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P004 059	Aerodynamic Issues in the Design of High-Lift Systems for Transport Aircraft.
P004 060	An Update of the Canada/U.S.A. Augmentor-Wing Project.
P004 061	Aircraft Drag Reduction Technology.
P004 062	Theoretical Study of Boundary-Layer Control.
P004 063	Drag Reduction due to Boundary-Layer Control by Combined Blowing and Suction.
P004 064	Design Studies of Thick Laminar-Flow Airfoils for Low Speed Flight Employing Turbulent Boundary Layer Suction over the Rear Part.
P004 065	Technology Developments for Laminar Boundary Layer Control on Subsonic Transport Aircraft.
P004 066	Turbulent Drag Reduction Research.
P004 067	On the Relaxation of a Turbulent Boundary Layer after an Encounter with a Forward Facing Step.
P004 068	Full Scale Experiments into the Use of Large-Eddy Breaku Devices for Drag Reduction on Aircraft.

COMPONENT PART NOTICE (CON'T)

AD#:	TITLE:
P004 069	Pneumatic Turbulators - A Device for Drag Reduction at Reynolds Numbers below 5, 000, 000.
P004 070	Active and Passive Shock/Boundary Layer Interaction Control on Supercritical Airfoils.
P004 071	Transonic Shock Interaction with a Tangentially-Injected Turbulent Boundary Layer.

An Update
of the Canada/U.S.A. Augmentor-Wing Project

by

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1.0 INTRODUCTION

According to the published guidelines "it is intended that this symposium bring together the practioners of various applications of boundary layer control with those interested in the underlying fluid mechanics for the purpose of mutual learning". This paper presents some views of a practitioner from the perspective of powered lift in which a substantial proportion of engine thrust is devoted to augmentation of wing lift. As such, control of the boundary layer takes place in rather a macroscopic way due largely to entrainment of secondary flow into a powerful jet or jet sheet.

The Augmentor-Wing powered lift concept has been the subject of investigation jointly by Canada and the United States since the late sixties. Following extensive tests of a half scale model in the NASA, Ames 40' × 80' wind tunnel, a decision was made to design and build a minimum cost flight demonstrator based on the de Havilland Buffalo airframe. ~~(Figure 1)~~ This technology demonstrator aircraft first flew in 1972 and subsequently underwent trials at NASA, Ames, accumulating a total of 650 flying hours.

Following completion of the NASA trials in 1980, work has continued in Canada covering four main areas of interest:

- additional flight trials on the technology demonstrator aircraft,
- propulsion system development,
- experimental investigation of a new compound supercritical airfoil, and
- project definition studies.

The paper touches briefly on these ~~four topics~~ expanding more so in areas likely to be of interest to the Fluid Dynamics Panel

2.0 DESCRIPTION

A powered lift STOL transport differs from one which relies solely on passive lift (such as the de Havilland Dash 7) in four fundamental ways, all of which relate to steep gradient approach at low speed:

(1) Power for approach is set at 50 to 60% of maximum thrust available as compared to idle approach power with a passive flap

(2) Forward components of thrust are nullified (by vectoring, by variable pitch fan or by bucket type reversers) to achieve a steep gradient approach.

(3) Restoration of forward thrust (e.g. by vectoring) becomes an essential part of the wave-off manoeuvre.

(4) A large imbalance in roll is likely to occur in the event of engine failure.

Wave-off following engine failure represents a particularly difficult combination (Figure 2).

Generally, in the case of External Blown Flap (EBF) or Upper Surface Blowing (USB), integration of engine thrust and flap serves both to augment wing lift by supercirculation and to vector thrust for steep gradient approach. However, since the entire thrust of the engine is devoted to flap blowing, it follows that the flap must be partially retracted to re-vector thrust for wave off and a substantial transient loss of wing lift is unavoidable. Again, wave-off with one engine failed is difficult, especially in combination with a large roll imbalance; in the case of the YC-14, flap retraction on the "live wing" is necessary to achieve roll balance causing a further lift loss Such issues are important when considering the airworthiness of powered lift aircraft.

The Augmentor-Wing internally blown system attends to some of these issues by having separate control over the propulsive and blowing components of thrust and by introducing cross-ducting to eliminate roll upset in the event of engine failure. Thus, at constant engine speed, lift of the blown flap may be considered as equivalent to that of a passive flap, whereas thrust vectoring (or V.P fan) can be used to modulate forward thrust in lieu of the throttle. Hence the characteristics and mode of flight can be related to the conventional and thereby correlated directly with existing airworthiness rules.

The Augmentor-Wing concept is comprised of four elements in all:

- A propulsion/blowing engine (Figure 3) which delivers about one third of total thrust for wing lift augmentation.
- An effecient ejector flap (Figure 4) which generates high lift by supercirculation and which serves also to augment nozzle thrust Thus, in combination with thrust recovery, thrust margin for takeoff is substantially increased (this being especially important for climb-out with one engine inoperative).

- Ducting which supplies blowing air to the wing to maintain roll balance in the event of engine failure and to enhance control power at low flight speeds by means of the augmentor choke (Figure 5).
- A thick supercritical compound airfoil otherwise known as a cruise augmentor flap (Figure 6).

3.0 FLIGHT TRIALS

Early in 1980, a team from the National Aeronautical Establishment assumed operational control of the Buffalo/Spey research aircraft at NASA, Ames and in 1981 flew the aircraft to their own laboratory located in Ottawa. A new central data computer was installed by NAE to replace the Sperry STOLAND unit which had been retained by NASA for other use.

The new computer unit restored the longitudinal SAS, the speed hold system and the controls integration capability. In broad terms, speed hold is achieved by modulation of (Pegasus type) nozzle angle whereas glide path tracking can be improved by controls integration, such as throttle into choke or pitch attitude into choke with a transient wash-out. Important handling qualities experiments were carried out in Canada but are considered outside the direct interest of the Fluid Dynamics Panel.

Following check-flights by NAE in the summer of 1982, the aircraft was handed over to de Havilland for further evaluation. Two series of tests each of 2 ½ months duration have taken place at Canadian Forces Base, Mountain View, Ontario. Some of this work is reviewed in Reference 1. Three subjects have been selected for comment, one relating to powered lift stalling characteristics, another to the maximum effort takeoff performance with vectored thrust and a third to no-flare landing techniques.

3.1 Powered Lift Stall

Suction generated by the augmentor flap serves to establish a spanwise line of low pressure at about 60% of the chord. This acts as a powerful means to prevent flow separation in a macroscopic fashion since an entire layer of upper surface flow is accelerated and ingested by the ejector. Half scale model tests in the NASA Ames 40′ x 80′ wind tunnel showed that onset of stall occurs at the wing/fuselage junction at about $\alpha = 20^{\circ}$ and is confined to that general region well beyond peak lift at an angle of attack in excess of 30°. The model was equipped with a blowing slot across the upper surface of the fuselage located at about 10% chord. this was designed to suppress flow separation at the wing root and encourage lift "carry-over". In the wind tunnel,tests were conducted with and without body blowing on both straight and swept wings. Results were as follows:

- On the straight wing at high C_J, body blowing gave a small increase in lift for $\alpha > 20^{\circ}$, a small increase in $C_{L_{max}}$ of order 0.3 and generally a smoother lift curve at high α. The wing and body was tufted liberally. at a yaw angle of 10° (say) and body blowing off, the tufts became quite agitated whereas with body blowing, the tufts remained smooth generally over the whole model.
- On the swept wing, body blowing was shown to have no effect. Lift curves were smooth to high α, and the lift peak was quite flat: maximum lift was slightly greater for the swept wing at the same level of blowing coefficient.

To minimize risk, it was decided that body blowing (accounting for 7% of the blowing flow available) would be fitted to the research aircraft. If, as suspected, the benefit is indeed quite small, it follows that this flow could be put to better use in a future design. Thus it became important to determine the effect of body blowing by flight test. Accordingly, modifications were made to remove this flow from the fuselage and discharge it through a plain propulsion nozzle at the rear. Stalls and steady sideslips were performed both with and without body blowing. At a weight of about 43,000 lb., tests were conducted at 8000 to 10,000 ft. with flaps 65°, nozzle angle 80° and engines at 94% rpm. Minimum speed occurred at 43 to 45 kt. depending upon weight. In the same configuration, steady sideslips were performed at 65 kt. to a maximum of 15° It was found that removal of body blowing had no discernible effect on stalling speed or handling qualities in steady sideslip.

3.2 MAXIMUM EFFORT TAKEOFF

Flight trials at NASA Ames focussed upon glide path tracking for a steep gradient 7½° STOL approach followed by flare and touchdown so that the effect of thrust vectoring on takeoff performance remained enexplored. Tests were planned to determine the optimum combination of flap and vector angle to minimize takeoff ground roll.

Standard takeoff flap is 20° with a thrust vector angle of 6°. ground roll is in the order of 750 ft. and distance to 50 ft is about 1250 ft. It was found that flap 40° with nozzles at 36° gave a minimum ground roll of 350 ft. to lift-off and about 850 ft. at the 50 ft screen height. In this latter case, speed at the start of rotation was 50 kt. EAS, lift-off speed was 53 kt. EAS with a peak rotation rate of nine degrees/second. Figure 7 presents a time history of this particular takeoff.

3.3 LANDING

Performance and technique for landing without flare were explored in the Canadian trials. At W = 40,000 lb, flaps 70° and nozzles at 60°, it was possible to capture a 4½° glide slope at $\alpha = 6^{\circ}$ giving a slight nose up attitude for nose wheel clearance at touchdown : the corresponding $C_{L_{app}} = 3.9$.

For a given wing loading, approach speed is a good indicator of the degree of powered lift. It is of interest to determine the levels of blowing thrust loading ($TB/_S$) and blowing thrust to weight ratio ($TB/_W$) for the above case and then to extrapolate to a value of wing loading more in keeping with an advanced tactical transport while holding wing area and blowing coefficient constant, at 865 sq.ft. and 0.59 respectively.

In the table below, line one relates to the experimental flight case, line two to a transformation of the research aircraft in which lift coefficient is adjusted to account for changes in wing geometry and removal of body blowing, and line three to an increase in weight to raise (or to increase) wing loading to 90 lb./sq.ft. as for a typical advanced STOL transport. It can be seen that for W/S=90, an approach speed of 78 kt. requires that TB/W = 0.136 and TB/S = 12.23. The former ratio provides some measure of powered lift efficiency whereas the latter, the relative ease of duct accommodation in the wing.

	DESCRIPTION	AR	t/c	W lb.	Vr kt	$TB/_S$	$TB/_W$
1	Experimental Case	7.2	0.16	40,000	60	7.17	.155
2	New wing less body blowing	12	0.21	45,600	60	7.17	.136
3	Increase in weight	12	0.21	77,850	78	12.23	.136

4.0 PROPULSION

Control of boundary layer for high lift is generally achieved not by suction but by blowing for wing flaps, for leading edge devices or for control surfaces. Even for supplementary purposes, the quantity of flow is generally such that it cannot be removed from the HP compressor without a significant loss in engine performance (especially for high bypass ratio). Thus it becomes advantageous to consider an engine having an oversize intermediate compressor to generate a blowing source at a pressure ratio of about three.

For high lift systems such as jet flap (requiring a significant proportion of total thrust) it is possible to separate the hot and cold streams of a low bypass engine as was done for the Buffalo/Spey research aircraft. This procedure may find application for a high performance powered lift fighter aircraft but is less well suited for transport type aircraft on account of high noise level and poor fuel consumption at low altitude. Again, the need arises for a high bypass engine which generates blowing air as part of the basic engine cycle.

To meet the need, Rolls-Royce has proposed the RB419 series of propulsion/blowing engines. Furthermore, it has been shown possible to synthesize one such engine using existing components with the Spey 202 as core, the TF 41 fan as intermediate compressor and the Dowty/Rotol variable pitch fan as a single stage LP compressor. This engine, known as the RB419 03, generates three streams:

(1) low pressure bypass stream
(2) intermediate pressure blowing stream
(3) residual hot core stream.

Tabulated data for the RB419 are given below, whereas Figure 8 shows the variation of non blowing thrust versus blowing thrust. growth potential is of the order 20% based on uprating of the core.

The engine provides separate thrust for propulsion and blowing with the ability to modulate the propulsive or forward thrust while maintaining constant blow, as described earlier. On the overall, it does appear that the propulsion/blowing engine will become the generic type for powered lift transport aircraft just as the vectored thrust Pegasus engine has become for combat aircraft.

RB419-03 LEADING PARTICULARS

Parameter	Takeoff ISA SLS	Cruise 36,000 ft Mach 0.7
Thrust (lb)	18,200	3,930
Sfc (lb/hr/lb)	0.425	0.700
Mass flow (lb/sec)	671	280
Overall pressure ratio	18.4	21.7
Blowing mass flow (lb/sec)	147	59
Blowing pressure ratio	2.6	3.8

5.0 THE CRUISE AUGMENTOR FLAP

The cruise augmentor flap is a supercritical compound section designed to operate at high subsonic speed with ejector blowing. Interest in the configuration arose from a desire to simplify the Augmentor Wing STOL concept by eliminating the need both to divert blowing flow and close down the flap elements for cruise while, at the same time, to gain some aerodynamic advantage. In particular, it was thought that drag rise Mach number could be delayed by achievement of aft loading on the upper shroud (by virtue of the powerful mid-chord control of boundary layer) and that propulsion efficiency could be improved on account of boundary layer ingestion by the ejector itself. Also it was thought that the compound section would operate satisfactorily for quite large values of thickness/chord (say 20% or more) and provide an improvement in buffet boundary due to blowing (jet flap effect). Recovery of pressure toward the trailing edge of the upper surface (with consequent thickening of the boundary layer) is of special concern in the design of supercritical airfoils (Figure 6). This concern is alleviated somewhat for the compound section in that recovery takes place in two stages, first to the ejector throat where pressure is substantially less than that at the trailing edge and secondly within the ejector itself where the remaining pressure rise takes place in a controlled manner. A family of compound airfoils is shown in Figure 9.

Experimental work was undertaken, both 2-D (NAE 5′ × 5′ tunnel) and 3-D (NASA, Ames 11′ × 11′ tunnel), on an 18% $t/_c$ section. Test results confirmed the expectations listed above and provided further understanding as follows:

- The compound airfoil operates well with or without blowing.
- The section is very tolerant to off-design operation having a very flat C_D vs C_L characteristic.
- Tight control of the boundary layer at mid-chord ameliorates drag creep with Mach number as M_D is approached.
- Pressures on the shroud upper surface remain essentially constant throughout the α range, thus shroud shape can be determined to satisfy requirements at the design point with no fear of flow separation or shock wave formation at higher α. Similarly in the region of drag rise, shock waves form first on the main body, not on the shroud.
- A thickness increase from 0.18 to 0.24 resulted in essentially no drag penalty (at the corresponding design point and below drag rise).

- Leading edge devices are not needed at low speed/high lift on account of the large leading edge radius of these thick sections.

Based on in-house test data, some comparisons are presented between a 16% $t/_c$ plain supercritical airfoil and the compound section at 18% and 24% $t/_c$.

5.1 BUFFET BOUNDARY

Wing buffet was found to correlate well with "drag break". The latter was more readily available and could be defined more precisely and was therefore taken as the limit of useable lift. Figure 10 shows a substantial advantage for the 18% $t/_c$ compound section as compared to the 16% plain foil. The flight boundary improves further with ejector blowing.

Taking M = 0.66 as the design speed for the 24% $t/_c$ section, it displays an advantage of $\Delta C_L = 0.15$ as compared to the corresponding compound foil at 18% $t/_c$.

5.2 DRAG

Interest surrounds level of drag and the point of drag rise. Drag creep characteristics of the plain and compound sections differ substantially so that conventional methods for defining drag rise Mach number are of little value, therefore comparisons have been made on the basis of drag level at the cruise design point which is more meaningful in any event.

Both 2-D and 3-D test data are available in-house for airfoils with C_L (design) = 0.35 whereas for C_L (design) = 0.6, only 2 D data exist. The variation of design Mach number with thickness was taken as follows:

Thickness/chord ratio	0.16	0.18	0.24
Design Mach number	0.725	0.70	0.66

5.2.1 Two-Dimensional Test Data

The NAE 5 x 5 wind tunnel is equipped with wall inserts to form a two dimensional working section for testing at high subsonic speed. Typically, the model Reynolds number is about 20×10^6.

On the left, Figure 11 shows the variation in drag at $C_L = 0.6$ for three foils with the corresponding design Mach number shown for each. At low Mach number without blowing, the compound sections exhibit a higher level of drag (compared to a conventional foil) but show less drag creep at high Mach number. At the respective cruise design points, the drag level of all three airfoils is essentially the same. this point is examined in more detail in Figure 12 where drag (at design point) is plotted versus thickness/chord ratio. It is shown that increase in drag with thickness is very small for the compound section which implies that the boundary layer has been controlled effectively even at 24% $t/_c$.

Blowing has been shown to reduce effective drag where $C_{D_{eff}} = C_{D_{measured}} + C_J$ (nozzle) and C_J (nozzle) = measured nozzle static thrust (shrouds off) + qS,
for example, Figure 11 shows that the skin friction penalty of the compound foil is partially offset in the mid Mach number range, whereas for $M < 0.5$, a net benefit results.

Figure 13 illustrates the off-design tolerance of the 24% $t/_c$ compound section. Although designed for M = 0.66 and $C_L = 0.6$, drag increase is very small even at $C_L = 0.75/0.80$. On a typical aircraft of aspect ratio 12,this equates to a cruise $L/_D$ correspondingly higher by about 10%.

5.2.2 Three-Dimensional Tests

Test data were available for a reflection plane model having a compound section (18% $t/_c$ root to tip) and a full span model having a conventional section (16% $t/_c$ at the root, 13% $t/_c$ at the tip). Design lift coefficient in each case was 0.35.

Equivalent profile drag for the 3-D tests was obtained in the usual manner by subtracting the "ideal" level of lift dependent drag $(C_L{}^2/\pi A)$ from balance drag. This procedure results in a level of profile drag somewhat higher than the true 2 D value. On the right of Figure 12 it is again shown that drag of plain and compound foils are comparable at the design point. The figure illustrates once more the off-design tolerance of the compound section with the attendant opportunity to cruise at higher C_L for improved $L/_D$.

6.0 PROJECT STUDIES

A substantial experimental data base has been established as a result of the joint Canada/USA powered lift research program. De Havilland is currently under contract to the Canadian government (Department of Industry, Trade and Commerce) to conduct application studies and to carry out additional experiments. In particular, project studies have been undertaken on a powered lift STOL transport and a sea based support type aircraft capable of short takeoff and vertical landing.

6.1 POWERED LIFT STOL TRANSPORT

Consideration has been given to transport aircraft powered by two, three and four RB419 propulsion/blowing engines. A comprehensive parametric/trade-off study has been undertaken on the twin engined variant encompassing a range of wing aspect ratio (8, 10, 12), section thickness/chord ratio (0.18, 0.21, 0.24) and wing sweep (0°, 20°, 27.5°).

Details of the basis for the study are quite complex and not discussed here except to point out that each combination of wing sweep and thickness/chord ratio was explored over a range of wing loading so that aircraft were derived covering a wide spectrum of STOL capability.

It is postulated that a military transport of this kind would serve a dual purpose: in time of peace for routine transport duties and in time of emergency in a tactical role for supply into a remote site or battle damaged runway (Figure 14). In drawing up a transport aircraft specification, the director of operational requirements is generally aware that some penalty would result if field performance demands were too stringent or cruise speed set too high, therefore he requires trade-off data in order to make a sensible compromise. For example, he may wish to trade transport fuel efficiency in routine duty against field performance at the mid point of the tactical supply mission. Figures 15 and 16 show the form of such a trade-off for the twin-engined variant of aspect ratio ten.

Payload-range for the strategic supply mission is determined by an interactive procedure. Each aircraft has payload equal to 25% of design gross weight and wing area derived first* such that fuel capacity of the wing equals the fuel required for the mission and then exceeds it by 10%, 20% and 30% increments. Each such aircraft is then exercised in the radius mission and STOL performance is determined on arrival and departure at the mid-point. In Figure 15, payload miles per pound of fuel for the strategic supply mission is plotted versus takeoff ground roll at the mid point of the tactical mission. Figure 16 shows a cross plot at a ground roll of 900 ft. to illustrate the trade-off of fuel efficiency against cruise speed. Observations are as follows:

- A choice of 900/1100 ft. as takeoff ground roll incurs a relatively moderate penalty in fuel efficiency for regular transport duty (Figure 15).
- This degree of STOL performance at the mid-point is compatible with takeoff field size of about 8000 ft. at DGW for regular transport duty and is therefore well matched for the dual role.
- Figure 16 shows that choice of a lower cruise speed provides a clear advantage in fuel efficiency.
- For a given cruise speed, the choice of a thick wing in combination with some degree of sweep angle provides for greater fuel capacity and thereby the ability to exchange payload for greater range.
- Thick wing sections make possible the low speed/high fuel efficient option by providing for necessary fuel capacity without unduly large wing area.

The parametric study data base has been used to predict the performance of various point designs. In particular consideration has been given to a twin-engine, powered lift version of the C 130 Hercules (Figure 17). For the same payload-range, this powered lift variant would reduce ground roll by 50% or more, increase cruise speed by 100 kt. and display a much smaller radar signature.

Propfan technology has the potential for improvement in specific fuel consumption. In Ref. 2, Coplin has suggested a hybrid engine described as a turbofan-prop which combines turbofan and propfan propulsion. In fact, it is a three-stream engine similar to the RB419. This leads to the possibility of a propulsion/blowing engine with propfan and an energy efficient powered lift STOL transport of the future as shown in Figure 18. Power to the propeller would be substantially less than for the conventional propfan and therefore gearbox development presents less of a problem.

6.2 POWERED LIFT STOVL SUPPORT AIRCRAFT

The Augmentor-Wing concept lends itself readily to a twin engine layout capable of vertical landing such as might be required for sea based operations in AEW & ASW roles. The developments in thick supercritical sections permit containment of ducting in the wing for ejector blowing and for engine-out balance. Two layouts are depicted, one based on the Pegasus engine (Figure 19) the other on the projected RB419 engine (Figure 20). The excellent buffet boundary characteristics of thick wing make it well suited for AEW surveillance at high altitude.

7.0 REFERENCES

1. Augmentor-Wing: Testing Toward Operational Goals.
   M. P. Rose'Meyer, the de Havilland Aircraft of Canada, Limited
   CASI Flight Test Symposium, Hull, Quebec, 1983.

2. The Accelerating Pace of Advancing Aero-Engine Technology.
   J. F. Coplin, Rolls-Royce, U.K.
   R.Ae.S. Lecture, London, November 1983.

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* This first case is the one having maximum transport capacity (PR) but no flexibility to exchange payload for fuel and thereby extend range (without addition of external tanks).

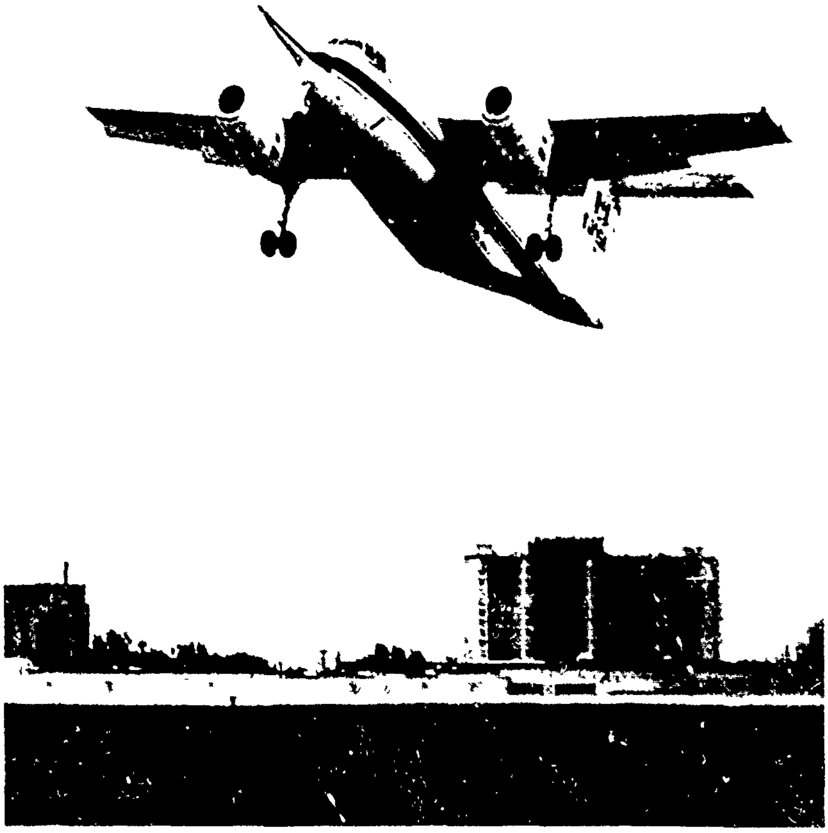


FIGURE 1

THRUST MANAGEMENT FOR WAVE-OFF

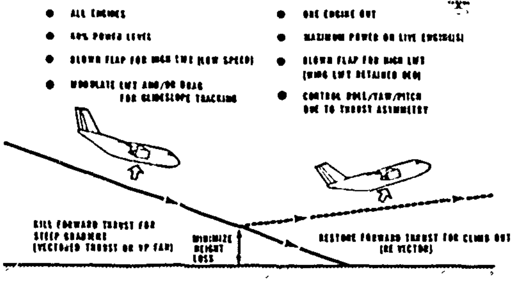


FIGURE 2

EFFICIENT BLOWN WING
WITH EJECTOR FLAP FOR STOL

(STATIC THRUST AUGMENTATION APPROXIMATELY 1.5)

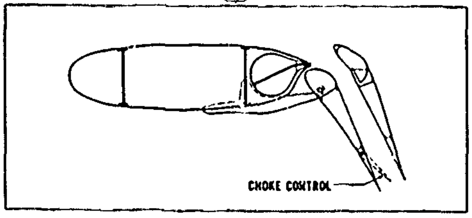


FIGURE 4

PROPULSION/BLOWING ENGINES

ROLLS-ROYCE
SPEY MK 801 SF
WITH VECTORING NOZZLES

ROLLS-ROYCE RB-419
BASED ON V.P. FAN
AND SPEY CORE

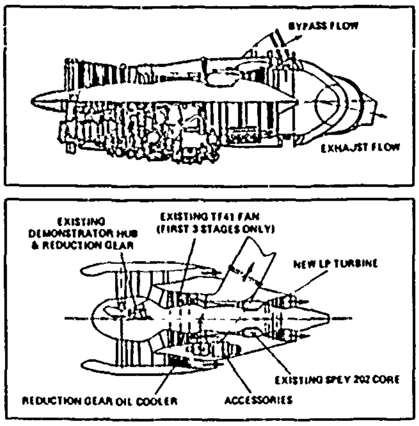


FIGURE 3

CROSS-DUCTING SCHEMATIC

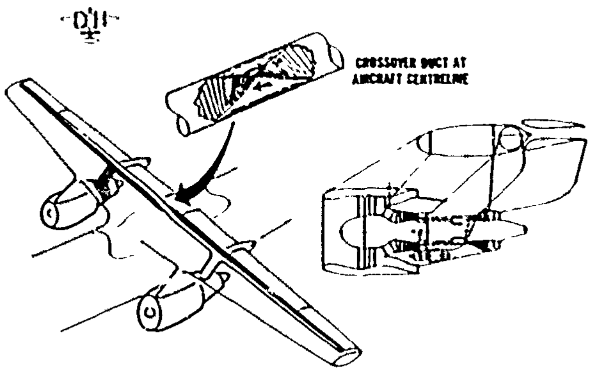


FIGURE 5

SUPERCRITICAL AIRFOIL DEVELOPMENT

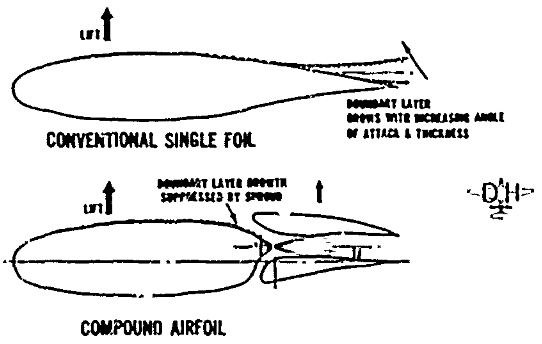


FIGURE 6

AWRA MAXIMUM EFFORT TAKEOFF 42,000 LB

FLAP 40° NOZZLES 36° HEADWIND 5.4 KT : 20°C

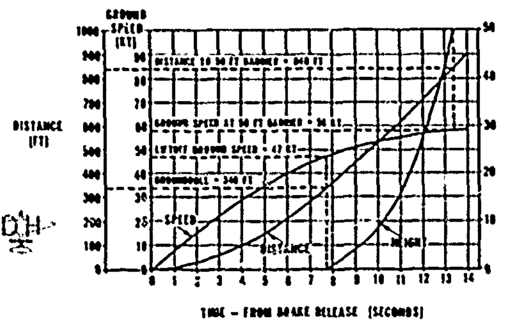


FIGURE 7

RB419-03
ENGINE APPROACH PERFORMANCE

ASSOCIATED CONDITIONS:
1. ISA
2. SPEED = 70 KNOTS
3. HEIGHT = 500 FEET

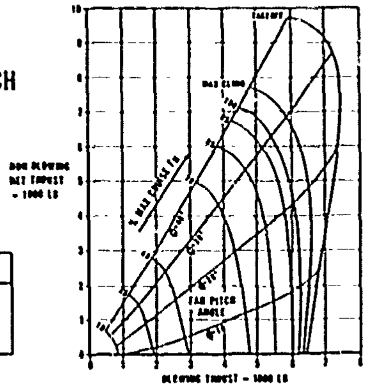


FIGURE 8

A FAMILY OF
SUPERCRITICAL COMPOUND AIRFOILS

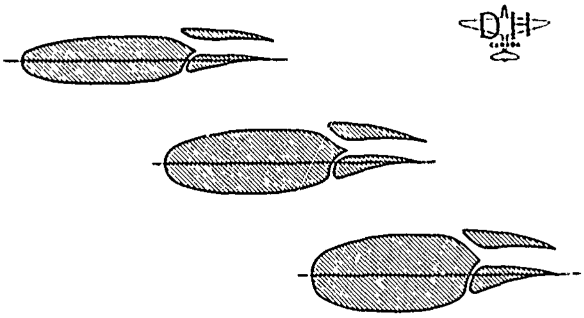


FIGURE 9

FLIGHT BOUNDARIES FOR COMPOUND AIRFOIL

YIELDS:

HIGH ALTITUDE FOR:

- CRUISE EFFICIENCY
- AIRCRAFT EARLY WARNING

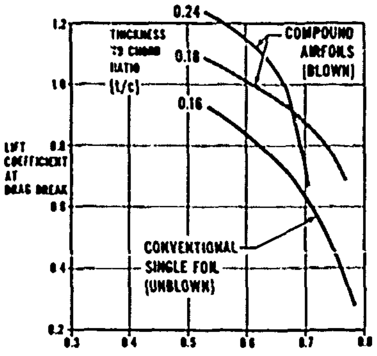


FIGURE 10

DRAG CHARACTERISTICS OF COMPOUND AIRFOIL

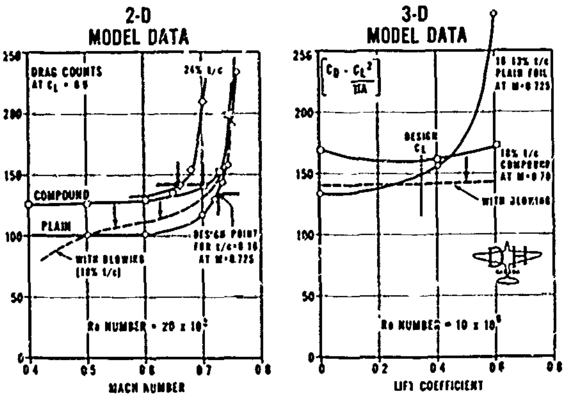


FIGURE 11

DRAG vs THICKNESS/CHORD FOR $C_{L_{DES}} = 0.6$

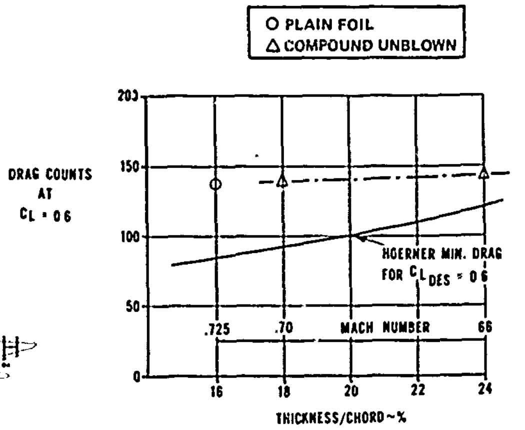


FIGURE 12

DRAG POLARS: t/c = 0.24

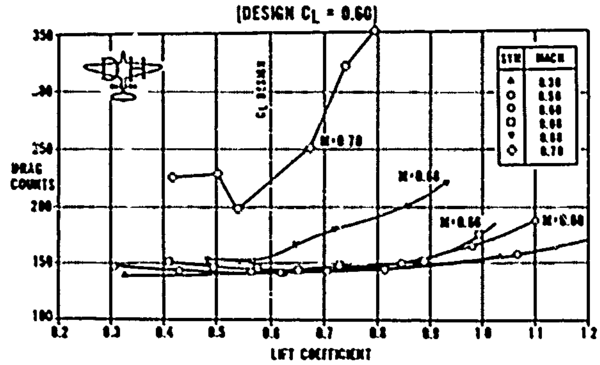


FIGURE 13

MILITARY TRANSP' "T MISSIONS

(TRADE-OFF STUDY: PAYLOAD = 0 · DESIGN GROSS WEIGHT)

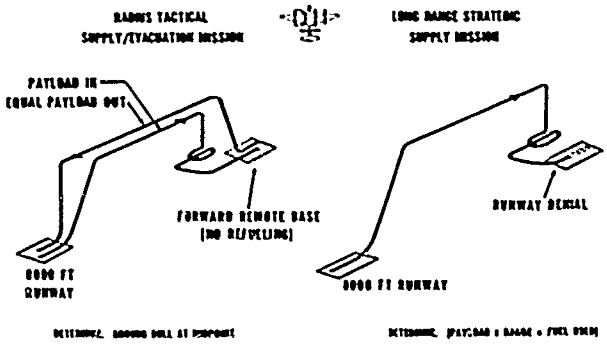


FIGURE 14

TRANSPORT FUEL EFFICIENCY vs REMOTE BASE GROUND ROLL

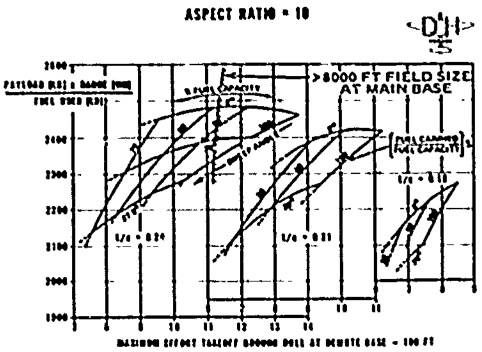


FIGURE 15

TRANSPORT FUEL EFFICIENCY vs CRUISE MACH NUMBER

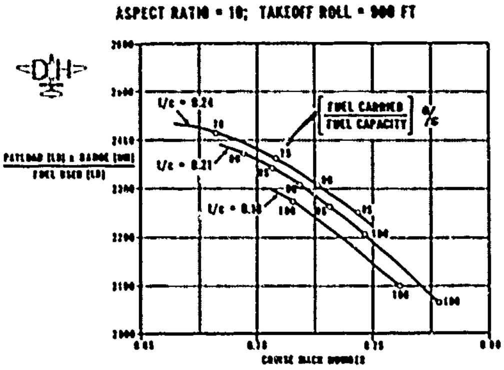
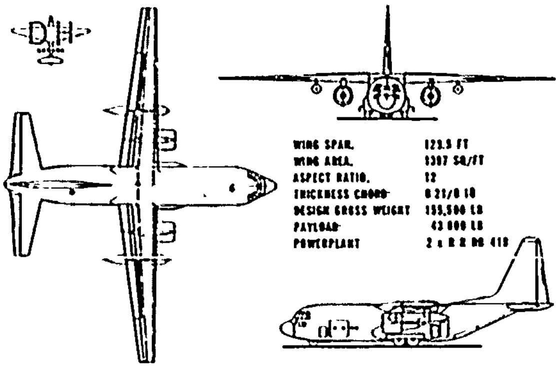


FIGURE 16

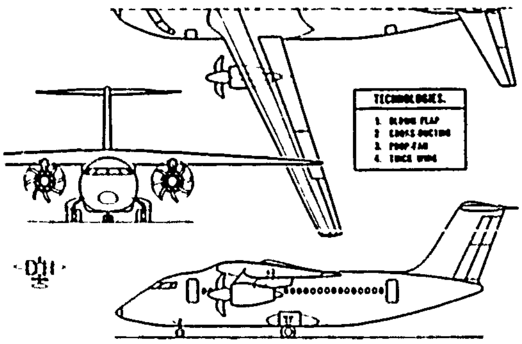
ADVANCED STOL TRANSPORT: C-130 FUSELAGE



WING SPAN.	123.5 FT
WING AREA.	1307 SQ/FT
ASPECT RATIO.	12
THICKNESS CHORD	0 21/0 18
DESIGN GROSS WEIGHT	155,500 LB
PAYLOAD	43 000 LB
POWERPLANT	2 x R R RB 419

FIGURE 17

ADVANCED POWERED LIFT TRANSPORT WITH TURBOFAN-PROP

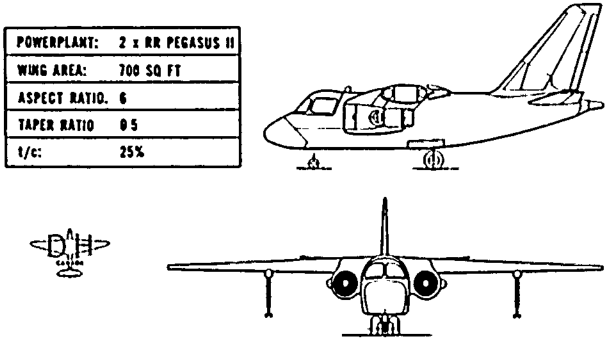


TECHNOLOGIES.

1. BLOWN FLAP
2. CROSS DUCTING
3. PROP FAN
4. THICK WING

FIGURE 18

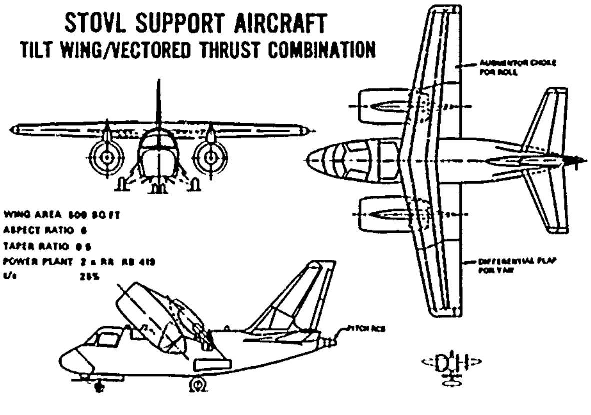
STOVL SUPPORT TYPE AIRCRAFT
WITH SHOULDER MOUNTED
ROLLS-ROYCE PEGASUS ENGINES



POWERPLANT:	2 x RR PEGASUS 11
WING AREA:	700 SQ FT
ASPECT RATIO.	6
TAPER RATIO	0 5
t/c:	25%

FIGURE 19

STOVL SUPPORT AIRCRAFT
TILT WING/VECTORED THRUST COMBINATION



WING AREA 600 SQ FT
ASPECT RATIO 6
TAPER RATIO 0 5
POWER PLANT 2 x RR RB 419
t/c 25%

FIGURE 20