JSF Comparison

Presented by
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Presentation Outline

» Overview of JSF Competition
» Concepts
  – Boeing X-32
  – Lockheed X-35
» Powered Lift Solutions
» Analysis of Concepts
» Closing Remarks

JSF Requirements

- Cost
  - CTOL $28 million
  - STOVL $35 million
  - CV $38 million
- Weights
  - CTOL/STOVL
    - Empty Weight 22,000 lb
    - Fuel Capability more than 15,000 lb
    - Payload Capability more than 13,000 lb
  - CV
    - Empty Weight 24,000 lb
    - Fuel Capability more than 16,000 lb
    - Payload Capability more than 17,000 lb
  - Max TOGW approximately 50,000 lb all variants

The Joint Advanced Strike Technology (JAST) was initiated in 1993 by the Department of Defense to consolidate various initiatives into a single program. The goal of this program was to provide a next generation fighter for each military service that would be relatively cheap, but surpass current aircraft abilities. Affordability was one of the primary initiatives of the program because defense budgets do not allow for excessive spending on expensive aircraft. A cheap strike fighter would allow for a large number of aircraft to be produced and reduce the need to rely on aging aircraft to accomplish missions.

JSF Service Needs

» Affordable Next Generation Strike Fighter

– US Navy	- compliment to F/A-18E/F
– US Air Force	- compliment to F-22A
– US Marine Corps	- replace AV-8B and F-18
– UK Royal Navy UK Royal Air Force	- replace Sea Harrier and GR.7
– Other Allies	- replace F-16, F/A-18, and AV-8B

Affordability has once again been stressed here because it encompasses many factors. The most important of which is common design. Commonality reduces manufacturing costs and the life cycle cost of the aircraft. The JSF programs that were awarded contracts presented designs that were 70-90% common among all variants. Considering the number of branches of the military that are interested in this aircraft and the wide variety of roles it is expected to perform, this degree of similarity was not easy to accomplish.

The Navy's interest is in complementing the F/A-18E/F. The Air Force intends to use this aircraft as an air to ground strike aircraft, which will complement the F-22, the air superiority fighter. The Marines are looking for an aircraft to replace all of their current strike aircraft and assume the role of the only strike aircraft in the USMC. The United Kingdom is also looking to replace their aging aircraft in both their Air Force and Navy. In addition, the JSF program will probably find interest from other allies.

Boeing X-32A (CTOL & CV)

- Overall
  - Wingspan = 36 ft
  - Length = 47.4 ft
  - Height = 13.3 ft
- Planform
  - Wing Area = 554.2 ft^2
  - AR = 2.34
  - LE Sweep = 55 degrees
  - Taper Ratio = 0.30
- X-32B (STOVL)
  - Wingspan = 30 ft

http://www.boeing.com/defense-space/military/jsf/jsfphotos7.htm

Boeing essentially has two variants for the JSF solution. The X-32A is designed to accomplish Conventional Take-off and Landing (CTOL) and Carrier operations (CV). The X-32B is equipped with the direct lift system to enable it to perform short take-off and vertical landing operations (STOVL). The main difference between the CTOL and CV will be increased structural strength and landing gear strength for carrier operations. All of these aircraft are designed to have supersonic capabilities and carry internal and external weapons.

Lockheed X-35A/B (CTOL & STOVL)

X-35A

- Overall
  - Wingspan = 35 ft
  - Length = 50.5 ft
  - Height = 13.8 ft
- Planform
  - Wing Area = 458 ft^2
  - AR = 2.67
  - LE Sweep = 34 degrees
  - Taper Ratio = 0.286
- X-35C (CV)
  - Wingspan = 43 ft
  - Length = 50.8 ft

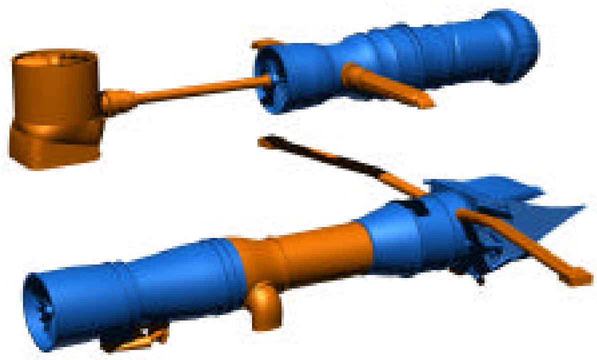
http://www.lmaeronautics.com/fighter_programs/jsf/jsf_ctol.html

Similar to Boeing, the X-35 has two basic planforms. Lockheed that the carrier based aircraft was the odd mission. The X-35A and X-35B test demonstrators are going to be the same aircraft. First Lockheed intends to demonstrate the CTOL performance. The X-35A will then be fitted with the lift fan and will be redesignated as the X-35B. The X-35C has a much larger planform than it's sibling. The wingspan increases by 8 feet for carrier operations to improve the low speed flight characteristics.

STOVL Configuration Comparison

X-35
Concept

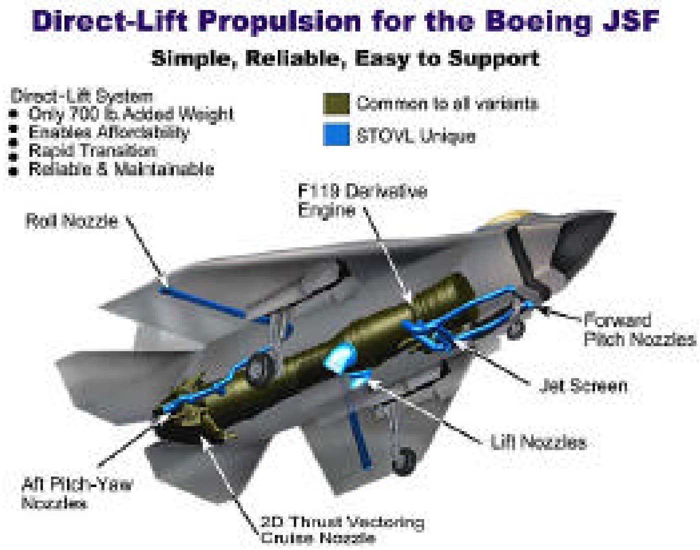
X-32
Concept



http://www.anser.org/vstol/jsf.htm

The Lockheed and Boeing teams came up with radically different concepts to handle the challenges presented by the STOVL requirement. Boeing's X-32 uses a direct lift system. The X-35 essentially adds another small engine mounted in the vertical direction to provide added lift beyond that of the redirected engine thrust.

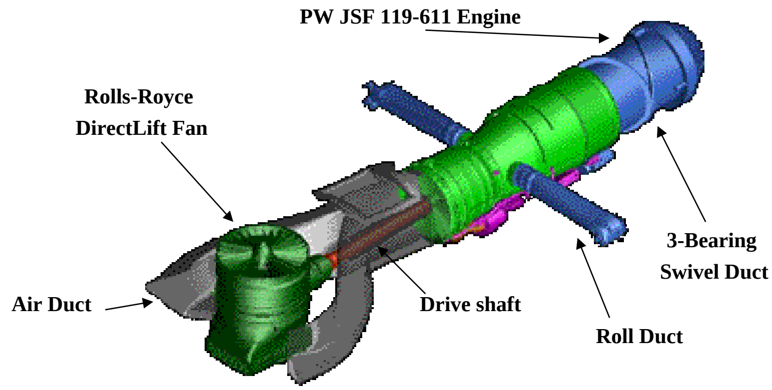
Boeing STOVL Solution



http://www.boeing.com/defense-space/military/jsf/images/STOVL_directLift.jpg

Boeing’s solution to the STOVL problem is clearly outlined above. Their goal was to use simple, proven technology to accomplish the mission objective. The Direct-Lift system used on the JSF is similar to that of the AV-8B. Lift is primarily achieved by redirecting the engine thrust to two lift nozzles and a jet screen. In addition to the three points, there are also additional vents to control roll, pitch and yaw. The main benefits that Boeing is stressing is that this solution is simple and therefore reliable. In addition it only adds 700 pounds to the aircraft weight and does not involve the addition of more major parts.

Lockheed STOVL Solution



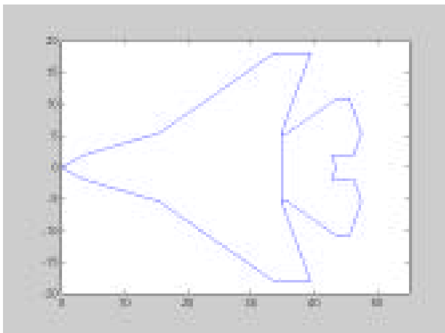
- Weight increase of 4,000 lb.
- 60% more vertical thrust than JSF 119 alone

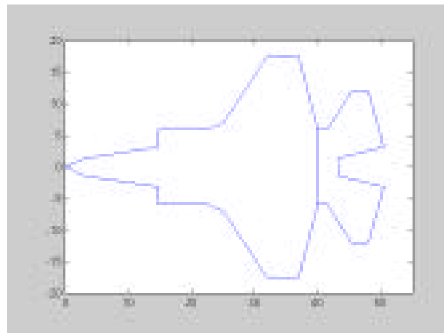
http://www.jast.mil/Concepts/Images/lm_611_3d.gif

Lockheed's solution to accomplishing STOVL criteria is effective, but complex. The engine has two inlet ducts, which allow for the placement of a direct lift fan along the centerline of the fuselage. To perform vertical landings the direct lift fan engages and the swivel duct on the end is directed downward. Lockheed claims that this solution increases vertical thrust by 60% over the direct lift capabilities of the JSF 119 engine alone. This configuration also uses roll, pitch and yaw ducts to maintain aircraft stability in the vertical landing configuration. The direct-lift fan causes the an increase in weight of roughly 4,000 pounds. While the second engine provides the benefits of extra lift, it carries a penalty of increased weight and higher complexity.

Stability Analysis

- X-32A
  - True Area = 800 ft^2
  - Static Margin = -0.1176
  - $C_{L\alpha}$ = 3.50 1/rad
  - C_{Di} = 0.129
- X-35A
  - True Area = 750 ft^2
  - Static Margin = 0.0594
  - $C_{L\alpha}$ = 3.90 1/rad
  - C_{Di} = 0.115





Using VLM4998, the stability of each configuration was examined. Shown in the pictures are the node locations chosen to perform the vortex lattice calculations. Each configuration used two planforms. One thing to note with this calculation is that the vertical tail projections onto the horizontal plane were not taken into account. The Boeing planform is similar to that of a delta wing. The Lockheed design is more conventional with less blending of the surfaces. Using .25 mac as the moment reference location, the X-32A comes out as being 11.76% stable and the X-35A is found to be 5.94% unstable. The X-35A seems reasonable; however, the X-32A result seems to be overly stable. Strike fighters are typically marginally stable and modern avionics reduces the need for an aircraft to be nearly 12% stable. The results for $C_{L\alpha}$ and C_{Di} are also shown above.

Closing Remarks

» Affordability and Commonality
  - X-32 is 85% common
  - X-35 is 70% common

» STOVL Concepts

» Prediction

Affordability is usually a major design issue; however, the JSF project strives to go above and beyond in costs issues. The JSF is designed to accomplish many missions, but still remains highly common within each variation. The Boeing team appears to be aiming for proven technology and simplicity in their design. The Lockheed team is trying to obtain better performance by increasing the complexity of their design slightly. The STOVL concepts both achieve their objectives. The complexity of the lifting fan has already caused problems for Lockheed though, since the fan has malfunctioned during flight tests.

My prediction is that the Boeing JSF will ultimately win this competition. This design appears to easily accomplish its objectives and involves a simpler approach to achieve them. The aircraft and its variants involve a higher degree of similarity than the Lockheed aircraft. In addition, the Boeing team achieved first flight before Lockheed and have logged more testing hours. The Lockheed aircraft also appears to have been designed around the STOVL variant, which is not that important to many of the interested parties. Boeing on the other hand seems to have added STOVL as a minor adjustment. For these reasons, I think Boeing is going to emerge from this on top.