AIAA 79-1283R

Impact of Mission Requirements on V/STOL Propulsion Concept Selection

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In recent years a wide variety of V/STOL propulsion concepts has been advanced as a way to perform vertical takeoff and landing. This paper presents results of a recent Vought study which examines four supersonic V/STOL propulsion concepts. Aircraft sized to common design criteria and missions are compared for three lift/cruise concepts and one lift plus lift/cruise concept. Both fighter escort and deck-launched intercept mission requirements are considered. Sizing constraints include acceleration capability, sustained load factor, ceiling, maximum speed, specific excess power, vertical takeoff thrust-to-weight, and engine-out thrust-to-weight. Results emphasize the importance of well-founded operational requirements. An engine-out vertical landing requirement is shown to be an important design driver. Each propulsion system concept is sized by different critical constraints, and each concept demonstrates a different sensitivity to variations in these requirements.

Nomenclature

A/B	= afterburning
ACCEL	= acceleration
ASAP	= Aircraft Synthesis Analysis Program
BCAV	= best cruise altitude and velocity
BOT	= burner outlet temperature
BPR	= bypass ratio
CRT	= combat rated thrust
DLI	= deck-launched intercept mission
EOL	= engine-out landing
FE	= fighter escort mission
IOC	= initial operational capability
L + L/C	= lift plus lift/cruise
M	= Mach number
MRT	= military rated thrust
Nz	= maneuver load factor
Ps	= specific excess power
RFB	= remote fan burning
SEP	= specific excess power
SL	= sea level
STO	= short takeoff
TF	= tandem fan
TOGW	= takeoff gross weight
T/W	= thrust-to-weight ratio
VATOL	= vertical attitude takeoff and landing
VL	= vertical landing
VTO	= vertical takeoff

Introduction

THIS paper describes the results of recent supersonic V/STOL studies at Vought. Four V/STOL concepts are investigated to satisfy postulated supersonic V/STOL requirements. These concepts include VATOL, lift + lift/cruise, remote fan burning, and a variable cycle tandem fan. A significant finding of the study is the impact which operational requirements can have on each of the V/STOL concepts studied. Some concepts are affected dramatically by operational requirements which have little impact on other concepts. The sensitivity of each of the concepts to key operational requirements is identified and emphasizes the importance of having well-founded requirements.

Presented as Paper 79-1283 at the AIAA/SAE/ASME 15th Joint Propulsion Conference, Las Vegas, Nev., June 18-20, 1979; submitted Aug. 2, 1979; revision received March 3, 1980.

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Design Requirements

Vought has postulated an operational concept for supersonic V/STOL fighter aircraft that includes missions, operational requirements, missiles, and technology projections consistent with a mid-1990 IOC.

The two design missions illustrated in Fig. 1 are both considered in aircraft sizing and weighted equally. They are: 1) a 150 n.mi. radius supersonic DLI mission, and 2) a 400 n.mi. radius subsonic FE mission. The sizing or critical mission is concept dependent. Some concepts do better on the supersonic mission; others excel on the subsonic mission. Therefore, in order to ensure valid concept comparisons, all concepts are initially sized to meet or exceed all requirements of both missions.

The mission loading postulated for both DLI and FE missions is two advanced AIM-7 Sparrow missiles plus two advanced AIM-54 Phoenix missiles. Vought estimates of weight, size, and capability advances for these missiles are incorporated. Missiles are retained throughout the missions.

Operational constraints have been selected that reflect an extension of current high-performance fighter trends. Key performance objectives include:

1) Trimmed flight vertical takeoff $T/W \geq 1.05$.
2) Trimmed flight vertical landing $T/W \geq 1.05$.
3) Trimmed flight engine-out vertical landing $T/W \geq 1.03$.
4) Maximum Mach number ≥ 2.2.
5) $Ps \geq 1000$ ft/s at 1 g, Mach 0.9, 10,000 ft.
6) Acceleration time ≤ 60 s from Mach 0.9 to 1.6 at 36,000 ft.
7) $Nz \geq 6.0\,g$ at Mach 0.65, 10,000 ft.
8) Combat ceiling $\geq 60{,}000$ ft.

These objectives are representative of those used in similar studies, and reflect nominal goals for a supersonic V/STOL fighter.[1,2] Sequential relaxation or elimination of these constraints will be shown to have dramatic effects on concept selection.

Vought technology projections for the mid-1990s time frame are used to establish materials mix, systems and equipment weights, propulsion cycle parameters, control requirements, etc.[3-9] All designs reflect comparable levels of technology.

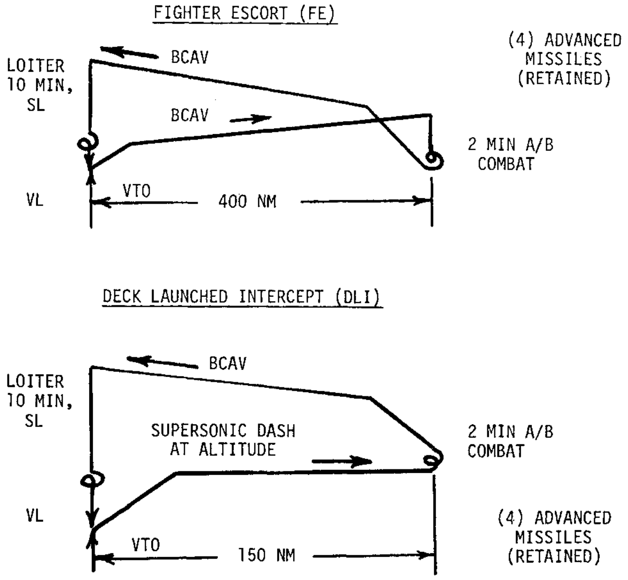

Fig. 1 Design mission profiles.

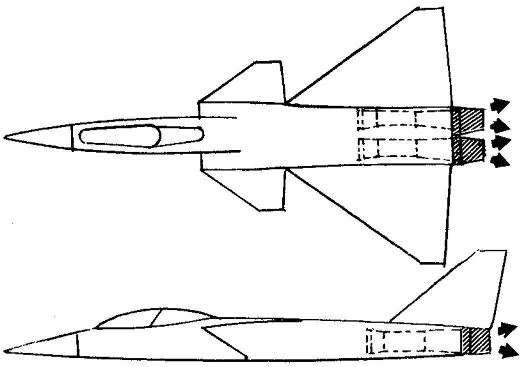

Fig. 2 VATOL configuration.

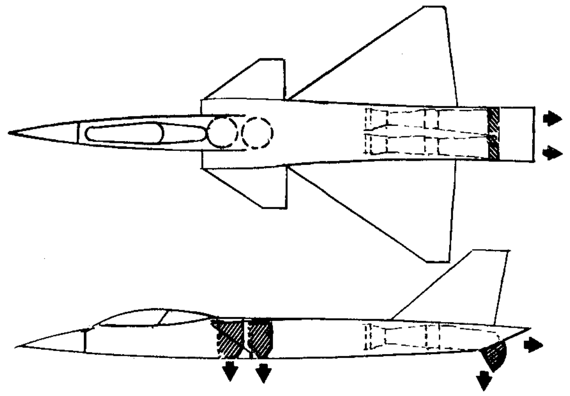

Fig. 3 Lift + lift/cruise configuration.

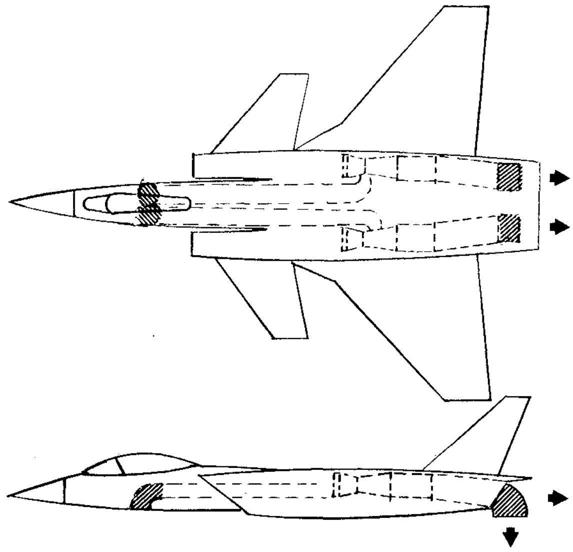

Fig. 4 Remote fan burning configuration.

Concept Description

Four V/STOL aircraft designs were sized to meet the specified weapon system requirements. These included VATOL, lift + lift/cruise, remote fan burning, and a variable cycle tandem fan. All are twin-cruise-engine designs and all feature canards. Details of each of the concepts are summarized below.

VATOL

The VATOL aircraft (Fig. 2) is powered by two conventional afterburning turbofan engines. Takeoff and recovery in the VTO mode is accomplished from a pivoting platform which is engaged by a trap device on the nose gear of the aircraft. By placing this platform at the deck edge the engine exhausts are directed overboard, allowing any degree of afterburning up to maximum to be utilized. The engines installed in the VATOL aircraft are BPR = 1.0 mixed-flow turbofans with an overall pressure ratio of 24 and a maximum BOT of 2800°F. Nozzles are gimbaled 15 deg to provide attitude control during vertical operations.

Lift Plus Lift/Cruise

The L + L/C aircraft (Fig. 3) has two advanced technology lift turbojet engines and two lift/cruise turbofans with deflected nozzles. The lift engines provide 10% continuous bleed and 12.5% intermittent bleed for aircraft control during vertical operations. Thrust-to-weight ratio of the lift engines is 20:1 uninstalled and they provide 60% of the lift thrust at VTO. Maximum exhaust temperature of the lift engines is 2000°F. The lift/cruise engines are conventional mixed-flow turbofans with BPR = 1.0, an overall pressure ratio of 24, and a maximum BOT of 2800°F. Exhaust temperature of the lift/cruise engine in the vertical operating mode is 1000°F since it is sized by in-flight requirements and throttled in the VTO mode.

Remote Fan Burning

The remote fan burning aircraft (Fig. 4) is a "four-poster" design which ducts a large part of the fan air forward and burns it to a temperature of 2800°F before directing it downward through a convergent nozzle. The fan bleed air provides about 35% of the total thrust. The lift/cruise engine has a BPR = 1.25 and an overall pressure ratio of 20. The mixed-flow exhaust is burned to 2800°F before being deflected in the nozzle.

Tandem Fan

The variable cycle tandem fan (Fig. 5) is a derivative of Vought's subsonic tandem fan system designed to minimize frontal area and to match VTO and cruise operating conditions more effectively. This "four-poster" system has four fans with the forward fans providing 60% of the total vertical thrust. The aft fans supercharge the cores during vertical operations and provide 40% of the thrust. During cruise operations, both the forward and aft fans supercharge the core. A simple cross shaft connects the two fan sets so that all four fans can be powered by the remaining engine when one engine becomes inoperative. In this configuration the overall pressure ratio is 24 and the maximum BOT is 2800°F. All exhaust streams are burned to 1200°F in the VTO operating mode and 2000°F at engine-out. Control forces during vertical operations are provided with variable inlet guide vanes and nozzle deflection.

Design Synthesis

Configuration synthesis has been performed using Vought's Aircraft Synthesis Program (ASAP). ASAP combines Vought fighter/attack aircraft aerodynamic, performance, weight, propulsion, cost, and design analyses in one digital computer routine to "size" the aircraft to user-specified mission and operational requirements. Interactive computer graphics provide a man-machine interface which permits the engineer to generate parametric carpet plots and selectively apply constraints. Figure 6 is a functional diagram of ASAP.[10]

Figure 7 is a typical takeoff gross weight carpet generated via ASAP for the L + L/C concept performing the DLI mission. The point design aircraft (numbered 1) that meets all design requirements at a minimum takeoff gross weight is established by the intersection of acceleration time and combat ceiling requirements. Point designs 2-5 represent the impact of sequential relaxation of design requirements. (L + L/C point designs 1-5 are tabulated in Table 6.)

Point Design Definition

Critical aircraft sizing criteria for fully compliant designs are summarized in Table 1. The lift/cruise engine of the

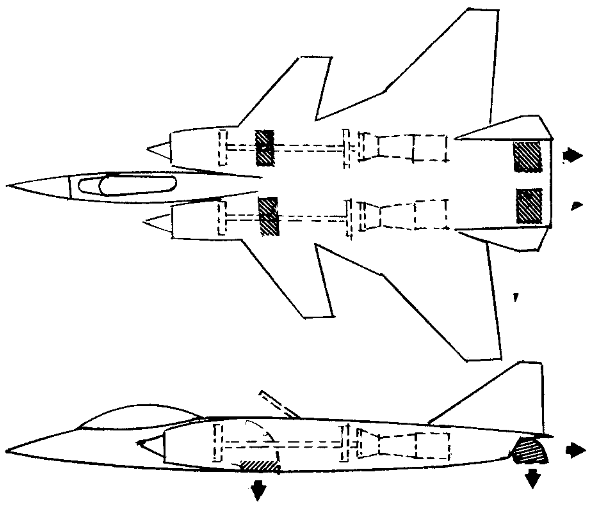

Fig. 5 Tandem fan configuration.

Table 1 Critical aircraft sizing criteria

Configuration	Propulsion system	Wing area	Critical mission
VATOL	Engine-out VL	Maneuver Nz	FE
L + L/C	Accel time	Ceiling	DLI
Remote fan burning	Engine-out VL	Maneuver Nz	FE
Tandem fan	VTO	Maneuver Nz	FE

L + L/C concept is sized by in-flight performance requirements because it has two lift engines to assist it in vertical flight. VATOL and remote fan burning propulsion systems are sized by engine-out vertical landing, because in these systems loss of an engine results in loss of half the available thrust. The tandem fan propulsion system is sized at VTO; engine-out is not critical due to the ability of the remaining engine to drive all four fans.

Wing areas of all study concepts except L + L/C are sized by sustained maneuver load factor. Combat ceiling can be improved by increasing thrust or wing area. The L + L/C wing is sized by ceiling because its cruise propulsion system is not "oversized" by vertical flight requirements.

Each concept is affected differently by the conflicting requirements of the supersonic DLI and subsonic FE missions. Since vertical T/W requirements size the propulsion systems of the tandem fan, remote fan burning, and VATOL, these concepts have large cruise engines which provide efficient supersonic performance for DLI. These engines are oversized for subsonic FE operations; thus the FE mission becomes critical.

As previously noted, the cruise engine of the L + L/C concept is sized by in-flight requirements (i.e., acceleration time and combat ceiling) so it is smaller relative to concepts sized by vertical T/W requirements. These smaller engines are sufficiently fuel-efficient on the subsonic FE mission so that DLI requirements size L + L/C designs.

Point designs representing each of the four study concepts are summarized in Table 2. Propulsion system simplicity makes the VATOL aircraft significantly lighter than the other concepts. However, required shipboard handling equipment reduces its operational attractiveness, and makes the "flat riser" approaches more competitive.

Table 3 summarizes the mission capabilities of the various concepts. The typical impact on DLI mission capability of reducing the FE radius of the three VATOL designs is illustrated in Fig. 8.

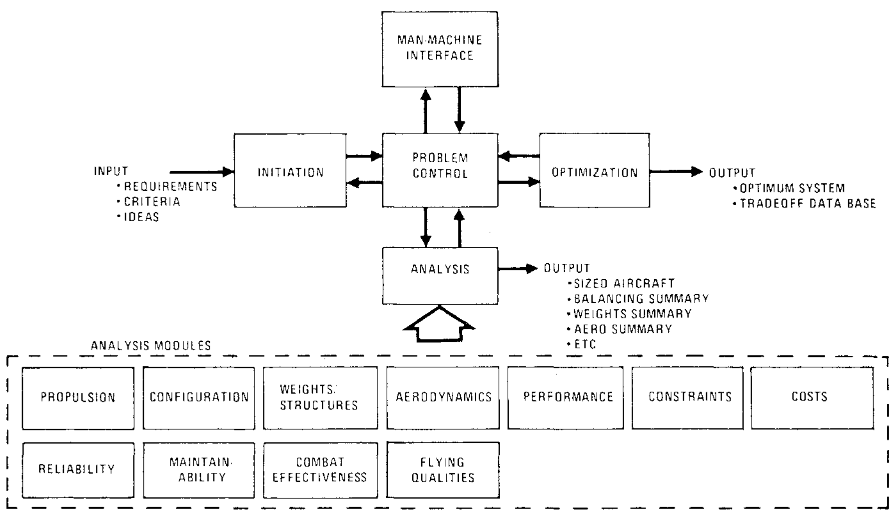

Fig. 6 Functional diagram of aircraft synthesis analysis program (ASAP).

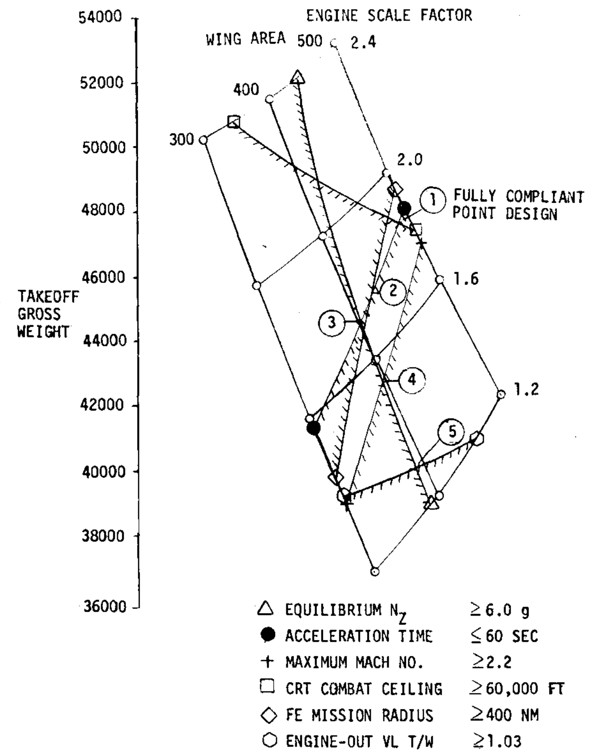

Fig. 7 Sizing carpet for L + L/C concept.

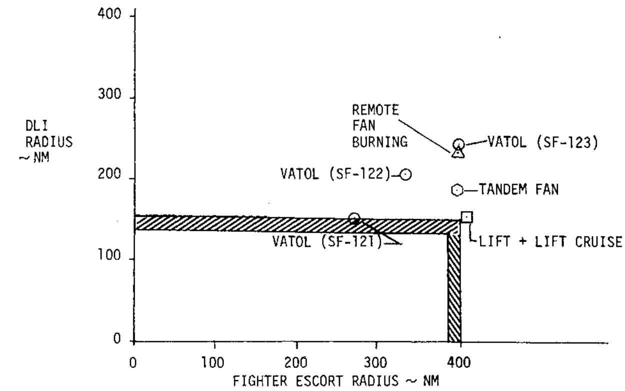

Fig. 8 Mission impact on aircraft sizing.

Tables 4 and 5 show fuel utilization on the FE and DLI missions, respectively. L + L/C is penalized by having additional fuel allowances required for lift engine operation at takeoff and landing, but excels at combat requirements defined at maximum thrust at a given condition because its cruise engines are smaller. Mission definition inequities such as these tend to cancel one another and should not affect concept comparisons. However, significant excursions in speed and/or radius requirements must be examined for their impact on individual concepts.

Sequential Relaxation of Requirements

VTOL, fighter performance, and design mission requirements interact differently to define point designs for each concept. Table 6 shows progressive reduction in weight/size of VATOL, L + L/C, remote fan burning, and tandem fan designs as requirements are sequentially relaxed. Comparison is difficult because the sequence of "criticality" is unique to each individual concept.

To simplify comparison, an order of requirement relaxation is postulated in Table 7 in which requirements have been judgmentally ordered. Most proposed V/STOL operational scenarios include STO operation. The VTO requirement is therefore relaxed to STO first. Engine-out vertical landing can be replaced by diverting to a land base or to a ship with a barricade or, in the extreme, by ditching. Thus, engine-out VL is relaxed second. In-flight fighter performance and mission are judged most important so they are relaxed last. As each requirement is relaxed, designs become sized by the next most critical constraint. If the

Table 2 Point design summary

Item	Requirement	VATOL	L + L/C	Remote fan burning	Tandem fan
TOGW, lb	...	40,610	47,710	58,470	48,990
Fuel, lb	...	15,870	16,080	21,310	17,140
Zero fuel weight, lb	...	24,740	31,630	37,160	31,850
Takeoff T/W	1.05	1.25	1.56	1.27	1.05[a]
Normal VL T/W	1.05	1.72	2.20	1.73	1.54
Engine-out VL T/W	1.03	1.03[a]	1.23	1.03[a]	1.11
Maximum Mach, 36,000 ft	≥2.2	2.4+	2.28	2.4+	2.4+
$Ps, M=0.9$, 10,000 ft	≥1000	1339	1030	1429	1448[a]
Acceleration time, $M=0.8 \rightarrow 1.6$, 35,000 ft, s	≤60.0	41.6	60.0[a]	38.9	37.7
Nz, $M=0.65$, 10,000 ft	≥6.0	6.0[a]	6.66	6.0[a]	6.0[a]
CRT combat ceiling, ft	≥60,000	61,500	60,000[a]	65,700	63,000
FE radius of action, n. mi.	≥400	400[a]	415	400[a]	400[a]
DLI radius of action, n. mi.	≥150	233	150[a]	232	183

[a] Sizing criteria.

Table 3 Mission impact on aircraft sizing

	Propulsion concepts							
Criteria	L + L/C		Remote fan burning		Tandem fan		VATOL	
DLI, radius of action, n. mi.	150[a]	146	150[a]	232	150[a]	183	150[a]	233
FE, radius of action, n. mi.	415	400[a]	169	400[a]	320	400[a]	278	400[a]
TOGW, lb	47,710	47,520	54,800	58,470	47,500	48,990	38,170	40,610

[a] Sizing criteria.

Table 4 Point design fuel utilization on FE mission

Criteria	VATOL	L + L/C	Remote fan burning	Tandem fan
Warmup and takeoff allowance, %				
Cruise engines	9.9	6.1	15.4	9.4
Lift engines	...	8.3	...	...
Climb and cruise to 400 n.mi. at BCAV, %	28.6	24.5	22.4	23.9
2 min. A/B combat, %	29.7	27.3	35.2	39.2
Climb and cruise back at BCAV, %	22.1	20.0	17.9	18.3
Landing, %				
Cruise engines	4.7	4.0	4.1	4.2
Lift engines	...	4.8	...	...
5% fuel reserve, %	5.0	5.0	5.0	5.0
Total fuel required, lb	15,870	15,840	21,310	17,140
Design mission	Yes	No	Yes	Yes
FE TOGW, lb	40,610	47,460	58,470	48,990

Table 5 Point design fuel utilization on DLI mission

Criteria	VATOL	L + L/C	Remote fan burning	Tandem fan
Warmup and takeoff allowance, %				
Cruise engines	12.3	6.0	18.5	10.3
Lift engines	...	8.2	...	...
Climb and dash to 150 n.mi, in minimum time at specified supersonic speed, %	50.7	53.5	44.7	51.3
2 min. A/B combat, %	18.0	12.3	19.8	22.3
Climb/cruise back at BCAV, %	8.8	6.4	7.0	6.5
Landing, %				
Cruise engines	5.2	4.0	4.9	4.6
Lift engines	...	4.7	...	...
5% fuel reserve, %	5.0	5.0	5.0	5.0
Total fuel required, lb	13,670	16,080	17,680	15,690
Design mission	No	Yes	No	No
DLI TOGW, lb	38,420	47,710	54,840	47,540

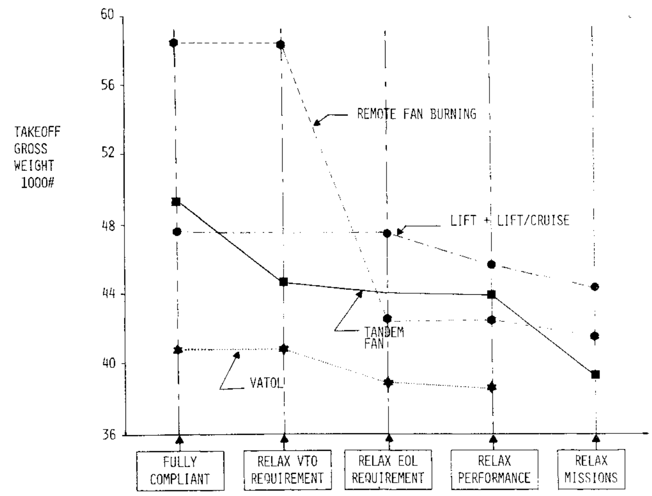

Fig. 9 Summary of requirement relaxation results.

requirement being relaxed is not sizing, the design remains unchanged.

Table 8 and Fig. 9 summarize effects of requirement relaxation in the order postulated above.

The figures show that relaxation of VTO as a requirement reduces tandem fan TOGW by 4520 lb, but has no effect on VATOL, L + L/C, or remote fan burning designs because these concepts are not sized by VTO.

Relaxation of the engine-out vertical landing requirement has no effect on L + L/C, reduces tandem fan TOGW by only 470 lb, reduces VATOL TOGW by 2260 lb, but has the most significant effect on the remote fan burning concept. TOGW is reduced by almost 16,000 lb for this concept if the requirement for engine-out vertical landing is eliminated. This one design ground rule is pivotal with respect to the attractiveness of the remote fan burning concept. Figure 9 shows that remote fan burning goes from the heaviest "flat riser" concept to the lightest when engine-out VL is eliminated.

In our postulated sequence, a relaxation of in-flight performance affects only VATOL and L + L/C. VATOL TOGW is reduced 640 lb if a 1700 ft degradation in combat ceiling is allowed. L + L/C TOGW is reduced 2190 lb for an 800 ft decrease in combat ceiling. Remote fan burning and tandem fan designs are driven by DLI mission requirements. Tandem fan designs have superior in-flight performance because all hardware used to generate vertical thrust is also used in horizontal flight.

Relaxation of alternate mission capability affects the L + L/C and remote fan burning concepts by reducing TOGW by 1080 and 870 lb, respectively. Acceleration time and sustained load factor requirements become critical for both when alternate mission capability has been degraded only 7 n.mi. However, tandem fan TOGW decreases 4900 lb, because DLI radius can be reduced 35 n.mi. before the combat ceiling becomes critical. DLI mission radius becomes critical to VATOL only after all in-flight performance requirements have been relaxed. Therefore, within the ground

Table 6 Aircraft sizing summary

	L + L/C					Remote fan burning					VATOL				Tandem fan			
Criteria	Fully compliant	Relax ceiling	Relax FE	Relax ACCEL	Relax to EOL	Fully compliant	Relax EOL	Relax DLI	Relax ACCEL	Relax max, *M*	Fully compliant	Relax EOL	Relax VTO	Relax ceiling	Fully compliant	Relax VTO	Relax EOL	Relax DLI
TOGW, lb	47,710	45,520	44,450	42,780	40,870	58,470	42,480	41,610	39,500	38,800	40,600	38,580	38,340	37,700	48,990	44,480	44,020	39,120
Wing area, ft^2	489	428	396	391	397	507	425	425	428	429	470	447	444	436	431	415	410	390
Lift engine scale factor	1.40	1.33	1.29	1.17	0.99	–	–	–	–	–	–	–	–	–	–	–	–	–
Cruise engine scale factor	1.86	1.76	1.72	1.55	1.31	2.30	1.40	1.35	1.23	1.19	1.67	1.45	1.42	1.25	1.35	1.15	1.13	0.92
Takeoff T/W	1.56	1.55	1.55	1.45	1.28	1.27	1.06	1.05[a]	1.01	0.99	1.25	1.05	1.03	0.91	1.05[a]	0.99	0.98	0.91
NL T/W	2.20	2.18	2.17	2.05	1.85	1.73	1.39	1.36	1.30	1.28	1.72	1.52	1.49	1.38	1.54	1.43	1.42	1.28
EOL T/W	1.23	1.22	1.21	1.14	1.03[a]	1.03[a]	0.83	0.82	0.78	0.77	1.03[a]	0.94	0.92	0.82	1.11	1.03[a]	1.02	0.92
SEP at M 0.9, 10,000 ft	1030	1026	1025	942	805	1429	1120	1097	1037	1017	1339	1185	1162	1045	1448	1334	1332	1181
Nz at M 0.65, 10,000 ft, g	6.7	6.3	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]	6.0[a]
Accel time, M 0.8→1.6, 35,000 ft, s	60.0[a]	60.0[a]	60.0[a]	67.3	81.6	38.9	58.3	60.0[a]	64.8	66.5	41.6	50.0	51.4	60.0[a]	37.7	42.3	42.7	48.7
Max n. mi. at 36,000 ft	2.28	2.29	2.29	2.20	2.05	2.59	2.29	2.29	2.20[a]	2.18	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
CRT combat ceiling, ft	50,000[a]	59,200	58,700	58,200	57,800	65,700	61,400	61,100	60,300	60,000	61,500	60,200	60,000[a]	58,300	63,000	61,700	61,600	60,000[a]
MRT combat ceiling, ft	49,700	48,800	48,300	47,400	46,100	49,900	47,800	47,700	47,500	47,400	48,600	48,100	48,000	47,400	49,100	48,500	48,300	47,400
FE F/A, n.mi.	415	400[a]	393	439	525	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]	400[a]
DLI radius of action, n.mi.	150[a]	150[a]	150[a]	150[a]	150[a]	232	150[a]	142	123	116	233	199	194	183	183	152	150[a]	115

[a] Sizing criteria.

Table 7 Postulated trade study sequence

Ground rules change	Deisign impact VATOL	L+L/C	Remote fan burning	Tandem fan
Fully compliant designs (VTOL)	Base	Base	Base	Base
Relax VTO requirement	↓	↓	↓	STO/VL operation
Relax engine-out VL requirement	Divert or ditch for engine-out	↓	Divert or ditch for engine-out	Divert or ditch for engine-out
Relax in-flight performance	Combat ceiling missed	Combat ceiling missed	Divert or ditch for engine-out	Divert or ditch for engine-out
Relax alternate mission	Unacceptable compromises to in-flight	Combat ceiling, FE mission missed	Divert or ditch for engine-out, DLI mission	STO/VL operation divert or ditch for engine-out, DLI

Table 8 Summary of requirement relaxation

			Mission, n.mi.		Performance					T/W	
Criteria	Aircraft	TOGW, lb	FE	DLI	*Ps*, ft/s	*Nz*, *g*	ACCEL, s	M_{max}	Ceiling, ft	VTO	EOL
Fully compliant	VATOL	40,600[a]	400	233[a]	1339	6.0	41.6	2.4+[a]	61,500	1.25	1.03
	L+L/C	47,710	415[a]	150	1030	6.7[a]	60.0	2.28	60,000	1.56[a]	1.23[a]
	RFB	58,470	400	232	1429	6.0	38.9	2.4+[a]	65,700[a]	1.27	1.03
	TF	49,000	400	183	1448[a]	6.0	37.7[a]	2.4+[a]	63,000	1.05	1.11
Relax VTO requirement	VATOL	40,600[a]	400	233[a]	1339	6.0	41.6	2.4+[a]	61,500	1.25	1.03
	L+L/C	47,710	415[a]	150	1030	6.7[a]	60.0	2.28	60,000	1.56[a]	1.23[a]
	RFB	58,470	400	232	1429[a]	6.0	38.9[a]	2.4+[a]	65,700[a]	1.27	1.03
	TF	44,480	400	152	1334	6.0	42.3	2.4+[a]	61,700	0.99	1.03
Relax EOL requirement	VATOL	38,340[a]	400	194[a]	1162	6.0	51.4	2.4+[a]	60,000	1.03	0.92
	L+L/C	47,710	415[a]	150	1030	6.7[a]	60.0	2.28	60,000	1.56[a]	1.23[a]
	RFB	42,480	400	150	1120	6.0	58.3	2.29	61,400	1.06	0.83
	TF	44,020	400	150	1332[a]	6.0	42.7[a]	2.4+[a]	61,600[a]	0.98	1.02
Relax performance	VATOL	37,700[a]	400[a]	183[a]	1045	6.0	60.0	2.4+[a]	58,300	0.91	0.82
	L+L/C	45,520	400[a]	150	1026	6.3[a]	60.0	2.29	59,200	1.55[a]	1.22[a]
	RFB	42,480	400[a]	150	1120	6.0	58.3	2.29	61,400	1.06	0.83
	TF	44,020	400[a]	150	1332[a]	6.0	42.7[a]	2.4+[a]	61,600[a]	0.98	1.02
Relax mission	VATOL	–	–	–	–	–	–	–	–	–	–
	L+L/C	44,450	393	150[a]	1025	6.0[a]	60.0	2.29	58,700	1.55[a]	1.21[a]
	RFB	41,610	400[a]	142	1100	6.0[a]	60.0	2.29	61,100[a]	1.05	0.82
	TF	39,120[a]	400[a]	115	1181[a]	6.0[a]	48.7[a]	2.4+[a]	60,000	0.91	0.92

[a] Superior concept.

rules of this study, no sizing criteria remain for VATOL that would yield a realistic design.

A rational comparison sequence has been defined and examined. This is certainly not the only rational order in which the requirements can be relaxed. Rather, this order is chosen as illustrative of relaxation effects on concept selection. Sufficient data are presented to allow the reader to postulate and examine other relaxation sequences.

Conclusions

This study has clearly demonstrated the need for well-founded and prioritized operational requirements early in a program. Arbitrary requirements can result in the elimination of an otherwise promising concept or can impose severe penalties to that concept. The most influential requirement identified was that of a vertical landing with one engine out. If this requirement is replaced by diverting the damaged aircraft to a land base or to a ship with a barricade, the TOGW of the remote fan burning system decreases by 16,000 lb. However, this mode of operation may restrict the flexibility of deploying and using the system since it will be necessary to provide appropriate diversion facilities or, alternately, to accept high operational attrition due to engine failures. Other concepts studied were not significantly affected by the engine-out landing requirement, but were sensitive to other requirements such as VTO and in-flight acceleration. The importance of fixing these requirements at the very beginning of a new program cannot be overstated.

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