General Dynamics
F-16 Fighting Falcon


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AOE 4124
Outline

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• Trim Drag
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Purpose/Mission

- RFP (issued Jan. 16, 1971)
- Provide an aircraft with maximum usable maneuverability and effectiveness in both the air-to-air and air-to-ground combat arenas but within the constraints of minimizing the cost and complexity
  - Superior maneuver performance and handling qualities at subsonic and transonic speeds (0.6\(<\)M\(<\)1.6)
  - Superior acceleration
  - The carriage of a variety of the latest air-to-ground weapons and their accurate delivery
  - A subsonic-cruise lift-to-drag ratio sufficient to provide effective mission radii with a variety of payloads
  - High T/W ratio
  - TOGW < 20,000lbs
  - Operate at altitudes between 30 and 40 thousand feet
Aerodynamic Configuration

• Leading Edge Extensions
  – Provide controlled vortex lift
    • Produces lift on the inboard portion of the wing and straightens the flow over the outboard portion of the wing
  – Strake geometry and its interface with the forebody and wing were developed over many hours of wind tunnel testing of more than 50 configurations
  – Net increase in lift at high angles of attack is over 25 percent
  – Reduces buffet intensity
  – Improves directional stability
  – Increases trimmed lift-to-drag ratio

• Tail
  – Chose single tail over twin
  – Less buffeting from strake vortices at high alpha

• Engine Intake
  – Located below the nose a
  – Avoids gun gas ingestion and landing FOD
Aerodynamic Configuration

• **Automatic Variable Camber**
  
  – Provides an aerodynamically efficient wing surface throughout the flight envelope
  
  – LE flap is automatically positioned to minimize drag and buffet at all flight conditions
    - Optimizes the wing camber for turning maneuvers, cruise, and acceleration
  
  – At M > 1, LE and TE flaps are fixed at -2 degrees
    - Reduces profile drag at low angles of attack
    - Improves acceleration characteristics
  
  – Improves directional stability at high lift coefficients
  
  – Increases sustained and instantaneous lift up to 12 percent
  
  – Reduces buffet intensity by almost 60 percent
Aerodynamic Configuration

- **Relaxed Static Stability**
  - Increases lift-to-drag ratios at subsonic and supersonic speeds
  - Reduces down-load on the horizontal tail required to trim at high lift coefficients and at supersonic speeds
    - Increases total lift available at sustained-turn conditions (2% at subsonic cruise, 4-8% at M = 0.9, and 8-15% at M = 1.2)

- **Blended Wing/Body**
  - Provides additional volume for fuel storage, increasing range
  - Reduces wetted surface area, reducing drag
  - Increases structure rigidity

- **Supersonic Area Ruling**
  - Decreases wave-drag
  - Particular attention was given to the bubble canopy in the final area ruling of the fuselage/strake/nacelle combination
$C_{D0} \approx 0.0175$

Planform Issues and Analysis

- **Span e**
  - $e \approx 0.9084$ at $C_L = 0.4$

- **Vortex Lattice Method Results**

<table>
<thead>
<tr>
<th></th>
<th>Tornado (M=0.8)</th>
<th>VLMpc (M=0.8)</th>
<th>Wind Tunnel (M=0.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL alpha (per deg)</td>
<td>0.0489</td>
<td>0.08104</td>
<td>0.09</td>
</tr>
<tr>
<td>Cm alpha (per deg)</td>
<td>-0.0284</td>
<td>-0.0448</td>
<td>-0.01125</td>
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Airfoil Issues and Analysis

- Airfoil
  - NACA 64A204
  - Variable Camber

Performance

- Empty Weight – 16,285 lb
- Combat Takeoff – 26,536 lb
- Maximum Takeoff Weight – 37,500 lb
- Wing Loading – 88 lb/ft²
- Maximum Thrust – 23,830 lb (27,000 lb for later models)
- Thrust/Weight Ratio – 0.94-1.08
- Maximum Velocity – Mach 2.0(+)
- Ceiling – 50,000 ft
- Climb Rate – 50,000 ft/min
- Maximum Range – 2,425 miles
- Max G-rating – 9g with 100% fuel (7.33g with 80% fuel)
- AOA Limiter (basic, roll rate, and yaw rate)
- ARI Schedule (-AOA, -Mach)
- Rudder Authority Limiting
<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tr>
<td>• Relatively long range</td>
<td>• Deep stall possible at 60 deg AOA</td>
</tr>
<tr>
<td>• Lower TOGW from various config. Option allows an increased turning rate (10%) and acceleration (30%)</td>
<td>• Fixed engine inlet geometry reduces TOGW, but limits M&lt;2</td>
</tr>
<tr>
<td>• Small size = low radar returns</td>
<td>• OEI is a problem with only one engine</td>
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<tr>
<td>• Bubble canopy has large range of vision</td>
<td>• Possible problem with control system (fly-by-wire) when struck by lightning</td>
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<tr>
<td>• Designed to carry more missiles than specified</td>
<td></td>
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<tr>
<td>• Lower cost from using common components</td>
<td></td>
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<tr>
<td>• Upgradeable</td>
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<tr>
<td>• Increased life in airframe</td>
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F-16 Experimental Variants

F-16XL

• Optimized for supercruise

http://www.brockmoore.com/images/military/F-16XL.jpg
F-16 Experimental Variants

AFTI/F-16

• Experimentation with decoupled flight

http://www.combatsim.com/archive/images/img_arc-13/aft002.jpg
References


