Multidisciplinary Aero/Struc Shape Optimization Using Deformation (MASSOUD)

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MultiDisciplinary Optimization Branch (MDOB)

Slides are available from MDOB WWW Site
http://fmad−www.larc.nasa.gov/mdob/MDOB
Or use Lantern, search with "MDOB" keyword

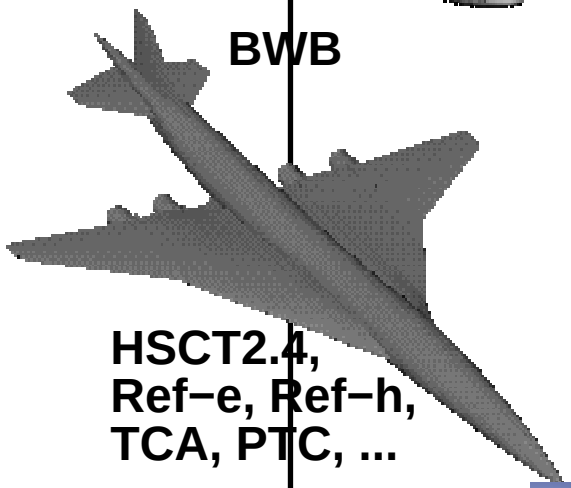
Agate

F16

Boxwing

HL−20

BWB



HSCT2.4,
Ref−e, Ref−h,
TCA, PTC, ...

DC−XA

Hyper−X

X33

X34

Commercial RBCC

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Background

Future advanced geometry design tools must:

- **analyze the whole problem, not just one discipline**
- **must parameterize all models consistently**
- **be high−fidelity (detailed grids)**
- **be automated (affordable design cycle time)**
  (grid generation is still manual and labor intensive for most disciplines)
- **provide accurate sensitivity data (gradient based optimization)**

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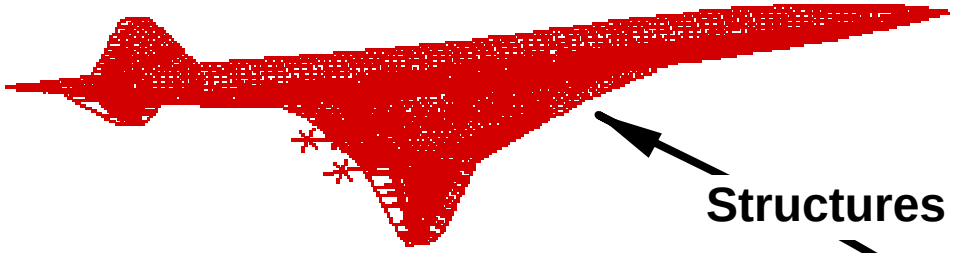
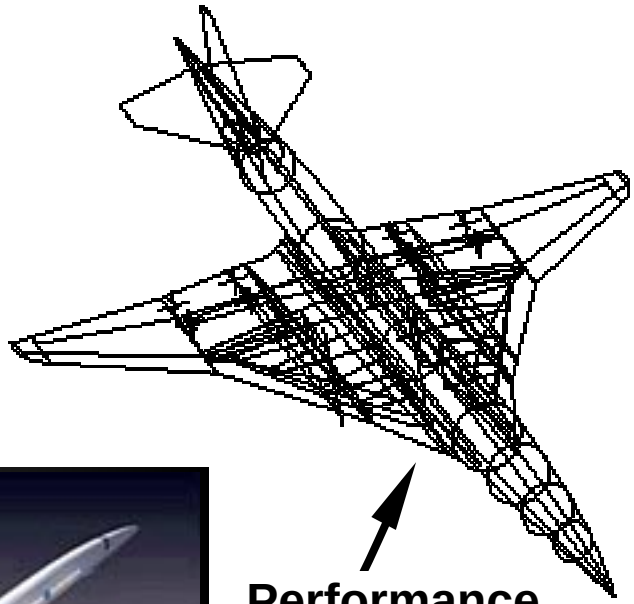
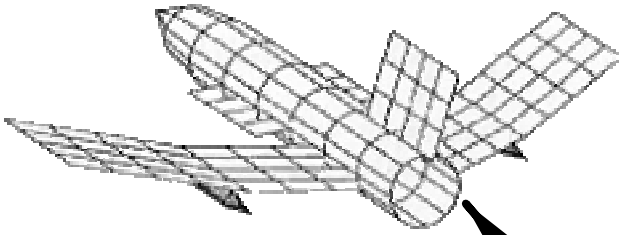
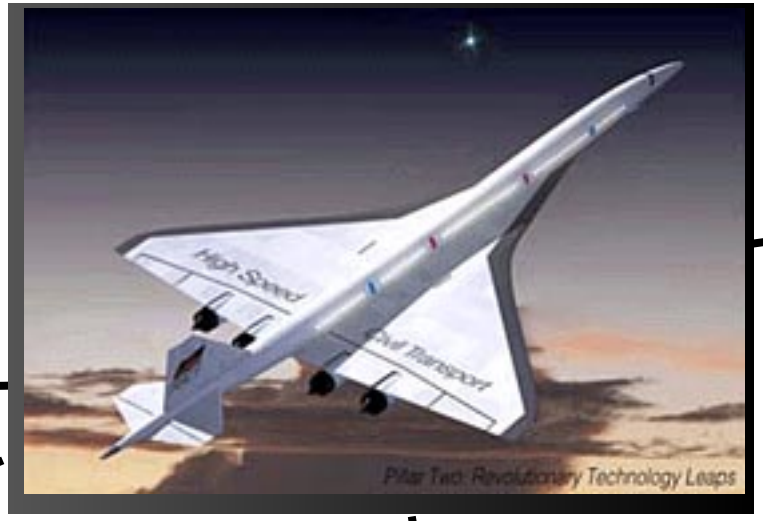


Structures



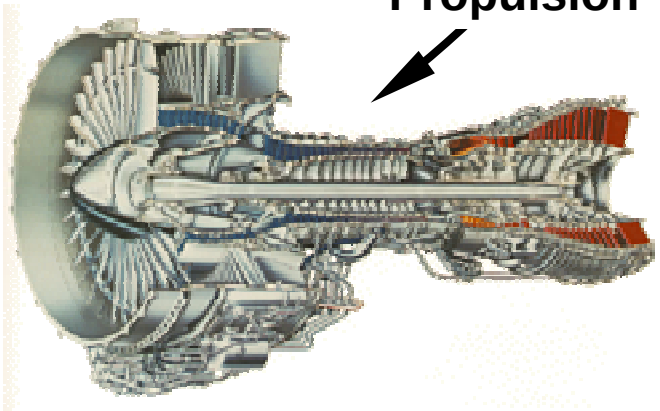


Flutter

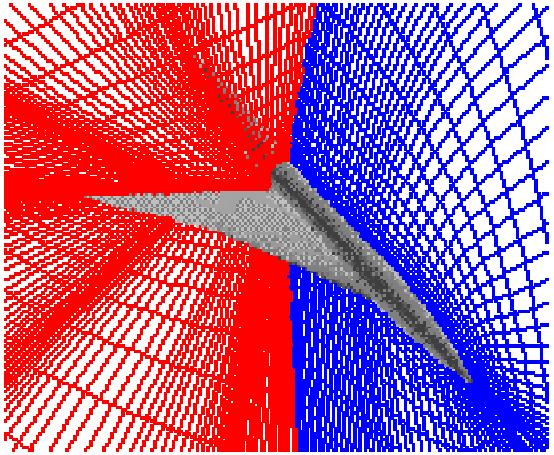


Performance

Propulsion



Aerodynamics



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Geometry and Grid Sensitivity

Gradient based optimization requires sensitivity data. $\dfrac{\delta \text{Response}}{\delta \text{Design Variable}}$

e. g., $\dfrac{\delta \text{Stress}}{\delta t}$, $\dfrac{\delta Cd}{\delta t}$

$$\frac{\delta C_d}{\delta t} = \underbrace{\frac{\delta C_d}{\delta Grid_V}}_{\text{CFD}} \times \underbrace{\frac{\delta Grid_V}{\delta Grid_S}}_{\substack{\text{Volume}\\ \text{Grid}\\ \text{Generation}}} \times \underbrace{\frac{\delta Grid_S}{\delta Geometry}}_{\substack{\text{Surface}\\ \text{Grid}\\ \text{Generation}}} \times \underbrace{\frac{\delta Geometry}{\delta t}}_{\substack{\text{Geometry}\\ \text{Modeler}}}$$

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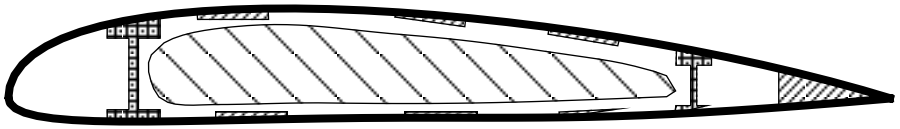
Approach

- **Parameterize the discipline grids**
  (Avoids manual regeneration of grids)



Components: Aero (skin), Structures (skin, spars, ..), Weight(fuel tank), Control(.....)

- **Parameterize the changes in shape, not the shape itself**
  (Provides a compact set of design variables)

$$G(V) = G_{initial} + \Delta G(V)$$

- **Use soft object animation for deforming grids**
  Computer−Animated Features: Toy Story, Bug's Life
  (Allows fast grid regeneration)
  - **Nonlinear global deformation (Twist and Dihedral)**
  - **Deformation of parametric NURBS surfaces (Camber and Thickness)**
  - **Free−form deformation (Planform)**

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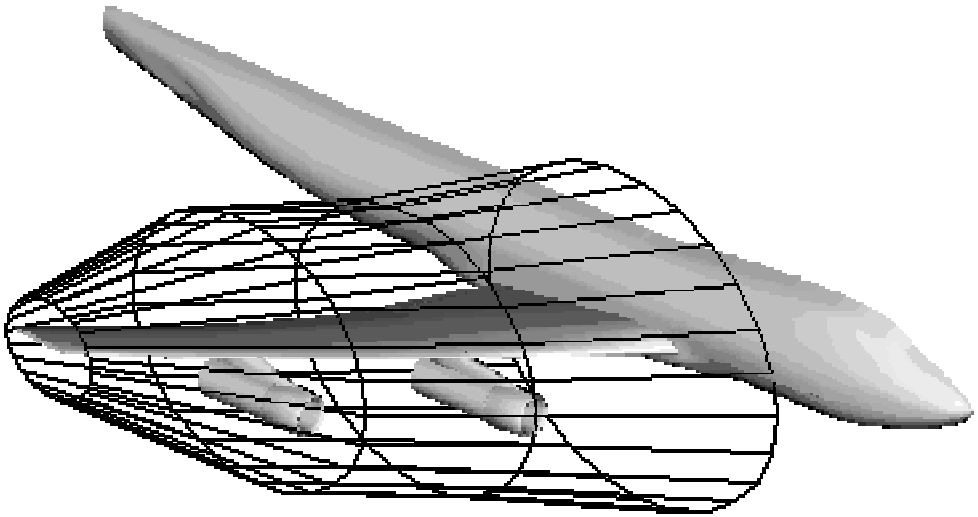
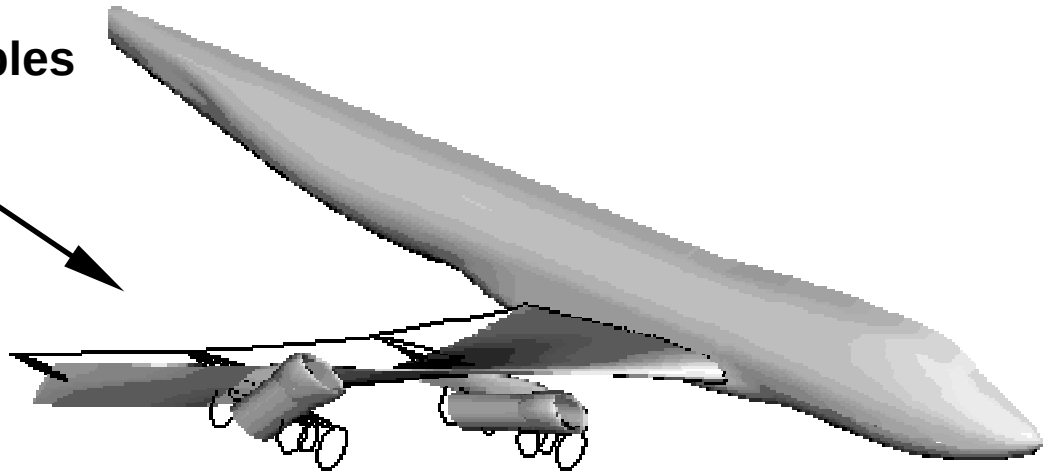
Nonlinear Global Deformation
(Twist and Dihedral)



Twist: 3 Design Variables



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Deformation of Parametric NURBS Surfaces

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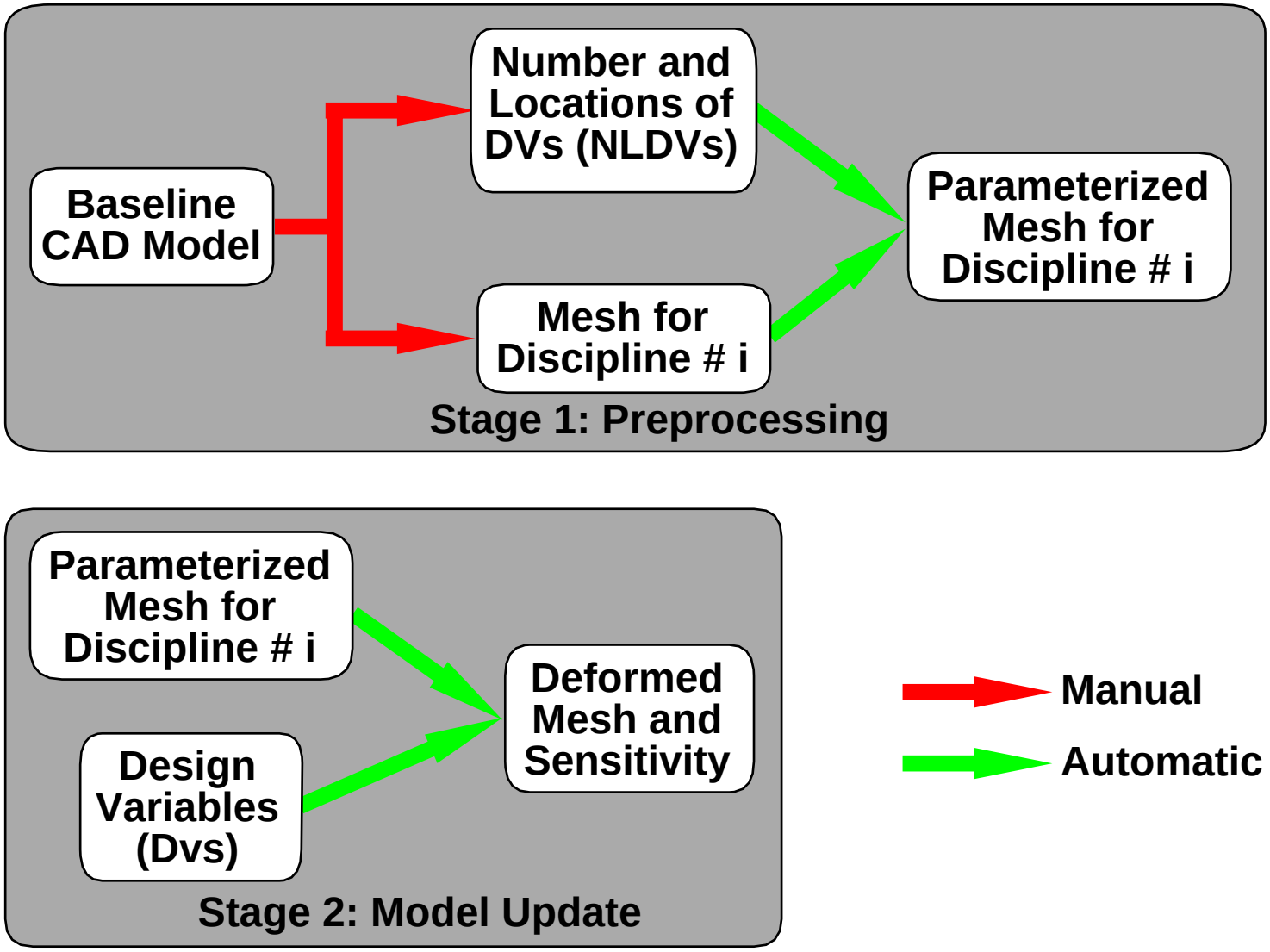
Process



Discipline #i = (CFD, FEM, Noise, CE, Propulsion, Performance, S&C, ...)

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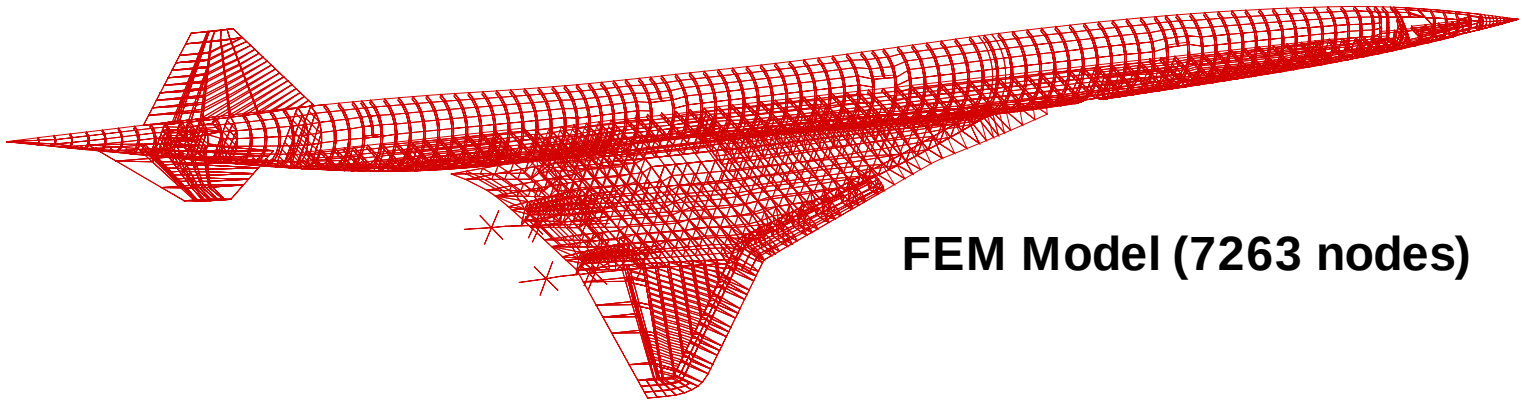
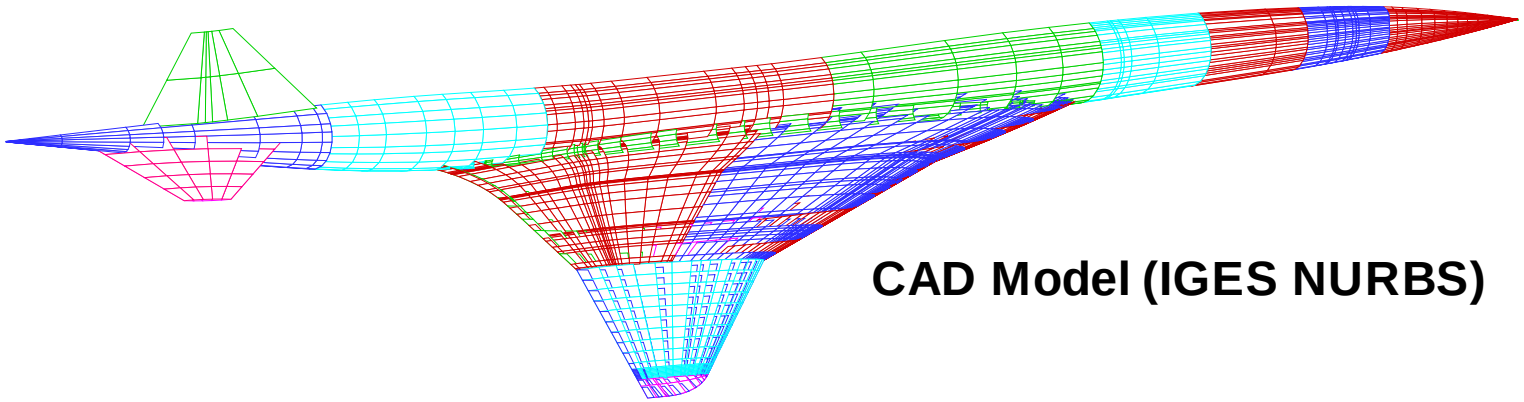
High−Speed Civil Transport



FEM Model (7263 nodes)



CAD Model (IGES NURBS)

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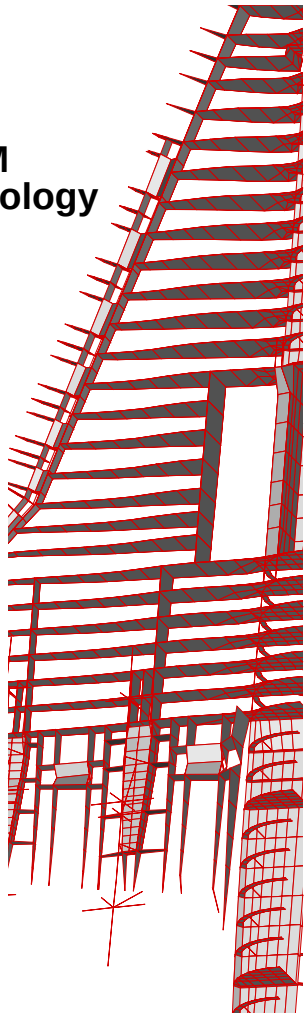
Applications

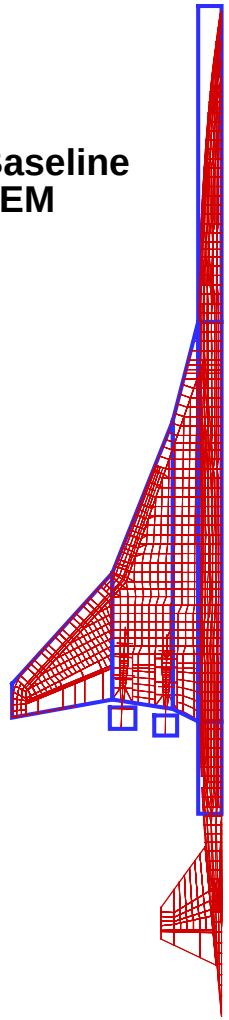
High−Speed Civil Transport
(27 Design Variables: Structured Nonlinear CFD, Linear Aero, Structures, Performance, Scrape, Weight)

HSCT Structures Model

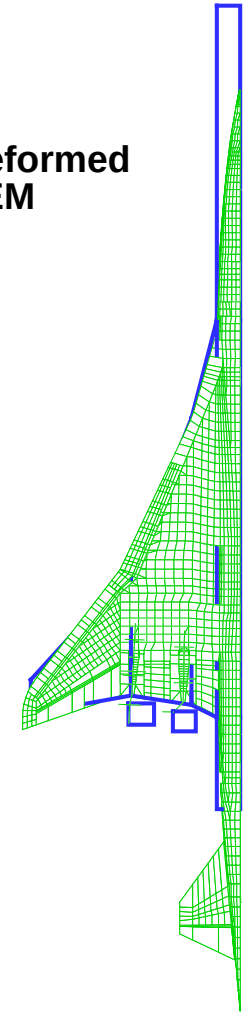
FEM Topology



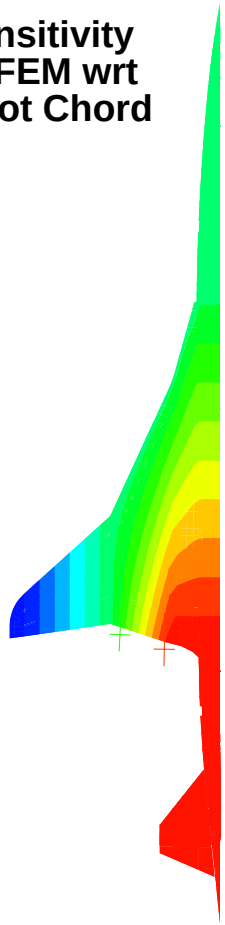
Baseline FEM



Deformed FEM



Sensitivity of FEM wrt Root Chord



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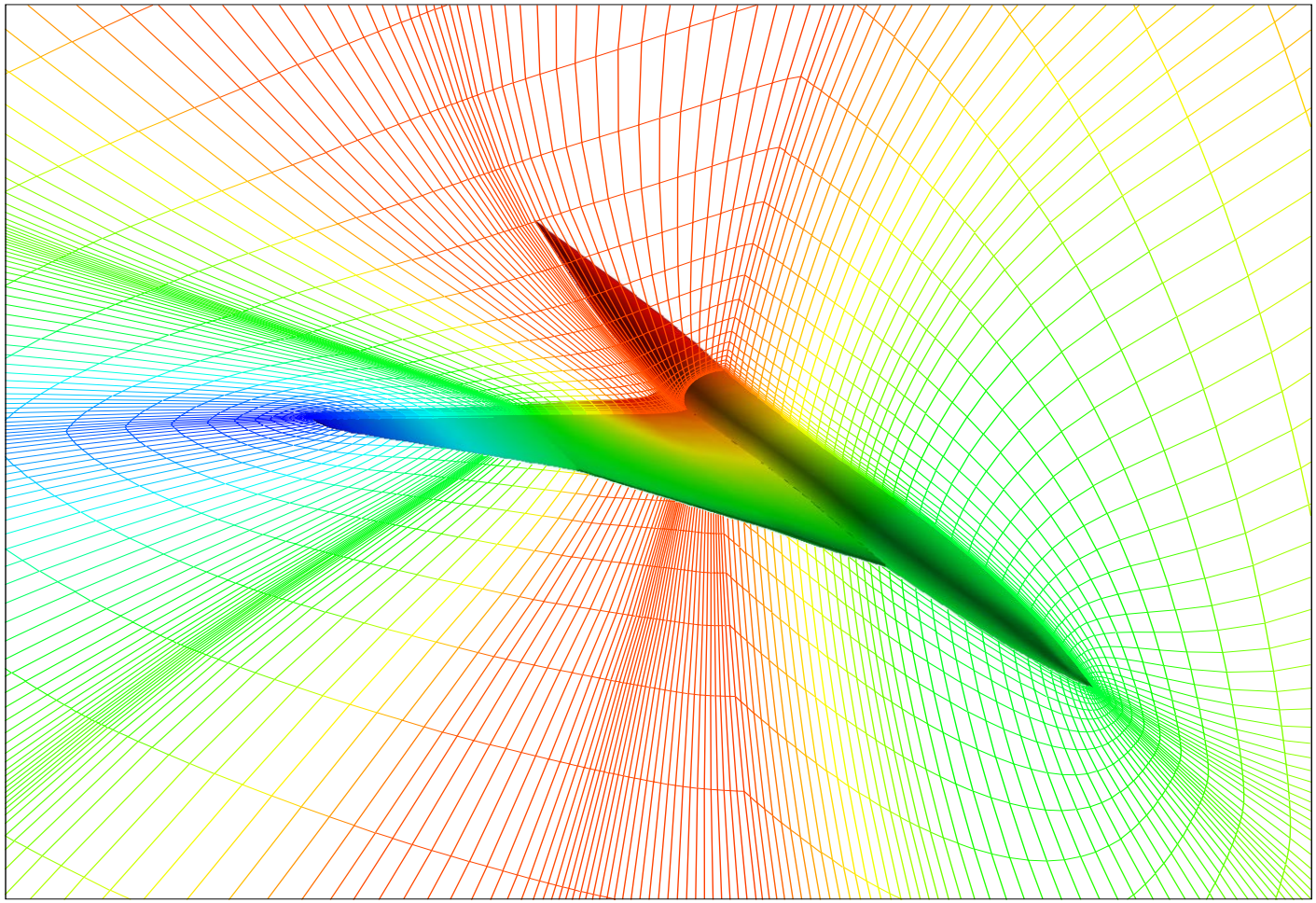
CFD Volume Grid for an HSCT

Sensitivity of CFD volume grid wrt root chord (CSCMDO)



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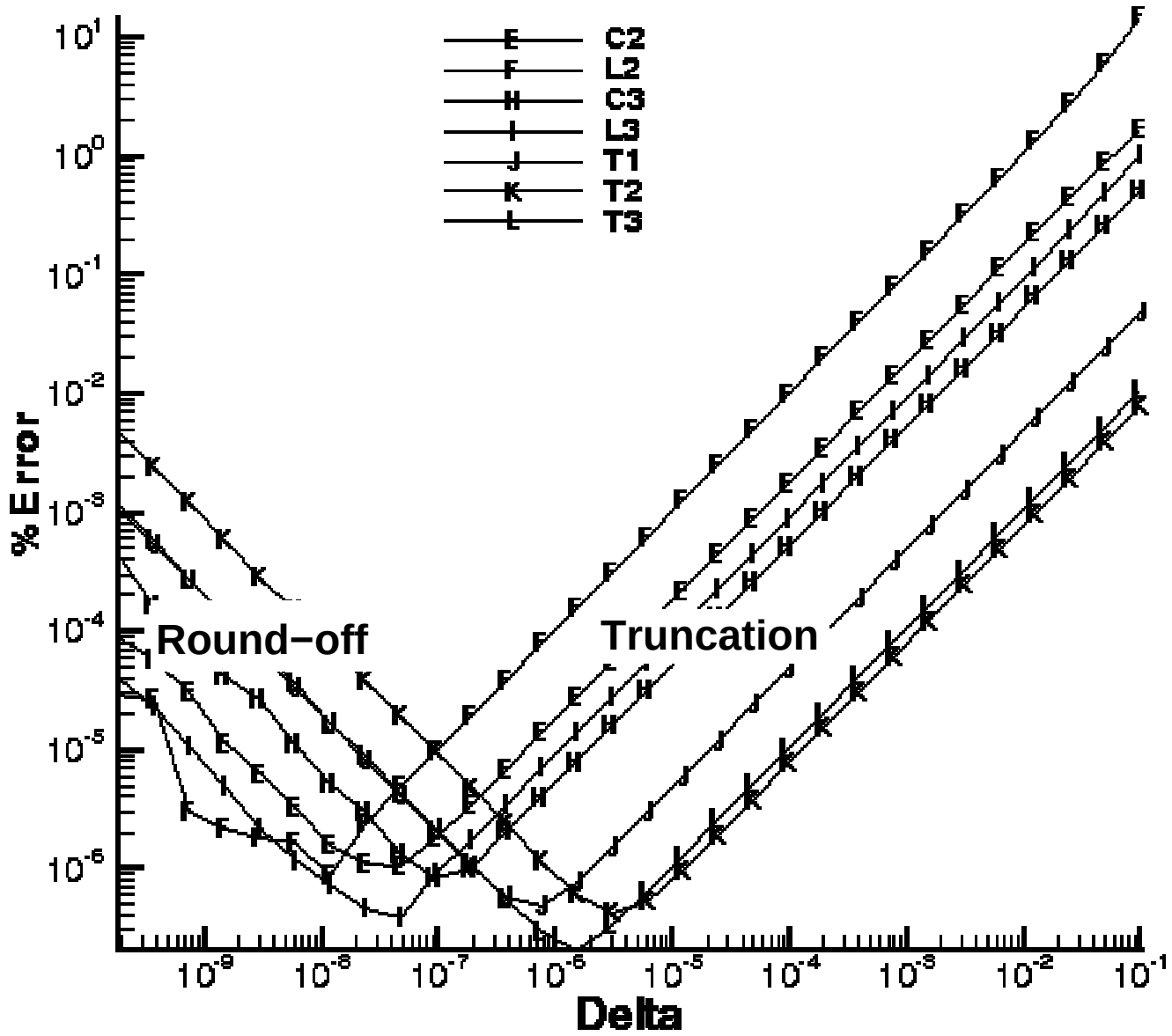
Geometry and Grid Sensitivity Comparison
(Dependence on Finite Difference Step Size)



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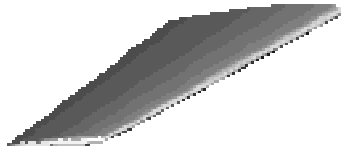
Applications

Configurations			
Researchers	Jamshid Samareh Bob Biedron Kyle Anderson Eric Nielsen (VPI) MDOB, AAMB	Jamshid Samareh	HPCCP Team MDOB, CSB, AAMB
Projects	HPCCP*, ASCOT	FACT*	HPCCP*, HSR, MAD
Applications	Aerodynamics Shape Optimization, one discipline	Aero/Structures Analysis and Shape Optimization, two disciplines	MDA and MDO of an HSCT Model, Future: 800 shape design variables six disciplines
Customers & Industry Partners	AAMB	Boeing (Long Beach)	Boeing (Seattle)

*Funding Source

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Possible Future Applications

- Trade studies
  (What−if Alternative Value Engineering (WAVE))
- Include disciplines in other areas
  - Aerothemodynamics
  - Thermal Protection Systems
  - Computational electromagnetics
  - Stability and control
- Sensitivity analysis with a CAD system
- Boeing’s Structural Engineer’s Assistant (SEA) project
- Rapid Prototyping
- Aero/structure interaction

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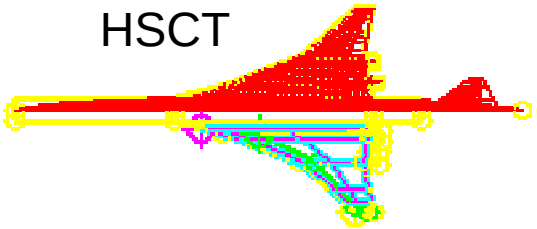
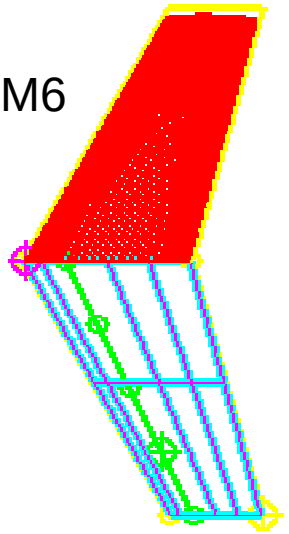
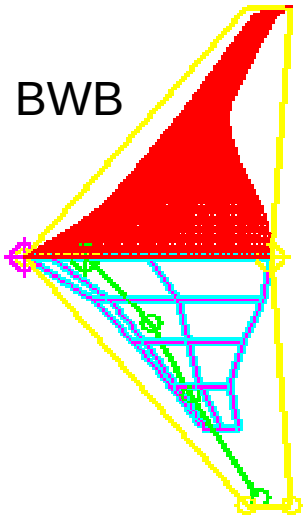
Optimization Applications







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Geometry Demonstrations (half a day)