General Arrangement

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Length</td>
<td>50 ft</td>
</tr>
<tr>
<td>Span</td>
<td>35 ft</td>
</tr>
<tr>
<td>Wing area</td>
<td>450 sq ft</td>
</tr>
<tr>
<td>Empty Weight</td>
<td>30,000 lbs</td>
</tr>
<tr>
<td>AB Thrust</td>
<td>40,000 lbs</td>
</tr>
<tr>
<td>Vertical Lift</td>
<td>40,000 lbs</td>
</tr>
</tbody>
</table>

DISTRIBUTION STATEMENT  Approved for public release; distribution is unlimited.
Relative Size of Naval JSF

1. **Length**: 51 ft
   **Span**: 43 ft
   **Wing Area**: 620 ft²
   **Internal Fuel**: 19,500 lb
   **Spot Factor**: 1.09

2. **Length**: 47 ft
   **Span**: 30 ft
   **Wing Area**: 240 ft²
   **Internal Fuel**: 7,900 lb
   **Spot Factor**: .82

---

**DISTRIBUTION STATEMENT** Approved for public release; distribution is unlimited.
Service Needs

- **USMC** 609
  STOVL Strike Fighter to Replace the AV-8B and F/A-18C/D

- **RN and RAF** 150
  Supersonic STOVL Replacement for the Sea Harrier and GR-7

- **USAF** 1763
  Stealthy Strike Fighter to Replace the F-16 and A-10

- **USN** 480
  Stealthy Strike Fighter

3000 US/UK Joint Strike Fighters

DISTRIBUTION STATEMENT Approved for public release; distribution is unlimited.
JSF Family of Aircraft

CTOL
- Length: 50 ft
- Span: 35 ft
- Wing Area: 460 ft²
- Internal fuel: 18,500 lbs

STOVL
- Length: 50 ft
- Span: 35 ft
- Wing Area: 460 ft²
- Internal fuel: 13,250 lbs

Naval
- Length: 51 ft
- Span: 43 ft
- Wing Area: 620 ft²
- Internal fuel: 19,500 lbs

DISTRIBUTION STATEMENT  Approved for public release; distribution is unlimited.
JSF Commonality

- STOVL Variant
- CTOL Variant
- CAT Variant
Cousin Parts

- Common Billet Size (And Possibly Material)
  - USAF - Al-Li Billet

- Common N/C Setup
  - USN - Ti Billet

- Different Thicknesses (Different N/C Tape)
  - 0.61
  - 0.59
  - 0.71
  - 1.00

- Common Assembly Fixture
  - USAF Fuselage Component
  - USN Fuselage Component
Designed for Self Defense

- AESA Long Range Radar
- 360° Visibility
- Low W / S
- High C_{L_{max}}
- Low Span Loading
- Twin Verticals
- High T / W
- 2 Internal AIM 120’s

DISTRIBUTION STATEMENT  Approved for public release; distribution is unlimited.
Designed for Ground Attack

- Low IR Signature
- Internal Precision Guided Weapons
- Agile
- Stable Target Tracking
- Good Field of View
- Low Vulnerability
- Supersonic Speeds
- Internal EO Systems

DISTRIBUTION STATEMENT  Approved for public release; distribution is unlimited.
Designed for Low Vulnerability

- Dry Bay Fire Protection
- Air Start System
- Multiple Load Paths
- Pilot Protection
- Hot Parts Aft
- Jettisonable Weapons
- Redundant Control Surfaces
- Multiple Fuel Tanks
- Fuel Tank Inerting
Designed for Maintainability

Self Contained Ladder

Auxiliary Power Unit

OBOGS

OBIGGS

Advanced Cockpit

On Board Diagnostics

Integrated Subsystems

Benign Footprint

Single Point Systems Check

DISTRIBUTION STATEMENT  Approved for public release; distribution is unlimited.
Air to Air Combat Performance

Instantaneous G’s
- F-16C
- USAF
- F/A-18C
- USMC/RN
- USN

Sustained G’s
- F-16C
- USAF
- F/A-18C
- USMC/RN
- USN

Transonic Acceleration
- F-16C
- USAF
- F/A-18C
- USMC/RN
- USN

DISTRIBUTION STATEMENT Approved for public release; distribution is unlimited.
Naval F-35C Mission Performance

USN Profile: (2) 2K lb JDAM + (2) AIM-120

Opt M/Alt
Cruise

Drop A-G Weapons
Combat @ 35K ft

Mission Radius - nm

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>JSF</th>
<th>768</th>
<th>F/A-18C</th>
<th>329</th>
<th>547</th>
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<tbody>
<tr>
<td>600 w/ Tanks</td>
<td>730 w/ Tanks</td>
<td>927</td>
<td>2x 480 gal Tanks</td>
<td>3x 330 gal Tanks</td>
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</table>

DISTRIBUTION STATEMENT  For Official Use Only
USMC F-35B Mission Performance

USMC Interdiction B: (2) 1K lb JDAM + (2) AIM-120

Ingress/Egress
- 540 KTAS/15,000 ft

Drop A-G Weapons

Opt M/Alt Cruise

Mission Radius - nm

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Base Mission Radius</th>
<th>Max Mission Radius</th>
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<tbody>
<tr>
<td>JSF</td>
<td>473</td>
<td>663</td>
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<tr>
<td>F/A-18C</td>
<td>375</td>
<td>504</td>
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<tr>
<td>AV-8B</td>
<td>273</td>
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</table>

Lot XIX w/ (2)1K JDAM+(2)AIM-120+(5)Pylons + Gun

2x 480 gal Tanks

2x 330 gal Tanks

DISTRIBUTION STATEMENT For Official Use Only
How We Won: The X-Planes

“Lockheed won by proposing a very innovative lift fan” - Boeing

“Lift Fan Puts LockMart over the Top” - Aviation Week

“Lift Fan Carries LM to Victory” - Interavia
Lift Fan Propulsion System

- Lift Fan
- Clutch
- Fan Drive Shaft
- Roll Control Jets
- Thrust Vectoring Nozzle
- Cruise Engine
AV-8 Harrier Adopted by US Marine Corps
1970
The Harrier Approach Isn’t Supersonic

F-104 Starfighter
15,000 lbs Thrust
Mach 2

AV-8B Harrier
20,000 lbs Thrust
M < 1
Design Missions

Interdiction

Deck Launched Intercept

Combat Air Patrol
VTOL Requirement Sizes the Engine

- VTOL Design Point
- CTOL Design Point
- Sustained Turn
- Instantaneous Turn
- Transonic Acceleration

Thrust to Weight Ratio ($T_{SL} / W_{TO}$)

Wing Loading ($W_{TO} / S$)
Engine Requirements Analysis

Segment
- Short Take Off
- Subsonic Cruise
- Combat
- Supersonic Acceleration
- Vertical Landing

Need
- Wing Lift
- Jet Lift
- High T/W
- Low SFC
- High T/W
- Low IR
- Low Drag
- High T/W
- Low SFC
- Reaction Control
- High T/W
- Low HGI

Feature
- Jet Flap
- Vector Thrust
- High BPR
- Mixed Flow
- Aft Nozzle
- Low BPR
- Balance
- Thrust Transfer
- High BPR
- Cold Jets

Variable Bypass Ratio
The Basic Problem:
Not Enough Thrust, and It’s Too Far Aft

Thrust, 20K lbs
Weight, 30K lbs

Conventional F-16

Thrust, 18K lbs
Weight, 30K lbs

“V/STOL” F-16
Solving the Basic Problem
Not Enough Thrust, and It’s Too Far Aft

Means to Produce Thrust
- Fans
- Rockets
- Pulse Jets
- Ram Jets
- Ejectors
- Explosions
- MHD
- EFD

Means to Transfer Power
- Shafts
- Ducts
- Heat Pipes
- Laser Beams
- Chain Drive
- Fiber Optics
- Wires
- Hydraulics

Means to Extract Power
- Turbines
- Scoops
- Regeneration
- Heat Pipes
- Alternator
- Generator
- MHD
- EFD
Shaft Driven Lift Fan Propulsion Concept
F-35 Propulsion System
Alternative Types of Turbine Engine

Turbofan Engine
Provides Cruise Thrust, but no Shaft Power

Turboshaft Engine
Provides Shaft Power, but no Cruise Thrust
Extracting Shaft Power
Comparison with LM Lift/Cruise System

at 40,000 lbs of thrust
Design Options

WING PLANFORM

WING POSITION

HORIZONTAL STABILIZERS

VERTICAL STABILIZER

INLET LOCATION
Number of Alternative Aircraft Is Too Large
# Horizontal Stabilizer Assessment

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<tr>
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<th>THREE SURFACE</th>
<th>WING / CANARD</th>
<th>SIMPLE DELTA</th>
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<td>HIGH ALPHA CAPABILITY</td>
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<td>RECONFIGURABILITY</td>
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<td>3</td>
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</tbody>
</table>
Lift Fan Installation

Horizontally Mounted

Strong Points
Weak Points
Inlet Performance
Balance

Vertically Mounted

Hover Thrust
Weight
JSF STOVL Propulsion System
AV-8B Harrier and the F-35 Musketeer

Fan Augmentation
Hot Gases Aft
Continuous Thrust Vectoring
Lift Improvement Devices
Poor Supersonic Area Distribution
Overtemp Reduces Engine Life
Water Injection Required
Side by Side Jets Permit Hot Gas Ingestion
Compressor Air for Reaction Control Jets

Fan Augmentation
Hot Gases Aft
Continuous Thrust Vectoring
Lift Improvement Devices
Good Supersonic Area Distribution
No Reduction of Engine Life
No Water Injection Required
Tandem Jets Prevent Hot Gas Ingestion
Fan Air for Reaction Control Jets
Lockheed Martin Common Strike Fighter

STOVL

CTOL
TFX: The Challenge of Joint Aircraft

USAF F-111

USN F-14 (F-111N)
Technology Assessment Contracts
1993

- **Lockheed Skunk Works**
  - Shaft Driven Lift Fan $40M

- **McDonnell Douglas**
  - Gas Driven Lift Fan $35M

*Demonstrate propulsion and airframe performance through ground test*
Lockheed Martin Large Scale Powered Model 1995
Lockheed Martin Large Scale Powered Model
NASA Testing
Boeing Large Scale Powered Model
1996
Boeing X-32
Lift / Cruise Engine

- Mature Technologies to Reduce Risk
- Build Aircraft to Validate Performance
- Refine the Design, as Necessary

Lockheed Martin X-35
Shaft Driven Lift Fan
Lockheed Martin Demonstrator Approach

- Build Two Aircraft, but Fly All Three Variants
- Fly the Production Configurations
- Demonstrate STOVL Performance and Supersonic Speed
- Prove Handling Qualities and Carrier Suitability
X-35 Commonality

X-35 Number 1

CTOL X-35A

STOVL X-35B

Carrier X-35C

X-35 Number 2
Validation by High Fidelity Demonstrators
CTOL USAF Variant

- 27 Flights totaling 27.4 Hours over 30 Days
- LM, BAE SYSTEMS, MOD, and DOD Pilots Flew the X-35A
- “People were stunned” Gen Mike Hough, USMC
Conversion to STOVL Variant
Only Aircraft To Fly Supersonically, Hover, and Land Vertically in the Same Flight

– Major Art Tomassetti, USMC, 20 July 2001

38 Flights in 21.5 Hours
Lift Jet Characteristics

40,000 lbs of Vertical Lift from Just 4 Nozzles
Infrared Lift Jet Visualization
Naval Variant Over Annapolis

First X-plane to fly across the US
- 2 Flights
- 5.9 Flight Hours

Edwards Air Force Base
- 38 Flights in 33.2 Hours
- Use of a Side Stick Demonstrated
- Carrier Approaches Flown

Pax River Naval Air Station
- 33 Flights in 18.9 hours
- Carrier Landings Simulated
- Envelope Expanded to M = 1.2

DISTRIBUTION STATEMENT  Approved for public release; distribution is unlimited.
JSF STOVL Variants

32,000 lbs of Thrust

40,000 lbs of Thrust
What You See, Is What You Get!
2001 Collier Trophy

Awarded for "the greatest achievement in aeronautics or astronautics in America, demonstrating during the preceding year" to the F-35 Lift Fan Propulsion System
Joint Strike Fighter - Economies of Scale

F-16 Falcon

USAF  1765
USN  480
USMC  610
UK  150
FMS  3000

A-10 Warthog

F-18 Hornet

Total of 6000 aircraft
Total of $200B

AV-8 Harrier
International Coalition Investing in JSF