AIAA 80-1812R

CTOL/VSTOL Comparison—A View from the Deck

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Aircraft carrier capabilities are compared for catapult launched and arrested landing aircraft—CTOL aircraft, and short takeoff and vertical landing aircraft—V/STOL aircraft. The V/STOL aircraft are capable of takeoff and landing in the vertical mode with increased mission payload and performance when operated in an STO (short takeoff) overload condition. Investigations were conducted on how future generic aircraft were affected by the ship environment and how aircraft operations could be optimized. Starting with the CTOL aircraft, investigations were performed to determine the limiting operational factors and constraints. This established baseline parameters for the operational sensitivity studies. Sensitivity studies were then made comparing equal size and equal cost airwings. Results of these studies parametrically show the impact on sorties over all mission ranges out to 700 n.mi. at various cost levels.

Nomenclature

CL = launch cycle time, min = time from launch to launch for succeeding launch groups
CT = turnaround cycle time, min = time from launch to launch for the same launch group
L = launch time, min
$\dot{L}$ = launch rate, min/aircraft
MA = manning time, min
MI = mission flight time, min
N = number of launches in operating period
OP = operating period, min
PL = postlaunch time, min
R = recovery time, min
$\dot{R}$ = recovery rate, min/aircraft
RM = mission range, n.mi.
RS = respot time, min
$\dot{\text{RS}}$ = respot rate, min/aircraft
S = service time, min
$\dot{S}$ = service rate, min/aircraft
S_N = maximum number of sorties generated in operating period
TC = number of towing crews
Vc = aircraft cruise velocity, knots
WC = number of weapons loading crews
X = number of aircraft in a launch
X_R = number of aircraft required to support maximum sortie generation

Introduction

RECENT studies have provided new insight into V/STOL aircraft operations aboard aircraft carriers. While many supporters see V/STOL as the wave of the future, even the most optimistic of these supporters would not suggest that a V/STOL aircraft will ever equal a CTOL aircraft in certain aspects of performance per cost or performance per weight. A penalty in size and weight is inherent to the V/STOL design. However, viewing the comparison of V/STOL vs CTOL from the realistic constraints imposed by the ship deck, a new argument can be raised in support of V/STOL—one which will, in effect, demonstrate that for several important measures of effectiveness V/STOL will surpass CTOL.

Presented as Paper 80-1812 at the AIAA Aircraft Systems and Technology Meeting, Anaheim, Calif., Aug. 4-6, 1980; submitted Sept. 10, 1980; revision received May 18, 1981.

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Measures of Effectiveness (MOE)

V/STOL and CTOL aircraft are compared operating in a power projection role from a single aircraft carrier. The primary MOE in this study are "sorties." A sortie is defined as a completed aircraft mission. Closely associated with sorties is the MOE based on the distance to the target or "range." Combining sorties and range results in another MOE—"mission performance."

In order to concentrate the evaluation of the effects of deck cycle constraints upon aircraft mission performance, notional V/STOL and CTOL aircraft designs were used with equivalent payload, cruise speed, and maximum range capabilities. It should be noted that for a given aircraft size, CTOL performance (range and payload) would exceed that of V/STOL. In order to achieve equal performance the V/STOL aircraft will be larger and more costly. Other comparisons of CTOL and V/STOL effectiveness are based on numbers of aircraft required and flyaway costs.

Flight Deck Operations

This study uses the large deck aircraft carrier as an avenue for investigation of the operational effectiveness of CTOL vs V/STOL aircraft for several important reasons. The first, and most obvious, is that sea-based CTOL aircraft can only be operated from large deck carriers. Secondly, the size of the flight deck allows a full examination of V/STOL capabilities. Unlike the smaller air capable ships in which the military air posture is either offensive or defensive, the large deck carrier can perform both at the same time. Finally, if the decision is made to convert the Navy's air arm to an all V/STOL force, the aircraft carrier will provide, at the very least, a transition platform.

Flight deck operations for CTOL have been developed and refined over many years. V/STOL operations, on the other hand, are largely unknown. In order to establish the ground rules for a V/STOL operation, a study was undertaken to determine how the deck would be run to make the most effective use of V/STOL's unique capabilities. The resulting optimized V/STOL deck operation and the known CTOL operation are described below.

Launch Operation

In both the CTOL and V/STOL launch operations, the flow of aircraft are similar. Generally they move from the after portions of the flight deck forward to the launching areas. The CTOL case, shown in Fig. 1, directs aircraft from the stern parking areas (shaded) to the waist catapults. The bow catapults are fed from the forward-starboard and amidship parking areas (shaded).

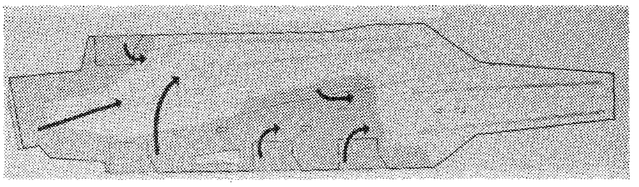

Fig. 1 CTOL aircraft launch flow.

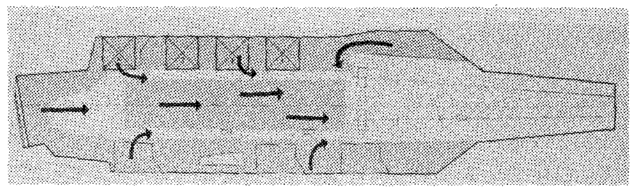

Fig. 2 V/STOL aircraft launch flow.

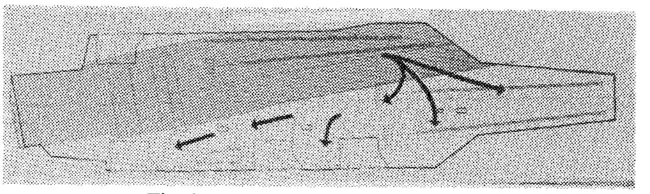

Fig. 3 CTOL aircraft recovery flow.

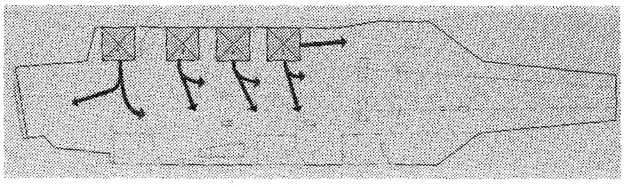

Fig. 4 V/STOL aircraft recovery flow.

In the V/STOL operation, shown in Fig. 2, aircraft are moved from the stern, port, starboard, and amidship parking areas (shaded) to the bow runways. STO launches are used exclusively to improve payload and endurance capabilities of the aircraft. The aircraft flow in a V/STOL launch has an advantage over the CTOL—all aircraft are channeled to a single launch area leaving more of the flight deck available for parking and taxiing of the aircraft. Aircraft spotting studies have shown that this increased parking and taxi area allows the V/STOL aircraft to be approximately 30% larger than CTOL aircraft and still achieve the same size (numerical) carrier airwing.

Recovery and Respot Operations

The recovery and respot operations are the portions of the aircraft mission evolution that exhibit the most significant differences. In the CTOL case, a runway must remain clear in order for aircraft to make conventional arrested landings. (See shaded area in Fig. 3.)

This area is required for a safe approach with sufficient ramp clearance, a touchdown area, a decelerating cable runout area and when recovery is complete, a turnout area. The aircraft then taxies forward to the bow and is parked. Later when the total recovery is completed, the aircraft must be respotted by towing them from the bow to their prelaunch positions (or to an elevator to be lowered to the hangar). These prelaunch positions are those shown in the shaded parking areas of Fig. 1. While recoveries are being conducted, respot and launch operations are not possible because the required deck areas are fouled by the recovery operations. Likewise, while respot is underway, no launching or recovery can be accomplished. This is due to the large and/or frequent recoveries demanded for this study and is typical of today's operations on a carrier.

In the V/STOL case, shown in Fig. 4, the recovery and respot operations are simplified. Vertical landing pads along the port side of the ship encompass much less area than the single landing area for CTOL. An aircraft is recovered on one of the pads and is taxied directly to its prelaunch spots and is parked. The recovery and parking operations can be conducted simultaneously and have little impact on launching operations that could be underway at the same time.

Servicing

Upon recovery, each aircraft requires several servicing functions prior to its next mission. Various checks are conducted, the aircraft is refueled and, if appropriate, rearmed. Servicing can start as soon as the aircraft lands and taxies to its prelaunch spot. Servicing has little impact on the deck operation mentioned previously, but is a significant factor in determining how many sets of aircraft are required to support continuous sortie generation.

Summary of Deck Operations

In summary, the significant factor that differentiates the flight deck operations of the V/STOL from the CTOL is the recovery mode. The V/STOL deck operation does not experience the problems associated with the large recovery area required for CTOL. Since all three major deck operations (launch, recovery, and respot) can occur simultaneously, the deck is never fouled for a particular operation and consequently has less impact on sortie generation capability. The limiting factor in sortie development for V/STOL generally becomes the rate at which aircraft can be serviced.

Approach

In order to compare the CTOL and V/STOL operating from a large deck with all the deck constraints considered, a model was developed to predict sorties. Equations were generated to systematically quantify all ship interface operations (such as launch, recovery, aircraft handling, and servicing) in terms of time required and numbers of aircraft and crews available. The assumptions made are consistent with those used in current Navy studies and realistically represent known carrier operations.

Assumptions

1) The mission role considered for comparison is "power projection" against a designated land-based target. The operating period (OP) is 12 h accomplished during daylight Visual Flight Rules (VFR) conditions. The last launch in the operating period must have its mission complete prior to the end of the 12-h period. Final recovery, respot and servicing may be conducted after this period.

2) Launch rate ($\dot{L}$)

a) CTOL: Four catapults are used and always available. Each catapult can launch an aircraft every 2 min. Therefore the overall launch rate is ½ min per launch.

b) V/STOL: Two bow STO runways are used. An aircraft can take off from each runway every minute. Therefore the overall rate is ½ min per launch.

3) Postlaunch time (PL)

a) CTOL: Two minutes are provided to allow for clearing of all catapult launch hardware in order to prepare the deck for follow-on recoveries in the waist catapult area and parking on the bow.

b) V/STOL: No time is required. STO launches are conducted from the bow only. Since this area is not required as an interim parking zone prior to respot to the prelaunch parking position (as with CTOL), there is no requirement for clearance of any launch associated deck hardware.

4) Recovery rate ($\dot{R}$)

a) CTOL: Every minute one aircraft is recovered. Recovery is accomplished with conventional arresting gear which is always available. Missed arrestments (bolters) are not considered.

b) V/STOL: Every ½ min one aircraft is recovered.

Recovery is accomplished in the vertical mode using one of the four landing pads available.

5) Respot rate ($\dot{R}S$)

a) CTOL: Six towing crews (TC) and tractors are available. Each crew requires 9 min per recovered aircraft to convert the deck from the post recovery to the prelaunch condition. The last aircraft in a recovery taxies directly to its prelaunch position.

b) V/STOL: Six towing crews (TC) and tractors are available. Each crew requires 4 min to respot one aircraft. Following a landing each aircraft taxies under its own power to a spot near its prelaunch position. At this point 2 min is required for hookup to the tow tractor, 1 min for aircraft positioning, and 1 min for disconnect to complete the 4-min respot evolution.

6) Servicing rate ($\dot{S}$): For both CTOL and V/STOL 12 weapons crews (WC) and 6 fueling crews are available. The servicing evolution, driven by the weapons loading requirement, takes 30 min per aircraft per crew. In both cases servicing begins 4 min after the first recovery. In the case of CTOL, servicing continues up until the start of respot. Thereafter it continues on a not-to-interfere basis with respot. In the case of V/STOL, respot begins immediately after recovery (no interim parking step required as with CTOL) and as such does not interrupt the servicing cycle.

7) Manning time (MA): For both CTOL and V/STOL, manning time, including all prelaunch checks, is 10 min.

8) Aircraft cruise performance: For both CTOL and V/STOL best cruise altitude is 40,000-45,000 ft at a velocity (Vc) of 0.8 Mach or 460 knots.

9) Aircraft mission profile: For both CTOL and V/STOL the total aircraft mission time (MI) includes a time of 14 min (2 min for takeoff, 2 min for formation, 5 min for combat, and 5 min for landing) plus the cruise out and back times at Vc.

Whenever assumptions are made, there is always an element of doubt. The assumptions noted were, in general, made to give the benefit of the doubt to CTOL. Assumptions 2 and 4, in particular, illustrate an advantage that has been given to the CTOL operation in the calculation of sorties. The CTOL launch and recovery rates are believed to be optimistic from the standpoint of the cycle times presented. This is because a 100% availability of the rather complex catapult and arresting gear machinery must be maintained in order to sustain the noted rates. On the other hand, the rates presented for V/STOL are considered realistic in that launch and recovery operations for the most part are independent of any large-scale electromechanical equipment. Similar advantages may also be found in the assumption of a zero bolter rate for CTOL and the effect of unscheduled flight incidents on sortie generation.

Derivation of Equations

CTOL

Flight deck operations for a CTOL airwing are efficient when the launch evolution proceeds in a cyclic fashion. This means that at repeating intervals of time constant size air groups are launched. The time from launch to launch, including recovery, respot, servicing, and manning never varies throughout the day. Launch operations conducted in other than constant length cycles produce operational inefficiencies that reduce sorties. In a cyclic operation the launch interval is dependent on the number of aircraft in the launch groups and the mission time. Optimization occurs, that is total sorties within the operating period are at a maximum, when the launch intervals are chosen such that no idle deck time exists from the start of the second launch to the completion of respot on the next to last launch. This is further qualified by requiring that launch, recovery, and respot be conducted separately, thus precluding the development of a foul deck situation. Figure 5 presents a hypothetical CTOL flight deck air operations plan which has been optimized.

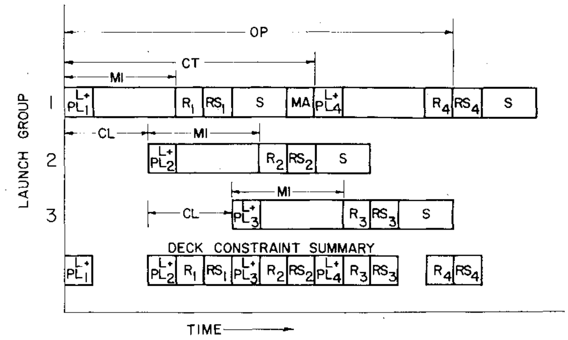

Fig. 5 Optimized CTOL flight deck air operation plan.

Figure 5 shows that the mission time for any launch group encompasses the launch and postlaunch times for two groups and the recovery and respot times for a single group. Note that before the first aircraft in group 2 can complete its mission (MI), the remainder of group 2's aircraft must be launched (L_2), the deck must be made ready (PL_2) for recovery of group 1's aircraft (R_1), launch group 1 must be respotted (RS_1), and finally, launch and postlaunch for group 3 ($L_3 + PL_3$) must be conducted. If the sum of these separate deck functions were to exceed the mission time (MI), launch 3 would have to be aborted in order to allow the remainder of the launch schedule to proceed as planned. Because of this, sorties would be lost. If the mission time exceeds the time required for these separate deck functions, idle time is built into the air operations plan. Again, sorties would be lost. Optimization, as shown in Fig. 5, occurs only when neither a conflict or idle time exists between these separate deck functions. That is, mission time is exactly equal to their sum. Expressing mission time in terms of the noted deck constraints, we get, for the optimized deck cycle

$$\mathrm{MI} = R + \mathrm{RS} + 2(L + \mathrm{PL}) \tag{1}$$

The right-hand side of Eq. (1), excepting the constant PL, may be expressed in terms of the number of aircraft in a launch (X), or

$$R = \dot{R}X$$

$$\mathrm{RS} = \dot{\mathrm{R}}\mathrm{S}\left[\frac{X-1}{\mathrm{TC}}\right]^{\uparrow\ddagger}$$

$$L = \dot{L}X$$

and

$$PL = 2$$

Substituting for R, RS, L, and TC with the information presented in the assumptions and combining terms we get

$$\mathrm{MI} = 4 + 2X + 9\left[\frac{X-1}{6}\right]^{\uparrow} \tag{2}$$

Equation (2) shows that for any launch size (X) an optimum mission time exists. Conversely, it also shows that mission time determines the number of aircraft that a launch can accommodate without creating a foul deck situation.

Thus far we have expressed the optimum deck cycle in terms of units of time. The mission range (RM) associated with any deck cycle time is a function of the mission profile and the aircraft cruise performance. Summing mission times for each leg of the profile as described in assumption 9 we get

$$\mathrm{MI} = 14 + 2\left[\frac{\mathrm{RM}}{\mathrm{Vc}}\right]$$

‡[ ]↑denotes raise to the next whole integer.

Substituting for Vc with the information presented in assumption 8 and adding the appropriate conversion factor for knots (nautical miles per hour) to nautical miles per minute, we get

$$\mathrm{MI} = 14 + 2\left[\frac{\mathrm{RM}(60)}{460}\right]$$

Solving for RM we get,

$$\mathrm{RM} = 3.83\mathrm{MI} - 53.6 \tag{3}$$

Having described the optimum deck cycle, mission time, launch size, and mission range the next logical step is to determine how often the cycle may be repeated and ultimately the number of sorties generated. The total number of launches (N) that can be conducted is simply the number of launch cycles (CL) that can be fit within the operating period (OP). Reference to Fig. 5 shows that

$$\mathrm{CL} = \mathrm{MI} - (L + \mathrm{PL})$$

With the further qualification that the mission time for the last launch be completed within the designated operating period, we get

$$N = \left[\frac{\mathrm{OP} - \mathrm{MI}}{\mathrm{CL}}\right]^{I} \tag{4}$$

The number of sorties generated (S_N) then becomes the product of the number of launches (N) and the number of aircraft in a launch (X), or

$$S_N = NX \tag{5}$$

The number of aircraft required to support the optimized deck cycle is a function of the turnaround cycle (CT), the launch cycle (CL), and the launch size (X).

By definition,

$$\mathrm{CT} = \mathrm{MI} + R + \mathrm{RS} + S + \mathrm{MA} \tag{6}$$

with

$$S = \dot{S}\left[\frac{X}{\mathrm{WC}}\right]^{I} \qquad \mathrm{MA} = 10$$

Reference to Fig. 5 shows that during the course of launch group 1's turnaround cycle (CT), the deck allows two additional launches to be conducted. In order to conduct these launches two additional sets of aircraft are needed. It can be seen that the number of sets required is simply the number of launch cycles (CL) that can be fit within the turnaround cycle (CT). Accounting for the launch size (X), the equation for aircraft required becomes,

$$X_R = \left[\frac{\mathrm{CT}}{\mathrm{CL}}\right]^{I} X \tag{7}$$

V/STOL

Like CTOL, flight deck operations for V/STOL are optimized for maximum sortie generation when launches are conducted in a repeating constant length cycle. Unlike CTOL, however, in which the launch cycle is driven by the requirement for separation of launch, recovery, and respot, V/STOL is capable of conducting these operations simultaneously. The driver for V/STOL then becomes the rate at which aircraft can be serviced. Optimization is achieved when no idle time occurs between servicing cycles for successive launches. A continuous stream of servicing time should exist from the servicing of the first launch group's aircraft to that of the last group. Figure 6 presents a hypothetical V/STOL flight deck air operations plan which has been optimized.

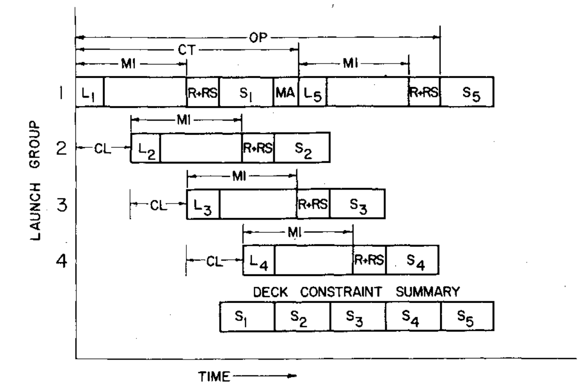

Fig. 6 Optimized V/STOL flight deck air operations plan.

It can be seen here that the launch interval (CL) is exactly equal to the service cycle interval (S). Like CTOL, the service cycle interval is dependent on the number of servicing crews (WC), the servicing rate ($\dot{S}$), and the number of aircraft in the launch (X). The launch interval (CL) equation then becomes

$$\mathrm{CL} = \dot{S}\left[\frac{X}{\mathrm{WC}}\right]^{I} = S \tag{8}$$

Again like CTOL, the number of launches (N) that can be conducted within the operating period is equal to the number of launch cycles (CL) that can be fit into the operating period (OP).

As before,

$$N = \left[\frac{\mathrm{OP} - \mathrm{MI}}{\mathrm{CL}}\right]^{I} \tag{4a}$$

Because aircraft cruise performance and mission profile have been assumed equal for CTOL and V/STOL, mission time (MI) and range (RM) are also equal. As with CTOL,

$$\mathrm{MI} = 14 + 0.261\mathrm{RM} \tag{3a}$$

The total number of sorties generated in the operating period is again, as with CTOL, the product of the number of launches (N) and the number of aircraft per launch (X), or

$$S_N = NX \tag{5a}$$

Reference to Fig. 6 shows that the equation for determining the number of aircraft required to support the optimized deck cycle (X_R) also takes the same form as the CTOL equation, or,

$$X_R = \left[\frac{\mathrm{CT}}{\mathrm{CL}}\right]^{I} X \tag{7a}$$

The launch cycle (CL) has already been defined in Eq. (8). The turnaround cycle (CT) equation also takes the same form as that of CTOL, or,.

$$\mathrm{CT} = \mathrm{MI} + R + \mathrm{RS} + S + \mathrm{MA} \tag{6a}$$

Here MI, and S are as previously defined for V/STOL in Eqs. (3a) and (8), MA, as with CTOL, is 10 min (assumption 7), and

$$R = \dot{R}X$$

and

$$\mathrm{RS} = 5$$

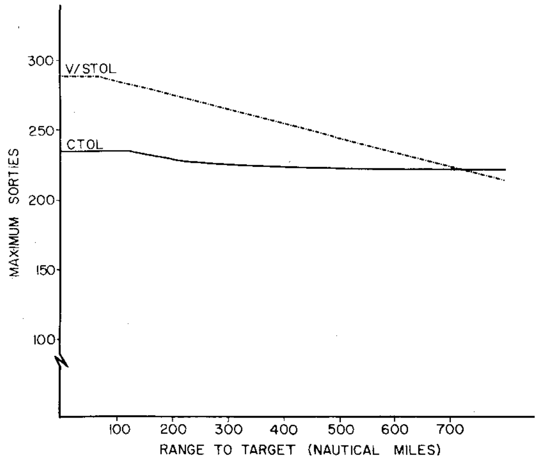

Fig. 7 Maximum sorties unlimited aircraft—CTOL vs V/STOL.

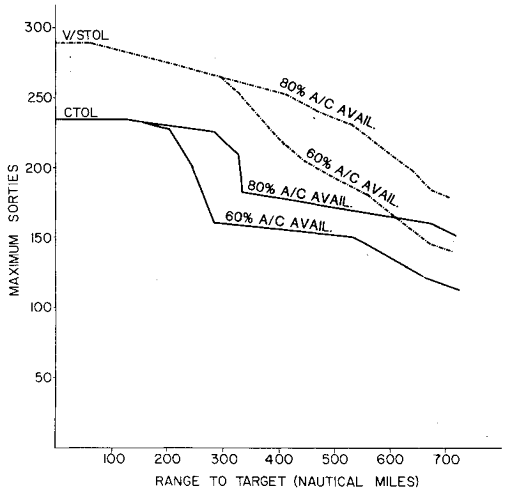

Fig. 8 Maximum sorties equal size airwing—CTOL vs V/STOL (100 aircraft).

for the special case of 12 weapons crews, 6 tow crews, and a respot rate of 4 min per aircraft per crew (assumptions 5 and 6).

Results

The equations developed in the Approach were used to generate the MOE data presented in Figs. 7-14. Detailed explanations follow.

Maximum Sorties vs Range for Unlimited Aircraft

In order to demonstrate the extent of influence the deck constraints have on sorties, the simplified case removing the real world constraints of limited aircraft with limited availability was calculated. Figure 7 illustrates this case. It can be seen that the deck constraints limit the maximum number of sorties for both CTOL and V/STOL and that, in general, the maximum number of sorties decrease with increased range. For V/STOL, increased range to the target delays the start of the first servicing cycle and hence limits the number of launch cycles that can be accomplished within the operating period.

For CTOL, like V/STOL, increased range to the target limits the number of launch cycles that can be conducted in the operating period. However, unlike V/STOL, which operates most efficiently with a fixed launch size, CTOL can accommodate a greater number of aircraft per launch as the mission range and time increases. This tends to offset any

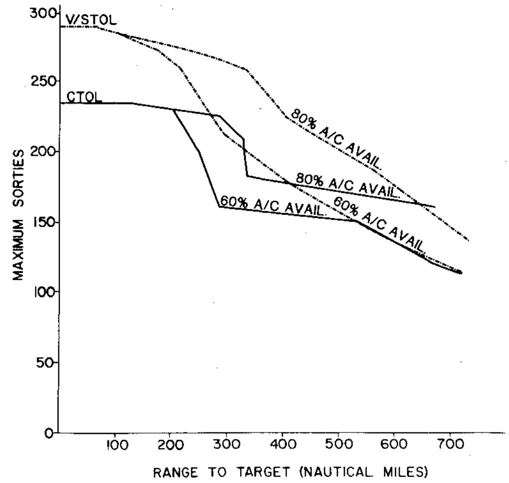

Fig. 9 Maximum sorties equal cost airwing—CTOL vs V/STOL (CTOL: 100 A/C, V/STOL: 79 A/C).

losses in maximum sorties due to decreased launch cycles. The slight decrease in maximum sorties with range is a result of inherent respot inefficiencies with large launch sizes. A large group of aircraft requires slightly more time to respot than an equivalent number of aircraft distributed among smaller launch groups.

Maximum Sorties vs Range for Various Airwings

When considering a finite complement of aircraft and limited availability sorties are further reduced beyond the levels set by the flight deck operational constraints shown in Fig. 7. In order to illustrate this effect, comparisons were made with a baseline CTOL airwing of 100 aircraft at 60 and 80% availability (shown in Figs. 8 and 9). This is a nominal representation of today's large deck carrier airwings with a growth factor in availability incorporated for anticipated advances in reliability and maintainability for future aircraft.

It can be seen that for both CTOL and V/STOL the short-range performance is coincident with the unlimited aircraft performance (Fig. 7). As range increases, more and more aircraft are required. When the 100 aircraft limit for the given availabilities is reached, both sets of curves depart from the unlimited aircraft curves.

CTOL pays this penalty (loss of sorties) sooner than V/STOL. At any given range the turnaround cycle (CT) for CTOL will be greater than that for V/STOL (recovery and respot are inherently longer and therefore CT will be larger). This means that more sets of aircraft are required to maintain maximum sortie generation [see Eq. (7)]. When the airwing sizes are identical the requirement for all available aircraft is reached sooner with CTOL. Sorties diverge from the unlimited aircraft performance at the "break-point" ranges because the deck cycle constraints provide launch slots that cannot be filled simply because aircraft are not available. CTOL shows an immediate steep drop because over the relatively short range shown an inefficient use of respot crews and the loss of a launch cycle occurs along with the ever-increasing deficit of aircraft for available launch slots. Thereafter the curve becomes relatively flat. Although range points exist along this curve where respot crew use is inefficient, and launch cycles are lost, their combined negative effect on sortie levels is attenuated for two reasons that are both unique to the CTOL operation and the particular mission range and times shown. First, at the range shown, the mission time has increased to a point that allows a reduction in sets of aircraft required [Eq. (7)]. Secondly, this reduction in sets required provides excess aircraft that are used to increase the size of the launches dictated by the constraints of the deck cycle.

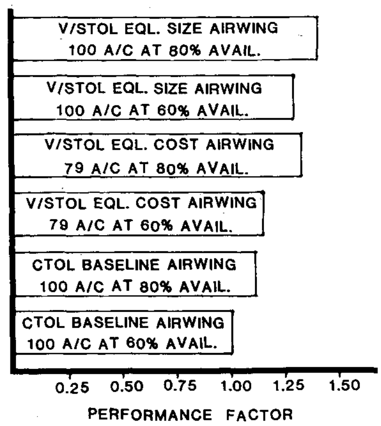

Fig. 10 Performance comparisons.

Equal Size Airwings

The first point of departure from the unlimited aircraft cases shown in Fig. 7 is a comparison of CTOL and V/STOL with 100 aircraft airwings. This is shown in Fig. 8.

V/STOL shows a relatively constant decrease in sorties beyond the range at which the 100 aircraft limit for the given availabilities is reached. The decrease shown is range dependent and is driven by the ever-increasing deficit of aircraft for available launch slots and the continuing loss of launch cycles. Clearly, for equal numbers of aircraft the maximum sorties attained for V/STOL are significantly greater than CTOL.

Equal Cost Airwings

The V/STOL performance was further constrained here by adding the requirement that the airwings be of equal cost. Using the relative V/STOL and CTOL cost trends cited in Ref. 1, the V/STOL airwing was reduced to 79 aircraft as compared to the baseline CTOL airwing of 100 aircraft. This performance is shown in Fig. 9.

The V/STOL performance shown exhibits the same general characteristics of sortie loss with range as the 100 aircraft V/STOL airwing illustrated in Fig. 8, except that the departure from the unlimited aircraft performance occurs at shorter ranges. The net effect except for very short ranges is a lowering of the V/STOL curves with respect to the baseline CTOL curves. It is clear that except for extended ranges (beyond 500 n.mi.), the V/STOL performance is still superior to the CTOL.

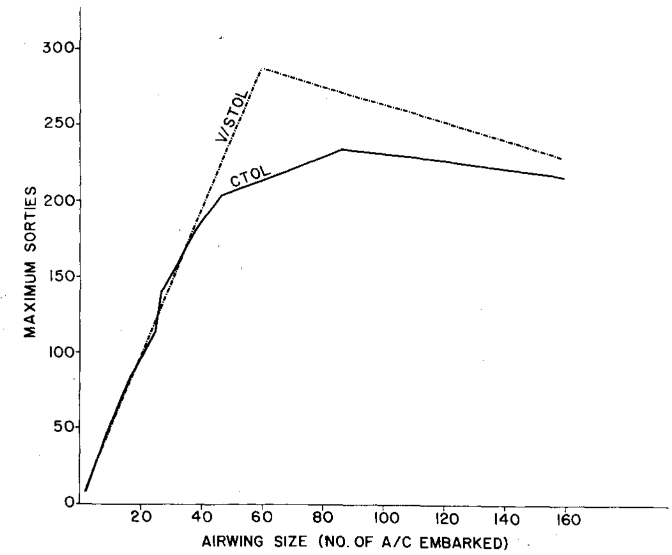

Fig. 11 Maximum sorties vs airwing size at 60% availability—CTOL vs V/STOL.

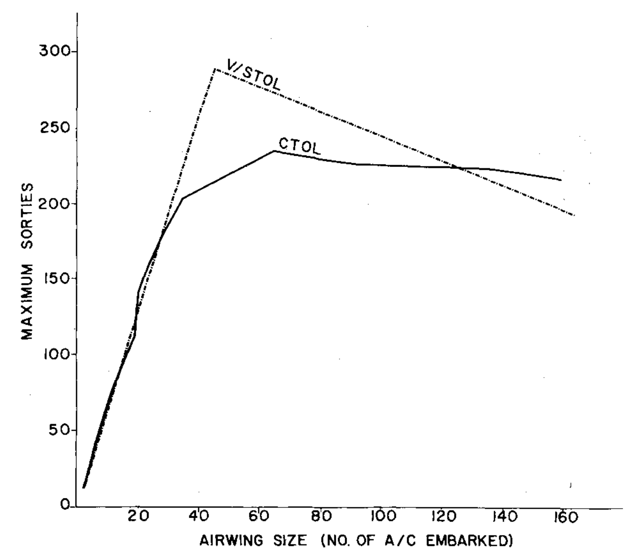

Fig. 12 Maximum sorties vs airwing size at 80% availability—CTOL vs V/STOL.

Performance Comparisons

Thus far, mission effectiveness has been measured by comparing maximum sorties as a function of range to target. Figure 10 summarizes these results using the integration of sorties with range (sortie miles) as the measure of mission performance. An equal weighting of the various ranges is implicit. CTOL performance with 100 aircraft at 60% availability has been set equal to unity and compared to the higher availability CTOL and all the V/STOL airwings.

The results show superior performance for the V/STOL airwings. Comparing alternatives in Fig. 10, it can be seen that V/STOL 1) achieves 15% better performance at 60% availability and 32% better performance at 80% availability for the *same* dollars, and 2) achieves 30% better performance at 60% availability and 41% better performance at 80% availability for 27% more dollars.

Airwing Size Considerations

To this point, the effect of deck constraints and aircraft availability on mission performance has been shown for a limited number of key V/STOL airwings. All the comparisons thus far have been based upon a single baseline condition of the CTOL 100 aircraft airwing. Figures 11-14 show performance comparisons for variations in airwing size.

Maximum Sorties vs Airwing Size

Figures 11 and 12 consider maximum sorties as the measure of performance. It can be seen that for small airwing sizes the CTOL and V/STOL maximum sorties are nearly equal, for intermediate size airwings V/STOL is clearly superior, and for very large airwings the curves converge. Two apparently unexpected results may be observed here. First, for both small and large size airwings, the CTOL and V/STOL are similar. Second, for both CTOL and V/STOL, once the maximum sortie condition has been reached, continued growth of the airwing size results in fewer sorties. The explanation for both of these observed conditions lies in consideration of the range parameter. Sorties alone provide only a part of the overall performance picture. Depending on its mission task, how far an aircraft may go is also important. Again, it must be pointed out that if maximum sorties are to be generated, the operational constraints of the deck cycle and not only the

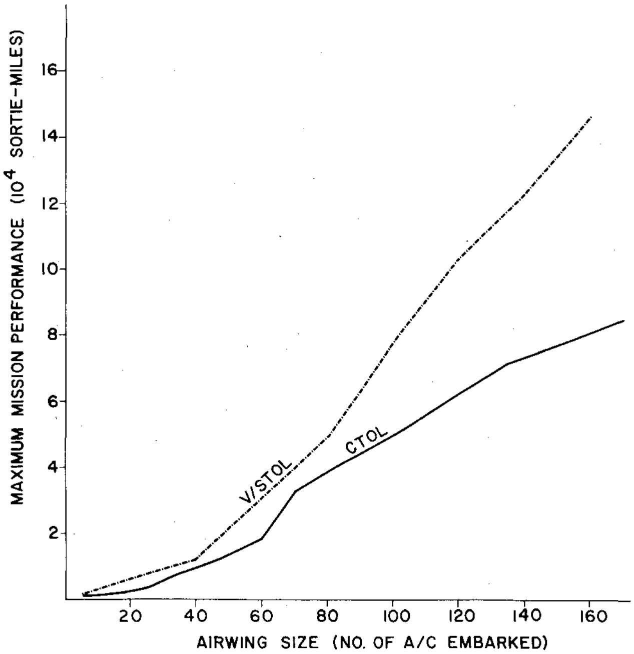

Fig. 13 Maximum mission performance vs airwing size at maximum sorties at 60% availability—CTOL vs V/STOL.

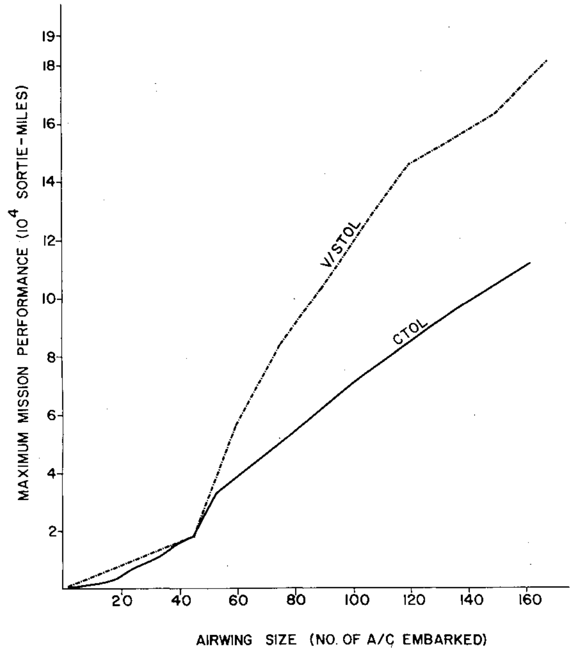

Fig. 14 Maximum mission performance vs airwing size at maximum sorties at 80% availability—CTOL vs V/STOL.

capability of the aircraft will dictate how far the aircraft may go. Even though maximum sorties for CTOL and V/STOL are similar for small and large airwings, range to target is not. The more efficient deck cycle operation for V/STOL allows the aircraft to fly farther than CTOL at these maximum sortie conditions. Airwing size is also driven by the range parameter. When range increases the turnaround cycle (CT) increases and results in more sets of aircraft being needed to support maximum sortie generation. That is, more aircraft are needed if you want to go farther. However, in going farther, the deck cycle takes away launch opportunities and therefore sorties. Thus, beyond their peak condition, both CTOL and V/STOL lose sorties as the airwing size increases. Figures 11 and 12 also show that increased aircraft availability has no effect on the level of maximum sorties, although the number of aircraft needed to generate the maximum condition is reduced. Again, it becomes clear how powerful the constraints of the deck cycle are. That is, independent of the number of available aircraft a maximum condition exists that cannot be exceeded. It may also be noted that today's large deck carrier airwings operate with approximately 85 to 95 aircraft and maintain about 60% availability. Reference to Fig. 11 indicates that considering maximum sorties only as the measure of performance, today's airwing size is at an optimum.

Maximum Mission Performance vs Airwing Size

As previously stated, sorties alone do not provide a complete measure of mission performance. Range must also be considered. In Figs. 13 and 14 range has been incorporated into mission performance by plotting the product of maximum sorties and the maximum range at which they can be conducted vs the required airwing size.

It can be seen here that the V/STOL operation is superior at all airwing sizes and exhibits a general trend of divergence from the CTOL performance as the airwing size increases. It should be clear that the V/STOL deck cycle allows the aircraft to fly farther than the CTOL cycle will allow when maximizing sorties for any given airwing size.

Concluding Remarks

Comparisons between CTOL and V/STOL have been made from equal size and cost airwings considering the deck constraints from which they must operate. The basic conclusion that has been reached is that V/STOL is superior for the MOE studied in a power projection role.

Given equal cost, V/STOL provides better mission performance with less aircraft.

Given equal numbers of aircraft, V/STOL provides substantially better mission performance.

V/STOL can provide equal or better performance with many less aircraft. The implications of this result are far reaching. The air platform from which V/STOL operates can be smaller than today's large deck carrier. The support costs, including logistics, maintenance, manpower, etc., are reduced for both the aircraft and ship.

Today's CTOL carrier airwing has reached a near optimum level of mission performance. That is, no increase in airwing size or availability will result in increased maximum sorties attainable. However, future improvements in sortie generation capabilities are possible. The addition of respot crews could reduce the total respot time and make more time available for launch and recovery operations. However, the improvement would be relatively small and would not relieve CTOL of its primary deck operations constraint; that is, the separate conduct of launch, recovery, and respot. A greater improvement in performance would require either a significant change in the way aircraft are recovered and launched or a redesign of the CTOL flight deck (increased area) to provide space for simultaneous launch, recovery, and respot.

V/STOL, on the other hand, has been shown to be limited by the servicing cycle only. Here significant increases in sortie generation capability are attainable simply by increasing the number of servicing crews.

Reference

[1]Chambers, C.E., Perkins, R.G., and Tyler, J.T., "An Assessment of Sea Based Air Master Study", AIAA Paper 80-1820, Aug. 1980.