

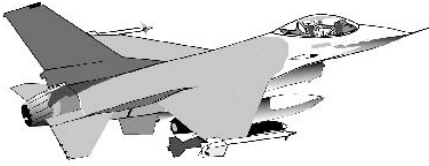
General Dynamics F-16 Fighting Falcon



<http://www.globalsecurity.org/military/systems/aircraft/images/f-16c-19990601-f-0073c-007.jpg>

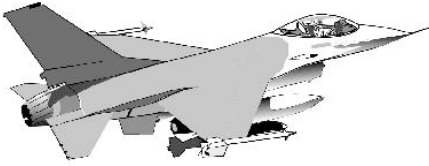
Adam Entsminger
David Gallagher
Will Graf

AOE 4124



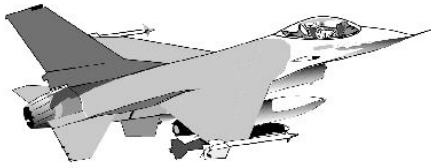
Outline

- **Purpose/Mission**
- **Aerodynamic Configuration**
- **Lift**
- **Drag**
- **Planform Issues and Analysis**
- **Airfoil Issues and Analysis**
- **Trim**
- **Trim Drag**
- **Performance**
- **Pros/Cons**
- **F-16 Experimental Variants**



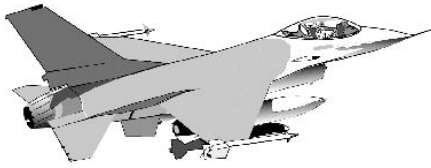
Purpose/Mission

- **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**



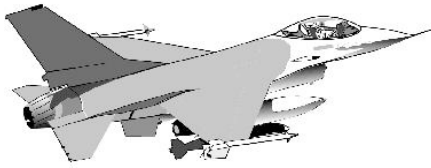
Aerodynamic Configuration

- **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



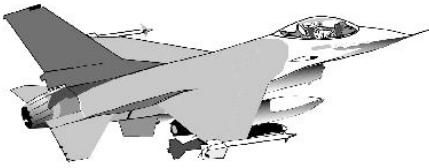
Aerodynamic Configuration

- **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

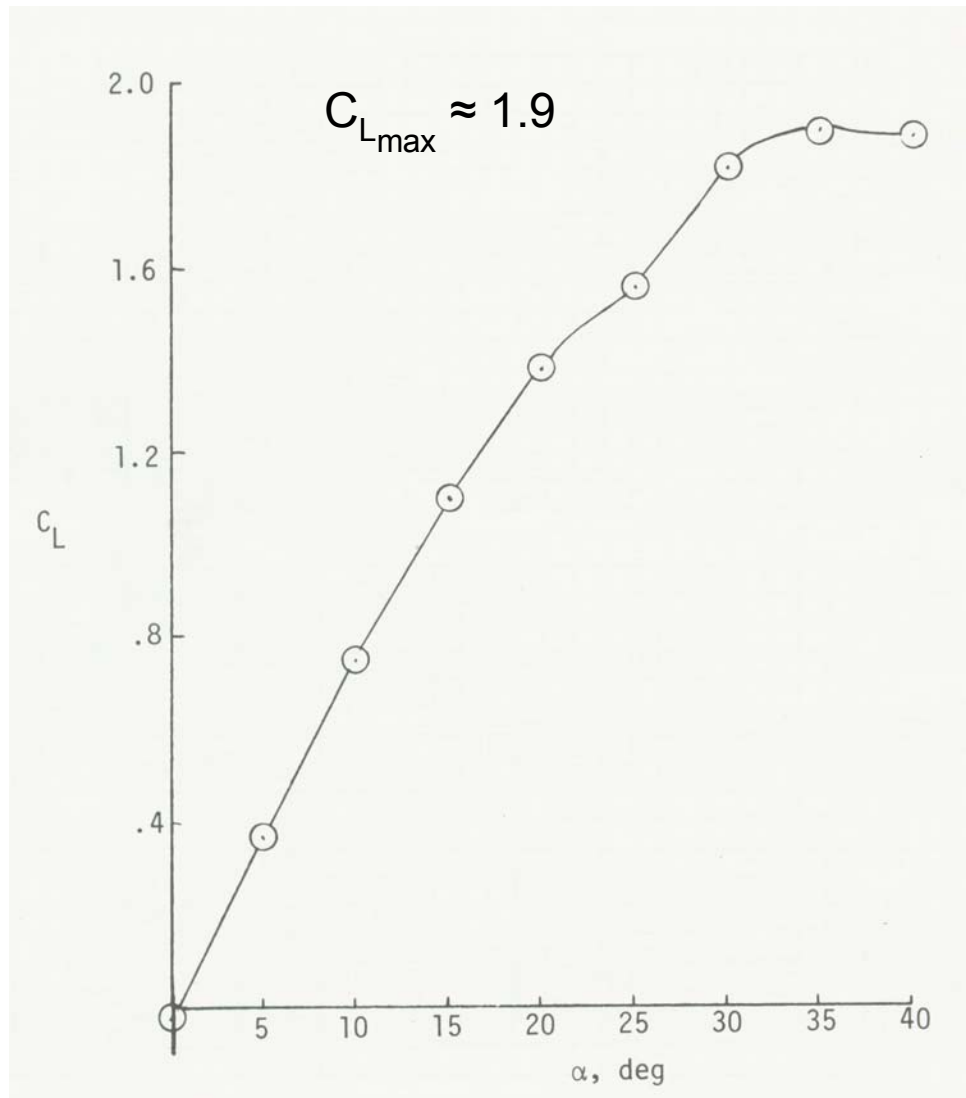


Aerodynamic Configuration

- **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

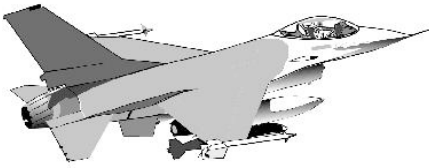


Lift

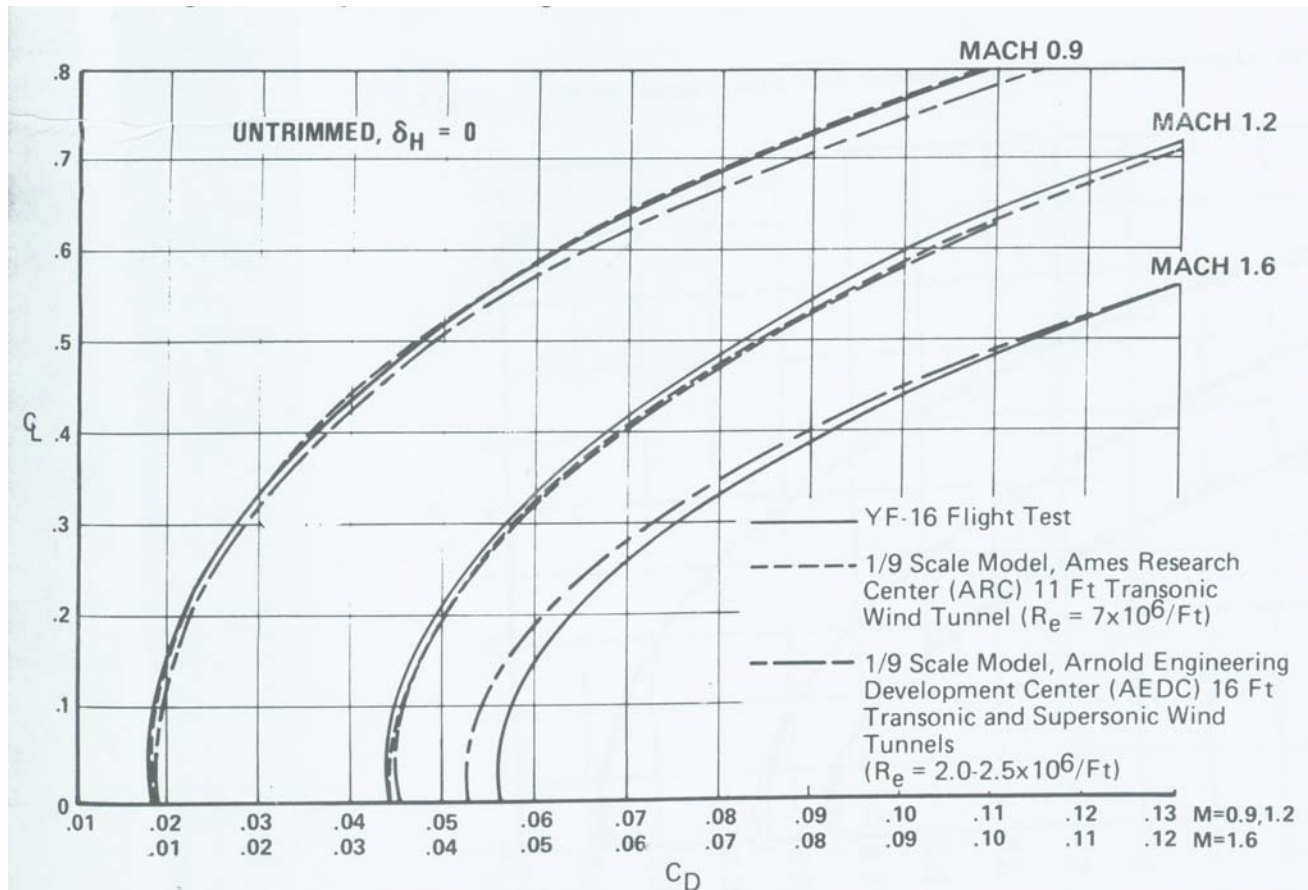


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Nguyen, Luat T. et.al. Simulator Study of Stall/Post-Stall Characteristics of a Fighter Airplane With Relaxed Longitudinal Static Stability. NASA Technical Paper 1538. Dec. 1979.

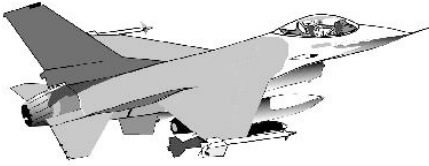


Drag



$$C_{D0} \approx 0.0175$$

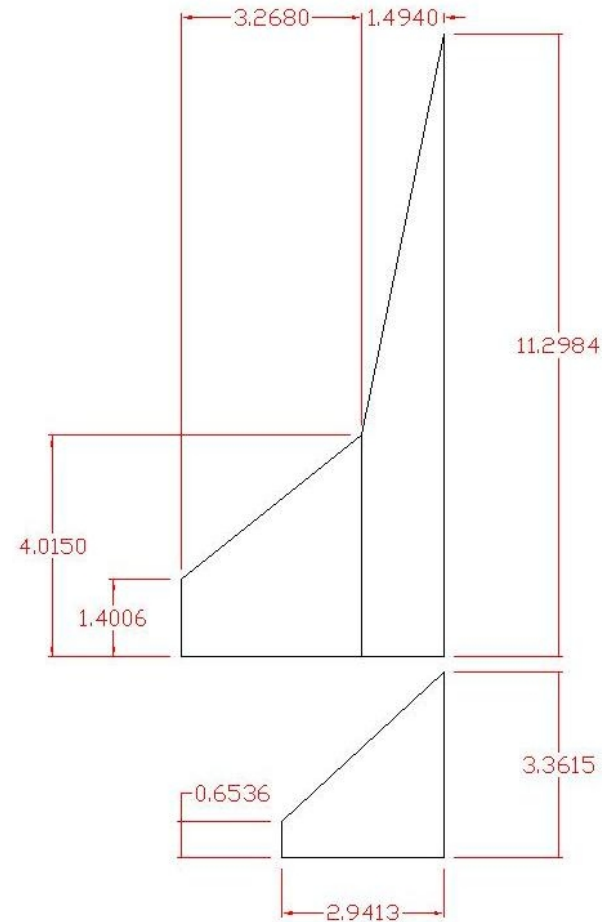
Webb, T.S., Kent, D.R., Webb, J.B. Correlation of F-16 aerodynamics and performance predictions with early flight test results. Agard Conference Proceedings. n 242. Oct 11-13, 1977.



Planform Issues and Analysis

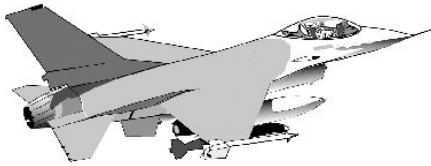
- **Span e**
 - $e \approx 0.9084$ at $C_L = 0.4$
- **Vortex Lattice Method Results**

	Tornado (M=0.8)	VLMpc (M=0.8)	Wind Tunnel (M=0.9)
CL alpha (per deg)	0.0489	0.08104	0.09
Cm alpha (per deg)	-0.0284	-0.0448	-0.01125



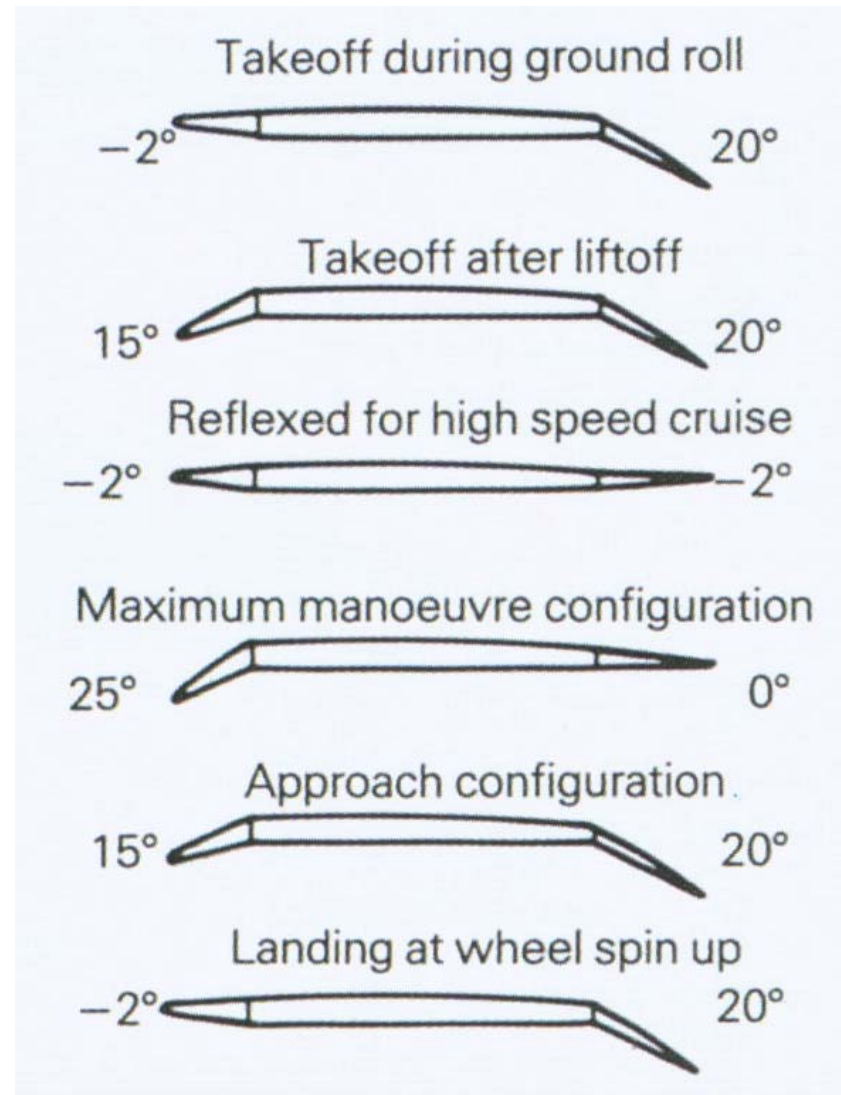
F-16
planform

dimensions
in meters

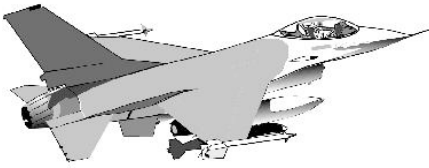


Airfoil Issues and Analysis

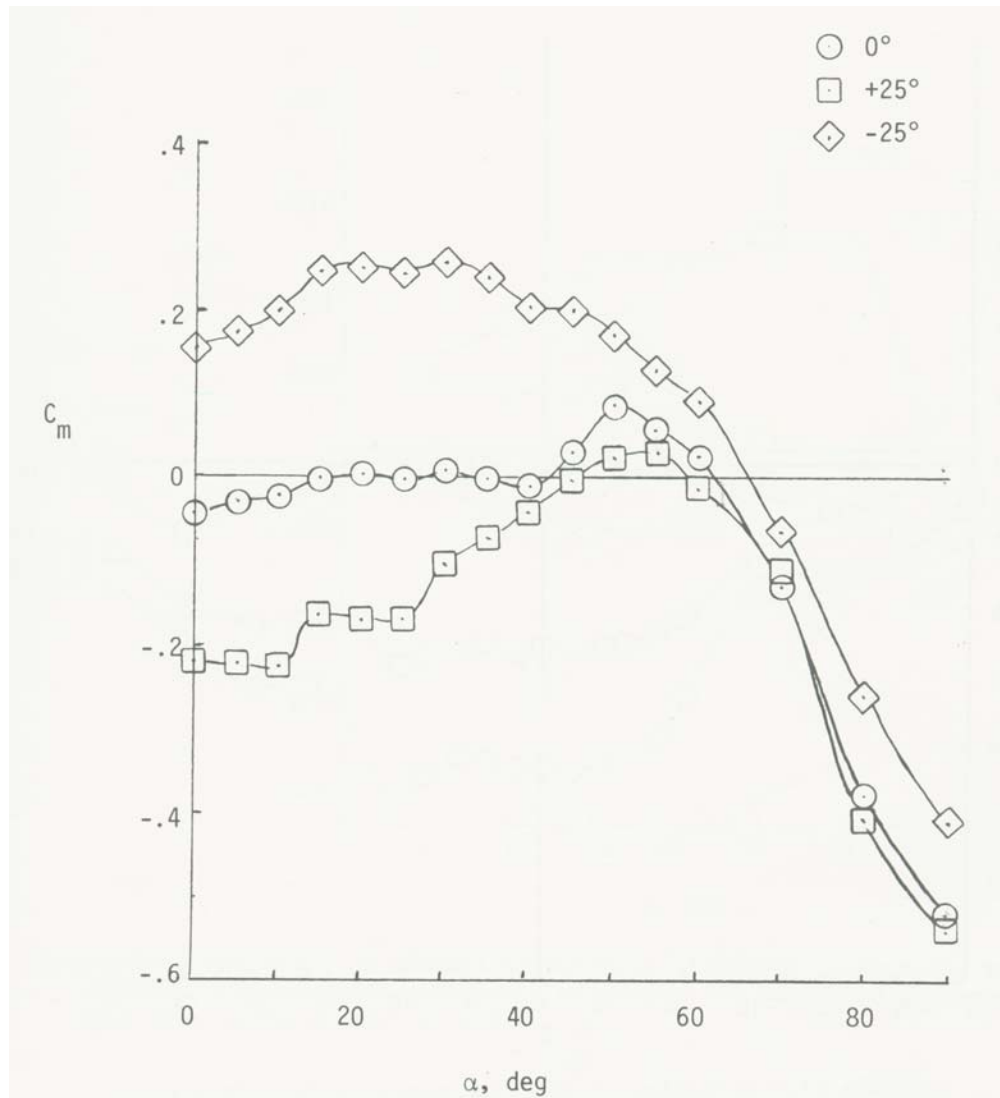
- **Airfoil**
 - **NACA 64A204**
 - **Variable Camber**



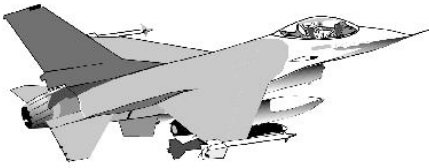
Spick, Mike, ed. The Great Book of Modern Warplanes. Salamander Books Ltd: London, UK, 2002.



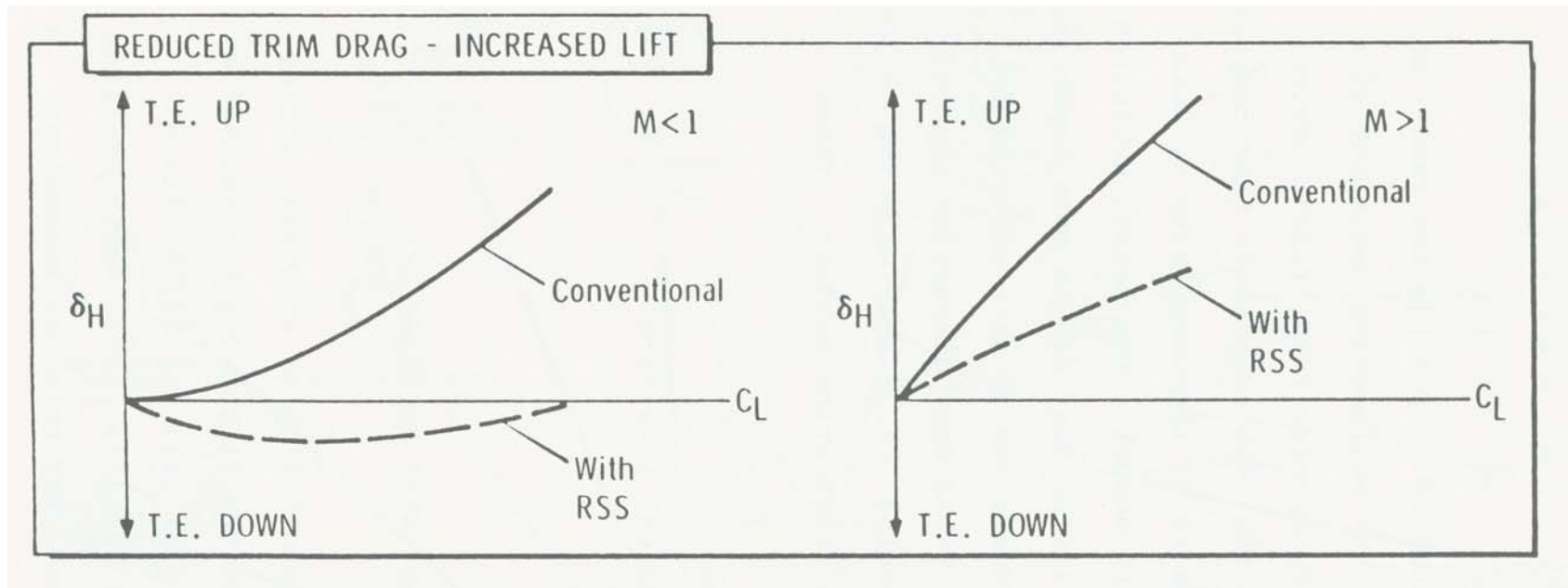
Trim



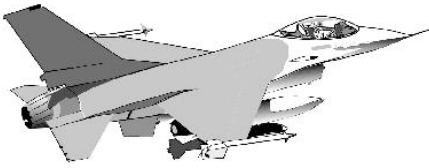
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Trim Drag

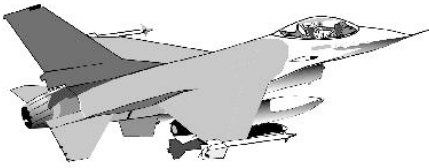


Droste, Carl S., Walker, James E. The General Dynamics Case Study on the F-16 Fly-By-Wire Flight Control System. AIAA Professional Study Series.

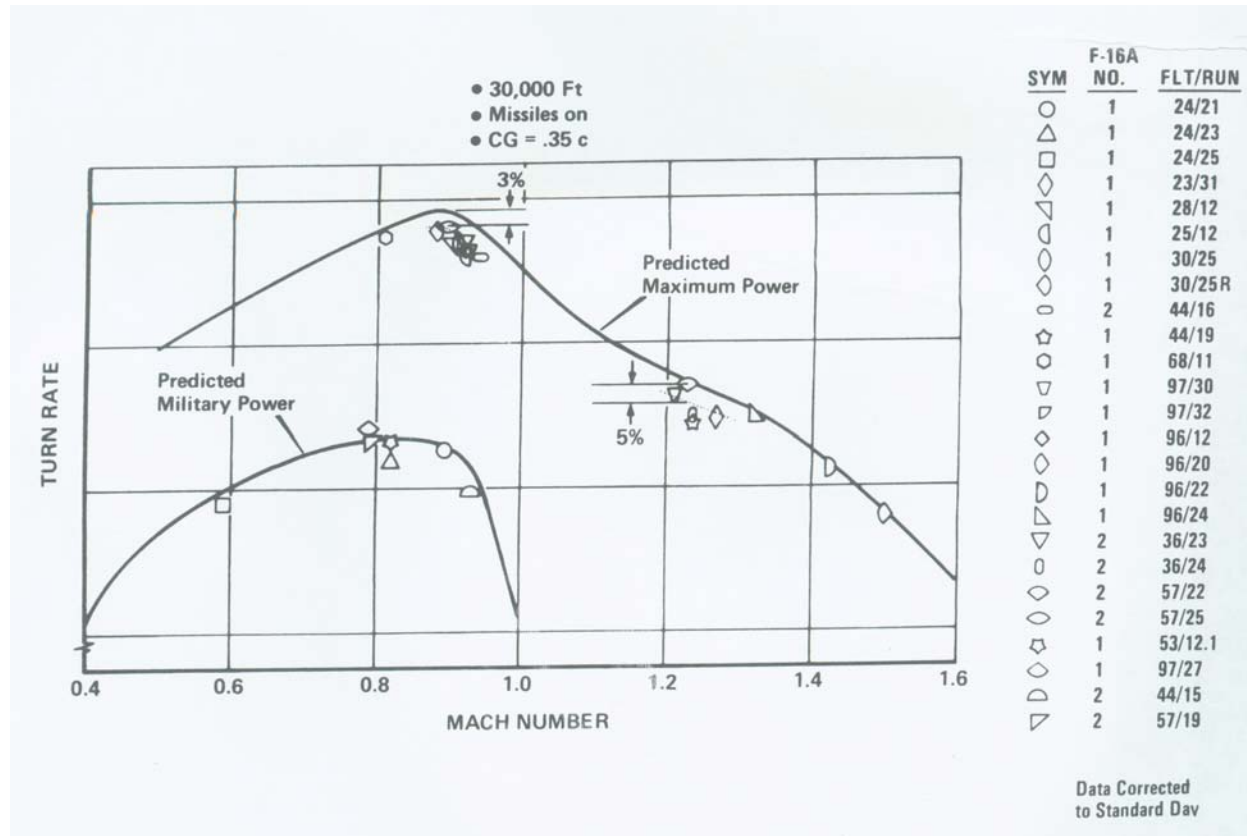


Performance

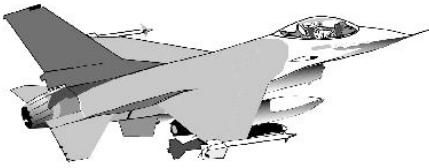
- **Empty Weight – 16,285 lb**
- **Combat Takeoff – 26,536 lb**
- **Maximum Takeoff Weight – 37,500 lb**
- **Wing Loading – 88 lb/ft²**
- **Maximum Thrust – 23,830 lb (27, 000 lb for later models)**
- **Thrust/Weight Ratio – 0.94-1.08**
- **Maximum Velocity – Mach 2.0(+)**
- **Ceiling – 50,000 ft**
- **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**



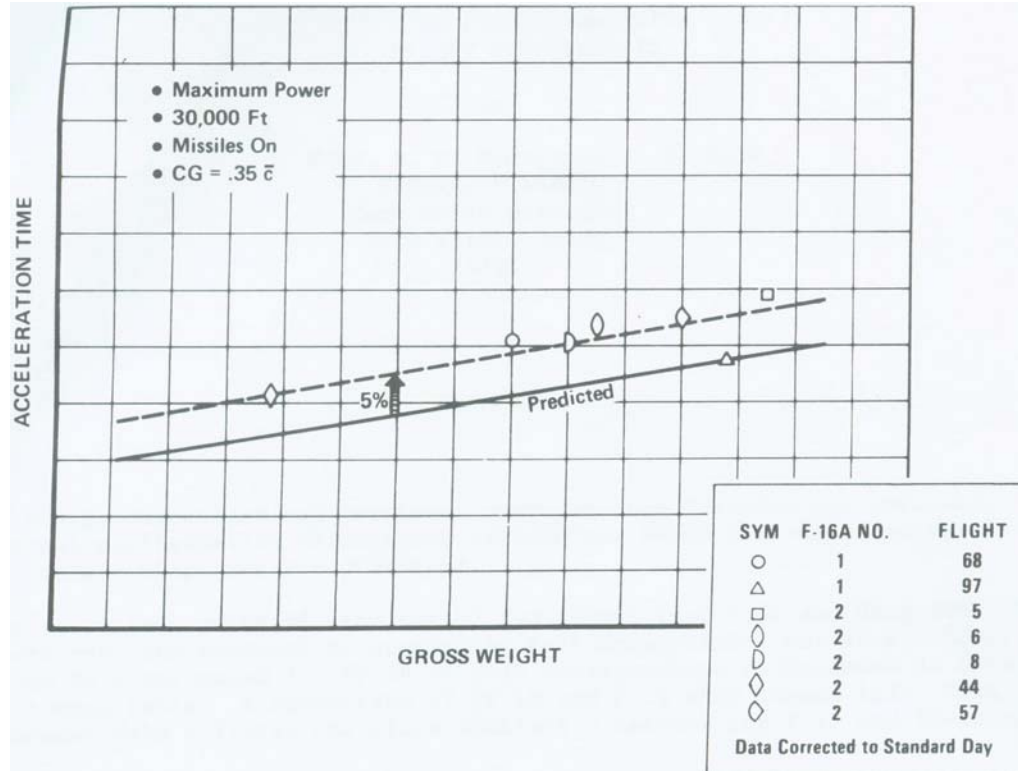
Performance



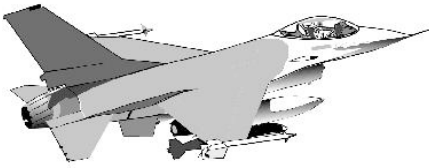
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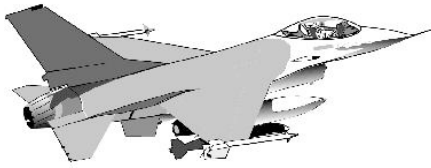
Pros/Cons

Pros

- **Relatively long range**
- **Lower TOGW from various config. Option allows an increased turning rate (10%) and acceleration (30%)**
- **Small size = low radar returns**
- **Bubble canopy has large range of vision**
- **Designed to carry more missiles than specified**
- **Lower cost from using common components**
- **Upgradeable**
- **Increased life in airframe**

Cons

- **Deep stall possible at 60 deg AOA**
- **Fixed engine inlet geometry reduces TOGW, but limits $M < 2$**
- **OEI is a problem with only one engine**
- **Possible problem with control system (fly-by-wire) when struck by lightning**



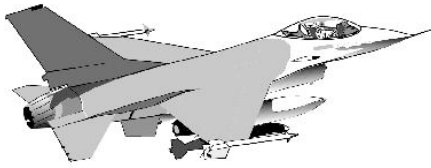
F-16 Experimental Variants

F-16XL



<http://www.brockmoore.com/images/military/F-16XL.jpg>

- **Optimized for supercruise**



F-16 Experimental Variants

AFTI/F-16

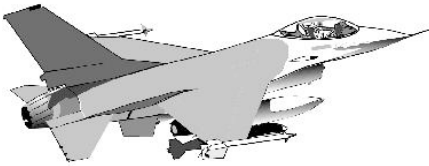


http://www.combatsim.com/archive/images/img_arc-13/aft002.jpg

• **Experimentation with decoupled flight**

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References

Droste, Carl S., Walker, James E. The General Dynamics Case Study on the F-16 Fly-By-Wire Flight Control System. AIAA Professional Study Series.

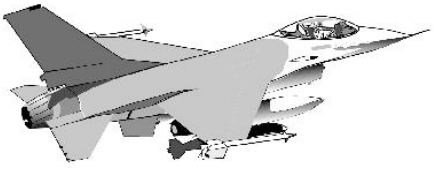
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***F16 falcon.com*. 19 April 2004. <<http://www.f16falcon.com>>**



Questions

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