



SHABP Use at LaRC

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TFAWS

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◆ Focus on use in Vehicle Analysis Branch

- AML environment
- Hyper-X

◆ In-house modified version of code

- NASP boundary layer transition criteria
- Link to GRAM-95 atmosphere
- Link to trajectory file
- Based on Mark IV version



Modeling Environment

- ◆ **SHABP is incorporated into a modeling environment created using AML (Adaptive Modeling Language) provided by Technosoft and developed under an SBIR**
- ◆ **AML provides geometry preprocessing, file setup, and data visualization for SHABP**
- ◆ **AML can provide geometry creation within tool as well as facilitate geometry import**
- ◆ **SHABP is linked with AML, not rewritten**
- ◆ **Other hypersonic airbreathing tools used at NASA LaRC either linked with AML or have native AML modules – allows use of a common model**
- ◆ **Information sharing and concurrent work at AFRL to link both rocket and airbreathing methodologies**



Propulsion Keel-line Development

Cowl - Inlet Nozzle Flap

Parameter	Value	Parameter	Value
Inlet Hinge Radius	NIL	Nozzle Hinge Radius	NIL
Inlet Length	NIL	Combustor Length	NIL
Step Height	0.0	Combustor Angle	0.0
Throat Height	1.6839		
Flap Length	NIL	Flap Angle	0.0
Minimum Thickness	NIL	In. Included Angle	10.0
Flap Length	325.0	Flap Angle	0.0
Minimum Thickness	NIL	In. Included Angle	10.0

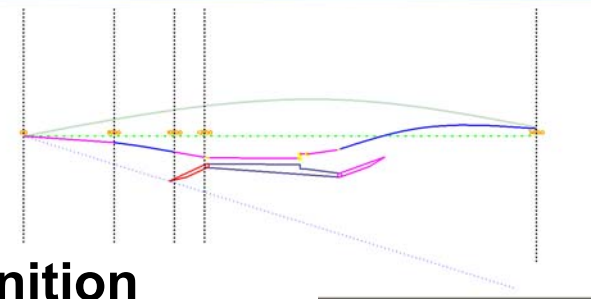
Select file name: C:\ProgramData\TechnoSoft\Products\AML\AML4.0\Default\prop.dat

View Area: Para SRGULL results

Item Name	Value
Free Stream Mach Number	2.718287620500
Free Stream Angle Of Attack	0.0%
Free Stream Dynamic Pressure	2763.3
Free Stream Velocity	6464.4
Altitude	10225.0
Free Stream Static Pressure	0.43225
Free Stream Total Temperature	286.89
Free Stream Density	0.2124e-5
Free Stream Area	607.00
Cowl Lip Mach Number	0.7028
Cowl Lip Dynamic Pressure	692.9
Cowl Lip Static Pressure	0.4630
Cowl Lip Total Temperature	367.29
Cowl Lip Velocity	3108.4
Cowl Lip Density	0.0006666
Cowl Lip Specific Heat Ratio	0.3025
Cowl Lip Area	156.53
Cowl Lip Moment About Inlet Edge (Centroid)	0.136068
Cowl Lip Air Flow Rate	14738.0
Cowl Lip Mass Moment About Inlet Edge (Centroid)	1.947080
Cowl Lip Perforated Area	0.066210
Cowl Lip Heat Loss	1.041800
Throat Mach Number	2.3102
Throat Dynamic Pressure	22467.0
Throat Static Pressure	28.766
Throat Static Temperature	2108.0
Throat Velocity	4481.2
Throat Density	0.0029372
Throat Specific Heat Ratio	0.3084
Throat Area	68.77

Body Static Pressure [across all runs]

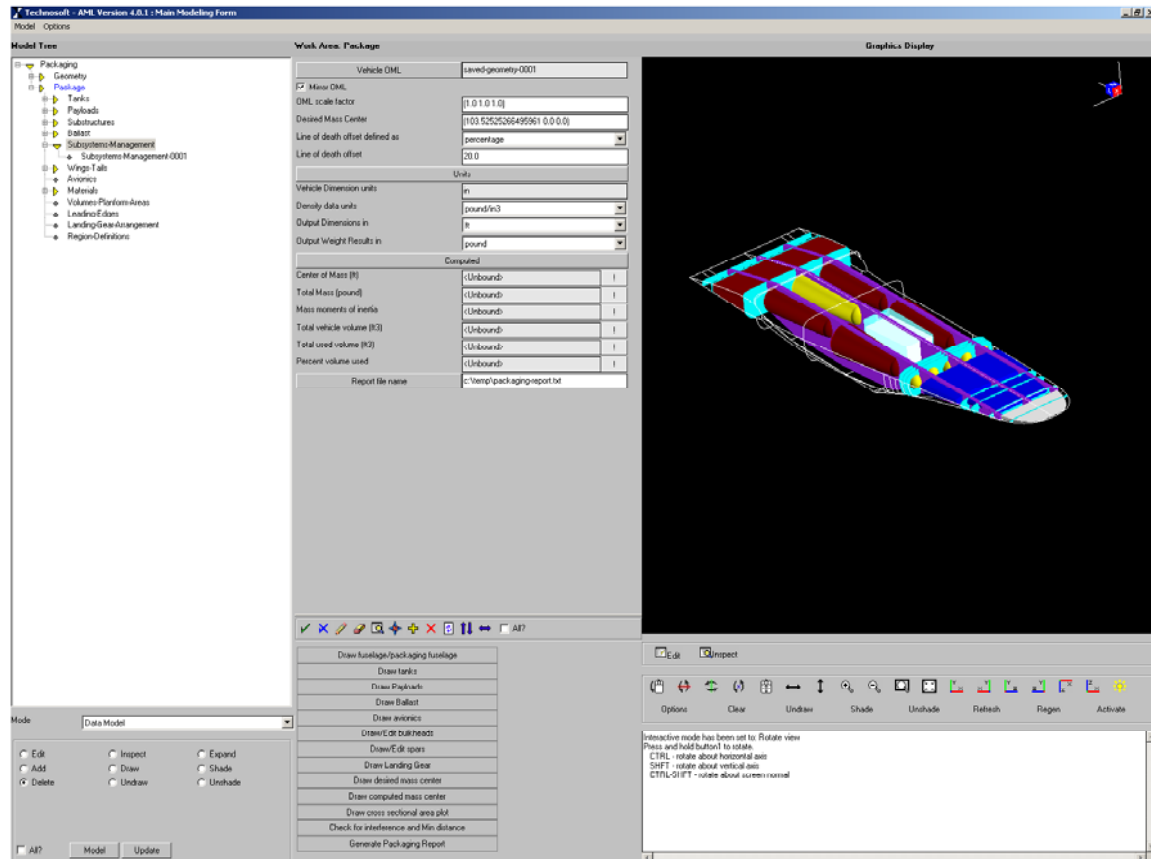
- ◆ Native AML tool for parametric keel-line definition following user-defined rules
- ◆ Prepares Design-of-Experiments files
- ◆ Output to SRGULL





Parametric Packaging/Sizing

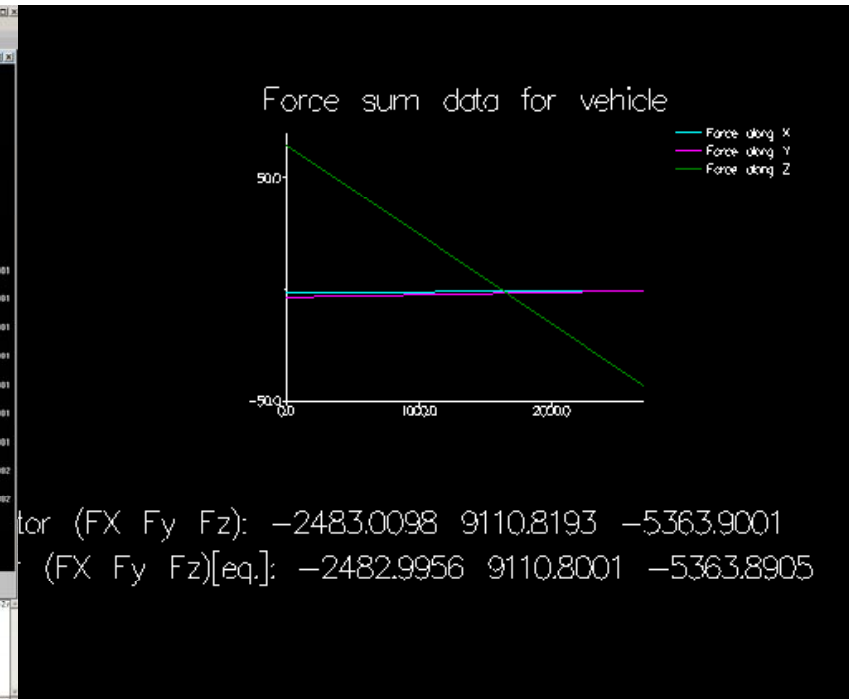
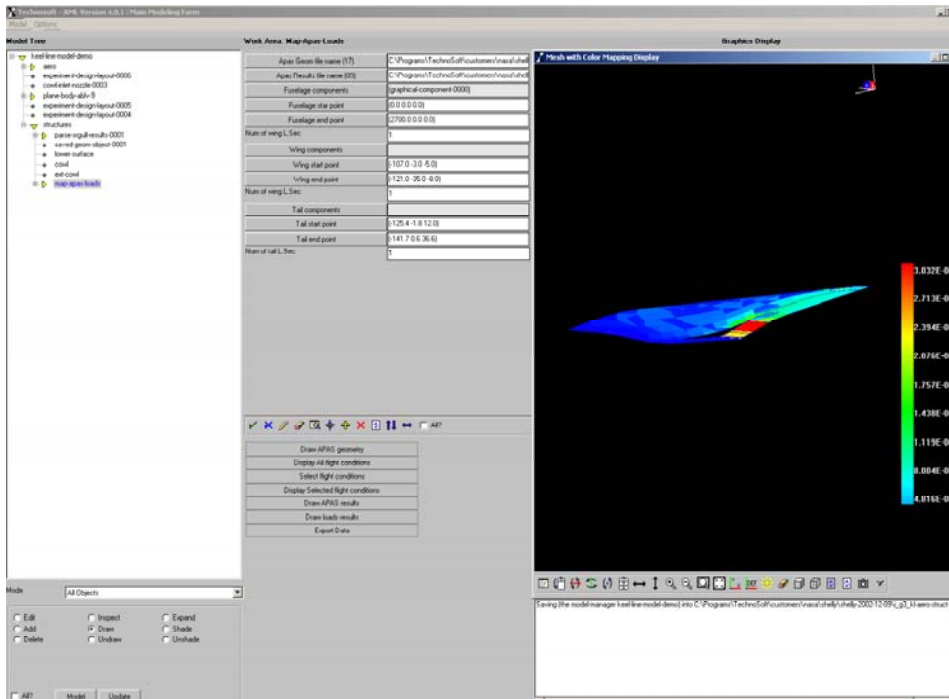
- ◆ Packaging and sizing can be defined in absolute or parametric terms
- ◆ Pre-defined library of parts
- ◆ Mass properties defined allowing calculation of moments of inertia and c.g.





Structures

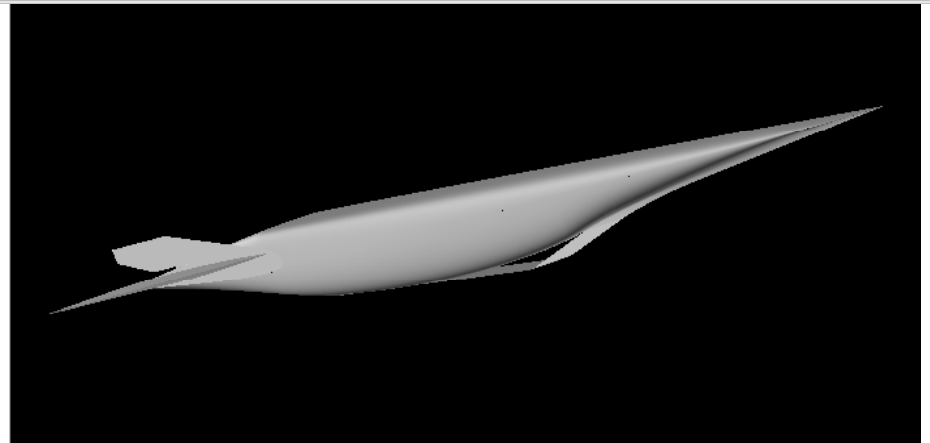
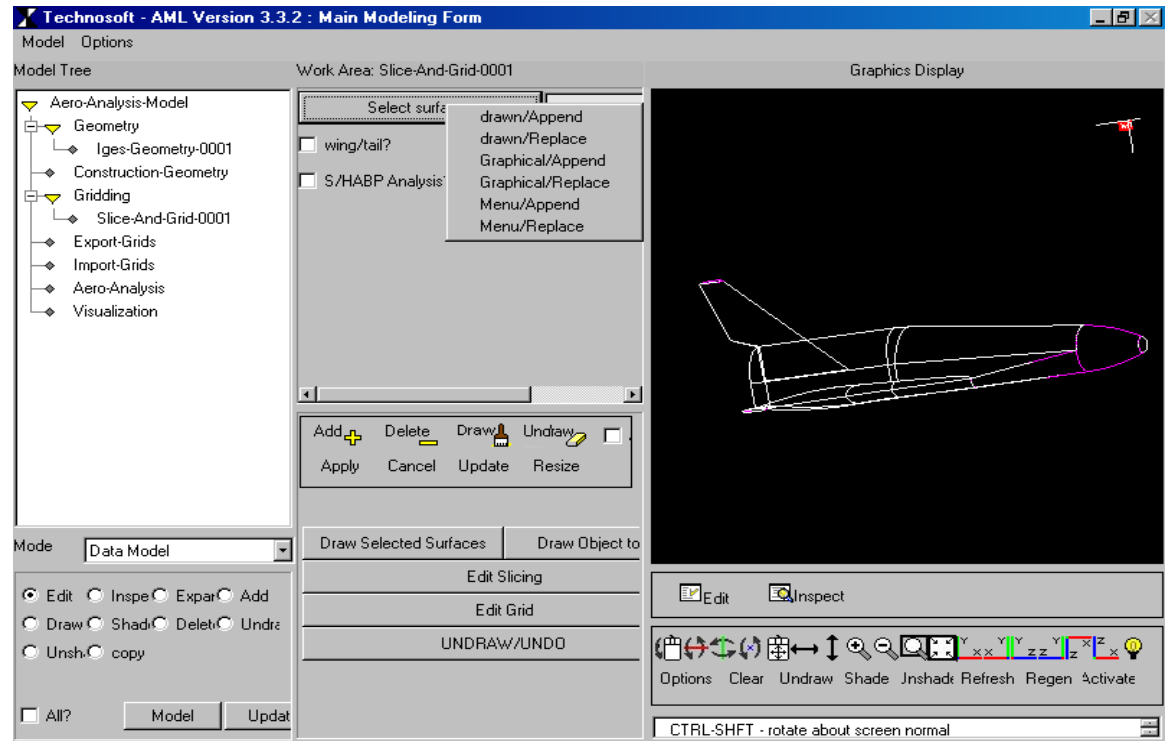
- ◆ Map pressure and heat loads from aero and propulsion onto structural line model
- ◆ Component based decomposition for structural sizing





Import CAD Model

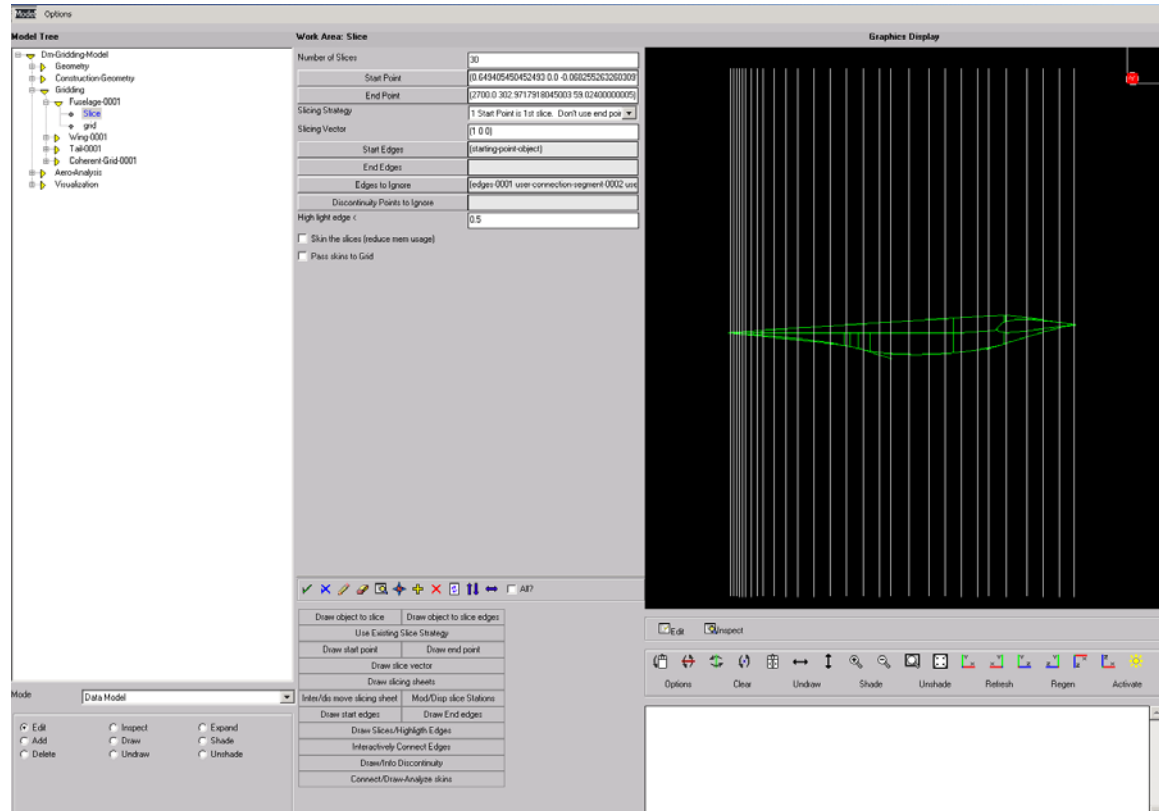
- ◆ Outer mold line imported into AML
- ◆ IGES is the typical import format but higher order geometries allowed
- ◆ Can be viewed as wireframe or solid
- ◆ Surfaces can be grouped and selected/deselected for ease of use
- ◆ Multiple models can be loaded together





Slicing Sheets

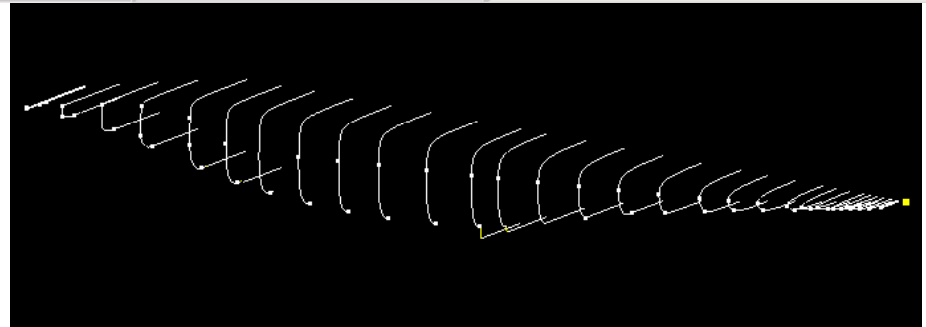
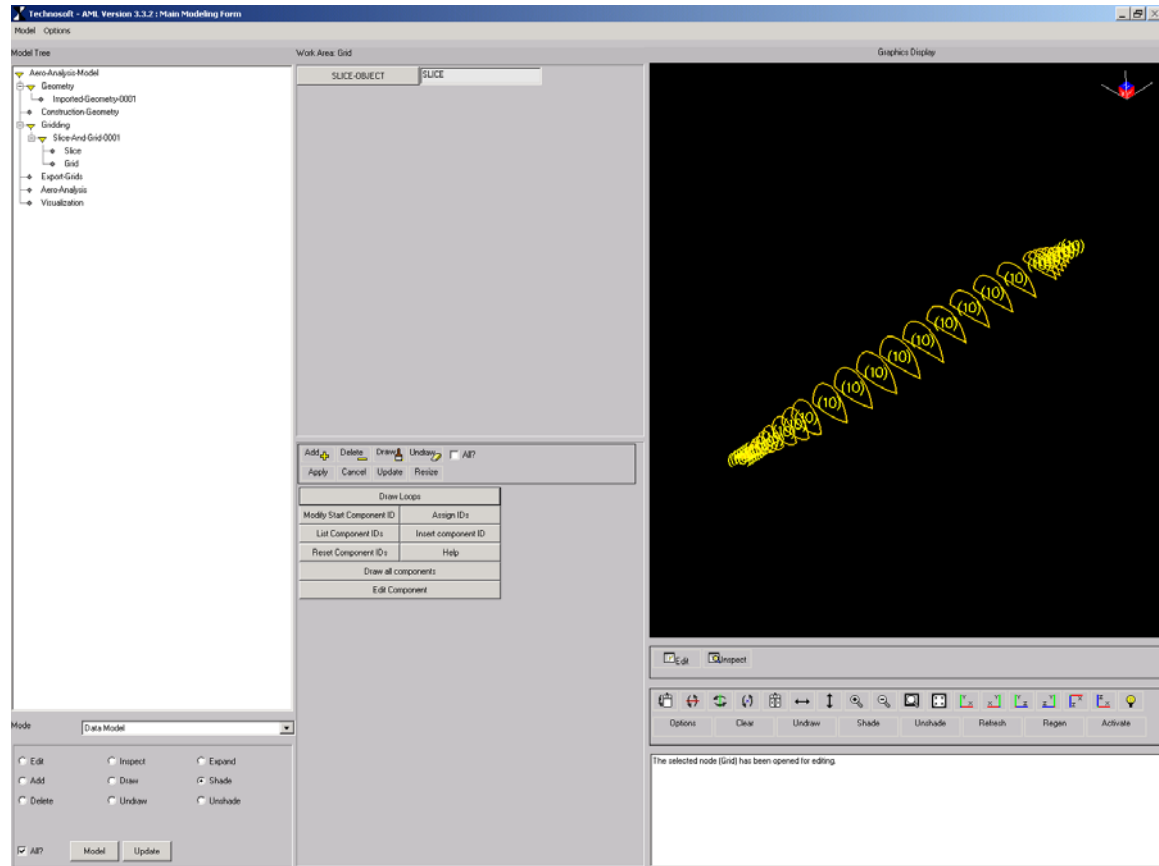
- ◆ User selects the number of slicing sheets desired
- ◆ The sheets are positioned to capture important geometric features
- ◆ Sheets can be given arbitrary orientations





Slices

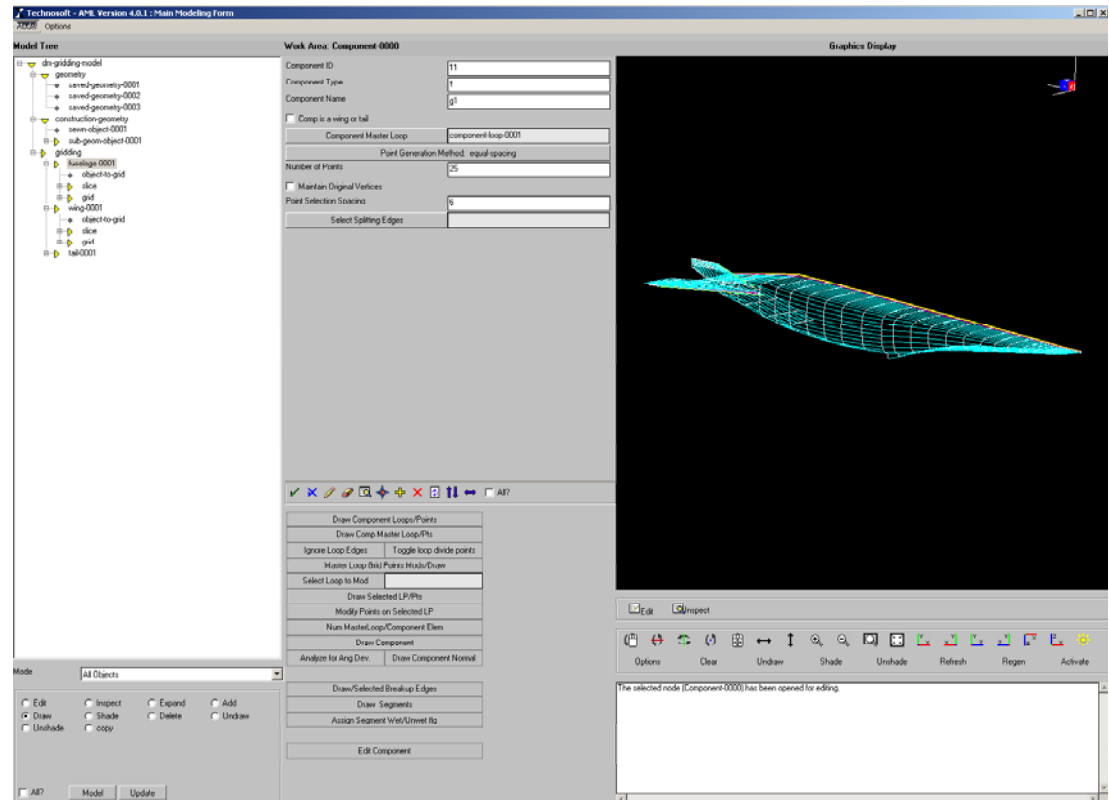
- ◆ A series of cross-sections (loops) are produced by the slicing sheets
- ◆ User specified tolerance determines what gaps are auto-closed
- ◆ Individual components are designated from loops





Aero/Aerothermal Model Export

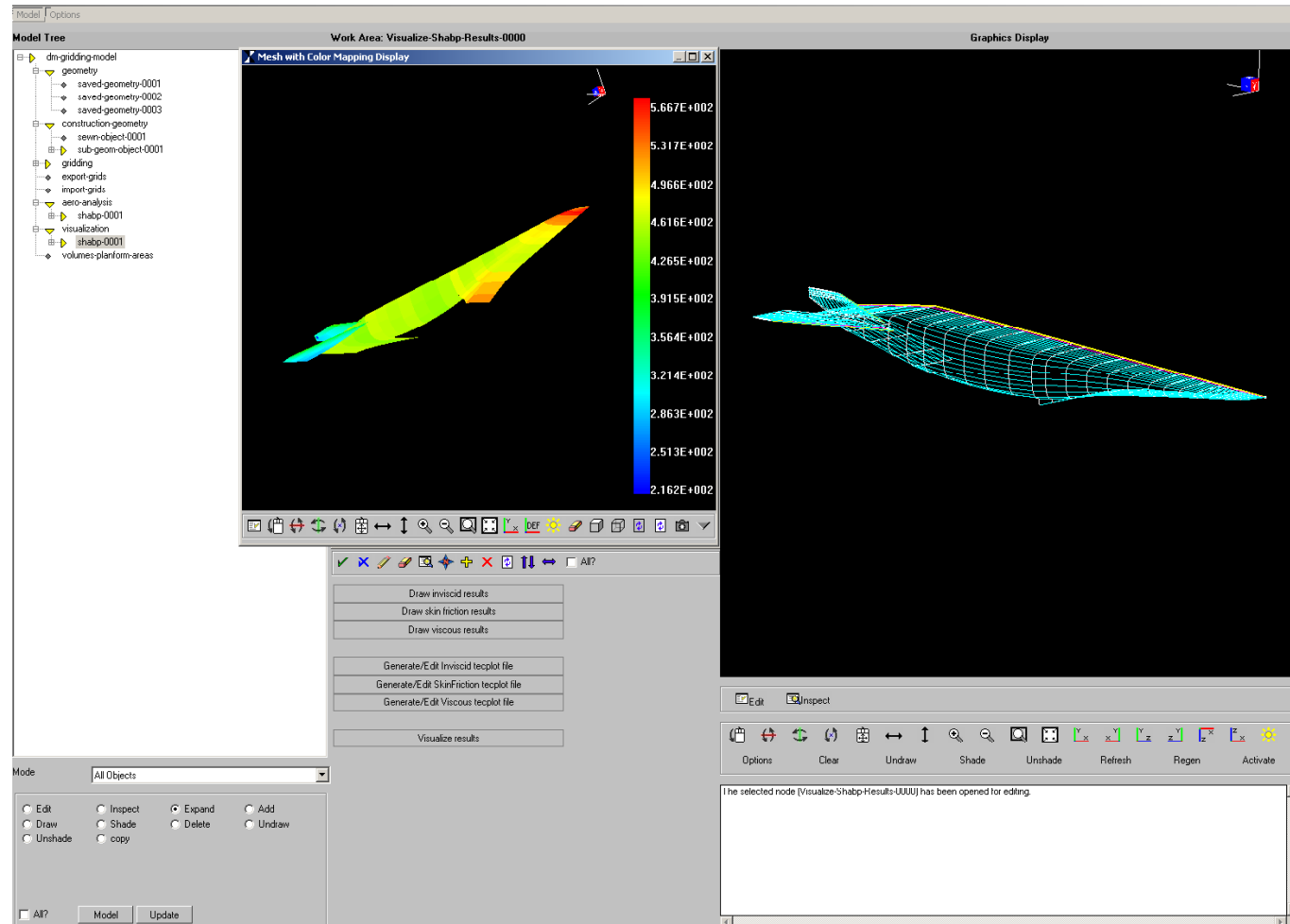
- ◆ Loops are concatenated to produce surface mesh based on user specified point distribution
- ◆ Analysis methods selected for each component
- ◆ Same interface can be used for APAS or SHABP





Results

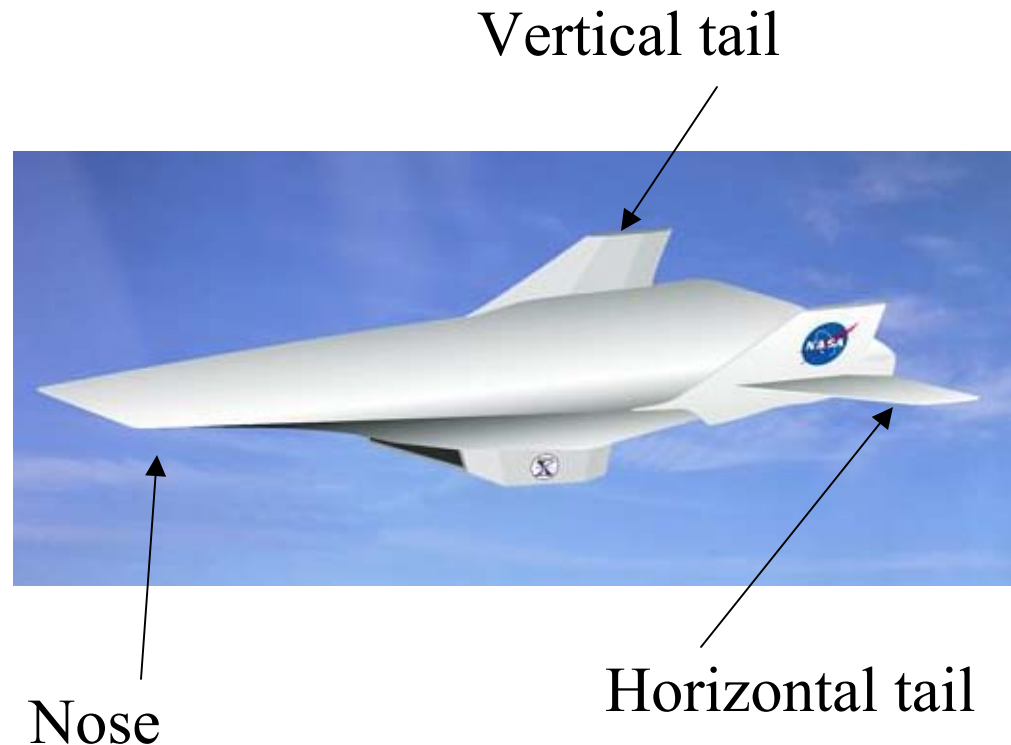
- ◆ Results can be visualized within AML
- ◆ AML module also can export to other data visualization tools (e.g. Tecplot)
- ◆ Results exported for use in other analyses (SINDA, structural sizing, trajectory)





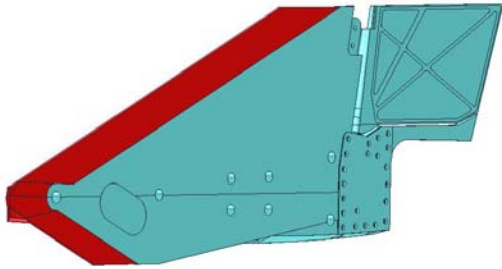
Use in the Hyper-X Program

- ◆ SHABP used to develop heat loads for X-43A hot structure (specified T_{wall})
- ◆ Used to check required TPS thickness (radiation equilibrium)
- ◆ Part of a process including thermal analysis and structural analysis on 3D geometries

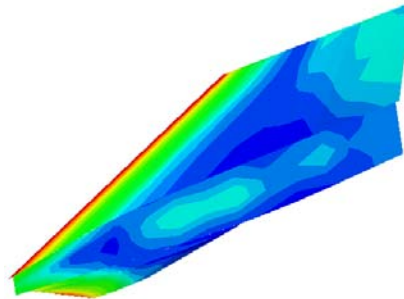




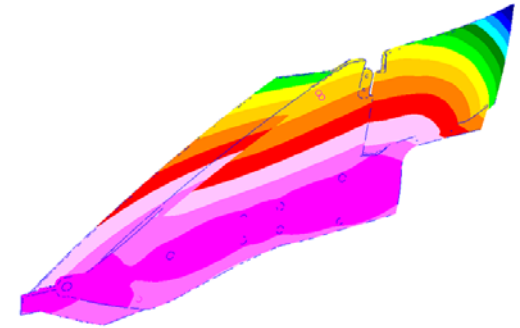
Hyper-X Thermal Analysis Process



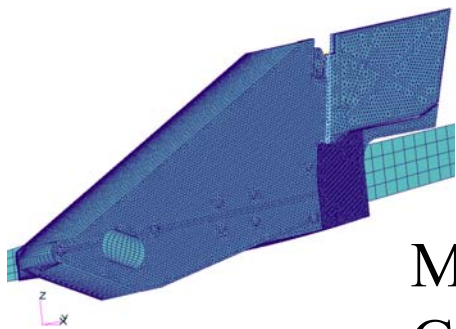
CAD Design



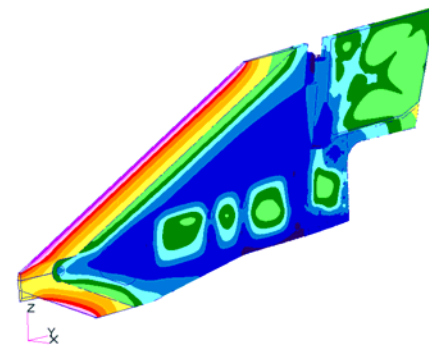
SHABP
Aeroheating



Structural
Analysis



Mesh
Generation

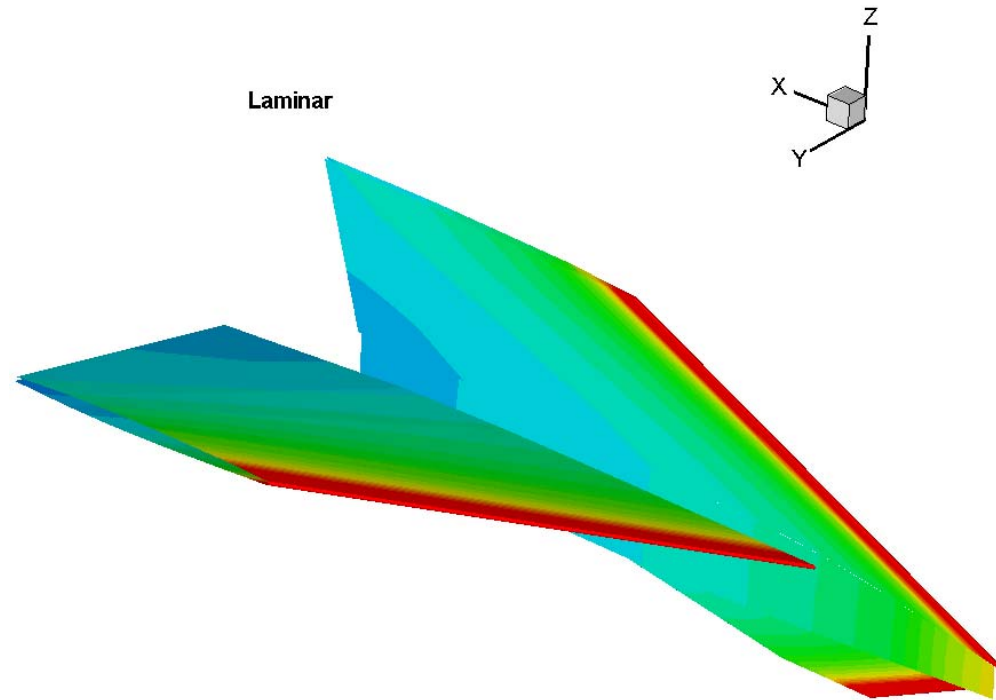


Thermal
Analysis



SHABP

- ◆ Fairly coarse grid (refined near leading edge) allowed for conceptual design
- ◆ Solves heat flux for a 3D temperature distribution or uniform T_{wall}
- ◆ Rapid turnaround allows consideration of multiple architectures quickly
- ◆ Over 400 runs on multiple architectures
- ◆ Allow approximately 30% uncertainty to account for methodology and trajectory uncertainty

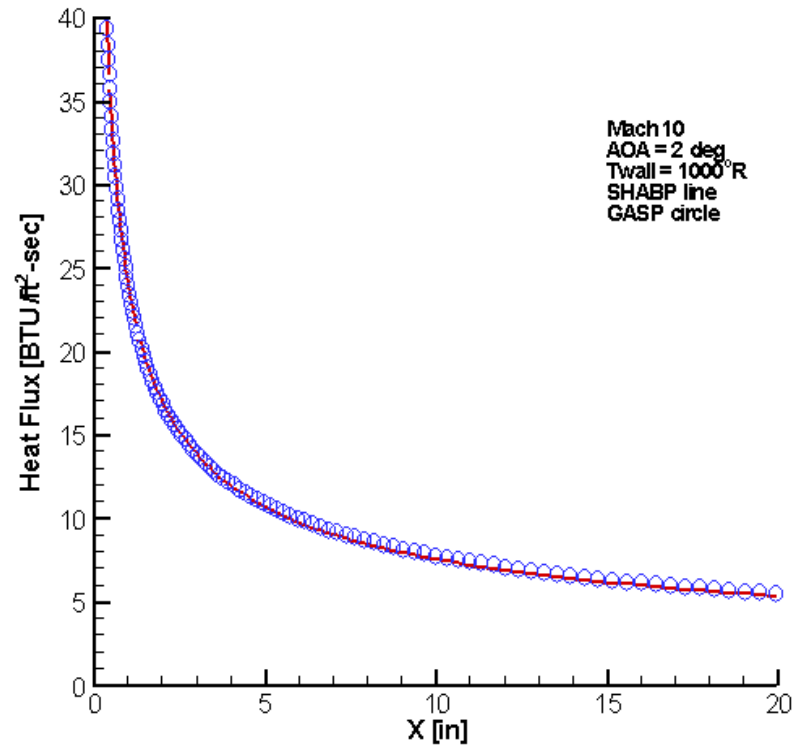




Validation

Heat flux calculations validated for multiple geometries for varying wall temperatures, angles of attack, Mach numbers, and boundary layer states

Hyper-X Forebody Heating





Limitations

◆ Vertical/horizontal tail junction and vertical tail/fuselage junction

- Shock impingement of horizontal sweeping across vertical solved with results from literature
- Corner flow: literature derived factors
- Gap heating: literature derived factors

◆ Bow shock

- Use CFD or wind tunnel data to characterize
- Use shock relations for heating augmentation

◆ Stagnation heating

- In-house code StagHeat
- Results are faired in with SHABP



Summary

- ◆ **SHABP has been incorporated into a practical environment for modeling hypersonic vehicles**
- ◆ **Allows for rapid and accurate analysis of multiple configurations**
- ◆ **Effective tool for conceptual aerothermal design by itself**
- ◆ **Coupled with targeted higher fidelity solutions can be used in final design**