DESIGN INTEGRATION OF CCW/USB FOR A SEA-BASED AIRCRAFT

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ABSTRACT

A design study is being conducted to apply the technologies of Circulation Control Wing with Upper Surface Blowing (CCW/USB) engine installation to a Navy/Lockheed sea based aircraft. Research and development in the CCW and USB concepts indicate that the application of the combined technologies may achieve a goal of operating the S-3 type aircraft from a ship deck without the catapult. The design emphasizes the integration of the propulsion system with a simple installation to obtain high lift or drag when required. Attention is also being directed to the cruise efficiency and the optimum design approach for stability and control.

INTRODUCTION

Various high lift concepts for fixed wing aircraft have been proposed during the past two decades. The intent is to increase the payload and/or to provide a short takeoff and landing (STOL) capability. Some of these concepts have been carried through flight demonstration with various degrees of success. From a technological as well as an operational point of view, two critical questions must be considered in the evaluation of a high lift device:

1. What is the mechanical complexity of the concept?
2. What power expenditure is required to obtain STOL or overload performance?

The first question involves the development risk, procurement cost, and maintenance requirements. The second question is also a measure of cost effectiveness in attaining the improvement for overload or STOL.

Two developments in high lift technology which appear to have a good potential for providing STOL capability and satisfying the evaluation criteria are the circulation control wing (CCW) and the upper surface blowing (USB) concepts. The CCW approach illustrated in Fig 1 blows air through a spanwise slot at the trailing edge of the wing over a round Coanda surface of a relatively small radius. The thin layer of blown air, attaching to the Coanda surface, induces higher circulation of air flow over the wing thereby deriving higher lift. The USB concept illustrated in Fig 2 also employs a curved Coanda surface in the form of a deployed flap aft of the turbofan engine which is installed over the wing. The USB device achieves high lift both by the induced super circulation as a result of entrained air flow with the engine efflux and by deflecting the engine thrust line downward over the deployed USB flap.

Both the CCW and USB concepts are powered lift devices employing the Coanda effect to achieve lift enhancement, and both have gone through flight evaluation. The CCW concept has been demonstrated by an A-6/CWW flight test aircraft(1); and the USB concept has been demonstrated by NASA/Ames Research Center's Quiet, Short-Haul Research Aircraft (QSRA)(2) and by Boeing YC-14 prototypes. It appears that the two concepts can logically be combined for potential improvement over either concept alone.

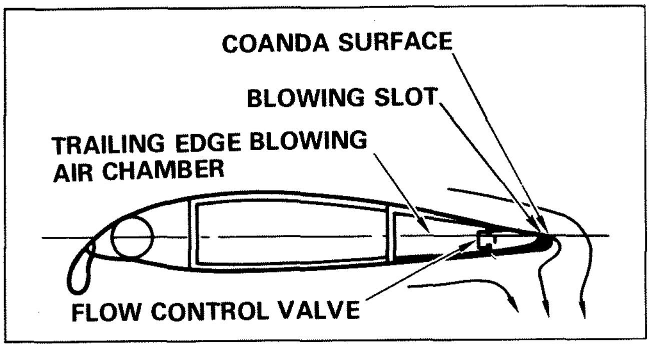

FIGURE 1. Circulation Control Wing (CCW)

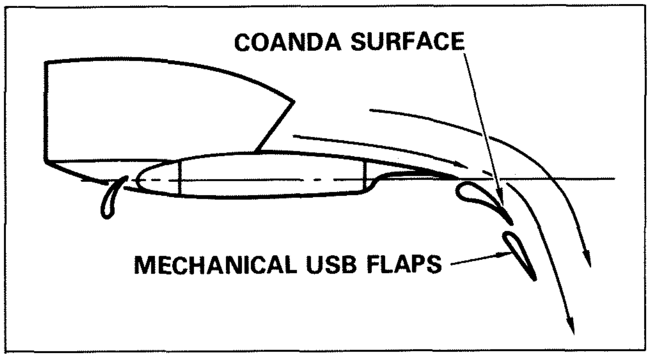

FIGURE 2. Upper Surface Blowing (USB)

The installation of the CCW is relatively simple in comparison with other high lift devices such as the conventional mechanical flaps. Subsequent to the A-6/CCW flight test, additional wind tunnel investigation has shown that the radius of the trailing edge Coanda surface can be as small as 0.9 percent chord length on a 17% thick supercritical airfoil to achieve significant high lift with blowing(3). The small fixed round trailing edge shows negligible drag penalty at subsonic cruise speeds. Using this configuration, the installation of CCW requires no moving parts for high lift except the blowing air flow control valves.

As a powered lift device, the USB concept has high efficiency of power utilization to achieve enhanced lift. When the USB concept is combined with the CCW concept, the large mechanical USB flaps can be replaced by a small rotary circular blowing flap as shown in Fig 3.

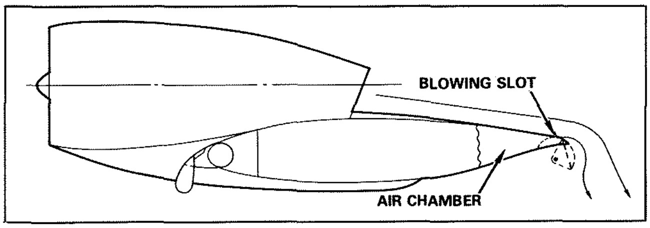

FIGURE 3. USB Engine Installation with CCW Trailing Edge

The David W. Taylor Naval Ship Research & Development Center (DTNSRDC), the developer of the CCW concept, has been undertaking the task of combining the CCW and USB technologies during the past three years.(4,5) The Lockheed-California Company, a division of Lockheed Corporation, has been investigating the development of a sea based aircraft with a capability for overload and STOL performance. This design study is being conducted to apply the concepts as shown in Fig 1 (CCW) and Fig 3 (CCW/USB) to the existing S-3A airframe with the objective to evaluate the effectiveness of the high lift capabilities.

Design Study Guidelines

To set a goal for the design study of an S-3 CCW/USB high lift or STOL aircraft, the following criteria are used for guidelines.

Wing loading: 75 to 85 lb/sq ft
Unassisted flat deck takeoff distance: 400 feet
Wind over deck: 0 to 20 knots, standard and 90°F day
Max C_L excursion after lift-off: 0.9 C_{LMAX}
Max sustained C_L: 0.8 C_{LMAX} (NOTE)
Acceleration after lift-off: 0.065g all engines
OEI at lift-off: Maintain trimmed attitude
Landing – Arresting gear

(NOTE) Tail down scraping angle of the existing aircraft is also a limiting condition.

CONFIGURATION

The U. S. Navy/Lockheed S-3A is a sea-based, subsonic, support aircraft primarily designed for the antisubmarine warfare (ASW) mission. The S-3B will incorporate the capability for anti-surface warfare (ASUW) mission as well. There are also other versions including a tanker (KS-3) and a carrier-onboard-delivery (COD) utility aircraft (US-3). Other potential versions include airborne early warning (AEW) and an armed AEW configuration with air-to-air missiles. The basic S-3A aircraft carries a four-man crew and has two TF34 high bypass ratio turbofan engines, pylon mounted under the wings.

Since the design study is constrained to applying new technology to an existing aircraft, some areas in the basic configuration cannot readily be changed. It is not feasible to use the simplest design approach as in developing a new aircraft. Nevertheless, the necessary changes to the S-3A basic aircraft incorporating the CCW/USB high lift techniques are by no means complicated. They consist of two major modifications:

1. New trailing edges replacing the mechanical flaps and the attendant tracks and actuation mechanism.
2. Over-the-wing engine nacelles that integrate the engine installation, bleed air supplies and air passages to trailing edge blowing.

Other minor modifications are: elimination of the inboard sections of the existing upper spoilers where the USB engines are installed, modification of the ailerons providing full span trailing edge blowing, and increase of the tail surface areas with double hinged rudder and elevators for low speed flight controls.

Figure 4 shows three views of the reconfigured S-3 CCW/USB. Following is a brief description of the modifications.

Engine Evaluation

As the engine installation is a major change (from under the wing pylon mount to over the wing nacelle for USB), an investigation was made to evaluate the merit of other candidate engines. Two other engines were evaluated in addition to the TF34 including its two uprated versions. The characteristics of these engines are listed below for comparison.

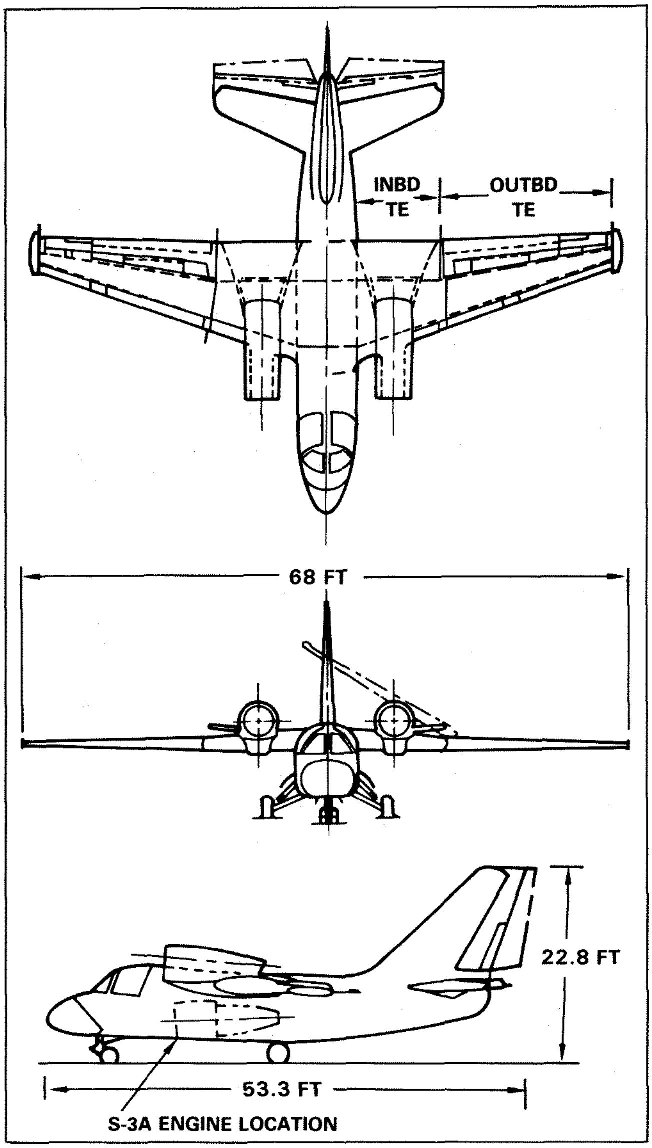

FIGURE 4. S-3 CCW/USB with (2) TF34 Uprated Engines

	TF-41-A2	JT8D-15	TF 34 (STATUS)		
	(SPEC)	(SPEC)	-GE-400	UR1*	UR2*
Rated thrust, lb	15000	15500	9579	10202	10824
Total gas flow, lb/sec	263	315	330	336+	–
Bypass ratio	0.74	1.10	6.2	–	–
Fan pressure ratio	2.5	1.9	1.5	–	–
SFC, lb/hr/lb	0.67	0.63	0.359	0.366	0.368
Dry wt. lb	3313	3389	1478	1478	1650

*UR1 & UR2 denote near-term uprated and far-term uprating respectively

The higher thrust of TF-41 and JT8D engines are desirable for takeoff performance. It enables the aircraft to reach the liftoff speed in a short distance unassisted by the catapult. The fan air pressure levels of these two engines are also desirable for CCW blowing. On the other hand, the low bypass ratios, higher specific fuel consumptions (SFC) and higher engine weights are undesirable characteristics for this application. For instance, the design study of two JT8D-15 engines on the S-3 CCW/USB airframe shows a drastic reduction of ASW mission endurance as compared with the S-3A even though its high lift capability and STOL performance are satisfactory.(6)

The manufacturer of the TF34 engines, General Electric Company, is currently developing the near-term uprated TF34 engines which are expected to be available in 1983, and is also proposing to develop a far-term uprated version. The undefined values in the above chart are expected to be approximately the same as those for the current version of the engine. The far-term uprated TF34 engines are selected for this design study. The results are also applicable to the current version and the near-term uprated TF34 engines with moderate increases in takeoff run distances to reflect the differences in thrust.

Engine Installation

Figure 5 shows a center line sectional view of the TF34 engine installed in an over-the-wing nacelle. The supporting structure of the nacelle is built around the existing S-3A wing box which is the internal fuel tank. Under the nacelle and above the existing upper wing surface is the fan bleed air passage to the trailing edge air chambers. A diverter is installed at the intersection of the fan air passage to the trailing edge chambers and fan air passage to the engine nozzle. The diverter is so shaped that the nozzle exhaust area is proportionately reduced when a certain percentage of the fan air is being diverted to the trailing edge air chambers.

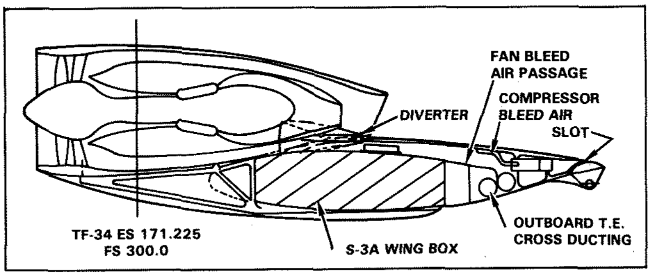

FIGURE 5. USB Engine Nacelle and Bleed Air Supplies to the Trailing Edges

The inboard wing airfoil profile is thus modified due to the nacelle installation integrated with the bleed air passage and the trailing edge air chambers. The constraints of the modification are: retention of the wing box structures and providing sufficient cross-sectional area for bleed air flow. The preliminary profile as shown follows the recommendations of the USB Cruise Study Program(7). Refinement of the profile is pending further study by computational analyses.

Over the wing engine mounting for USB makes the underwing space available for more external stores such as fuel tanks or Harpoons. Two other advantages are lower IR signature intensity for a military aircraft; and; reduced noise footprint over the airport for a commercial aircraft. No comparative test data have been obtained concerning the IR signature reduction in intensity. The expected benefit is derived from the fact that the mixed flow of the turbofan exhaust has lower temperature and is shaded by the wing. As for lower noise footprint, the QSRA has been used for this development.(2)

Trailing Edges

As shown in Fig 4, the trailing edge of the wing is divided into inboard and outboard segments at the wing fold joint.

The outboard trailing edge configuration is similar to that shown in Fig 1. The radius of the fixed Coanda surface is 0.9% of the local chord. An air chamber is incorporated inside the airfoil contour in front of the fixed round trailing edge over which a spanwise slot allows the air under pressure in the chamber to flow over the Coanda surface. The construction of the fixed Coanda trailing edge with blowing slot has been developed and manufactured at Lockheed in the experimental X-wing aircraft program.

The inboard segment of the trailing edge as shown in Fig 3 and 5 has a hinged rotary flap built into the modified airfoil contour aft of the trailing edge air chamber. The rotary flap has a radius of 5.2 percent of the local wing chord and serves as the Coanda surface when deployed. For blowing operation, air under pressure in the air chamber is expelled through the spanwise slot over the circular surface.

The inboard segment trailing edge is a replacement of the USB flaps as used on the QSRA or YC-14 prototypes. The CCW/USB static test on the QSRA and other wind tunnel scale model tests at DTNSRDC(4) used a round blowing trailing edge that has a radius of 3.6 percent of the local wing chord. Those tests showed significant lift enhancement as well as engine thrust line deflection when blowing air is applied over the fixed round trailing edge. There is strong indication that for a given set of constraints and lift enhancement, the blowing power required decreases as the radius of the Coanda surface increases and vice versa. Therefore, the optimum configuration of CCW/USB will depend on the tradeoff analysis of blowing power requirement and the size and weight of a simple rotary flap or even a fixed round trailing edge of a small radius. Cruise drag will impact this decision between a rotary flap and a fixed trailing edge.

Other Modifications

Spoilers and Ailerons – The spoilers are modified to the extent that the inboard section of the upper spoilers will be eliminated due to the USB engine installation. An analysis will be conducted to investigate the impact of this change. The ailerons are modified to incorporate trailing edge blowing at low air speed. Blowing air supplies are installed in the hinge torque tubes.

Empennages – Two tail configurations have been studied. One approach is to retain the existing locations of the vertical and horizontal tails as shown in Fig 4 but increase the chords to obtain larger surfaces. Double hinged rudder and elevators are assumed for analyses.

Another configuration is a T-tail which appears to have the benefit of minimizing the increased downwash effect from CCW/USB. Using the same sweep of the S-3A vertical stabilizer, the relocation of the horizontal stabilizer on top of the vertical has the added advantage of extending its moment arm length. However, changing to the T-tail configuration entails extensive aft fuselage structural changes. Other factors must be considered also for a sea based aircraft. The current study is based on the tail configuration shown in Fig 4.

Trailing Edge Blowing Air Distribution

The distribution of the engine bleed air for trailing edge blowing is shown in Fig 6. The cross ducting arrangement minimizes unbalanced roll moment in case one engine fails during STOL operation. Preliminary analysis of the one-engine-inoperative (OEI) condition as shown by the lower illustration indicates that the roll moment due to lift augmentation of CCW/USB is negligible when bleed air from one operating engine supplies trailing edge blowing on both sides of the aircraft.

The wing trailing edge has four independent blowing segments: the outboard and inboard on the left- and right-hand side of the aircraft. The outboard segment blowing air is supplied directly from the fan bleed. The inboard segment blowing air supply is a mixture of the fan and compressor bleed for the desired pressure level by appropriate flow control valves.

The outboard segment blowing can be regulated at differential levels on one side of the aircraft over the other. The differential blowing causes differential lift of the outer wing for roll

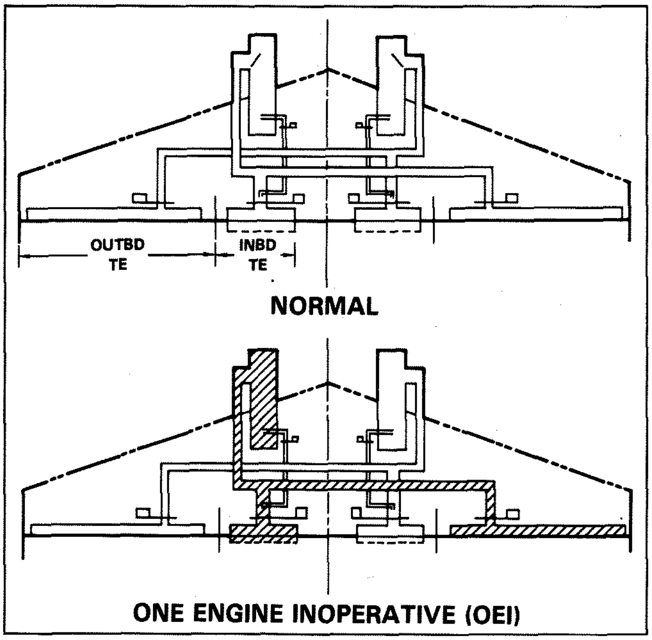

FIGURE 6. Schematic Diagram of Trailing Edge Blowing

control. The cross ducting augments the effectiveness of roll control by differential blowing due to the fact that the reduction of outboard blowing on one side will increase the air supply to the inboard blowing on the other side if the fan bleed of the engine is kept constant. With coordinated increased outboard blowing on one side and decreased outboard blowing on the other, the lift changes on both the outboard and inboard wing on the same side of the aircraft are additive.

Estimated Weight

The estimated weights of the S-3 CCW/USB aircraft with two TF34 far-term uprated engines and with two JT8D-15 engines(6) are tabulated below. The weight of the basic S-3A aircraft is also listed for reference.

WEIGHT STATEMENT
S-3 CCW/USB

Weight, lb	CL 1763-09 B (2) TF34	CL 1763-08 (2) JT8D-15	S-3A Baseline
Structure	14,743	14,629	14,100
Propulsion	3,446	7,664	3,485
Avionics	4,444	4,444	4,444
Other Systems & Equipment	5,452	5,074	5,666
Weight Empty	(28,085)	(31,811)	(27,695)
Oper. Equip.	1,712	1,732	.1,712
Stores	3,606	3,606	3,606
Fuel	13,142	13,142	13,142
Takeoff Gross Weight	(46,545)	(50,291)	(46,155)

PROPULSION SYSTEM

Power requirement of a powered-lift device is a great concern in the evaluation of the lift enhancement concept. In this design study, efforts were directed to establish a methodology which provides a quick reference to account for power consumption.

The CCW/USB high lift concept requires trailing edge blowing over a simple device. The blowing air power is taken from the engine bleed. The development of the design procedure is presented below.

Blowing Air Design Parameters

The pressure level of the TF34 fan air, at $P_F/P_\infty = 1.5$, is adequate for the outboard trailing edge blowing for CCW lift augmentation. According to currently available test data, however, the inboard trailing edge blowing to induce deflection of engine thrust line will require higher air pressure than that of the TF34 fan air. It is estimated that, with the selected radius of the Coanda surface equal to 5.2 percent of the local wing chord, the blowing air pressure ratio may need be about 2.0 excluding transmission losses. Evidently, a pressure booster device is required if the fan air bleed is to be used for inboard trailing edge blowing.

As it is desired to keep the installation as simple as possible, the search for higher pressure air supply comes logically to the engine compressor bleed. Unfortunately, the TF34 high by-pass ratio turbofan engine does not have high capacities for compressor bleed. Even a moderate amount of compressor bleed degrades the total thrust considerably. Figure 7 shows the thrust output of the TF34 engine as a function of fan bleed and compressor bleed. It indicates that the TF34 engine can supply considerable quantities of fan air with only small percentage reduction of thrust output.

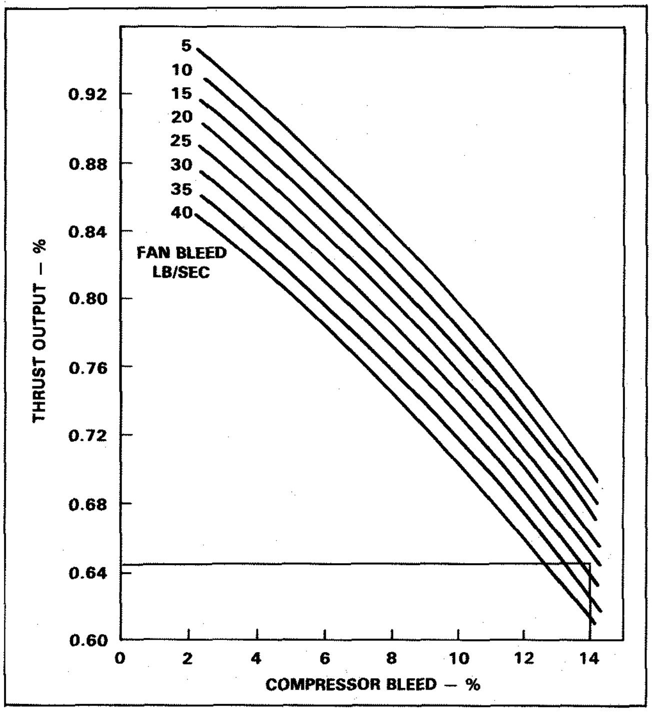

FIGURE 7. TF34 Thrust Output vs Fan/Compressor Bleed

One approach to obtain sufficient quantities of higher pressure blowing air is to mix the compressor bleed as the primary flow in an ejector device with the fan bleed supply as the secondary air. Figure 8 shows the resultant air pressure levels of various proportions of TF34 compressor bleed mixed with the fan air.

In the same figure, the inboard trailing edge blowing momentum coefficient C_μ is also presented. The blowing momentum coefficient is defined as follows

$$C_\mu = \frac{MV_j}{qS}$$

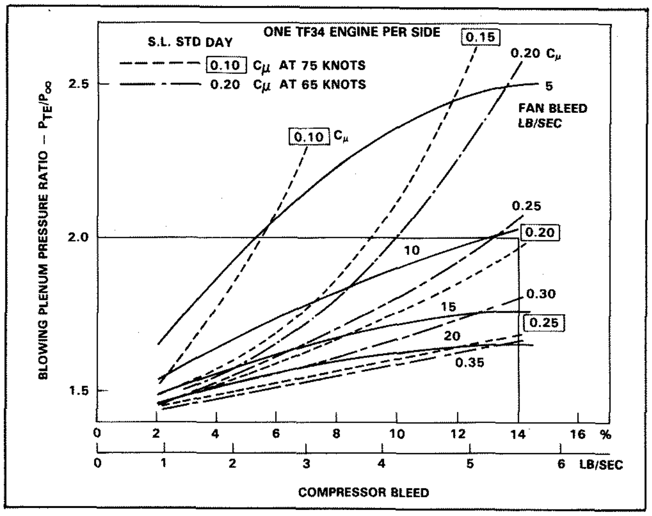

FIGURE 8. S-3 CCW/USB Inboard T.E. Blowing Air Supply

Where $\dot{M}$ is the mass flow rate of the blowing air, V_j is the air jet velocity with respect to the blowing slot, q the freestream aerodynamic pressure, and S the reference wing area. In this case, however, C_μ is computed by using the wing area bounded by the inboard trailing edge length. Figure 8 provides the design parameters of the blowing power for the inboard trailing edge by the TF34 engines. Figure 9 summarizes the inboard and outboard trailing edge blowing parameters as a function of air flow rates and pressure levels.

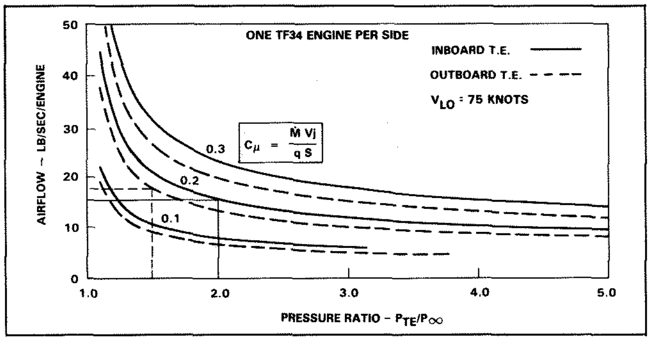

FIGURE 9. S-3 CCW/USB T.E. Blowing Parameters

Baseline Design

To establish a baseline design for evaluation, a preliminary value of the influential design parameter, the blowing momentum coefficient, $C_\mu = 0.2$ was selected. The rationale of using this value is based on the available test data of CCW/USB as shown in Fig 10 which is taken from Reference (5). This typical plot shows the lift coefficient as a function of CCW blowing on the outboard wing of the half-span model and CCW/USB on the inboard wing with different levels of simulated engine thrust. The model has a wing aspect ratio of 4, and the radius of the fixed round trailing edge was 3.6 percent of the local chord. The angle of attack and free stream aerodynamic pressure were kept constant. The data show that the lift coefficient, C_L, increases at higher rates up to $C_\mu = 0.2$; and the rate of increase diminishes gradually as C_μ increases beyond this value. As an initial approach in the design study, the average $C_\mu = 0.2$ along the span was selected.

Using this preliminary design average value of $C_\mu = 0.2$ for both the inboard and outboard trailing edge blowing, the air flow requirements from the engine bleed can be estimated as follows.

From Fig 9, the outboard trailing edge blowing coefficient $C_\mu = 0.2$ (dotted line) at pressure ratio of 1.5 indicates that the airflow requirement is about 17.5 lb/sec. This air supply can be obtained directly from the fan bleed. For the inboard trailing edge blowing coefficient $C_\mu = 0.2$ (solid line) at a pressure ratio of 2.0, the airflow requirement is about 16.0 lb/sec. This supply can be obtained from the compressor bleed and fan bleed. Refer to Fig 8 on the dotted line (at 75 knots) of $C_\mu = 0.2$ and the pressure ratio = 2.0, the required compressor bleed is about 5.5 lb/sec (14%), and the fan bleed air is about 10.5 lb/sec. Therefore, the total fan bleed flow is [17.5 lb/sec (outboard blowing) + 10.5 lb/sec (inboard blowing) =] 28 lb/sec. The compressor bleed for the inboard blowing is 5.5 lb/sec (14%). From Fig 7, it is seen that the combined bleed flow causes the remaining engine thrust output at about 64%.

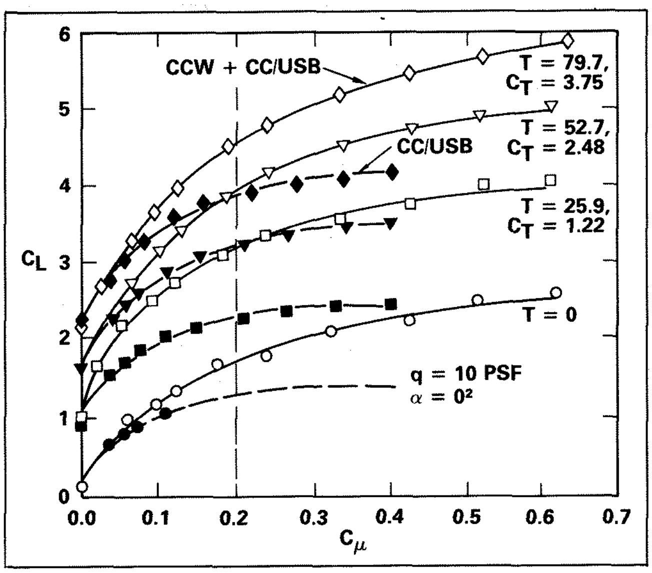

FIGURE 10. Test Data of Lift Enhancement by CCW + CC/USB

LOW SPEED FLIGHT CONTROL

The basic S-3A single engine climbout speed at 46,600 pounds is 125 knots. This capability is also retained by the S-3 CCW/USB. In other words, the reconfigured high lift aircraft can be treated as a conventional S-3A at and above this speed for flight controls with certain caution to account for the increased tail surface areas.

The powered lift operation speed of S-3 CCW/USB is projected to be 65 – 75 knots. Therefore, the primary concern of low speed flight controls is in the range of 65 to 125 knots.

Pitch Control

Two major factors must be considered in pitch control of a CCW/USB aircraft, they are:

- Increased nose down pitching moment, due to lift augmentation by blowing at the trailing edge.
- Different downwash fields due to USB engine efflux and the thrust angle changes.

Figure 11 shows the increased nose down pitching moment due to USB and CCW. To explore and develop a solution of this problem, Lockheed conducted a wind tunnel test on a 9-foot wing-body model with CCW trailing edge blowing and leading edge blowing both with and without a leading edge slat. Figure 12 shows the results of the experimental test. It was found that when 25 percent of the trailing edge blowing air was shifted to the leading edge blowing, the loss of lift is very slight, but the reduction of nose down pitching moment is rather significant. More pitching moment reduction might be expected if the leading edge blowing

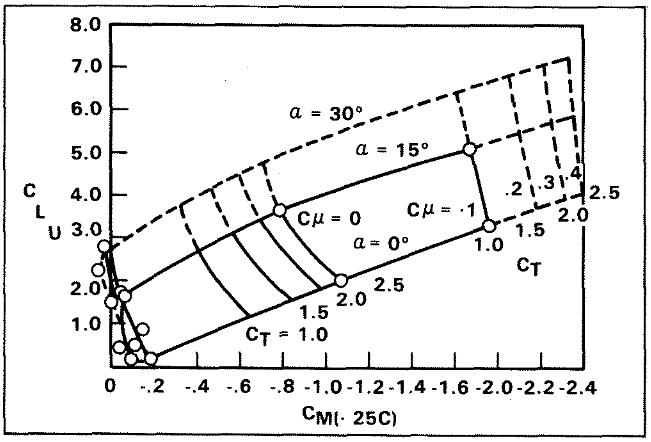

FIGURE 11. S-3 CCW/USB Pitching Moments

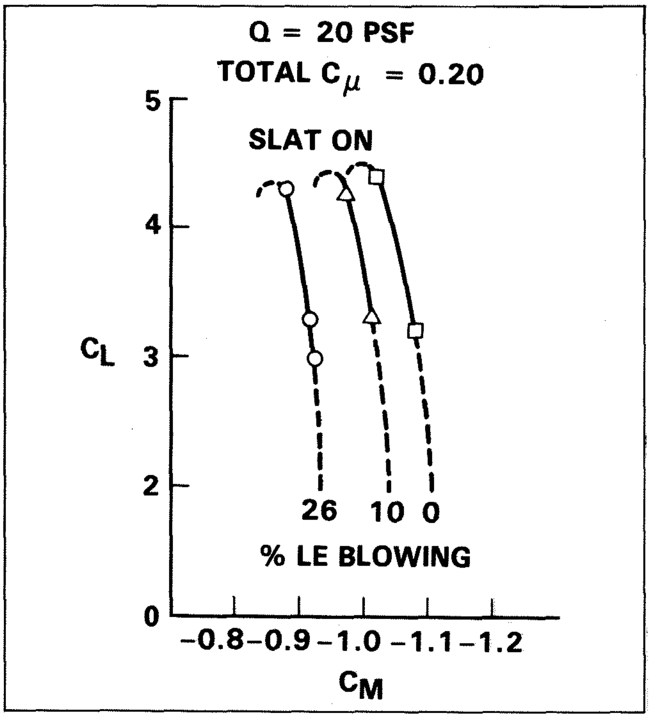

FIGURE 12. Effect of Leading Edge Blowing on Pitch Moment

configuration was optimized. No leading edge blowing, however, is included in this design study.

More tests and analyses in pitching moment reduction and downwash field definition are required to validate the actual design criteria. Some relevant downwash test data will be soon available from the QSRA downwash survey test conducted earlier in 1982 by NASA/Ames Research Center. DTNSRDC and Lockheed have a plan to conduct further wind tunnel development tests in the near future on a generic scale model resembling the S-3 CCW/USB configuration. The analyses presented herein are based on presently available data that appear to be applicable to this preliminary design configuration.

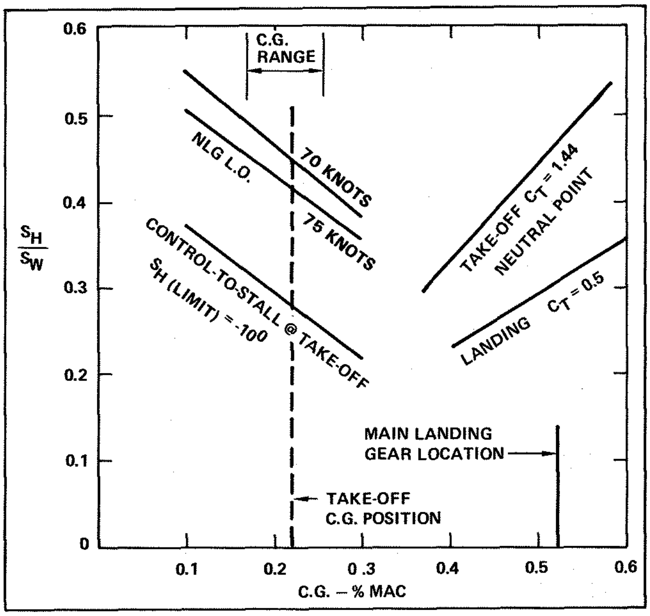

FIGURE 13. Horizontal Stabilizer Size

The critical condition for low speed pitch control is the requirement for takeoff rotation. Figure 13 defines the horizontal stabilizer size requirement of the S-3 CCW/USB shown in Fig 4. The center of gravity (cg) of the aircraft at takeoff is estimated to be at 22 percent mean aerodynamic chord (MAC). For the given landing gear geometry, the horizontal tail surface area required, as a percentage of the reference wing area, is 42 percent at the liftoff speed of 75 knots EAS. It shows that the required horizontal tail size decreases as the takeoff cg moves aft. Figures 14 and 15 are preliminary analyses of longitudinal stability characteristics at takeoff and landing respectively.

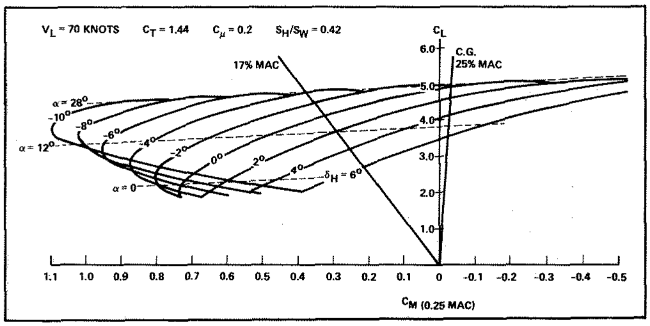

FIGURE 14. Longitudinal Stability Characteristics, Takeoff

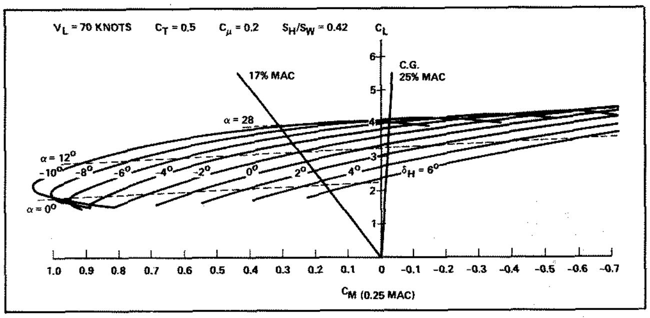

FIGURE 15. Longitudinal Stability Characteristics, Landing

Roll and Yaw Control

Roll control during powered lift operation is by differential CCW blowing. The ailerons will take over the roll control function after CCW blowing has been phased out as the air speed increases. At this preliminary state of the design study, the function of the existing lower spoilers during trailing edge blowing has not been investigated.

Detail design and analyses of roll control by differential blowing down to 65 knots are in progress. The initial study assumes the differential outboard trailing edge blowing of $\Delta C_\mu = 0.2$. (The normal blowing is assumed to be C_μ (L) = C_μ (R) = 0.2; the differential blowing being C_μ (L) = 0.3 and C_μ (R) = 0.1 and vice versa). The differential blowing of the outboard trailing edge alone, excluding the additional effect by the inboard wing, can provide the S-3 CCW/USB with a roll control angular acceleration of 0.6 rad/sec/sec at 65 knots and a TOGW of 46,600 pounds. The roll control power is expected to increase substantially if the lower spoilers are brought into action. This approach, however, requires more extensive investigation and wind tunnel tests.

The surface area of the vertical stabilizer has been increased 25 percent over that of the S-3A and a double hinged rudder is being evaluated. It is recognized that the increase of tail surface area for flight control during powered lift operation will exceed the basic S-3A conventional takeoff and landing design criteria. In the cruise flight regime, however, the basic S-3A flight control requirements apply to all conditions. Therefore, certain limiting devices will have to be incorporated in the mechanization to differentiate the flight control at low speeds and high speed operation.

One Engine Inoperative Mode

The condition of one engine inoperative (OEI) at liftoff is always a problem with twin engine sea-based aircraft. It is particularly critical for one with powered lift devices. This design study addresses this problem by the design requirement of maintaining a wing level attitude long enough for safe pilot ejection. This is similar to the condition of a cold catapult shot.

The OEI condition of trailing edge blowing is shown in Fig 6. The cross ducting blowing nearly balances the wing lift on both sides of the aircraft if either engine fails. Therefore, roll trim does not appear to be a problem for OEI. However, the total lift loss during OEI is estimated to be about 35 percent; and the yaw moment with one engine inoperative cannot be trimmed out by the proposed double hinged rudder at the air speed for STOL operation. One possible solution is to deploy the outboard upper and lower spoilers on the side where the outboard trailing edge blowing is inoperative. This may counteract the OEI yaw moment but will further degrade the lift. A probable solution is cross-duct blowing the outboard trailing edge segments from either engine so that the induced drag on both sides of the aircraft would be balanced to minimize the yaw moment with very little roll asymmetry. A comprehensive six-degree-of-freedom time history study of the OEI condition is necessary to further define the magnitude of the problem and hence to formulate the proper solution.

TAKEOFF, LANDING, AND MISSION PERFORMANCE

The takeoff performance of the aircraft with two far-term uprated TF34 engines is shown in Fig 16 as a function of takeoff gross weight (TOGW) and wind over deck (WOD). The aircraft has a tail down angle of 14°. Limiting the takeoff rotation to 12°, the takeoff speed for TOGW of 42,000 and 50,000 pounds are 70.1 and 76.5 knots respectively. The analysis indicates that the S-3 CCW/USB at 46,500 pounds can take off from a flat deck in 420 feet on a standard day with WOD of 20 knots. It requires 490 feet takeoff run distance on a tropical day at the same TOGW and WOD. The analysis also shows that for a given flat deck takeoff run distance of 400 feet and WOD of 20 knots, the S-3 CCW/USB with blowing $C_\mu = 0.2$ can take off at 46,000 pounds on a standard day, and at 43,000 pounds on a tropical day.

A brief evaluation was made to compare the takeoff performance using the current TF34-GE-400 engines. At TOGW of 42,000 pounds, WOD of 20 knots on a standard day, the flat deck free running takeoff distance of the S-3 CCW/USB would be 390 feet instead of 325 feet as shown in the lower chart of Fig 16 for two far-term operated TF34 engines.

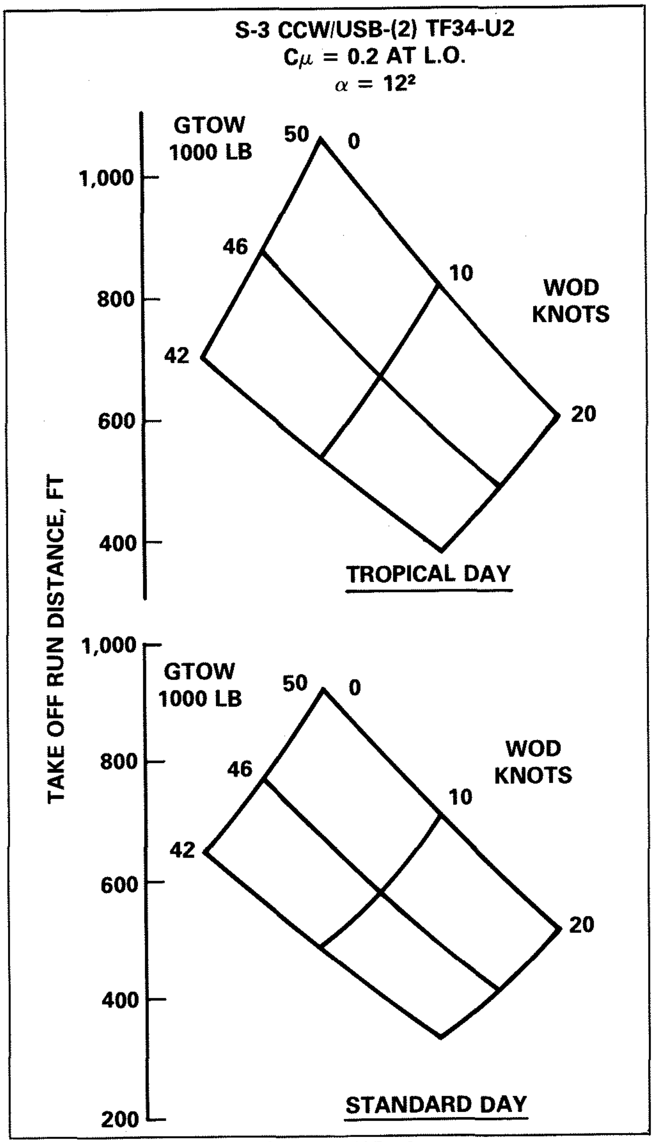

FIGURE 16. Takeoff Performance

Figure 17 shows landing performance as a function of WOD and tire-deck friction coefficient, μ_F, for non-skid braking. Free deck run braked landing is affected by many factors including deck surface conditions, weather and sea state. The S-3 CCW/USB aircraft, however, does retain the arresting hook for conventional arrested landing and the lower approach speed would require much lower energy of the arresting gear.

The landing performance is included to show the capability of S-3 CCW/USB aircraft under a set of given conditions. The analytic results of both takeoff and landing performance of the S-3 CCW/USB aircraft are comparable to the predicted carrier operation performance of the QSRA which went through a series of sea trials on USS Kitty Hawk in 1980 for unarrested landings and free deck takeoffs(8).

A preliminary estimate was made on the overload landing capability of S-3 CCW/USB within the basic S-3A structural design criteria of the landing gears and airframe. Maintaining the specification minimum sinking speed of 20.6 feet per second in a symmetrical landing configuration, the landing gross weight of S-3

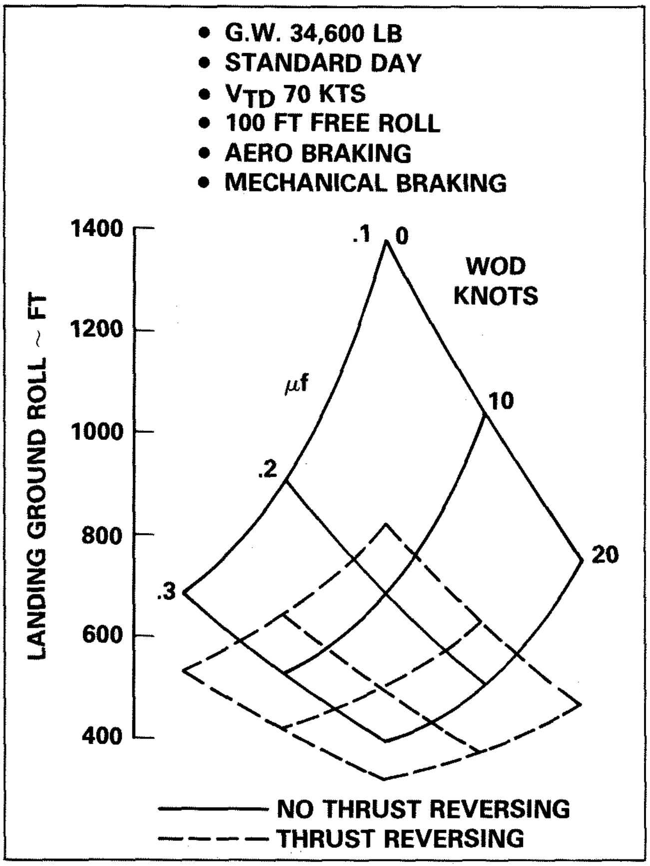

FIGURE 17. Flat Deck Landing Distance

CCW/USB can be increased to 44,500 pounds from the S-3A design landing gross weight of 37,750 pounds. Furthermore, the minimum sinking speed and approach angle for the conventional sea-based support aircraft can be modified to take advantage of the capabilities of a high lift aircraft such as the S-3 CCW/USB. The *landing weight* then can be increased up to the S-3A *maximum gross takeoff weight* of 57,000 pounds.

Figure 18 presents a comparison of the ASW mission performance of the S-3 CCW/USB with two far-term uprated TF34 engines, the basic S-3A, and another S-3 STOL version using two JT8D-15 engines(6). For this comparison, all three aircraft carry the same mission equipment load and fuel. At a radius of 400 n.mi., the S-3 CCW/USB has an on-station time of 4.55 hours compared with the basic S-3A of 4.85 hours. The cost of incorporating the STOL capability by the CCW/USB high lift technology in this case, from an operational point of view, is 0.3 hour of on-station time. The reduction of total fly time from the basic S-3A aircraft ASW mission performance is less than 4 percent. On the other hand, the high lift device provides an overload capability which enables the aircraft to carry more fuel to extend the mission endurance.

CONCLUSION

The preliminary design study, applying the high lift concept of CCW combined with USB to a sea-based support aircraft (the U.S. Navy/Lockheed S-3A), has demonstrated that the reconfigured S-3 CCW/USB can

- Operate from a conventional flat deck without the catapult
- Land with overload in conventional arresting mode
- Achieve STOL performance with less than 4 percent reduction of total mission flying time comparing with the S-3A on the basis of same equipment load and fuel.

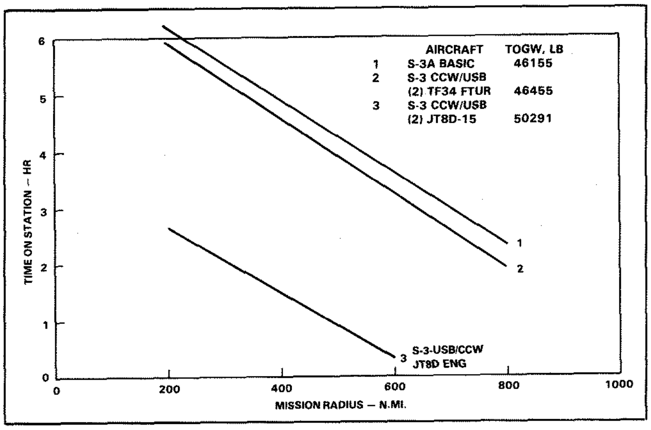

FIGURE 18. ASW Mission Performance

- Extend the mission time by additional fuel as the result of overload capabilities.

The CCW/USB powered lift concept requires very simple installations:

- The trailing edge blowing devices are simpler than other high lift designs including the conventional mechanical flaps.
- The CCW installation does not require moving mechanical parts except the blowing air flow control valves.
- The CCW/USB high lift installation has potentially high reliability, low maintenance requirement, and hence low life cycle cost.

The S-3 CCW/USB appears to have the following advantages:

- More underwing space for external stores
- Reduced IR signature intensity.

The modification of the engine installation from under-the-wing pylon mounted position to over-the-wing nacelles is not an easy task on an existing aircraft, but the new nacelle design integrating the engine bleed air controls and passages to trailing edge blowing can be installed readily over the existing box structures. The same design approach can be applied to new aircraft with commensurate increase in performance.

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