CAL POLY, San Luis Obispo

Presents

LOW COST COMMERCIAL TRANSPORT DESIGN

to:

NASA/USRA
Universities Advanced Design Program
10th Annual Summer Conference
Pasadena, CA

June 15, 1994

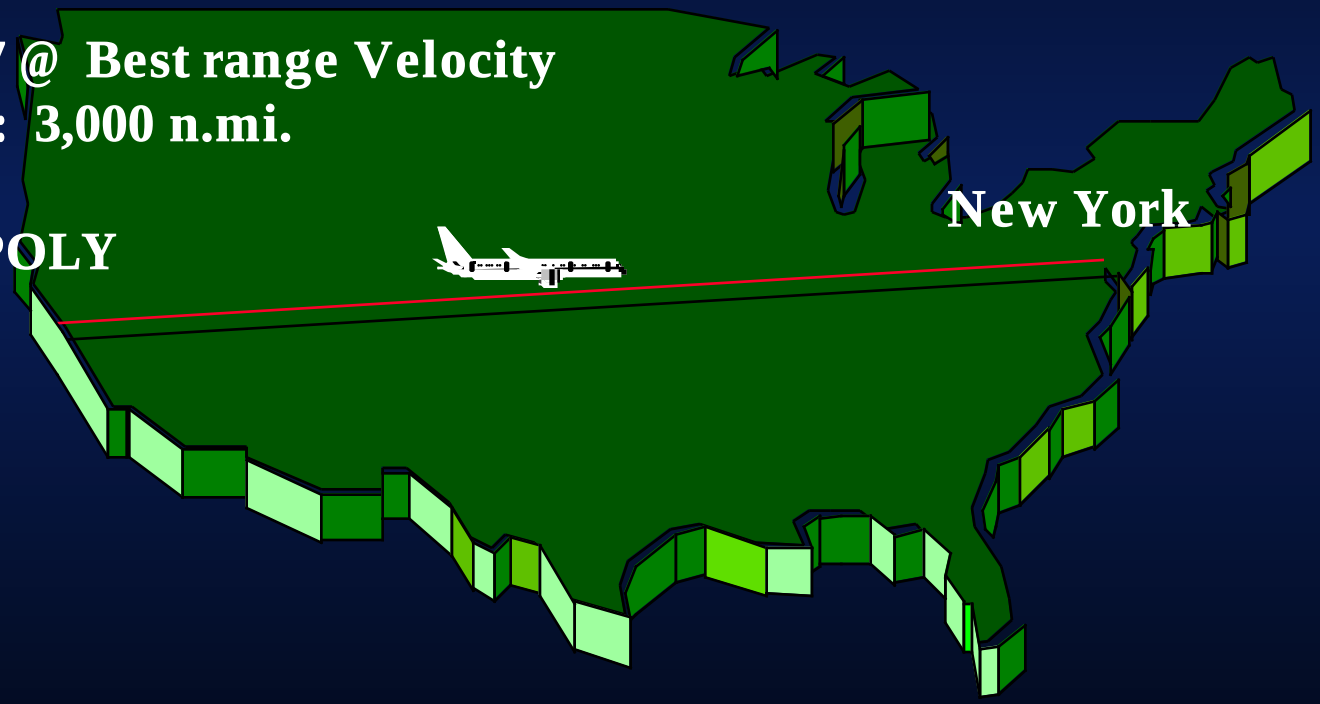
CAL POLY DESIGN CLASS

- Year Long Design Class
- 38 Senior Aero Engineering Students
- 5 Design Teams

RFP OVERVIEW

M>0.7 @ Best range Velocity
Range: 3,000 n.mi.

CAL POLY



PRESENTATION OUTLINE

- **ROMAN FRY**

  PLAN-IT X — OFP-6M
  FOWL ENTERPRISES — LCX
  CENTRAL COAST DESIGNS — 8-BALL EXPRESS

- **GREGORY KING**

  NON-SOLO — ALUMINUM FALCON

- **MIKE LUJAN**

  FLYING CIRCUS — FC-1D

- **ROMAN FRY**

  Concluding Remarks

PLAN-IT X OFP-6M

- **TWIN AISLE**

  Fineness Ratio 6.3

  Small C.G. Excursion

  Large Cross Sectional Area

  Optimal Total Volume/Total Wetted Area

  12 LD-3 Containers

- **Engines**

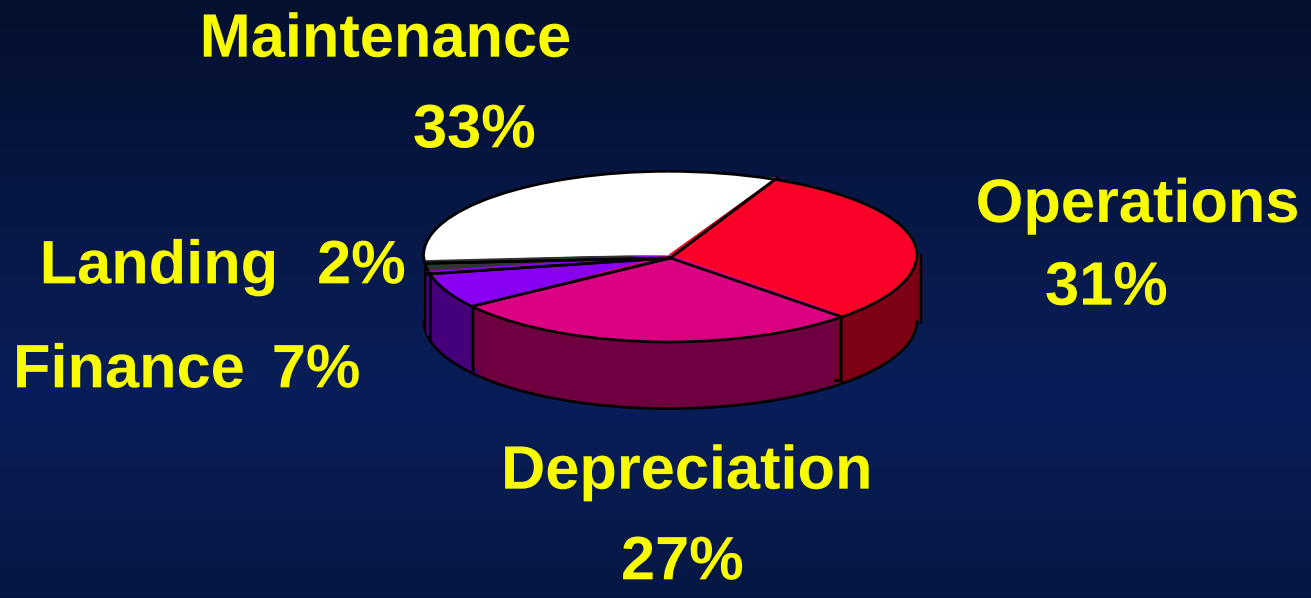
  High Bypass Ratio Advanced Ducted Prop

  Improved SFC

- **Aerodynamics**

  Near Midwing, Shark Fins, Small Tail Size

DOC BREAKDOWN

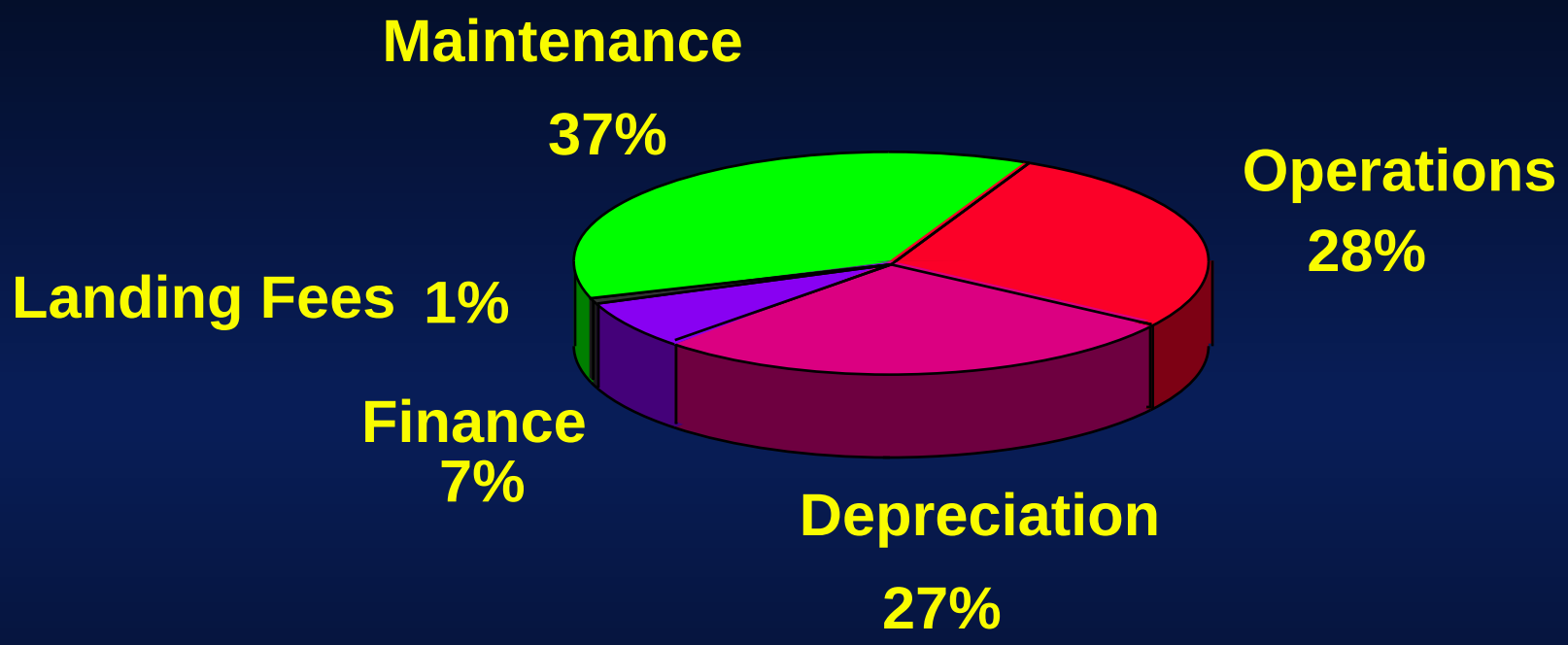


ACQUISITION COST = $ 29.5 M

FOWL ENTERPRISES LCX

- **Regional Airport Market**
  - Cross Country Routes
  - Hub & Spokes Relief
- **Aerodynamics**
  - HLFC
    - 10% Drag Reduction
    - L/D = 21.5
    - Mission Accomplished with System Failure
    - Not Fuel Price Sensitive
- **Low Cost**

DOC BREAKDOWN

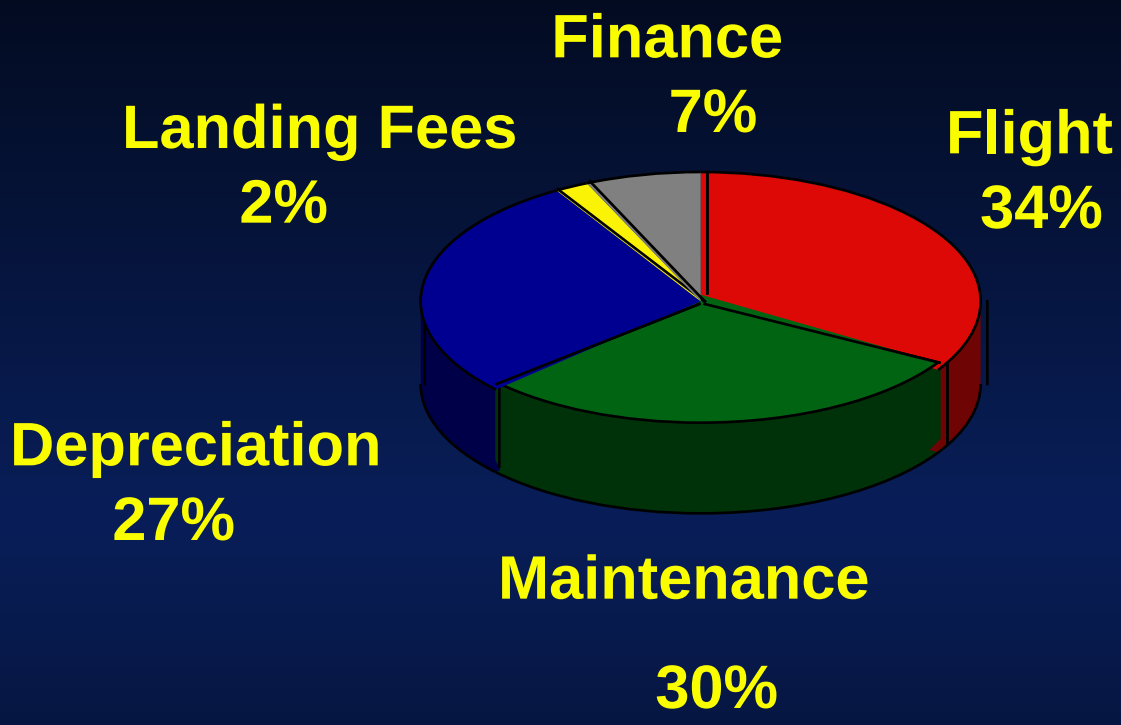


ACQUISITION COST = $29 M

CENTRAL COAST DESIGN 8-BALL EXPRESS

- **Conventional Design**
  - Lower Maintenance
    - Reduced DOC
  - Lower Acquisition Cost
    - Customer Appeal
- **Concurrent Engineering**
  - Ease of Design, Manufacturing, Production
  - Lower Production Cost
- **Cargo Capacity**
  - 8000 lbs
    - Extra Revenue Source

DOC Breakdown



ACQUISITION COST = $28 M

THE ALUMINUM FALCON

BY NON-SOLO DESIGN GROUP

CAL POLY, San Luis Obispo

THE ALUMINUM FALCON

- Innovative M-Wing Design
- Fly-by-Wire Flight Control System
- Judicious Use of New Materials
- Powerful High Lift System
- Low Cost

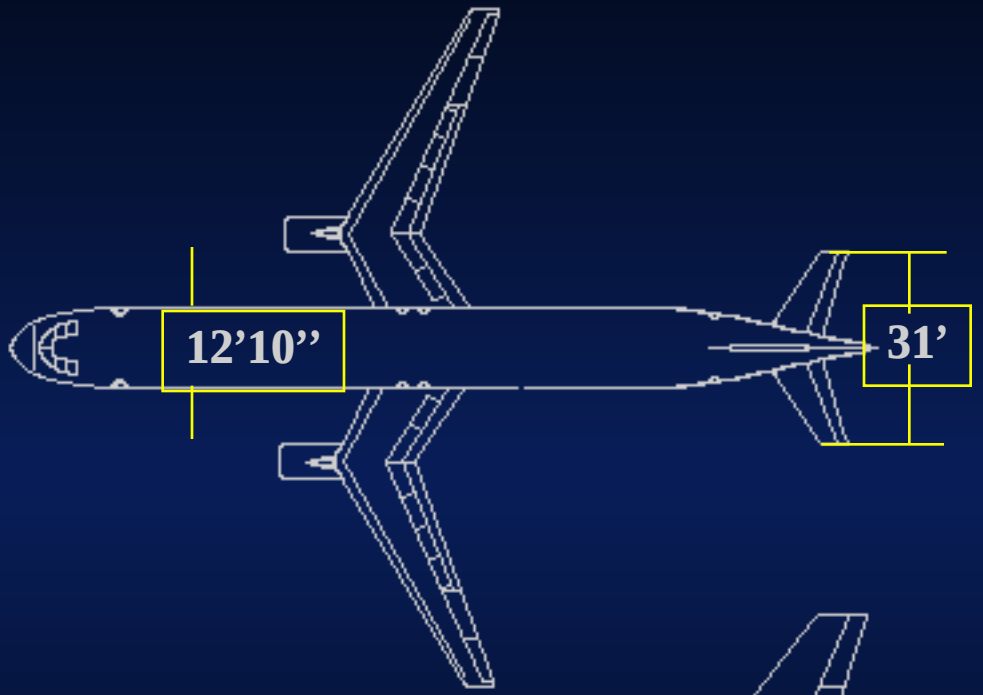
AF-1 DESIGN POINT

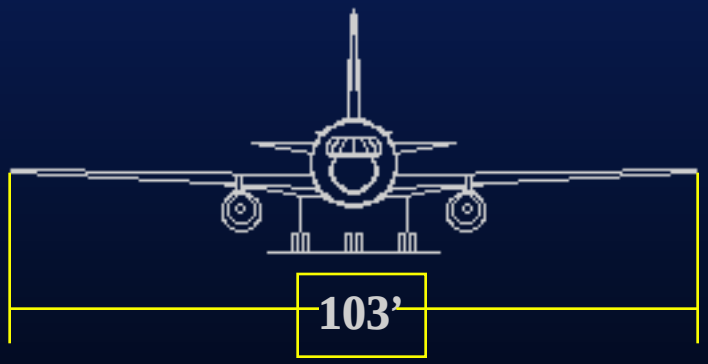
- **Wto = 140,000 lbs**
- **Takeoff W/S = 131 psf**
- **Wing Planform Area = 1069 sq ft**
- **Takeoff T/W = 0.32**
- **Required Total Thrust = 46,000 lbs**
- **Takeoff $C_{L_{max}}$ = 2.3**
- **Landing $C_{L_{max}}$ = 3.1**

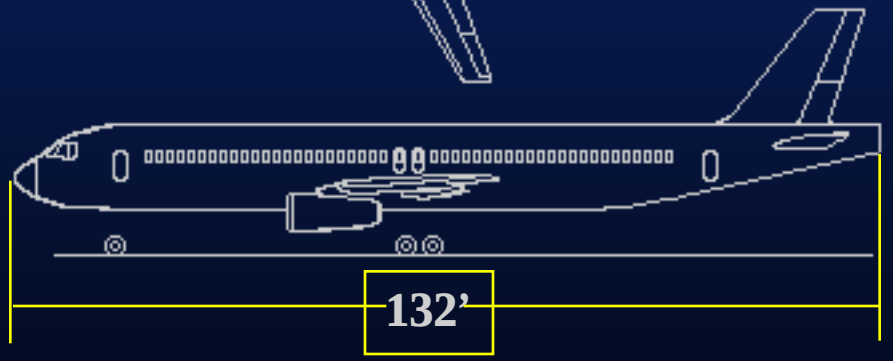
THE ALUMINUM FALCON

AF-1

Aspect Ratio = 10
Wing Sweep = 27 deg
Dihedral = 3 deg







CAL POLY, San Luis Obispo

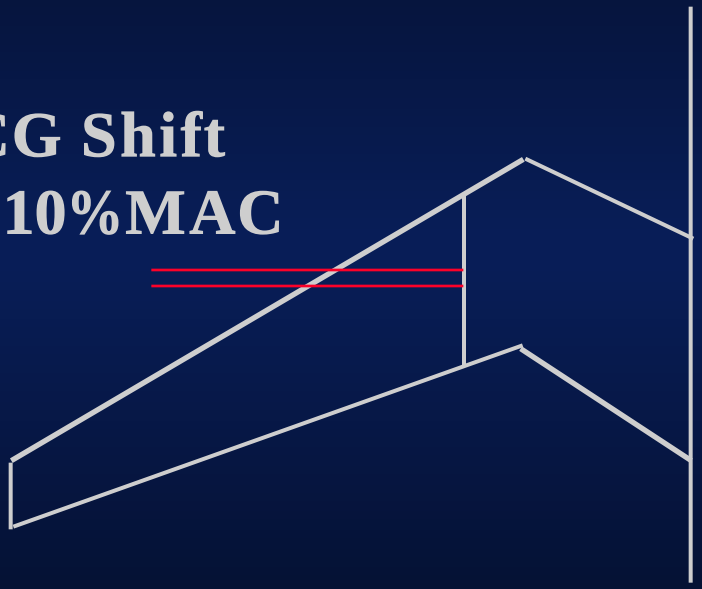
THE M-WING CONCEPT

- **Researched During the Second World War**
- **Offers Many Advantages of an Unswept Wing**
- **Advanced But Feasible**

CG SHIFT COMPARISON

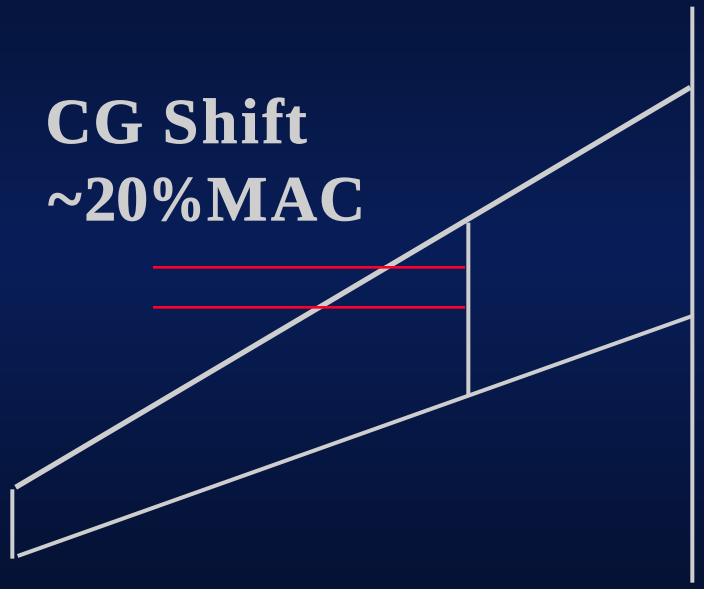
M-Wing

CG Shift
~10%MAC

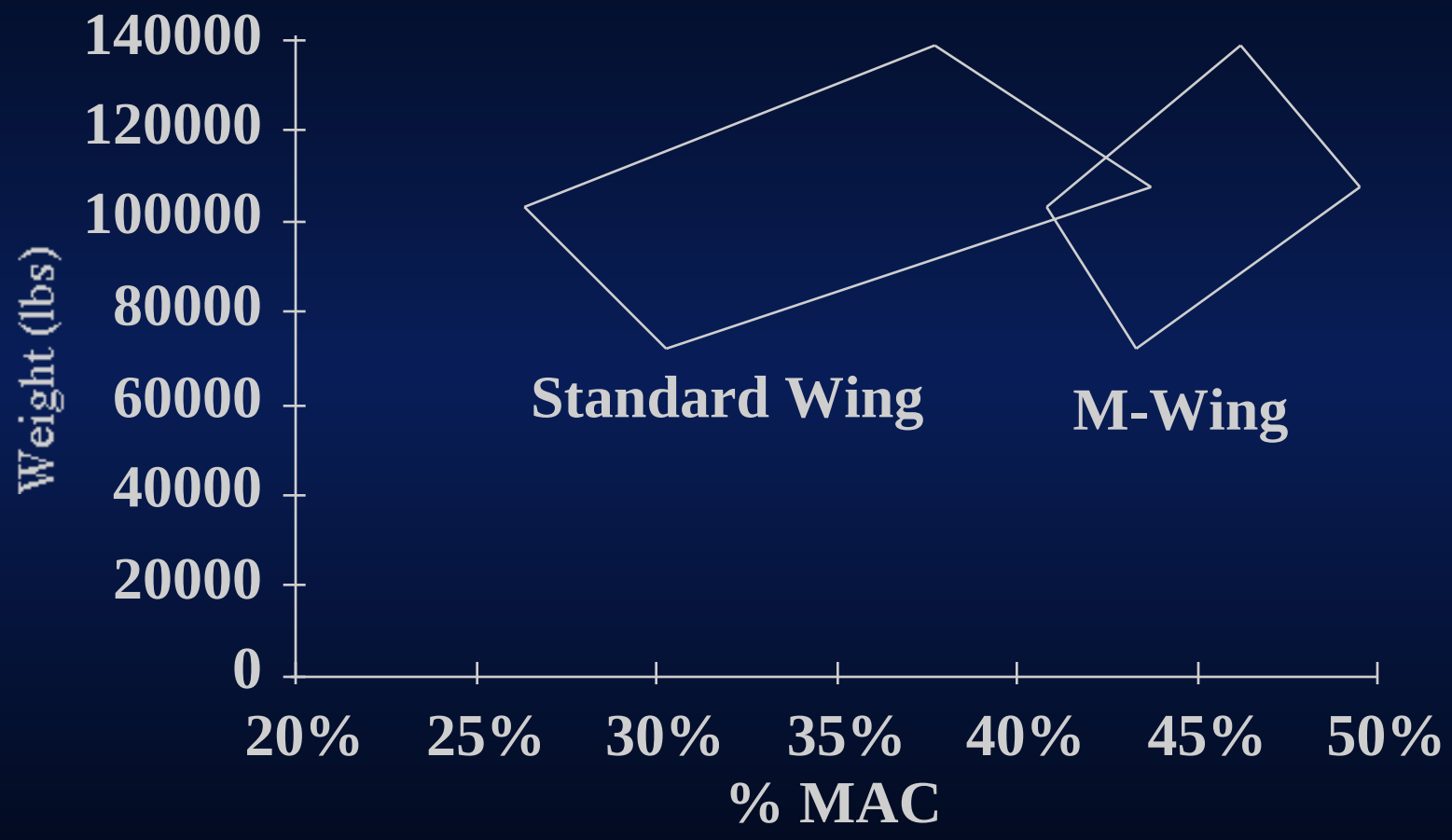


Aft Swept Wing

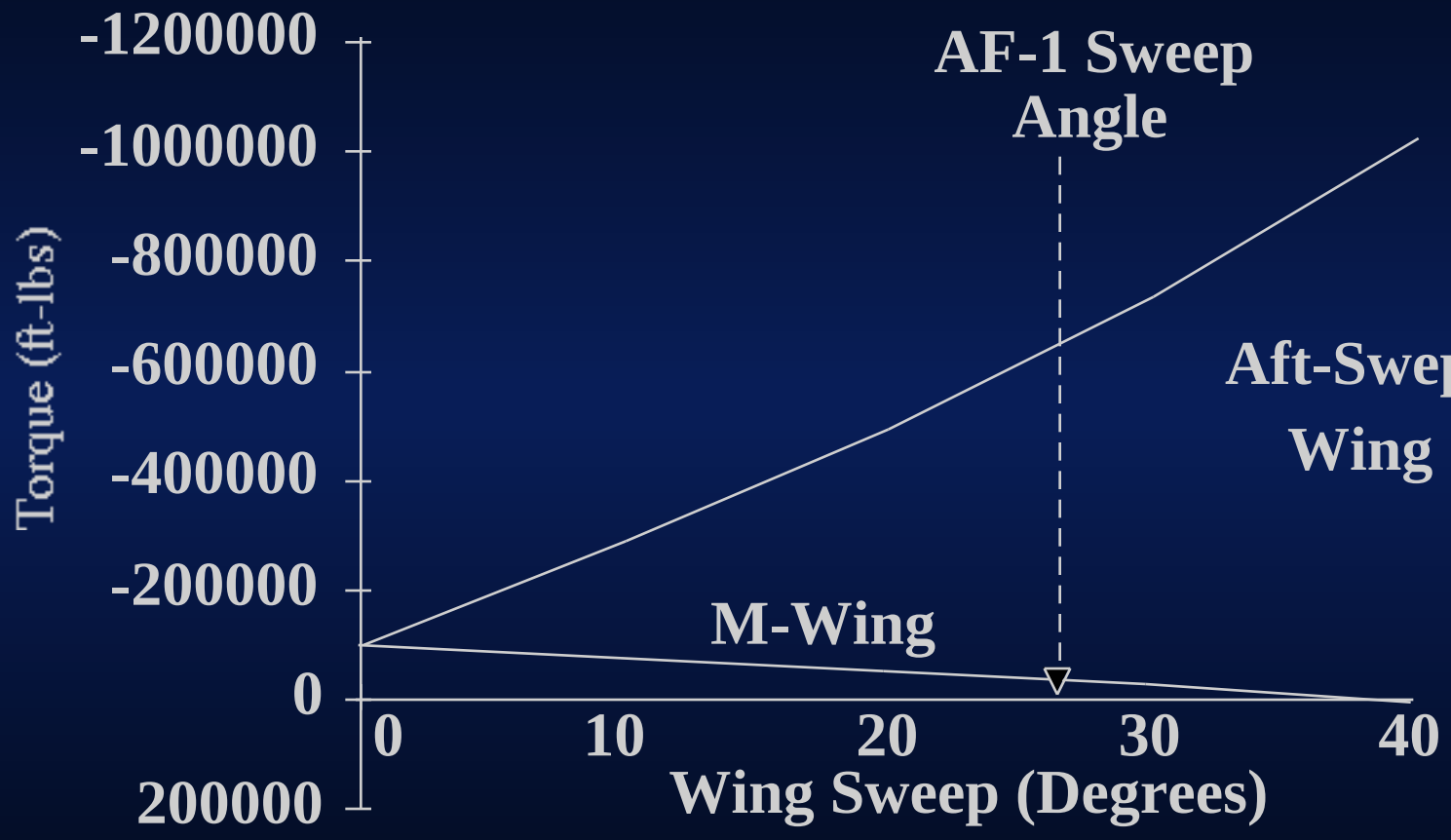
CG Shift
~20%MAC



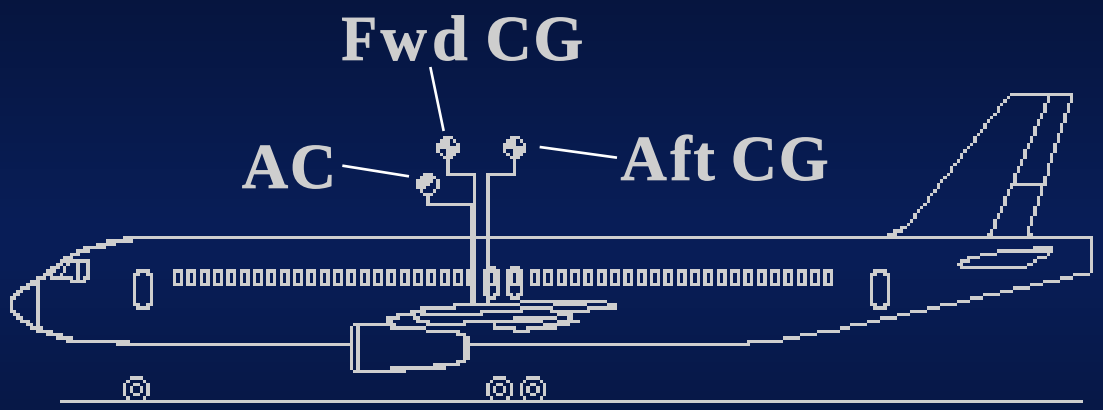
CG SHIFT COMPARISON



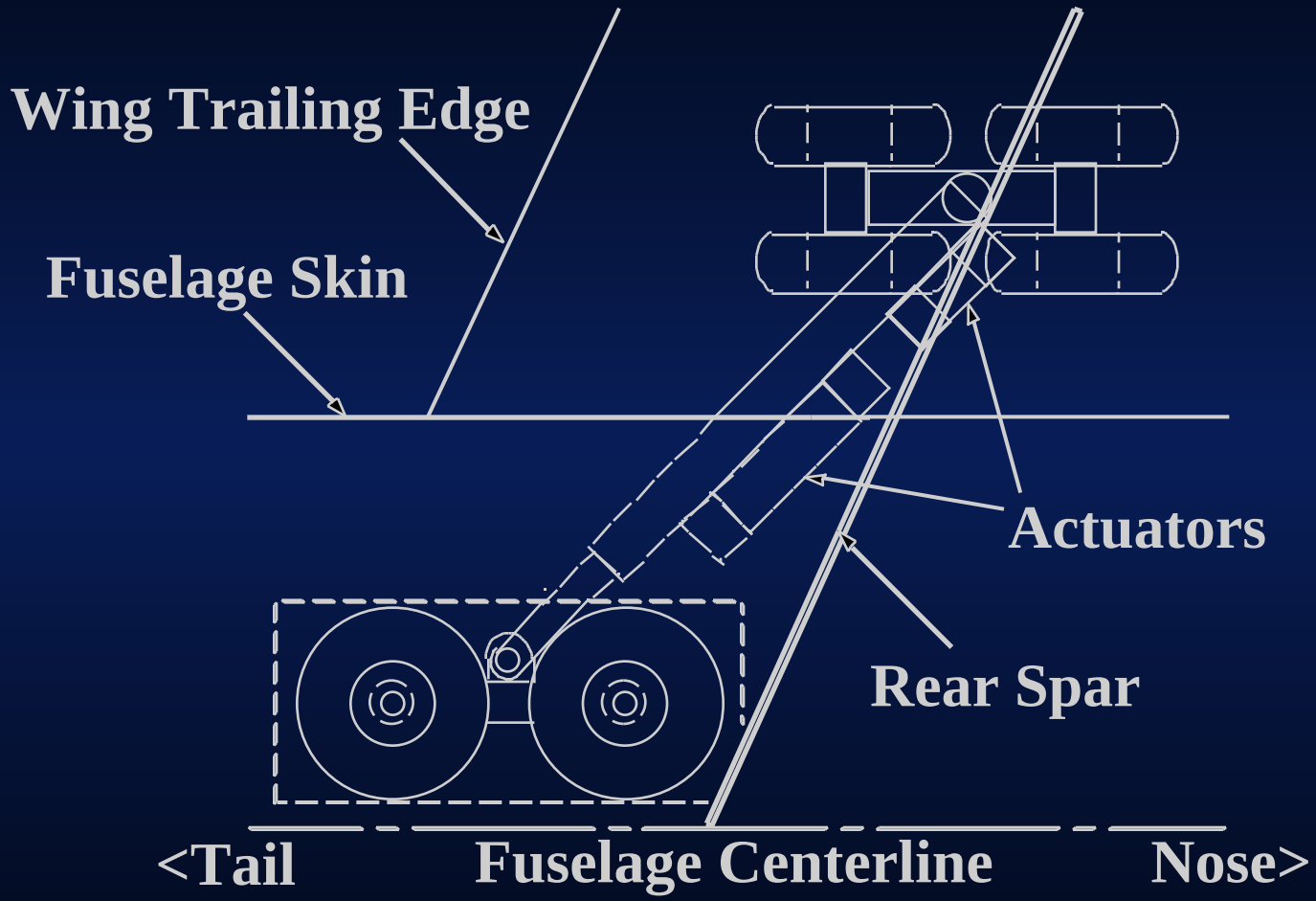
TORQUE COMPARISON



AF-1 FORWARD AC LOCATION



AF-1 LANDING GEAR LAYOUT



AF-1 LANDING GEAR

DOUBLE BOGIE VS. TWIN

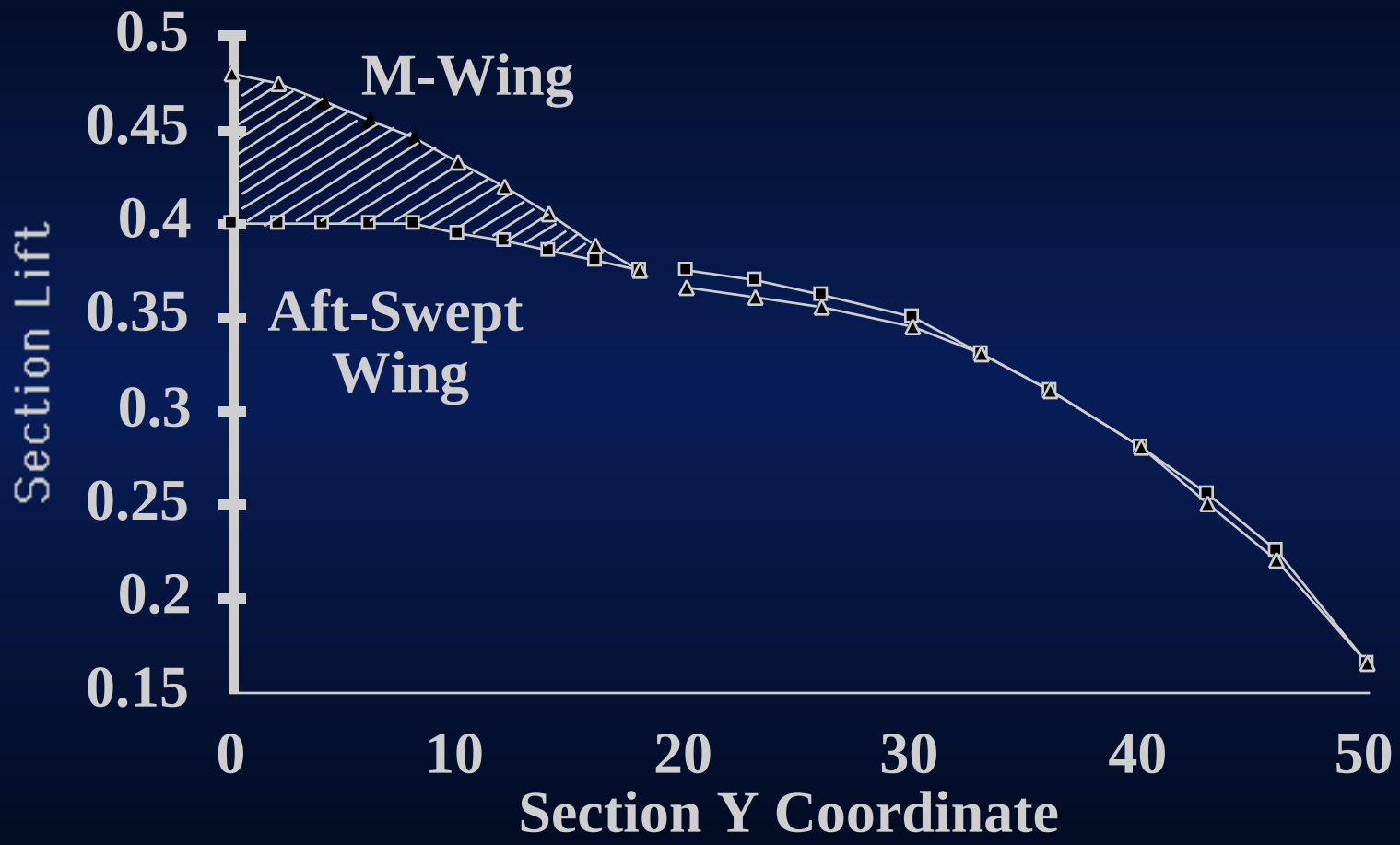
ADVANTAGES

- Extended Tire / Brake Life
- All Ten Tires the Same Size
- Extended Maintenance Interval
- No Fairing Required - Lower Fuel Cost
- Lower LCN

DISADVANTAGES

- Reduced Braking Effectiveness on Rear Tires
- Increased Production Cost

SECTION LIFT



M-WING VS AFT-SWEPT WING

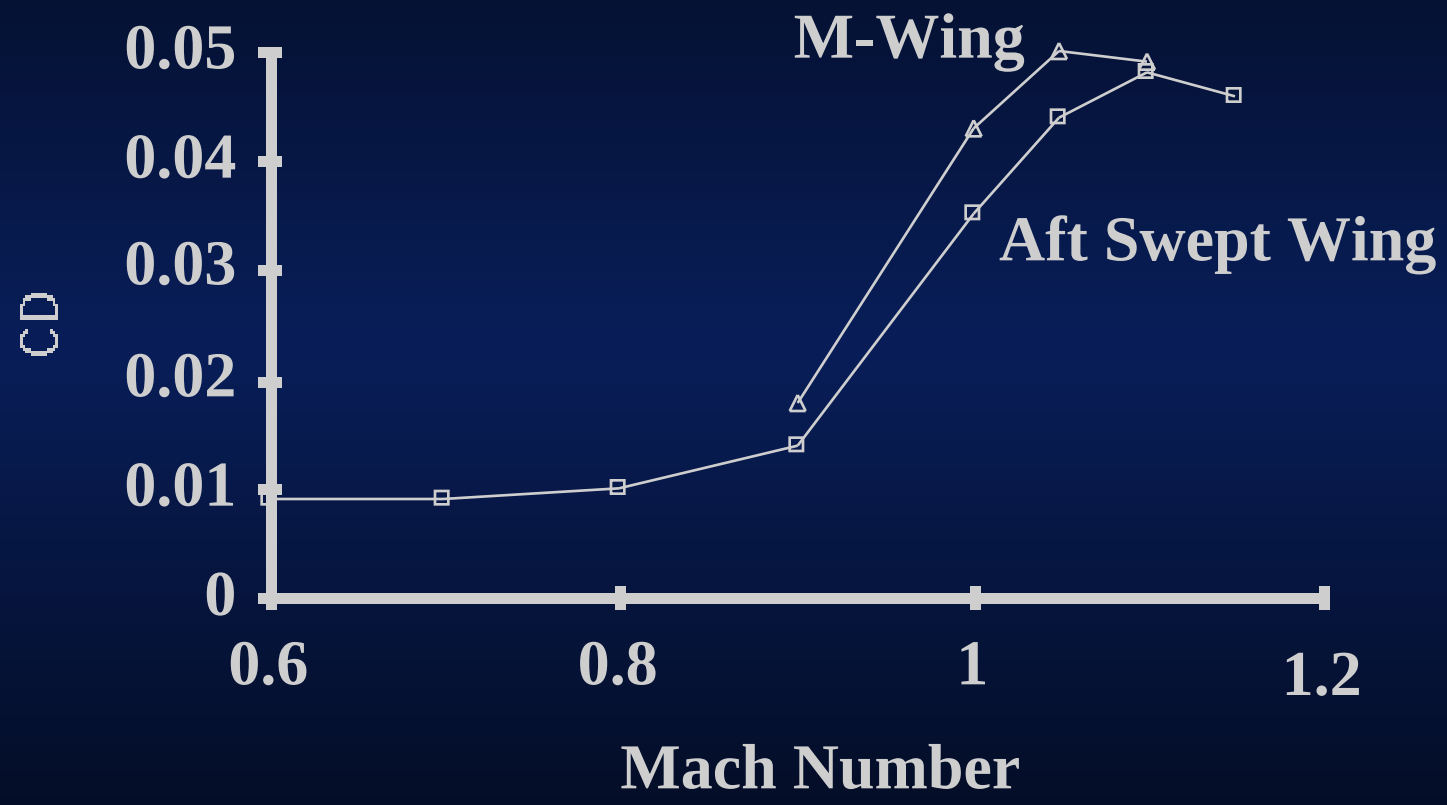
ADVANTAGES

- Reduced CG Travel
- Reduced Torque on Center Wing Box
- AC Located Further Forward
- No Yahudi or Fairing for Landing Gear
- Increased Inboard Lift Capability

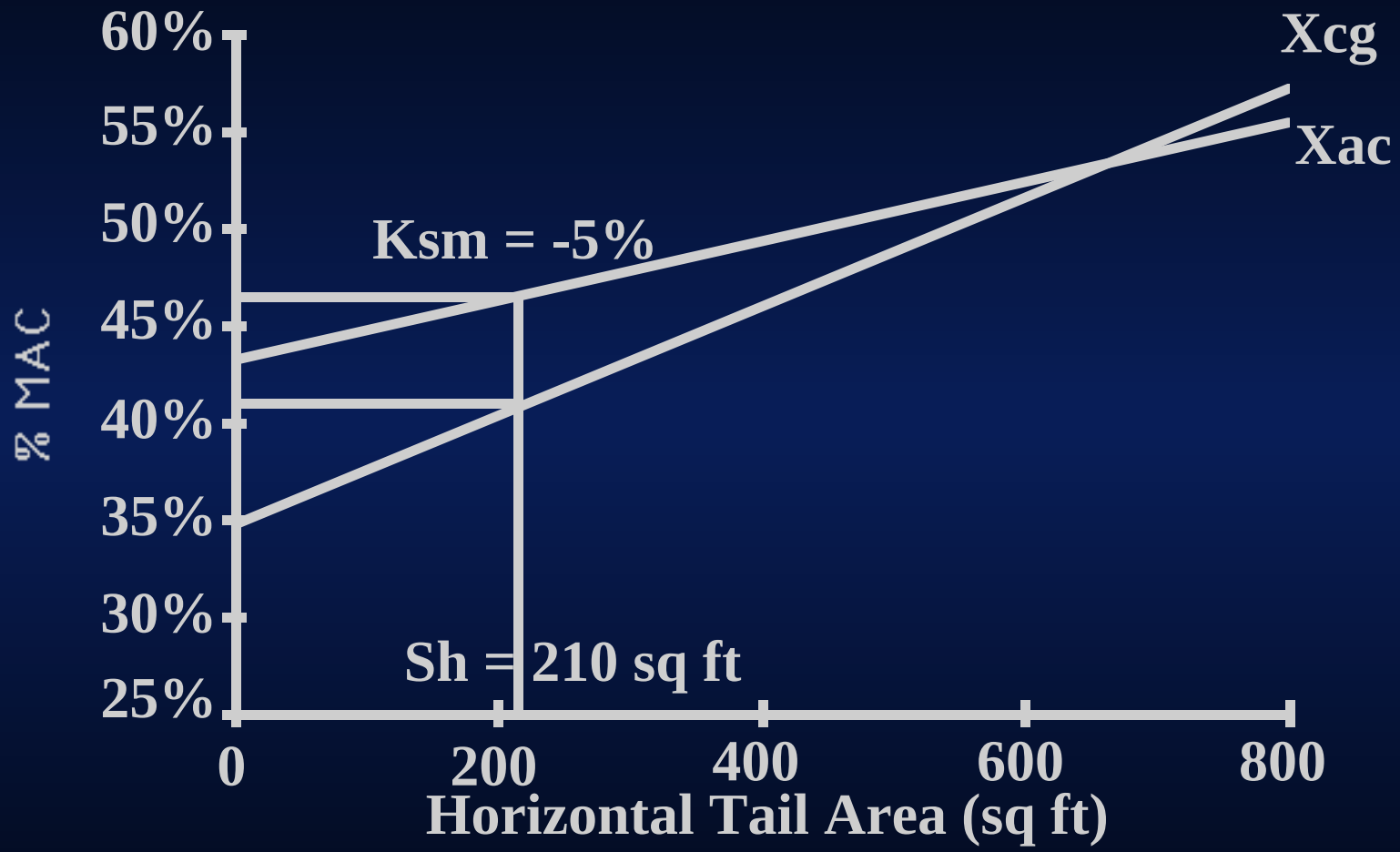
DISADVANTAGES

- Increased Wing Weight
- Wave Drag Penalty

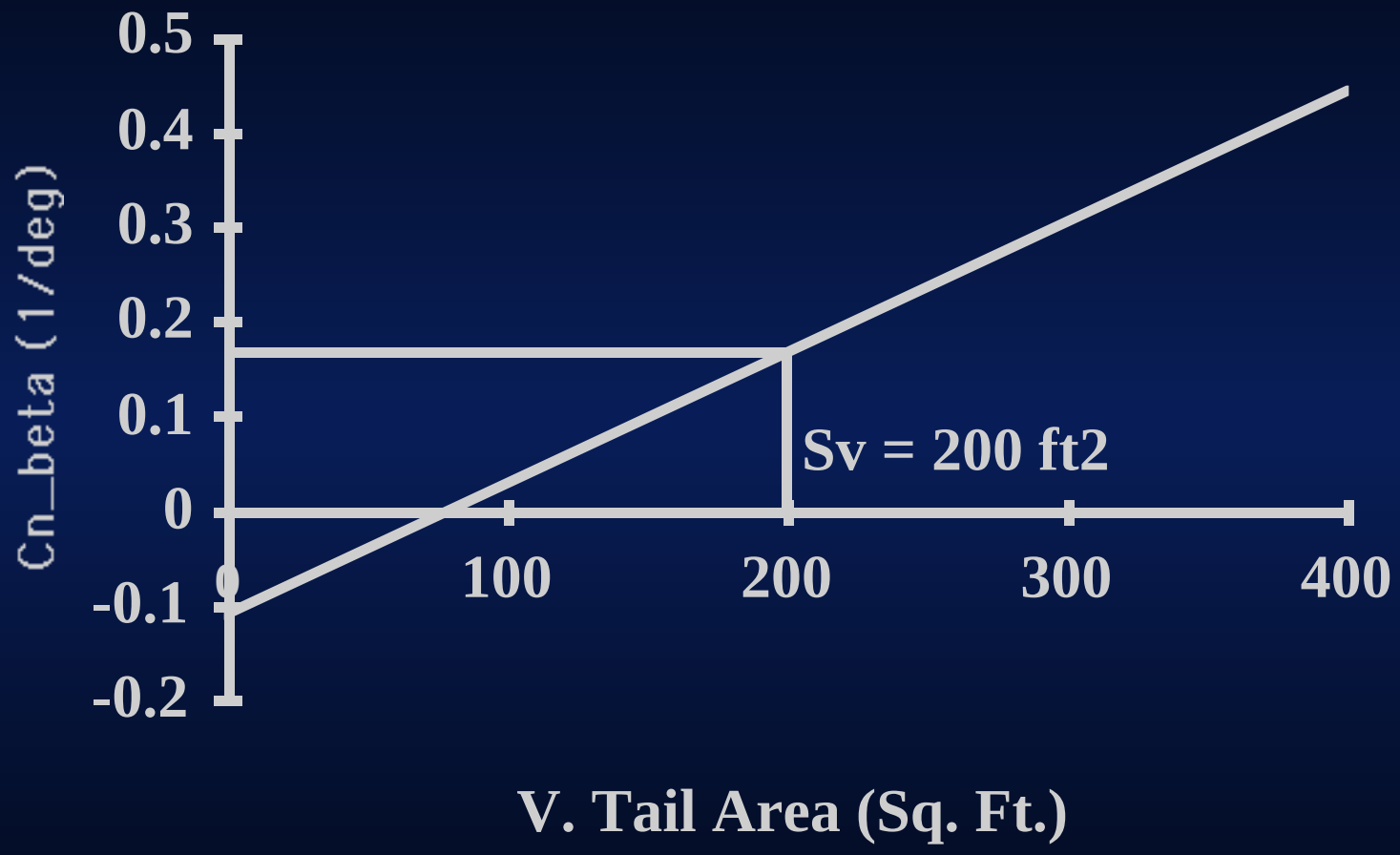
M-WING WAVE DRAG



AF-1 LONGITUDINAL X-PLOT



AF-1 DIRECTIONAL X-PLOT



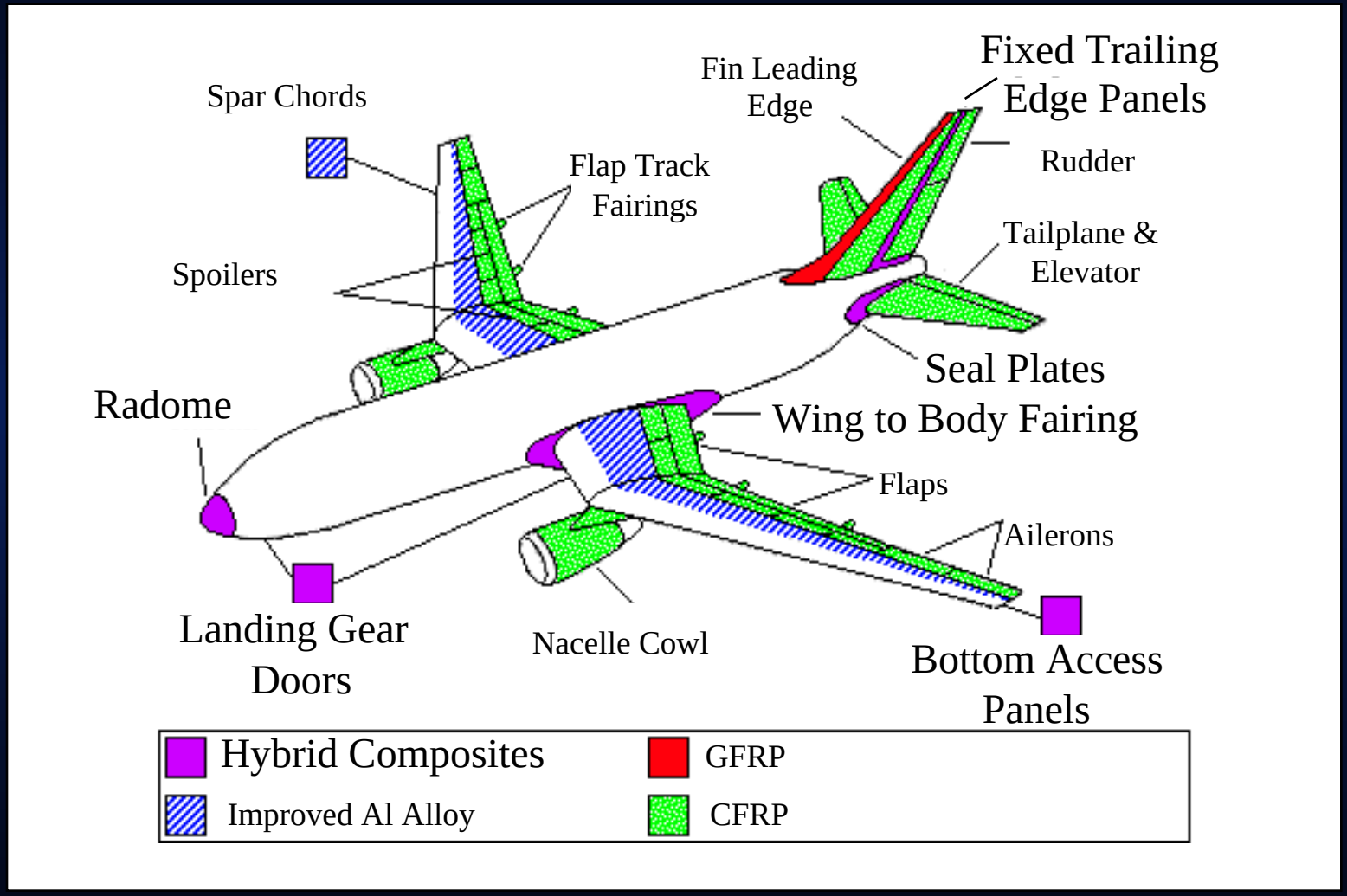
AF-1 FLIGHT CONTROL SYSTEM

- Three Axis Electronic Fly-by-Wire
- Triple Redundancy
- Stability Augmentation in Pitch Axis

COMPOSITE MATERIALS

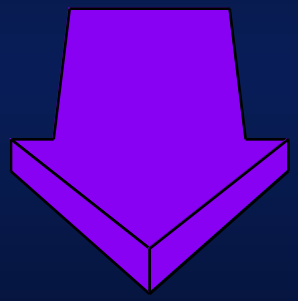
- **Weight Savings**
- **Fewer Parts - Assembly & Production Savings**
- **Greater Standardization**

AF-1 MATERIALS SELECTION



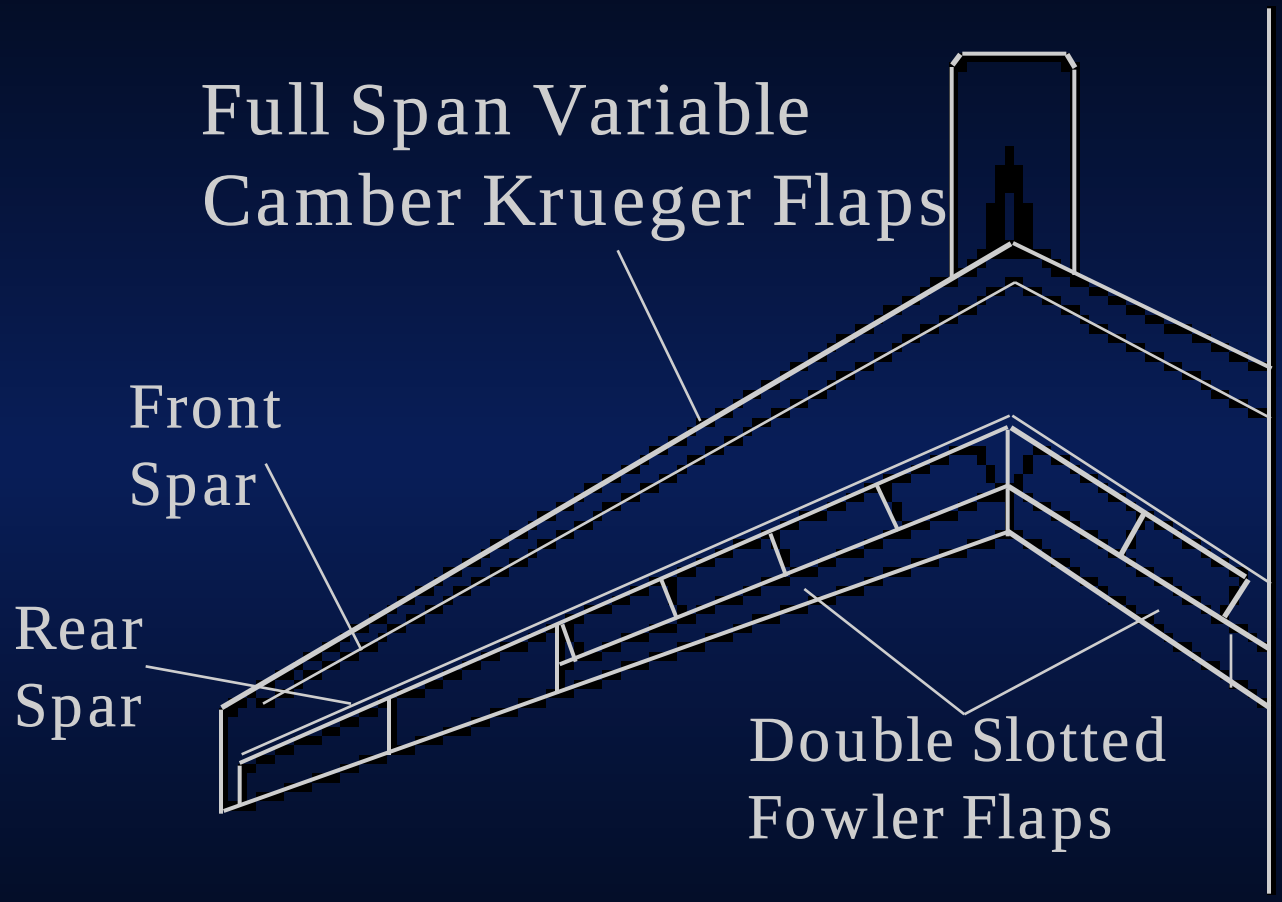
AF-1 HIGH LIFT SYSTEM

- Takeoff Maximum Lift Coefficient = 2.3
- Landing Maximum Lift Coefficient = 3.1



- **Full Span Double Slotted Fowler Flap**
- **Full Span Variable Camber Krueger Flap**

AF-1 HIGH LIFT SYSTEM



VARIABLE CAMBER KRUEGER FLAPS

RETRACTED

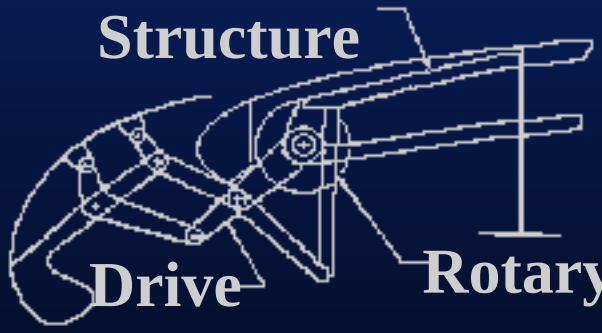
Space for Systems

Space for Anti-Icing

Front Spar

Support Structure

EXTENDED



Drive Arm

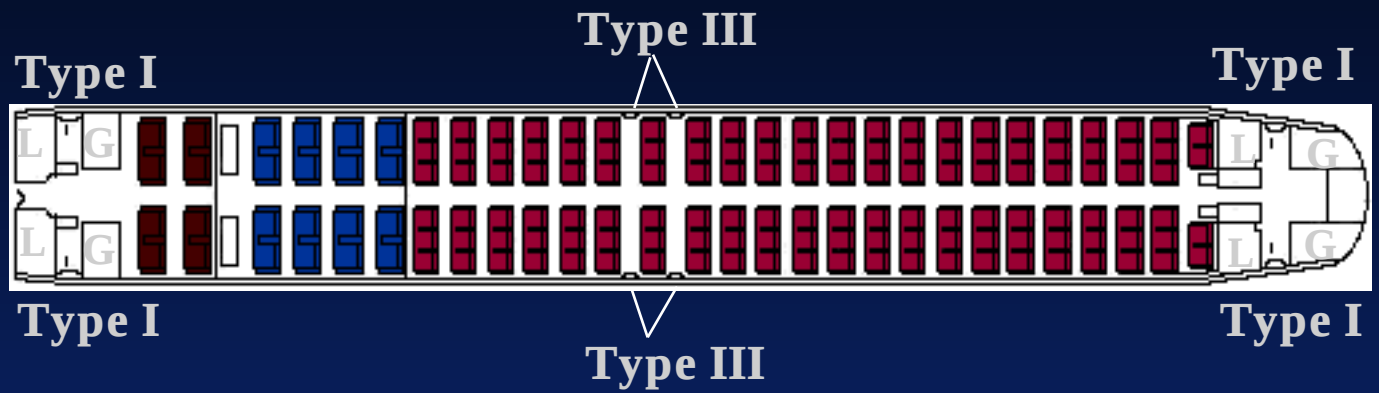
Rotary Actuator

AF-1 PERFORMANCE

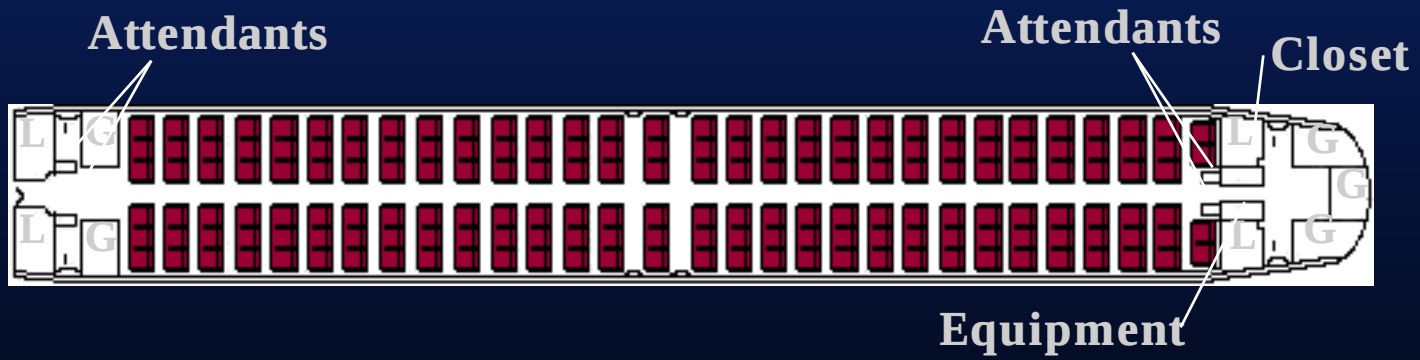
	B737-400	MD-83	A320-200	AF-1
W/S	127	126	125	131
Takeoff Field Length (ft)	8,200	8,375	7,680	6,960
Landing Field Length (ft)	6,070	5,200	5,040	4,940
Cruise M	0.73	0.76	0.80	0.80

AF-1 INTERIOR CONFIGURATION

154 PASSENGERS
THREE-CLASS
42/36/32 IN PITCH



178 PASSENGERS
ALL-ECONOMY
32 IN PITCH



AF-1 ADVANTAGE:

LOW COST

M-WING RISK ASSESSMENT

- **M-Wing Risk $128.8 Million**
- **Low Risk**

  Current engine

  Aluminum with standard composites

  Fly-by-wire available

AF-1 PRODUCTION COST

1994 US $ per aircraft

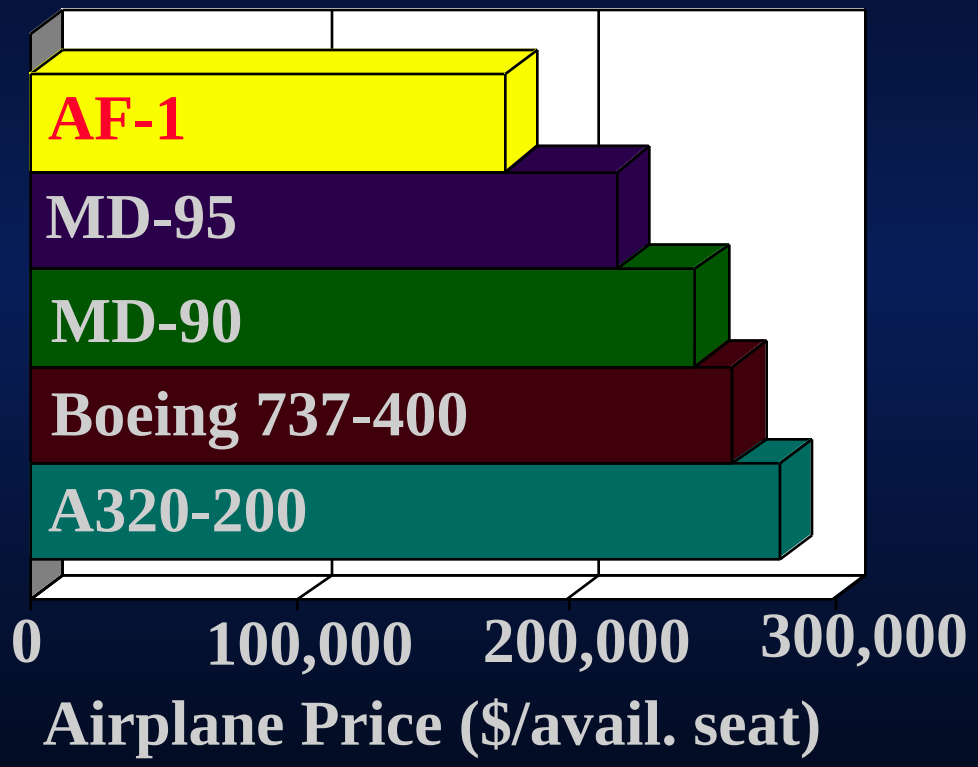
Engines and Avionics Cost	**16 million**
Interiors Cost	**0.3 million**
Manufacturing Materials Cost	**1.6 million**
Manufacturing Labor Cost	**3.3 million**
Tooling Cost	**0.3 million**
Quality Control Cost	**0.4 million**
Total Production Cost	22 million

AF-1 ADVANTAGE:

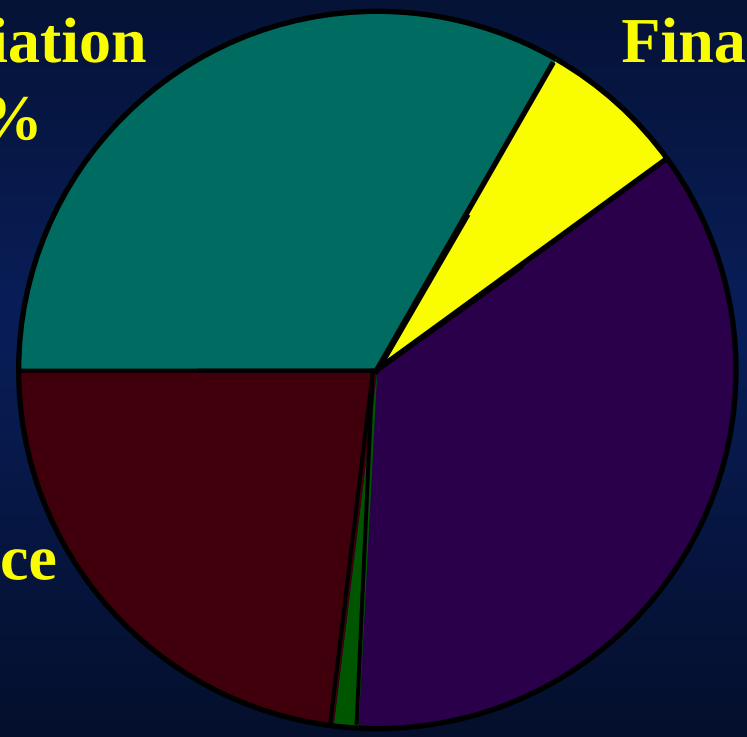
1994 US $

AIRPLANE ESTIMATED PRICE
$28 million

AIRPLANE PRICE COMPARISON



AF-1 DOC BREAKDOWN



AF-1 DIRECT OPERATING COSTS

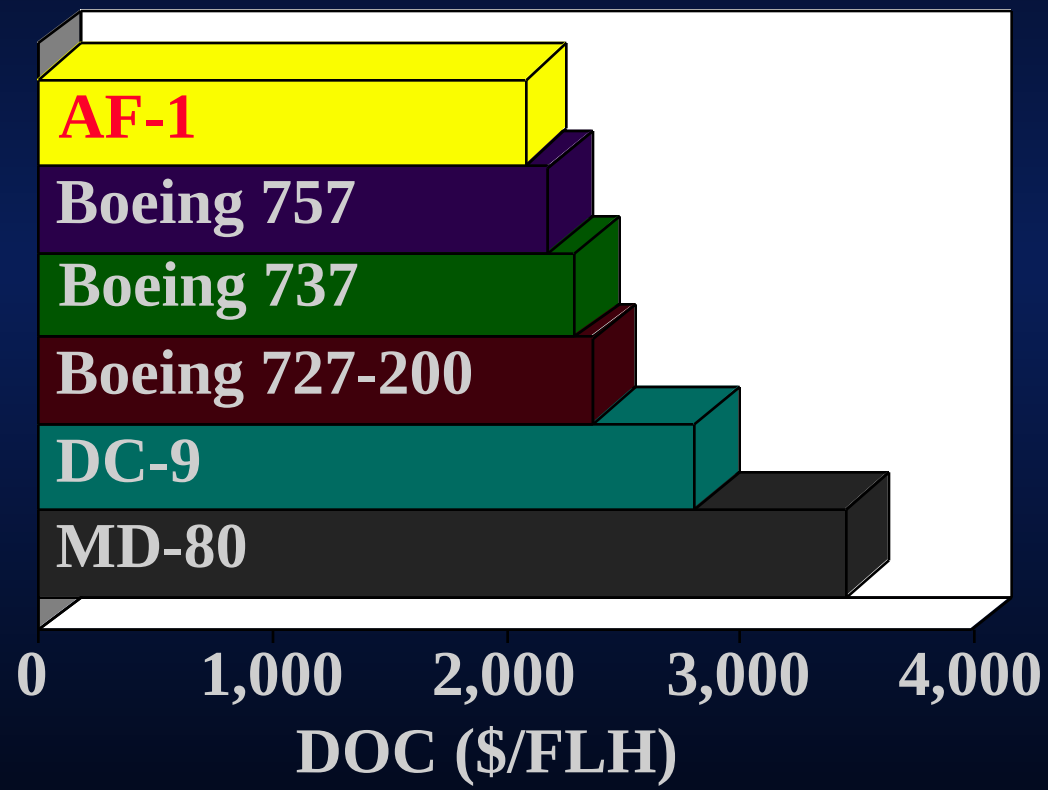
1994 US $

$5.28 per nmi

3.25 cents/ASM

DOC COMPARISON

1994 US $/FLH



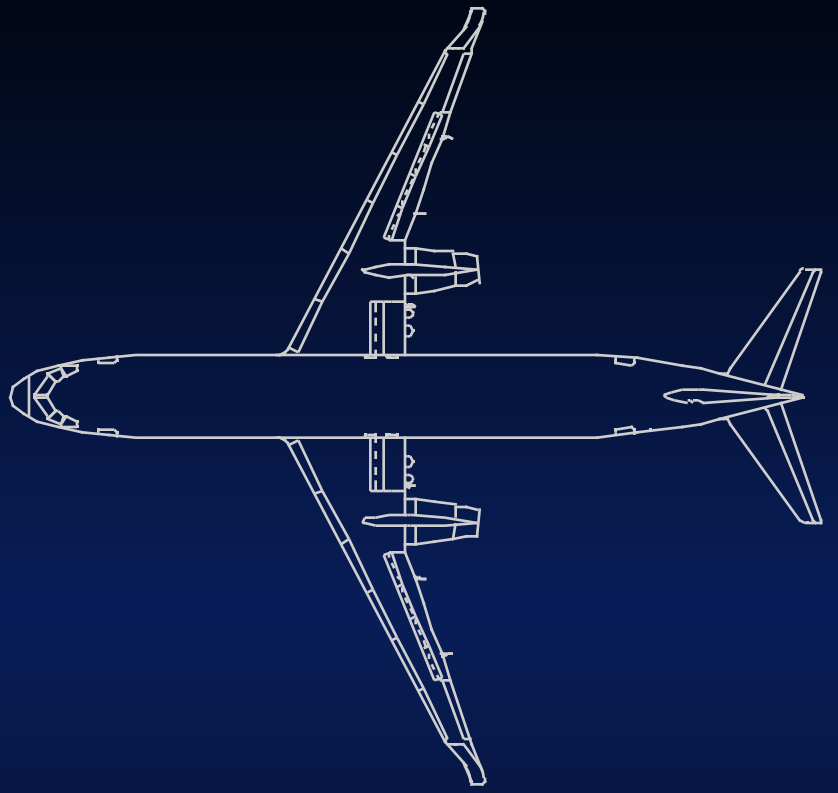
FLYING CIRCUS

FC-1D

CAL POLY, San Luis Obispo

The FC-1D

Max. Takeoff Weight: 135,200 lbs
Wing Area: 1150 Sq. ft.
Aspect Ratio: 10
Fuselage Diameter : 12.9 ft.
c/4 Sweep: 23.9°
Main Wing Dihedral: 6°

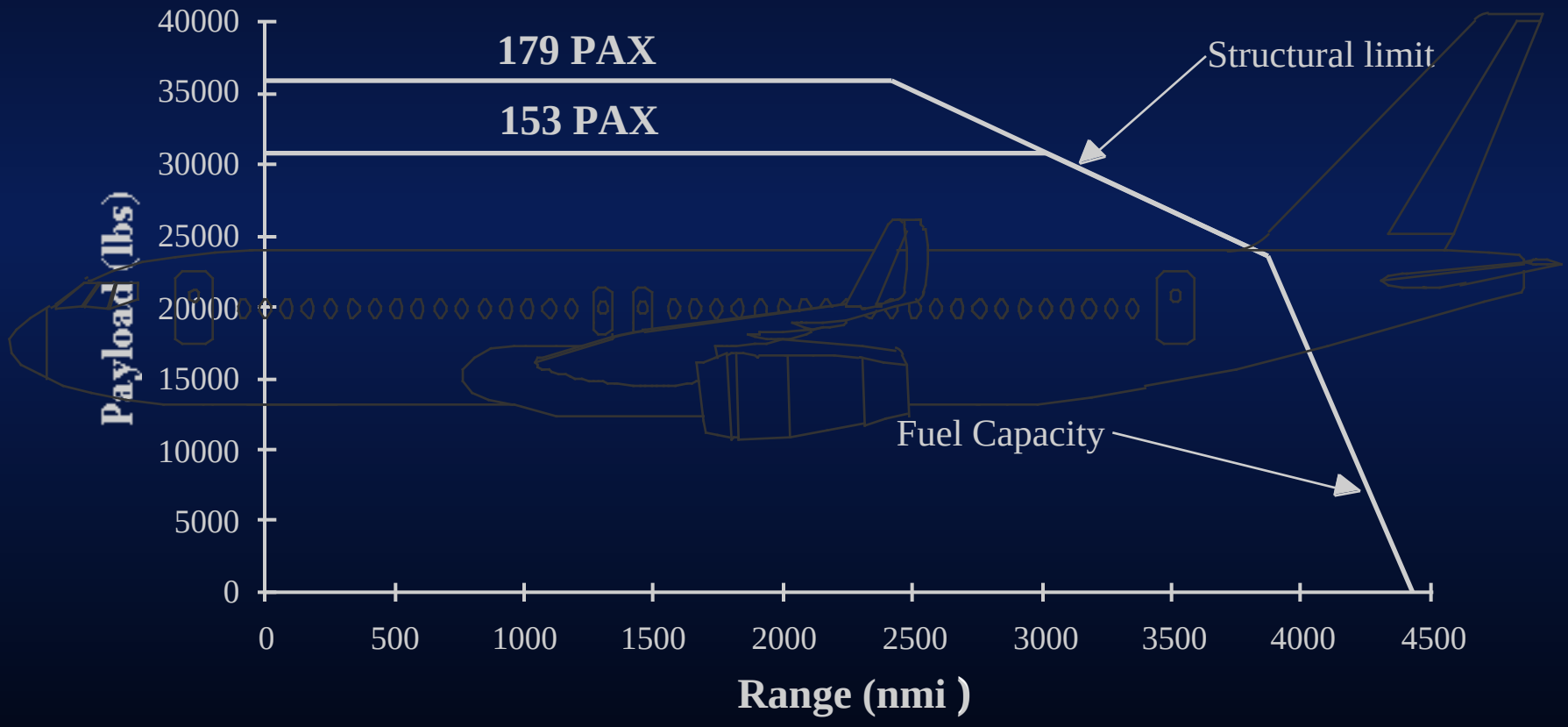


CAL POLY, San Luis Obispo

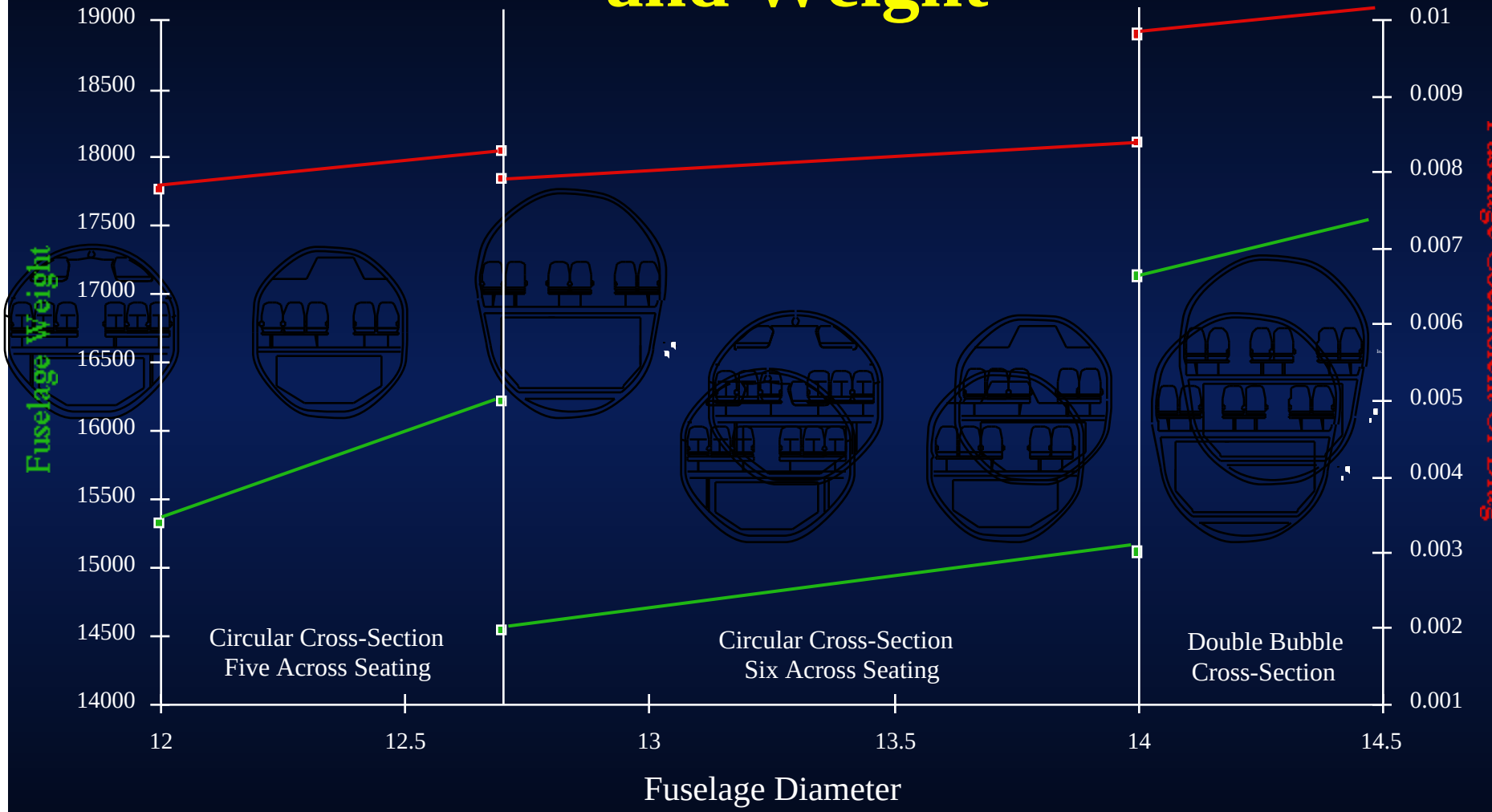
FC-1D Design Parameters

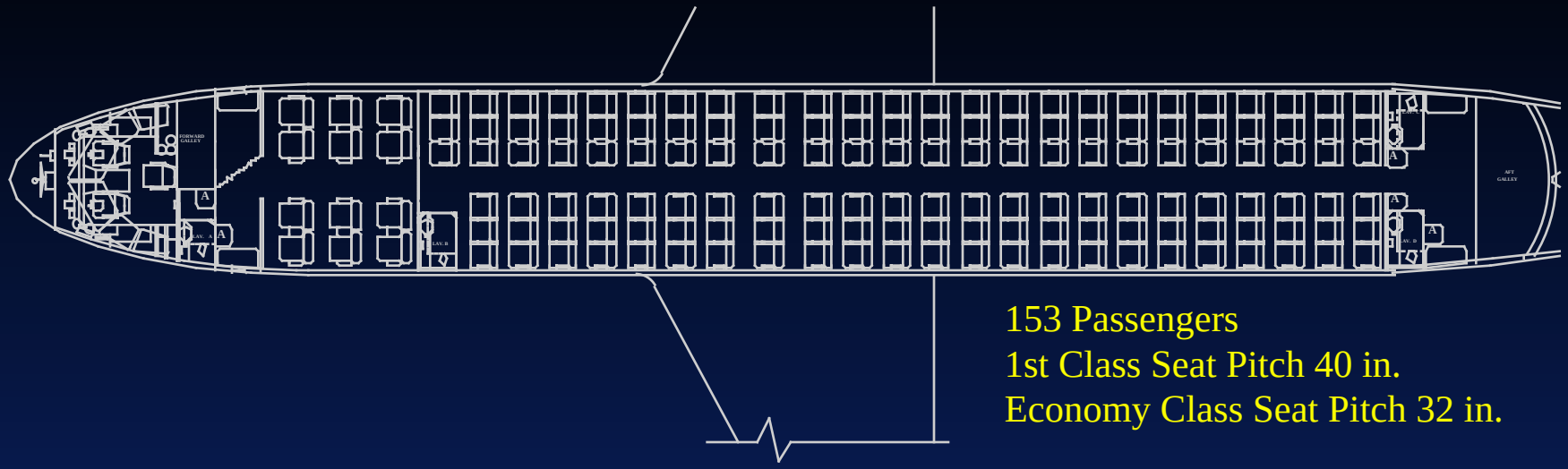
- MTOW = 135,200
- Wing Loading = 117 psf
- Wing Area = 1150 sq. ft.
- T/W = 0.37
- $C_{L_{MAX\ LANDING}} = 3.0$
- $C_{L_{MAX\ TO}} = 2.4$
- Cruise Mach = 0.8
- Cruise Altitude = 39,000 ft

Payload Range Diagram

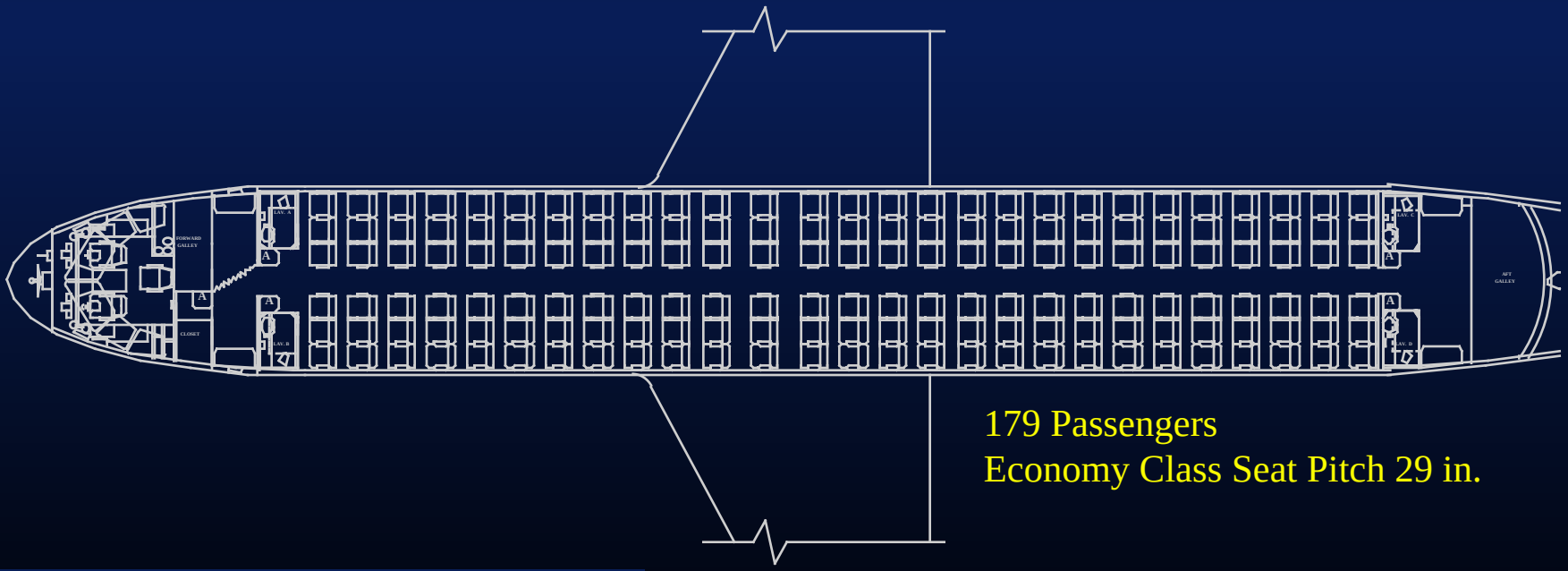


Effect of Fuselage Diameter on Drag and Weight





153 Passengers
1st Class Seat Pitch 40 in.
Economy Class Seat Pitch 32 in.



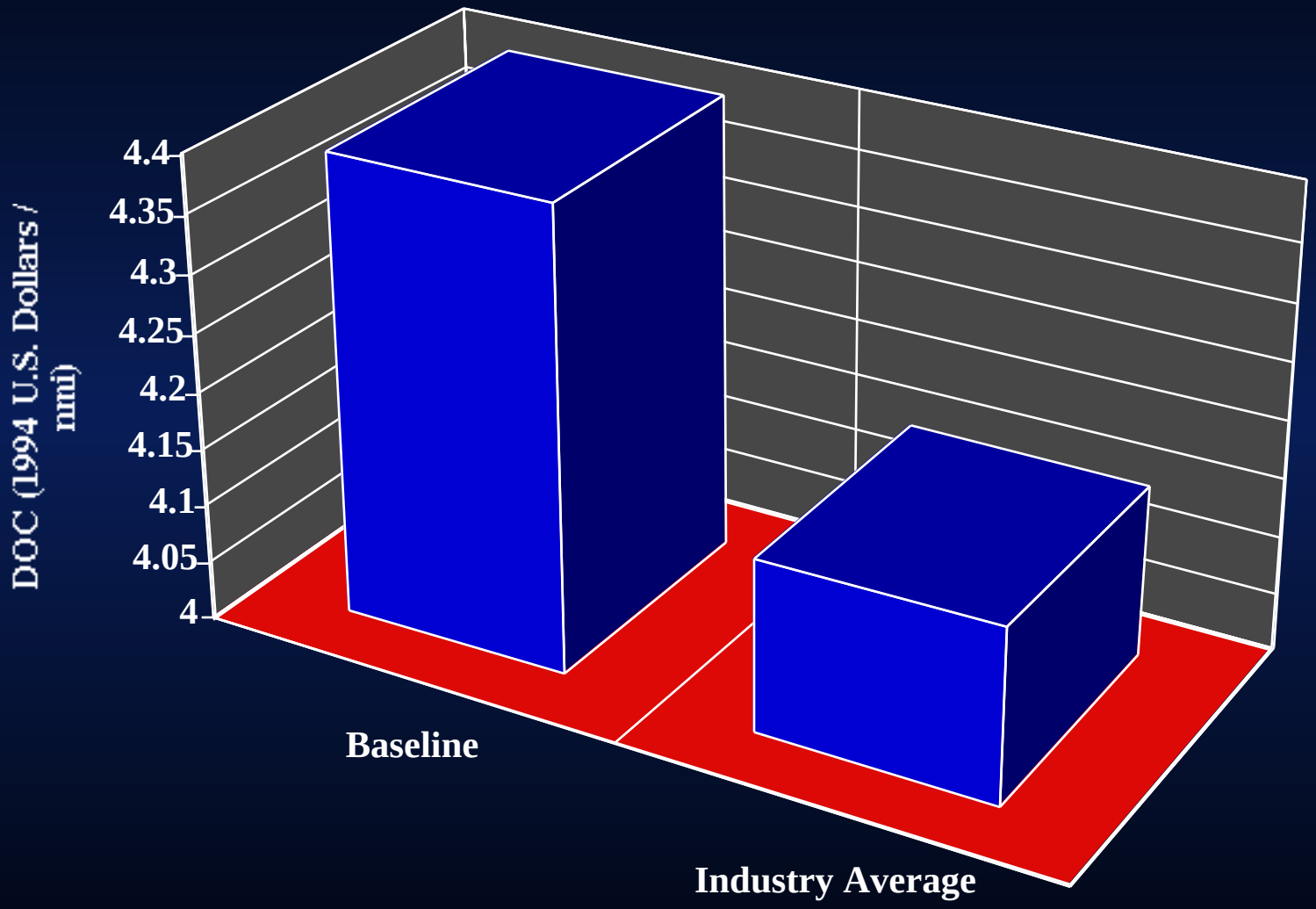
179 Passengers
Economy Class Seat Pitch 29 in.

CAL POLY, San Luis Obispo

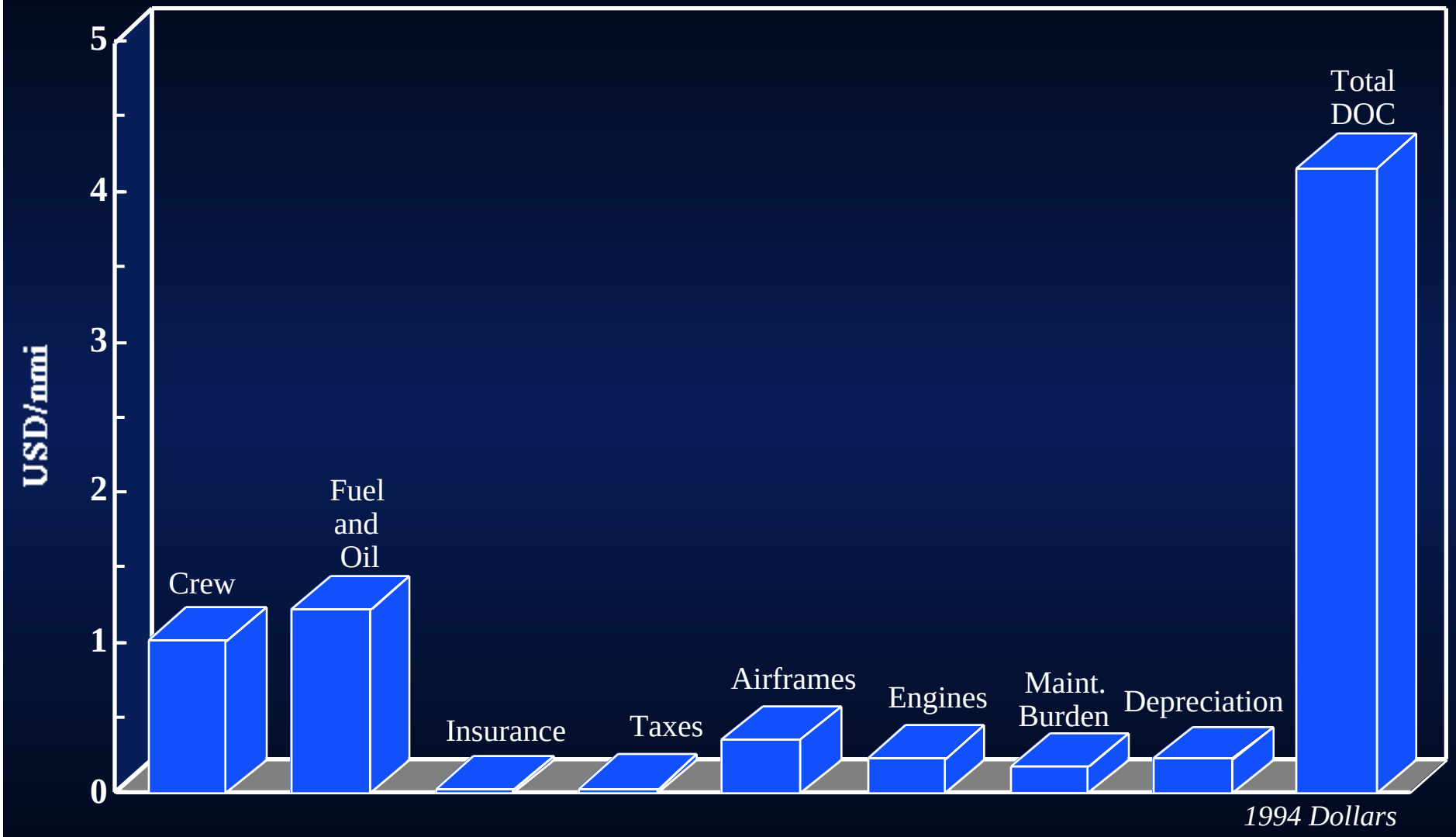
Baseline Aircraft

- Used as a Benchmark
  - A Model of Existing Aircraft
- Aircraft Specifications
  - RFP Performance Compliance
  - Conventional Design
  - All Aluminum
  - DOC Modeled Using Industry Data

Baseline vs. Industry DOC



Industry Average Breakdown

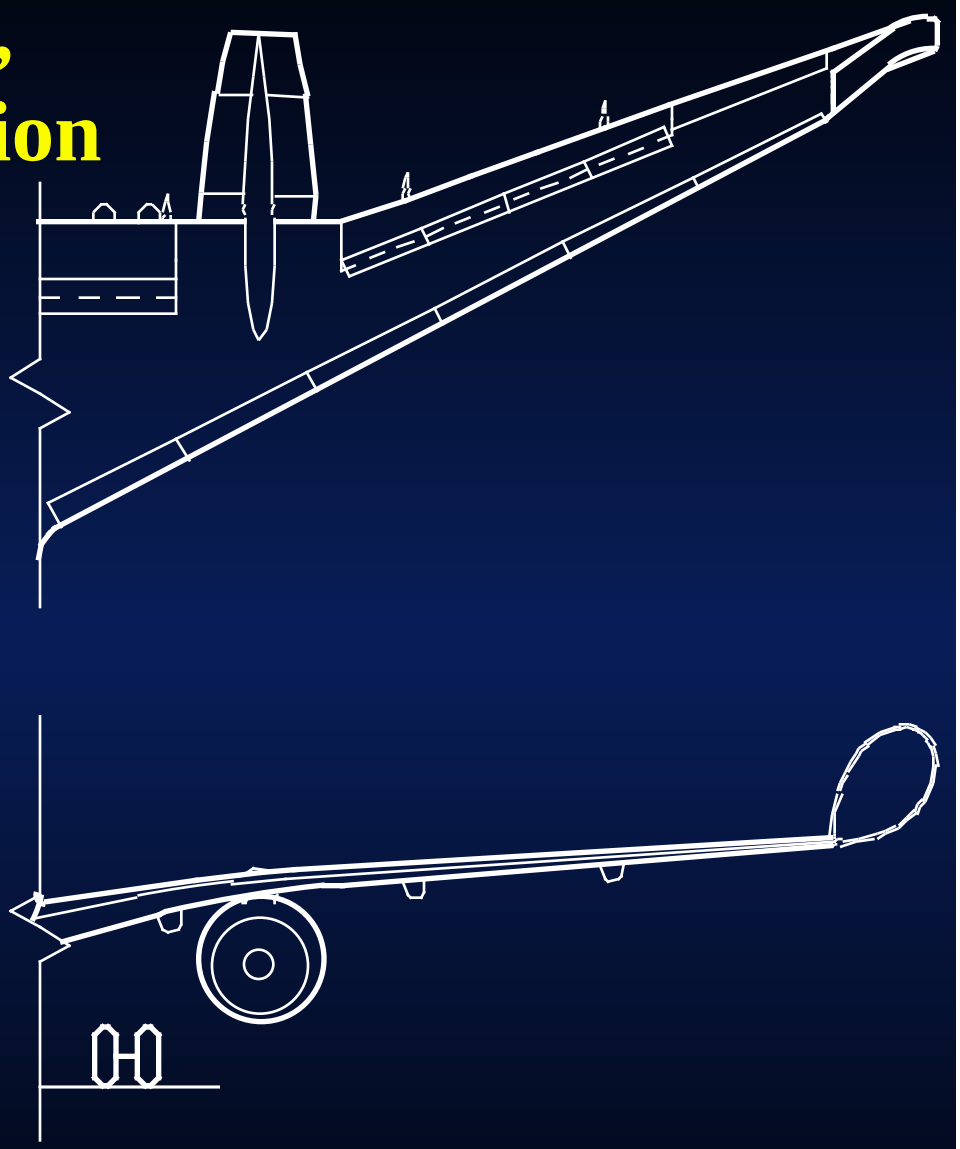


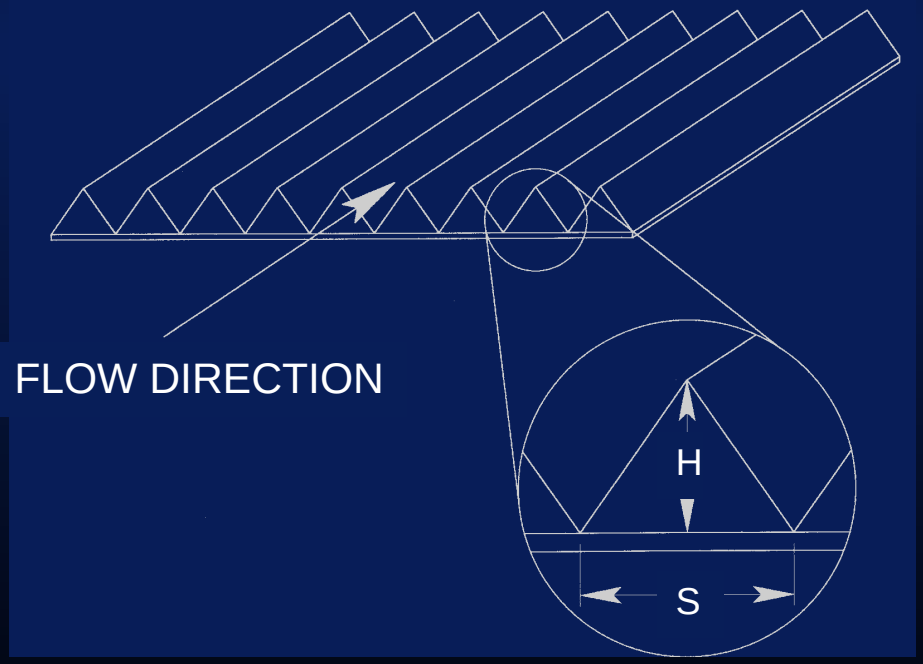
Technological Risk Assessment

- Target Improvement Areas
  - Aerodynamics
  - Propulsions
  - Materials

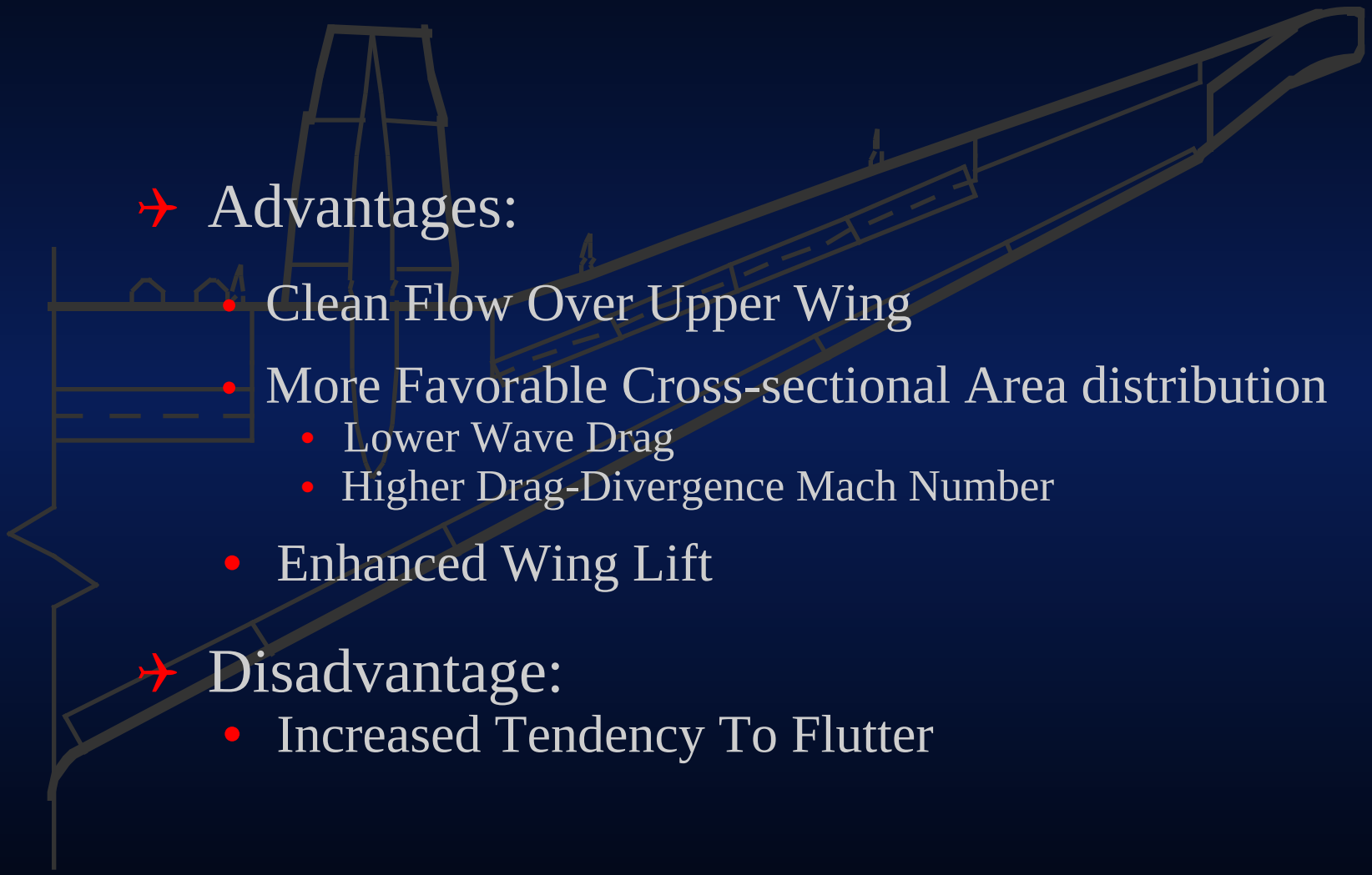
- Technology Selection Criteria
  - Near Term Technology (year 2000)
  - Existing in Prototype or Experimental Form
  - Wind Tunnel Tested

Aft Wing Nacelle, Riblets, and Spiroid Implementation





Aft Wing Nacelle

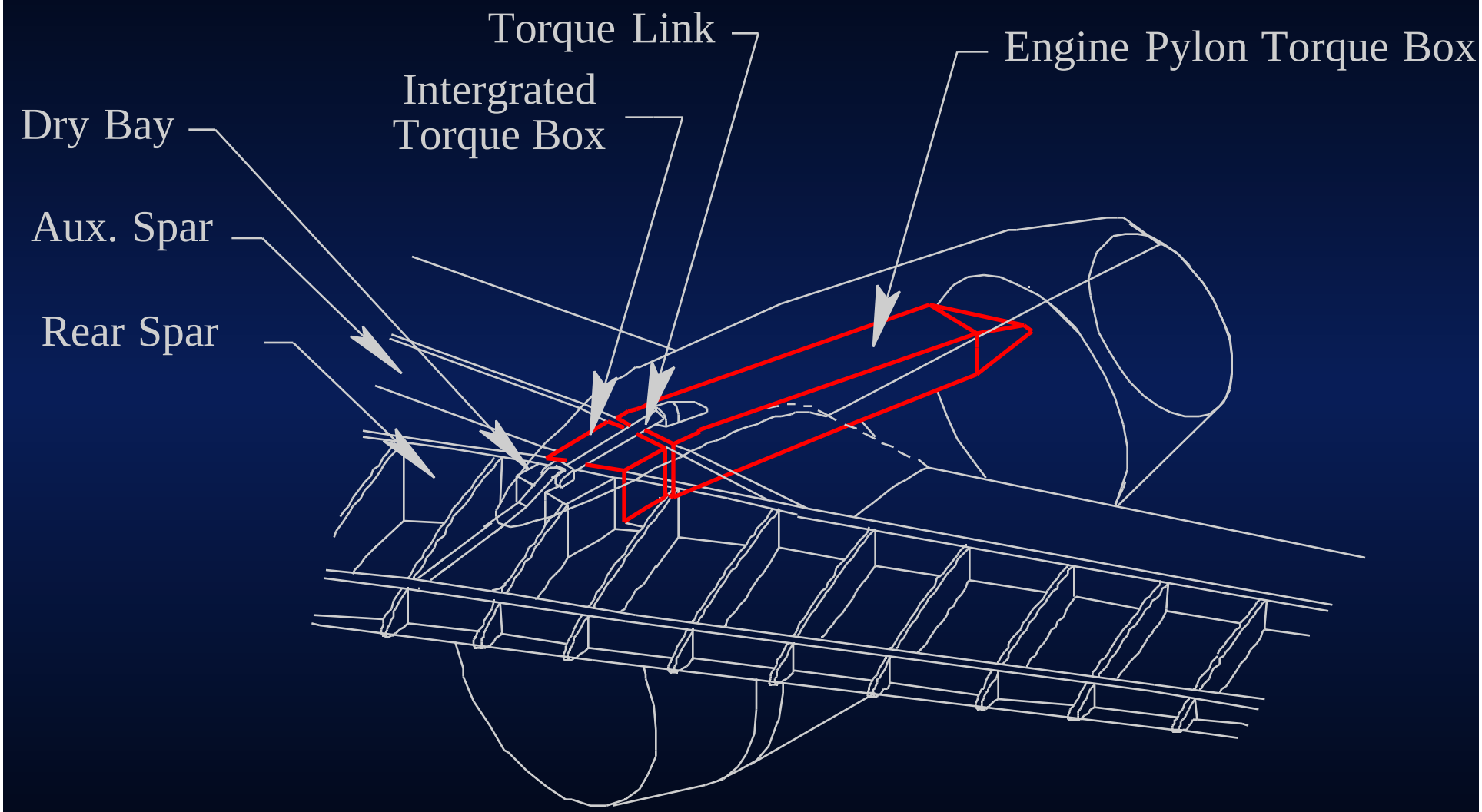


- Advantages:
  - Clean Flow Over Upper Wing
  - More Favorable Cross-sectional Area distribution
    - Lower Wave Drag
    - Higher Drag-Divergence Mach Number
  - Enhanced Wing Lift
- Disadvantage:
  - Increased Tendency To Flutter

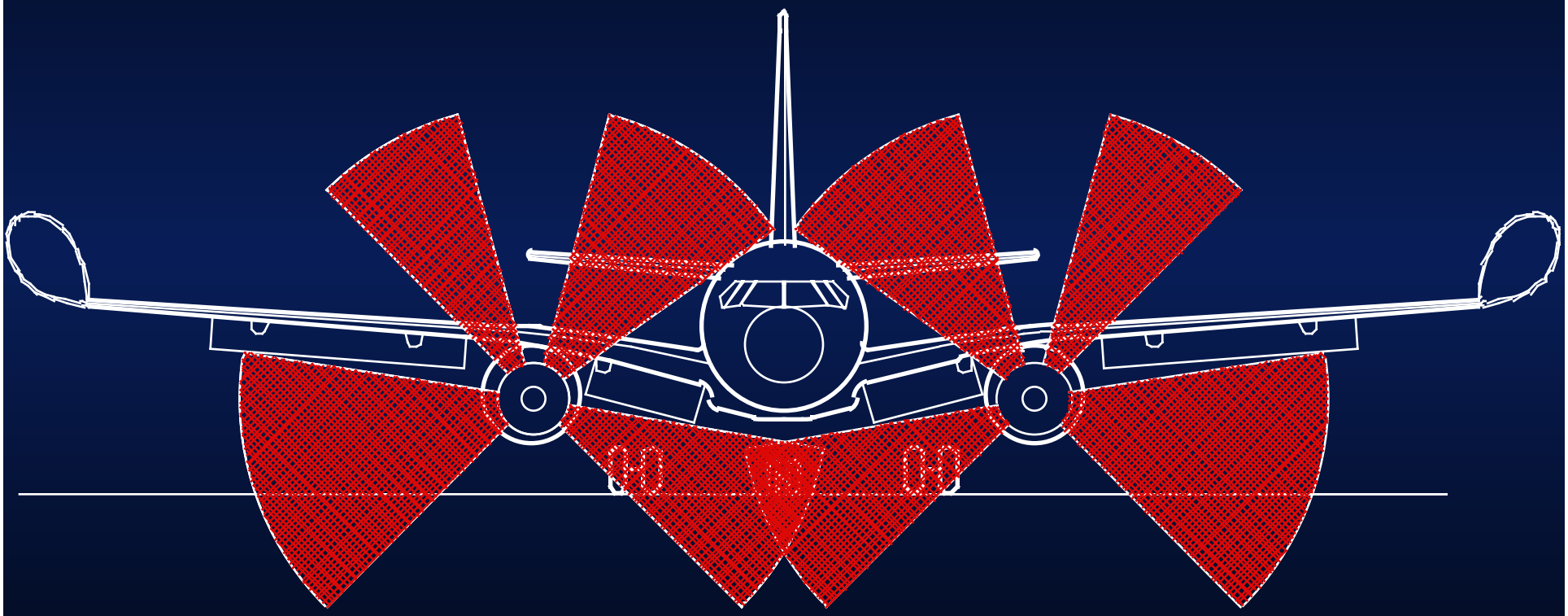
FC-1D Flutter Solutions

- Determine Critical Flutter Conditions Through Extensive Testing and Analysis
- Suppress Flutter to V_D
  - Stiffen Wing
- Implement Active Flutter Control System at Speeds Greater than V_D
  - Existing or Auxiliary Control Surfaces
  - Must Demonstrate High Reliability

Pylon Structural Arrangement

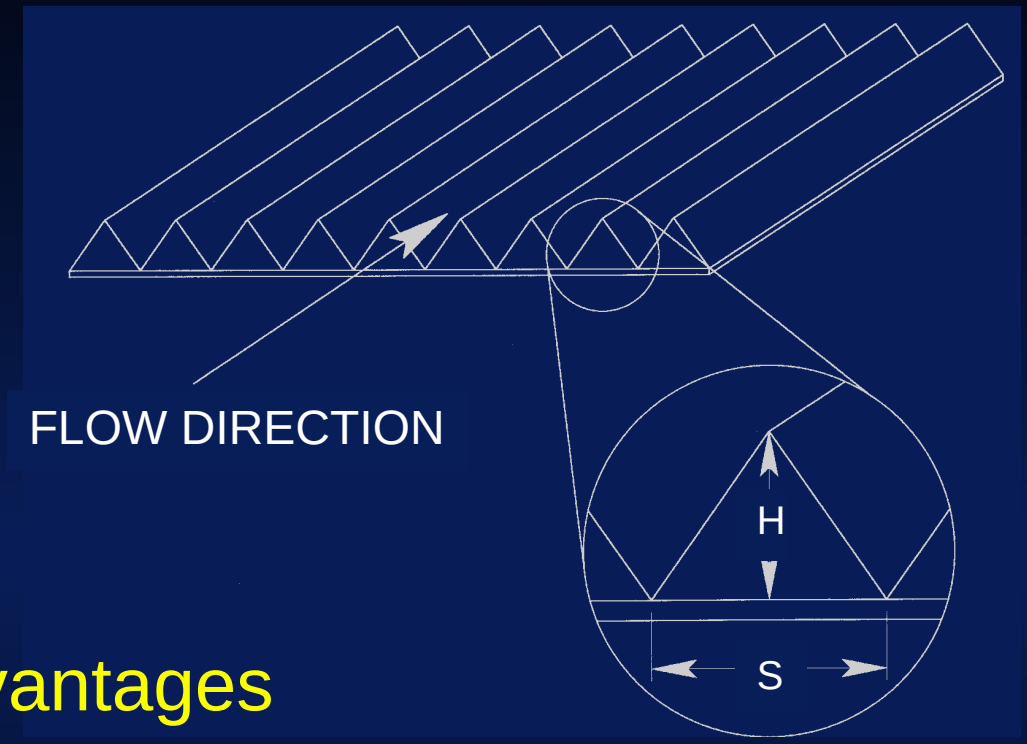


FC-1D Thrust Reversers



CAL POLY, San Luis Obispo

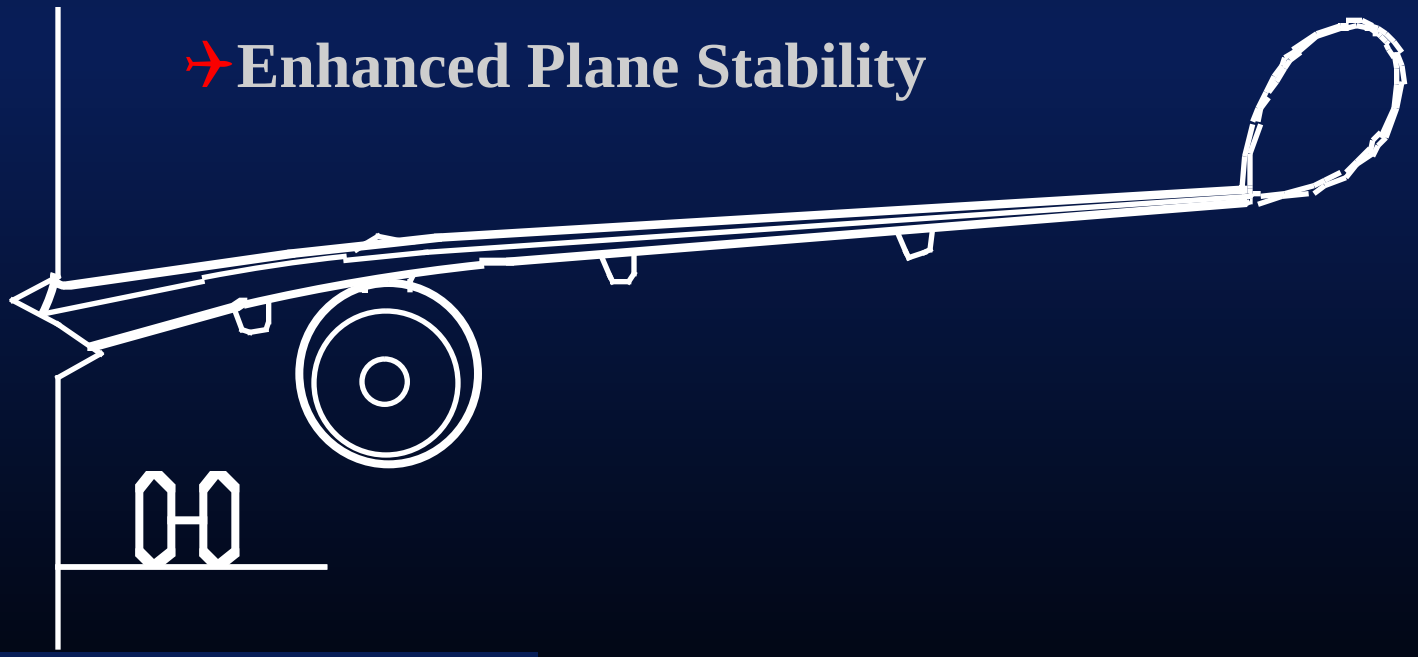
Riblets



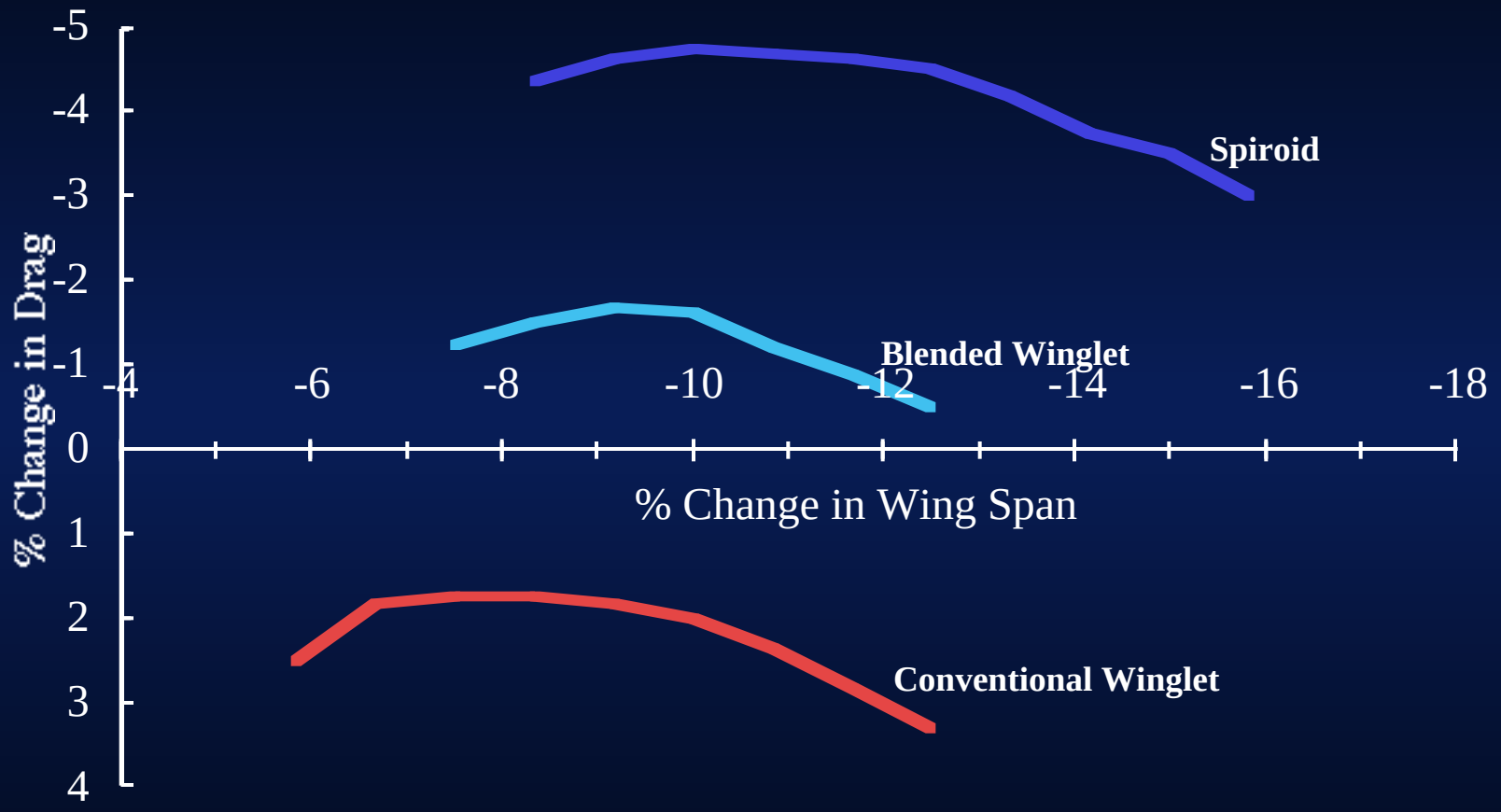
- Advantages
  - Minimizes Skin Friction Drag
  - Reduces Total Drag by 4%
- Disadvantages
  - Questions Remain About Durability
  - Sensitivity to Ultraviolet Radiation

Spiroids

- Reduce Total Drag by 2.0%
  - 1.7% Reduction in Fuel Burn
- Reduced Vorticity Levels
  - Decreased Separation Distance
- Enhanced Plane Stability

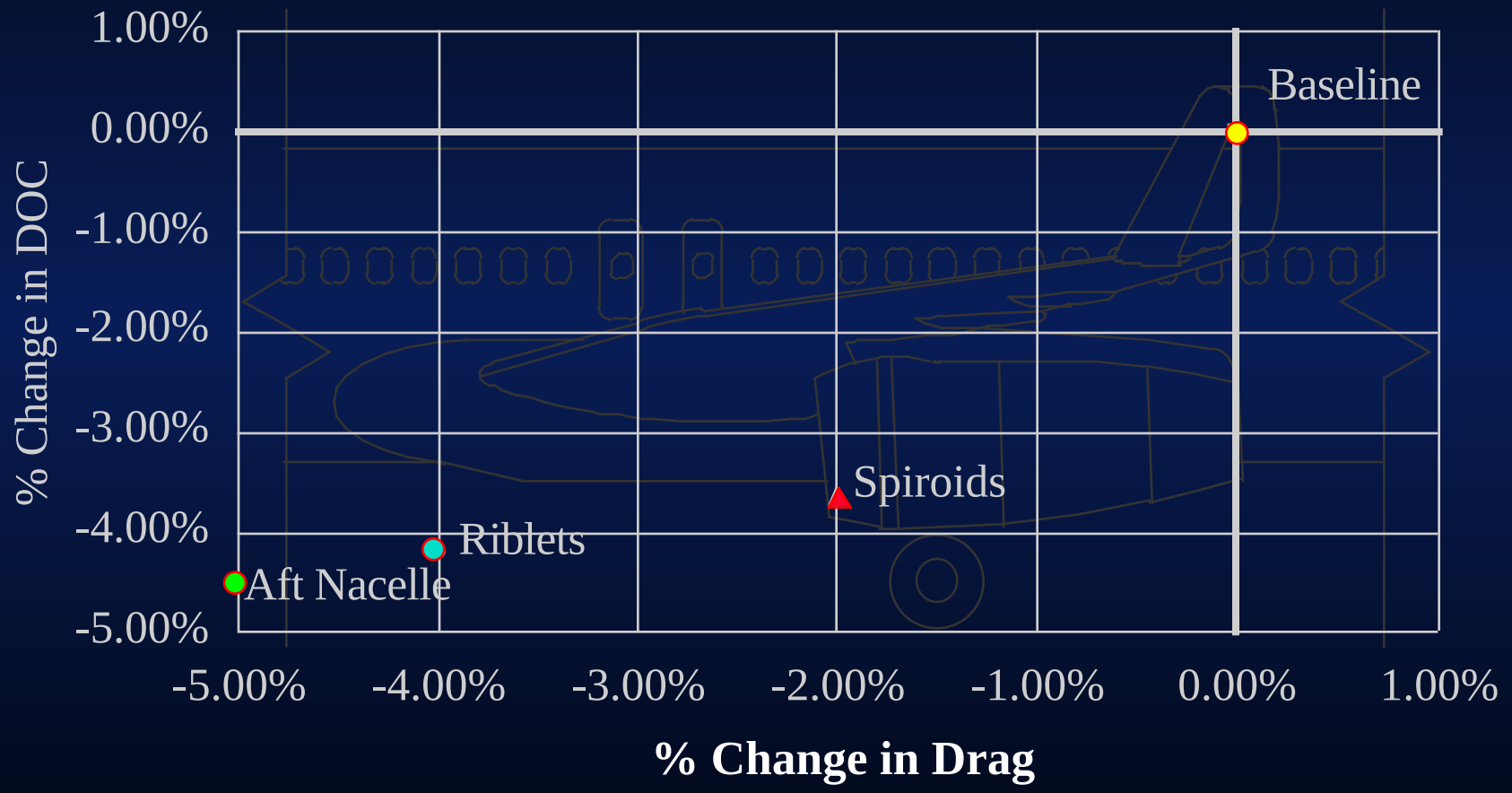


Drag Reduction Benefits Relative to a Planar Wing

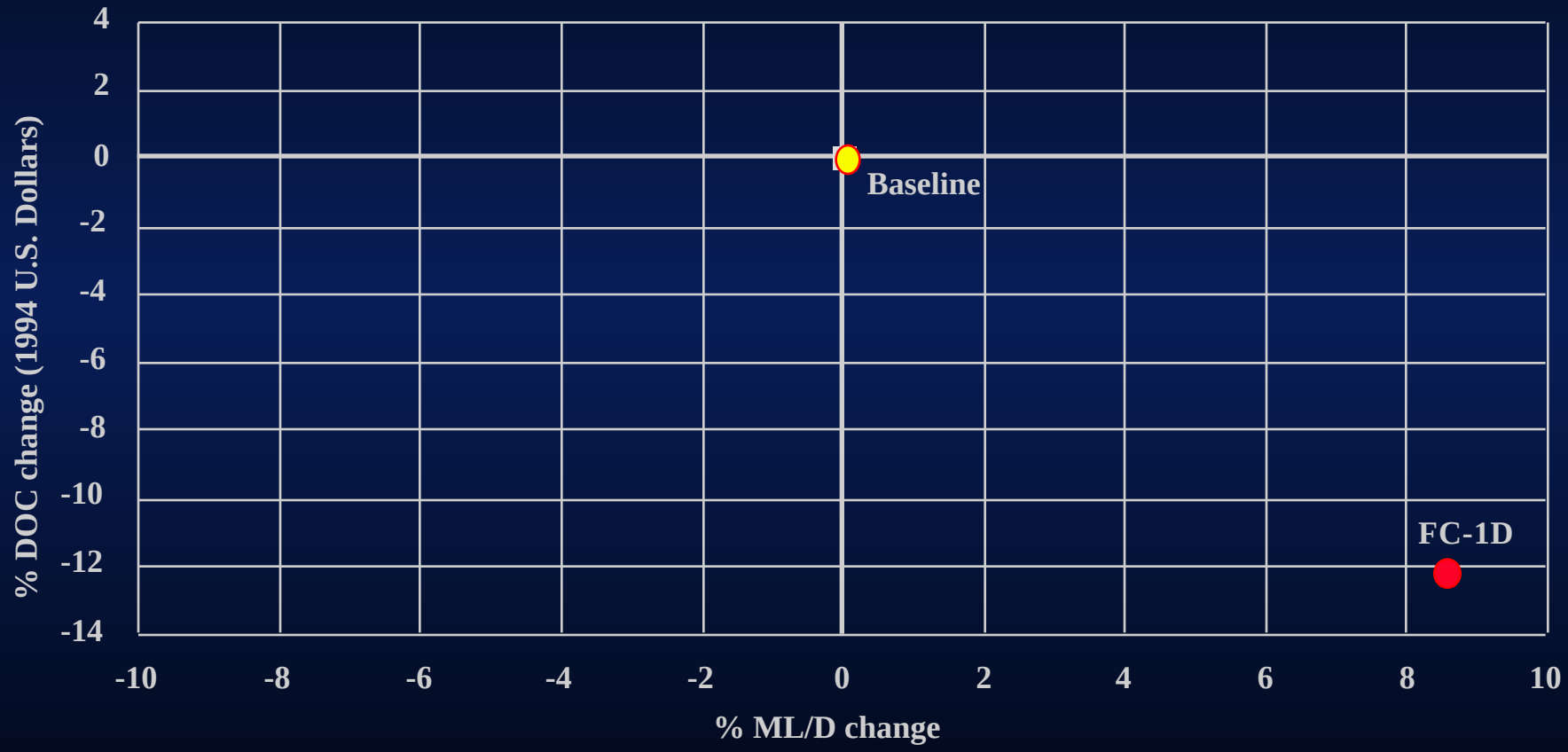


Courtesy Aviation Partners, Inc.

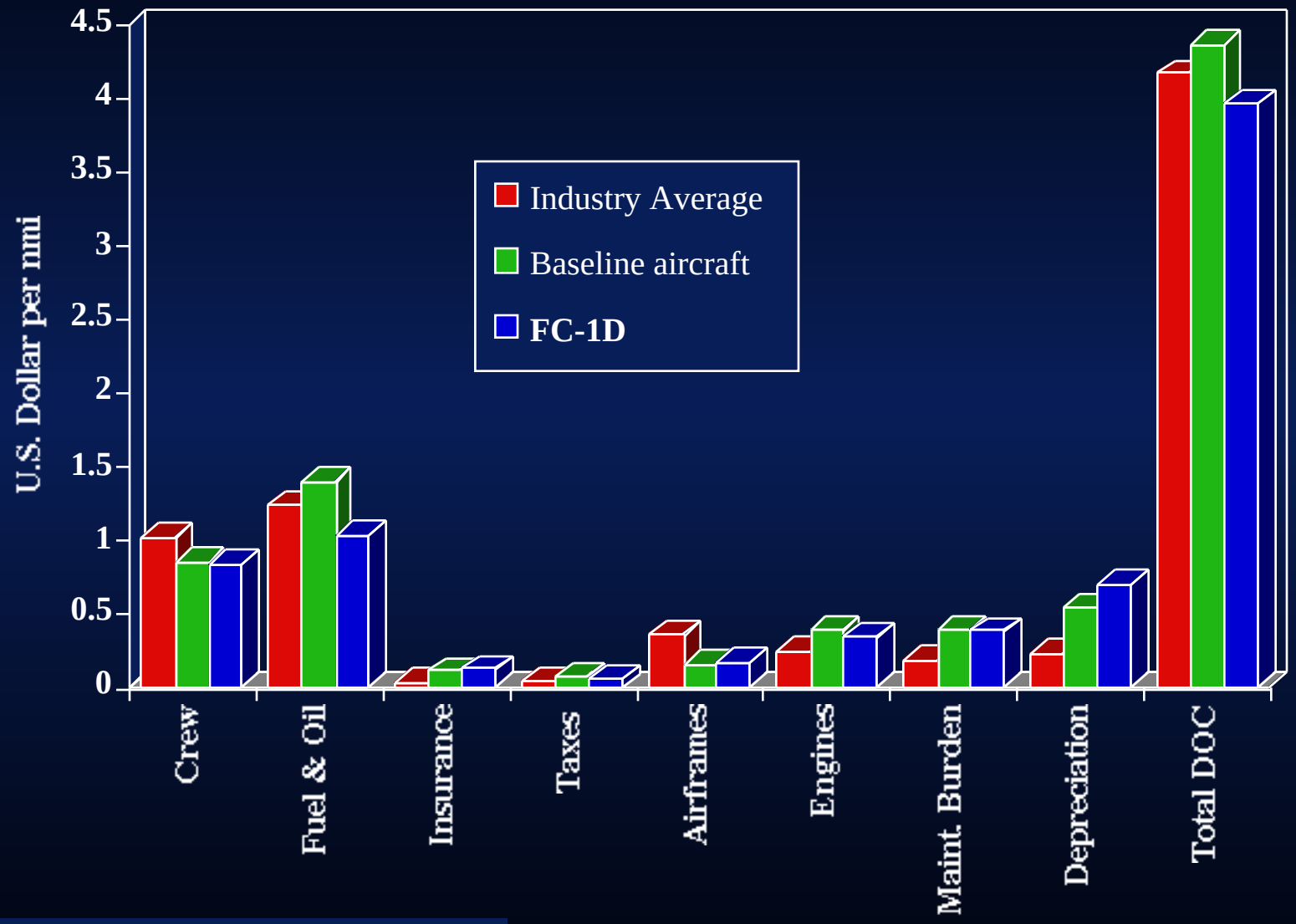
Effect of Advanced Technology On DOC



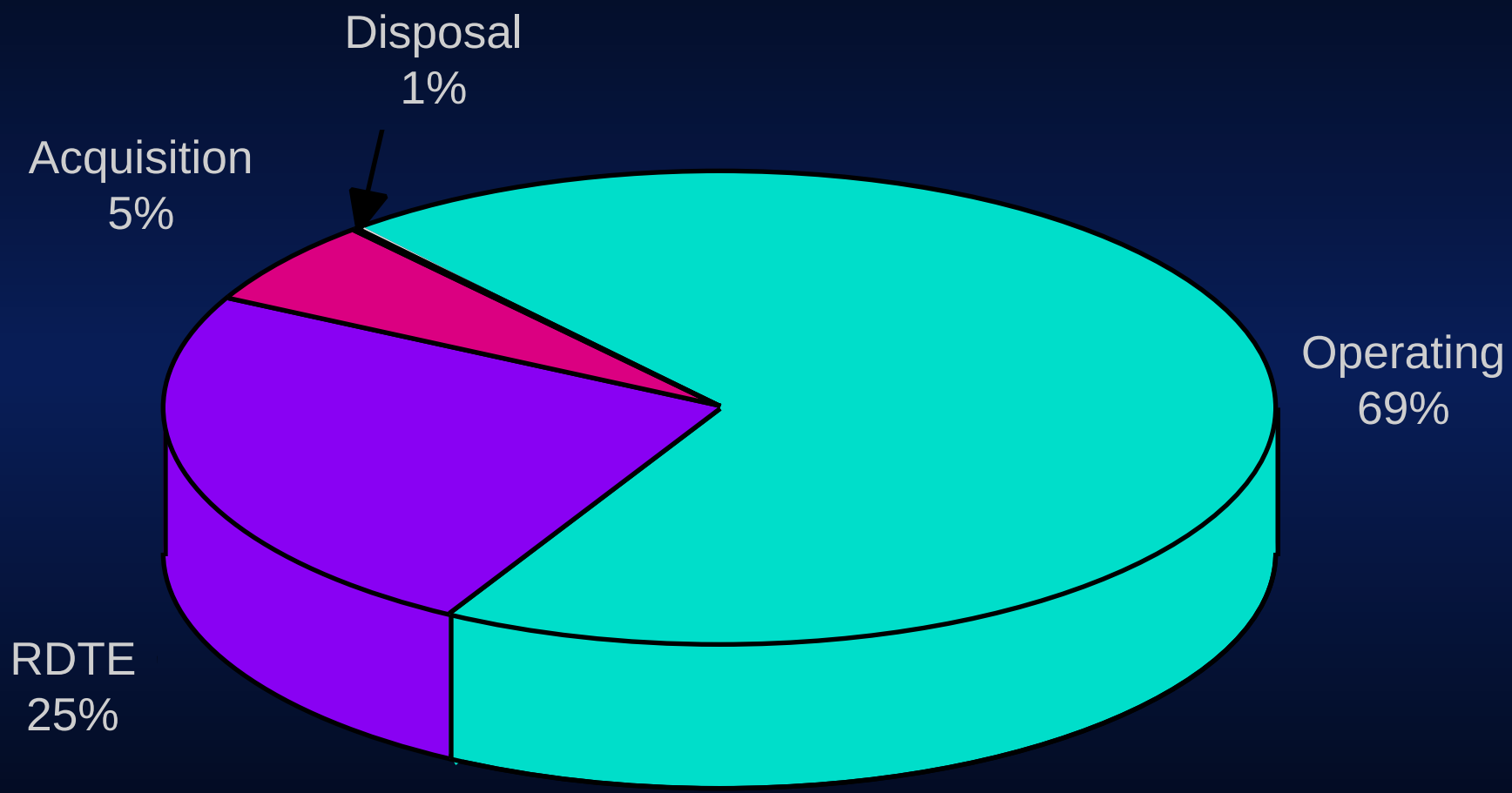
FC-1D Normalized to Baseline aircraft



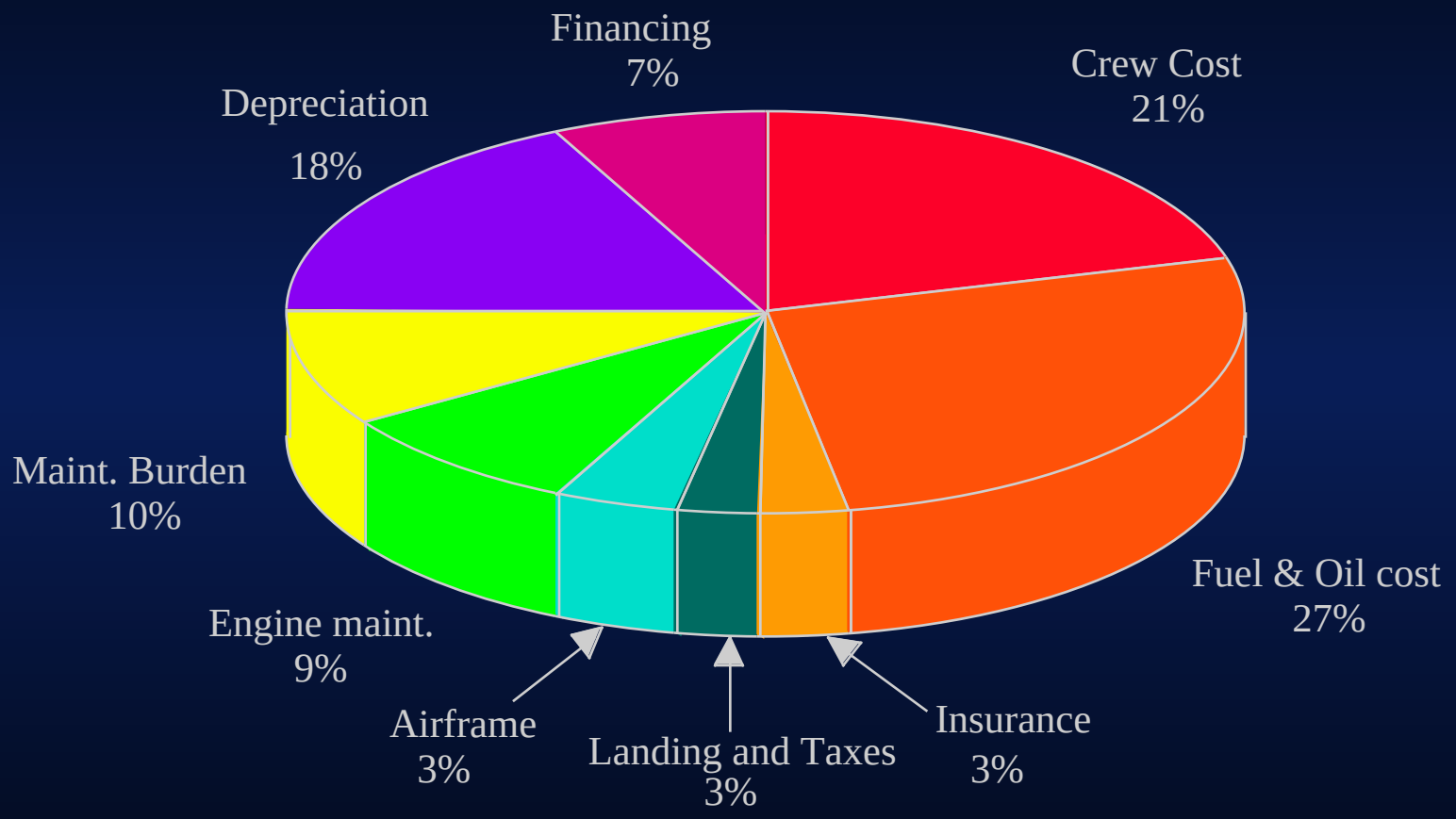
FC-1D vs. Baseline and Industry Averages



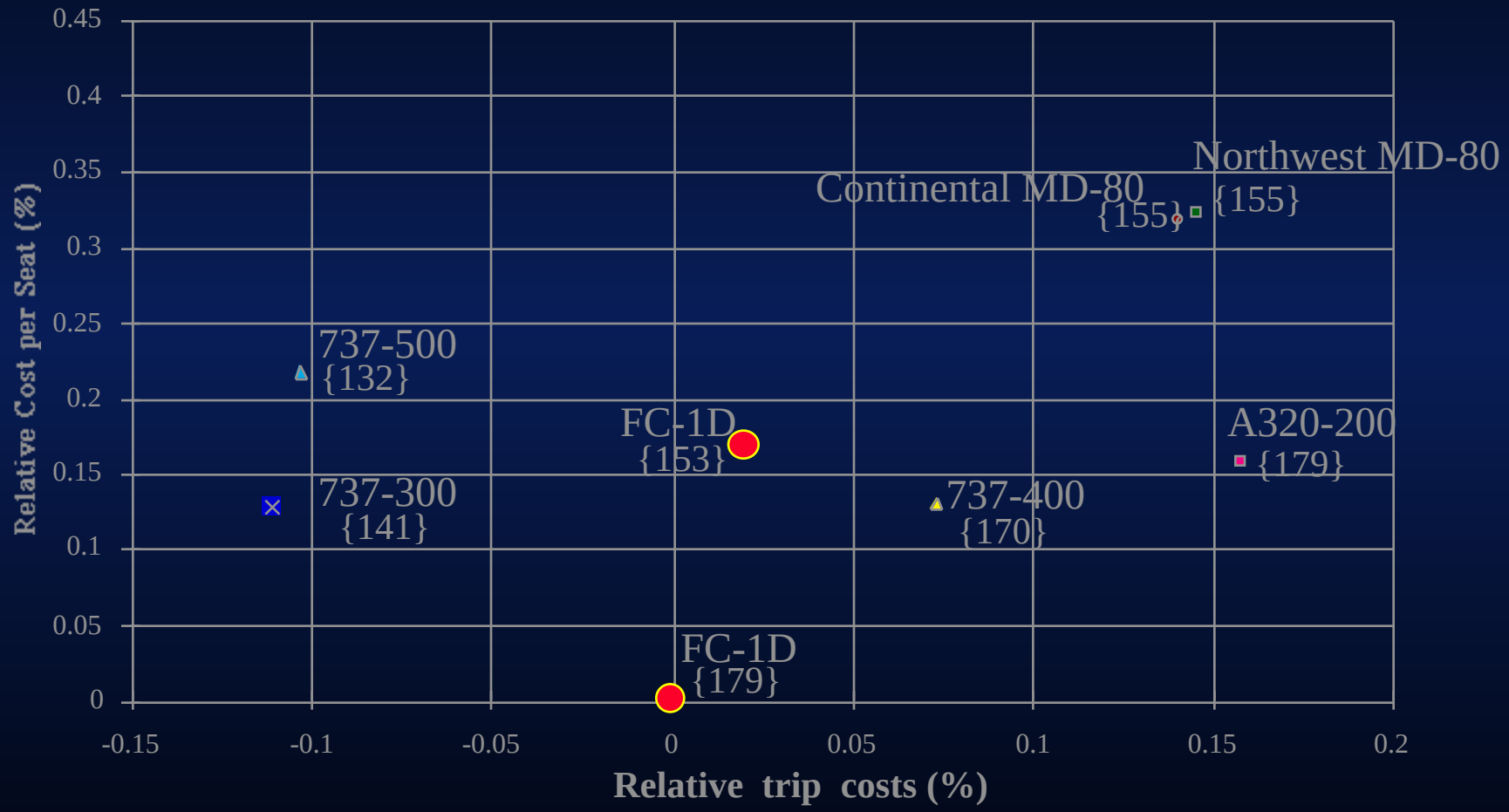
Life Cycle Cost Breakdown



DOC Breakdown of the FC-1D



DOC vs Competitors on a 3000 nmi trip



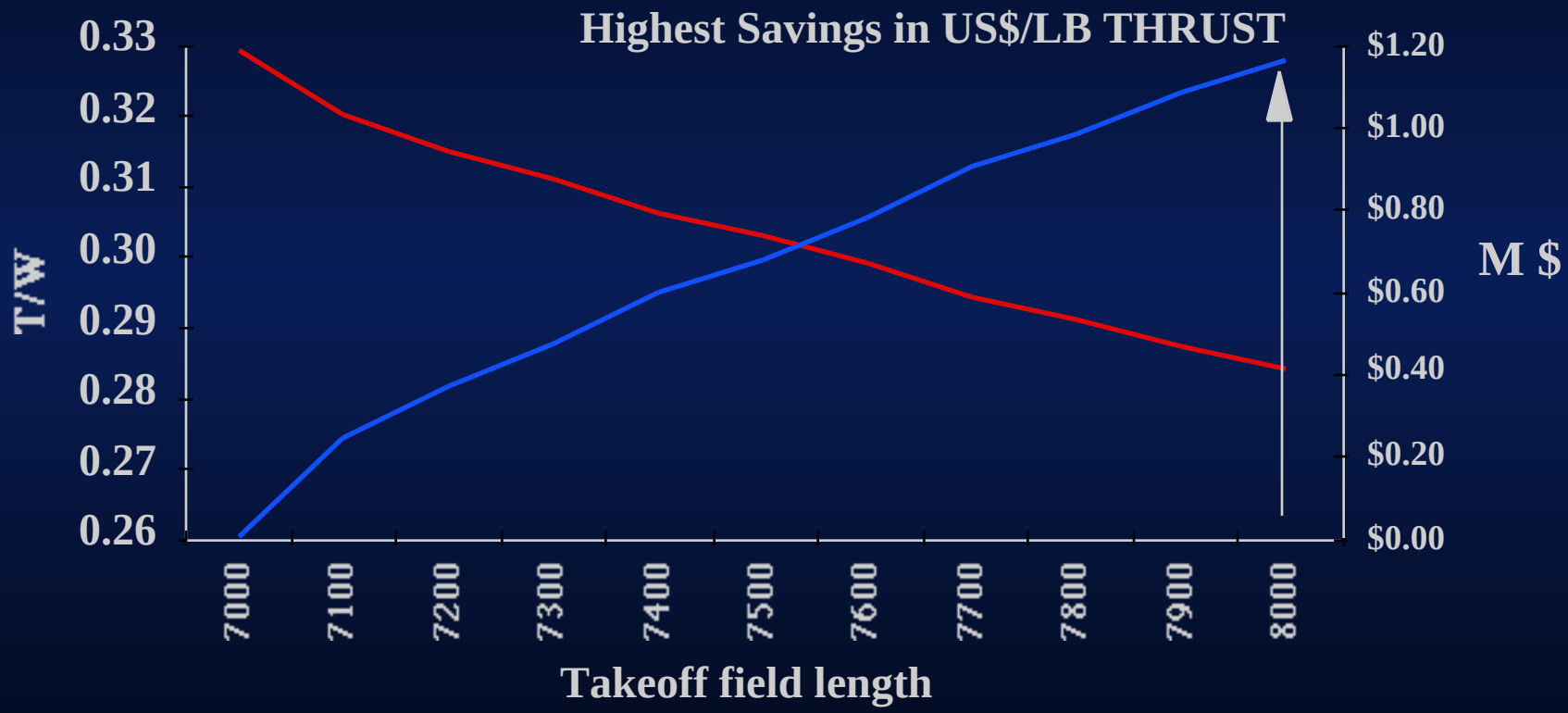
Conclusion

- Plan-It X
- Fowl Enterprises
- Central Coast Designs
- Non-Solo
- Flying Circus

RFP Compliance

- ☑ Passenger Capacity: Mixed Class, 153
- ☑ Front and Rear Galleys
- ☑ Takeoff within FAA Field Length of 7000 ft
- ☑ Climb at Best Rate to Best Cruise
- ☑ Cruise at 0.99 V_{br}
- ☑ Land with Domestic Reserves within FAA Field Length of 5000 ft
- ☑ Meets FAR Part 36, Stage III Noise Regulations
- ☑ Conforms to FAR for this Type of Aircraft
- ☑ **Low Cost Commercial Transport**

Recommendation



CAL POLY, San Luis Obispo

Low Cost Commercial Transport

M>0.7 @ Best range Velocity
Range: 3,000 n.mi.

CAL POLY

New York