL						
47	- EXTERNAL						
48	WING - INBOARD					718	
49	- OUTBOARD						
50							
51	AIR INDUCTION GROUP						2776
52	- DUCTS					2776	
53	- RAMPS, PLUGS, SPIKES						
54	- DOORS, PANELS & MISC.						
55							
56							
57	TOTAL STRUCTURE						42878

* CHANGE TO FLOATS AND STRUTS FOR WATER TYPE GEAR.

**LANDING GEAR "TYPE": INSERT "TRICYCLE", "TAIL WHEEL", "BICYCLE", "QUADRICYCLE", OR SIMILAR DESCRIPTIVE NOMENCLATURE.

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

58	PROPULSION GROUP	X	AUXILIARY	XX	MAIN	X	
59	ENGINE INSTALLATION						16312
60	ENGINES				12200		
61	ENGINE SYSTEMS					2123	
62	ACCESSORY GEAR BOXES & DRIVE						
63	EXHAUST SYSTEM						
64	ENGINE COOLING						
65	WATER INJECTION						
66	ENGINE CONTROL				471		
67	STARTING SYSTEM						
68	PROPELLER INSTALLATION						
69	SMOKE ABATEMENT						
70	LUBRICATING SYSTEM						
71	FUEL SYSTEM				1518		
72	TANKS - PROTECTED						
73	- UNPROTECTED						
74	PLUMBING, ETC.						
75							
76	DRIVE SYSTEM						
77	GEAR BOXES, LUB SY & ROTOR	BRK					
78	TRANSMISSION DRIVE						
79	ROTOR SHAFTS						
80							
81	FLIGHT CONTROLS GROUP						1625
82	COCKPIT CTLS. (AUTOPILOT	LBS.)					
83	SYSTEMS CONTROLS					1625	
84							
85							
86	AUXILIARY POWER PLANT GROUP			618			618
87	INSTRUMENTS GROUP					756	756
88	HYDRAULIC & PNEUMATIC GROUP						
89							
90	ELECTRICAL GROUP					1703	1703
91							
92	AVIONICS GROUP						2460
93	EQUIPMENT				1900		
94	INSTALLATION					560	
95							
96	ARMAMENT GROUP (INCL.PASSIVE PROT.		LBS.)				
97	FURNISHINGS & EQUIPMENT GROUP						6697
98	ACCOMMODATION FOR PERSONNEL					2012	
99	MISCELLANEOUS EQUIPMENT					2825	
100	FURNISHINGS					1623	
101	EMERGENCY EQUIPMENT					237	
102							
103	AIR CONDITIONING GROUP					1529	1529
104	ANTI-ICING GROUP					466	466
105							
106	PHOTOGRAPHIC GROUP						
107	LOAD & HANDLING GROUP						
108	AIRCRAFT HANDLING						
109	LOADING HANDLING						
110	BALLAST						
111	MANUFACTURING VARIATION						
112	TOTAL CONTRACTOR CONTROLLED			618		17448	18066
113	TOTAL GFAE		(ENGINES & AVIONICS)				14100
114	TOTAL WEIGHT EMPTY - PG 2-3						75044

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GROUP WEIGHT STATEMENT
USEFUL LOAD AND GROSS WEIGHT

PAGE
MODEL
REPORT

115	LOAD CONDITION						
116							
117	CREW (NO. 3)						645
118	PASSENGERS (NO.)						
119	FUEL LOCATION TYPE JP4	GALS.					19900
120	UNUSABLE					400	
121	INTERNAL					19500	
122							
123							
124							
125	EXTERNAL						
126							
127							
128	OIL						190
129	TRAPPED					50	
130	ENGINE					110	
131						30	
132	FUEL TANKS (LOCATION)						
133	WATER INJECTION FLUID (	GALS.)					
134							
135	BAGGAGE						
136	CARGO						50000
137							
138	GUN INSTALLATIONS						
139	GUNS LOCAT.FIX.OR FLEX.QUANTITY CALIBER						
140							
141							
142	AMMO.						
143							
144							
145	SUPP'TS *						
146	WEAPONS INSTALL. **						
147							
148							
149	CARGO HANDLING						726
150							
151	GROUND HANDLING						138
152							
153	AERO-MED CONVERSION						38
154							
155	GALLEY SUPPLIES & FOOD						180
156							
157							
158							
159							
160							
161							
162	SURVIVAL KITS						124
163	LIFE RAFTS						46
164	OXYGEN						
165	MISC.						69
166							
167							
168							
169	TOTAL USEFUL LOAD						72056
170	WEIGHT EMPTY						75044
171	GROSS WEIGHT						147100

IF REMOVABLE AND SPECIFIED AS USEFUL LOAD.
*LIST STORES, MISSILES, SONOBUOYS, ETC. FOLLOWED BY RACKS, LAUNCHERS, CHUTES, ETC. THAT ARE N PART OF WEIGHT EMPTY. LIST IDENTIFICATION, LOCATION, AND QUANTITY FOR ALL ITEMS SHOWN INCLUDING INSTALLATION.

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GROUP WEIGHT STATEMENT
DIMENSIONAL AND STRUCTURAL DATA

PAGE
MODEL
REPORT

1	WING, ROTOR + TAIL GROUPS	WING	H TAIL	V TAIL	CANARD	ROTOR (BLADS/RTR	
2							
3	RADIUS OR SPAN(FT)	90.6		23.7	39.4		
4	*SPAN AT .25 CHORD						
5	**ROOT CHORD(IN) - THEO.	452.8		324.5	150.6		
6	- MAX THICKNESS	72.4		35.7	16.6		
7	**PLANFORM BREAK-CORD (IN)						
8	- MAX THICKNESS						
9	**TIP CHORD (IN) - THEO.	90.6		149.3	69.3		
10	- MAX THICKNESS	10.9		14.9	6.9		
11	SWEEP ANGLE AT .25 CHORD						
12	ASPECT RATIO	4.0		1.2	4.3		
13	TAPER RATIO	.2		.46	.46		
14	MEAN AERODYNAMIC CHORD	452.8		188.9	115.0		
15	AREAS ***	2050		467.6	361.1		
16							
17	AREAS WING	SPD.BRK.	LE FLAPS	TE FLAPS	SLATS	SPOILERS	AIL
18	(SQ.FT.PER AIRCRAFT)						
19	FUS	SPD.BRK.	ELEV.	RUDDER	DORSAL		
20							
21							
22	ROTOR DISK AREAS - FWD		AFT		FOLDED	WING SPAN	·
23	WING .25MAC TO H TAIL .25MAC(IN)		-407	NOSE	TO WING	.25 MAC	715
24	WING .25MAC TO V TAIL .25MAC(IN)		454			LEMAC	
25	WING BOX SPAN AT FUS.INTERSECTION			WING BOX	LENGTH AT	C.L.	
26							
27		CAPTURE	BLOW-IN	DUCT	MAX.DES.	CIRCUM-	
28	ENGINE INLETS	AREA	AREA	LENGTH	PRESSURE	FERENCE	
29	-MAIN						
30	AUXILIARY						
31		LENGTH	DEPTH	WIDTH	WET.AREA	VOLUME	VOL.PRE:
32	BODY + NACELLE GROUPS	IN	IN	IN	FT²		
33	FUSELAGE OR HULL****	1321.0	193.5	193.5	4686		7.5
34	BOOMS						
35	NACELLES (INBD.B.L.	)					
36	(OUTBD.B.L.	)					
37	ALIGHTING GEAR GROUP	LENGTH-OL	EO EXT.	OLEO TR	AVEL	LENGTH AR	REST
38		AXLE-CL.	TRUNNION	EXT.TO C	OLLAPSED	HOOK TRUN	NION
39	- LOCATION	NOSE	WING	NOSE	WING	TO P	OINT
40	- DIMENSION(INCHES)	20	119	40	40		
41							
42	PROPULSION GROUP	(S.L.S.	UNINSTALL	ED THRUST	IN LBS./EN	GINE)	
43			MAXIMUM	INTERME	DIATE	MAX SLS	SHAFT R:
44	ENGINES		RATING	RA	TING	SHAFT HP	AT MAX
45	MAIN (NO. 2)		31200				
46	AUXILIARY (NO.)						
47							
48				OUTPUT	INTER	NUMBER	
49	ROTOR DRIVE SYSTEM	DESIGN	INPUT	RPM AT	ROTOR	GEAR	TORQUE
50		H.P.	R.P.M.	ROTOR	R.P.M.	BOXES	FACTOR
51	1/2 HOUR RATINGS - MAIN						
52	- TAIL						
53	- INTERMEDIATE						
54	CONT.RATINGS - MAIN						
55	- TAIL						
56	- INTERMEDIATE						
57							

THE NOTES FOR THIS PAGE MAY BE FOUND ON PAGE 8 OF PART I UNDERNEATH "AIRFRAME UNIT WEIGHT".

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MIL-STD-1374 - TAB
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GROUP WEIGHT STATEMENT
DIMENSIONAL AND STRUCTURAL DATA
(CONTINUED)

PAGE
MODEL
REPORT

1	FUEL SYSTEM	X PROTECTED		XX UNPROTECTED		XX INTEGRAL	
2	- INTERNAL * LOCATION	NO. TANKS	GALLONS	NO. TANKS	GALLONS	NO. TANKS	GALLONS
3	WING					4	3000
4	FUSELAGE						
5							
6	- EXTERNAL *						
7							
8	OIL ENGINE					2	16
9	APU					1	4
10							
11		QUANTITY X	GENERATOR	X	BATTERY RATING		EMERG
12		MAIN X	OUTPUT	X	(TYPE	)	GENERAT
13	ELECTRICAL GENERATING	GENERATRS X	D.C.	A.C. X	AMP-HOURS		(KVA)
14	SYSTEMS						
15							
16							
17		BODY					
18		PLUS INT	EXTERNAL	FUEL IN		DESIGN	ULTIMATE
19		CONTENTS	WEIGHT	WINGS		GROSS	LOAD
20	STRUCTURAL DATA - CONDITION	-LBS.	ON BODY	-LBS.		WEIGHT	FACTOR
21	FLIGHT - MANEUVER					147100	2.5
22	- GUST						
23	LANDING						
24	MAXIMUM GROSS WEIGHT WITH	ZERO	WING FUEL			127200	2.5
25	CATAPULTING						
26							
27	CRASH LIMIT LOAD FACTOR -	AXIAL		LATERAL		VERTICAL	
28	ULTIMATE LANDING SINK SPEED(FT/SEC)						
29	WING OR ROTOR LIFT ASSUMED FOR LDNG DSGN COND.						
30	STALL SPEED LDNG. CONFIGURATION-POWER OFF (KNOTS)						
31	APPROACH SPEED POWER ON (V-P KNOTS)						
32	ENGAGING SPEED (KNOTS)						
33	PRESSURIZED CABIN - ULTIMATE	DESIGN					
34	PRESSURE DIFFERENTIAL FLIGHT	(PSI)					
35	CARGO FLOOR AREA (DESIGN LOAD		LBS/SQ.FT.)		504.5**	159.5***	564
36	HYDRAULIC SYSTEM OIL CAPACITY (GALLONS)						
37	TAIL ROTOR CANT ANGLE (DEGREES)						
38							
39							
40	ROTOR TIP SPEED AT DESIGN LIMIT		R.P.M.	POWER	FT/SEC		
41	- MAIN						
42	- TAIL						
43							
44	DESIGN THRUST OR LIFT ON	WING		M ROTOR		T ROTOR	
45	ULTIMATE L.F. FOR THE ABOVE LOADS						
46							
47	MATERIAL BREAKDOWN IN PERCENT		STEEL	ALUM	TI	COMPOSITE	OTHER
48	OF STRUCT.WEIGHT(PAGE 2, LINE 57)						
49							
50	DESIGN SPEEDS AT S.L. (KNOTS)	LEVEL			DIVE		
51							
52	DESIGN SPEED AT BEST CRUISE		SPEED		ALTITUDE		
53	MAX. SPEED AND ALTITUDE		SPEED		ALTITUDE		
54							
55							
56	MODEL FIRST FLIGHT DATE						
57	AIRFRAME UNIT WEIGHT						56100

*TOTAL USABLE CAPACITY.

AIRFRAME UNIT WEIGHT

THE AIRFRAME UNIT WEIGHT TO BE ENTERED ON LINE 56 OF PAGE 6 OF THE GROUP WEIGHT STATEMENT SHOULD BE DERIVED BELOW IN DETAIL SHOWING THOSE ITEMS DEDUCTED FROM WEIGHT EMPTY. THE ITEMS BELOW FOLLOW THE DEFINITION OF AIRFRAME UNIT WEIGHT CARRIED IN THE DOCUMENT "CONTRACTOR COST DATA REPORTING SYSTEM" DATED 5 NOVEMBER 1973. AIRFRAME UNIT WEIGHT IS THE SAME AS PREVIOUSLY CALLED AMPR AND DCPR AND IS NOT TO BE CONFUSED WITH WORK BREAKDOWN STRUCTURE (WBS) AIRFRAME COST DEFINITION.

	WEIGHT EMPTY	75044
	DEDUCT THE FOLLOWING ITEMS DESCRIBED IN PART II	
1	WHEELS BRAKES, TIRES & TUBES	2065
2	ENGINES - MAIN AND AUXILIARY	12200
3	RUBBER OR NYLON FUEL CELLS	
4	STARTERS - MAIN AND AUXILIARY	
5	PROPELLERS	
6	AUXILIARY POWER PLANT UNIT	618
7	INSTRUMENTS	300
8	BATTERIES & ELECTRICAL POWER SUPPLY & CONVERSION	301
9	AVIONICS	1900
10	TURRETS & POWER OPERATED MOUNTS	
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NOTES FOR PAGE 5:

* INSERT INCHES FROM CENTER LINE OF THE ROTOR TO THE ELASTIC AXIS OF THE BLADE ATTACHMENT FOR THE ROTORS.

** PARALLEL TO THE CENTER LINE OF THE VEHICLE FOR WING AND TAIL.

*** THEORETICAL FOR ROTORS AND CONTINUOUS WING, EXPOSED FOR NON CONTINUOUS WING AND ALL OTHERS.

****NOSE TO AFT TIP OF FUSELAGE EXCLUDING EQUIPMENT PROTUBERENCES.

SYMBOLS

SYMBOL	DEFINITION
a	Speed of Sound
AFWAL	Air Force Wright Aeronautical Laboratories
APET	Advanced Propfan Engine Technology
APU	Auxiliary Power Unit
AR	Aspect Ratio
ASD	Aeronautical Systems Division (USAF)
ATP	Authority to Proceed
CASE	Computer-Aided Sizing and Evaluation Program
CD	Total Drag Coefficient; CD = CDO + CDI + CDC
CDA	Controlled Diffusion Airfoils
CDC	Compressibility Drag Coefficient
CDI	Induced Drag Coefficient
CDO	Parasite Drag Coefficient
CL	Coefficient of Lift
CLMAX	Maximum Coefficient of Lift
CONUS	Continental United States
CORE	Cost-Oriented Resource Estimating
CRAD	Contract Research and Development
CRT	Cathode Ray Tube
DoD	Department of Defense
e	Airplane Efficiency Factor; CDI = CL**2/(PI*AR*e)
ECO	Engineering Change Order
ECP	Engineering Change Proposal
f	Equivalent Parasite Drag Area; f = CDO*SW
FEBA	Forward Edge of the Battle
FLOT	Forward Line of Troops
FOB	Forward Operating Base
FRP	Fuselage Reference Plane
FSD	Full Scale Development
FSED	Full Scale Engineering Development
FY	Fiscal Year
IFV	Infantry Fighting Vehicle
IOC	Initial Operational Capability
IRAD	Independent Research and Development
L/D	Duct Length/Diameter
LAPES	Low-Altitude Parachute Extractions
LCC	Life-Cycle Costs
LFL	Landing Field Length
LIB	Light Infantry Brigade
M(L/D)	Aerodynamic Efficiency Factor; Mach*(Lift/Drag)
MAC	Mean Aerodynamic Chord
MAC	Military Airlift Command
MAPS	Multiple Application Propfan Study
MDC	McDonnell Douglas Corporation
MOB	Main Operating Base

SYMBOLS

SYMBOL	DEFINITION
MTOGW	Maximum Takeoff Gross Weight
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
O&S	Operating and Support Costs
PAA	Program Authorized Aircraft
PMA	Permanent Magnet Alternator
PSEC	Propulsion System Electronic Control
RF	Range Factor
SFC	Specific Fuel Consumption
SHP	Shaft Horse Power
STOL	Short Takeoff and Landing
SW	Reference Wing Area
USAF	United States Air Force
VSCF	Variable Speed/Constant Frequency Generator
VTOL	Vertical Takeoff and Landing
W/WMAX1	Weight Ratio: Takeoff to Maximum Cruise Weights
WE	Airframe Empty Weight
WF	Fuel Weight
WTO	Takeoff Weight

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16. Abstract

This study was conducted to ascertain potential benefits of a propfan propulsion system application to a blended wing/body military tactical transport. Based on a design cruise Mach no. of 0.75 for the design mission, the results indicate a significant advantage in various figures of merit for the propfan over those of a comparable technology turbofan. Although the propfan has a 1.6 percent greater takeoff gross weight, its life-cycle cost is 5.3 percent smaller, partly because of a 27 percent smaller specific fuel consumption. When employed on alternate missions, the propfan configuration offers significantly improved flexibility and capability - an increase in sea level penetration distance of more than 100 percent, or in time-on-station of 24 percent, or in deployment payload of 38 percent.

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