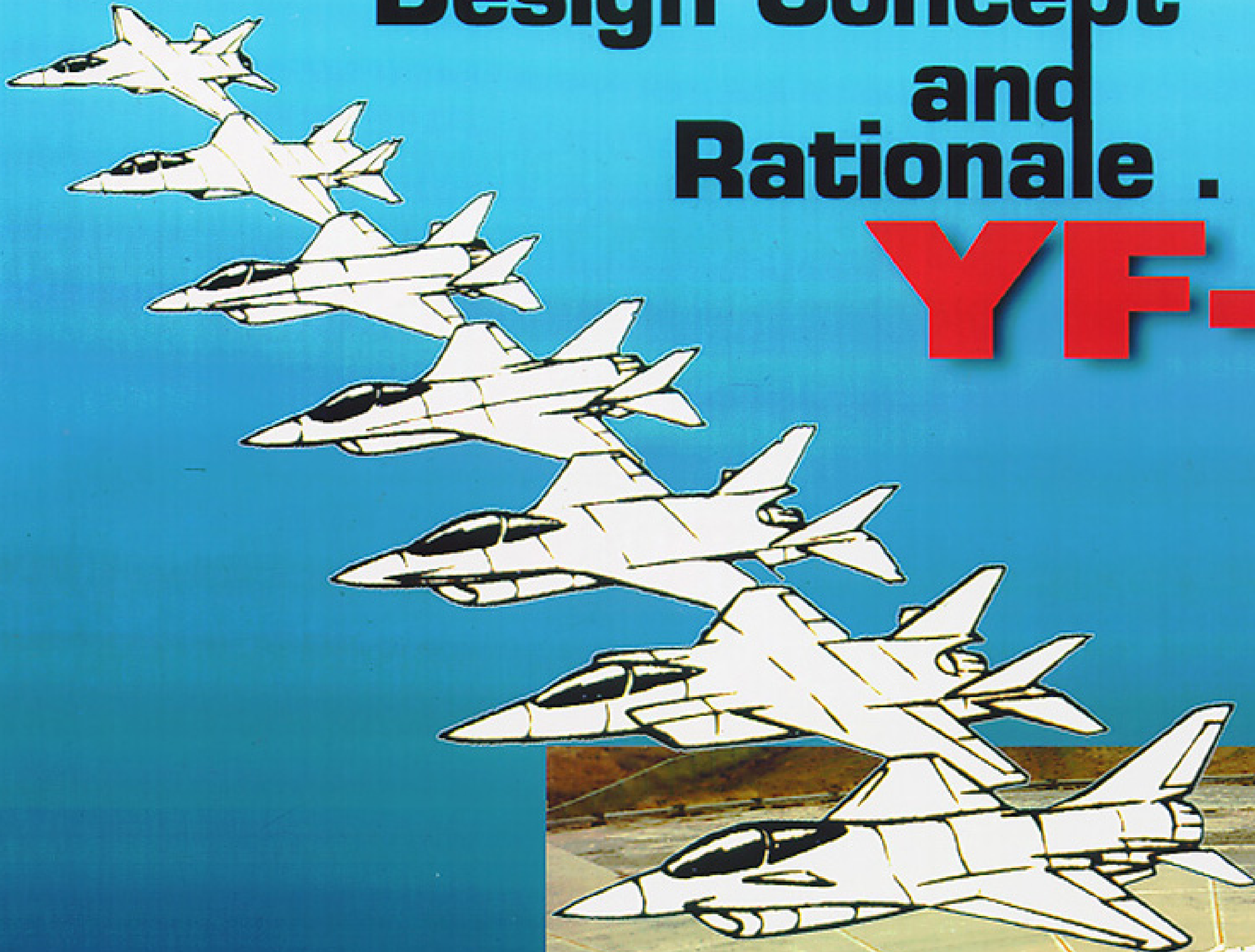
1965

Design Concept and Rationale . . . for YF-16



Presented By:

Harry J. Hillaker
Vice-President (Retired)

Lockheed
Fort Worth Company

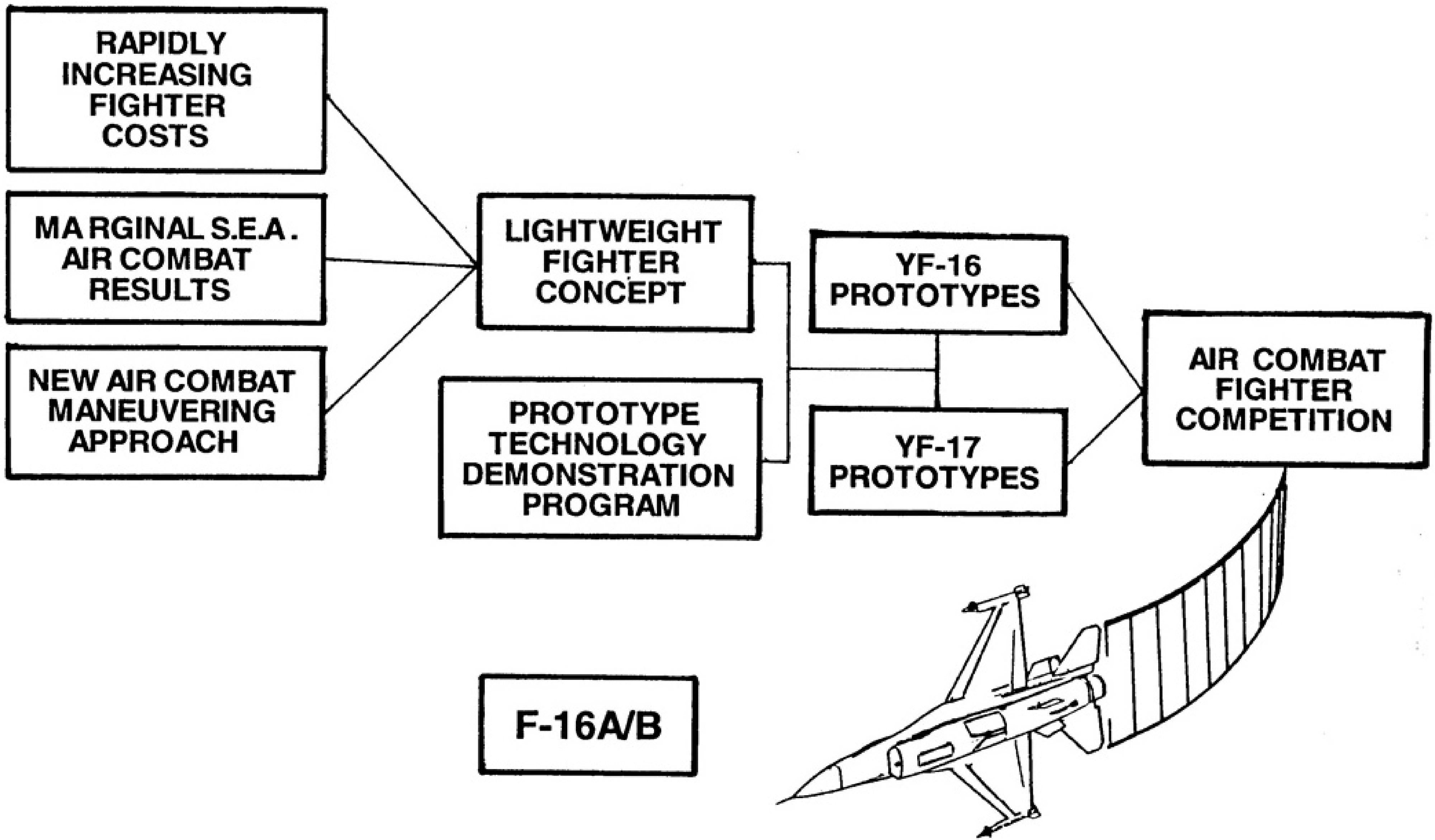
1972

SCOPE OF PRESENTATION

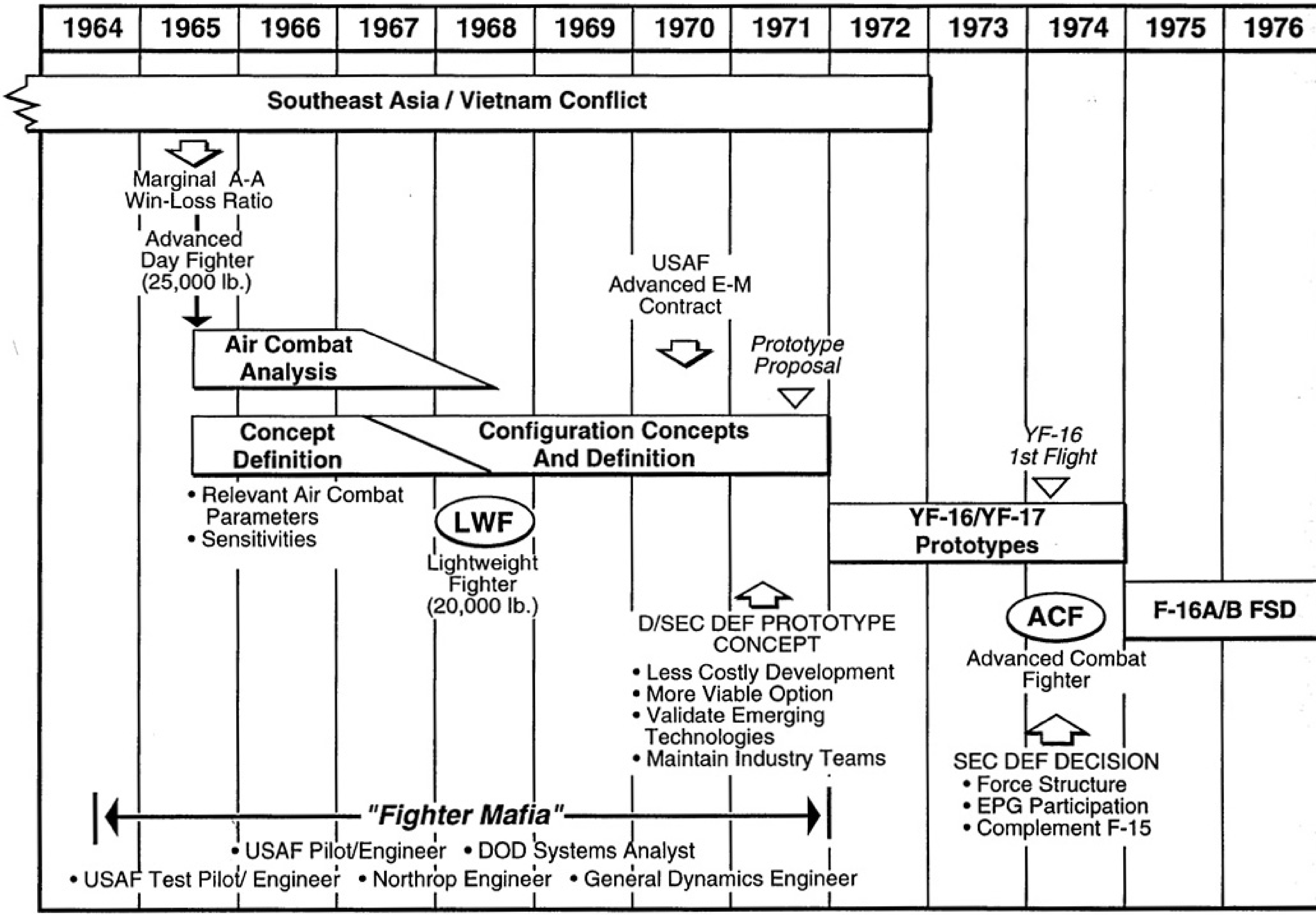
- + BACKGROUND LEADING TO F-16.

- + WHY THE F-16 LOOKS LIKE IT DOES.

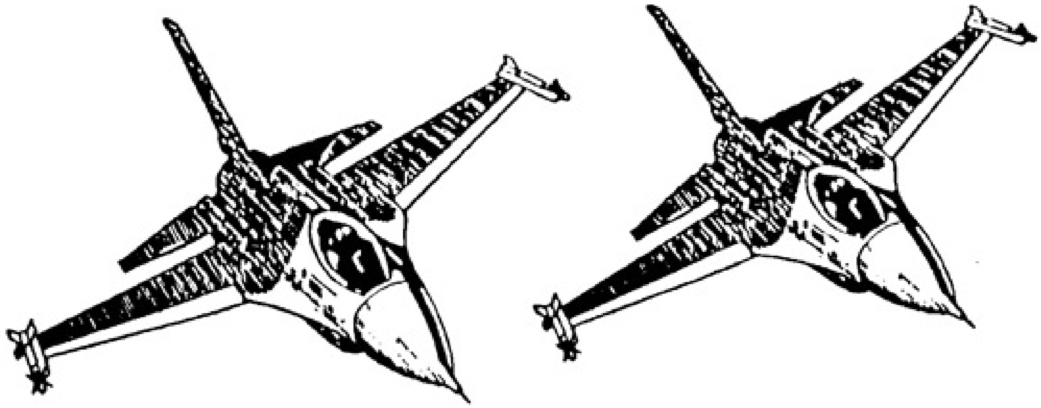
EVENTS LEADING TO F-16



Chronology Of F-16 Development



YF-16 PROTOTYPE PROGRAM



- **TWO YF-16 PROTOTYPES FOR TECHNOLOGY DEMONSTRATION.**
  - **Explore Potential Of Integrated Advanced Technologies**
    - *Emphasis on Airframe Technologies*
  - **Define Operational Utility and Suitability of Concept**
    - *30 Percent of Test Flights*

- **FLEW OVER 350 FLIGHTS TOTALING MORE THAN 400 HOURS IN 10 MONTH PERIOD**

- **TEST PILOTS: (2) Contractor**
  (2) Air Force Flight Test Center
  (1) Air Force Operational Test & Evaluation Center

FORCE SIZE POLICY CHANGED

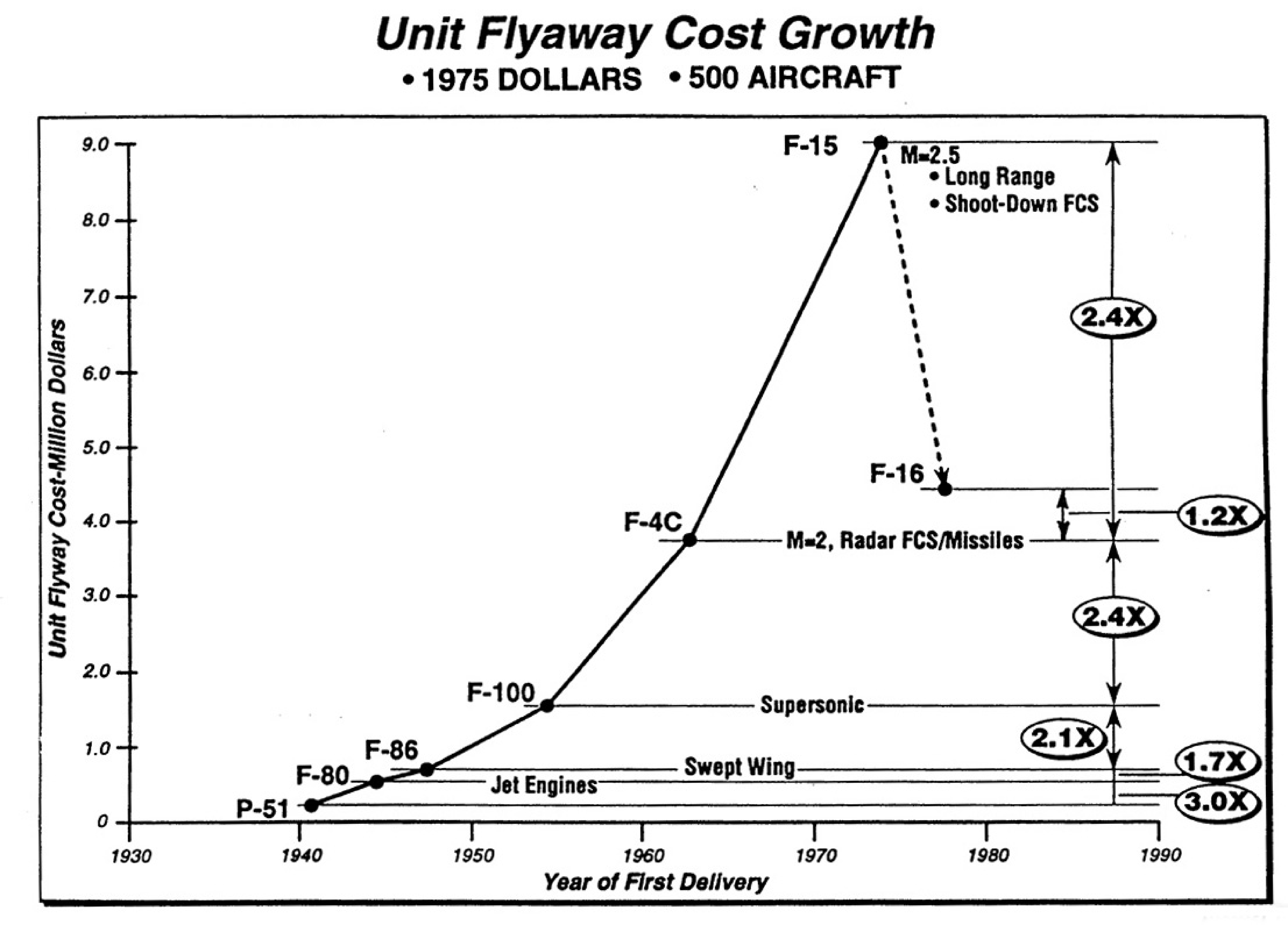
<u>THEN:</u> (1950-60-70)

Fixed Force Size (Numbers) ⇨ ***Cost Secondary***

⇩

<u>NOW:</u>

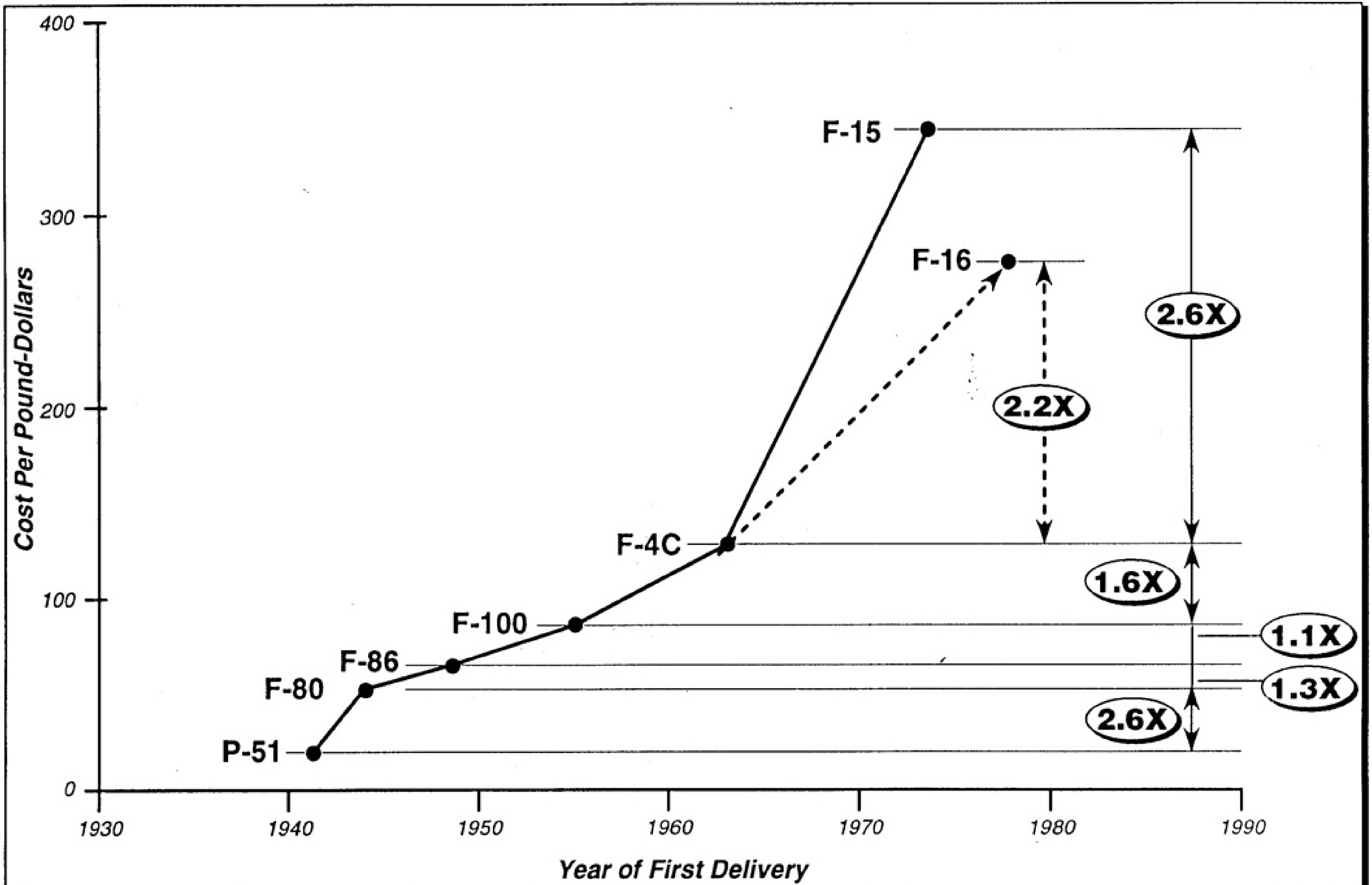
Fixed Budget (Dollars) ⇨ ***Cost Sensitive***



Unit Flyaway Cost Growth
• 1975 DOLLARS • 500 AIRCRAFT
Unit Flyaway Cost-Million Dollars
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1930
1940
1950
1960
1970
1980
1990
Year of First Delivery
P-51
F-80
F-86
F-100
F-4C
F-15
F-16
M=2.5
• Long Range
• Shoot-Down FCS
M=2, Radar FCS/Missiles
Supersonic
Swept Wing
Jet Engines
2.4X
1.2X
2.4X
2.1X
1.7X
3.0X

Cost Per Pound Growth

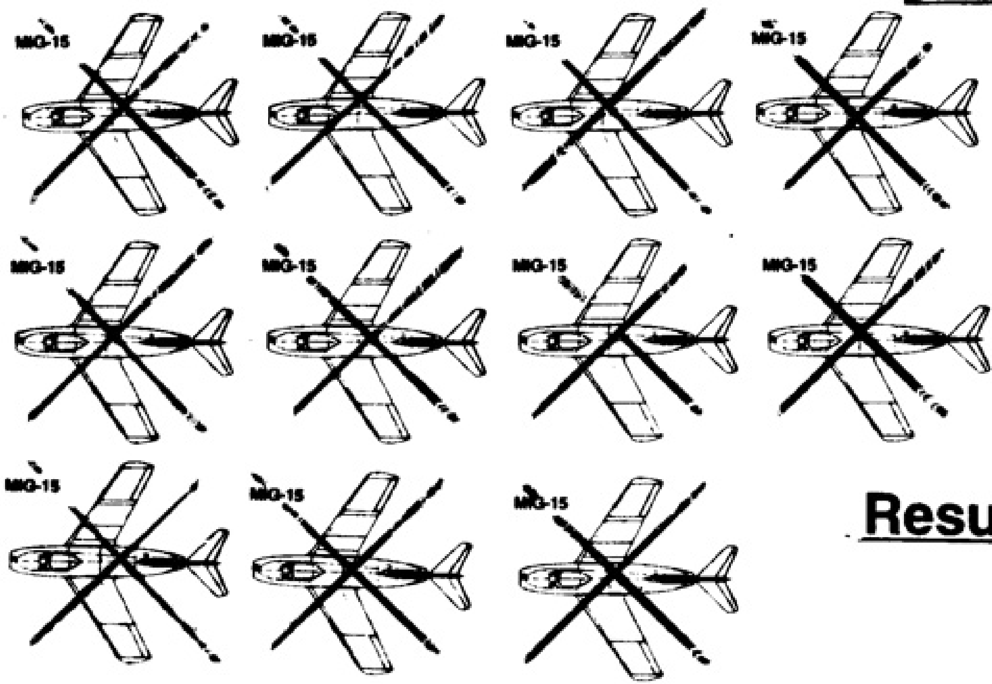
• 1975 DOLLARS • 500 AIRCRAFT



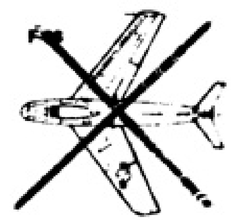
U.S. FIGHTERS LOST COMBAT EFFECTIVENESS

KOREAN WAR

They Lost



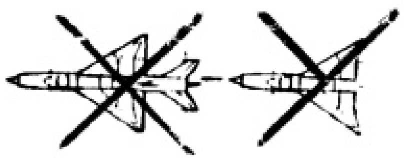
We Lost



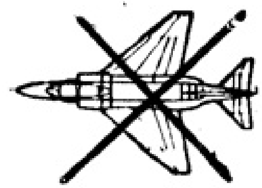
Result: For Every F-86 They Shot Down, We Shot Down 11 Mig-15s

VIET NAM

They Lost



We Lost



Result: For Every F-4 They Shot Down, We Shot Down Only 1.6 Mig-21s

LIGHTWEIGHT FIGHTER CONTROVERSY

- **Advocates** *("Fighter Mafia")*
  - TOO MUCH SOPHISTICATION/HIGHTECHNOLOGY:
    - + Degrades Useful Capabilities and Reliability
    - + Costs Too Much
  - FAVORED QUANTITY (Numbers) OVER QUALITY

- **Detractors**
  - SOPHISTICATION/HIGH TECHNOLOGY NEEDED TO COUNTER NUMERICAL ADVANTAGE OF THREAT
  - FAVORED QUALITY OVER QUANTITY (Numbers)

LIGHTWEIGHT FIGHTER ISSUES

- <u>SIZE:</u> *"TOO SMALL"*

  + "Can't Carry Anything, Can't GO Anywhere."
  + "Good Only For Hotdog Air Shows At County Fairs On Sunny Summer Afternoons."
  + Bitter, Caustic Attacks....Much Acrimony.

- <u>1 vs. 2 ENGINES:</u>

  + Highly Emotional And Biased.
  + Safety/Survival Perception.

AIR COMBAT ANALYSIS

- Initial "Fighter Mafia" Effort: ***Understand The Problem***

  + Define and Analyze Every Element Of Air Combat.
  + What Are Key Elements and Their Sensitivities?
  + Which Have Most Leverage?
  + What Are Interactions?
  + What Parameters Best Define Air Combat Capabilities?
  + What Are Critical Pilot-Airframe Interfaces?

LIGHTWEIGHT FIGHTER BASIS

- **KEY AIR COMBAT PARAMETERS....**

  (1) The Pilot Must First *Observe* and Interpret the Situation.

  (2) Become *Oriented* to the Condition and Intensity of the Situation.

  (3) Make a *Decision* on What Response to Make.

  (4) Put That Response into *Action*.

"OODA LOOP"

OBSERVATION-ORIENTATION-DECISION-ACTION

Accomplish In Shortest Possible Time

"FAST TRANSIENTS" CONCEPT

"FAST TRANSIENTS" CONCEPT

- OPERATE AT A ***FASTER TEMPO*** THAN ADVERSARY
  - + To Generate ***Rapidly Changing*** Conditions...
  - + To ***Inhibit*** His Capacity...
  - + To ***Adapt or React*** to Those Changes...
  - + And ***Suppress or Distort*** His Awareness
- INDUCE A "HODGE PODGE" OF ***CONFUSION AND DISORDER***
  - + To Cause Him to ***Over, or Under React***...
  - + To Conditions or Activities That Appear To Be ***Uncertain, Ambiguous or Incomprehensible***

↓

Maintain High Energy State and Rate of Change
Exceptional Situation Awareness

MANEUVERABILITY SUMMARY

- "FAST TRANSIENTS" ➧ "FAST" IN TERMS OF TIME, NOT NOT NECESSARILY SPEED.

⇩

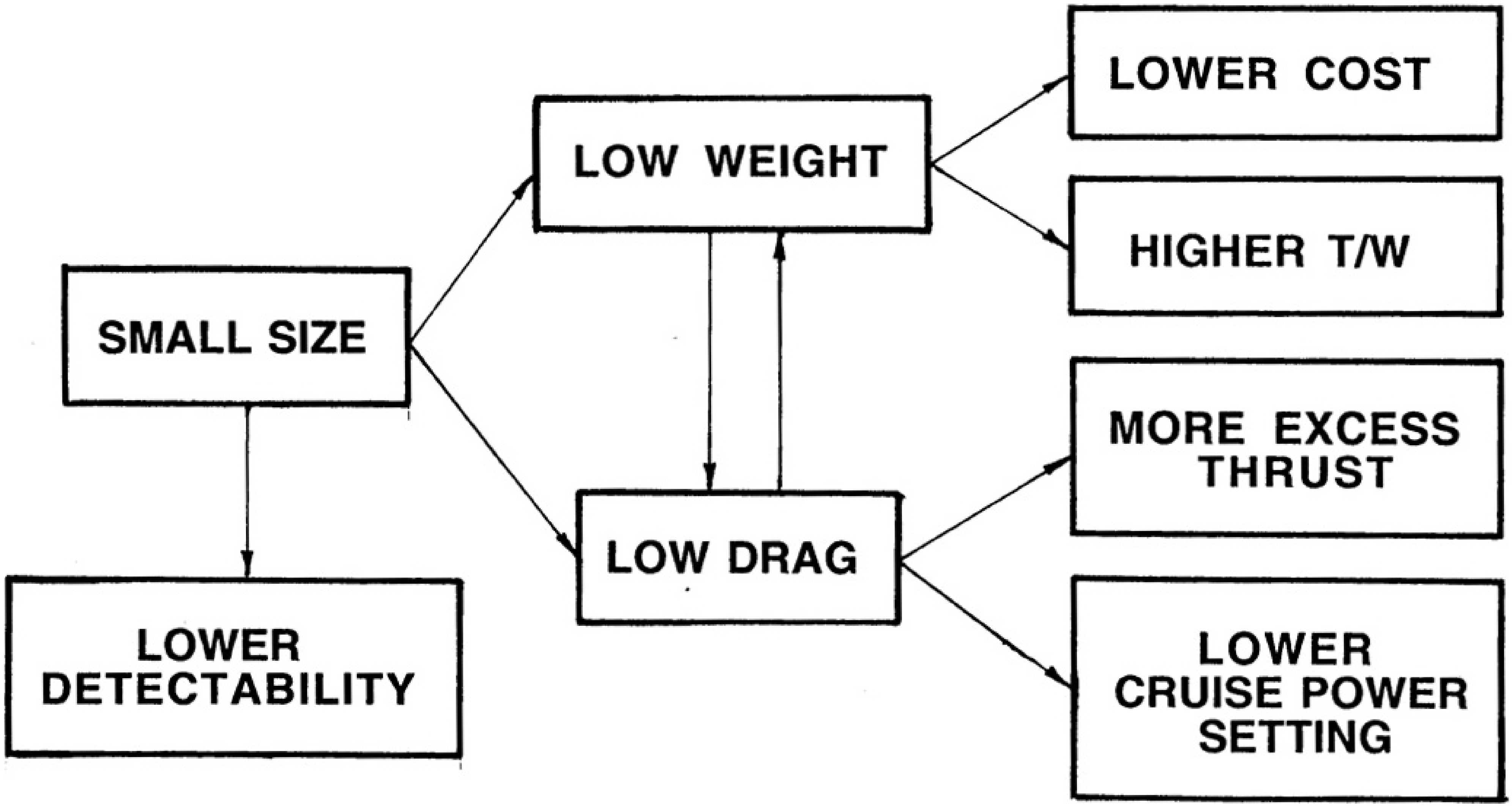
- HIGH ENERGY STATE and RATE OF CHANGE ➧ AGILITY.
  - Low Drag at All Flight Conditions.
  - High Thrust.
  - Responsive Control.

WHAT DOES THIS MEAN?

- **OLD PARAMETERS OBSOLETE**
  - **SUSTAINED TURN RATE** ⇨ **W/S Dominant**
  - **MAXIMUM SPEED (V_{max})** ⇨ **T/W Dominant**

- **RELEVANT PARAMETERS**
  - **INSTANTANEOUS TURN RATE**
    - *Lift*
    - *Pitch Rate*
    - *Moments of Inertia*
    - *Control Inputs*
    - *Roll/Yaw Rate*
    - *Mass Ratios*
    - *Damping*
  - **ACCELERATION**
    - *Excess Thrust*

SIZE and WEIGHT DOMINATE

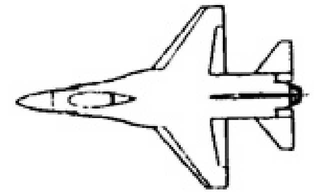


- *SIZE and WEIGHT HAVE INTERACTIVE BENEFITS*

IMPACT OF SMALL SIZE

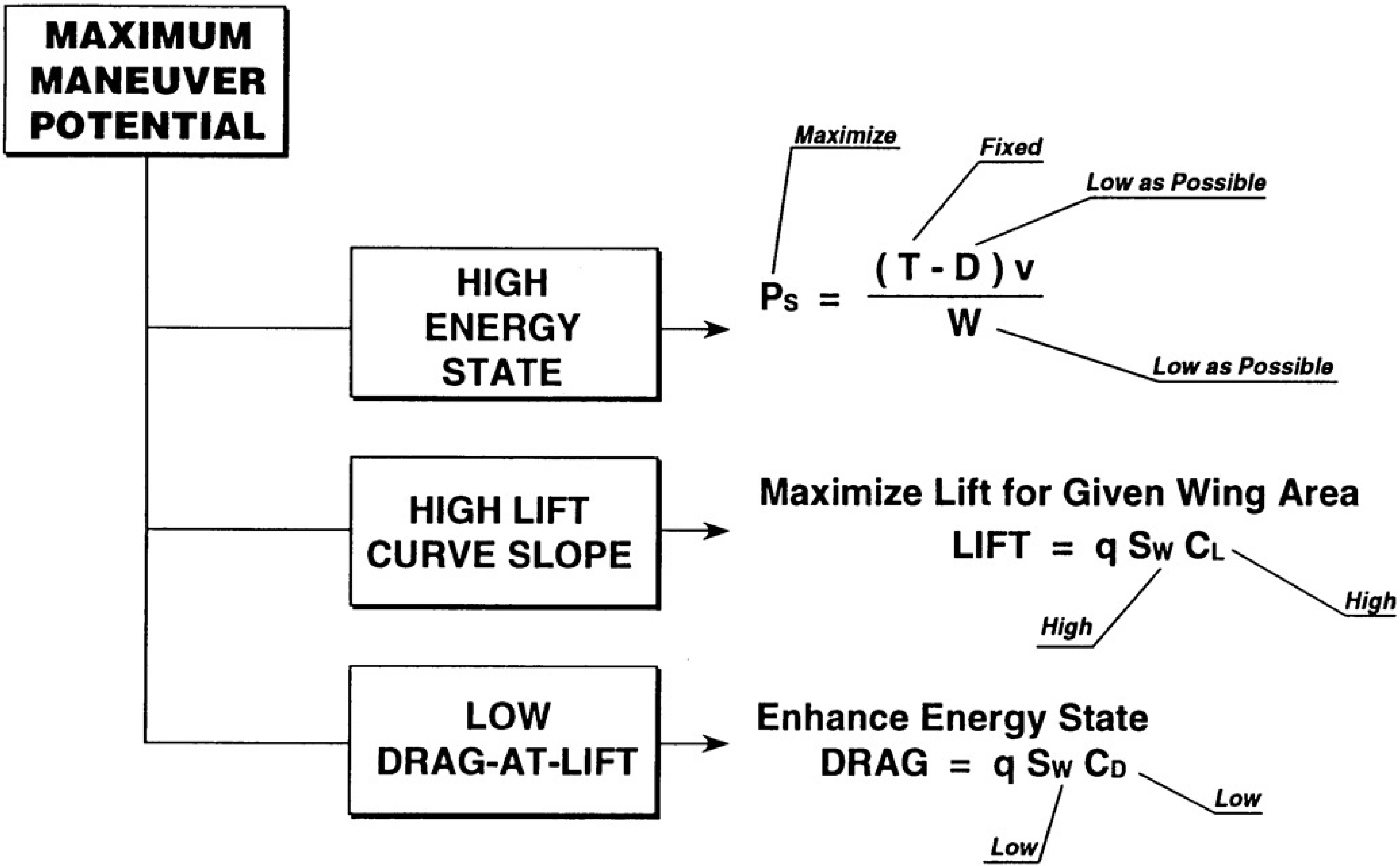
F-4E

F-16A

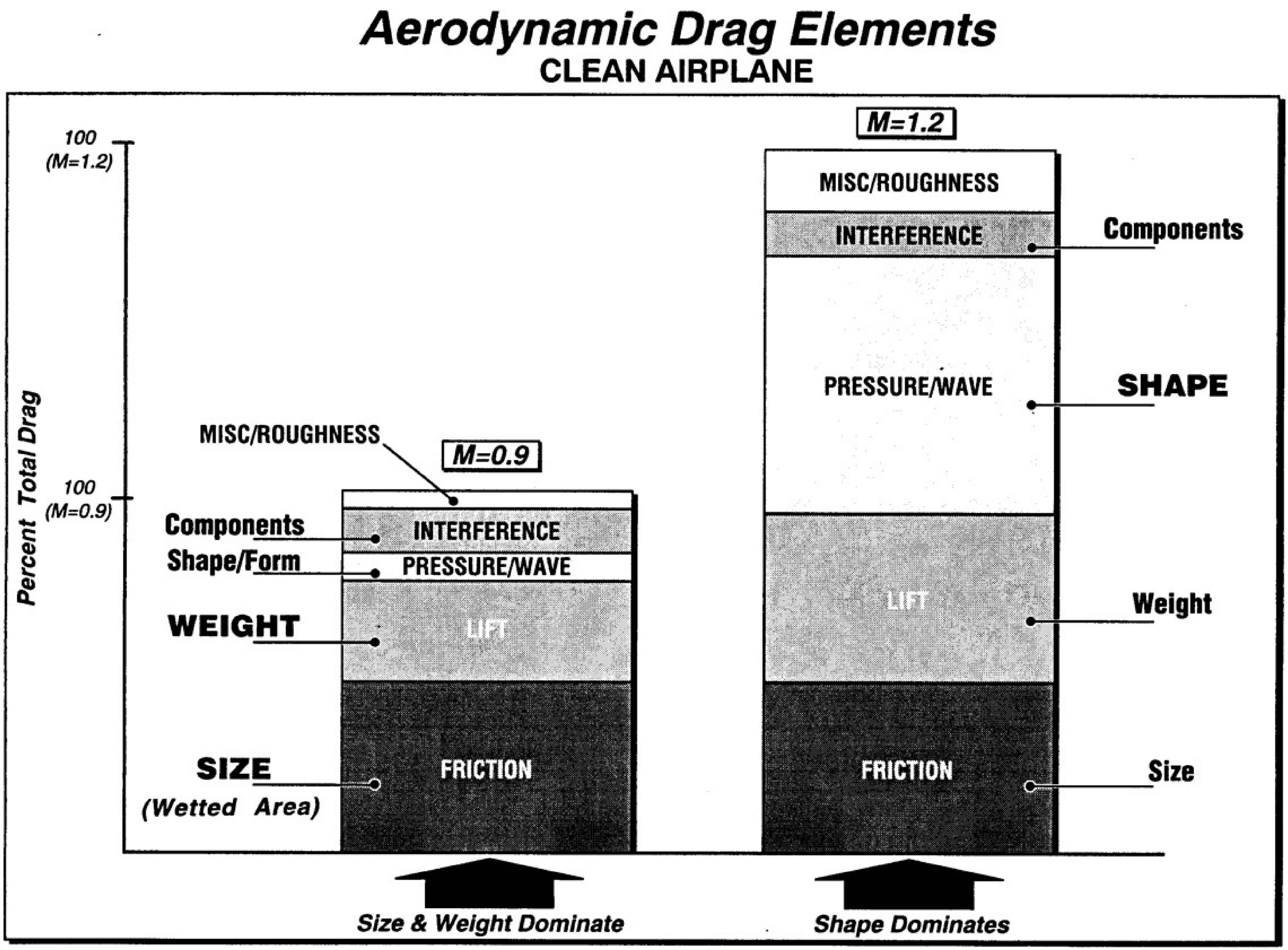


		F-4E	F-16A	
WETTED AREA		2063	1405	68%
CRUISE	Drag (lb) (lb/sq ft A_W)	5023 (2.43)	2514 (1.13)	50% (47%)
	Fuel Flow (lb/hr)	5488	1588	29%
COMBAT 5g @ M=.9/30K	Drag (lb)	74,446	14,676	20%
	Specific Energy Loss (fps)	-1243	-138	11%
	Fuel Flow (lb/hr)	42,180	25,780	61%

Key Maneuver Parameters



P_S = Specific Excess Power



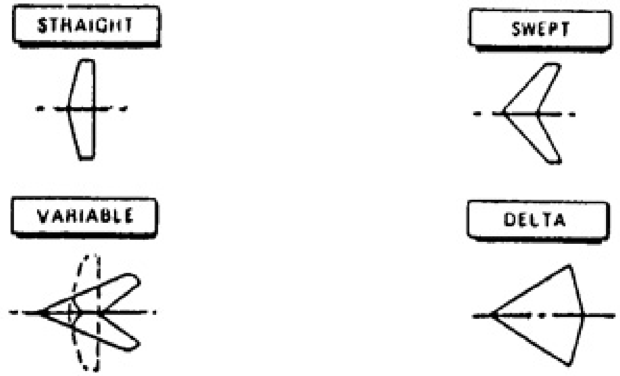
Aerodynamic Drag Elements
CLEAN AIRPLANE
Percent Total Drag
100 (M=1.2)
100 (M=0.9)
M=0.9
M=1.2
MISC/ROUGHNESS
INTERFERENCE
PRESSURE/WAVE
LIFT
FRICTION
Components
Shape/Form
WEIGHT
SIZE
(Wetted Area)
SHAPE
Weight
Size
Size & Weight Dominate
Shape Dominates

BASIC AIR-TO-AIR NEEDS

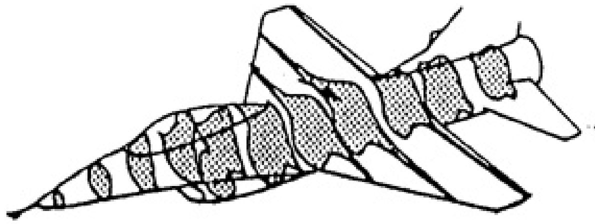
- **Enough:**
  - **Lift** to maneuver to an advantage.
  - **Precise, Responsive Contol** to manage the lift.
  - **Strength** to preserve that lift.
  - **"G" Tolerance** to be effective at that lift.
  - **Energy** to sustain the advantage.
  - **Visibility** to assess that advantage.
- **Plus,** the sensors, displays, controls, and weapons to convert the advantage into a "win."

LIFT GENERATION ELEMENTS...

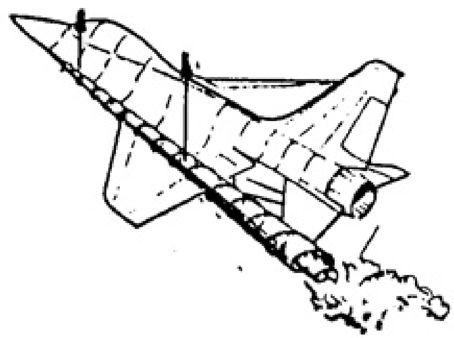
- **WING PLANFORM:**
  - **Area**
  - **Aspect Ratio (Span), Sweep, Taper Ratio**
  - **Airfoil Section: Camber and Thickness**



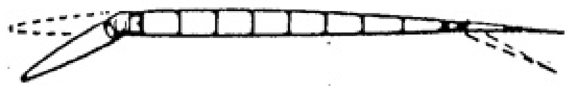
- **BODY:**



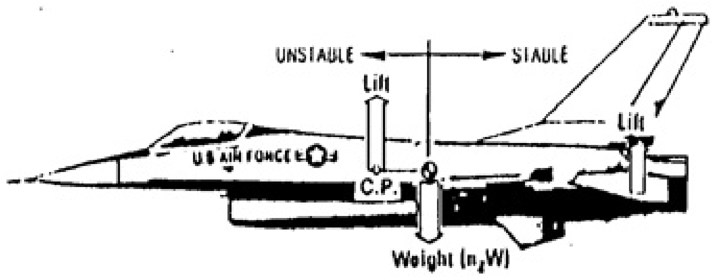
- **VORTEX INDUCED:**



- **VARIABLE WING CAMBER:**



- **LIFTING HORIZONTAL TAIL:**



KEY MANEUVERABILITY PARAMETERS

- WING LOADING (W/S) AND THRUST LOADING (T/W) USED ONLY AS NOTIONAL MEASURES OF MANEUVERABILITY.

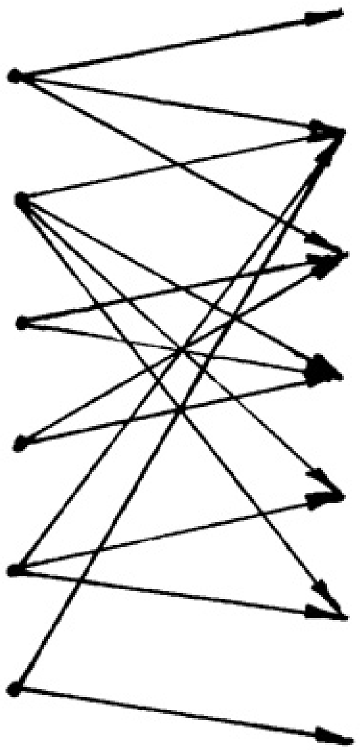
- THESE PARAMETERS WERE ANALYZED TO DEFINE ***MAXIMUM USABLE MANEUVERABILITY***......

    - Longitudinal instability or uncontrolled oscillations.
    - Lateral/directional divergence.
    - Spin divergence.
    - Buffet on-set.
    - Roll/pitch rate & time-to-bank/pitch.
    - Stick forces.
    - Engine stall margin/pressure recovery at angle-of-attack.
    - Engine spool-up time.

PRECISE, RESPONSIVE CONTROL...

- **<u>Function of:</u>**

  - Pitch Rate
  - Roll/Yaw Rate
  - Moments Of Inertia
  - Mass Ratio
  - Damping
  - Control Inputs

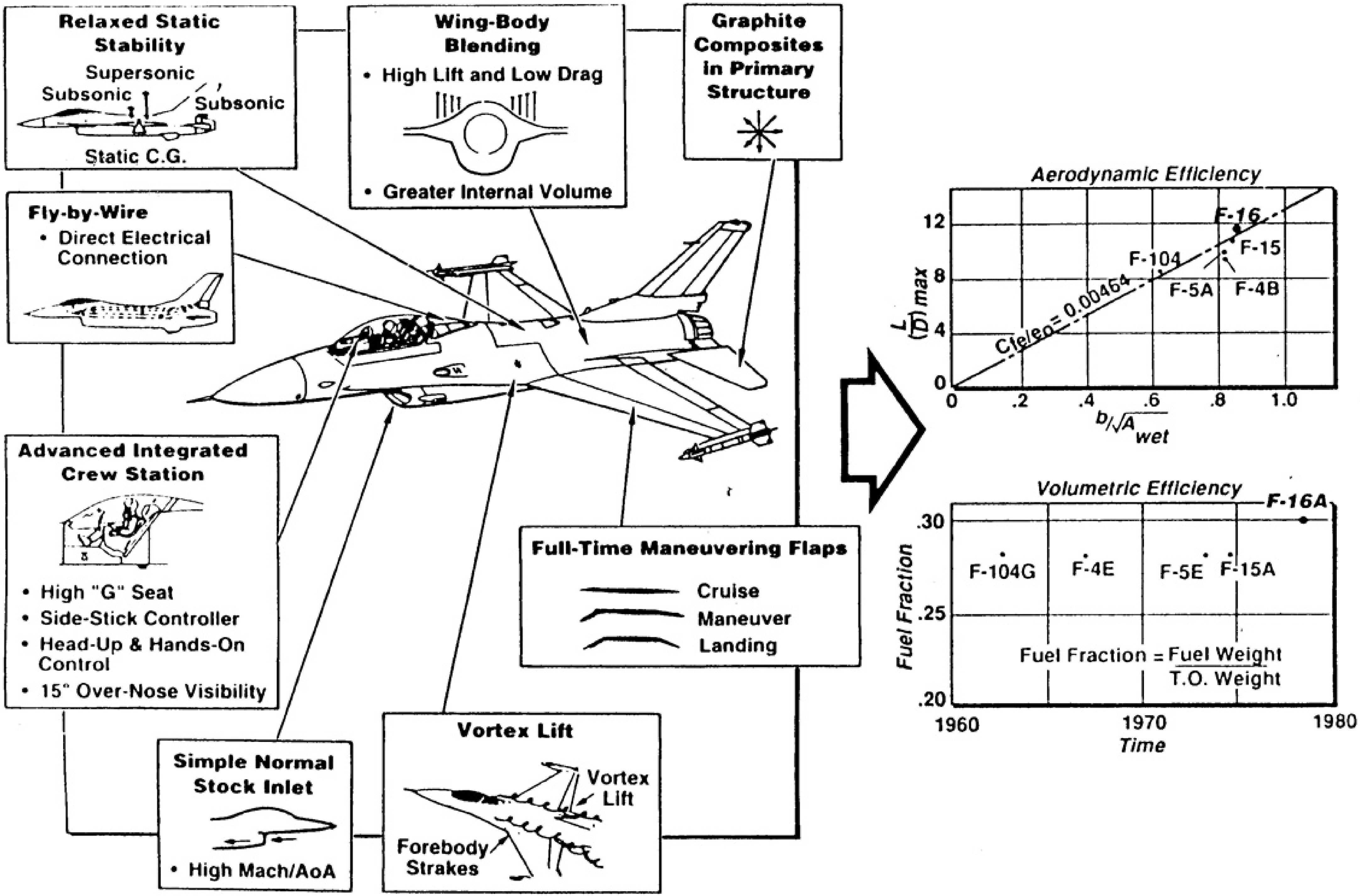


<u>Resulting form:</u>

Relaxed Static Stability
Fly-By-Wire
Short Fuselage
Short Wing Span
Combined Flaperons/Elevons
Vertical Tail/RudderSize
Side, Force Stick

- **<u>Key Agiliy Factor</u>:** e.g. Time-to bank parameter more important than roll rate.

ADVANCED TECHNOLOGIES APPLIED



ADVANCED TECHNOLOGY BENEFITS

- **ADVANCED AIRFRAME TECHNOLOGIES AS APPLIED TO YF-16 RESULTED IN:**
  - **Higher Maximum Usable Maneuverability**
  - **Lower Drag ➧ Higher Specific Range**
  - **Higher Fuel Fraction**
  - **Lower Weight ➧ More Affordable Cost**

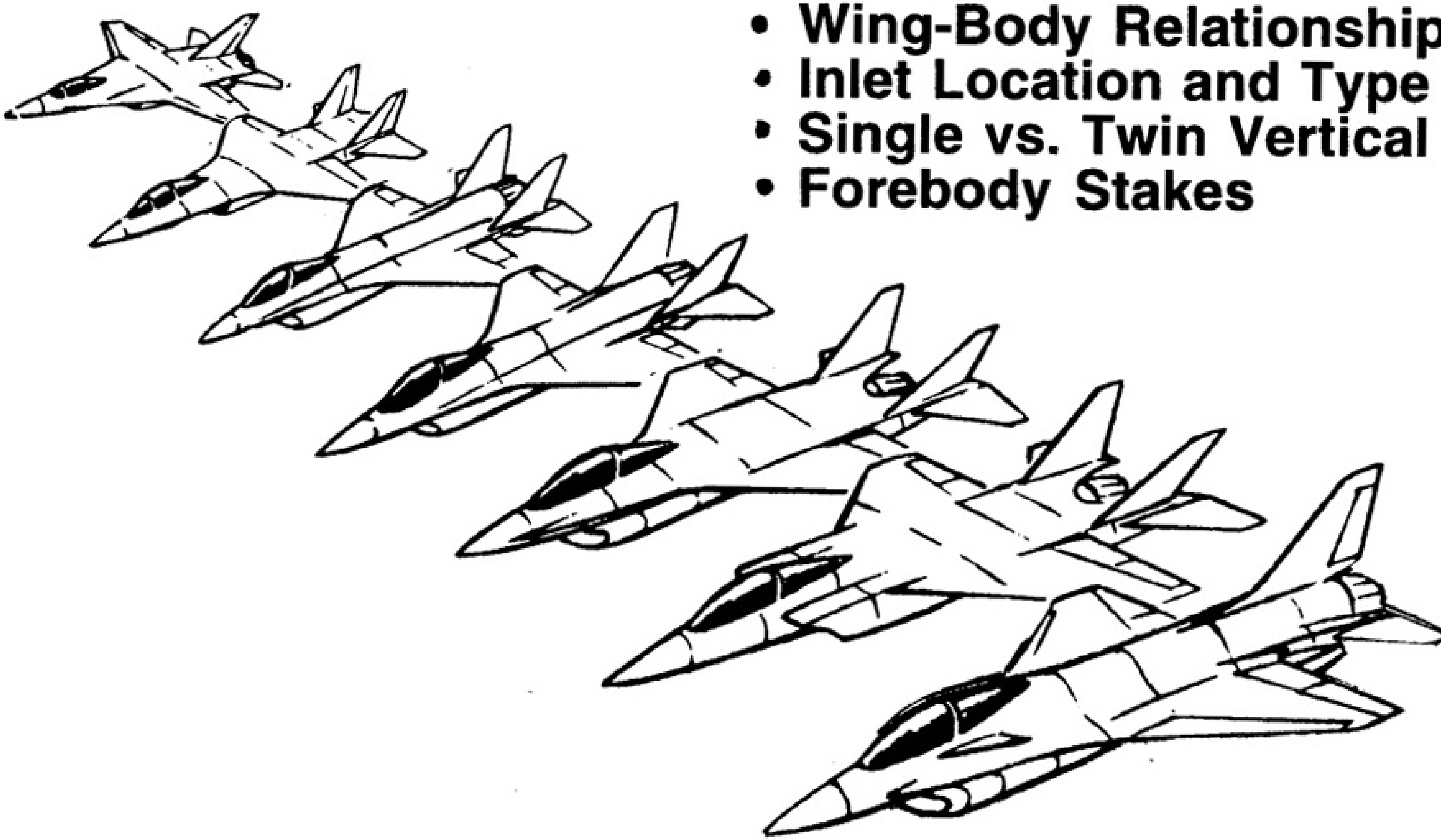
- **INTEGRATION REDUCED THE MISSION DESIGN GROSS WEIGHT BY 7280 LBS.** *Not Including 1 vs. 2 Engine Weight Difference*

- **YF-16 AIRFRAME TECHNOLOGIES HAVE SUSTAINED CONTINUED IMPROVEMENTS AND MOST ARE BEING DUPLICATED IN TODAY'S FIGHTERS**

CONFIGURATION ANALYSIS

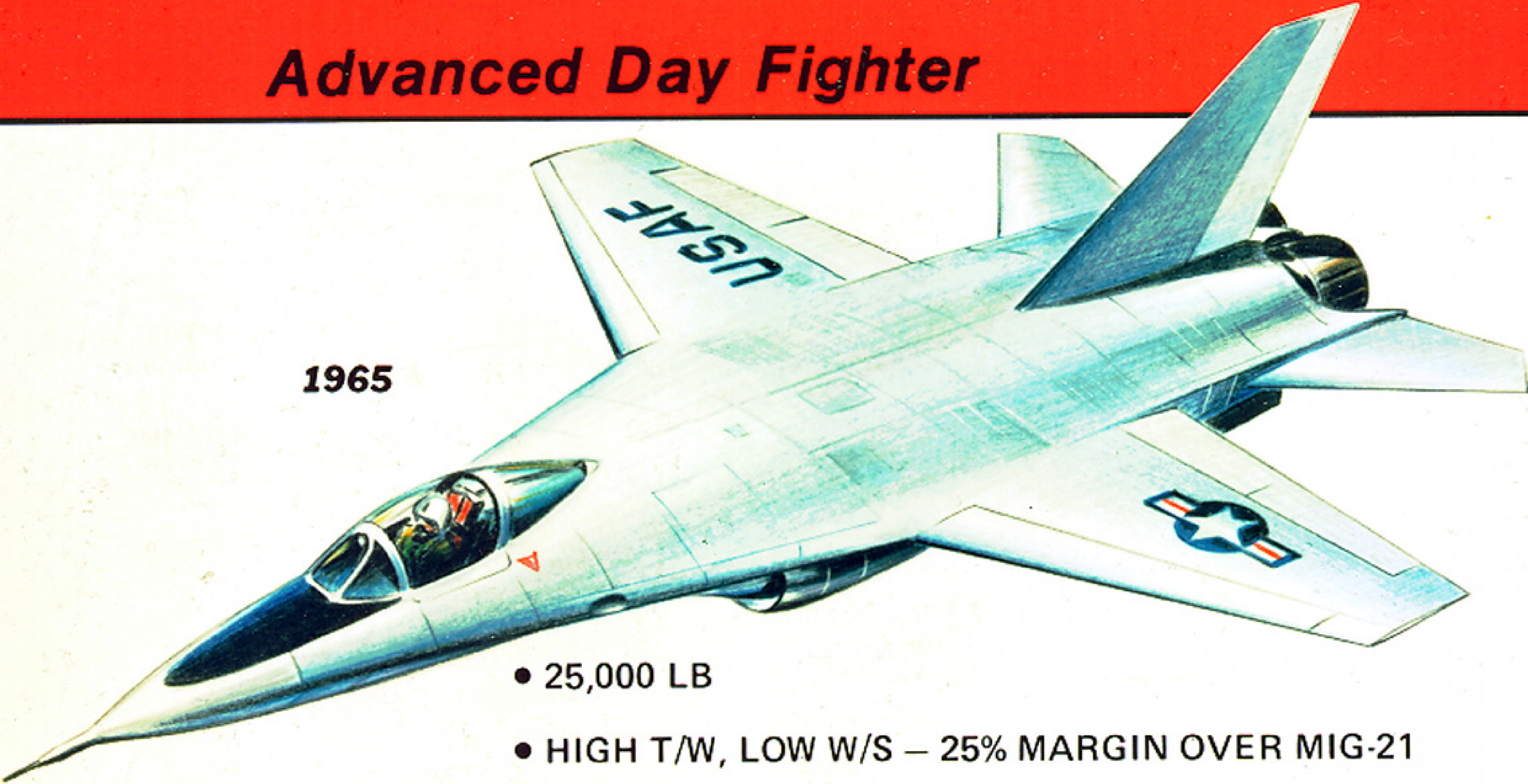
- **PRELIMINARY CONFIGURATIUON DEFINITION**
  - **EXPERIMENTAL DATA (WIND TUNNEL) BASED.**
  - **78 COMBINATIONS OF VARIABLES.**

- **Wing Planform**
- **Airfoil Section - Fixed and Variable**
- **Wing-Body Relationship**
- **Inlet Location and Type**
- **Single vs. Twin Vertical Tail**
- **Forebody Stakes**



Advanced Day Fighter

1965



- 25,000 LB
- HIGH T/W, LOW W/S – 25% MARGIN OVER MIG-21
- FOXBAT DISCLOSURE PRECIPITATED ALL-WEATHER, HIGH SPEED EMPHASIS

Lightweight Fighter

- 18,000 – 20,000 LB.
- HIGHER T/W (1.2–1.4), LOWER W/S (60)
- MINIMUM AVIONICS

LWF Force Models Tested

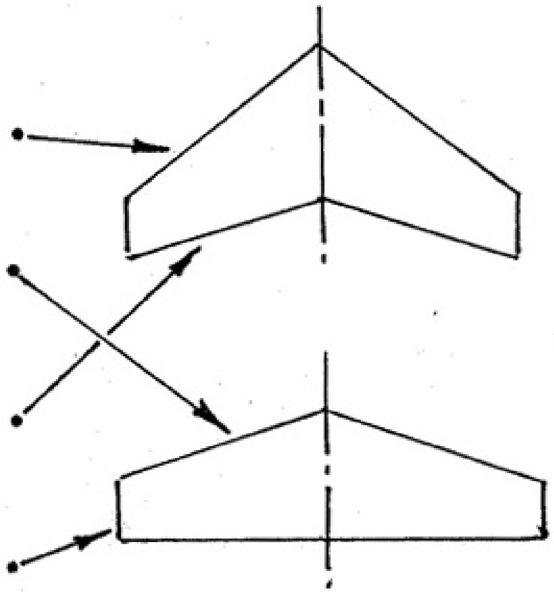
- 78 Significant Variations
- M=.2-2.2 • α =28° • β =12°

	Configurations Tested	WINGS Λ_{LE}	WINGS Fixed Camber	WINGS Variable Camber	WINGS Airfoil(s)	INLETS Side	INLETS Bottom	VERTICAL TAILS Twin	VERTICAL TAILS Single	VORTEX LIFT (Forebody Strakes)	WIND TUNNEL TEST HOURS
Coventional Forebody	785	40°	✓		64A205 & 64A403.5		✓		✓	✓	48
		35°	✓		64004.9 & 64043.5		✓		✓		20
	786 TWIN TAIL 785	40°		✓	64A205 & 64A403.5		✓	✓		✓	48
Wing/Forebody Shaping	401F-0	35°		✓	4% BICONVEX		✓	✓			187
		40°	✓		64A204		✓	✓		✓ (2) STRAKES	
	401F-2	40°		✓	64A204		✓ ✓	✓	✓	✓	91
		35°		✓	64004.9 & 64043.5			✓			
	401F-3 FERRI INLET	40°		✓	64A204		✓	✓			20
	401F-4 HIGH WING	40°		✓	64A204		✓	✓	✓	✓ (3) STRAKES	39
	401FS	40°		✓	64A204	✓		✓			29
	401F-5	40°		✓	64A204		✓	(3) HORIZ TAIL POSITIONS	✓	✓	130
	401F-5A	40°		✓	64A204		✓		✓	✓	30
	401F-10	40°		✓	64A204		✓		✓	✓	30
	401F-10A	40°		✓	64A204		✓		✓	✓	32
	401F-16	40°		✓	64A204		✓		✓ (2)	✓	442
		45°	✓	✓	CONICAL CAMBER 64A(X)5.9/64A203						
	401F-16E	40° Wing Moved Forward 14 inches		✓	64A204		✓		✓ (2)	✓	126

TOTAL WIND TUNNEL HOURS 1272

COMBAT RULES IMPACT ON WING GEOMETRY

Priority	Condition	Shape Effect
①	Mach 1.2 Turns (30,000 ft.)	
②	Mach 0.9 Turns (30,000 ft.)	
③	Acceleration (M = .8 - 1.6 at 30,000 ft.)	
④	Maximum "g" at M = .8 at 40,000 ft.	



- **Variable Sweep.....Fixed Airfoil Camber - Variable Planform (F-111).**

- **Suggests Variable Geometry Wing.**

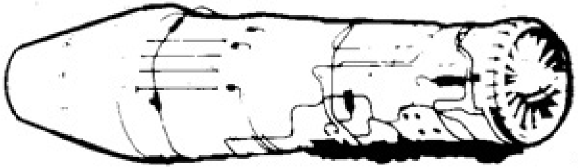
- **Variable Camber.....Fixed Planform - Variable Airfoil.**

SIZE & ENGINE BASIS

DEFINE TRADE-OFFS OF WEIGHT AND PERFORMANCE

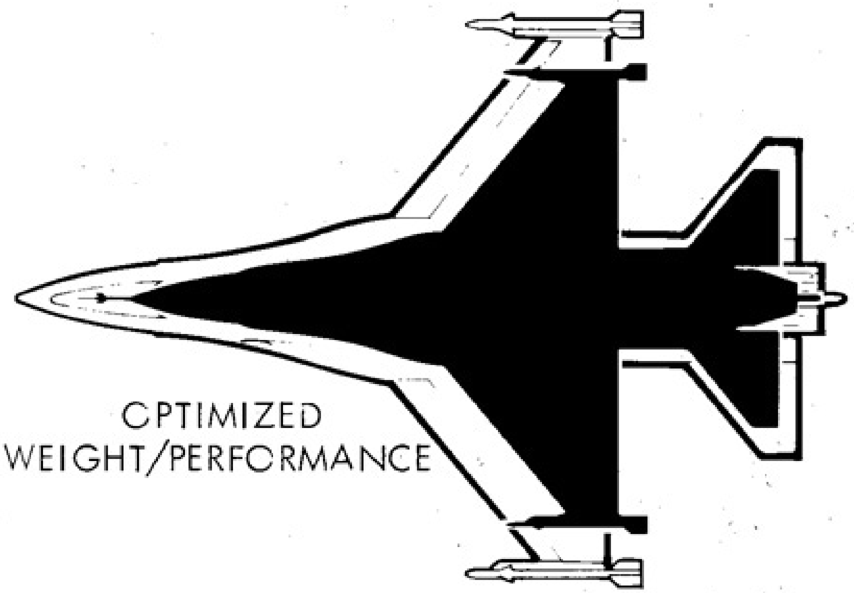
- BEST COMBAT PERFORMANCE
- LOWEST MISSION WEIGHT

DESIGN WEIGHT AND ENGINE

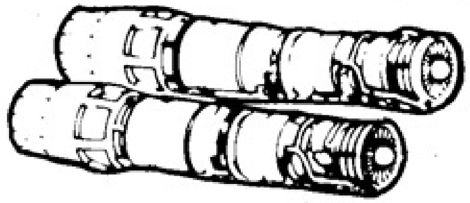


- SINGLE P&W ENGINE

17,050 LBS.



OPTIMIZED WEIGHT/PERFORMANCE



- TWIN GE ENGINES

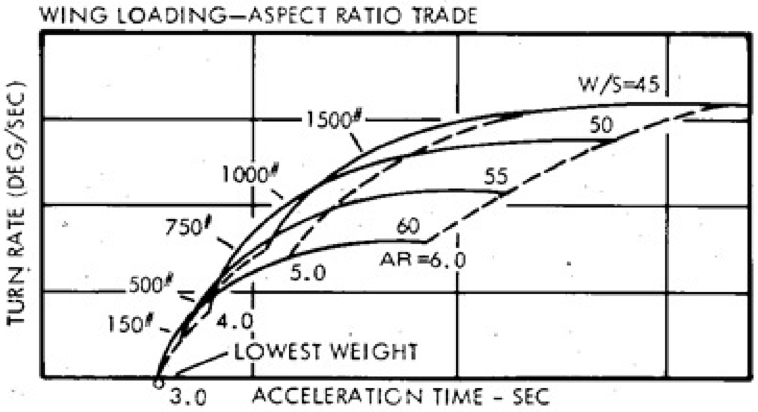
21,470 LBS.

- SINGLE GE ENGINE

COULD NOT MEET OBJECTIVE

WING GEOMETRY

WING LOADING VS. ASPECT RATIO TRADE

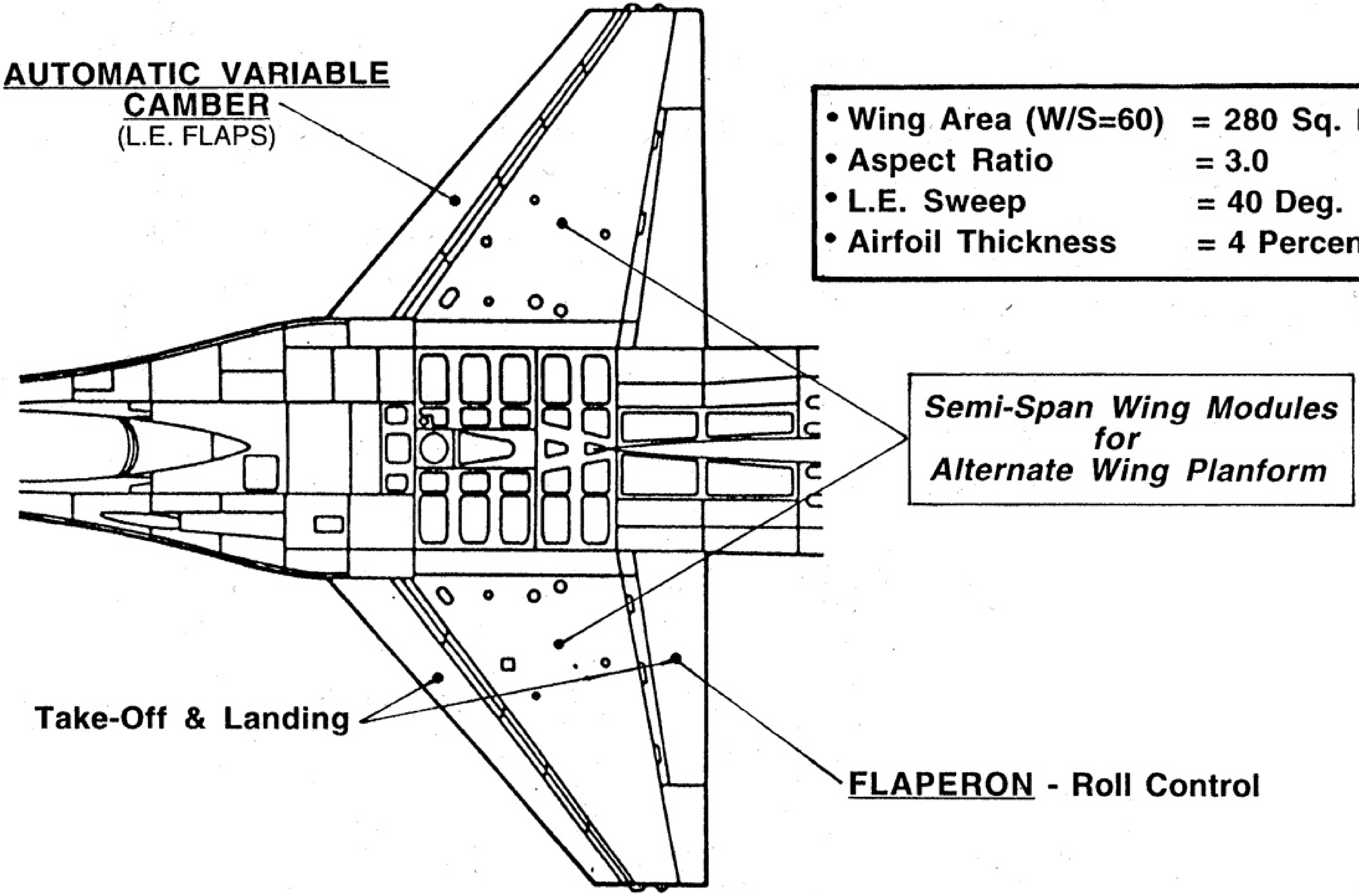


BEST BALANCE OF TURN RATE & ACCELERATION

WING GEOMETRY DEFINITION

Best Balance of Turn Rate and Acceleration

- Wing Area (W/S=60) = 280 Sq. Ft.
- Aspect Ratio = 3.0
- L.E. Sweep = 40 Deg.
- Airfoil Thickness = 4 Percent



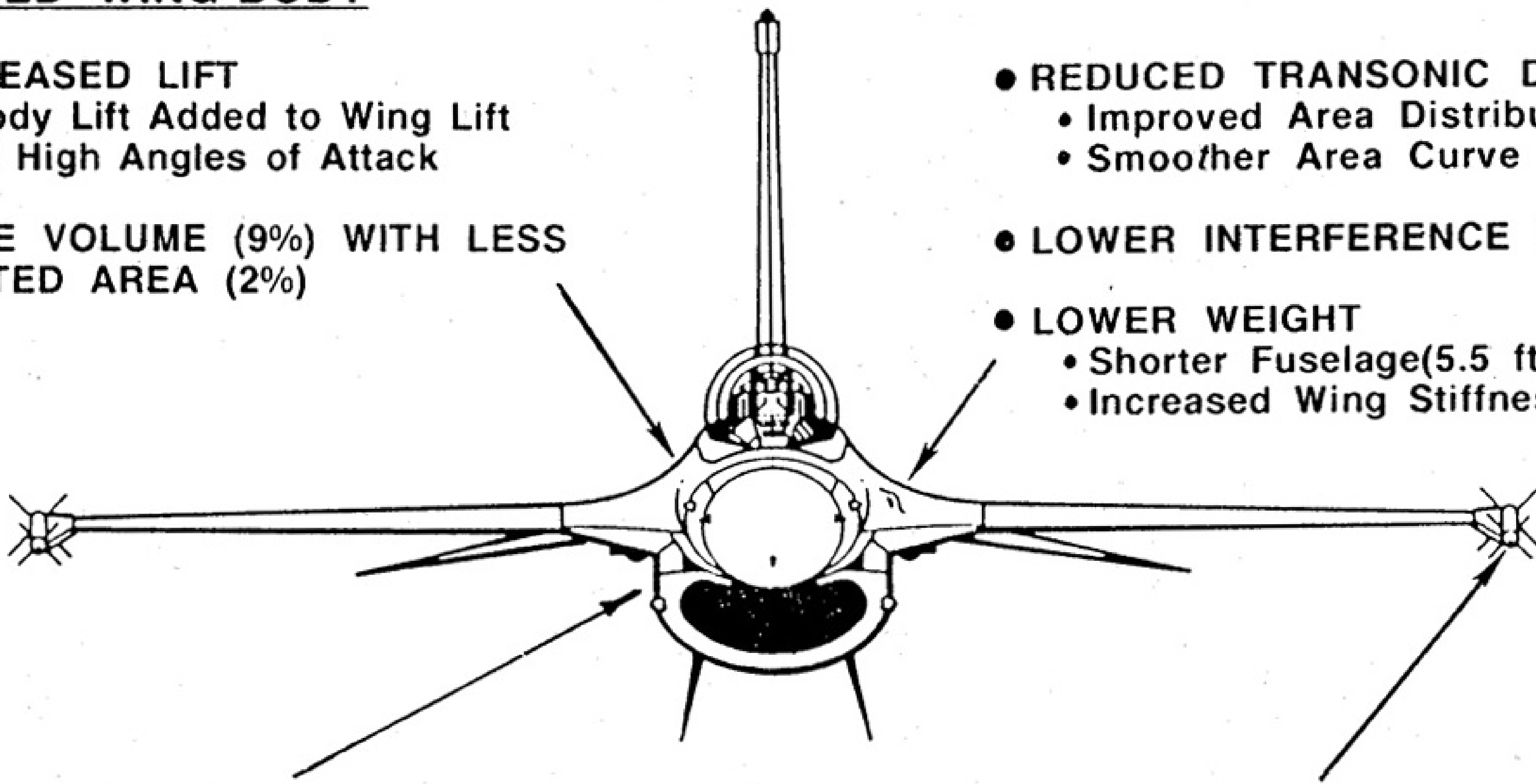
LIFT & DRAG FUNCTION

INCREASE LIFT, LOWER DRAG

BLENDED WING-BODY

- INCREASED LIFT
  - Body Lift Added to Wing Lift At High Angles of Attack
- MORE VOLUME (9%) WITH LESS WETTED AREA (2%)

- REDUCED TRANSONIC DRAG
  - Improved Area Distribution
  - Smoother Area Curve
- LOWER INTERFERENCE DRAG
- LOWER WEIGHT
  - Shorter Fuselage(5.5 ft.): -320 lb.
  - Increased Wing Stiffness: -250 lb.

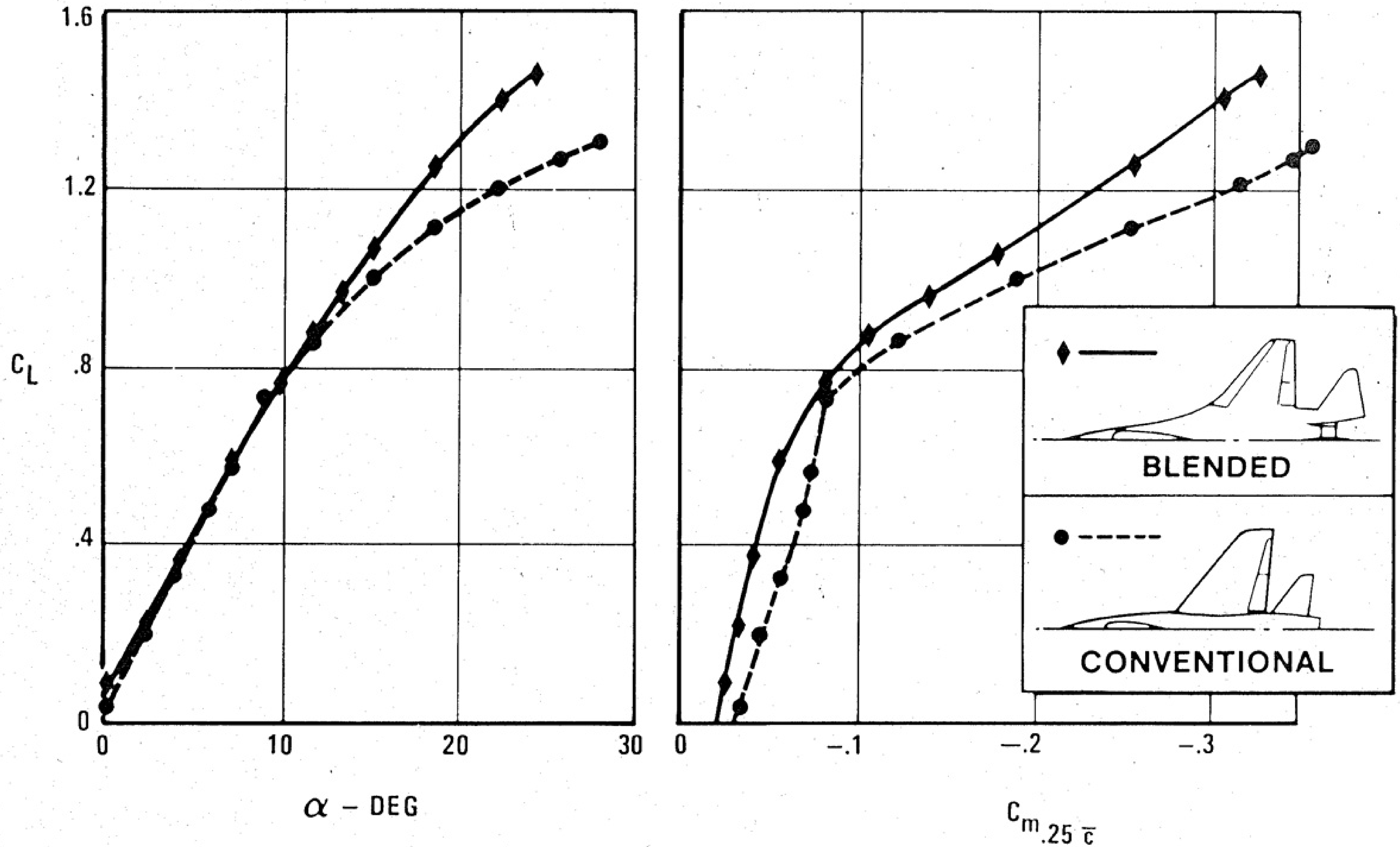


- LOWER PITCHING MOMENT
  - Vertical C.G. Closer To Thrust Line

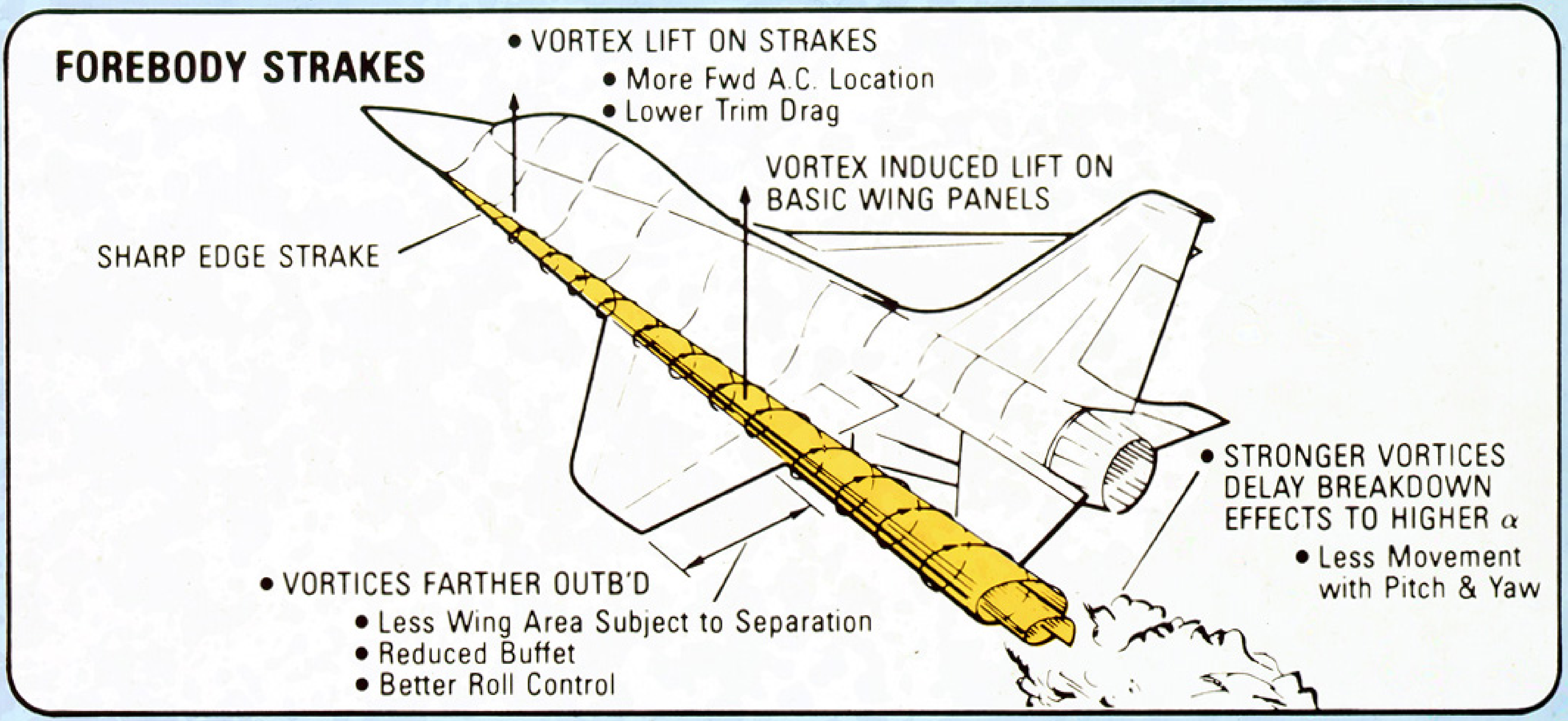
TIP MOUNTED MISSILES

- LOWER DRAG
- CLEANER FLOW FIELD FOR LAUNCH

Blended Body Superior to Conventional Body at High Lift

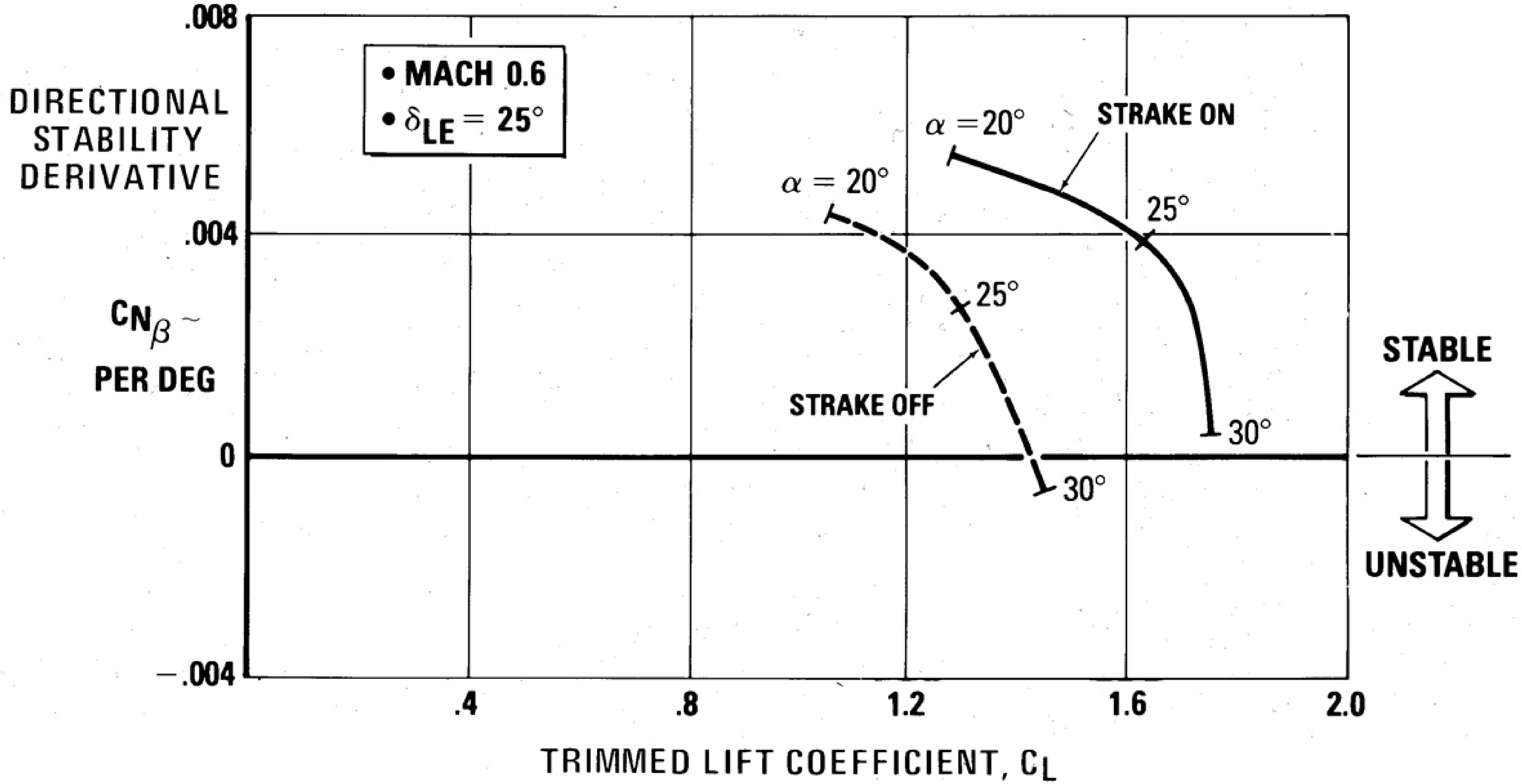


Controlled Vortex Lift

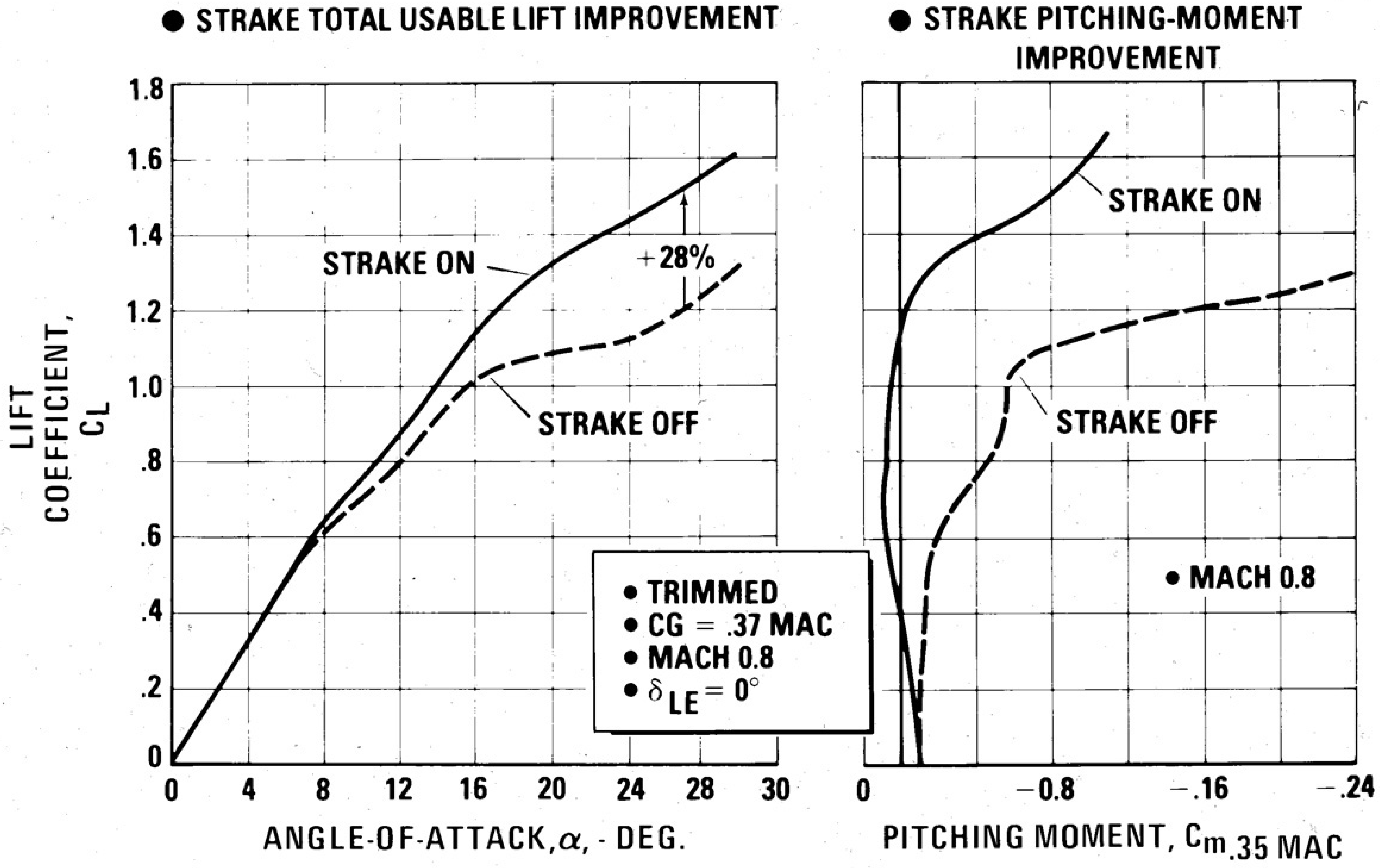


- **HIGHER LIFT PER UNIT OF EXPOSED WING AREA**
  - Effective W/S = 52 at M = .9 and 41 at M = 1.2 (Geom. = 60)
  - Equivalent Wing would Weigh +490 lbs
- **GREATLY IMPROVED DIRECTIONAL STABILITY**
  - Statically Stable to High Angles-of-Attack
- **REDUCES TRIM DRAG**
  - Straightens Pitching Moment Curve

Strake Directional Stability Improvement

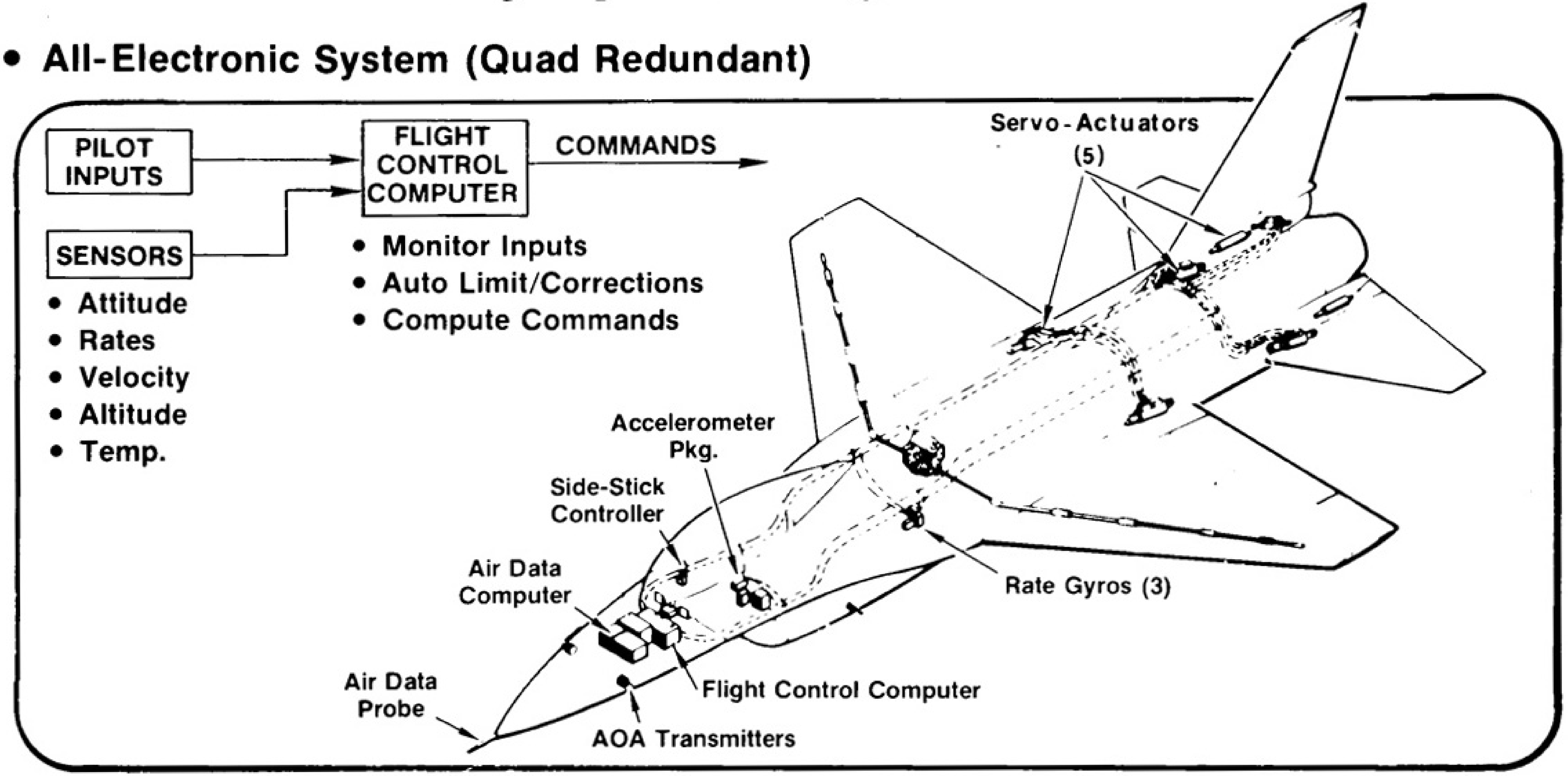


Vortex Lift/Strake Improvement



Fly-By-Wire Flight Control

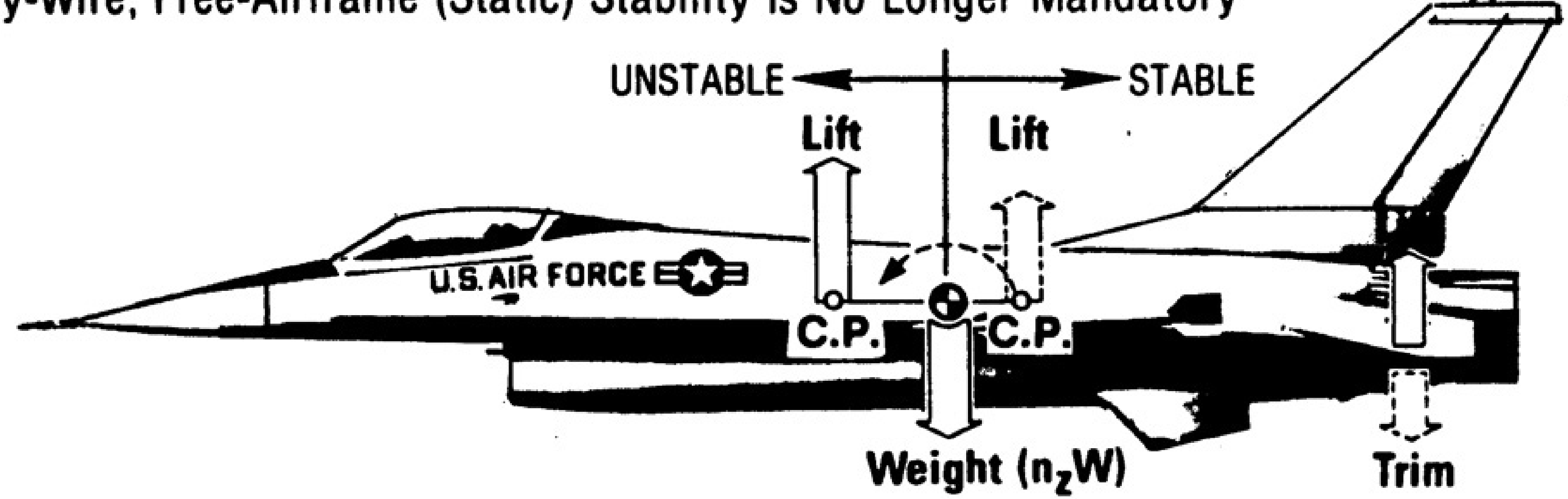
- **All-Electronic System (Quad Redundant)**



- **Better Kinematics (Reduced Lags & Overshoots) Provide:**
  - — Greatly Improved/Expanded Flying Qualities
  - — Significantly Improved Response & Precision for High Tracking Accuracy
- **Computer Commands Provide Same Response for Same Stick Force (Input)**
- **Stall/Spin Protection - Automatically Maintains Attitude Within Useful Limits**
- **Redundancy & Freedom of Routing Provide Improved Reliability (2½ Times) & Increased Survivability**

Relaxed Static Stability

- With Fly-by-Wire, Free-Airframe (Static) Stability Is No Longer Mandatory

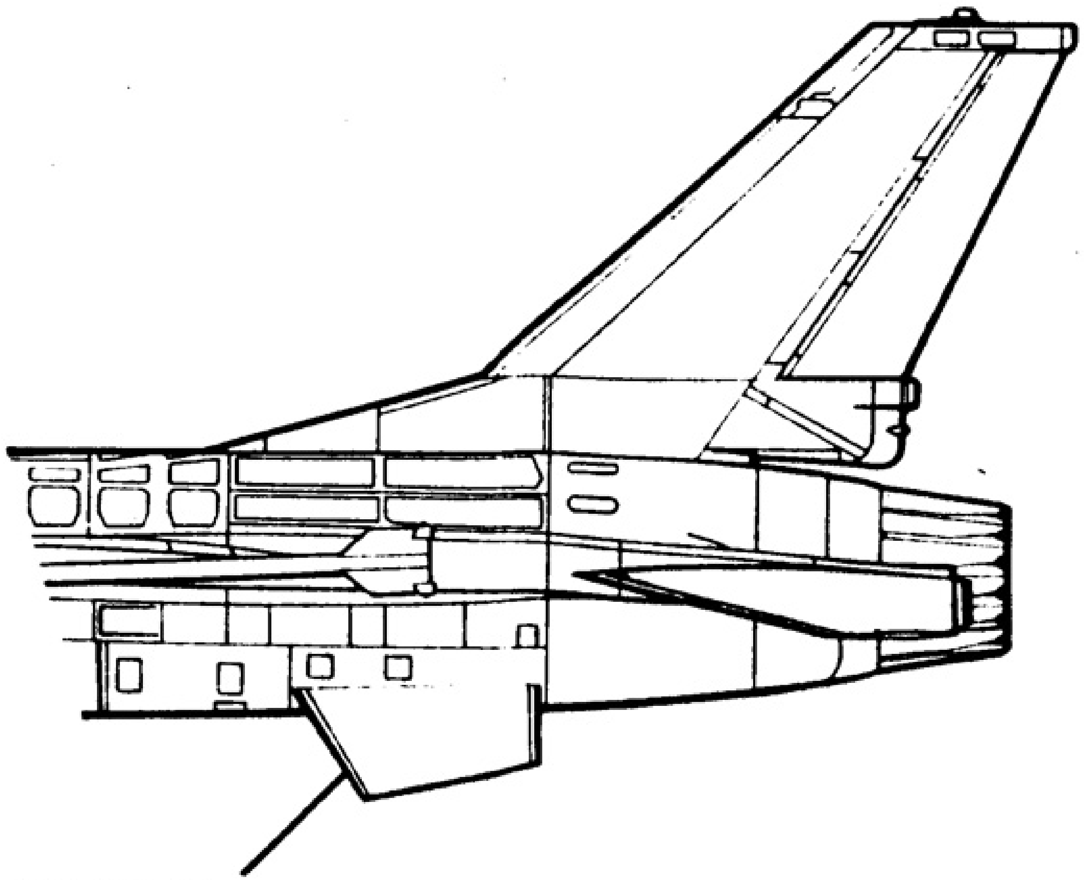


- **New Approach to Configuration Design**
  - **√ More Freedom to Achieve Maximum Balance of Performance and Flying Qualities**
  - **√ Smaller Control Surfaces**
- **More Responsive Maneuvering — Twice Conventional Configurations**
- **Lower Mission Weight: — 500 lb**

DIRECTIONAL CONTROL FUNCTION

VERTICAL TAIL

- COMPOSITE SKINS-
  - Rigidity-High Effectiveness
- TAIL SIZED FOR RUDDER POWER

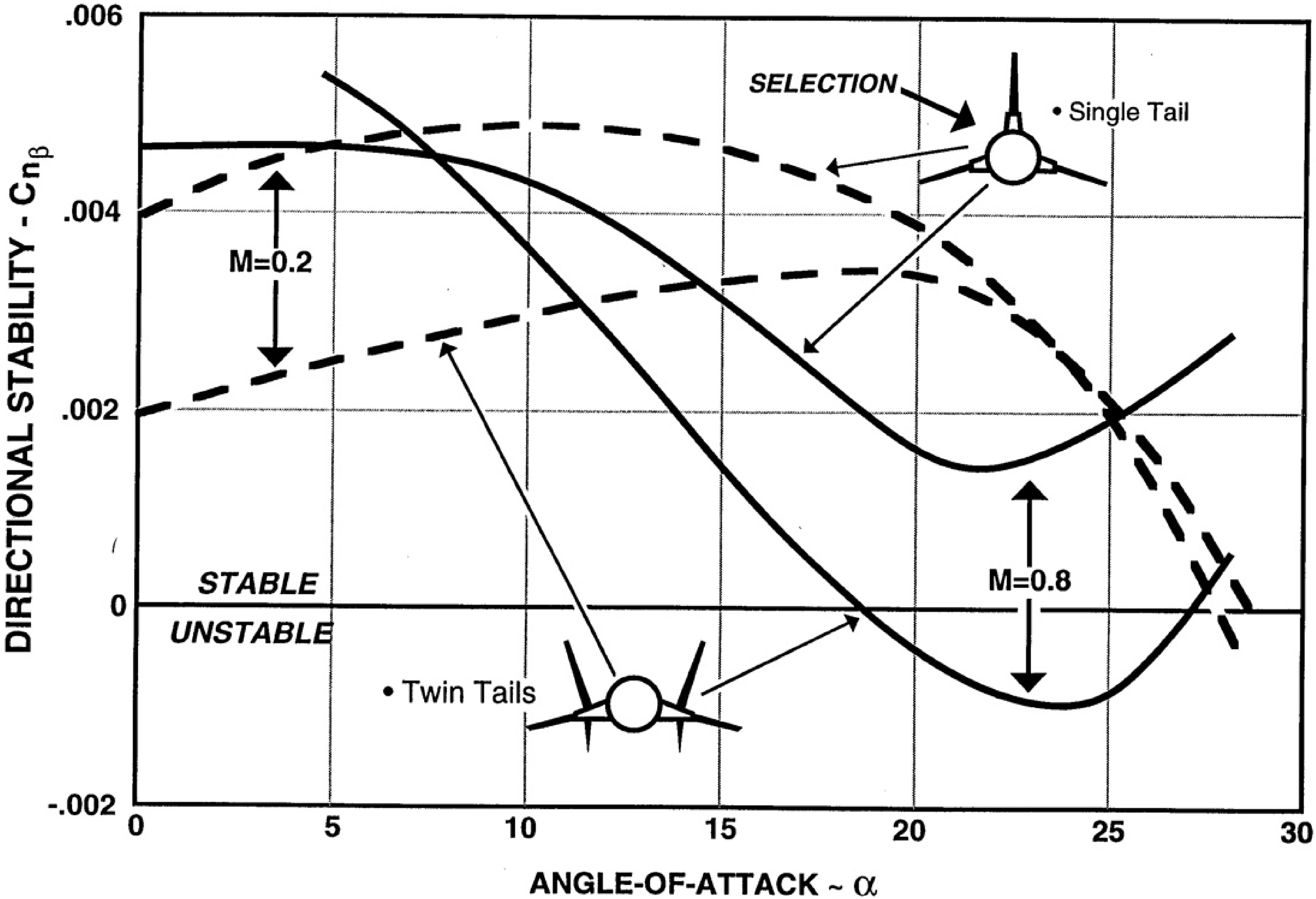


VENTRALS

- SPIN RESISTANCE
- DIRECTIONAL STABILITY AT HIGH SPEED AOA

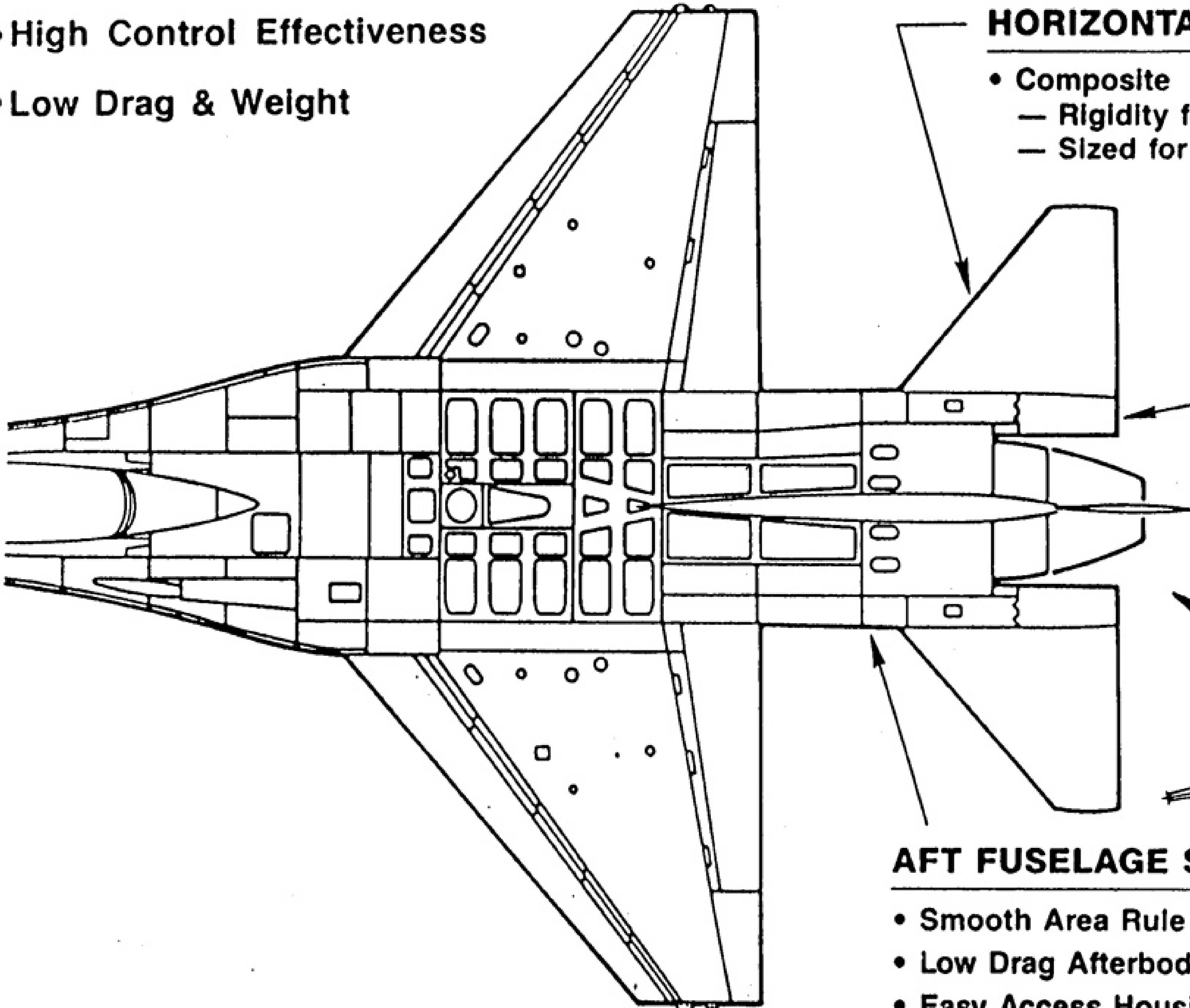
VERTICAL TAIL DEFINITION

- **Single Tail Provides Better Directional Stability**



HORIZONTAL TAIL DEFINITION

- High Control Effectiveness
- Low Drag & Weight

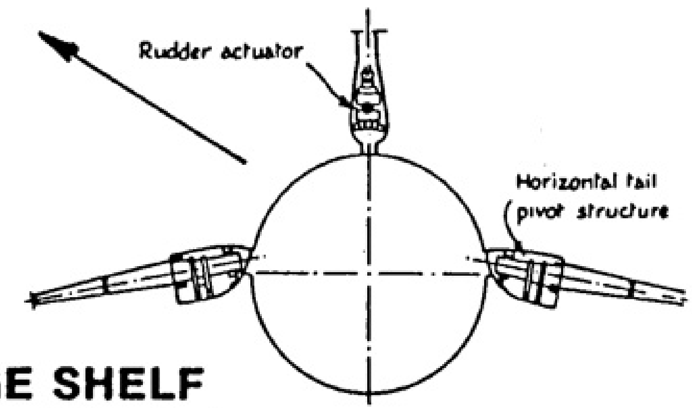


HORIZONTAL TAIL

- Composite
  - Rigidity for Small Size/Low Drag
  - Sized for Nose Gear Un-Stick

SPEED BRAKES

- No Pitch Effect
- No Flow Effect
- High Effectiveness



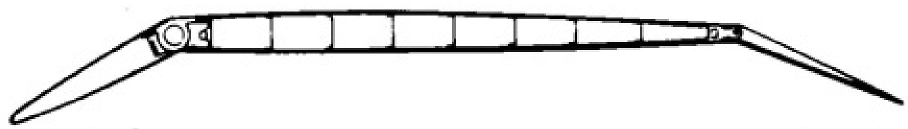
AFT FUSELAGE SHELF

- Smooth Area Rule
- Low Drag Afterbody Slope
- Easy Access Housing for Elevon & Horizontal Tail Actuators
- Flat Side-Limited Un-Porting of Control Surfaces

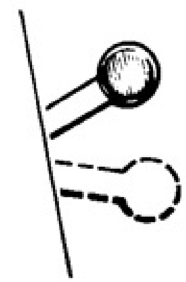
AUTOMATIC VARIABLE CAMBER – MANEUVERING FLAPS

- INCREASED DIRECTIONAL STABILITY AND REDUCED DRAG/INCREASED LIFT AT HIGH ANGLES OF ATTACK ($\approx 12^0$)
- BETTER BALANCE BETWEEN TURN RATE AND ACCELERATION (LESS WING AREA, THINNER WING)

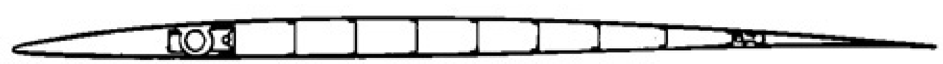
Take-off & Landing



Flap control

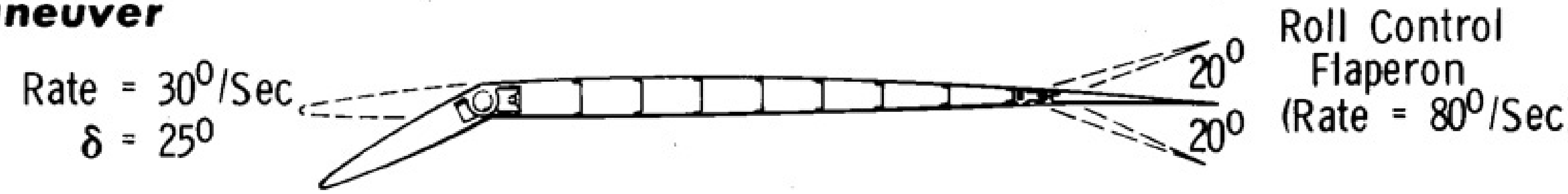


Cruise



- Basic Airfoil (64A204) Twisted (3^0) and Cambered ($C_L = .2$) for Low Angles of Attack ($C_L < .6$)

Maneuver

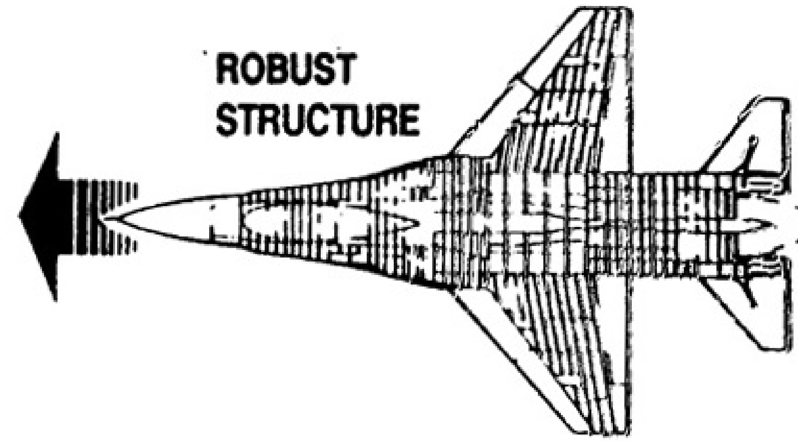


- L.E. FLAP FULLY AUTOMATIC PROGRAMMED FOR BEST FLAP POSITION (MAX L/D) AS A FUNCTION OF MACH NUMBER, ANGLE-OF-ATTACK, AND PITCH RATE

STRENGTH-WEIGHT RELATIONSHIP

- LIGHTWEIGHT NOT ACHIEVED WITH USE OF EXOTIC MATERIALS....OR BY REDUCING STRUCTURAL STRENGTH OR SERVICE LIFE.

  - Strength = 9g. at Full internal Fuel
  - Service Life = 8000 Hours



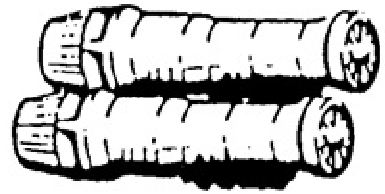
- STRENGTH IS CONSISTENT WITH AERODYNAMIC AND PILOT LIMITS.

- CONVENTIONAL ALUMINUM STRUCTURE....LIMITED USE OF COMPOSITES (Control Surface Stiffness)

PROPULSION ISSUES

- **THRUST LEVEL:**

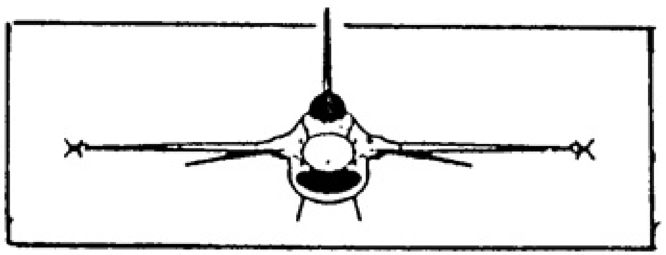
One TurboFan



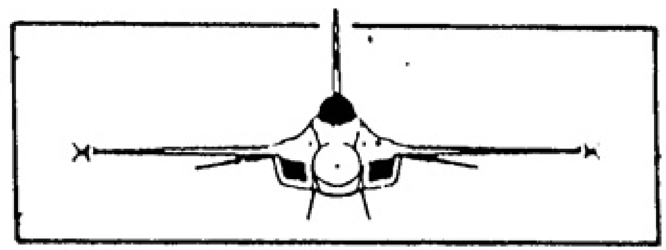
Two TurboJet

- **INLET AIR FLOW CAPTURE AREA & PRESSURE RECOVERY:**

  - Inlet Location

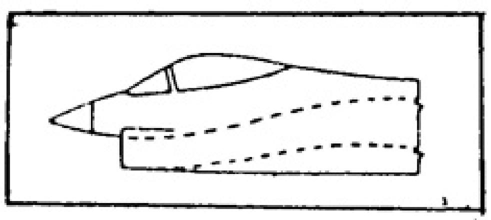


Bottom

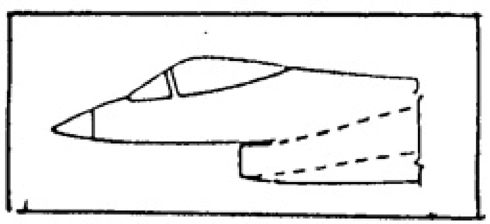


Side

  - Inlet Face

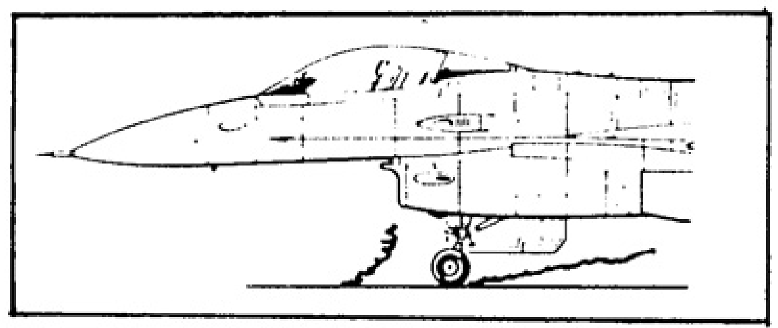


Forward



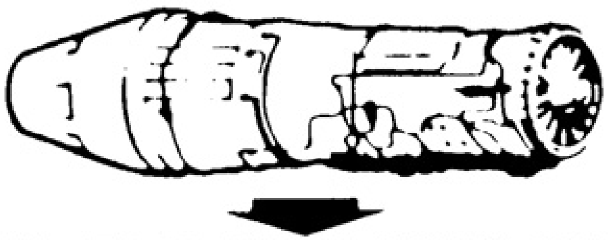
Aft

  - FOD Ingestion



ENGINE SELECTION

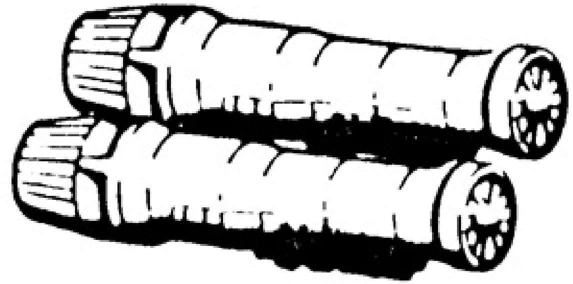
- Single P&WA F100



P&WA F100 TURBOFAN SELECTED

OR

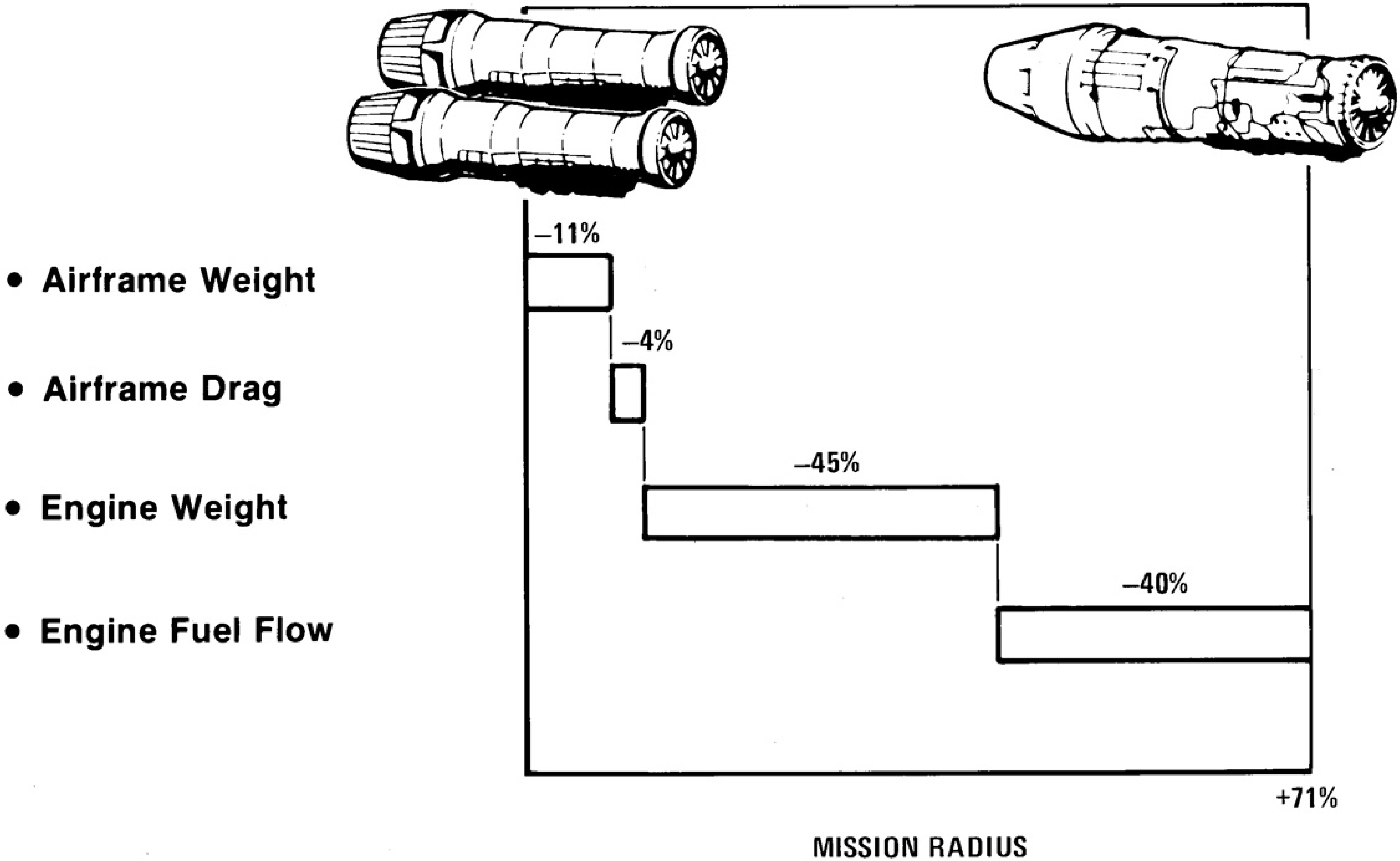
- Twin GE YJ101 (Now F404)



- **LOWER WEIGHT** (Combined Engine & Fuel Weight for 500 n.mi. Radius)
  - **7882 lbs. vs. 10,234 lbs.** **(Dry Weight 1024 lbs. Lower)**
- **LESS FUEL** (All Conditions)
  - **25% Less Cruise Fuel**
  - **14% Less Combat Fuel**
  - **45% Less Reserve Fuel**
- **HIGHER ENGINE T/W & HIGHER TOTAL THRUST AT V_{max}**
- **MORE INLET LOCATION OPTIONS**
- **LOWER BASE DRAG**

Twin-Engine Impact on Mission Radius

Constant TOGW

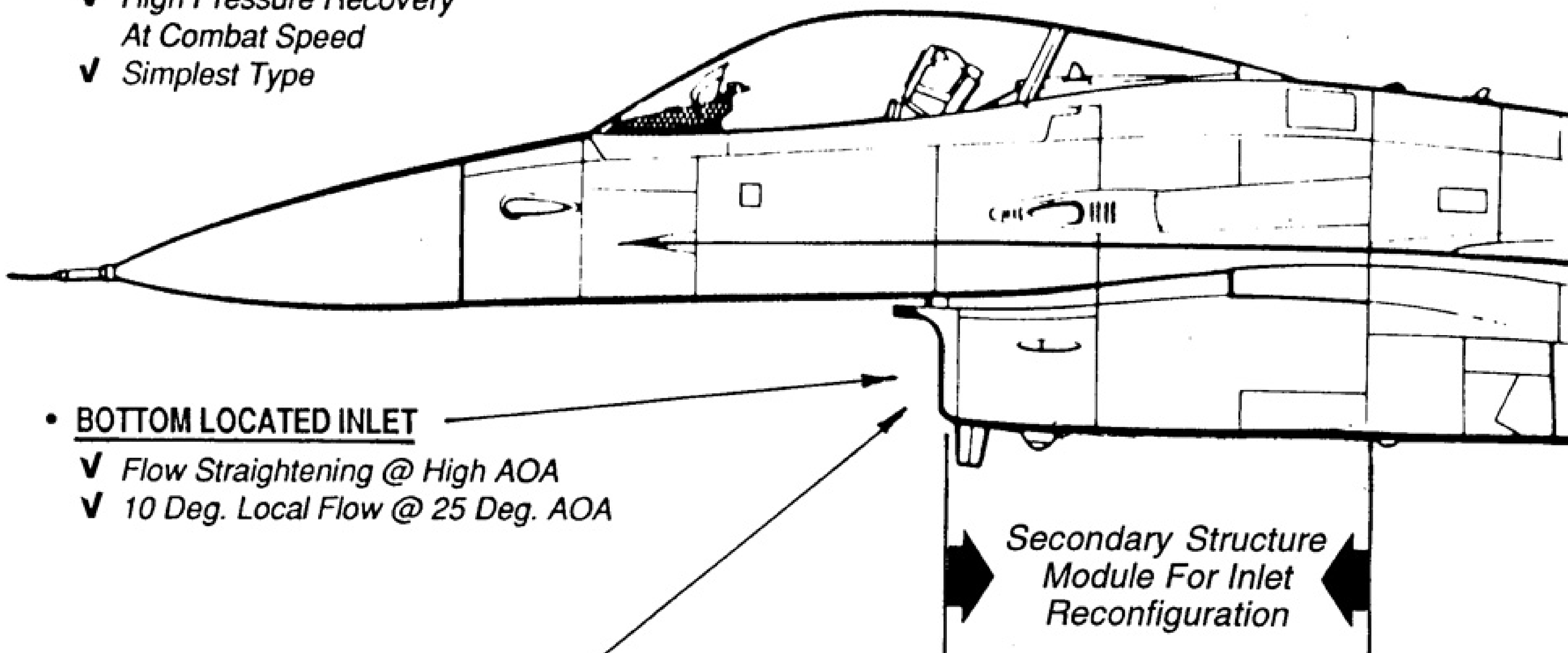


A24684

INLET / AIRFRAME INTEGRATION

Function: STALL-FREE, LOW DISTORTION, HIGH PRESSURE RECOVERY

- NORMAL SHOCK INLET
  - √ *High Pressure Recovery At Combat Speed*
  - √ *Simplest Type*

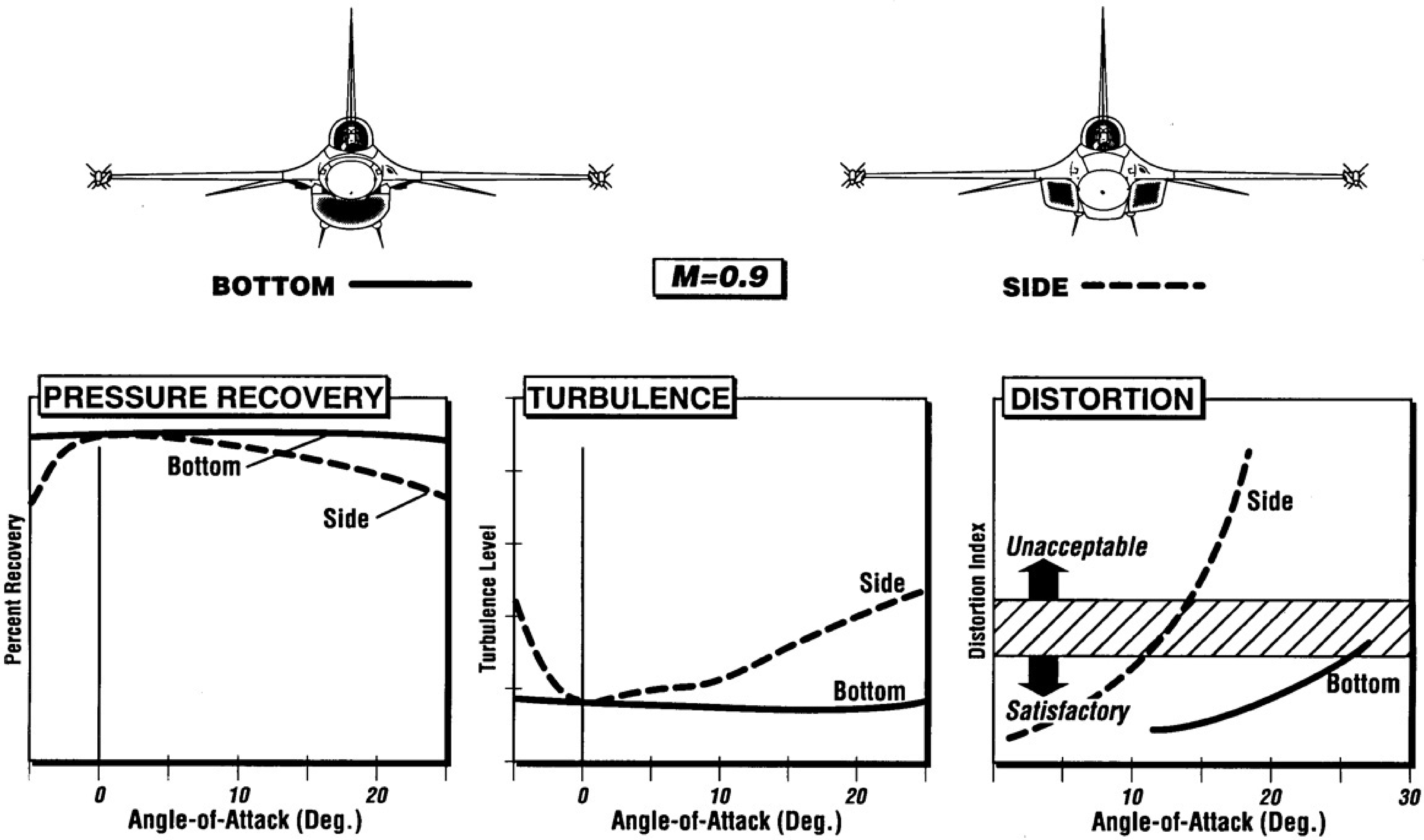


- BOTTOM LOCATED INLET
  - √ *Flow Straightening @ High AOA*
  - √ *10 Deg. Local Flow @ 25 Deg. AOA*

- SET BACK LOCATION
  - √ *Staggered With Canopy for Smoother Area Curve*
  - √ *Less De-Stabilizing*
  - √ *450 lb. Lower Weight*

Bottóm Inlet Location Best For High Angle-of-Attack Flight At All Speeds

Inlet Location Determination

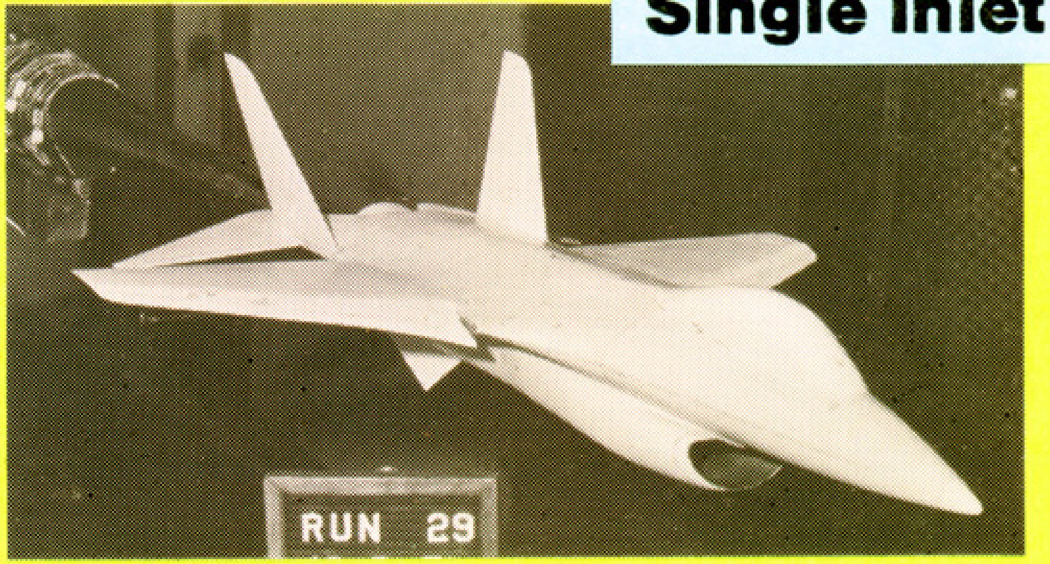


At M=1.6 and Above, the Pressure Recovery With the Bottom Inlet Increases With Angle-of-Attack

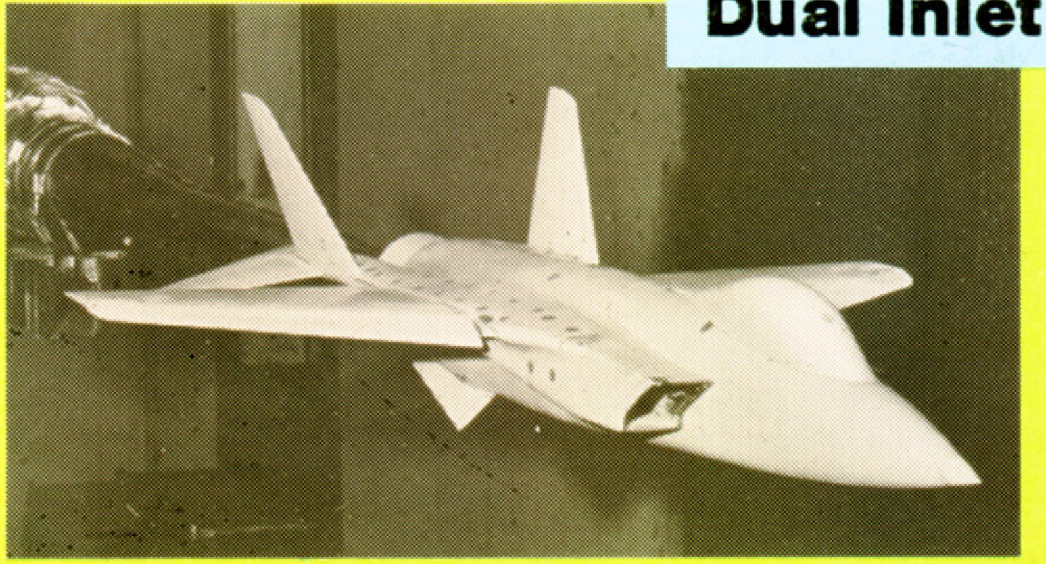
Single vs. Dual Inlet Drag

Equal Total Capture Area - 732 sq. in.

Single Inlet



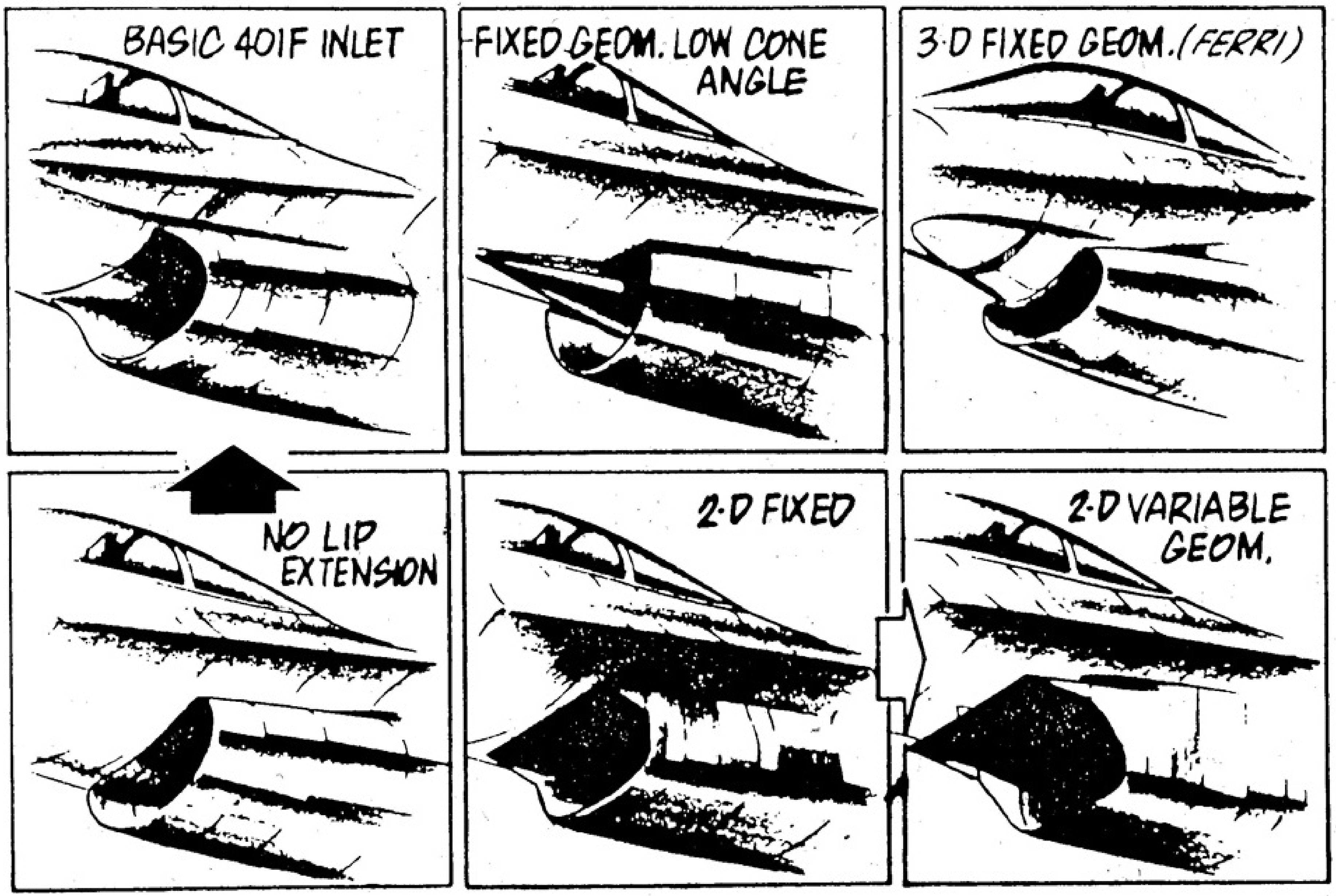
Dual Inlet



		Single Inlet	Dual Inlet
M = .80	C_D min	.0187	.0201
	L/D Cruise	11.03	10.39
	C_D at Cruise	.0318	.0337
	C_D at Maneuver (C_L = .8)	.1330	.1605
M = 1.2	C_D min	.0444	.0470
	C_D at Maneuver (C_L = .5)	.0873	.0916

THRUST FUNCTION

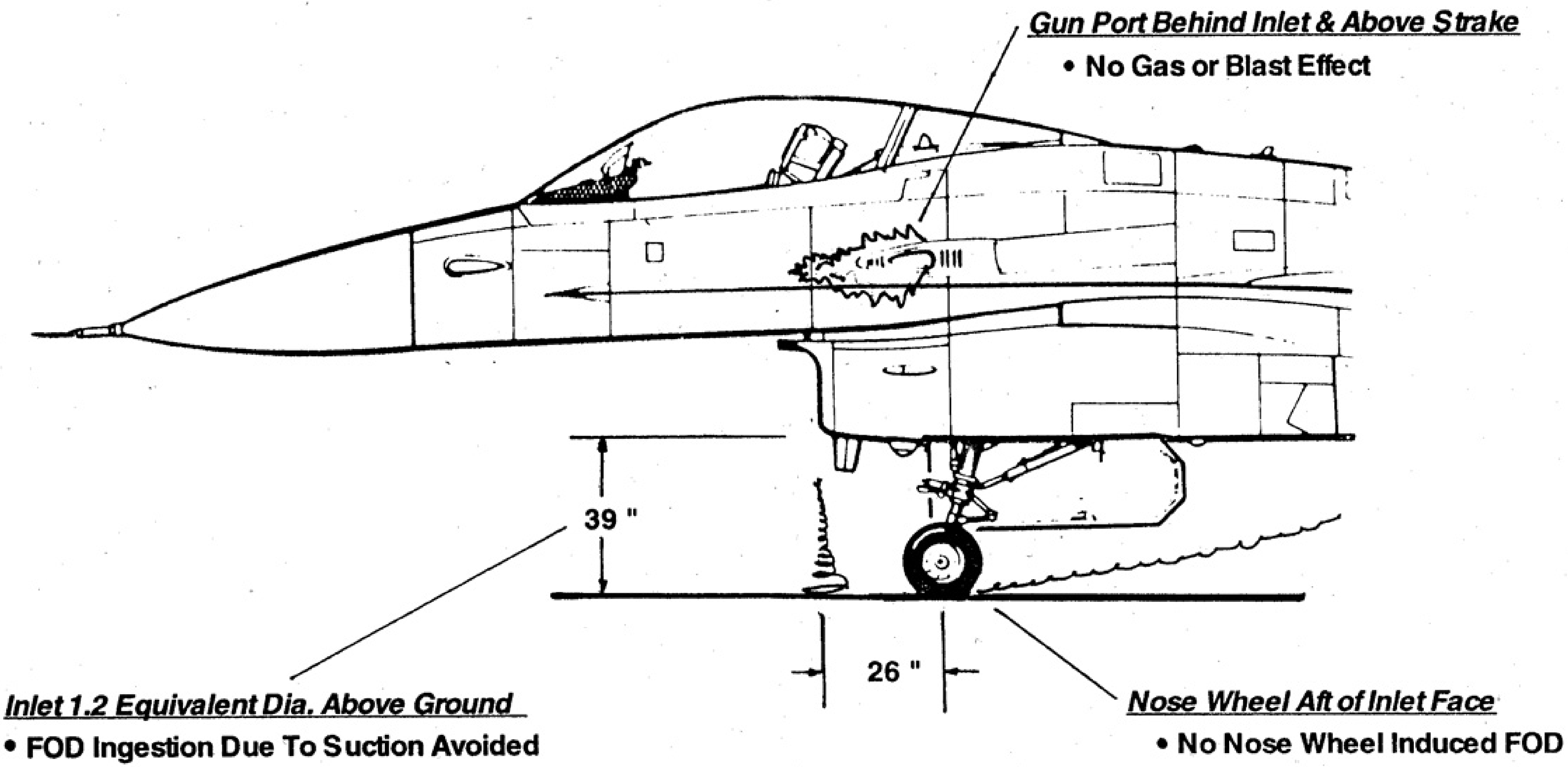
INLET GEOMETRY DEFINITION



INLET GEOMETRY SELECTED FROM WIND TUNNEL TESTS

- Analytical Procedures Not Accurate Enough To Estimate Pressure Recovery Or Drag

FOD INGESTION MINIMIZED



FOD ANALYSIS:

Suction Effects: B-707, B-737 (Inlets 20" Above Ground) ➡ Negligible Effect

Nose Gear Effect: F-100, F-111, F-4, F-15, F-5, AT-37, A-7: ➡ 2-Engine Aircraft With Side Inlets Many Times Worse Than 1-Engine Aircraft.

One vs. Two-Engine Safety Comparison

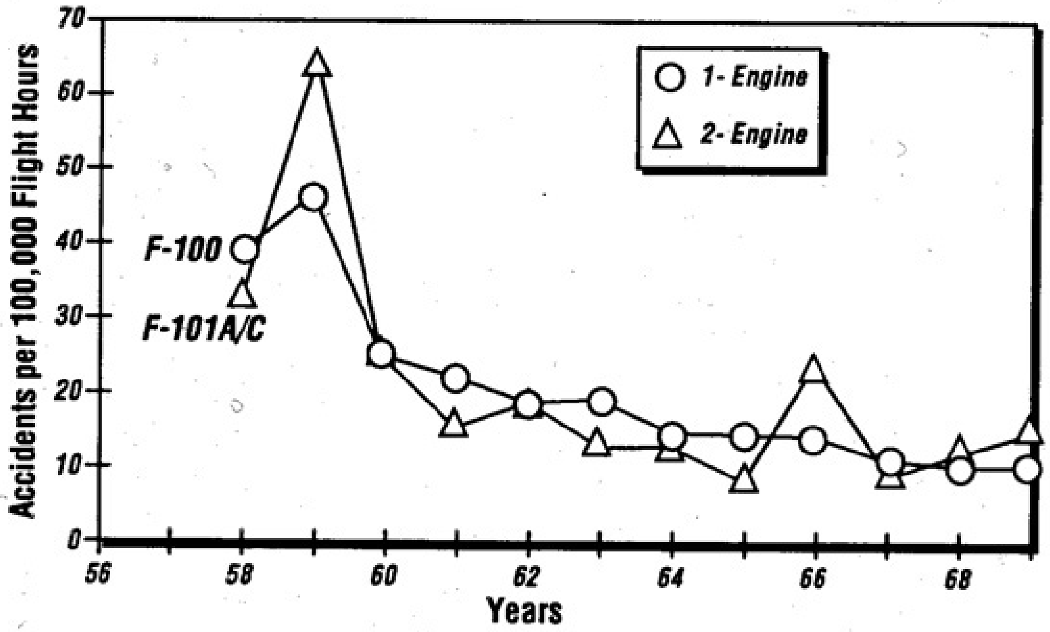
Data Source: ***U.S. Air Force Accident Bulletins***

Tactical Air Mission

- **Same Mission**
- **Same Time Frame**

F-100 – 1 P&W J57 Engine

F-101A/C – 2 P&W J57 Engines

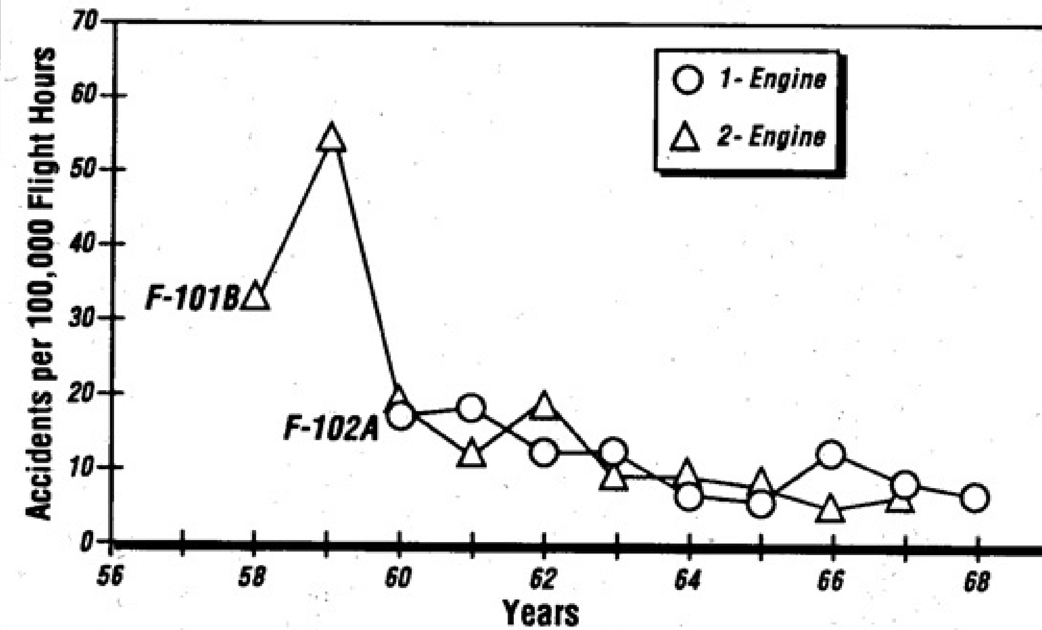


Air Defense Mission

- **Same Mission**
- **Same Time Frame**

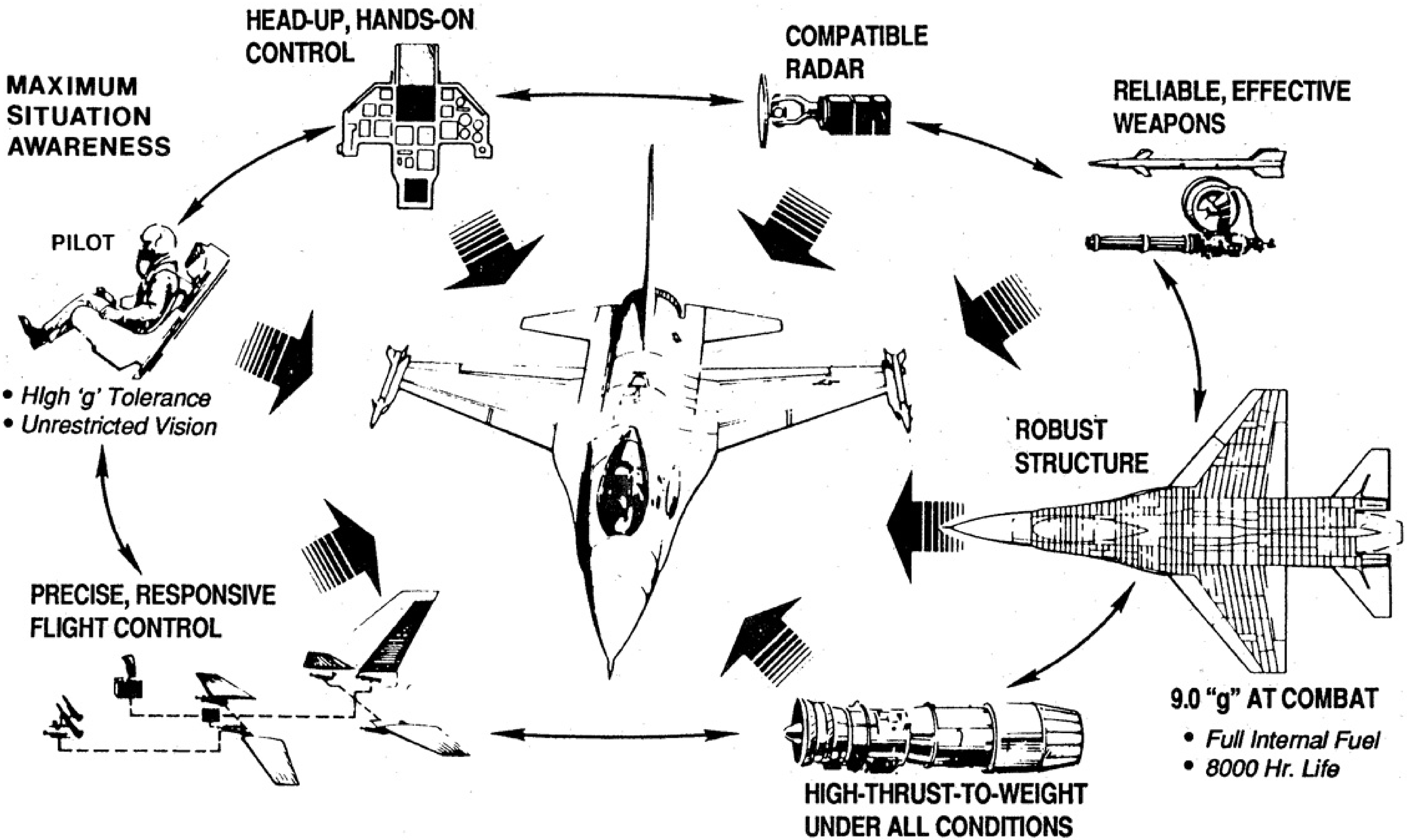
F-102A – 1 P&W J57 Engine

F-101B – 2 P&W J57 Engines



Conclusion ***Single Engine and Twin Engine Fighters Have Similar Accident Rates for Same Mission Risk***

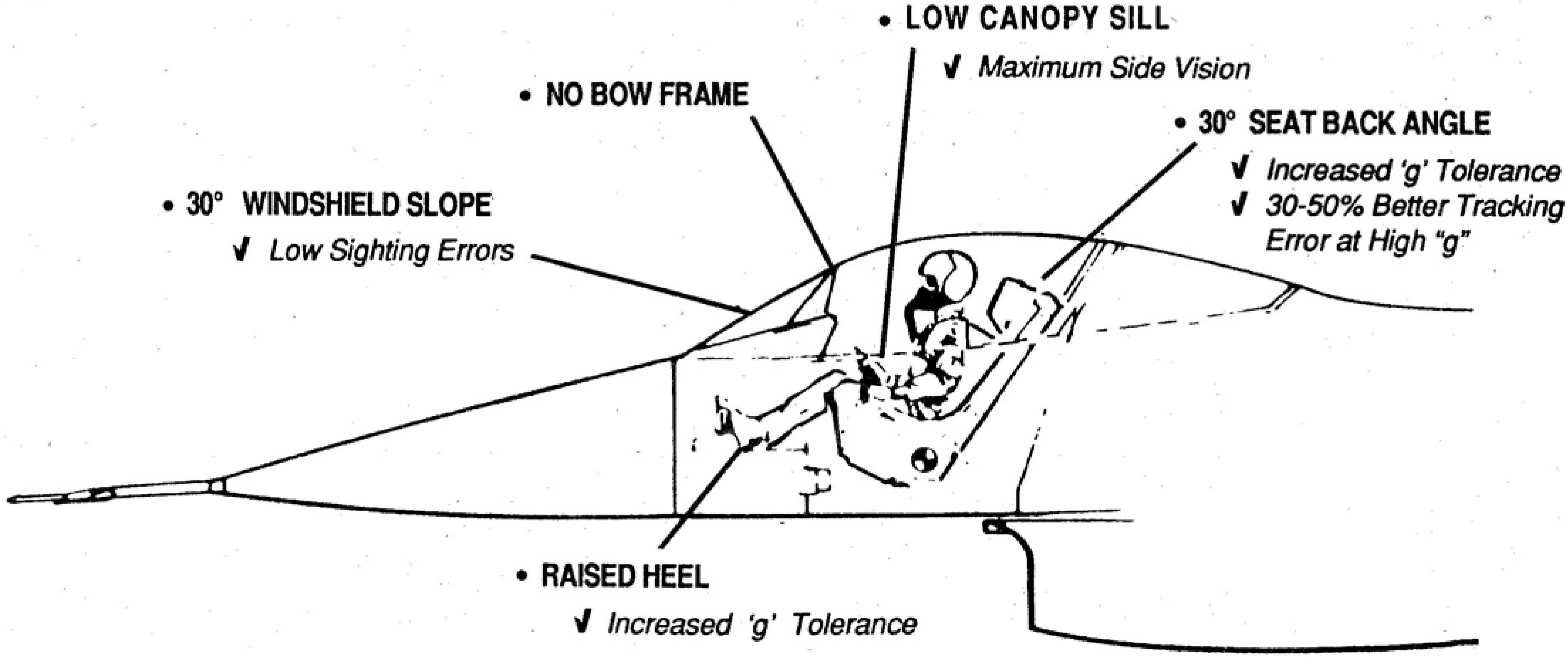
PILOT–VEHICLE FUNCTIONS FOR MAXIMUM COMBAT CAPABILITY



- PILOT NOT LIMITED BY VEHICLE
- VEHICLE AN EXTENSION OF PILOT'S CAPABILITIES

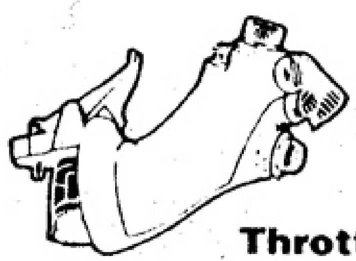
PILOT–VEHICLE INTERFACE

Function: HIGH "g" TOLERANCE, 360° SITUATION AWARENESS, PRECISE CONTROL INPUTS



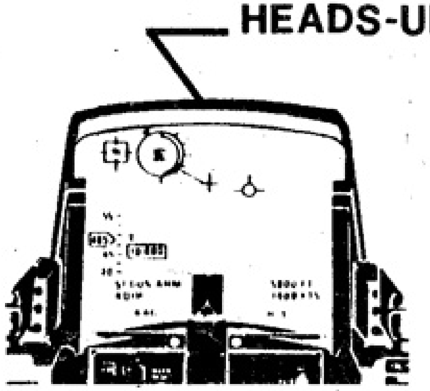
• **HEAD-UP, HANDS-ON CONTROL**

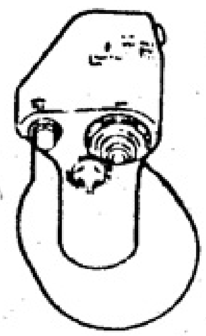
Combat Critical Functions Located on Throttle & Flight Controller



Throttle Grip

HEADS-UP DISPLAY





Side-Stick Controller

• **FORCE/LIMITED DISPLACEMENT SIDE-STICK CONTROLLER**

✓ *More Precise Inputs*

✓ *Minimum Inadvertent Inputs & Feed-Backs*

Unique Test Pilot Approach

① TEST PILOTS ASSIGNED (Full Time) AT PROGRAM START

- Contractor
- USAF Flight Test Center (AFFTC)
- TAC

② TEST PILOTS SELECTED COCKPIT CONFIGURATION

- 30° Seat Back Angle
- Side-Stick Controller
- Force Stick
- One-Piece Canopy (No Fixed Windshield)

③ GD PILOTS WROTE FLIGHT HANDBOOK

④ PILOTS SHARED ALL THREE TEST PHASES

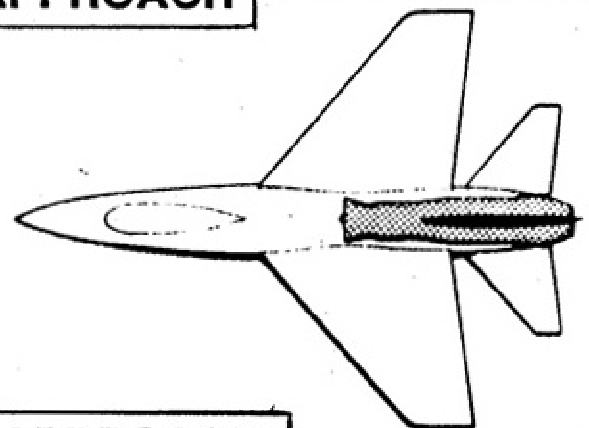
- AFFTC Pilot Flew 3rd Flight
- TAC Pilot Flew 12th Flight

ALTERNATE CONFIGURATION APPROACHES

- EVALUATED BY INDEPENDENT "RED TEAM"

CONVENTIONAL APPROACH

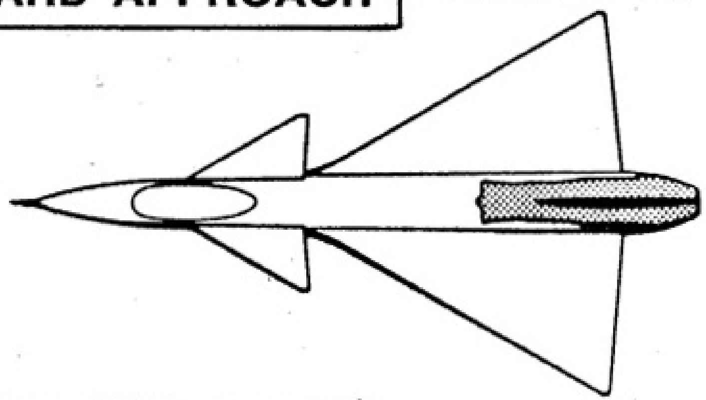
785



- Same Weight
- Less Performance

DELTA CANARD APPROACH

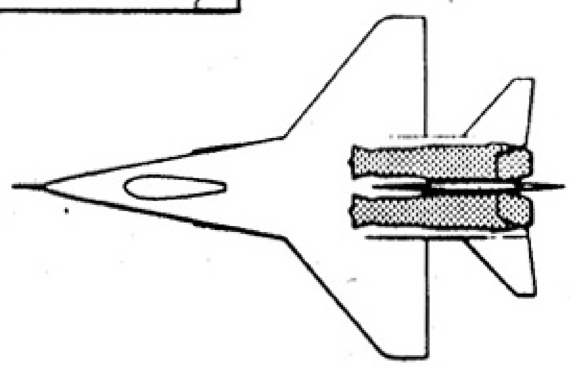
772



- Less Subsonic Performance
- Equal Supersonic Performance
- Heavier, More Complex

TWIN ENGINE APPROACH

503



- Same Performance
- Heavier

LWF PROTOTYPE PROGRAM LESSONS

- DIFFERENT, AND BETTER, AIRPLANE SELECTED

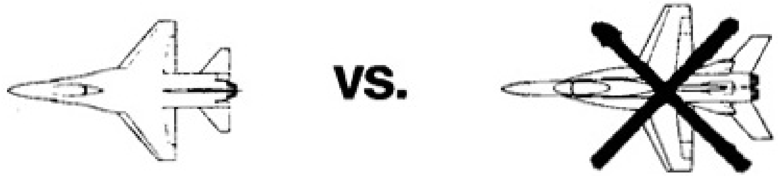
- YF-17 WOULD HAVE "WON" PAPER COMPETITION
  - "Bigger Airplane has more Capability" Syndrome
  - Twin-Engines
  - Low Cost Reputation
  - Lower Technical Risk (Less Innovation)

- HIGHER TECHNOLOGY FIGHTER FOR INVENTORY
  - Innovative Aspect Resisted by Operational People
  - Enthusiastically Accepted After Dramatically Demonstrated

- SOLID BASE FOR SUBSEQUENT FULL SCALE DEVELOPMENT
  - Unqualified Technical Success
  - Emphasis on Operational Systems and Support Elements

- REDUCED DEVELOPMENT PROGRAM
  - 8 A/C Vs. 20 A/C (F-15)
  - 2100 Flight Test Hours Vs. 5000 (F-15)
  - $629M Vs $2.2B (F-15)

USAF SELECTION RATIONALE

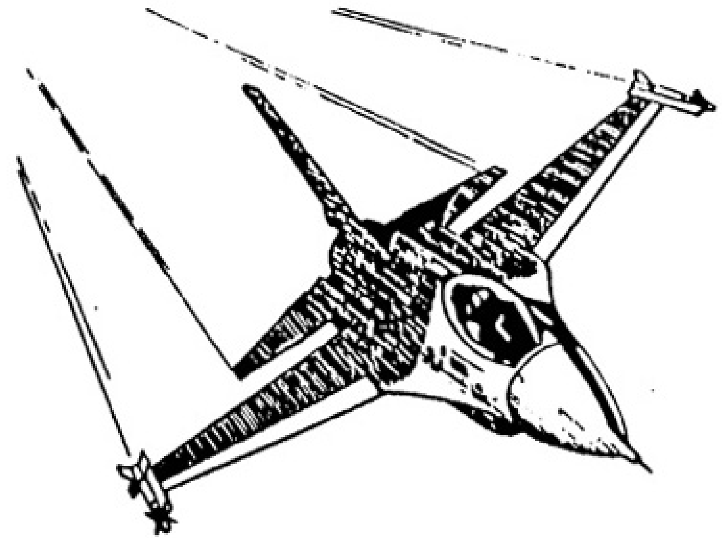


- **YF-16 DEMONSTRATED...**
  - \+ Better agility
  - \+ Better Acceleration
  - \+ Higher Turn Rate
  - \+ More Endurance
  - \+ Better Tolerance to High "g"
  - \+ Better Visibility
  - \+ Better Deceleration

- **YF-16 Costs More Believable and Lower By 6-7% With Lower Development and Life-Cycle Costs**

- **YF-16 Considered To Be Closer To Production Design**

SUMMARY....



- **THE YF-16 WAS AN UNQUALIFIED SUCCESS.**
  - **Performed Like No Other Fighter Has Ever Performed.**

    Advanced Airframe Technologies and Design Innovations Were Carefully Selected and Well Integrated to Produce Very High Performance at an Affordable Cost.
    - ***So Advanced As To Be Enduring For Continuous Improvement.***
    - ***Being Duplicated In Today's Fighters.***
  - **More Advanced Airplane Resulted Than From Normal Approach.**
- **YF-16 WAS FIRST FIGHTER TO TRULY INTEGRATE THE PILOT AND THE AIRFRAME** (Man-Machine Interface).