1998/1999 AIAA Foundation Graduate Team Aircraft Design Competition:

Super STOL Carrier On-board Delivery Aircraft

Patrick A. LeGresley, Teal Bathke, Angel Carrion, Jose Daniel Cornejo, Jennifer Owens, Ryan Vartanian, Juan J. Alonso, Ilan Kroo

Department of Aeronautics and Astronautics
Stanford University

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Outline

- Design Requirements & Design Philosophy
- Preliminary Weight & Performance Sizing
- Configuration Selection & Component Design
- Propulsion Selection & Installation
- Structural Layout
- Drag Estimation
- Performance Analysis
- Cost Estimation
- Design Optimization
- Conclusions

Design Requirements

- Super Short Takeoff and Landing (SSTOL) aircraft to provide center-city to center-city travel using river "barges"
- Also fulfill needs of US Navy to replace the C-2 Greyhound for Carrier On-Board Delivery (COD)

Design Requirements (cont.)

- Takeoff ground roll of **300 ft**, landing ground roll of **400 ft**
- 1500 nm cruise at 350 knots
- Payload of 24 passengers and baggage for commercial version
- Payload of 10,000 lb, capable of carrying two GE F110 engines for the F-14D, and a spot factor of 60 ft by 29 ft for military version
- Arresting hooks or catapult devices not allowed!
- Technology availability date is 2005

Design Philosophy

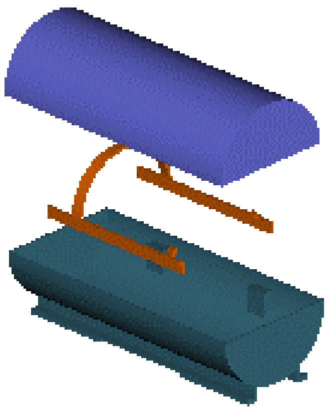
- Investigated two design approaches: tilt-wing and fixed-wing with upper surface blowing (USB) flaps
- Tilt-wing (as opposed to tilt-rotor) concept demonstrated by Canadair CL-84 and XC-124
- USB flaps utilized on NASA Quiet Short-haul Research Aircraft (QSRA) and Boeing YC-14

Preliminary Weight & Performance

- Used to estimate weight, wing area, and thrust or power to meet performance constraints (cruise speed and range, takeoff and landing ground rolls)
- Fixed-wing with USB flaps:
  - 48,635 lb takeoff weight
  - 1000 sq ft wing area
  - 30,000 lb installed thrust
- Tilt-wing:
  - 59,922 lb
  - 700 sq ft wing area
  - 10,500 installed horsepower

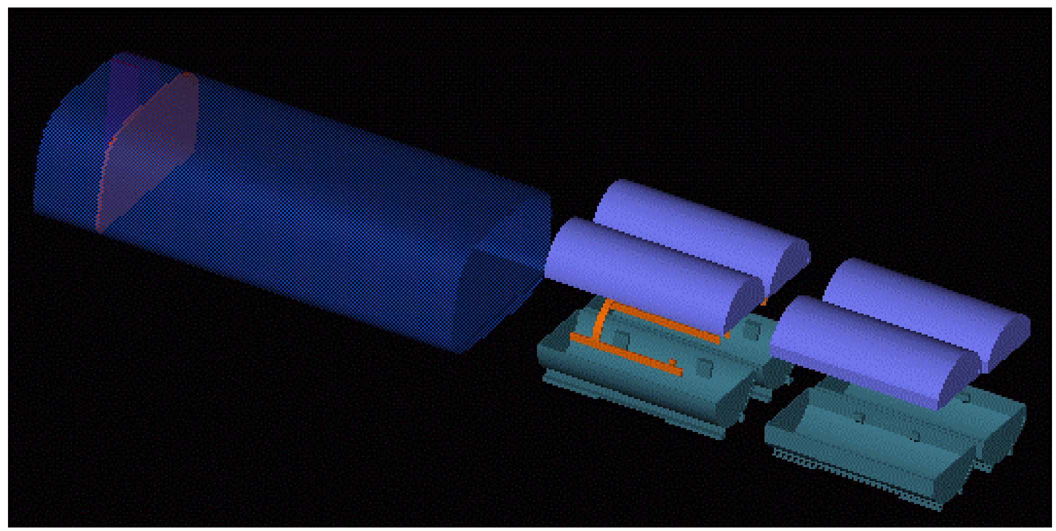
Fuselage

- Fuselage laid out around engine containers:

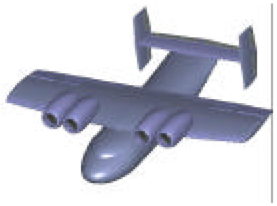


Turbine or Afterburner Container

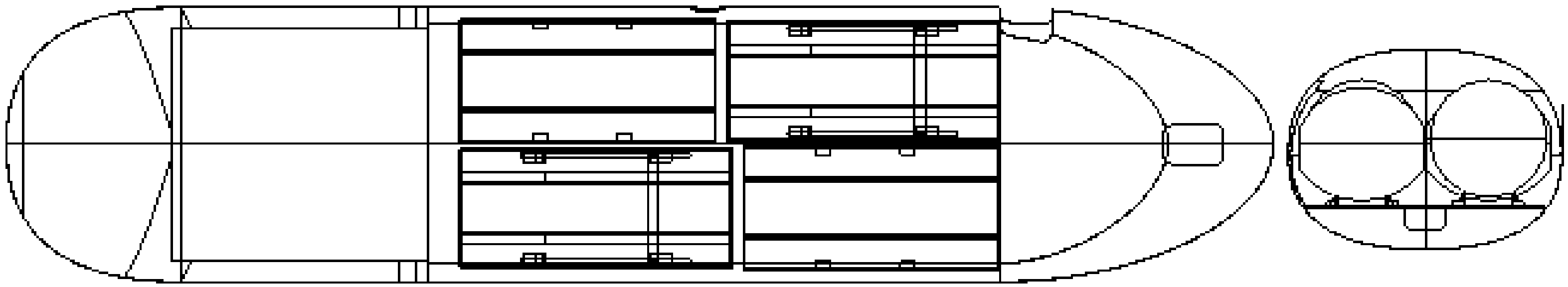
x 4 →



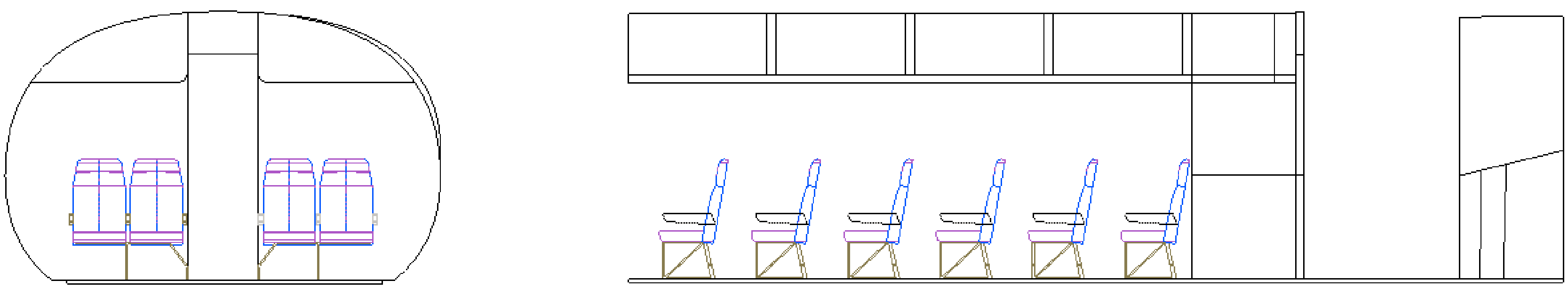
Total of 4 containers for the 2 GE F110 Engines



Fuselage (cont.)



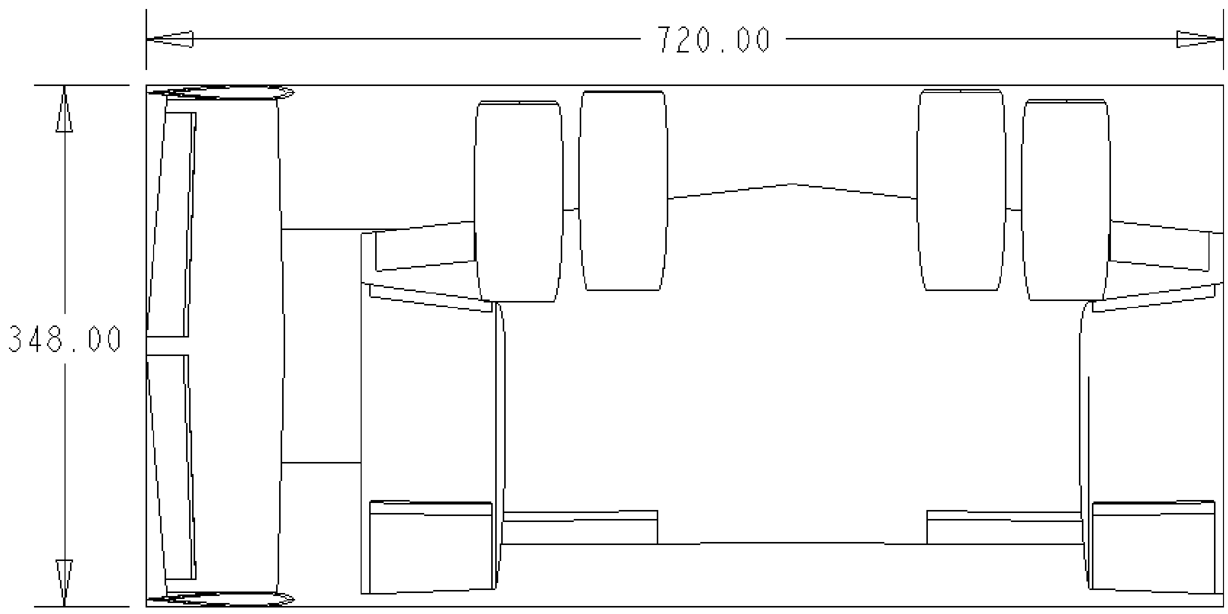
Military Version with two GE F110 engines for F-14D



Passenger version with accommodation for 24 passengers

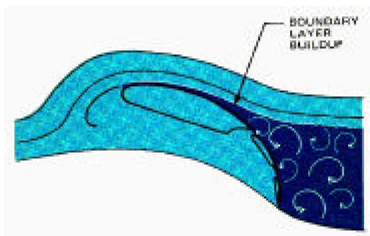
Wing

- Highly constrained by spot factor requirement (60 ft x 29 ft, wing folding allowed)
- Final design incorporated wing pivoting and folding

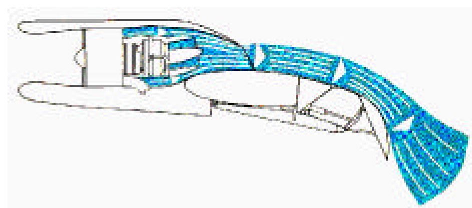


Propulsion & High Lift

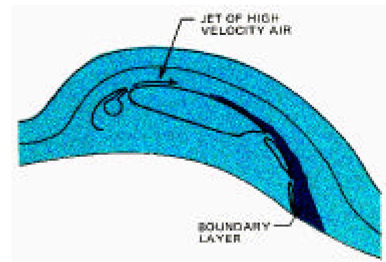
- Two different concepts for high lift:



(I)
Airflow over wing without BLC

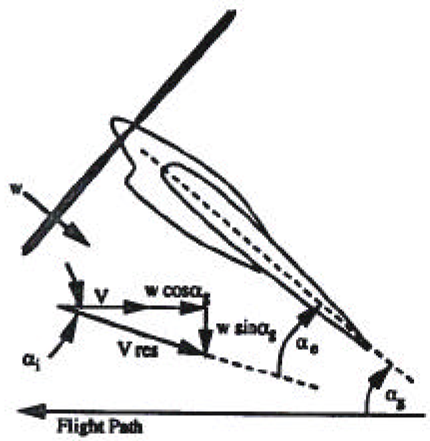


(II)
USB Concept



(III)
BLC used to delay boundary layer build-up

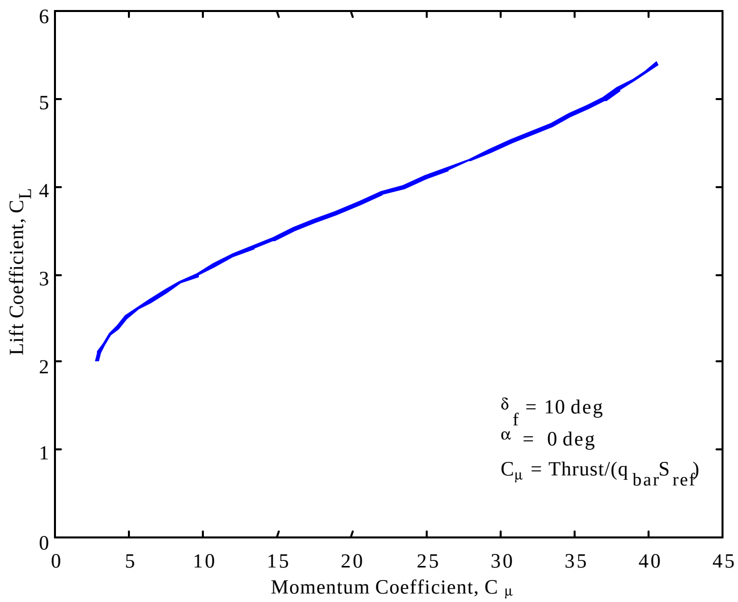
Upper Surface Blowing (USB) Flaps



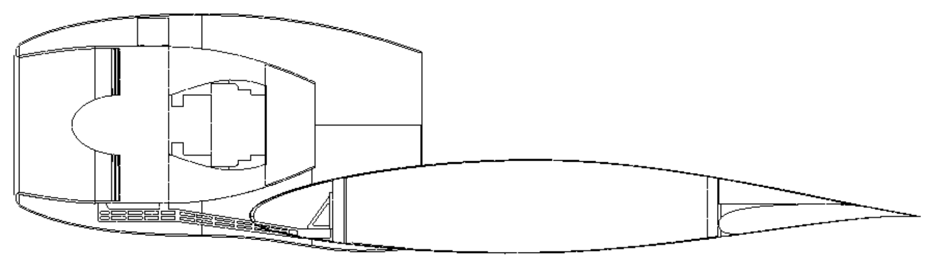
Tilt-wing

Propulsion & High Lift (cont.)

- Analyzed using methodology in Aerodynamics of V/STOL Flight by McCormick
- Flight test and wintunnel data for ‘sanity’ check



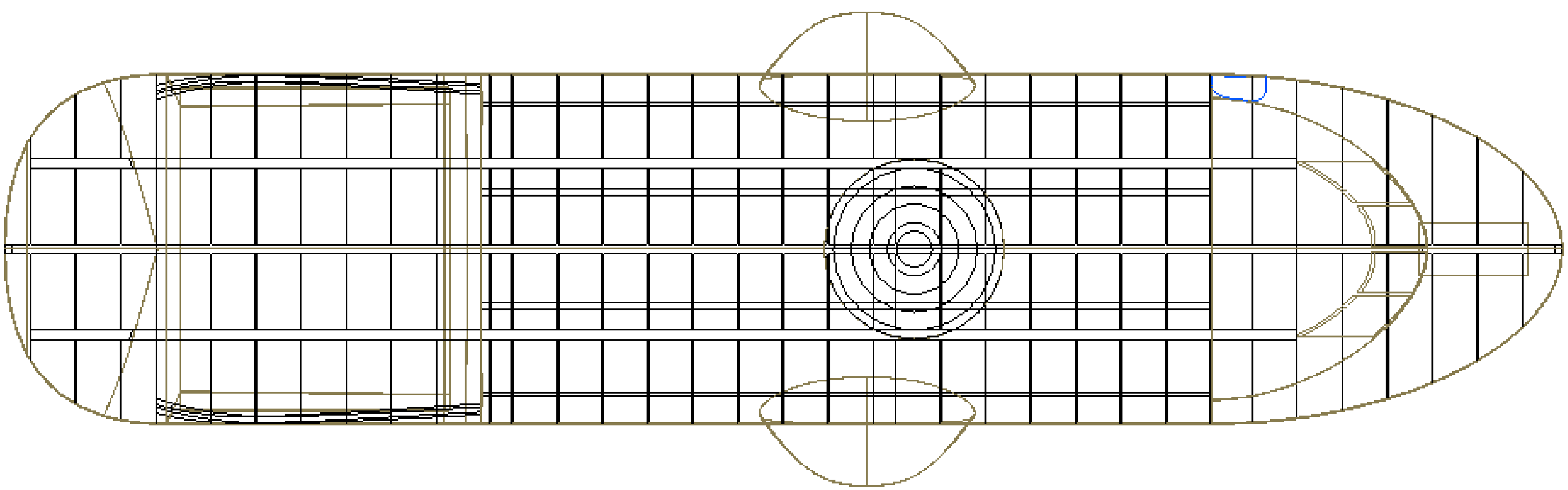
Sample Variation of Lift Coefficient



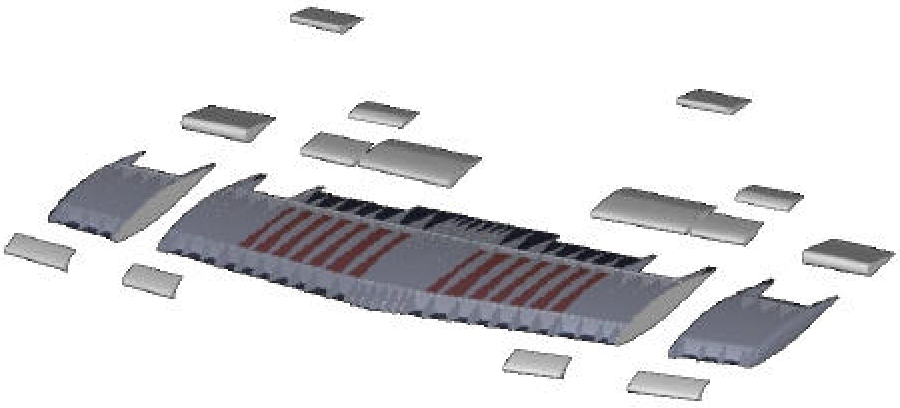
Engine Installation

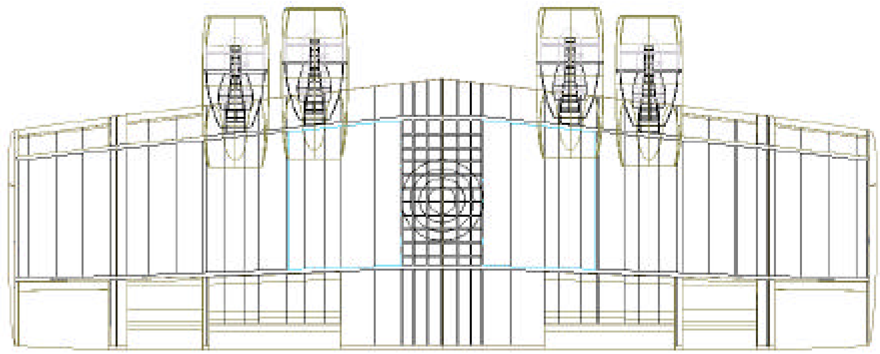
Structural Layout

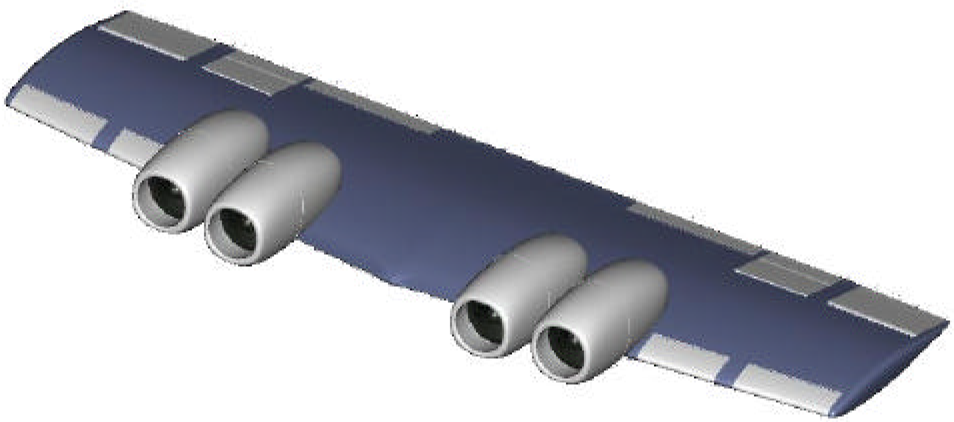
- Based on ‘typical’ configurations of cargo aircraft and consists of frames, longerons, ribs, and spars
- Efforts to make use of advanced materials where useful and cost effective



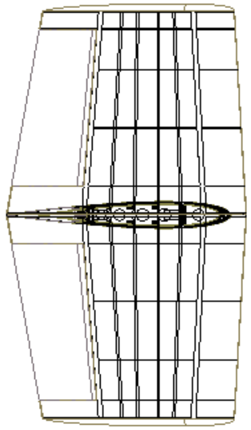
Wing Structure

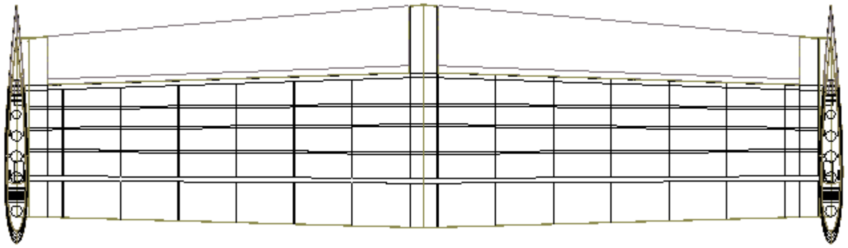






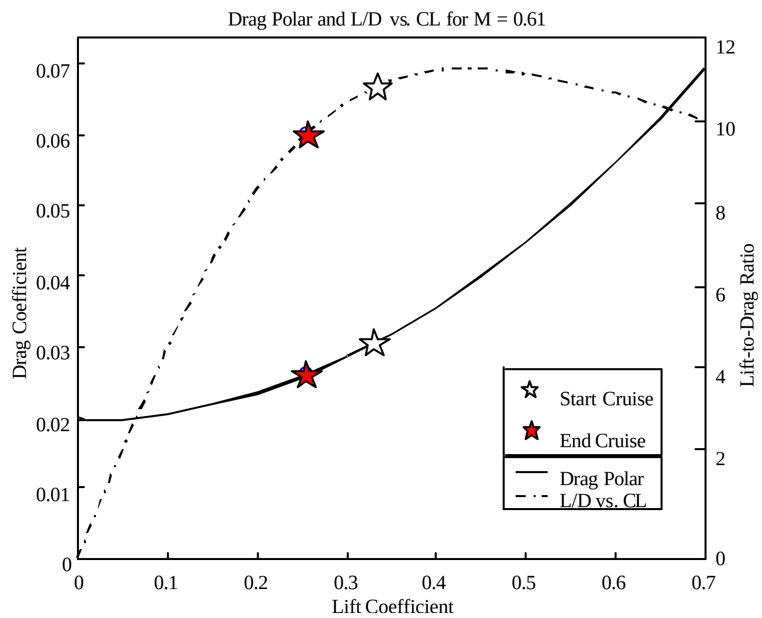
Empennage Structure





Drag Estimation

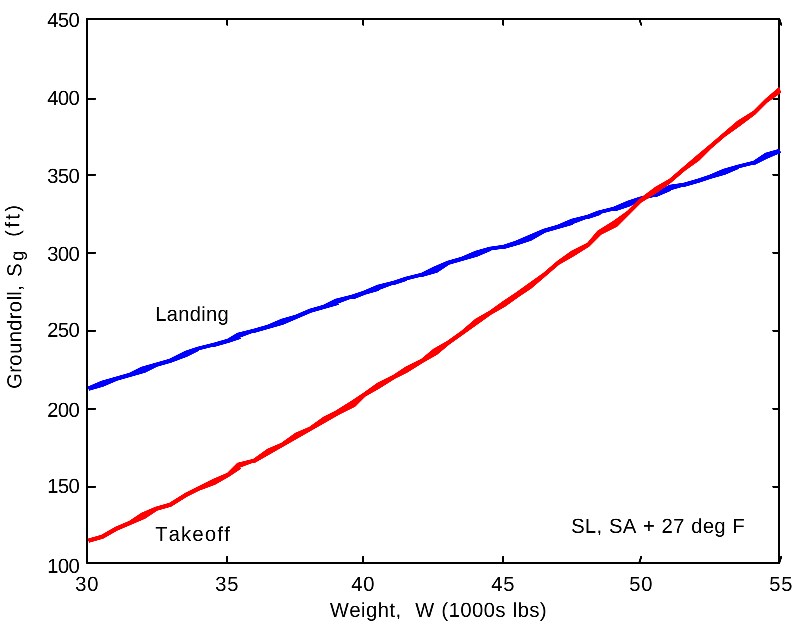
- Drag build-up approach: drag of each major component computed, plus interference effects
- Induced drag computed as function of wing/body lift coefficient



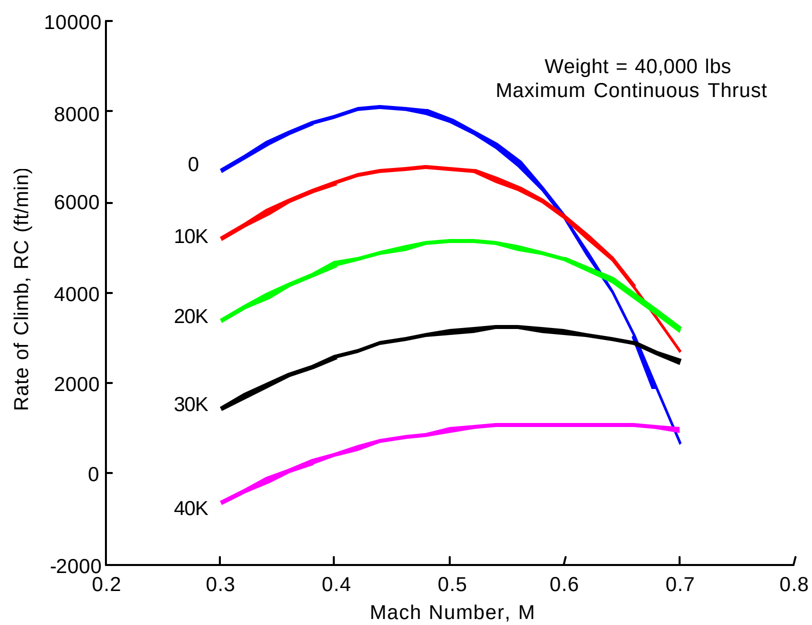
Cruise Drag

Performance Analysis

- Equations of motion numerically integrated to compute takeoff and landing ground roll
- Climb rate calculated from engine data & drag polar



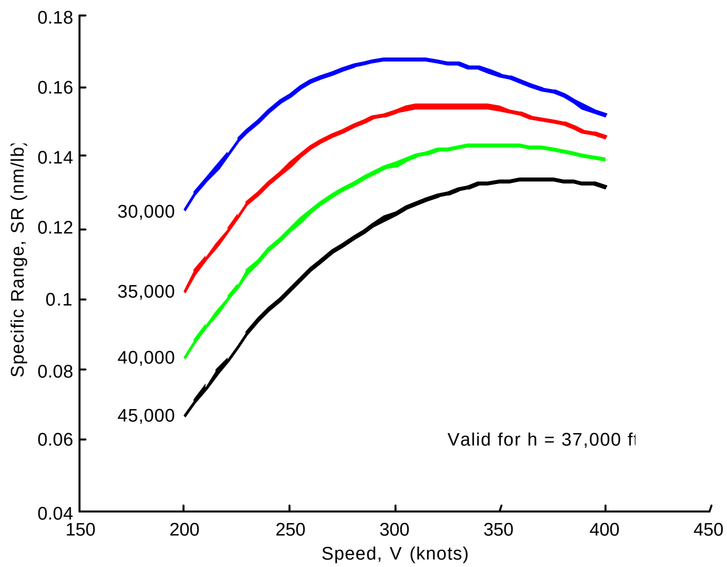
Takeoff and Landing Ground Rolls



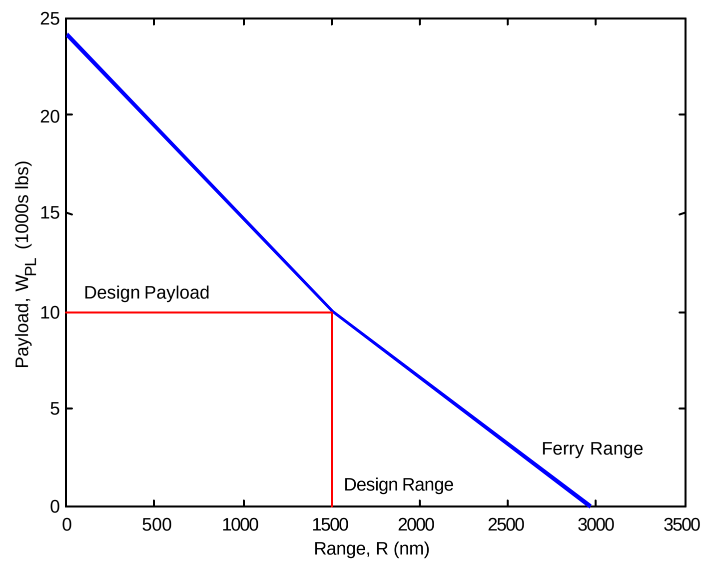
AEO Climb Rate

Performance (cont.)

- Specific range computed from drag polar and engine data for various weights
- Range calculated by integrating specific range, taking into account reserves requirements



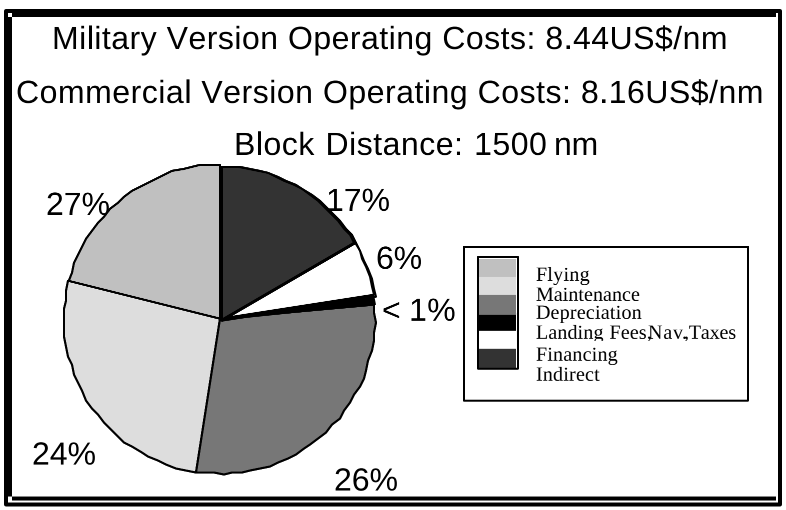
Specific Range



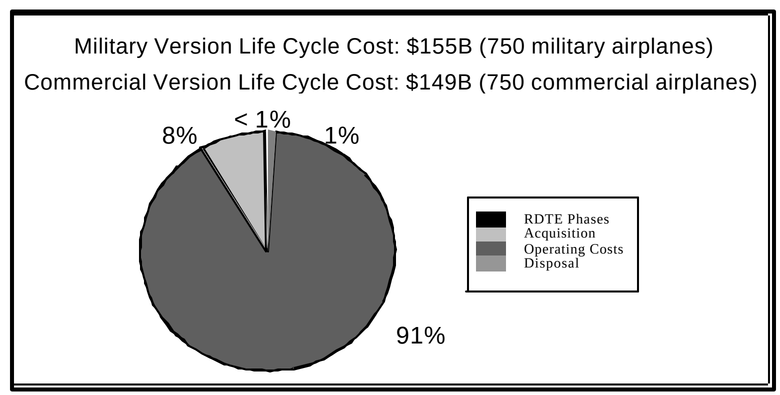
Payload-Range

Cost Estimation

- Cost estimation method based on statistical data gathered for many existing aircraft
- Research, Development, Test, and Engineering (RDTE), Acquisition, Operating, and Disposal costs were computed, leading to the Life Cycle Cost (LCC)



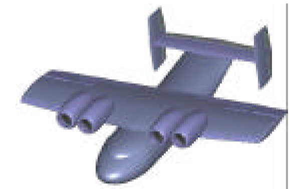
Operating Cost Breakdown



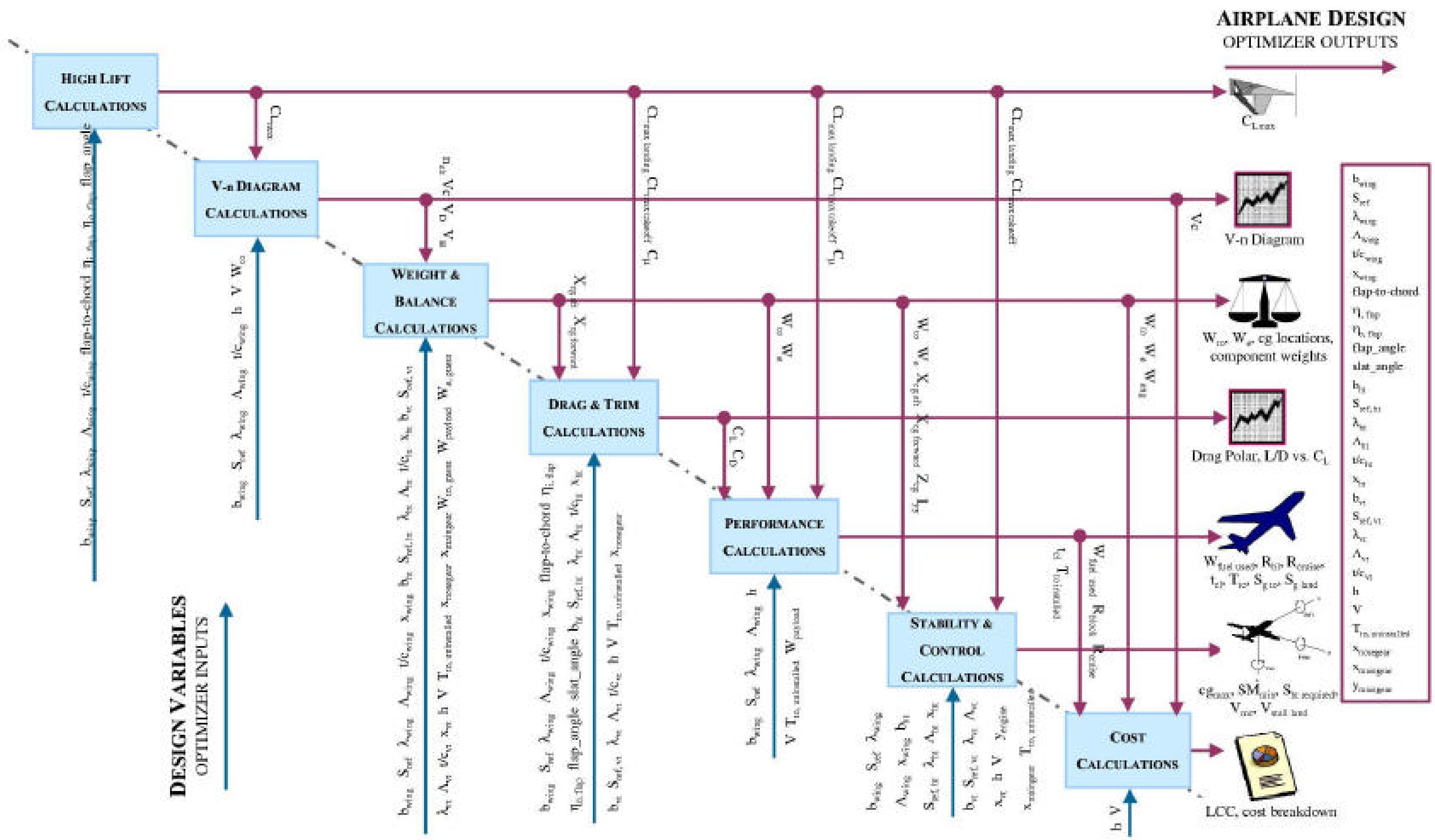
Life Cycle Cost

Design Optimization

- Various subsystem analyses (high lift, weight, propulsion, performance, cost, etc.) were combined into a collaborative optimization code
- The goal of the optimization was to produce the best design (in this case as measured by life cycle cost) which met all of the design requirements – takeoff and landing ground roll, cruise speed and range
- Constraints for FAR / MIL certification such as stability, climb gradients, tipover, etc. were also applied



Design Optimization (cont.)

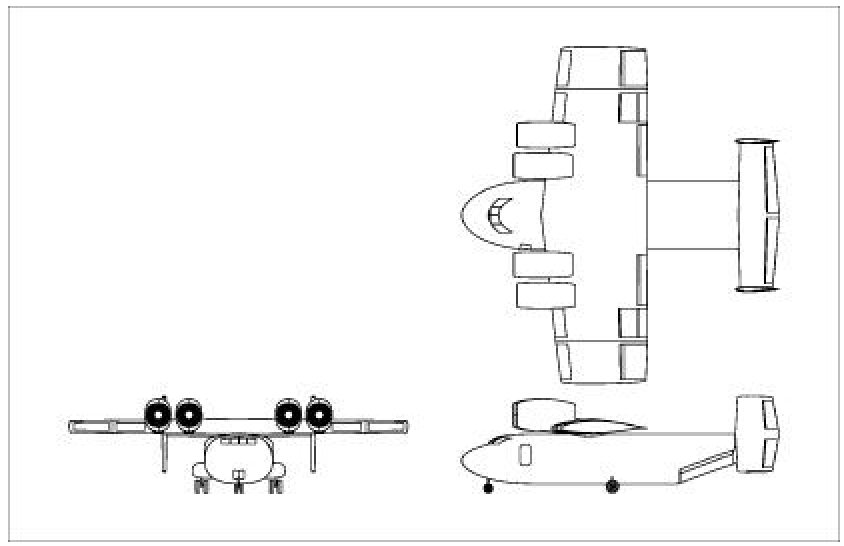


Design Optimization (cont.)

- A final design was selected based on the relative costs of the various designs:

Cost Comparison

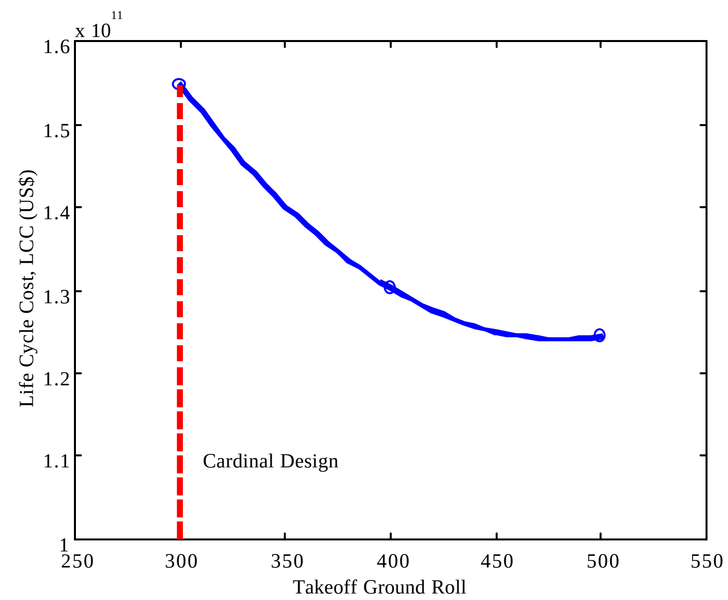
	Vertical Takeoff Tiltwing	***Short Takeoff Tiltwing***	***Short Takeoff Fixed Wing***
DOC	\$9.06/nm	\$7.82/nm	\$7.03/nm
IOC	\$1.81/nm	\$1.56/nm	\$1.41/nm
Fuel Price	\$1.20/gal	\$1.20/gal	\$1.20/gal
Engine Price (per engine)	\$1.09 M	\$0.81 M	\$0.52 M
AEP	\$20.8 M	\$18.0 M	\$17.1 M
AMP	\$19.7 M	\$17.3 M	\$16.7 M
LCC	**\$200.6 B**	**\$172.1 B**	**\$154.7 B**



Final Three-View

Trade Study on Performance Requirements

- Although performance requirements were specified, constraints were varied to analyze effect on LCC
- One of the more interesting is that for takeoff ground roll:



Variation of Life Cycle Cost with Takeoff Ground Roll Constraint

Conclusions

- Upper Surface Blowing (USB) flaps and tilt-wing considered as means to achieve Super Short Takeoff and Landing (SSTOL)
- Subsystem analyses methods developed for use in collaborative optimization
- A fixed-wing design with USB flaps was selected for its lower Life Cycle Cost
- Design studies showed that a relaxed takeoff constraint would have a significant effect on Life Cycle Cost