

ASPECTS OF CONCEPTUAL AIRCRAFT DESIGN

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Abstract. The paper primarily discusses aspects of conceptual military aircraft design by considering: design phases, design philosophy showing that there has often been little consensus on 'best' design and concludes with a review of JSF development choices.

Keywords. Military aircraft, JSF development.

1. Introduction

One of the most exciting and stimulating aspects of aircraft design is the conceptual phase. This is the starting process that attempts to merge emerging technologies with customer needs to evolve initial requirements. From these the use of historical data (if applicable) can be blended in compliance with contractor design philosophy to perform initial sizing to begin configuration formulation. A competing contractor designing to the same requirements may discover markedly different layouts to perform the same function. The number of configurations considered is inevitably large and along the way many will be found wanting so that perhaps 90 percent will be discarded leaving the rest to be studied in greater depth. Even when the winning concept is decided upon significant changes may be required.

2. Phases of Design

The design phases may be broken down into the three generally recognized areas (across which there will be some overlap): Conceptual, Preliminary and Detail. This paper discusses only conceptual design so it is the first column of Table 1 [1] that needs examination although the times allocated to duration of each of the three phases is, for **major** projects, greatly underestimated and is at least double the values shown. The table is self explanatory apart from two topics, namely RCS which in this context refers to Reaction Control System, and CEM: Computer Electromagnetic (signature) Modelling. The salient point to be made regards the significance of the conceptual design phase: it can determine around eighty percent of the life cycle cost when less than one percent of the programme expenditure has been made.

	Conceptual	Preliminary	Detail
Typical Duration:	6 - 12 Months	12 - 18 Months	24 - 42 Months
Objective:	<ul style="list-style-type: none"> Establish Configuration Size Vehicle and Prop. System Verify Concept Feasibility Produce First Cost/Perform Est. Balance Requirements 	<ul style="list-style-type: none"> Devel./Validate Conceptual Design Generate System/Struct. Layouts Produce Final Cost/Perform. Est. Negotiate Supplier Agreements Procure Long-Lead Hardware 	<ul style="list-style-type: none"> Freeze Configuration Produce Detail Drawings Build Tools Start Fabrication and Assembly
"Big Ticket" Items:	<ul style="list-style-type: none"> Low Speed Diagnostic Testing Low Cost Risk Reduction Testing (Hover/RCS/Etc.) Batch Simulation CFD; CEM 	<ul style="list-style-type: none"> High/Low Speed Diagnostic and Database Testing High/Low Speed Inlet Testing Propulsion Component Testing Jet Effects Testing CLAW Development Piloted Simulation Structural Coupon Tests 	<ul style="list-style-type: none"> Structural Element and Component Testing Subsystem Rig Tests Propulsion System Tests High/Low Speed Aero and Propulsion Database Tests Iron Bird Piloted Simulation
Significance:	Locks in ~80+% LCC with <1% Program Expenditure	Reduces Concept Risk Prior to Spending Big \$\$\$	The Devil's in the Details

Table 1: The three phases of design appropriate to a STOVL tactical aircraft [1]

This is illustrated in Figure 1 and was a point made by L M Nicholai [2]: "Aircraft designers have more influence over the first cost of an aircraft, its operations and support cost than any other group of people. Designers should appreciate their influence and recognize their obligation to design for reduced life cycle cost"

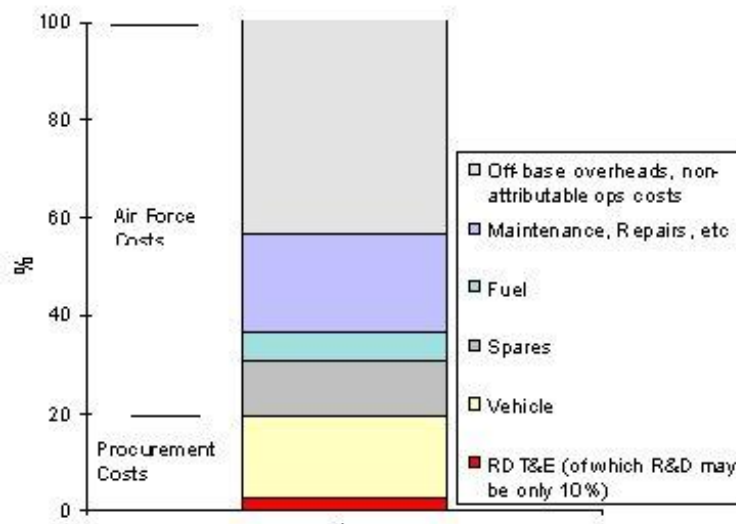


Figure 1. Approximate Breakdown of Life Cycle Cost

3. Design Philosophy

3.1 If one examines commercial aircraft design to contrast it with that for tactical aircraft significant differences emerge. Firstly, civil aircraft design is dominated by cost considerations with virtually all decisions being based on cost. Secondly, commercial aircraft configuration development is formulaic: they are subsonic, have circular fuselage cross sections, have two or four podded wing-mounted engines, are flown by two flight crew and have a conventional wing/body/tail configuration. In contrast, tactical aircraft design is dominated by ‘ilities’: Affordability, Lethality, Survivability, Supportability, etc. Implicit is the large number of independent variables and complex interaction of parameters that precludes in-depth analysis during conceptual design. Designers of tactical aircraft rely on ‘design philosophy’ to narrow the design space which emanates from prior experience, company culture and a willingness to assume risks. This implies that fighter/attack aircraft design is still very much an art with little consensus on ‘best’ design approach or configuration.

3.2 An early ‘jet-age’ example of little consensus on ‘best’ design approach or configuration was reported by Torenbeek [3] as shown in Figure 2. This was a clear example of design philosophy influencing a choice of configuration. The proponents of each solution were able to justify their configuration with sound technical arguments. Furthermore, it is salient to note that from the B-47 came the B-52, 707 and most subsequent commercial aircraft configurations.

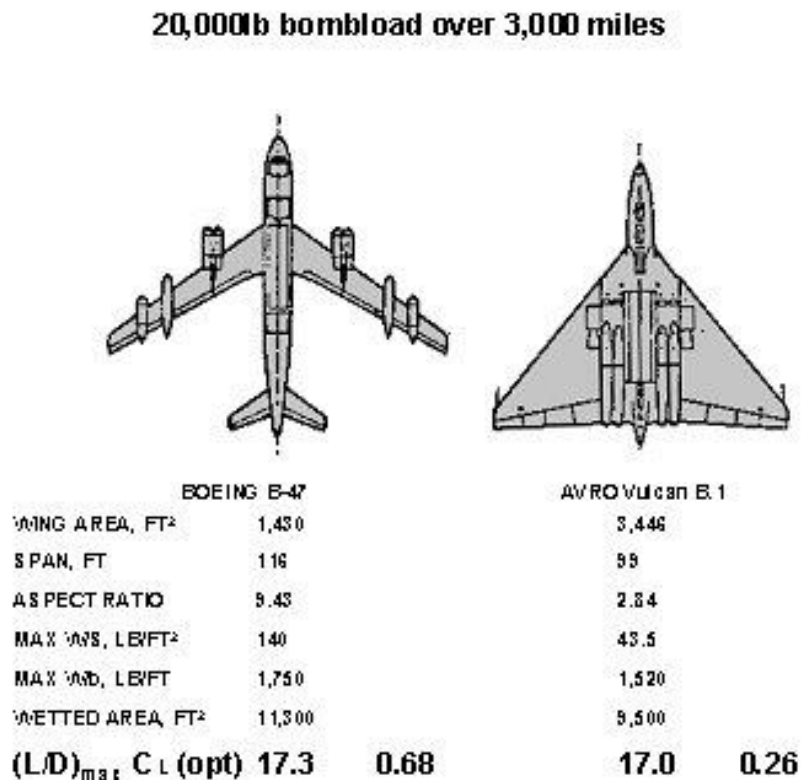


Figure. 2 Little consensus on ‘best’ configuration [3]

4. The elements of a robust conceptual design

These may be summarized as: The design point is centered in the design space to permit ‘tweaking’ the design during the preliminary design phase as requirements become firm. The proposal must have healthy performance margins as the quoted performance will never be better - “Paper aircraft are always better than real aircraft”. The design should conform to a historical database where applicable in terms of density, fuel fraction and maximum lift/drag ratio. It should also make provision for growth, say, 6-10% during development with margins for enhancements and upgrades. This last point is, however, contentious since designers may use up that built-in allowance prematurely. Finally, of course, the design must have sex appeal.

5. Strike Fighter Development Strategies

With the projected decline in the existing US military aircraft inventory American authorities were required to consider during the 1990s a future fleet of aircraft to replace ageing F-15s, F-16s, F-18s and AV-8Bs of the Air Force, Navy and Marines. Four development strategies were possible as shown in Figure 3. The selected strategy was Option D, namely one family of aircraft in three versions.

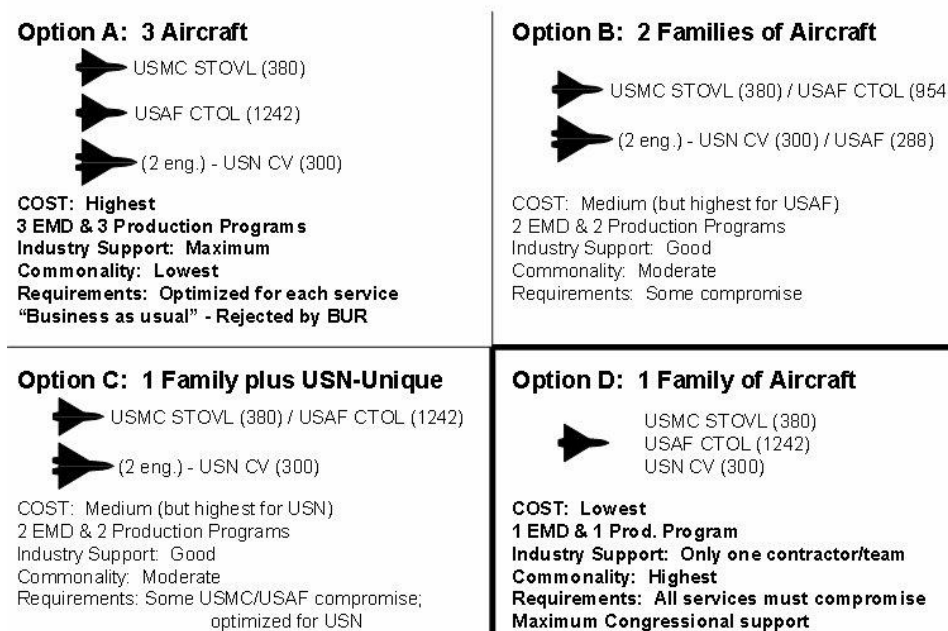


Figure 3. JSF Development Strategy Options [4]

The advantages to the customer (if not industry) of Option D are self-evident. However, to ensure an aircraft that would fulfil the JSF requirements two competing designs were produced and flight tested as shown in Figure 4. This is yet another example of ‘little consensus on best configuration’ and the figure shows the very different propulsion systems used for the STOVL version. At the heart of each of the competing designs was the heavy emphasis on commonality to achieve affordability.

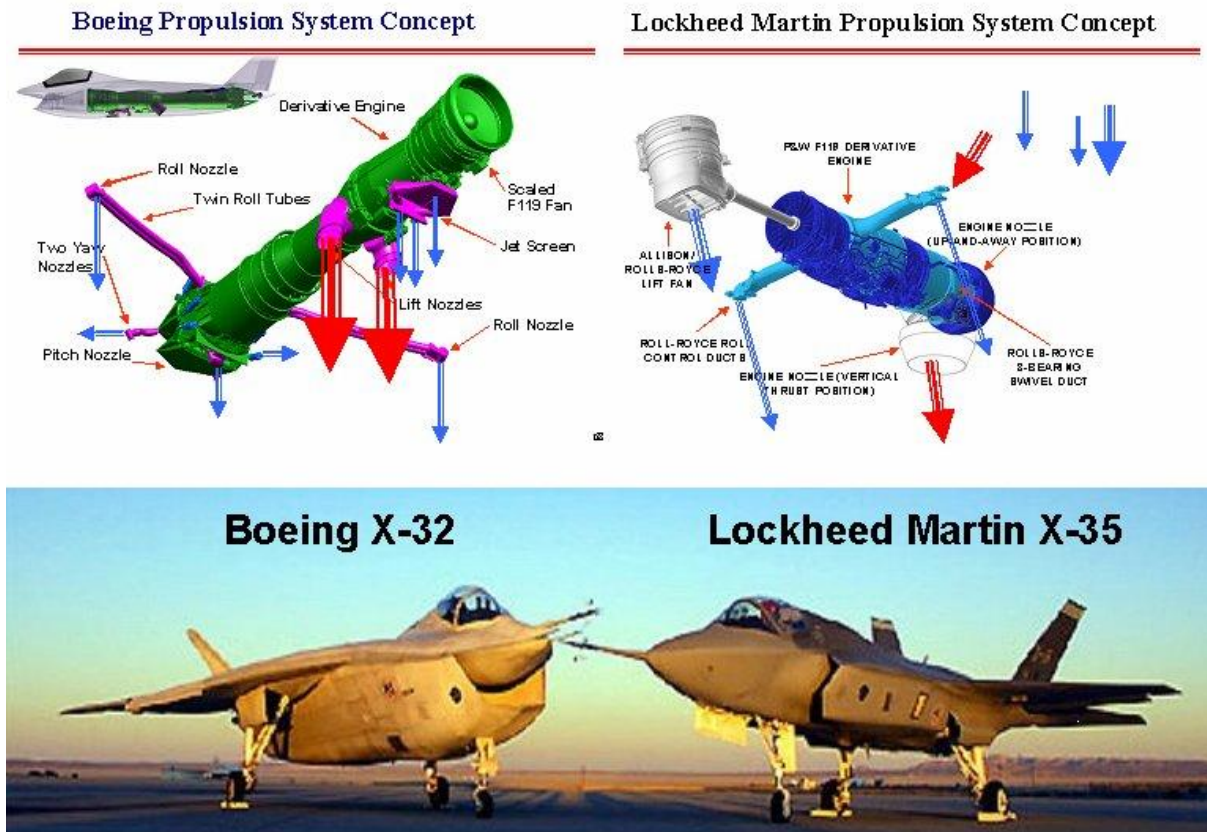


Figure 4. Competing JSF Concepts

5. Conclusions

Aircraft design involves (seemingly endless) compromise. Conceptual design locks in ~80+% of LCC at small initial cost. Balanced, rational requirements are the key to a solid design. Design of tactical combat aircraft is as much art as science. Aircraft are very weight sensitive - STOVL aircraft especially so. Performance always degrades from conceptual design levels. Aircraft balance is a fundamental configuration driver. Aero/propulsion integration can make or break a vehicle. Affordability is nowadays the key requirement and weighs as heavily as performance.

References

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