8th CEAS Workshop: Aeroacoustics of New Aircraft and Engine Configurations

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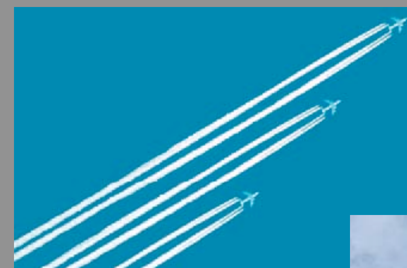

New Concepts for Quiet and Efficient Aircraft

Budapest , Hungary, Nov. 2004

Outline

- Introduction
  - Motivation
  - Approach
- Design Methods
- Example Results
- Configuration Concepts
- Conclusions and Future Directions

Introduction

- Motivation
  - Increasing importance of environmental considerations in aircraft design

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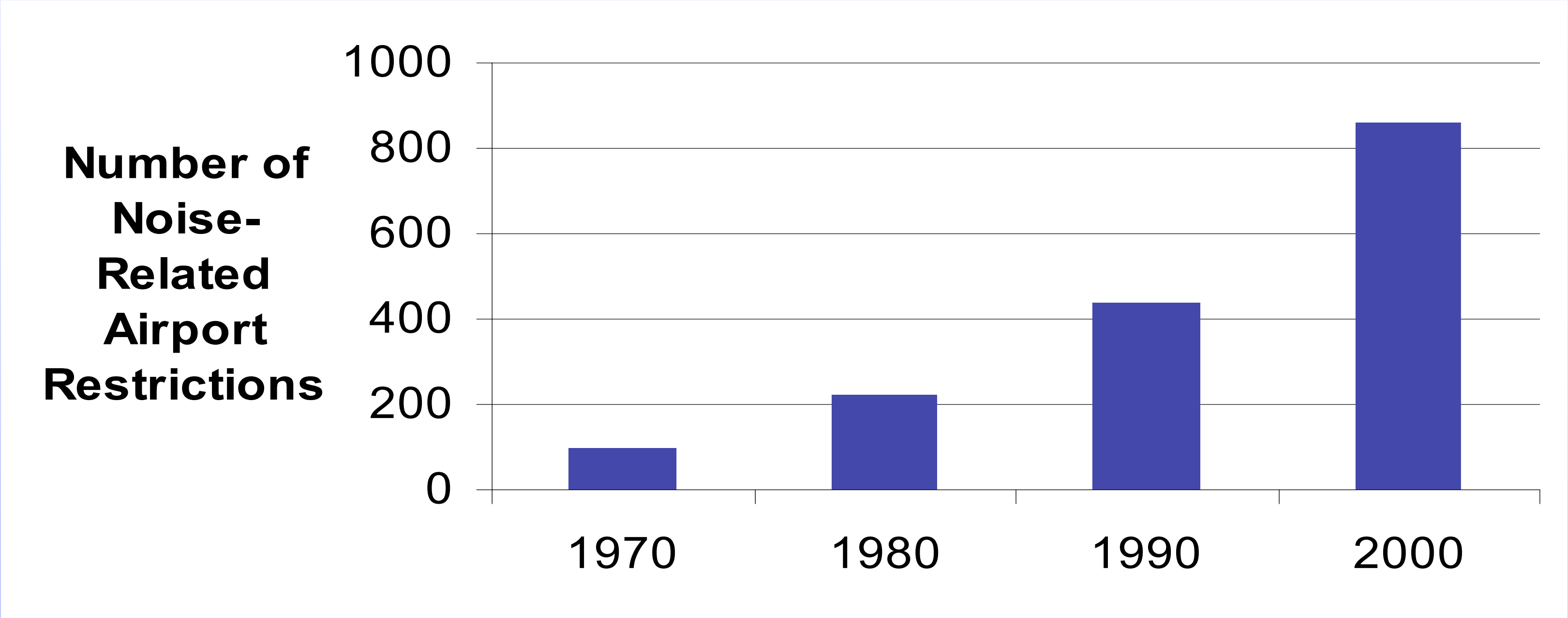
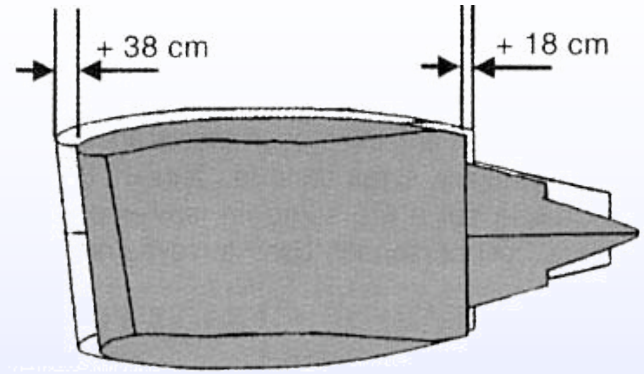


Introduction

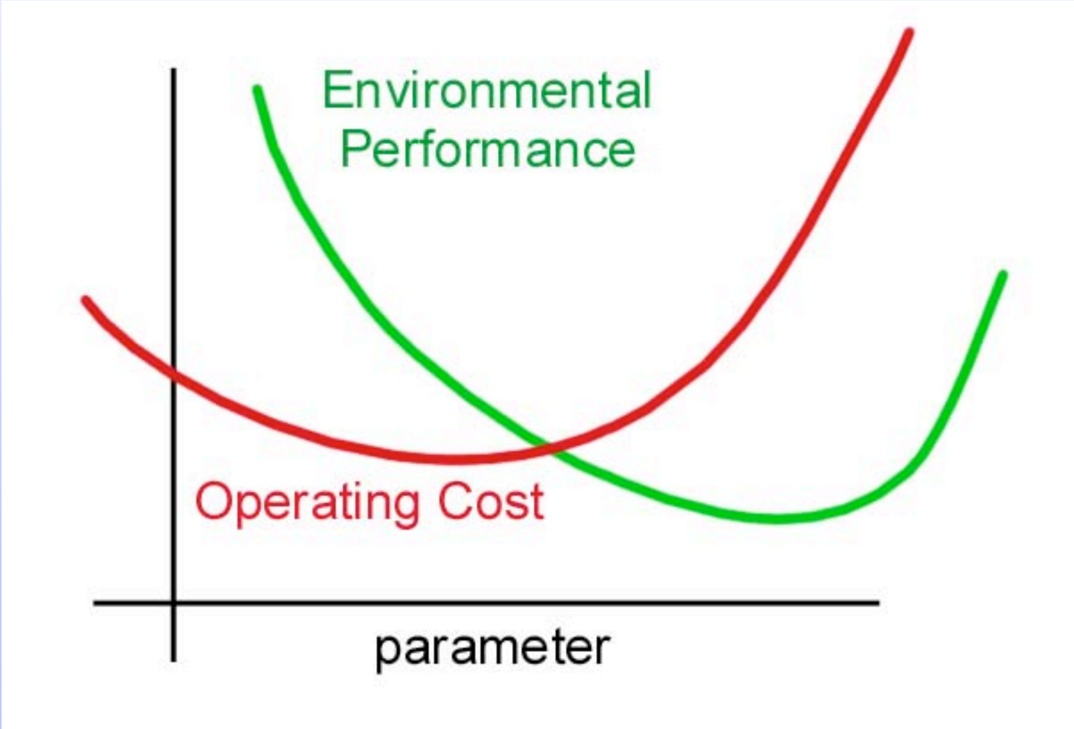
- To meet London Heathrow QC2 noise standards, A380 engines were modified late in the design stage.

- This resulted in a performance penalty that might have been avoided.



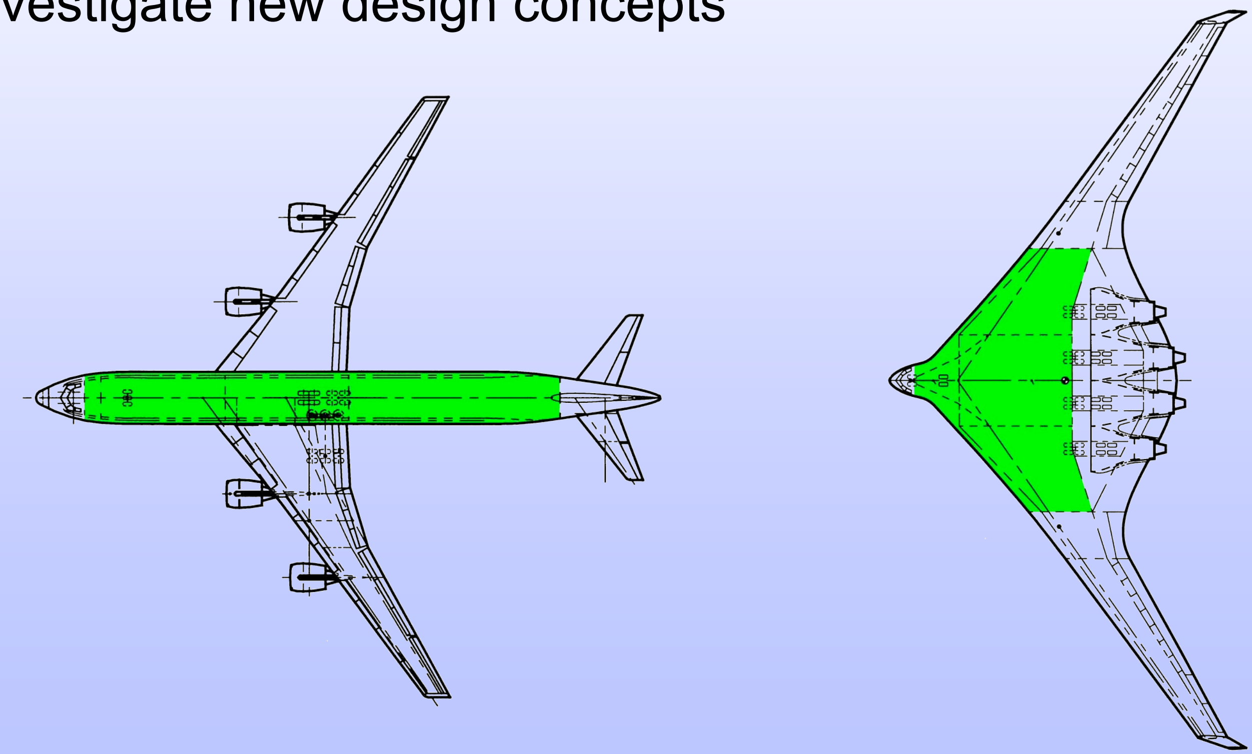
Introduction

- Objectives
  - Evaluate trade-offs between cost and environmental impacts during aircraft conceptual design using multidisciplinary optimization
  - Include configuration parameters and trades between environmental performance metrics (e.g. noise vs. emissions)



Introduction

- Objectives
  - Evaluate trade-offs between cost and environmental impacts during aircraft conceptual design using multidisciplinary optimization
  - Develop framework that can accommodate current and new designs
  - Investigate new design concepts



Green Aircraft

- Objectives
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  - Develop framework that can accommodate current and new designs
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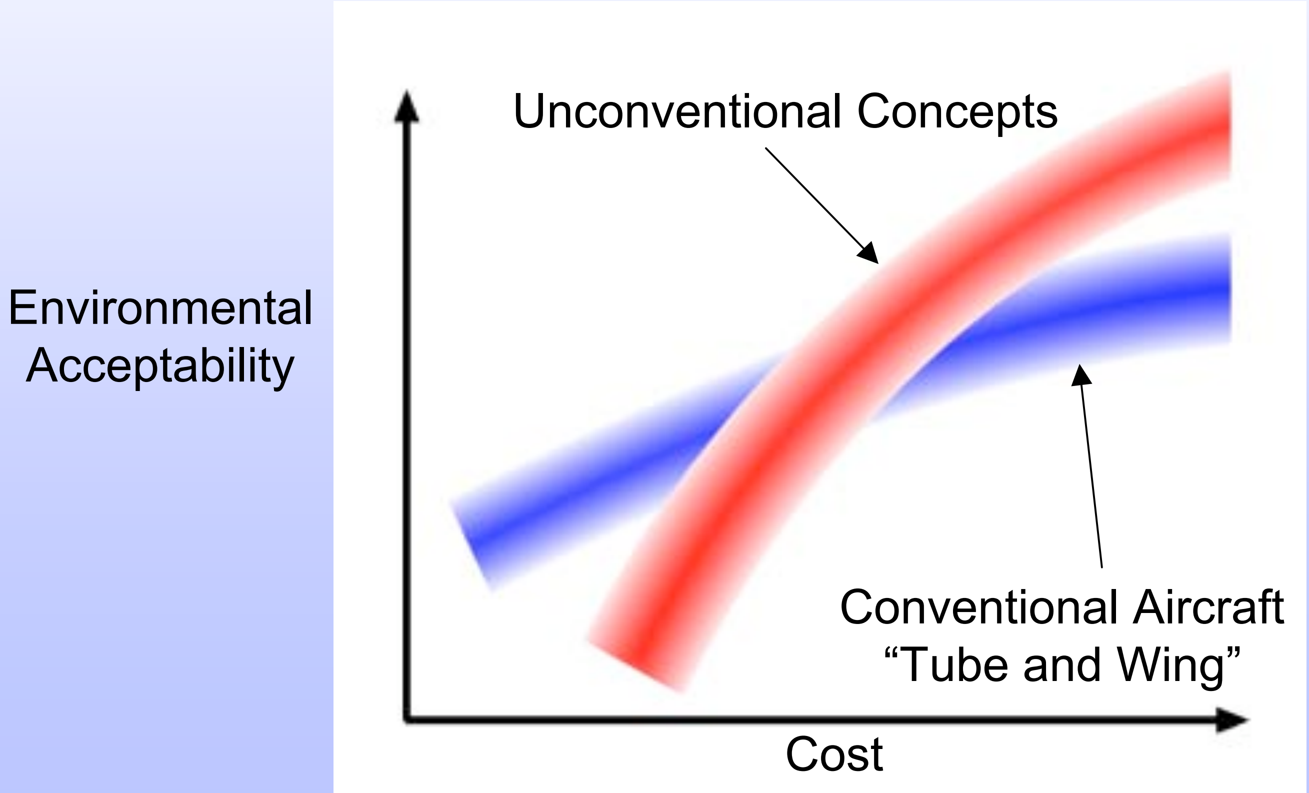

Outline

- Introduction
- **Design Methods**
- Example Results
- Configuration Concepts
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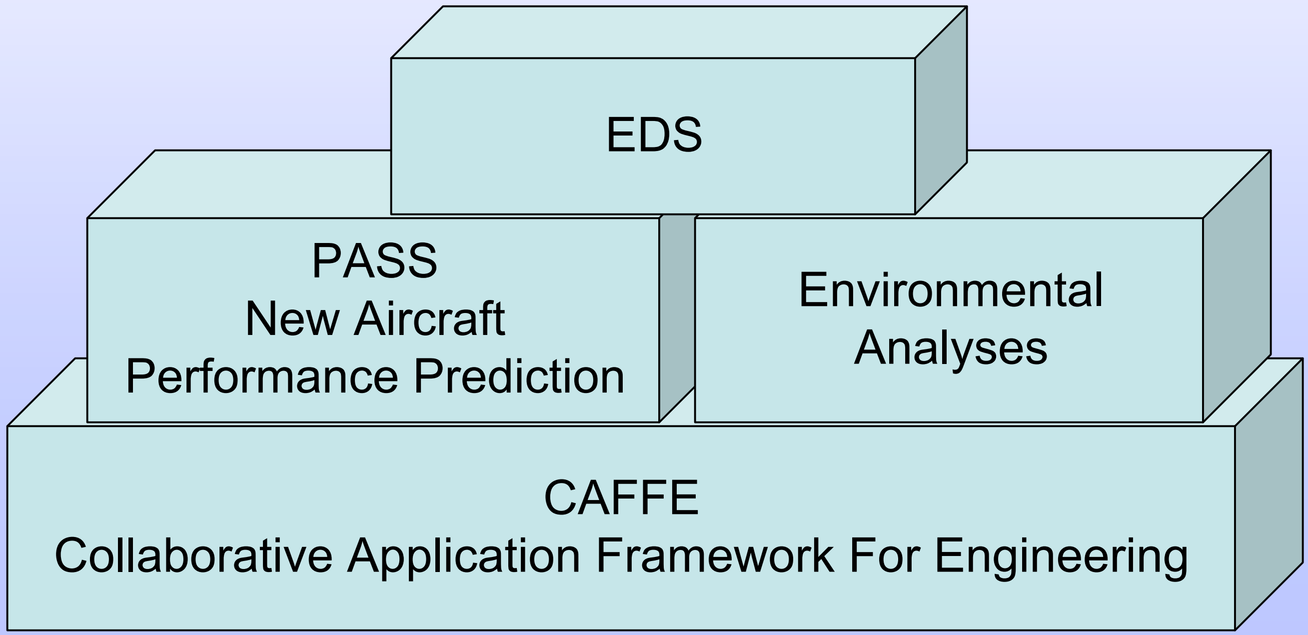
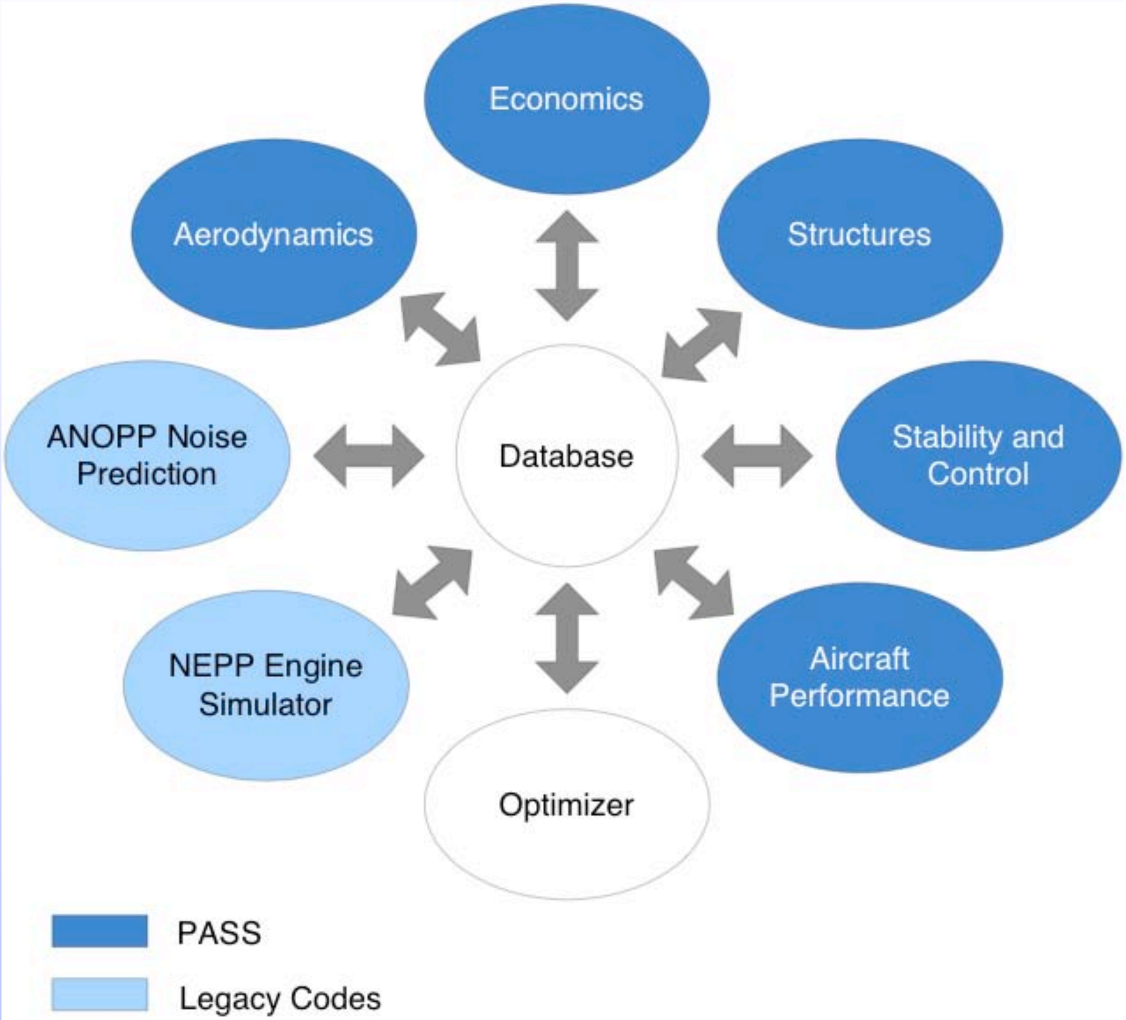
Design Framework

- Current tool builds upon existing framework and analyses
- Concept not dependent on fixed set of tools
  - Opportunity to use existing NASA, industry tools
  - Flexibility of modules is an important aspect of framework



Design Framework

- Conceptual design tool includes:
  - multidisciplinary analysis
  - legacy noise, engine simulation
  - optimization
  - database management
  - programming API's



Design Framework

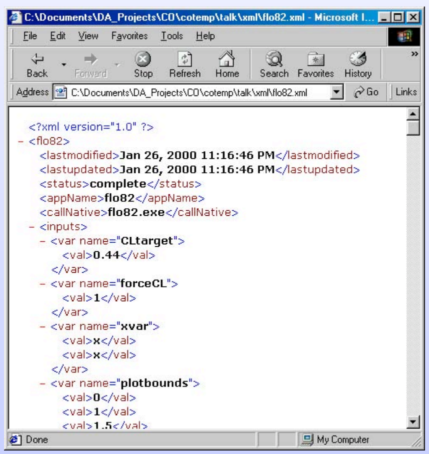
- Modern Java/XML-based framework
- Platform independent
- Dynamic linking of analysis modules
- Supports legacy code without source
- Hierarchical database API
- Remote execution
- Integrated optimization suite
- Custom user interface plug-ins

```
public class drag extends CaffeClass {

    pdrag parasite = new pdrag();
    idrag induced = new idrag();
    cdrag compress = new cdrag();
    trim trm = new trim();

    public void compute() {
        double CL, CD, loverd, doverl;
        double cdp, cdi, cdc;

        // get required inputs from database:
        CL = db.getd("cltotal");

        // calculations:
        trm.compute();
        parasite.compute();
        induced.compute();
        compress.compute();

        cdp = db.getd("cdp");
        cdi = db.getd("cdi");
        cdc = db.getd("cdc");

        CD = cdp + cdi + cdc;
        loverd = 0.;
        if (Math.abs(CD) > 0) loverd = CL/CD;

        // repack database:
        db.putd("cd", CD);
        db.putd("l/d", loverd);

    }
}
```

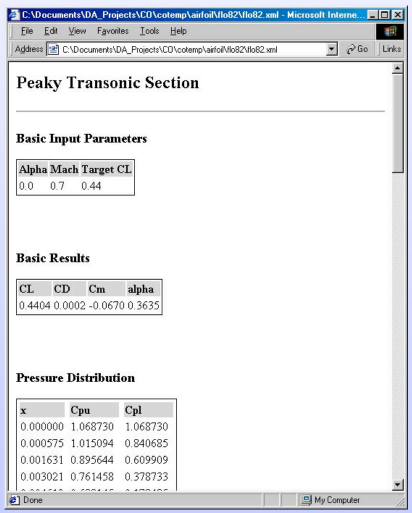
Design Framework: XML Data

- XML database format integrated with framework
- Standards-based format compatible with many existing tools

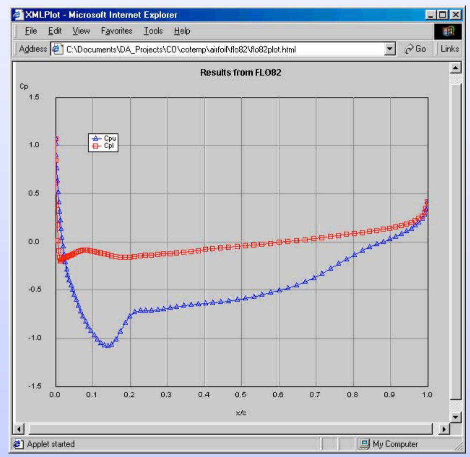
Source



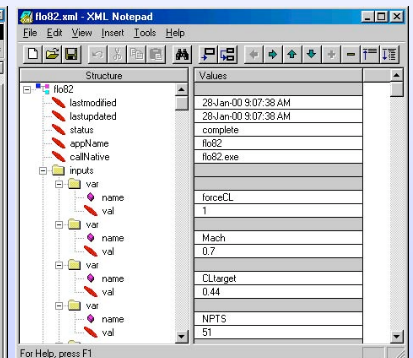
XSLT Formatted



Plot (Applet) View

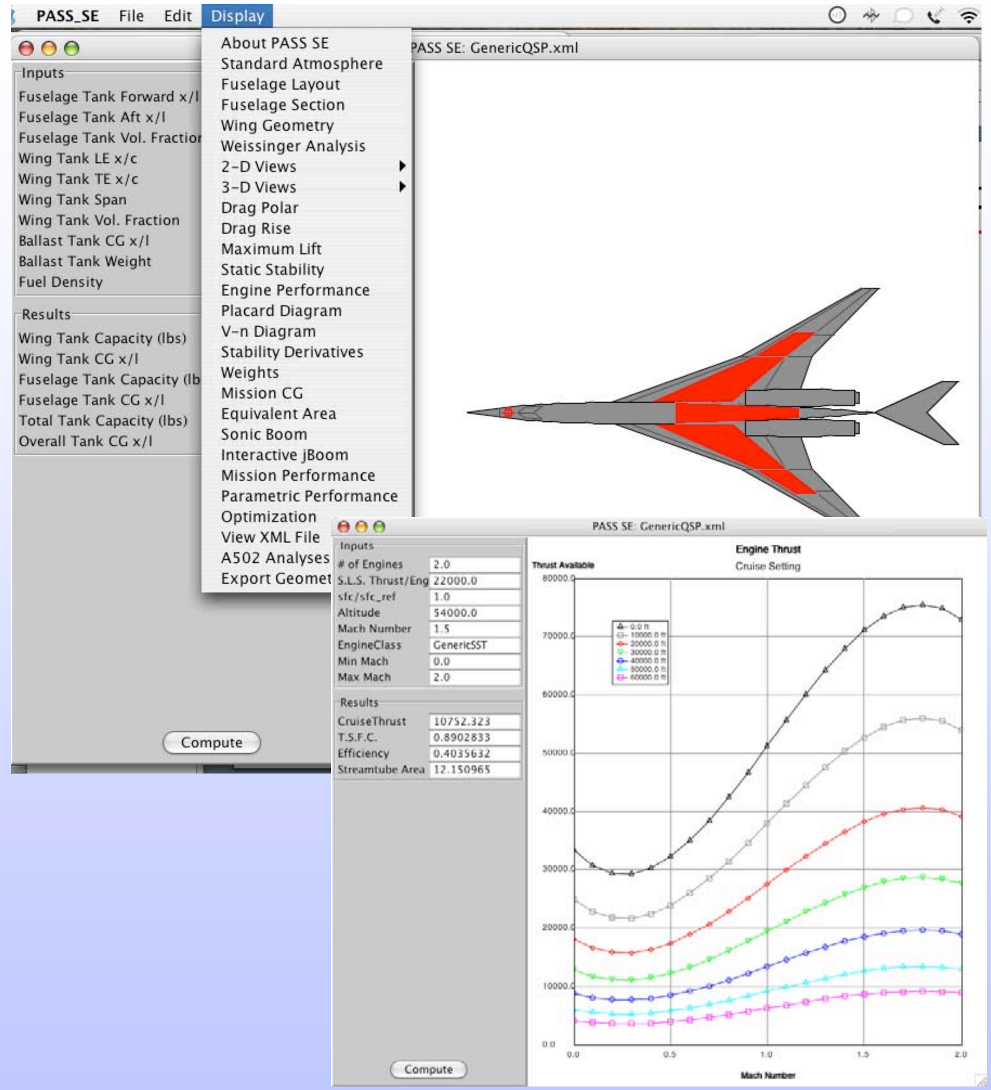


XML Editor



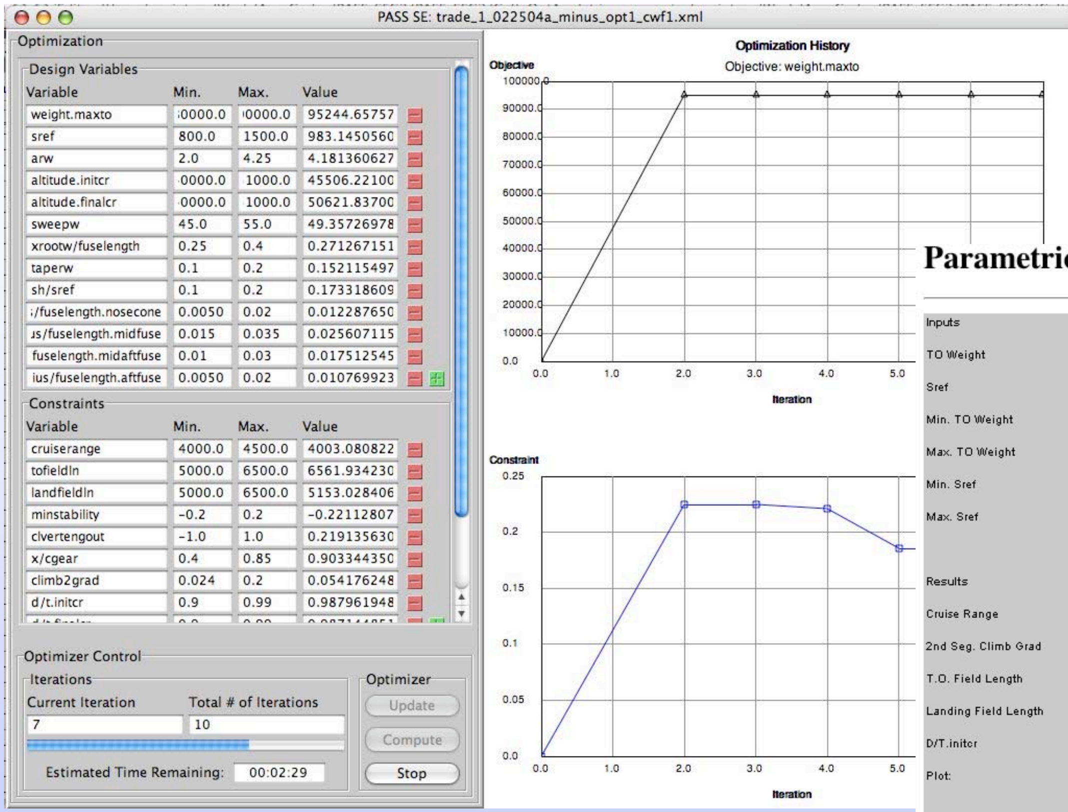
Design Framework: Interface

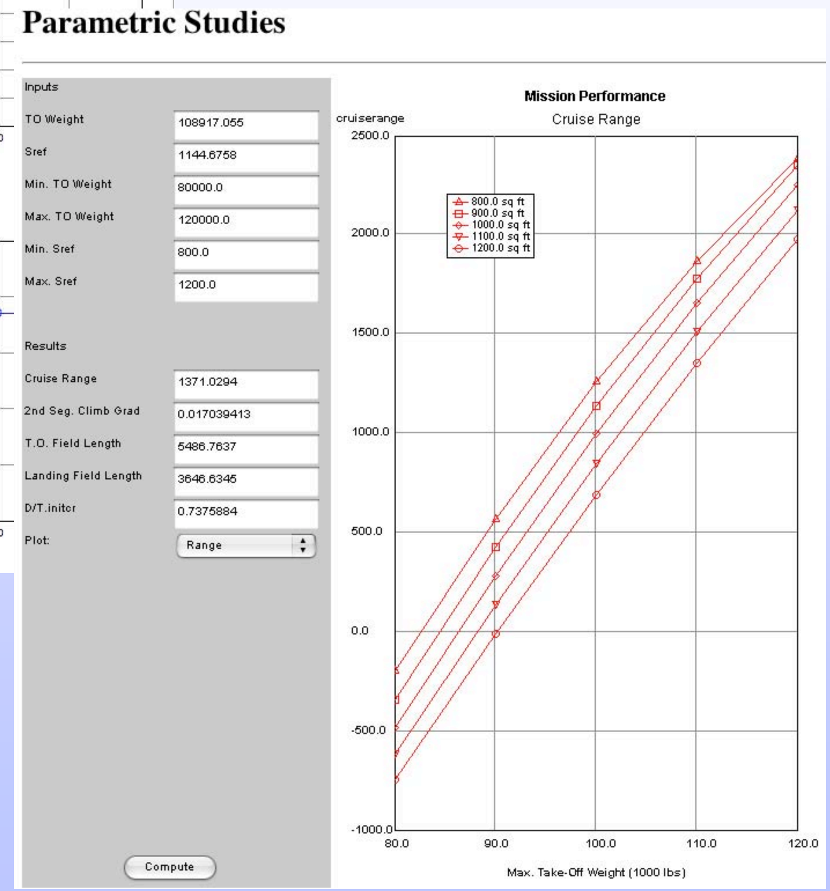
Command-Line Interface



Graphical Interface

Design Framework: Optimization



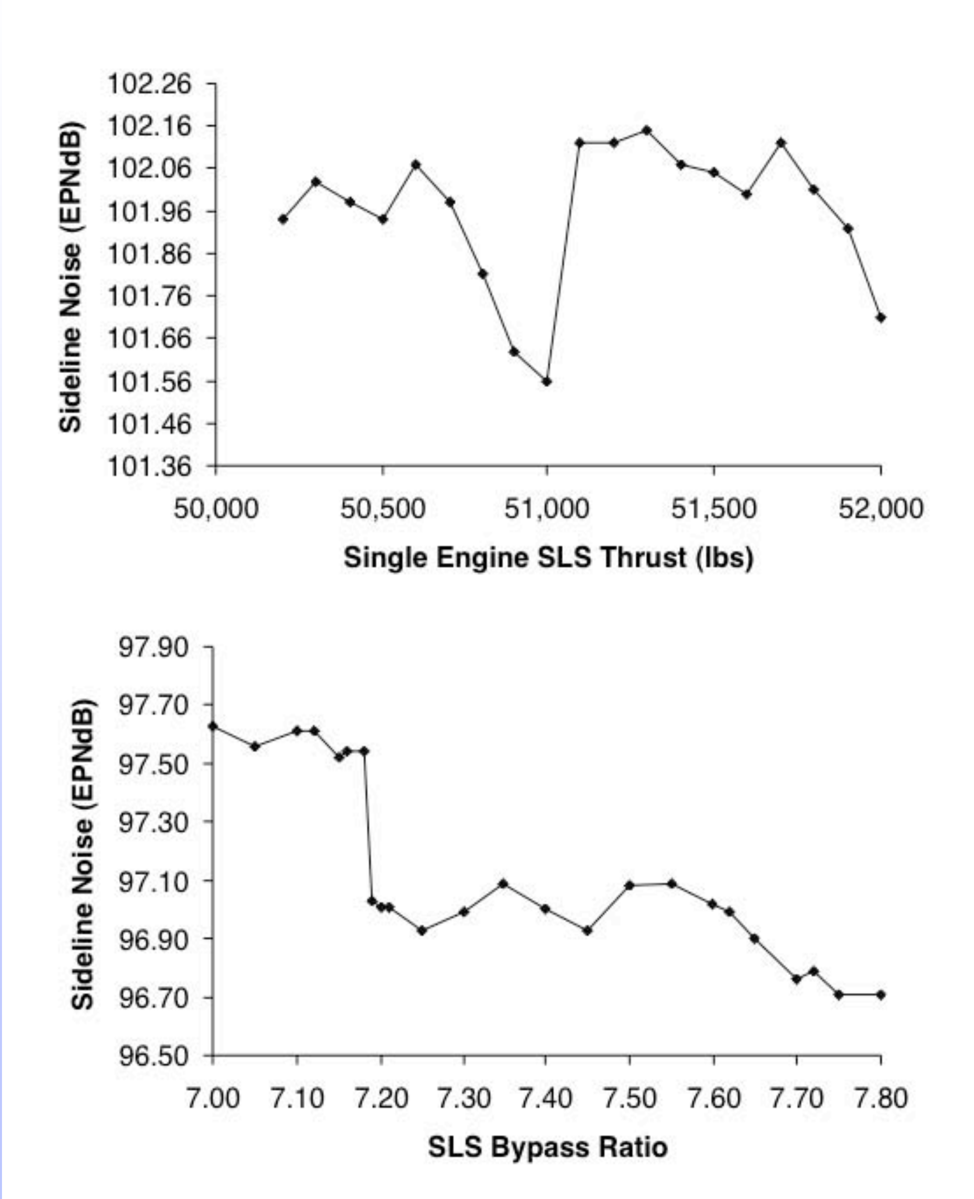


Application and web-based design interfaces

Design Framework: Optimization

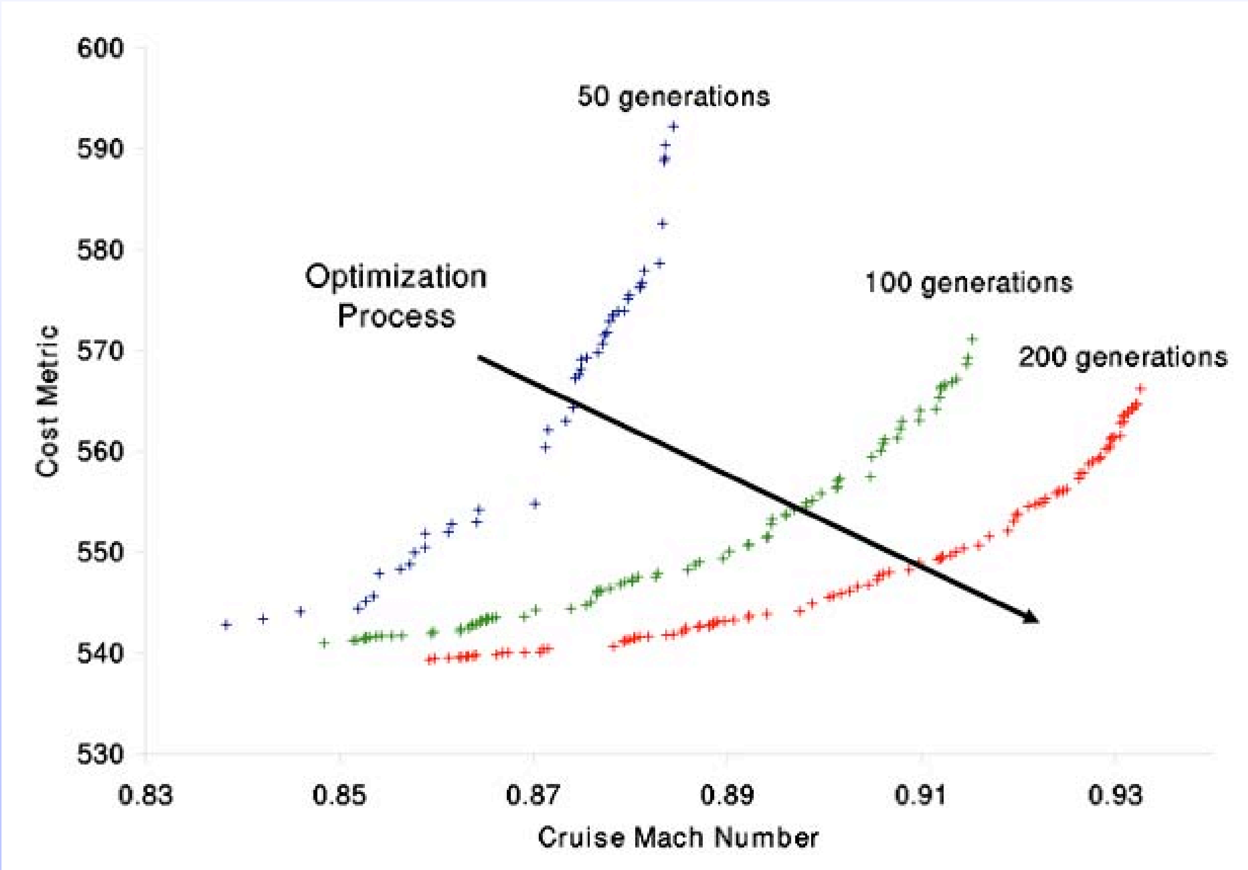
- Gradient-free optimization methods required for use with legacy codes

- Evolutionary methods (single and multi-objective) available in framework



Design Framework: Optimization

- Multiobjective GA directly provides trade-off information with Pareto-based selection



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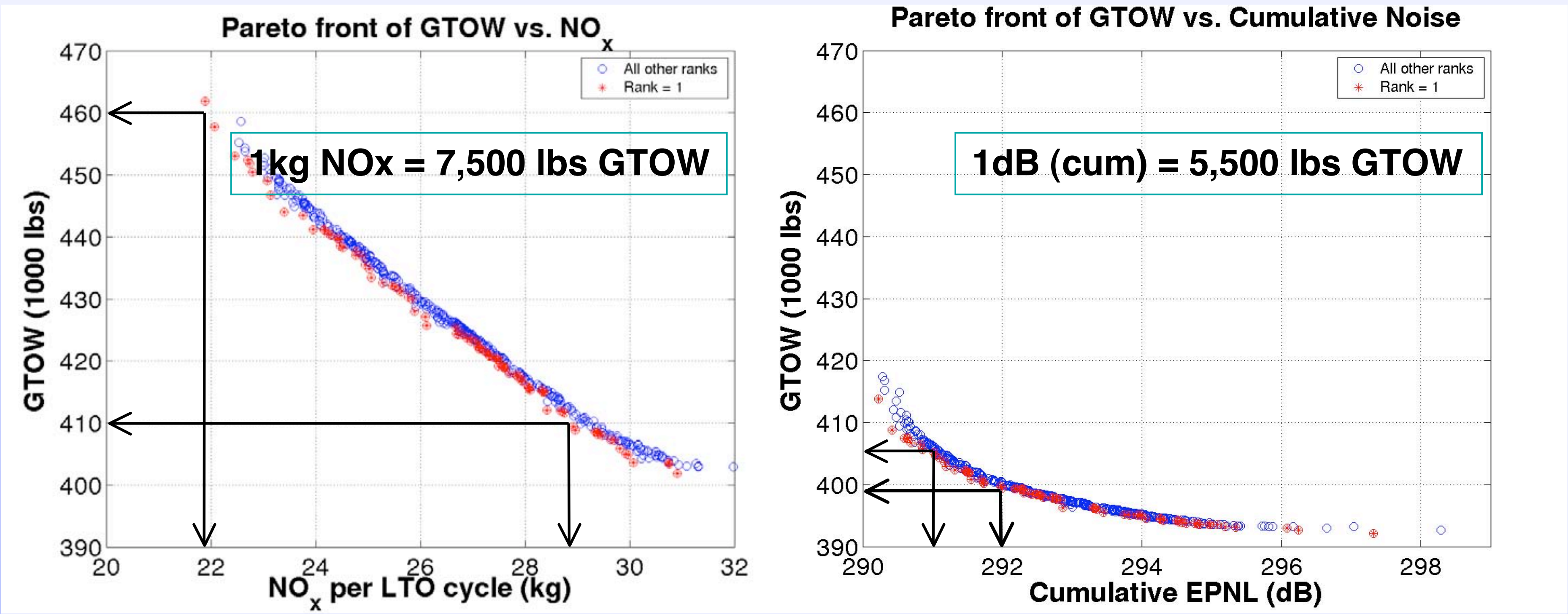
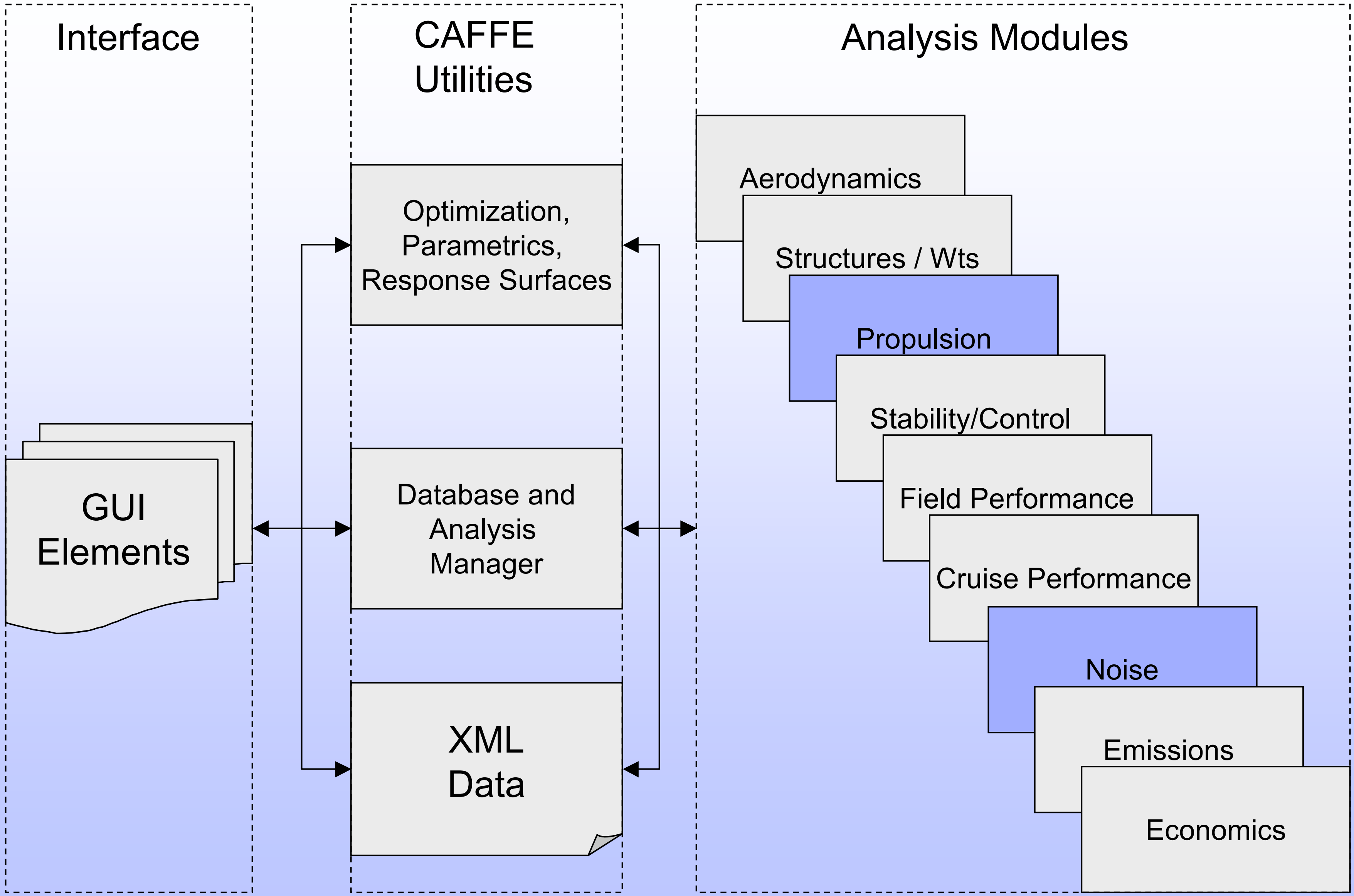


Design Framework: Analyses



Design Framework: Analyses

NASA Engine Performance Program (NEPP):

- 1-D steady state thermodynamics code developed at NASA Glenn
- Allows on-design and off-design scenarios

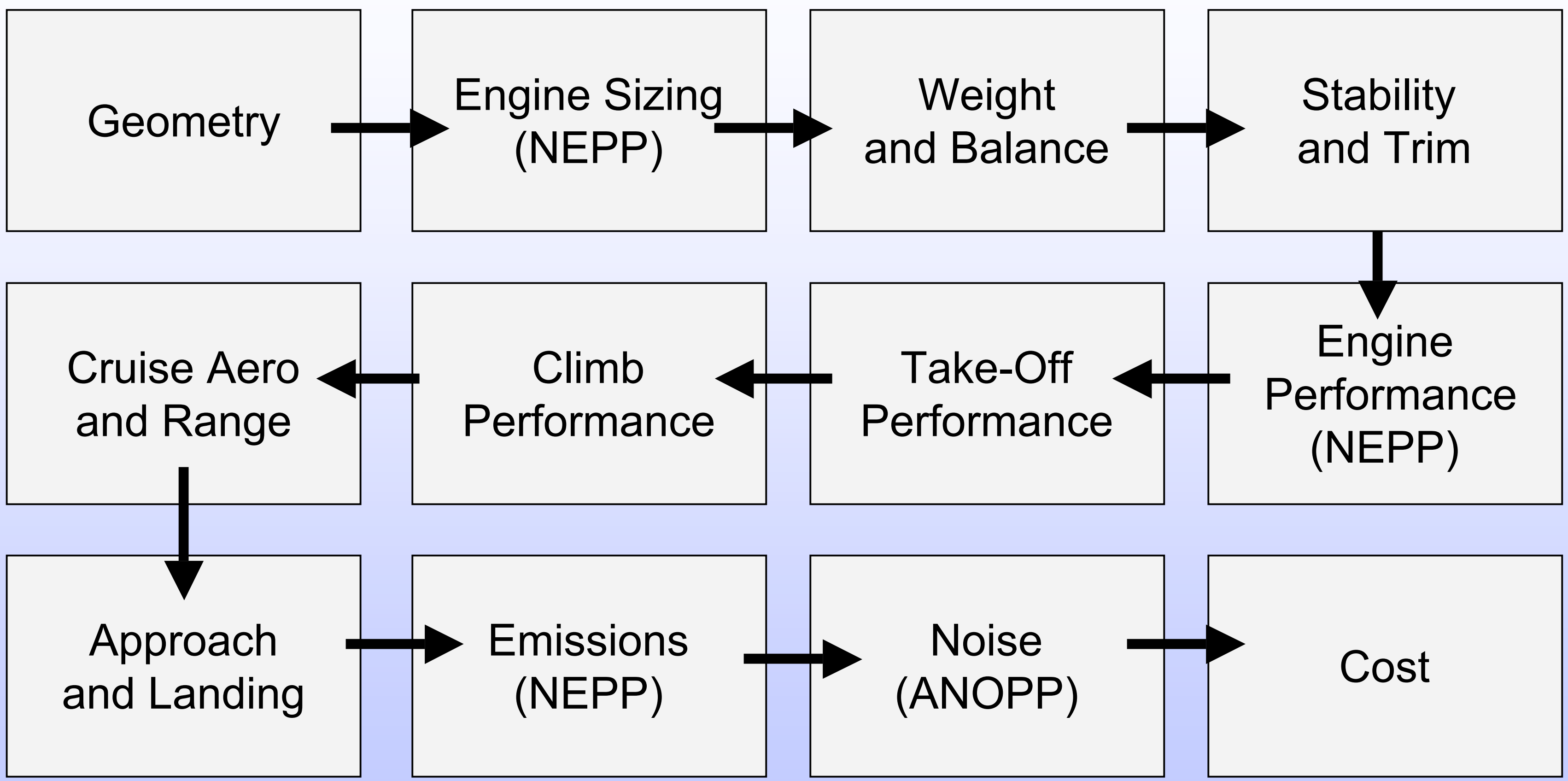
Aircraft Noise Prediction Program (ANOPP):

- A semi-empirical code developed by NASA Langley
- Uses latest publicly available noise prediction schemes
- Models both propulsion and airframe noise sources

Integration with PASS and CAFFE:

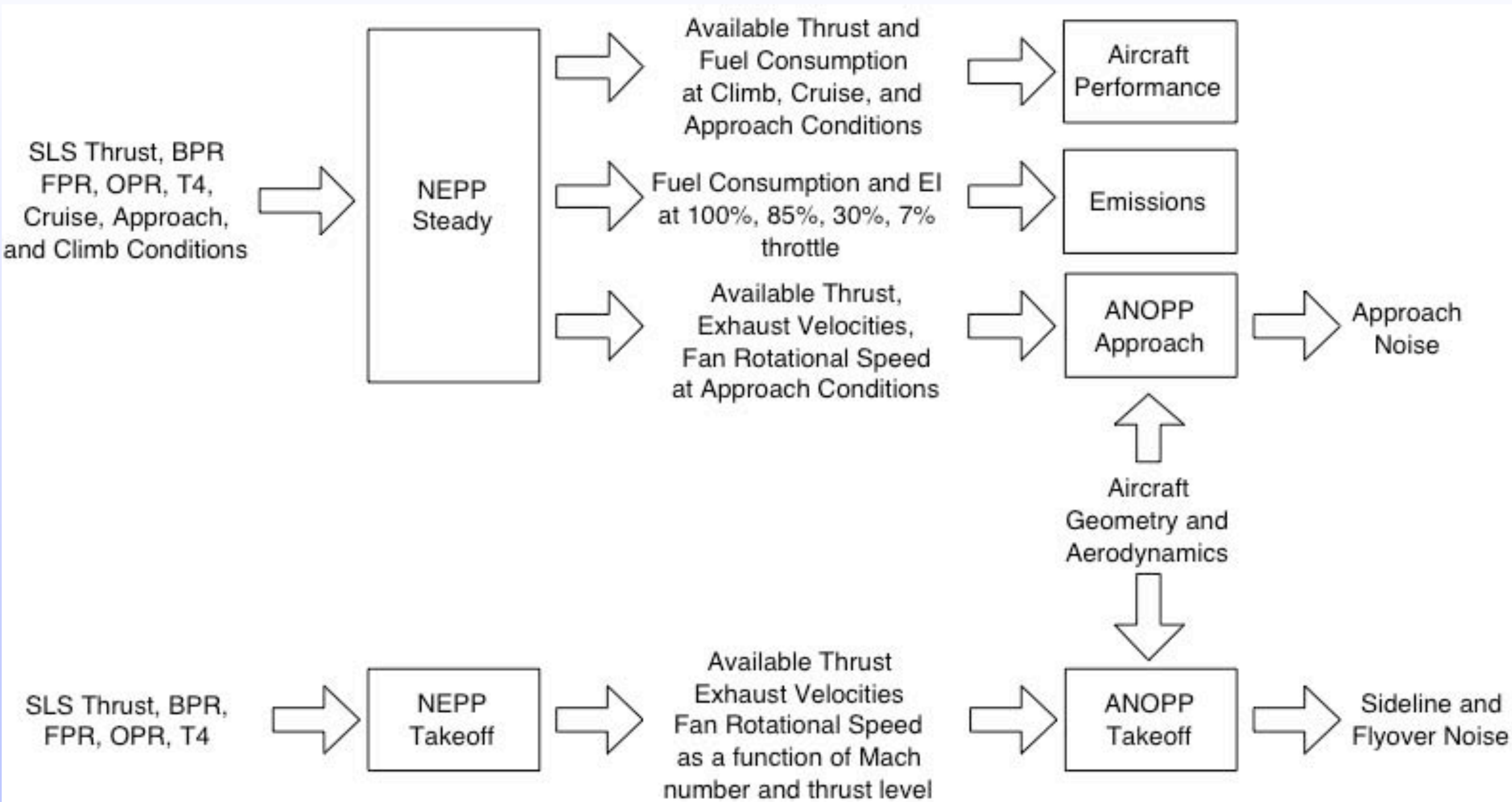
- Completed without source modification
- Run on compatible hardware

Design Framework: Analyses



Design Framework: Analyses

- Integration framework features necessary to integrate many complex codes



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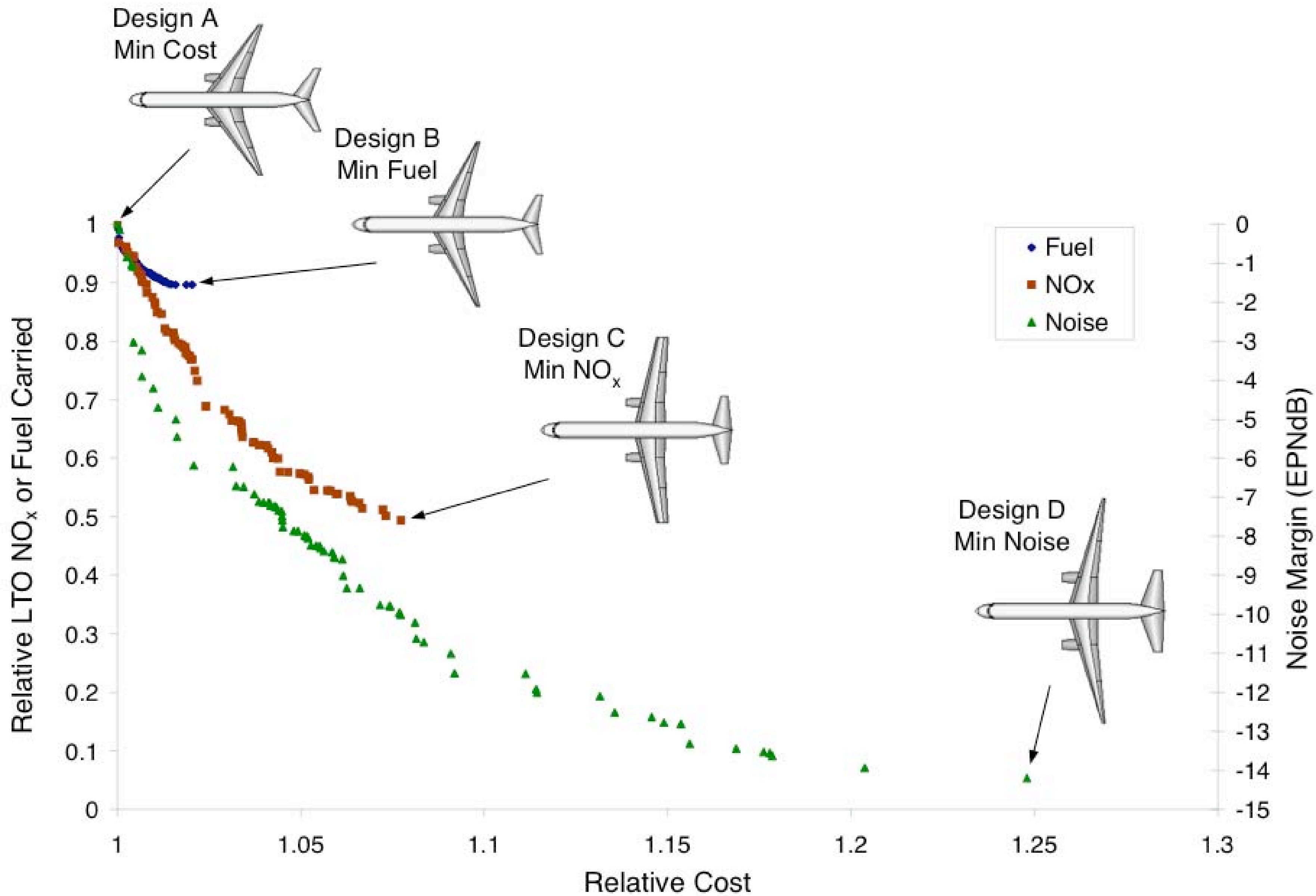
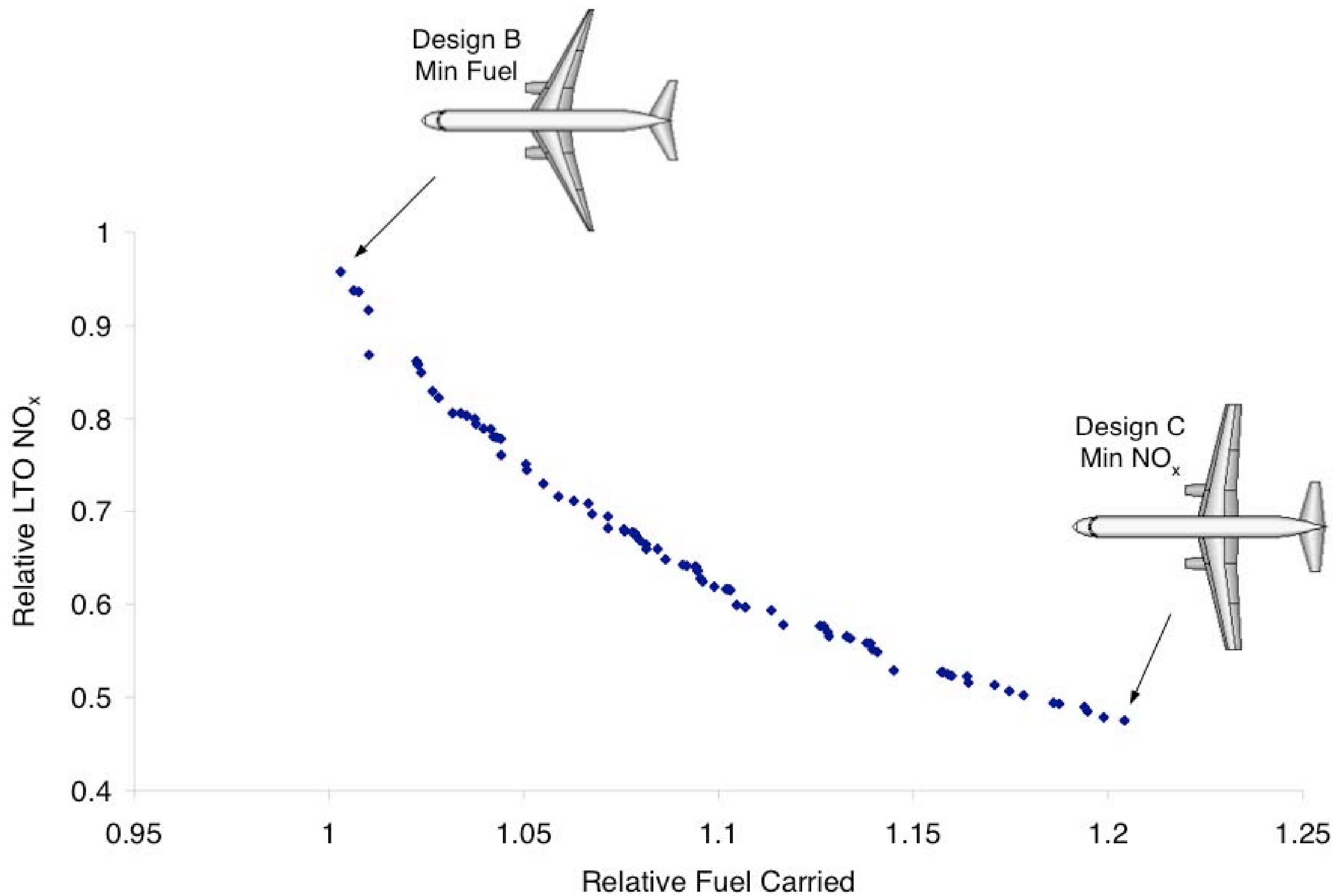
Example Results: Optimization Problem

Variable	Units	Min	Max
Maximum Take-Off Weight	lbs	280,000	550,000
Wing Reference Area	ft^2	1,500	4,000
Wing Thickness-over-Chord	%	0.07	0.20
Wing Location along Fuselage	%	0.2	0.6
Wing Aspect Ratio	—	4.0	15.0
Wing Taper Ratio	—	0.1	0.7
Wing Sweep	deg	0.0	40.0
Horizontal Tail Area	ft^2	225	600
Sea-Level Static Thrust	lbs	40,000	100,000
Turbine Inlet Temperature	$^\circ$F	3,000	3,300
Bypass Ratio	—	4.0	15.0
Engine Pressure Ratio	—	40.0	60.0
Initial Cruise Altitude	ft	20,000	40,000
Final Cruise Altitude	ft	20,000	50,000
Cruise Mach Number	—	0.65	0.95

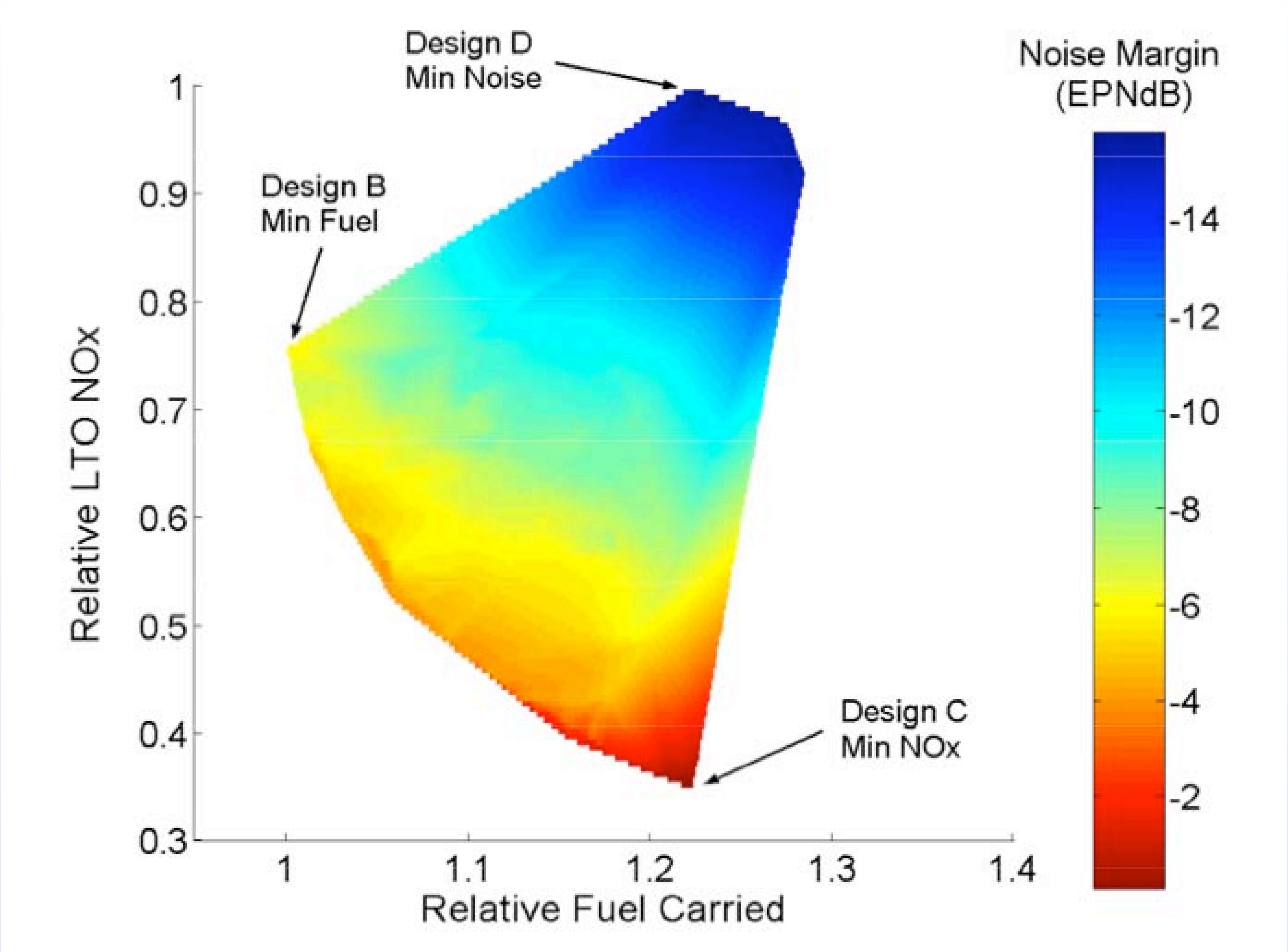
Example Results: Cost Trades



Example Results: Emissions Trades

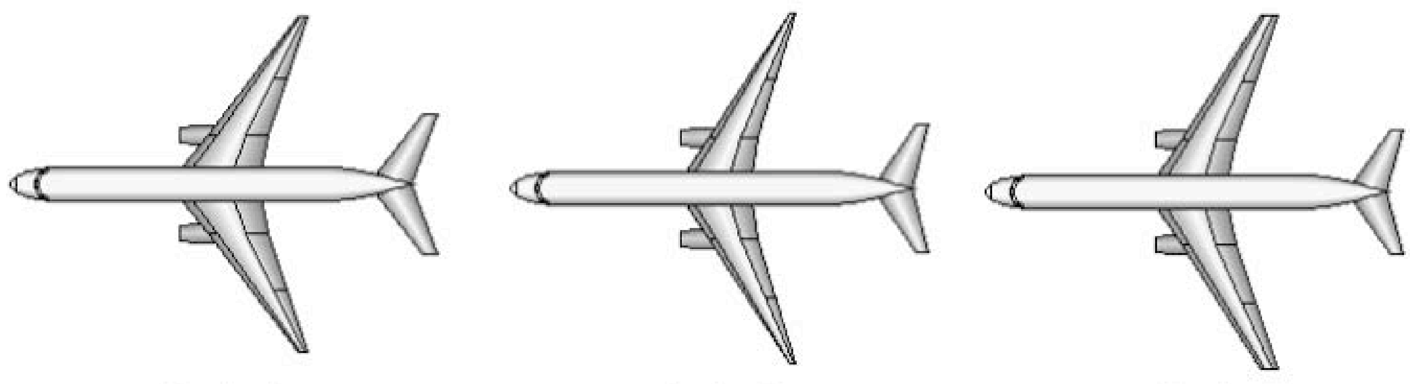


Example Results: Emissions & Noise



Example Results: Cruise Altitude Study

Restrict operating altitude to reduce contrail formation, effect of emissions on radiative forcing.



Altitude	32,957	28,000	24,000
Mach	.844	.762	.728
Cost	1.00	1.04	1.07
Fuel	119,018	112,950	127,069

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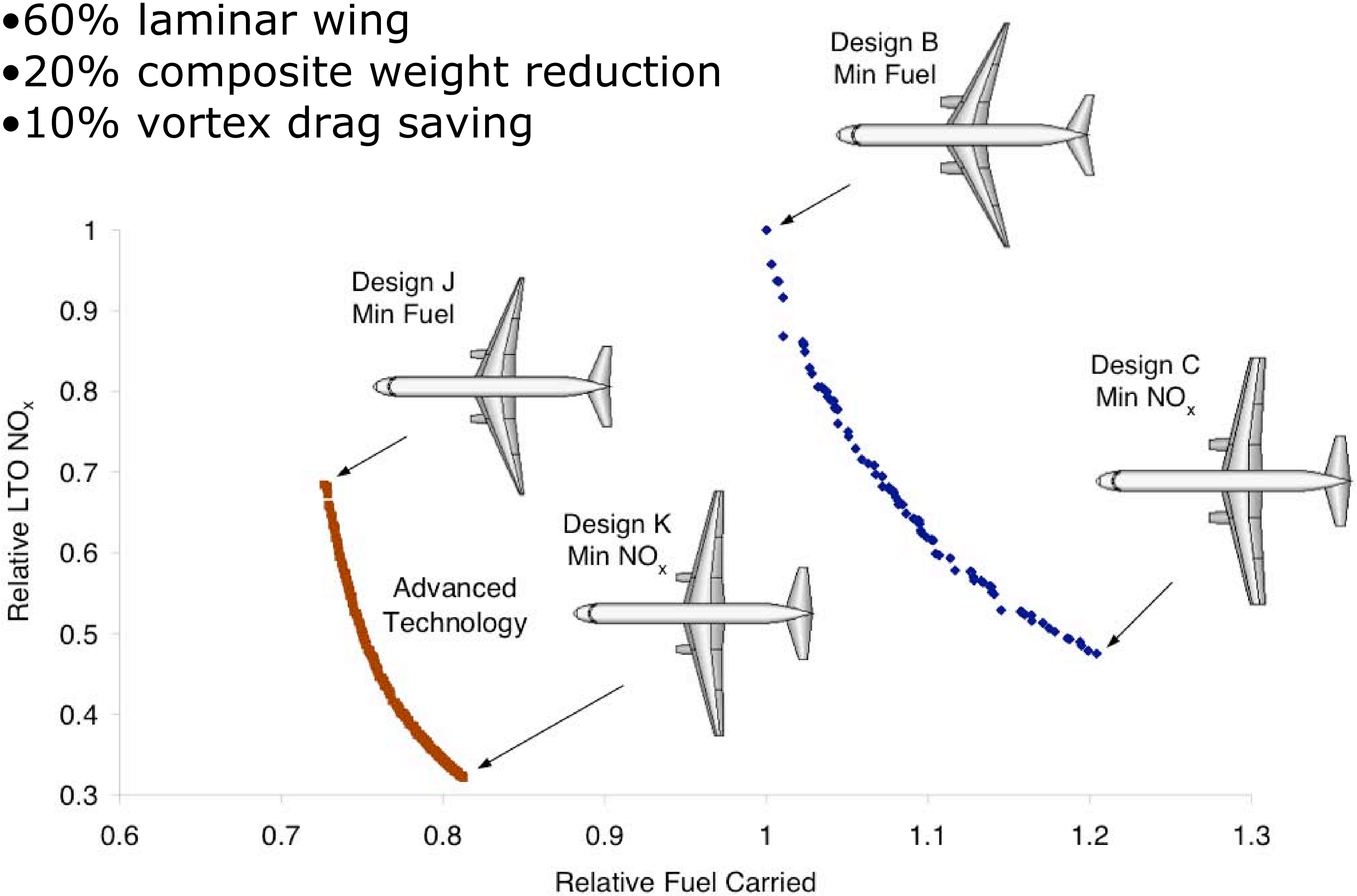
Configuration Concepts

- Fundamental advanced technology features:
  - Laminar flow reduces skin friction drag
  - Wing structural weight reduction
  - Lift-dependent drag reduction
  - Advanced propulsion

- Configuration features to achieve this:
  - High lift, laminar sections, reduced sweep
  - Gust and maneuver load control, composites
  - High AR, constructive interference
  - Very high bypass ratio ADP concepts

Results: Airframe Technology Study

- 60% laminar wing
- 20% composite weight reduction
- 10% vortex drag saving



Configuration Concepts: "Conventional"

Design elements

Very high bypass-ratio engines change take-off/cruise sizing considerations

Optimized for lower M operation

Configuration Concepts: “Conventional”

Design elements

High AR, low sweep wing:

Improved take-off performance or simpler high lift system

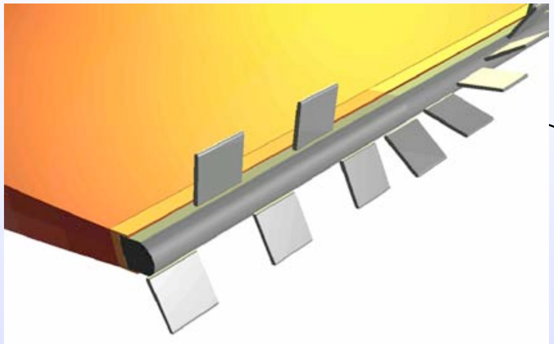
Reduced structural weight

Lower cross-flow for passive laminar flow

Potential for slotted NLF section

Configuration Concepts: “Conventional”

Design elements



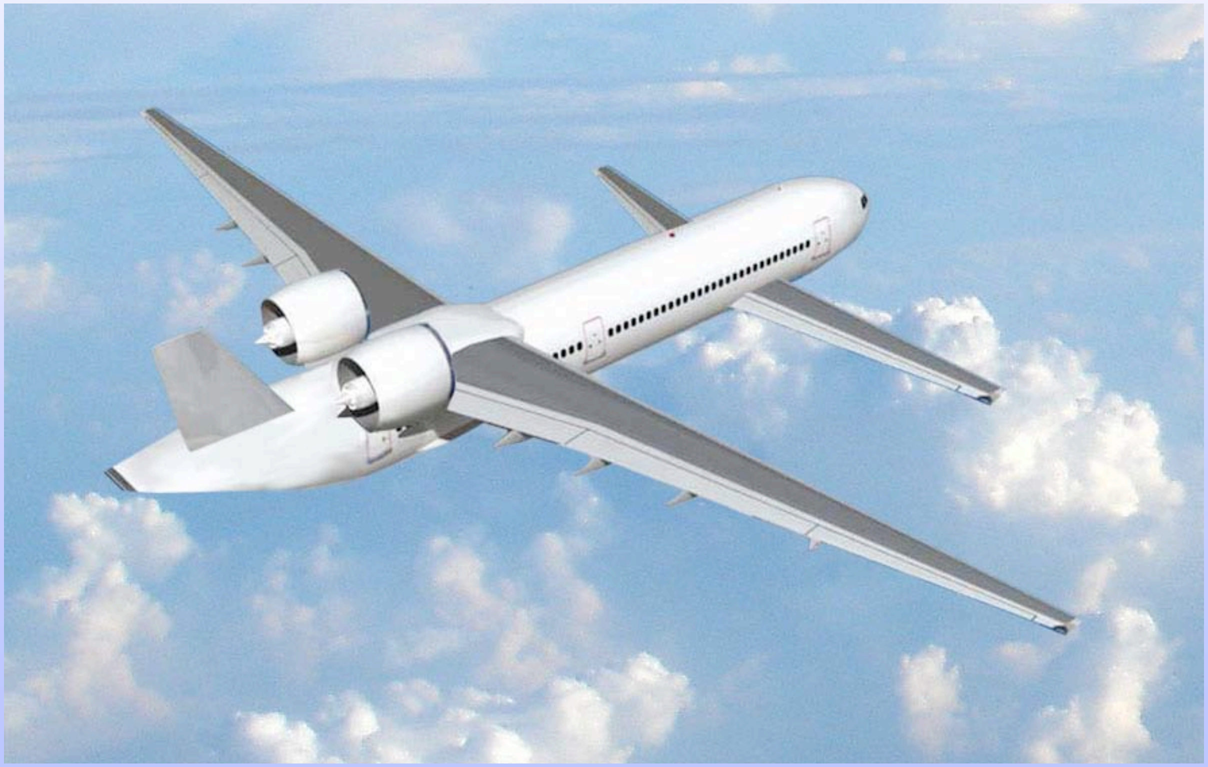
Active distributed control using MiTEs:

Aeroelastic control

Maneuver/gust load control

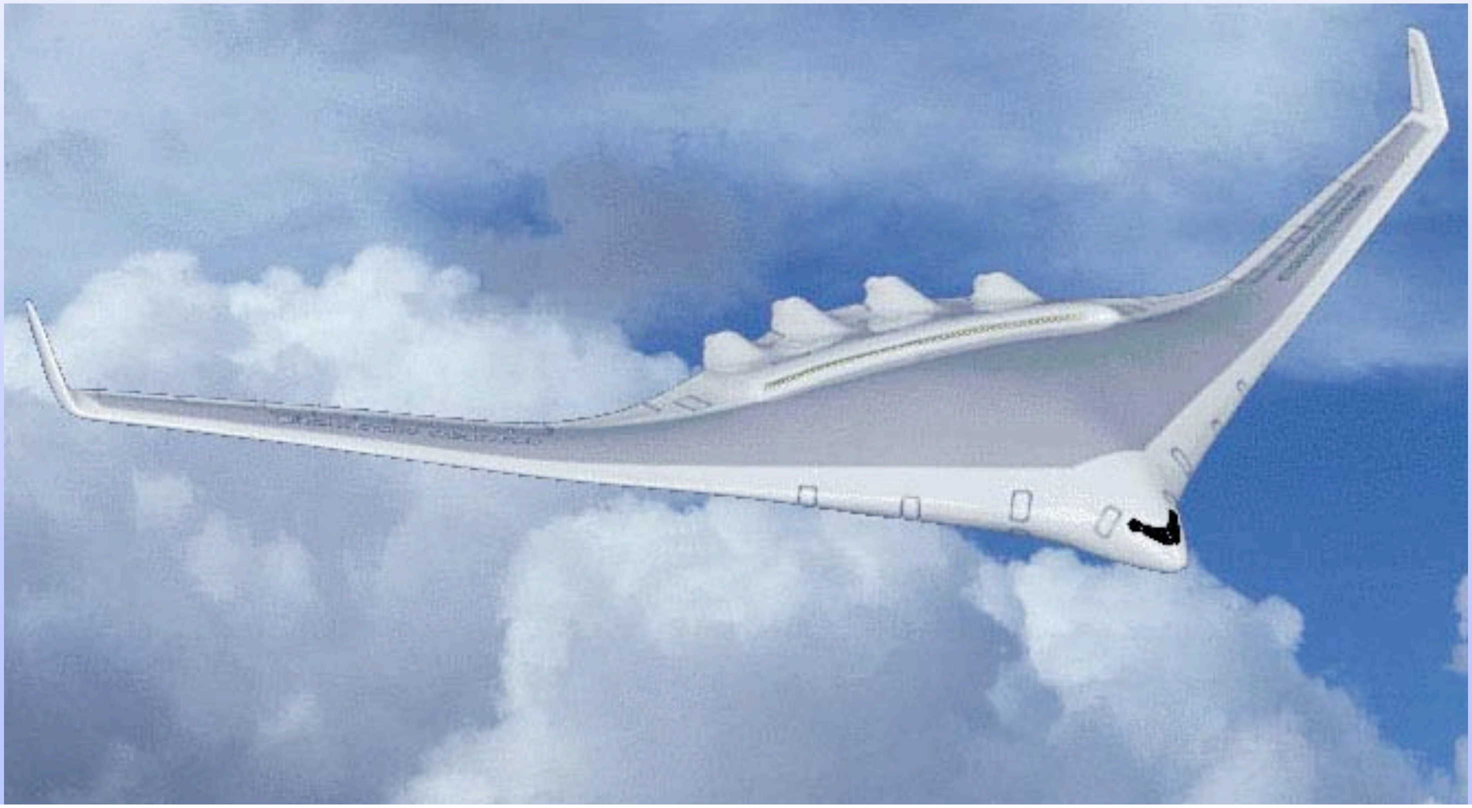
Configuration Concepts: Canard

- Design elements
  - Improved high-lift performance with reduced static margin
  - Forward fan shielding
  - Reduced noise high-lift system



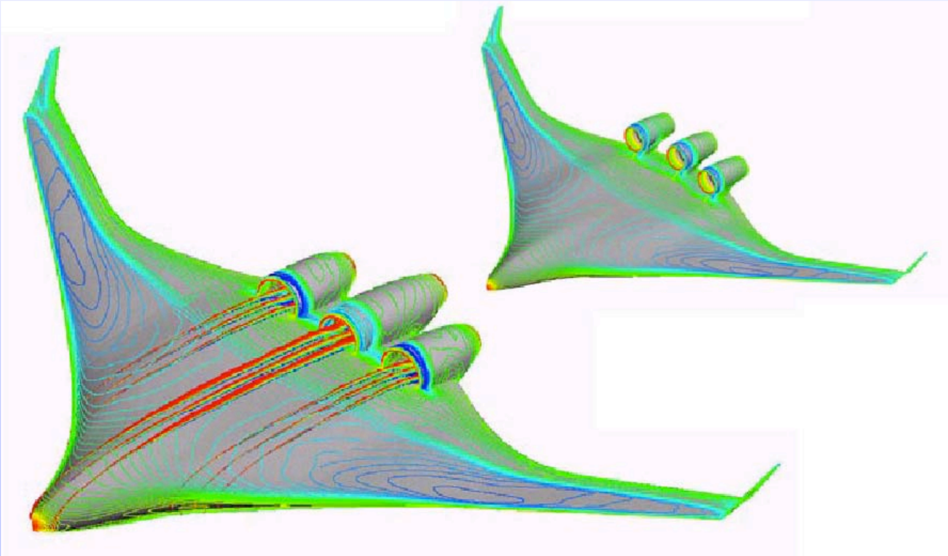
Configuration Concepts: BWB

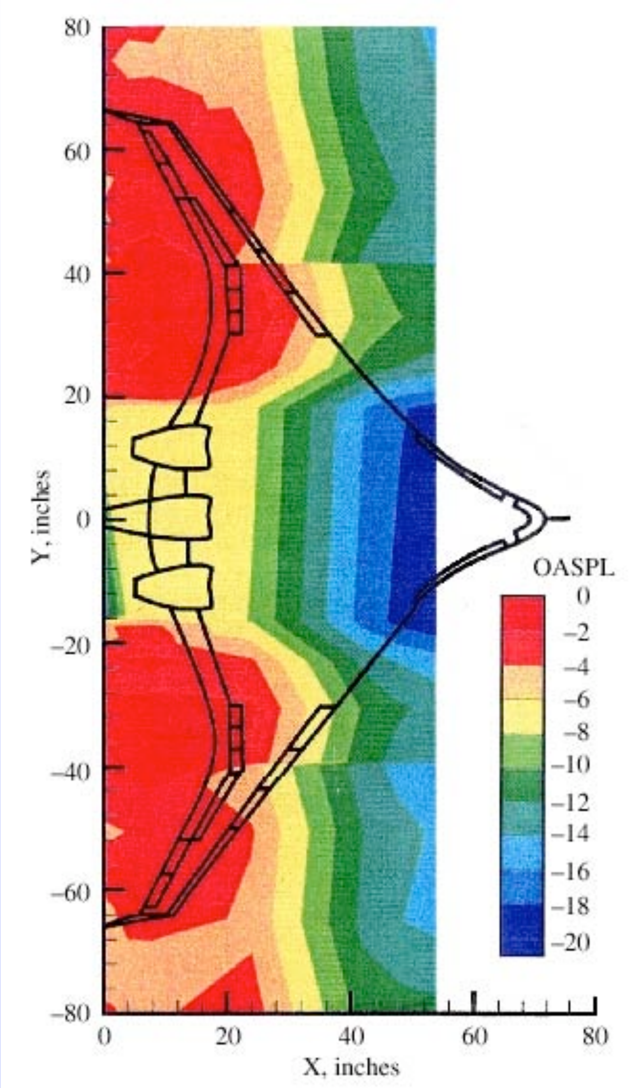
- Design elements
  - Efficient aero/structural design reduces take-off weight
  - Shielded fan, partially buried engines
  - Simple high-lift system



Configuration Concepts: BWB

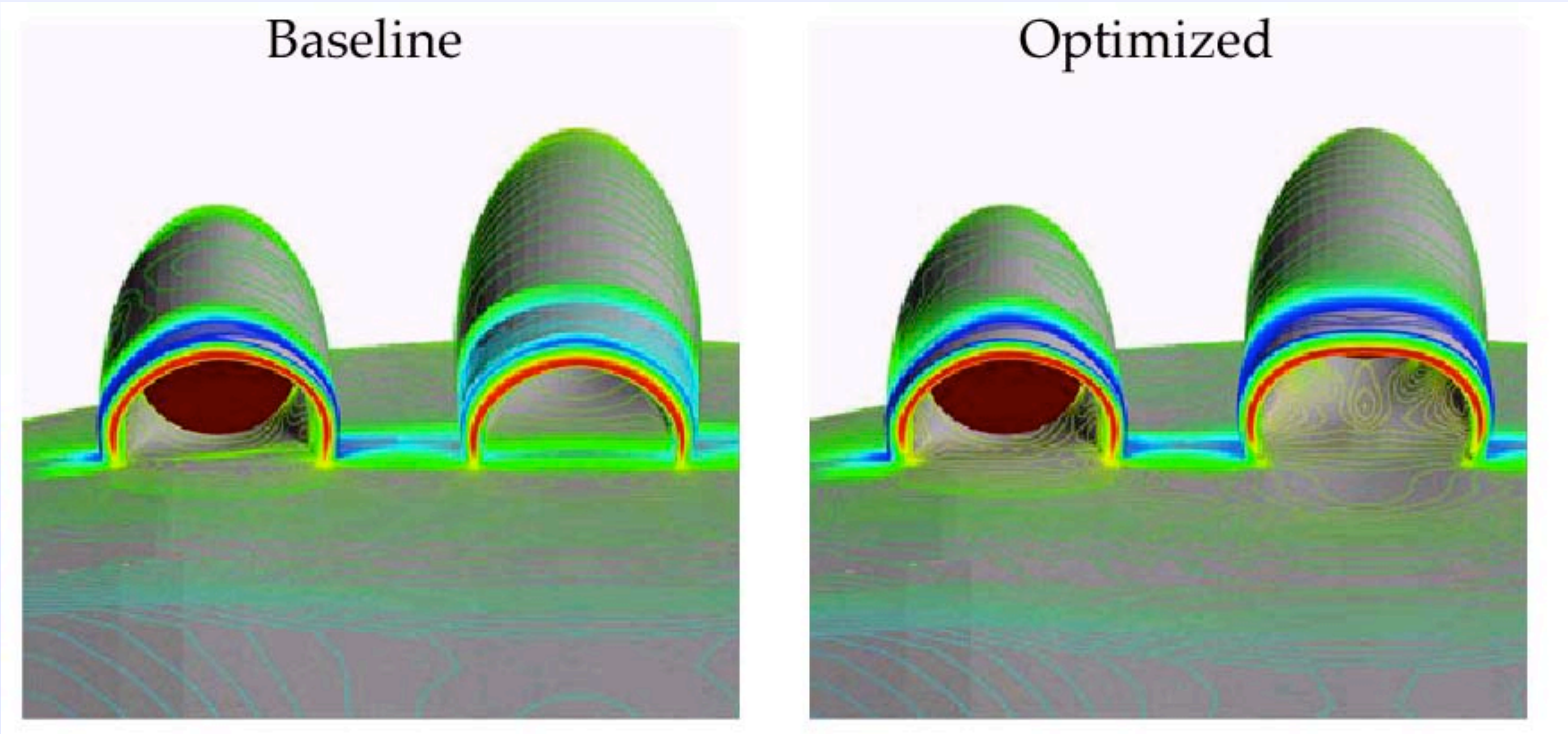
- Engine integration for BWB:
  - Shielding effects
  - Boundary layer ingestion





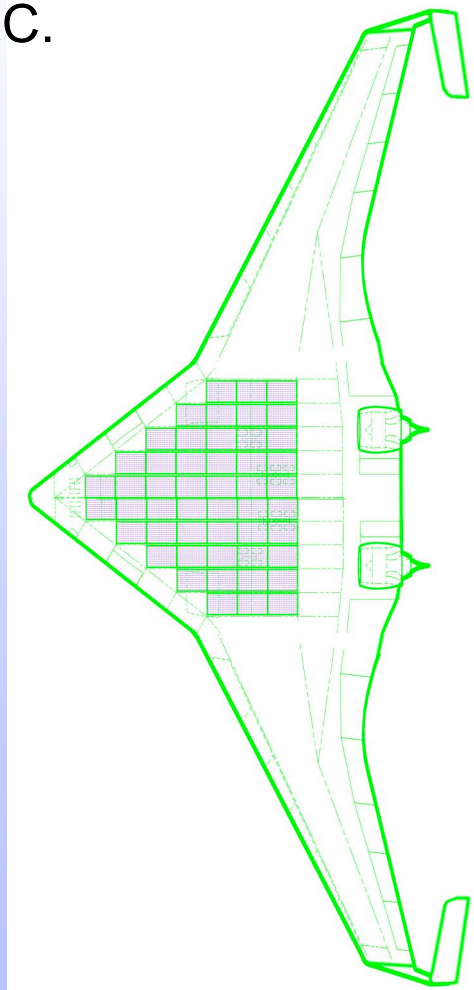
Configuration Concepts: BWB

- Integrated engine, nacelle, airframe design



Configuration Concepts: Laminar BWB

- Based on blended-wing-body concept
  - Reduced sweep to achieve laminar flow
  - C-wing increases effective span, improves S&C.
  - Simple high lift system



Configuration Concepts: Formation Flight

- Potential for large induced drag reduction
  - Direct effect on emissions
  - Indirect (but large) effect on noise via reduced take-off weight

Configuration Concepts: Small Supersonics

- Mach 1.4 - 1.6
- Natural laminar flow
- Good field performance with low sweep, low take-off weight
- Existing engines
- Shielded fans

Conclusions and Future Work

- Multi-objective optimization enables cost-environment trades in aircraft conceptual design
- Large potential savings possible with designs optimized for low noise, emissions
- Continuing studies include:
  - System-of-systems fleet design
  - Additional configurations and new technologies

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