JSF

Inventing the Joint Strike Fighter

Dr. Paul Bevilaqua
Lockheed Martin Skunk Works

General Arrangement

Length	**50 ft**
Span	**35 ft**
Wing area	**450 sq ft**
Empty Weight	**30,000 lbs**
AB Thrust	**40,000 lbs**
Vertical Lift	**40,000 lbs**

Relative Size of Naval JSF

Length	56 ft
Span	37 ft
Wing Area	400 ft^2
Internal Fuel	10,800 lb
Spot factor	1.0

Length	51 ft
Span	43 ft
Wing Area	620 ft^2
Internal Fuel	19,500 lb
Spot Factor	1.09

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

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

JSF Family of Aircraft

CTOL

Length	50 ft
Span	35 ft
Wing Area	460 ft^2
Internal fuel	18,500 lbs

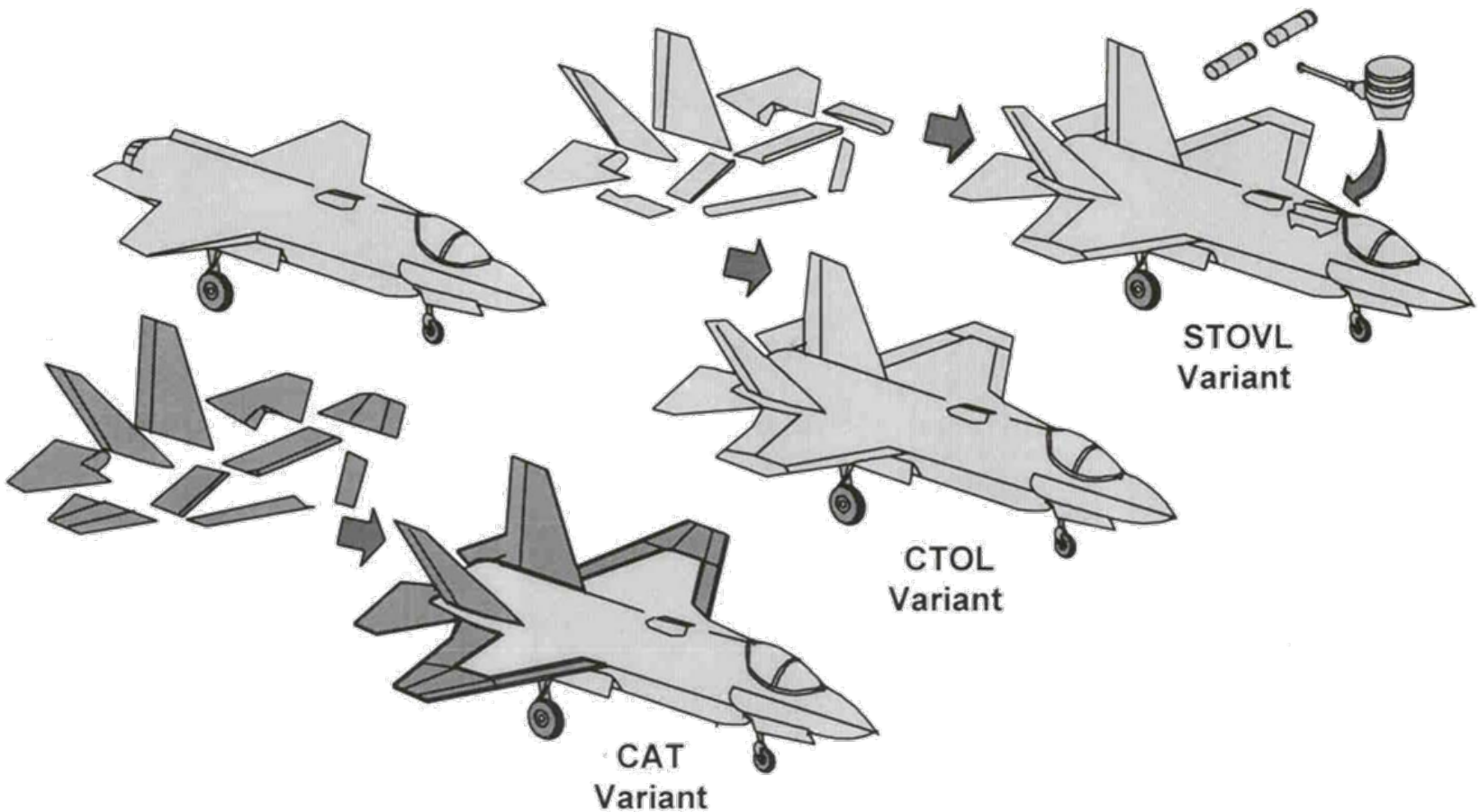
STOVL

Length	50 ft
Span	35 ft
Wing Area	460 ft^2
Internal fuel	13,250 lbs

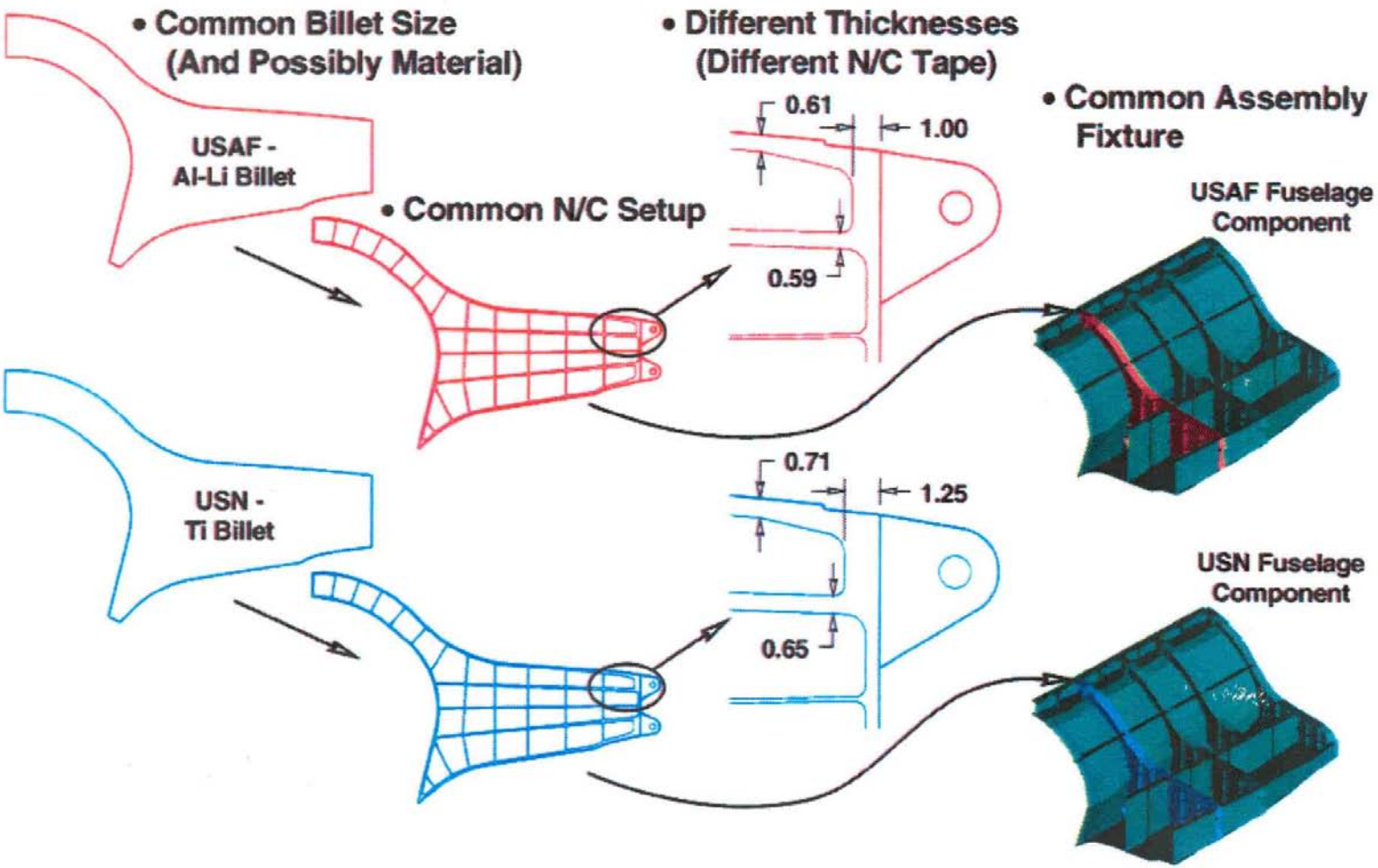
Naval

Length	51 ft
Span	43 ft
Wing Area	620 ft^2
Internal fuel	19,500 lbs

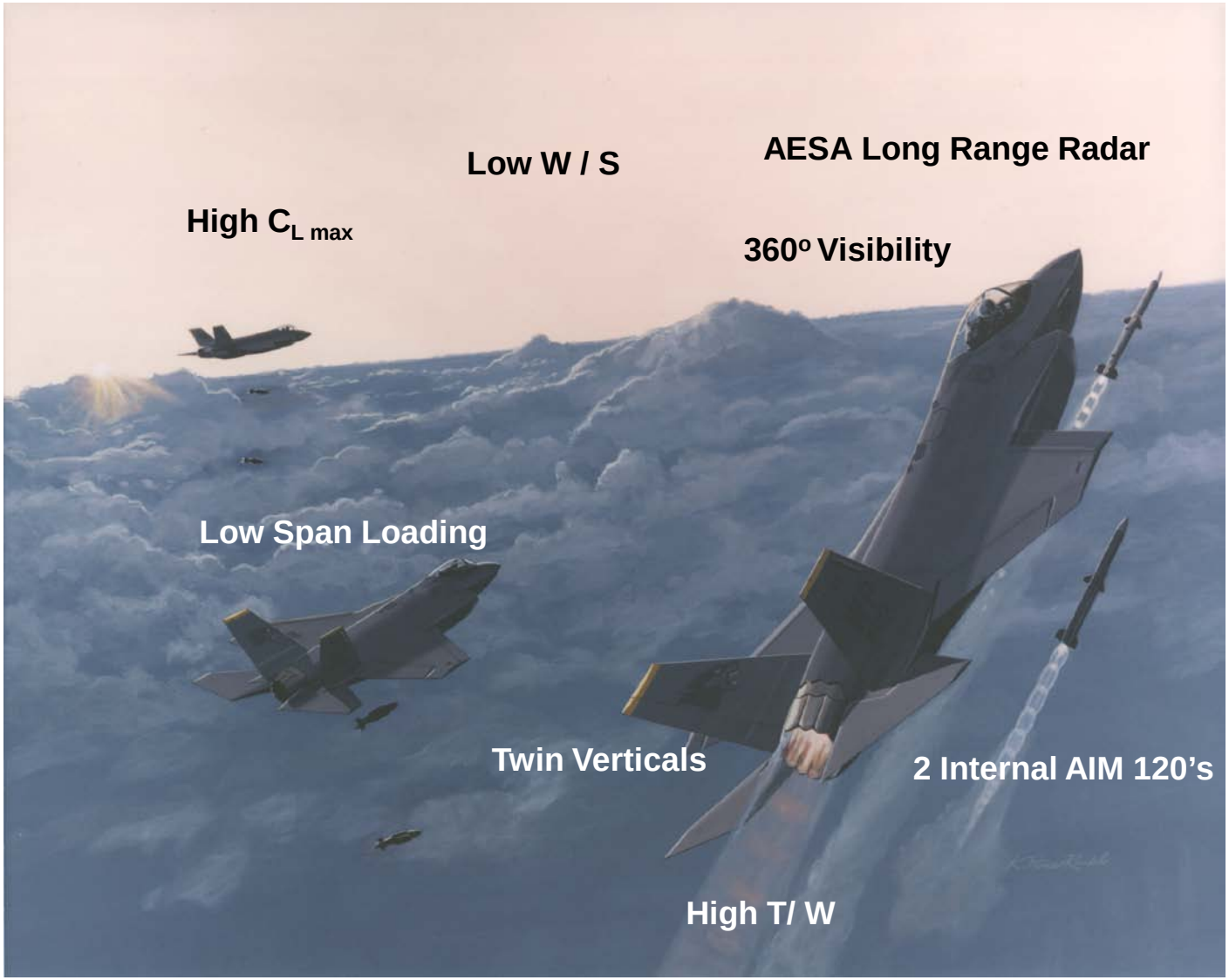
JSF Commonality



Cousin Parts



Designed for Self Defense

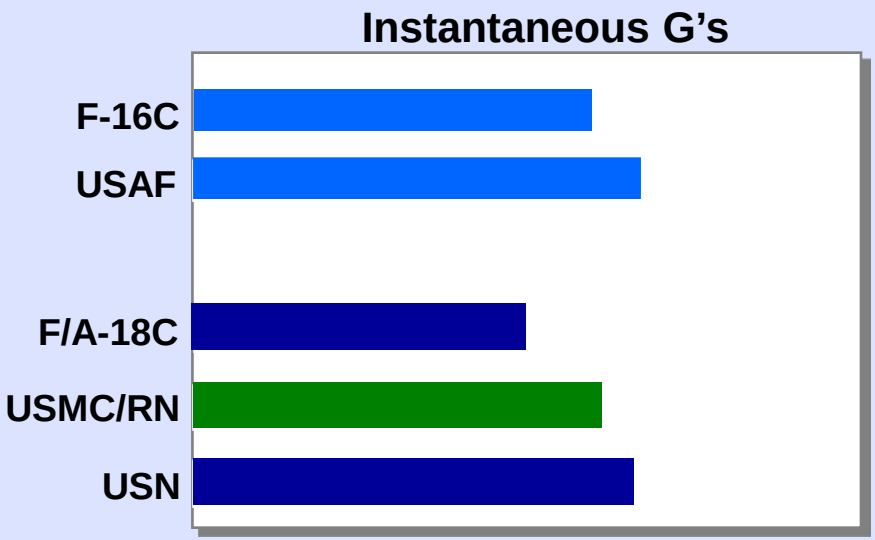


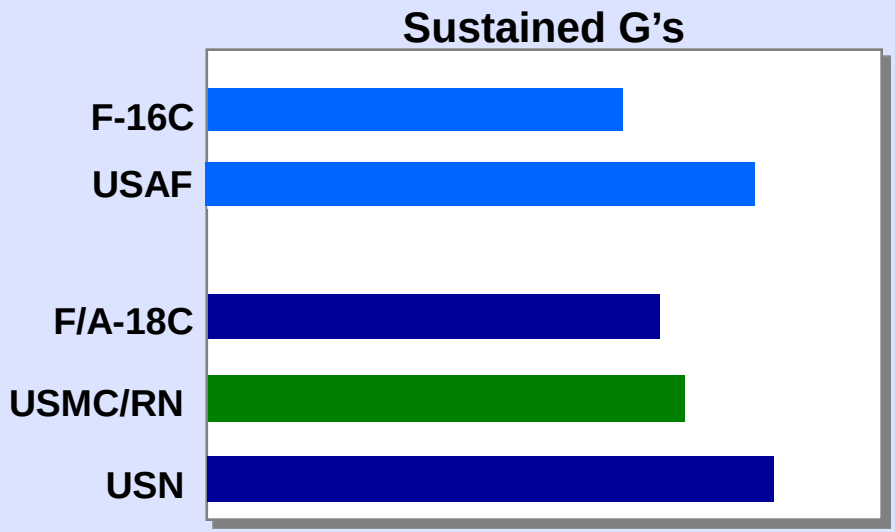
Designed for Ground Attack

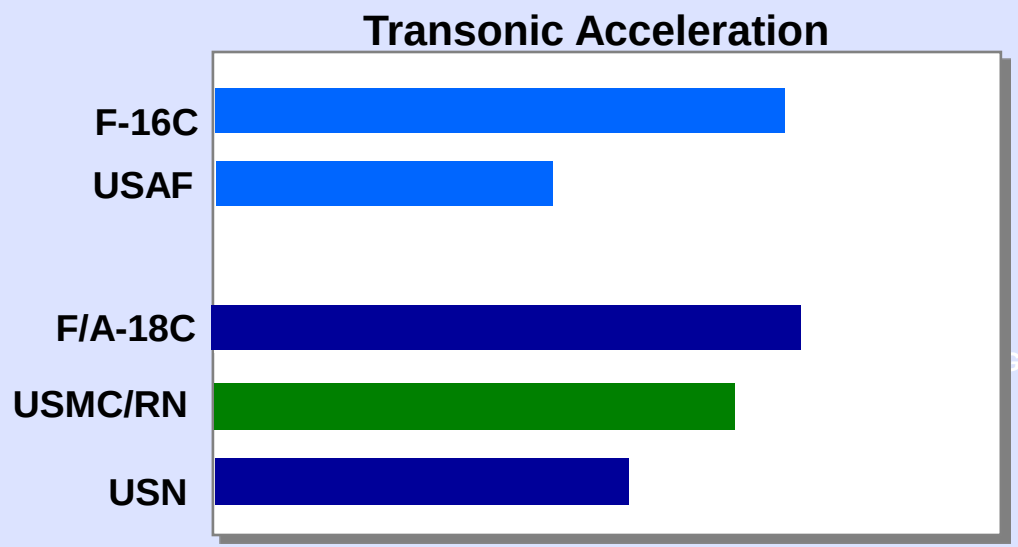
Designed for Low Vulnerability

Designed for Maintainability

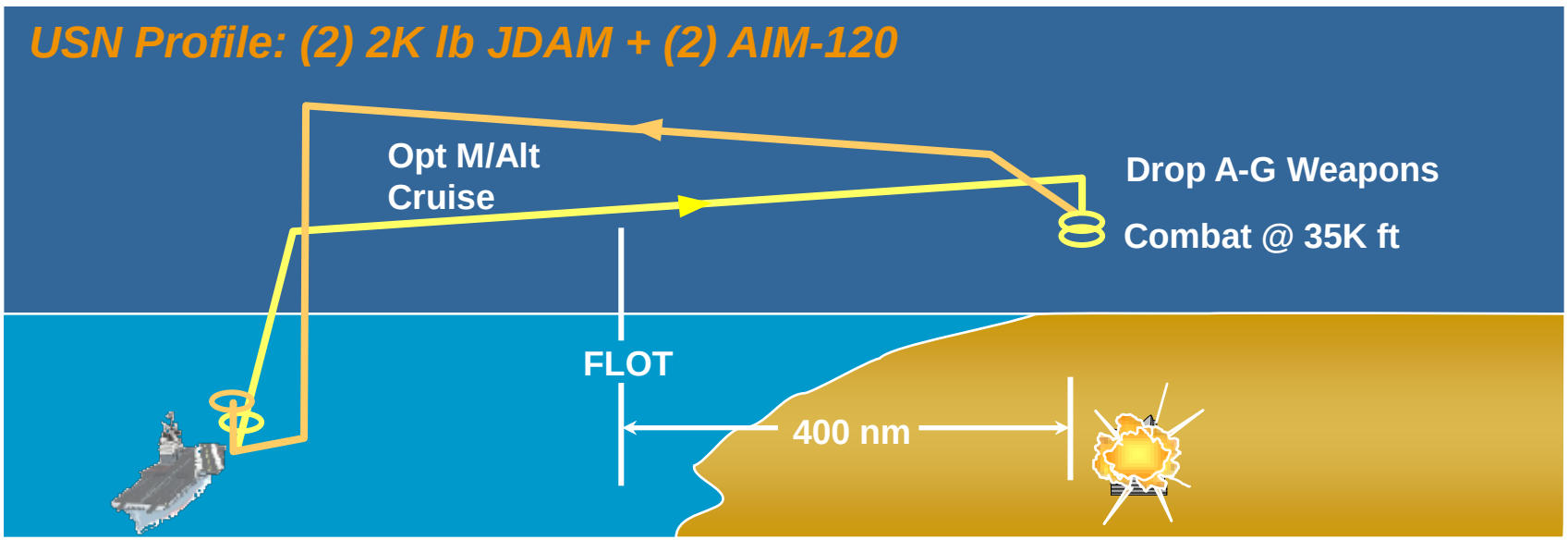
Air to Air Combat Performance

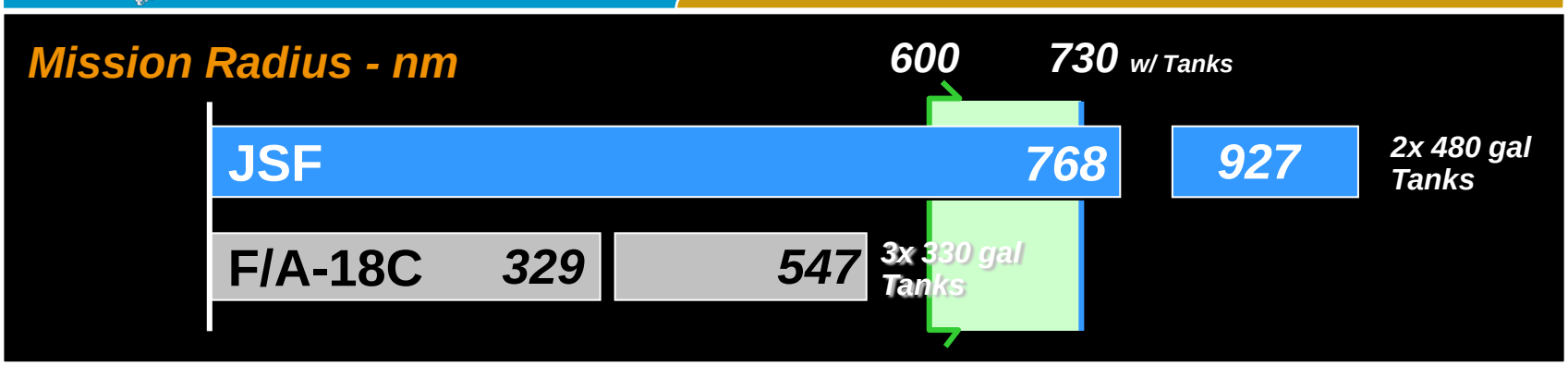




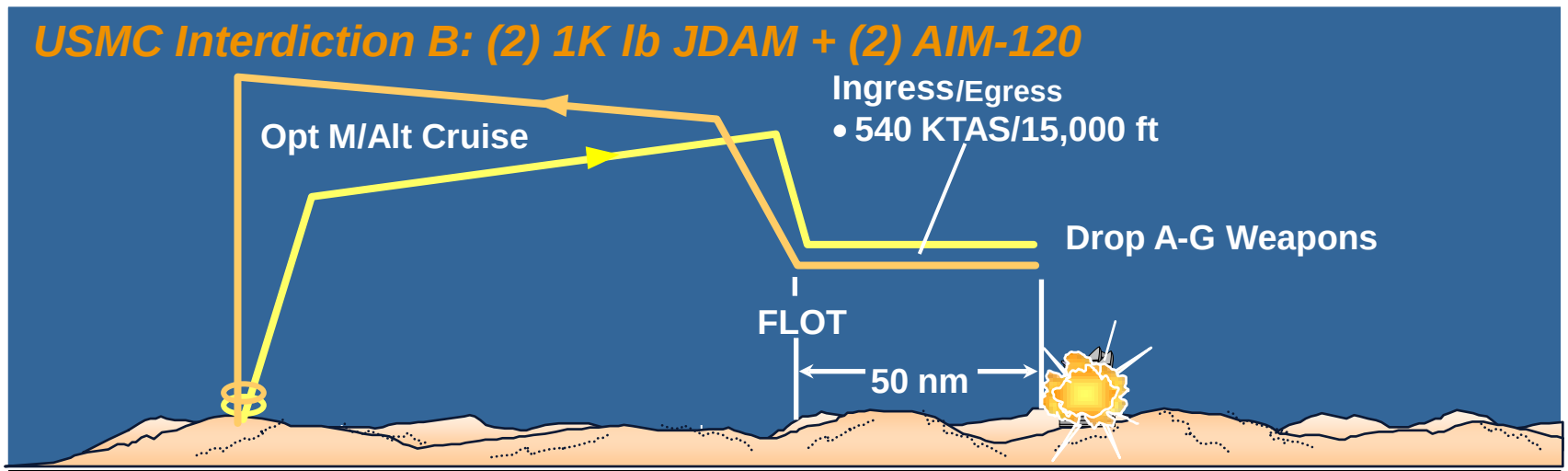


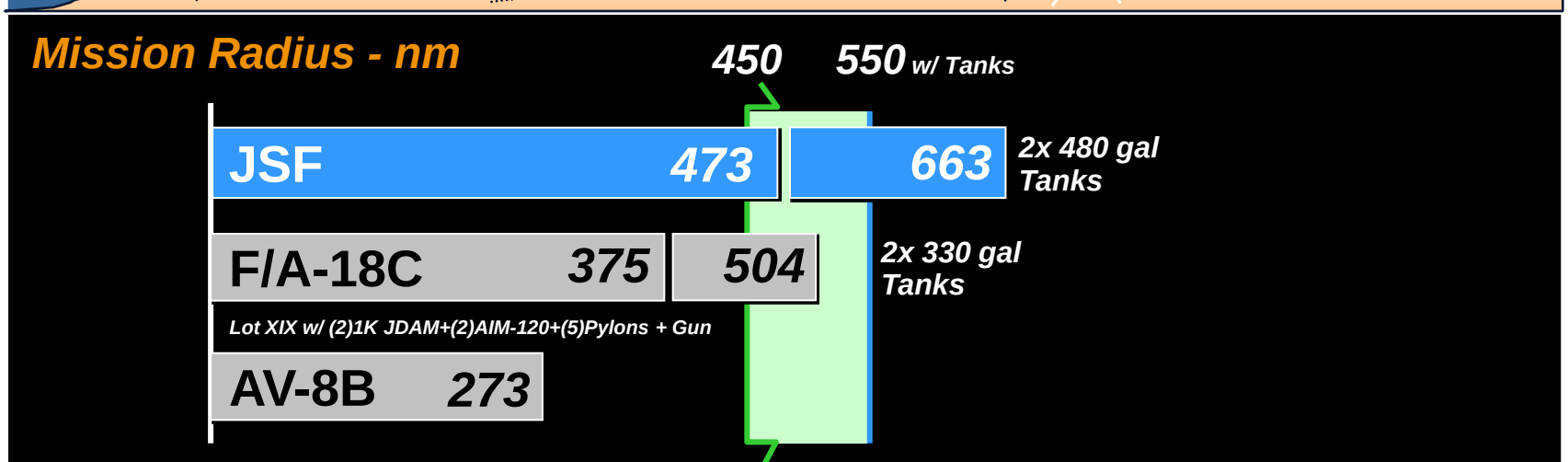
Naval F-35C Mission Performance





USMC F-35B Mission Performance





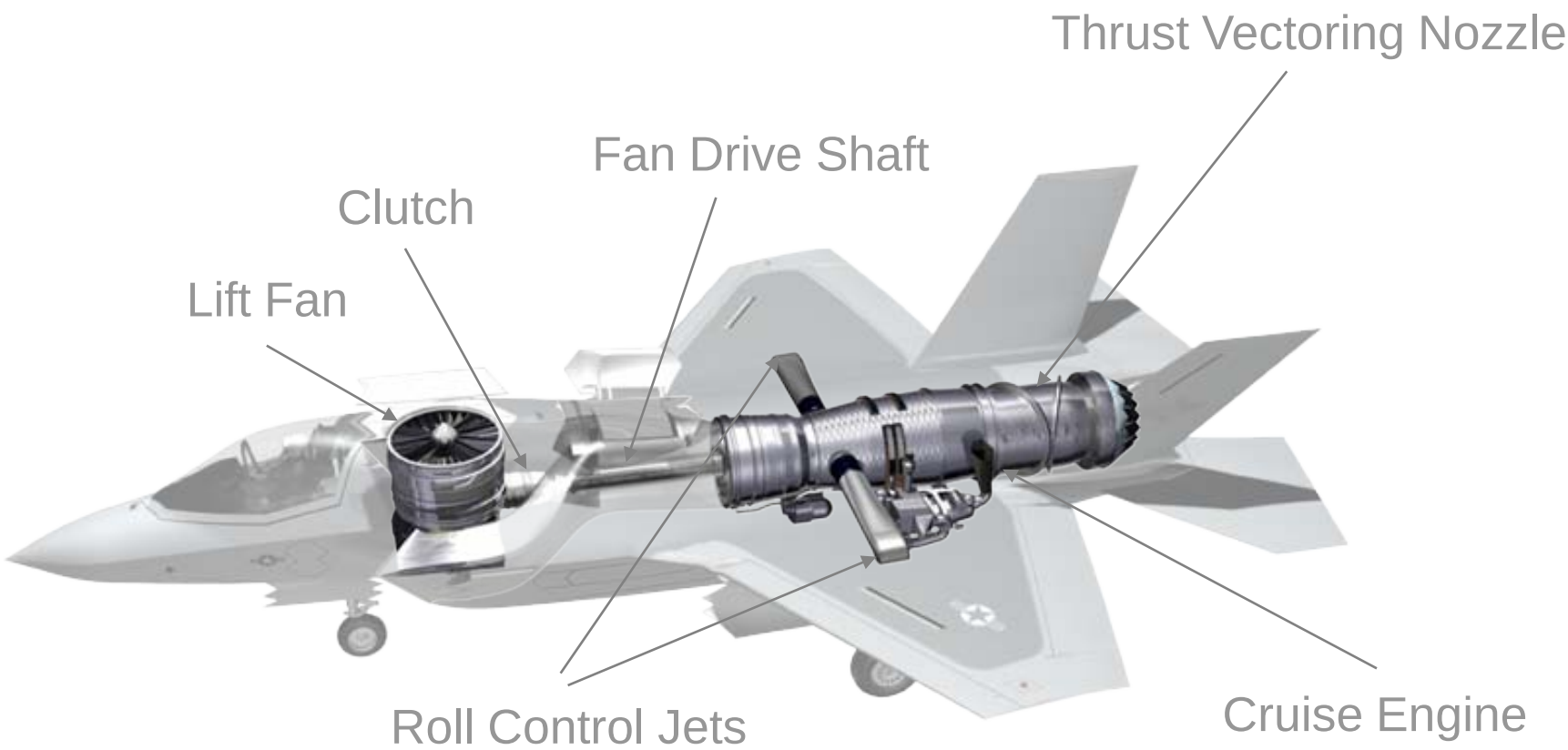
How We Won: The X - Planes

“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



AV-8 Harrier Adopted by US Marine Corps 1970

The Harrier Approach Isn't Supersonic

F-104 Starfighter

15,000 lbs Thrust

Mach 2

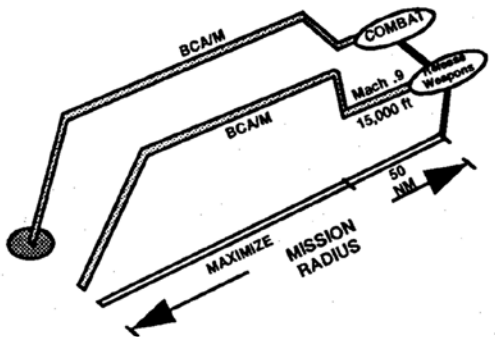
AV-8B Harrier

20,000 lbs Thrust

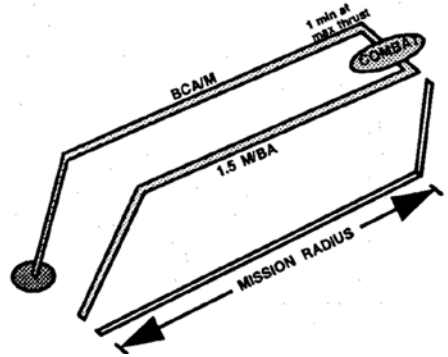
M < 1

Design Missions

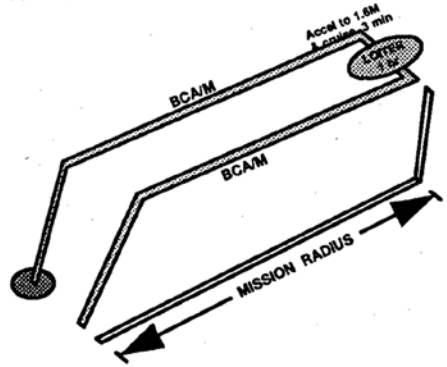
Interdiction



Deck Launched Intercept

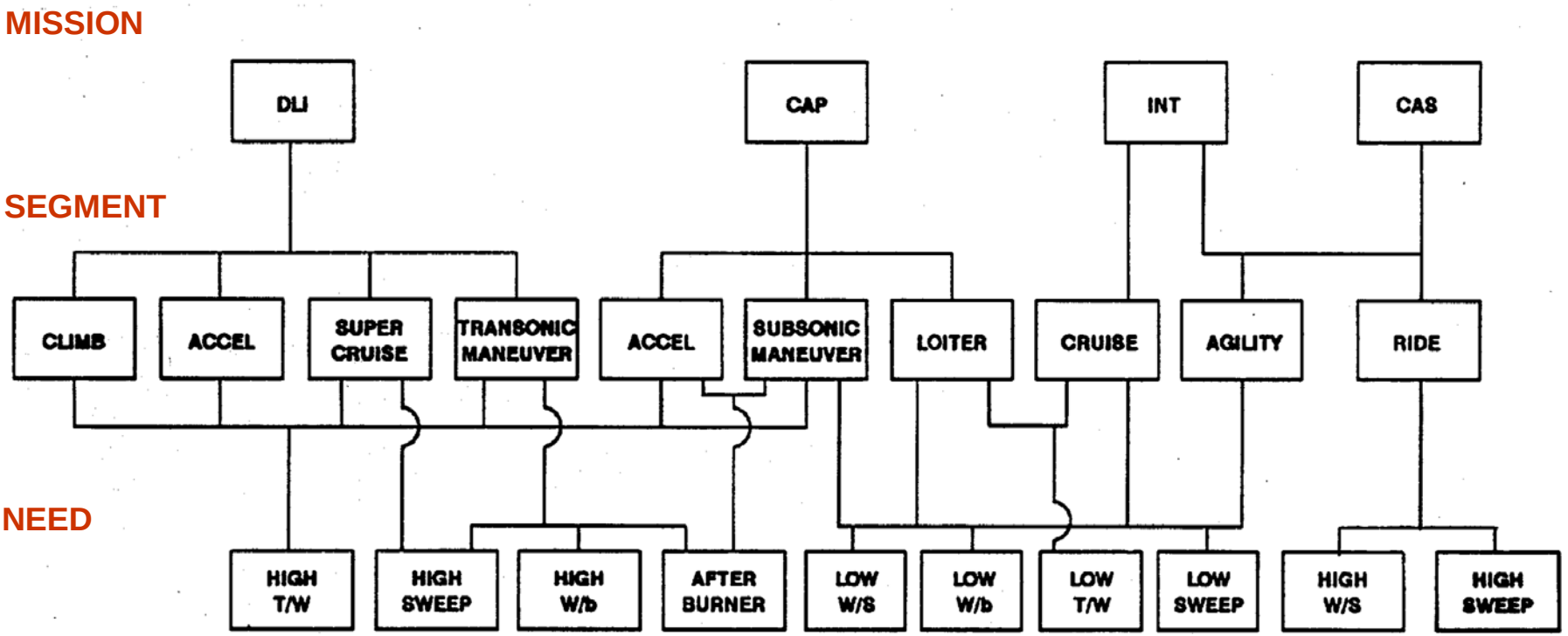


Combat Air Patrol

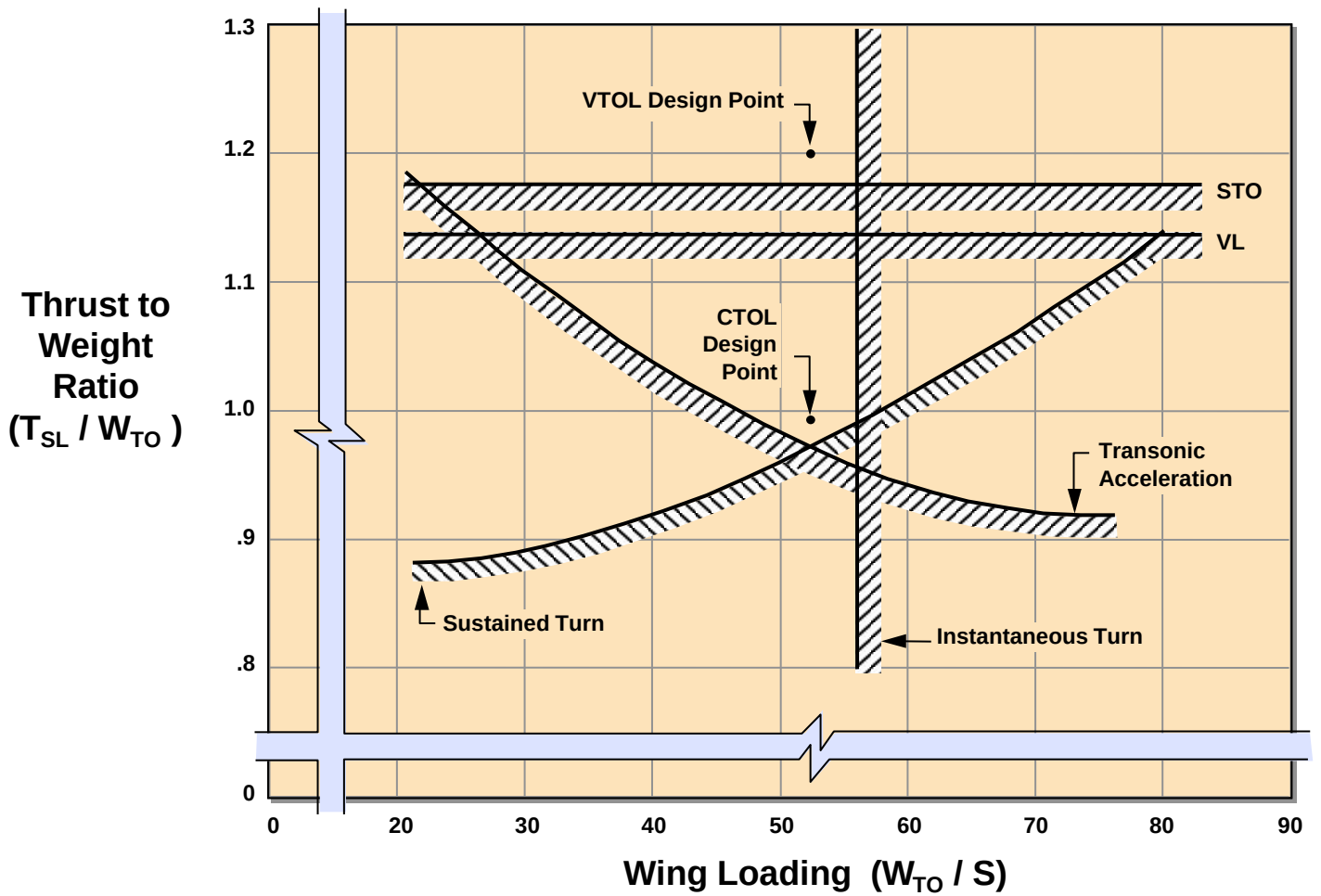


Requirements Analysis

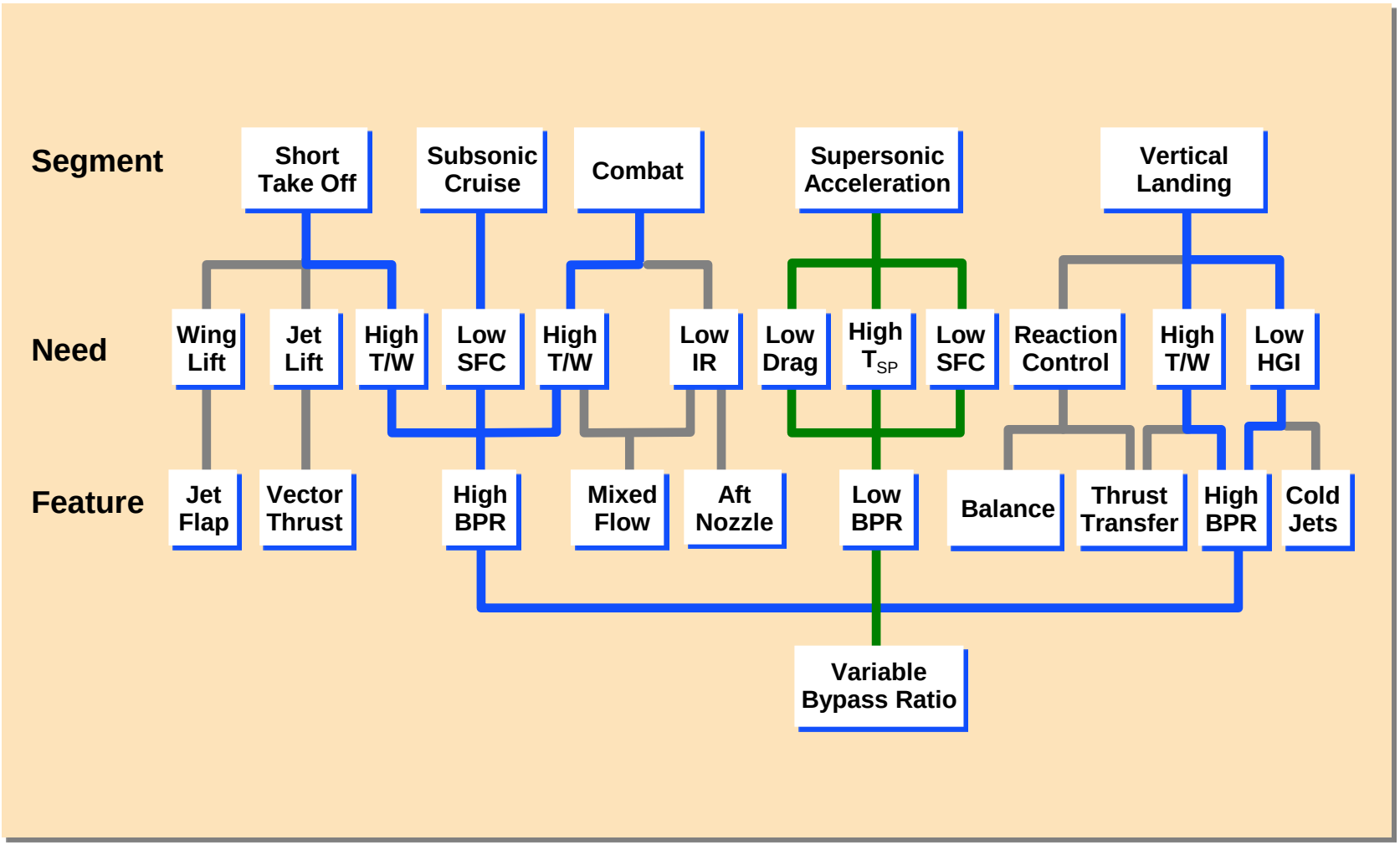
Willoughby Templates



VTOL Requirement Sizes the Engine

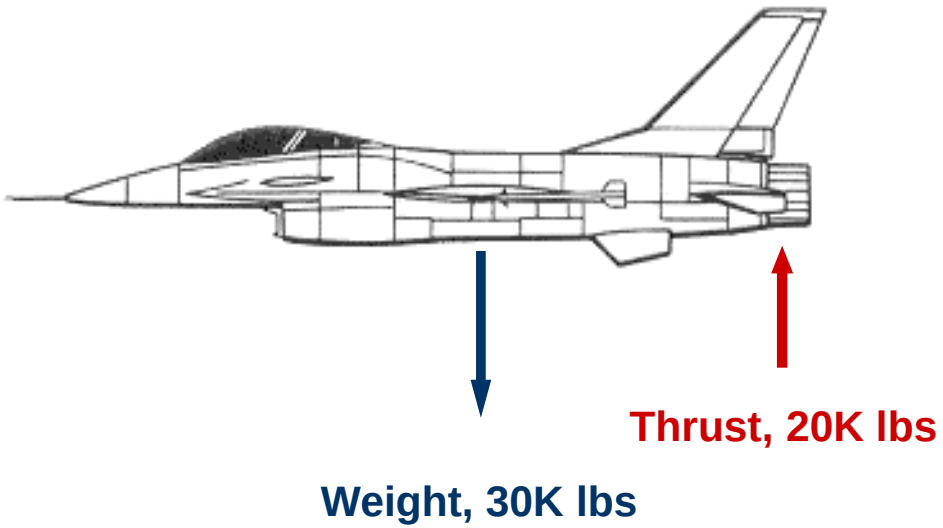


Engine Requirements Analysis

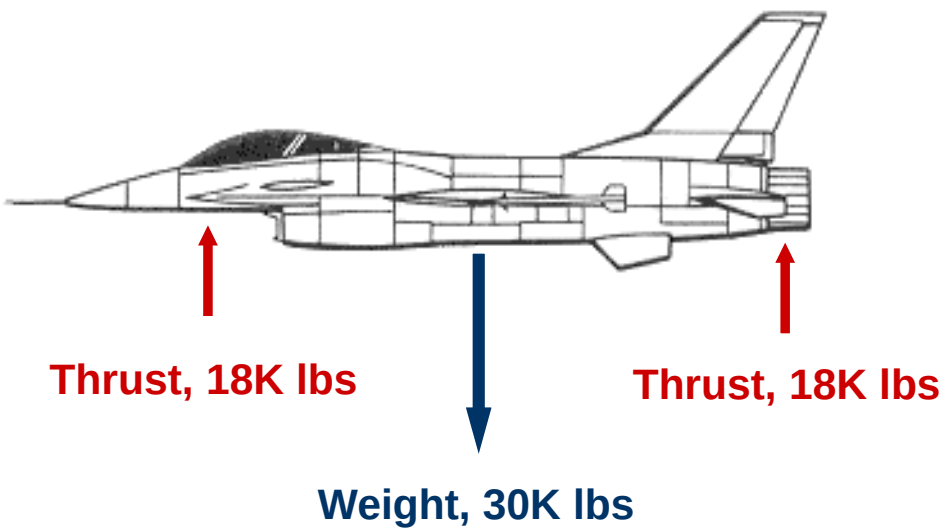


The Basic Problem:

Not Enough Thrust, and It's Too Far Aft



Conventional F-16



"V/STOL" F-16

Solving the Basic Problem

Not Enough Thrust, and It's Too Far Aft

Means to Produce Thrust

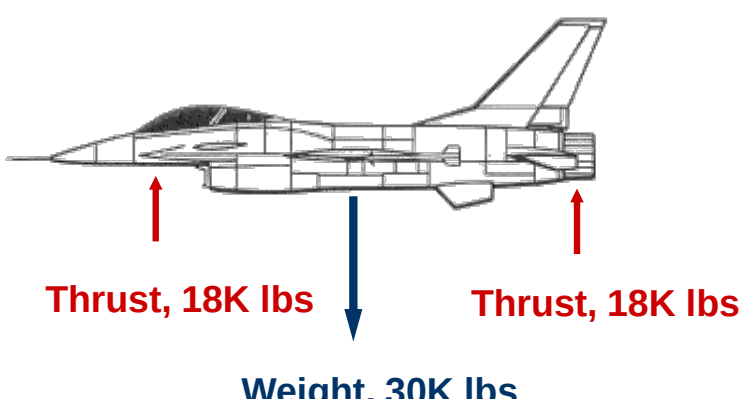
- *Fans*
- *Rockets*
- *Pulse Jets*
- *Ram Jets*
- *Ejectors*
- *Explosions*
- *MHD*
- *EFD*

Means to Transfer Power

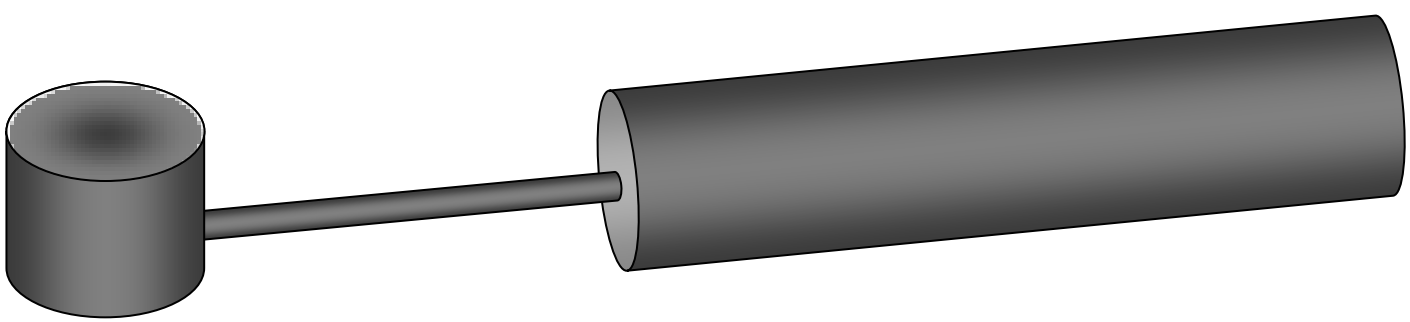
- *Shafts*
- *Ducts*
- *Heat Pipes*
- *Laser Beams*
- *Chain Drive*
- *Fiber Optics*
- *Wires*
- *Hydraulics*

Means to Extract Power

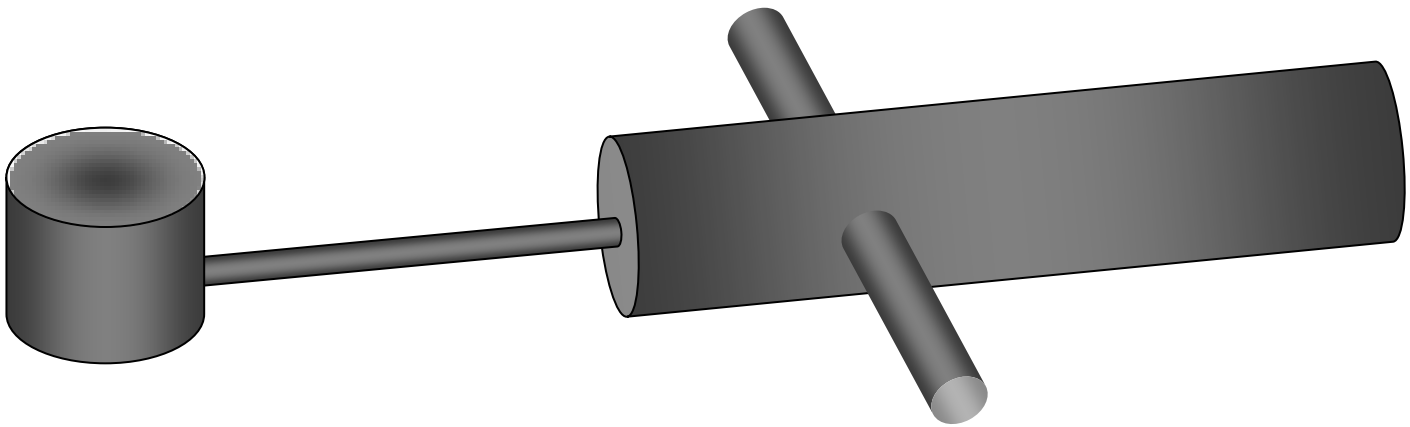
- *Turbines*
- *Scoops*
- *Regeneration*
- *Heat Pipes*
- *Alternator*
- *Generator*
- *MHD*
- *EFD*



Shaft Driven Lift Fan Propulsion Concept

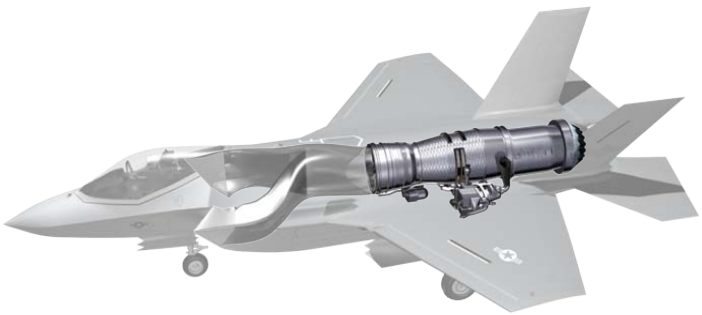


Shaft Driven Lift Fan Propulsion Concept



F-35 Propulsion System

Alternative Types of Turbine Engine



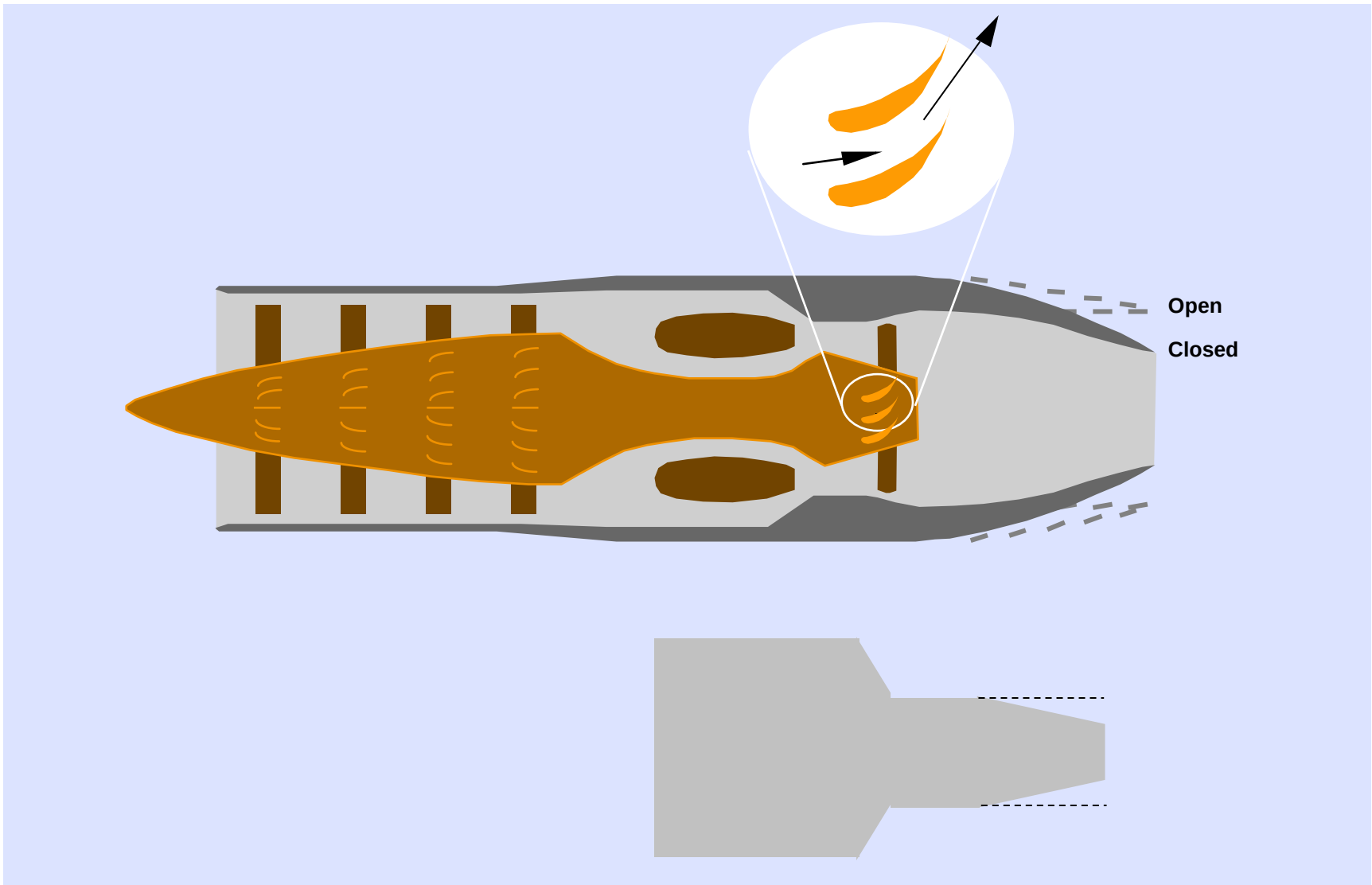
Turbofan Engine

Provides Cruise Thrust, but no Shaft Power

Turboshaft Engine

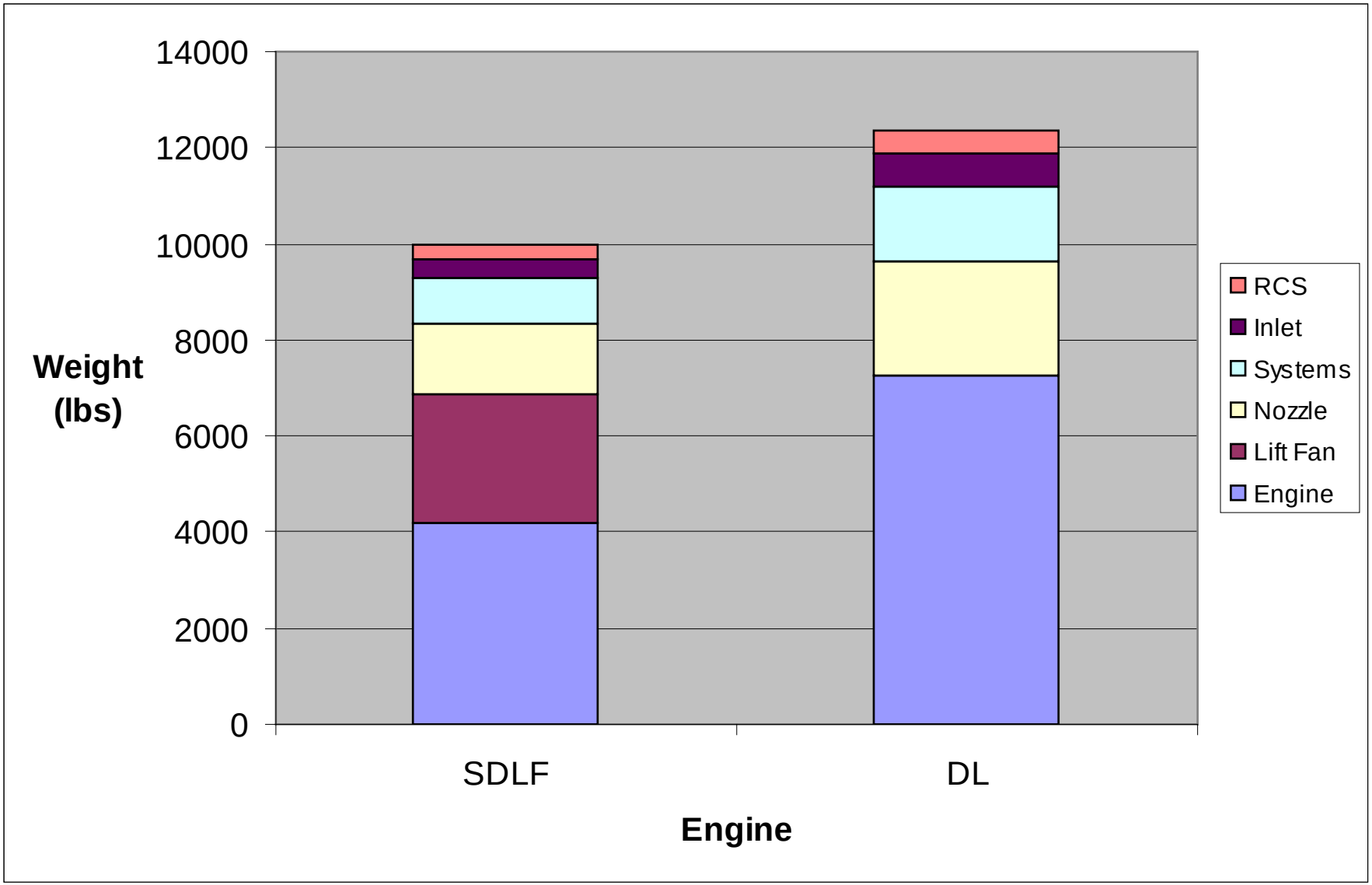
Provides Shaft Power, but no Cruise Thrust

Extracting Shaft Power



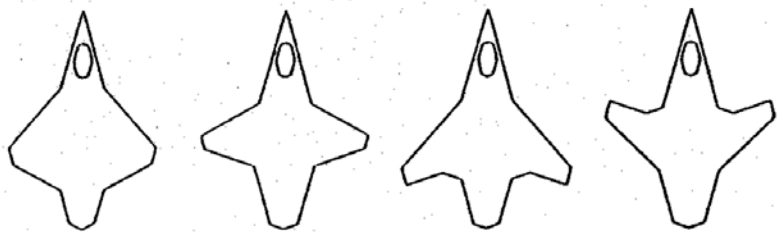
Comparison with LM Lift/Cruise System

at 40,000 lbs of thrust



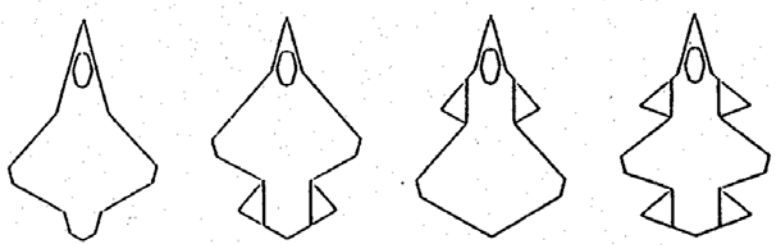
Design Options

WING PLANFORM



WING POSITION

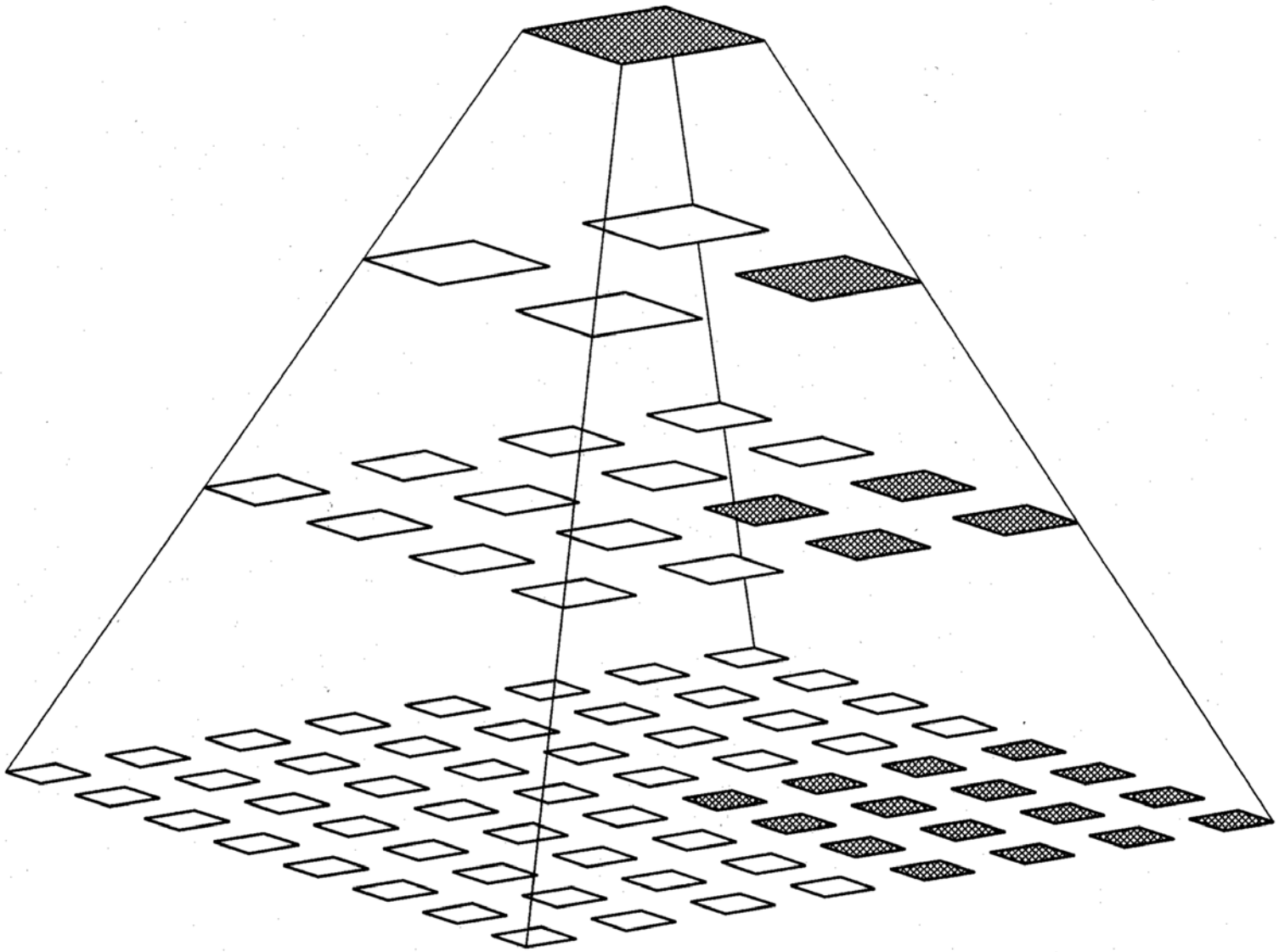
HORIZONTAL STABILIZERS



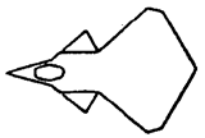
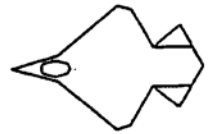
VERTICAL STABILIZER

INLET LOCATION

Number of Alternative Aircraft Is Too Large

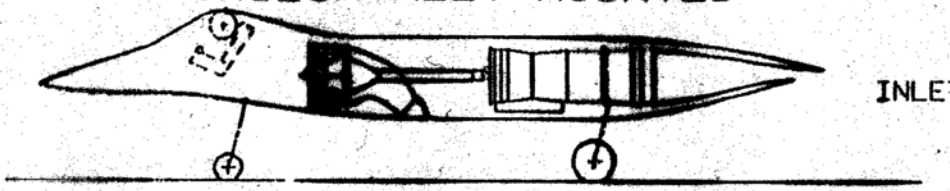


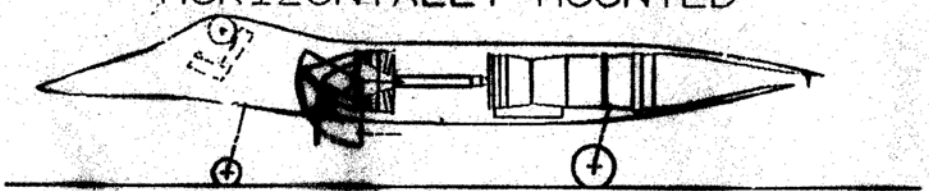
Horizontal Stabilizer Assessment

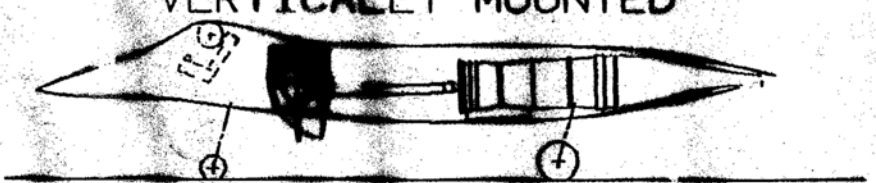
	 THREE SURFACE		 WING / CANARD		 SIMPLE DELTA		 WING / TAIL	
	STABLE	UNSTABLE	STABLE	UNSTABLE	STABLE	UNSTABLE	STABLE	UNSTABLE
FRICTION DRAG	3	3	2	2	1	1	2	2
INDUCED DRAG	1	1	2	2	4	4	2	2
WAVE DRAG	3	3	3	3	1	1	3	3
INTERFERENCE DRAG	3	3	2	2	1	1	2	2
SUBSONIC TRIM DRAG	1	1	2	2	3	2	3	2
SUPERSONIC TRIM DRAG	1	1	3	2	5	2	4	2
EMPENNAGE WEIGHT	3	3	2	2	1	1	2	2
FUSELAGE WEIGHT	1	1	2	2	2	2	3	2
HIGH ALPHA CAPABILITY	2	2	2	1	5	4	2	2
TRIMMED MAX LIFT	2	2	3	1	5	3	2	2
STD PERFORMANCE	1	1	1	1	4	4	2	2
IGE SUCKDOWN	2	2	2	2	4	4	2	2
SIGNATURE	4	4	2	2	1	1	2	2
ACTUATORS (R&D)	4	4	2	2	1	1	2	2
RECONFIGURABILITY	1	1	3	3	5	5	4	4

Lift Fan Installation

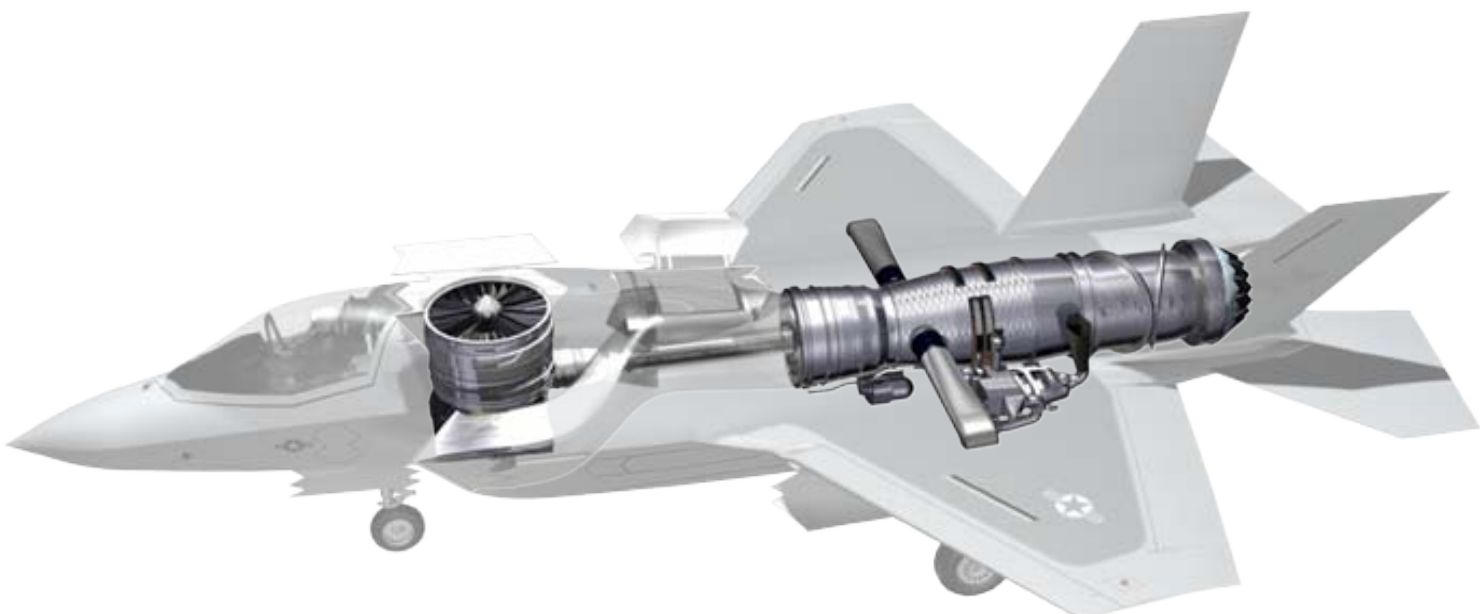
	STRONG POINTS	WEAK POINTS
HORIZONTALLY MOUNTED	INLET PERFORMANCE	BALANCE
HORIZONTALLY MOUNTED	BALANCE	INLET PERFORMANCE
VERTICALLY MOUNTED	HOVER THRUST	WEIGHT







JSF STOVL Propulsion System

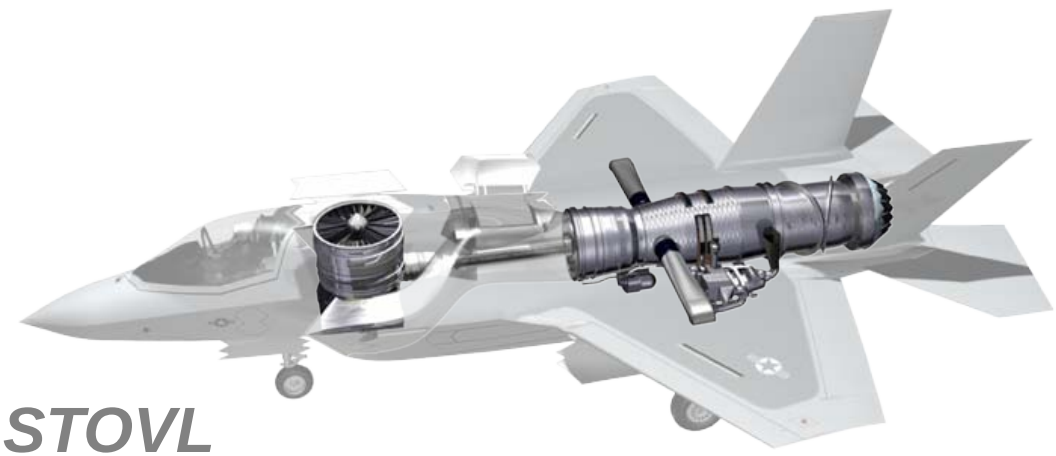


AV-8B Harrier and the F-35 Musketeer

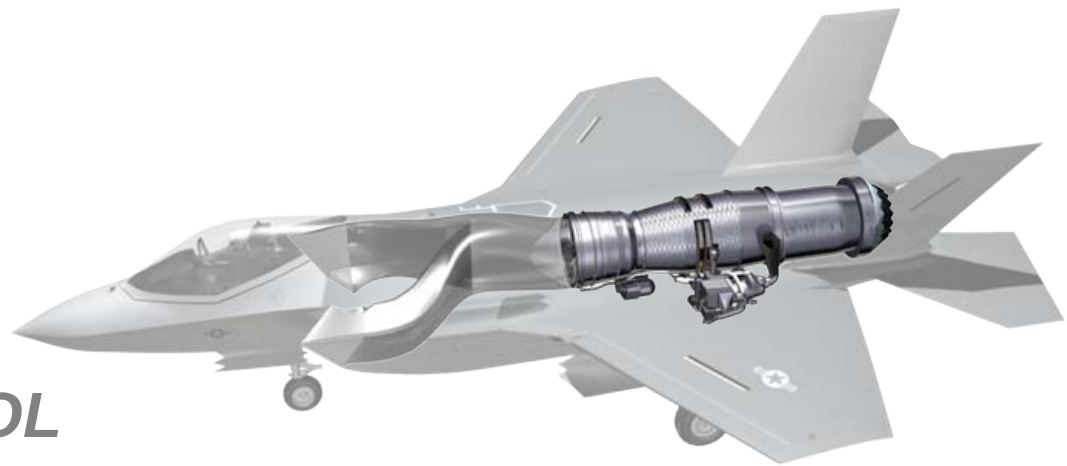
Fan Augmentation
Hot Gases Aft
Continuous Thrust Vectoring
Lift Improvement Devices
Poor Supersonic Area Distribution
Overtemp Reduces Engine Life
Water Injection Required
Side by Side Jets Permit Hot Gas Ingestion
Compressor Air for Reaction Control Jets

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

Demonstrate propulsion and airframe performance through ground test

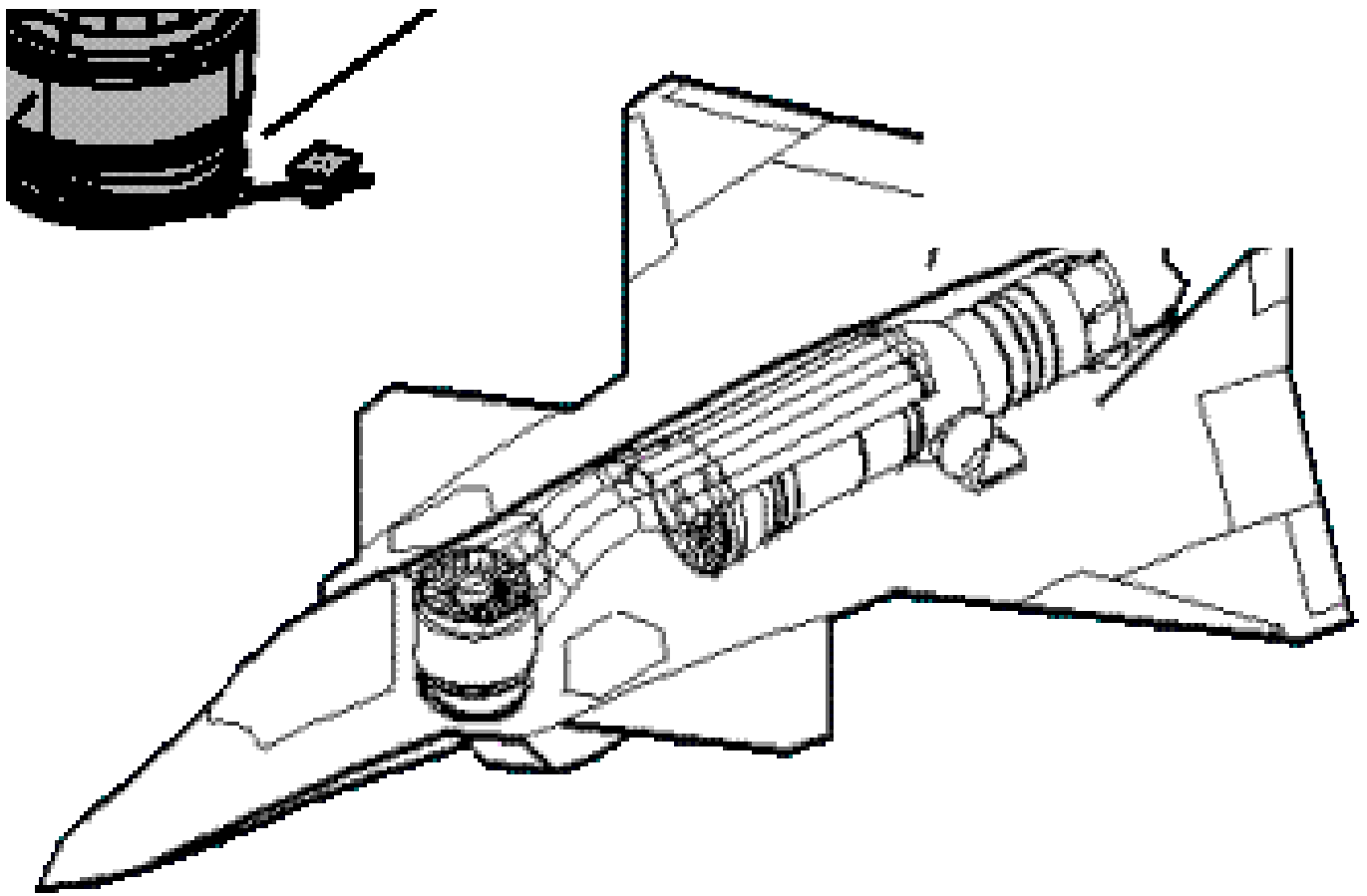
McDonnell Douglas

Gas Driven Lift Fan $35M

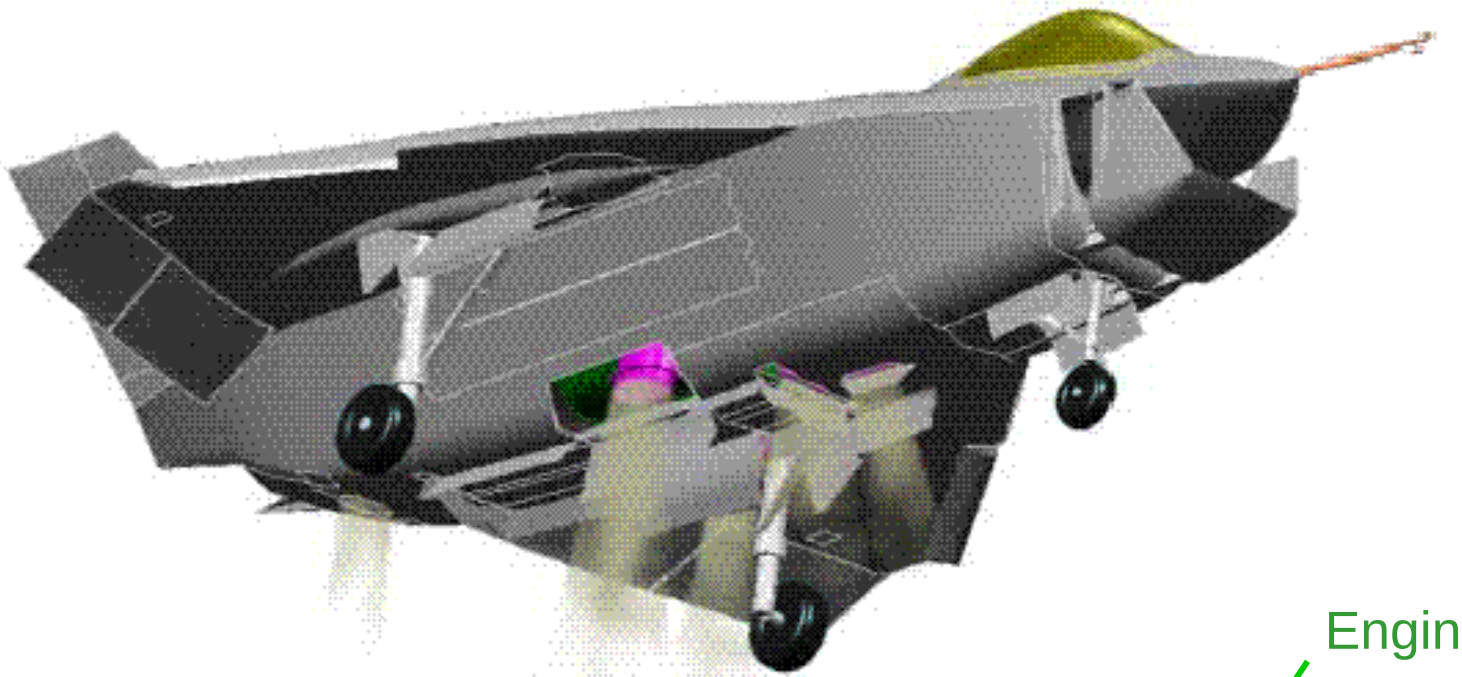
Lockheed Skunk Works

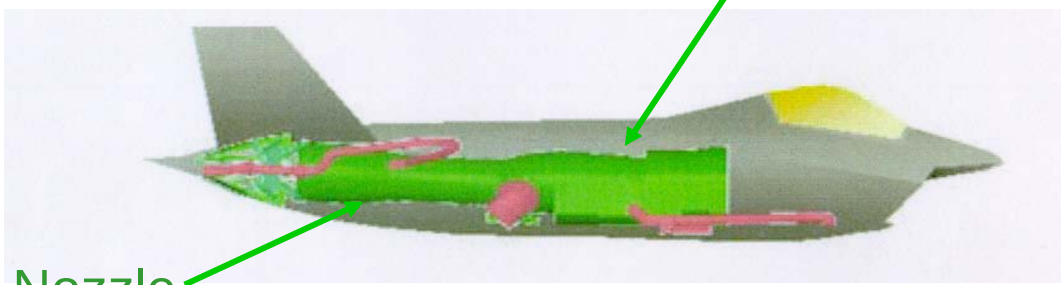
Shaft Driven Lift Fan $40M

McDonnell Douglas Gas Driven Lift Fan Concept 1993



Boeing Lift / Cruise Engine Concept
1994

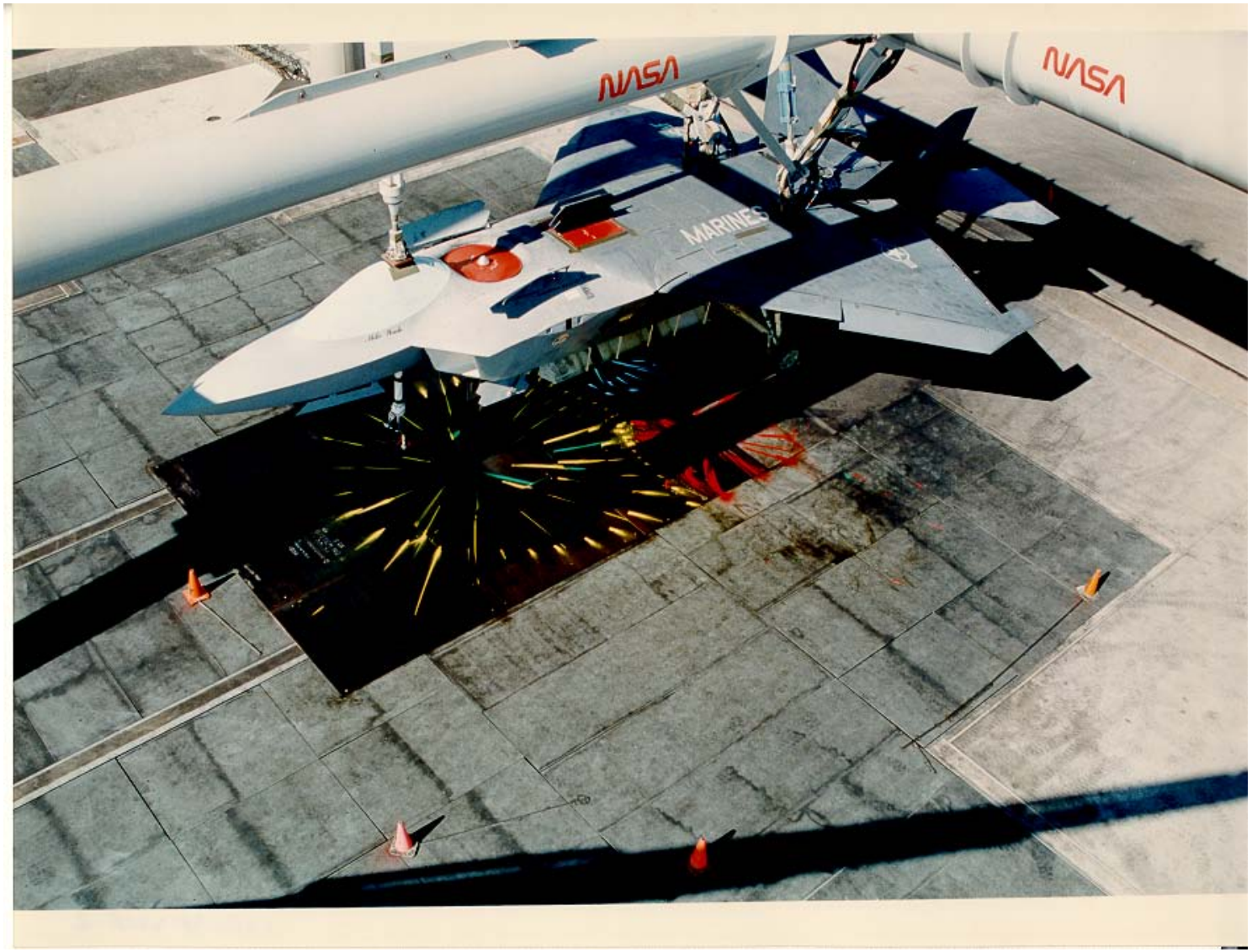




Lockheed Martin Large Scale Powered Model 1995

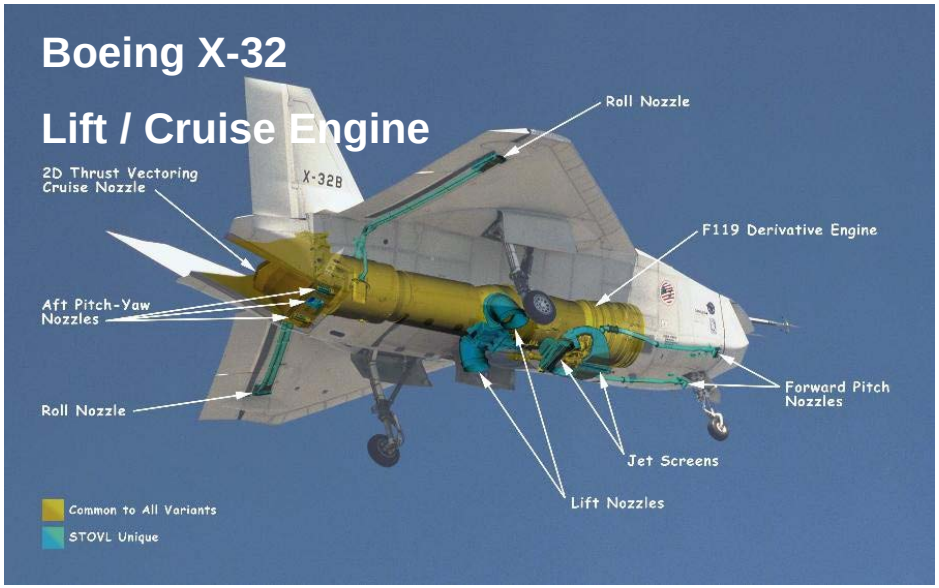
Lockheed Martin Large Scale Powered Model

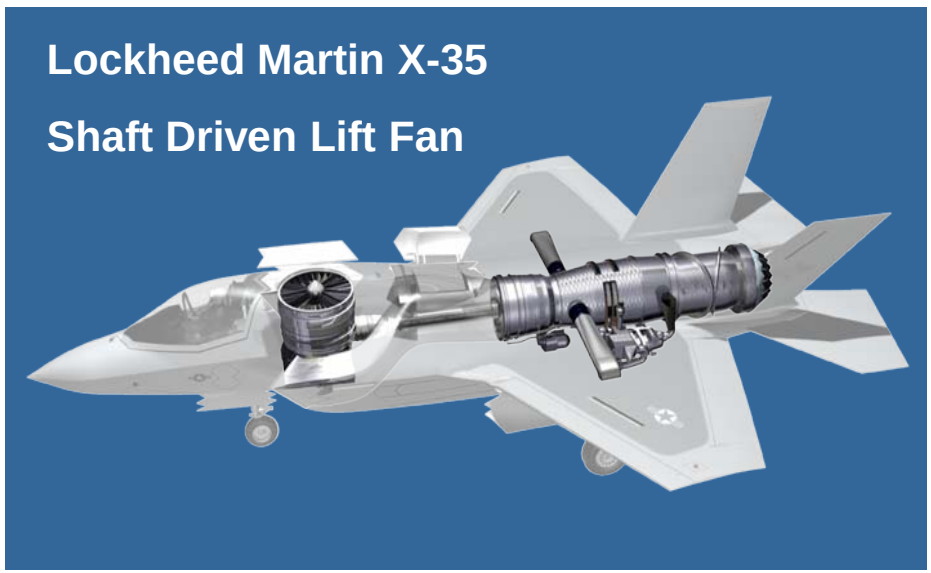
NASA Testing



Boeing Large Scale Powered Model 1996

JSF Concept Demonstrator Awards
1996





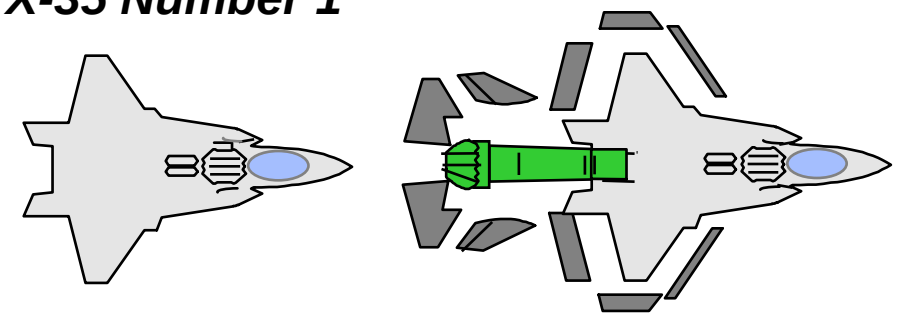
- **Mature Technologies to Reduce Risk**
- **Build Aircraft to Validate Performance**
- **Refine the Design, as Necessary**

Lockheed Martin Demonstrator Approach

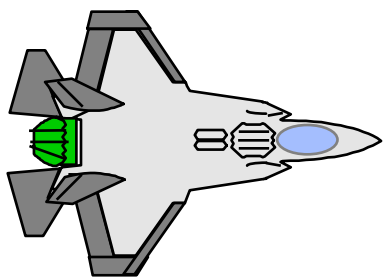
- Build Two Aircraft, but Fly All Three Variants
- Fly the Production Configurations
- Demonstrate STOVL Performance and Supersonic Speed
- Prove Handling Qualities and Carrier Suitability

X-35 Commonality

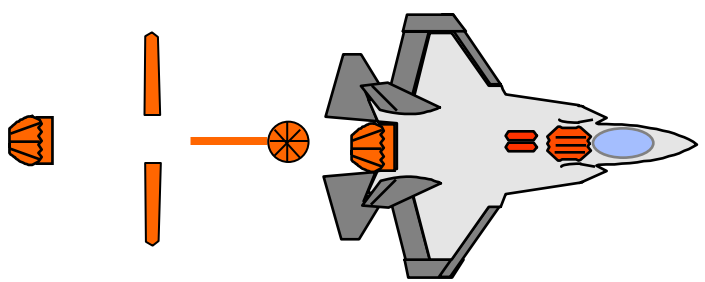
X-35 Number 1



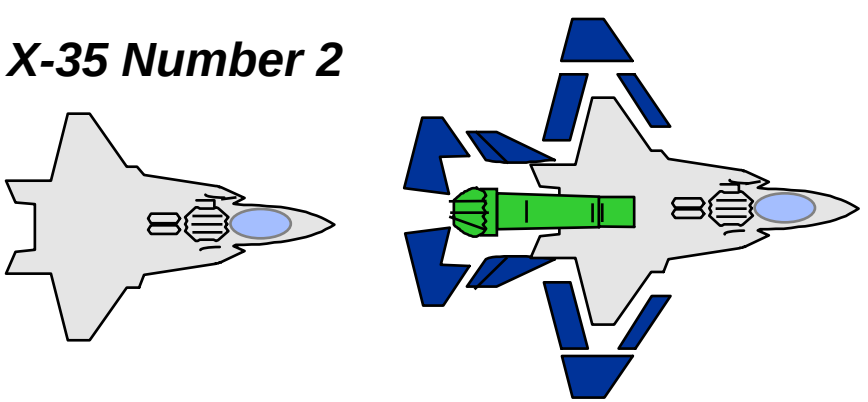
CTOL X-35A



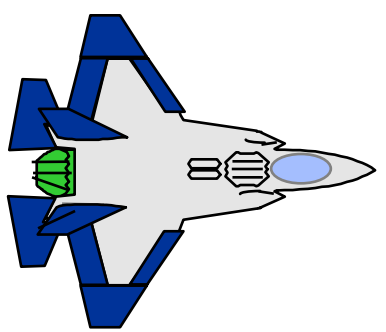
STOVL X-35B



X-35 Number 2



Carrier X-35C

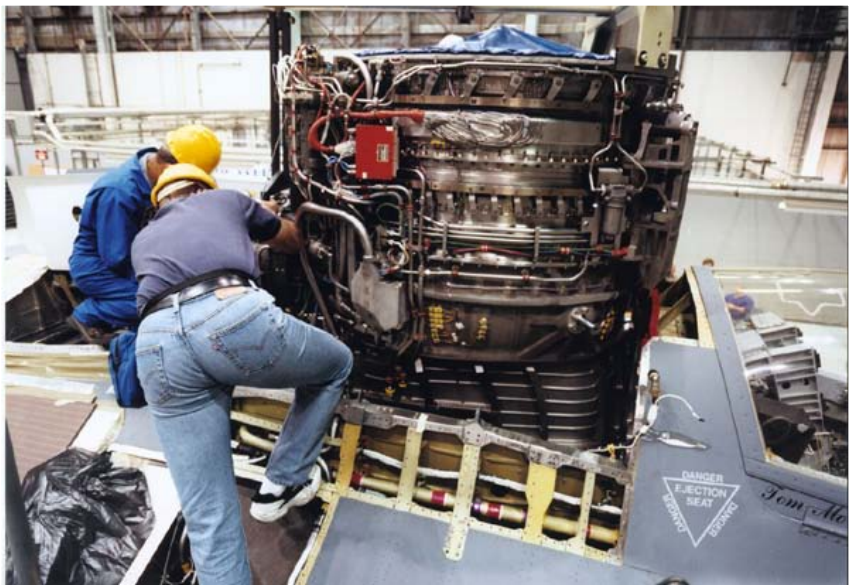


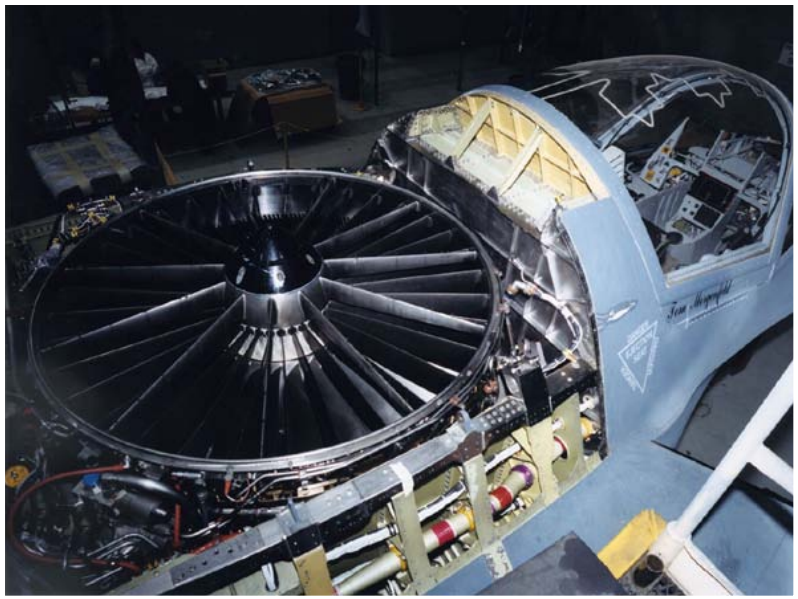
Validation by High Fidelity Demonstrators

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





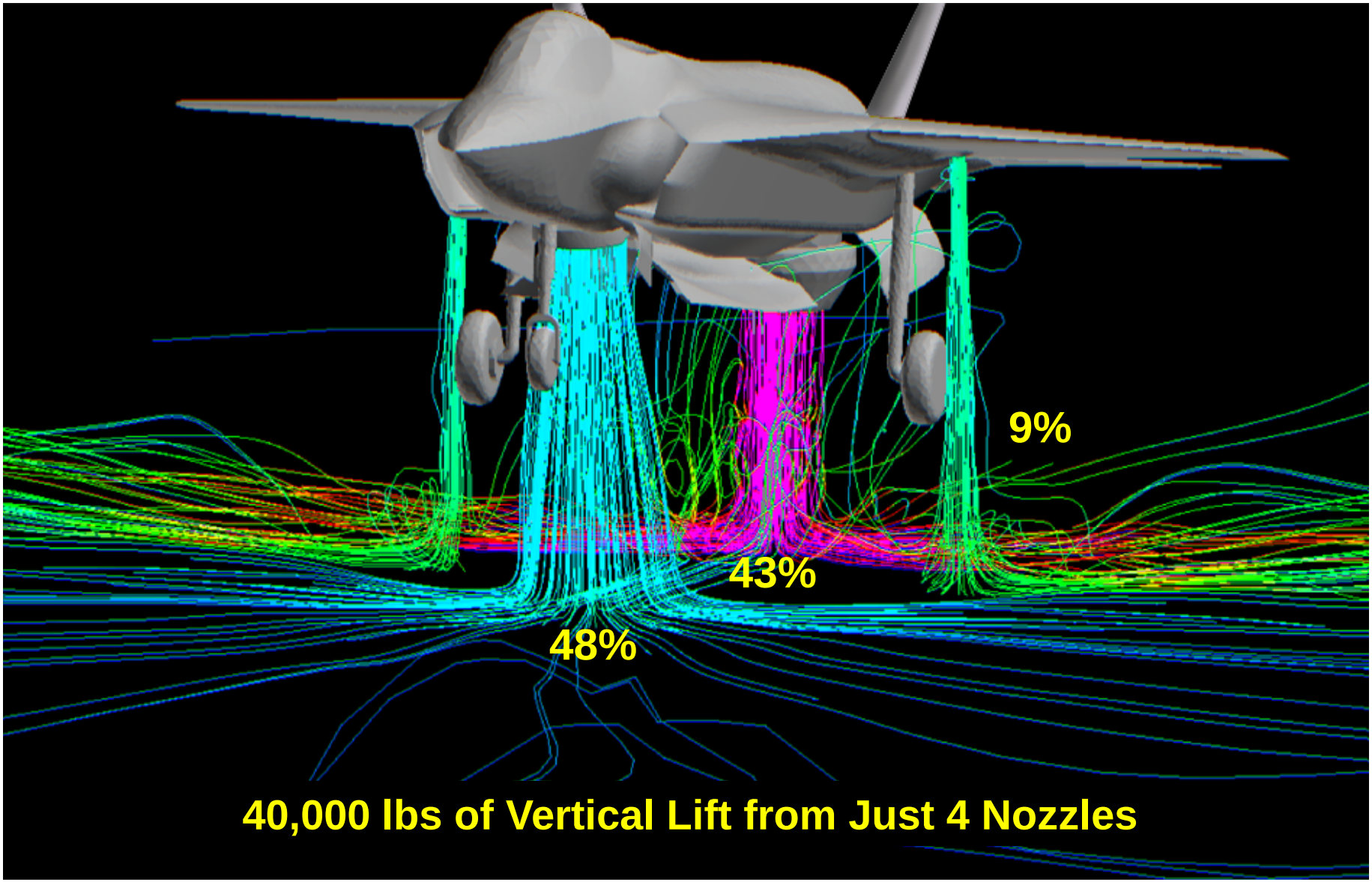
STOVL USMC / Royal Navy Variant

- **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



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

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, demonstrated 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

This is a Team Success