VSP-CAD-CFD Interaction & Advanced Modeling Techniques

2020 OpenVSP Workshop, Virtual Broadcast

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AERONAUTICS SYSTEMS ANALYSIS BRANCH

Overview

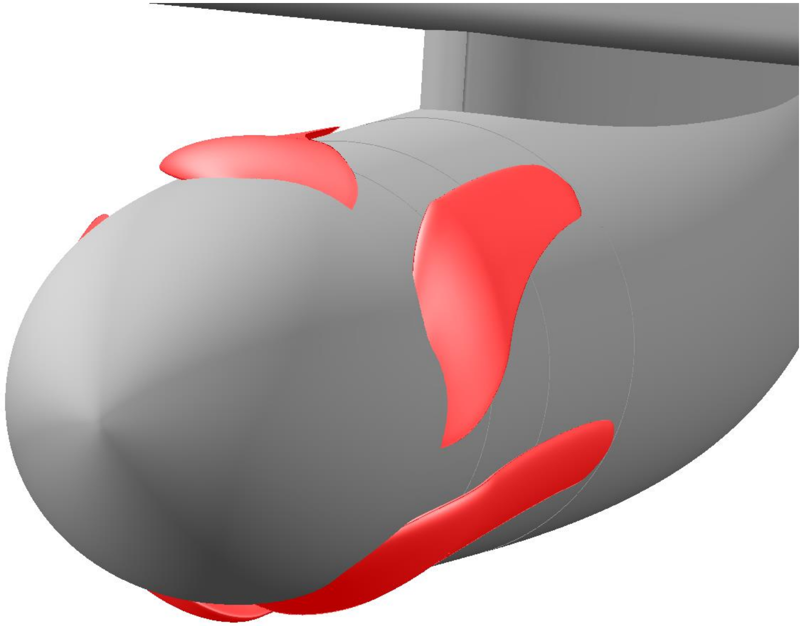
Introduction

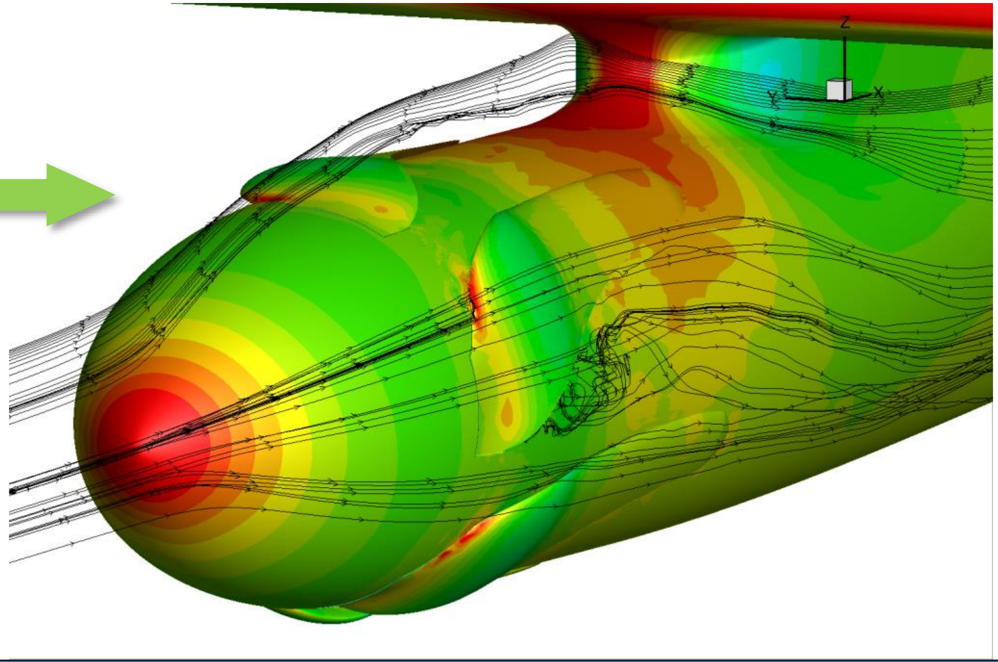
→ Tool Interaction

→ VSP Model Setup and Techniques

→ CAD Model Detailing and Adjustment

→ Grid Generation and Refinement





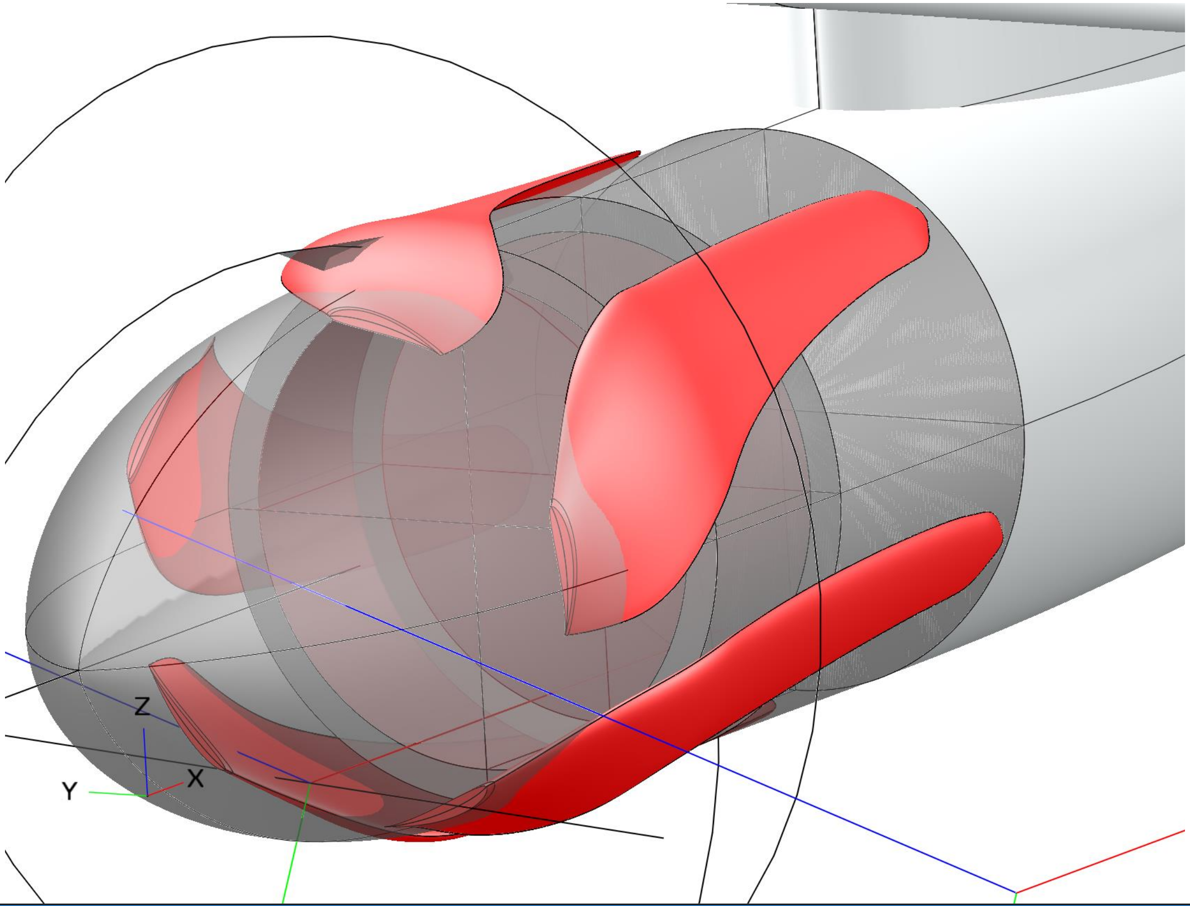
Introduction

- The boundaries between parametric modeling, CAD, and CFD are blurring.
- Advance knowledge of aerodynamic, structural, or manufacturing issues early in the design process saves time and costs later.
- Streamlining the iterative design processes between VSP, CAD, and CFD saves time and effort and helps to avoid miscommunication between teams.
- This presentation is intended to convey techniques and lessons learned from my experience using multiple design and analysis tools.
  - *This is neither a comprehensive list nor a "gospel" guide but rather a collection of successes. Your experience may differ.*

Tool Interaction

OpenVSP

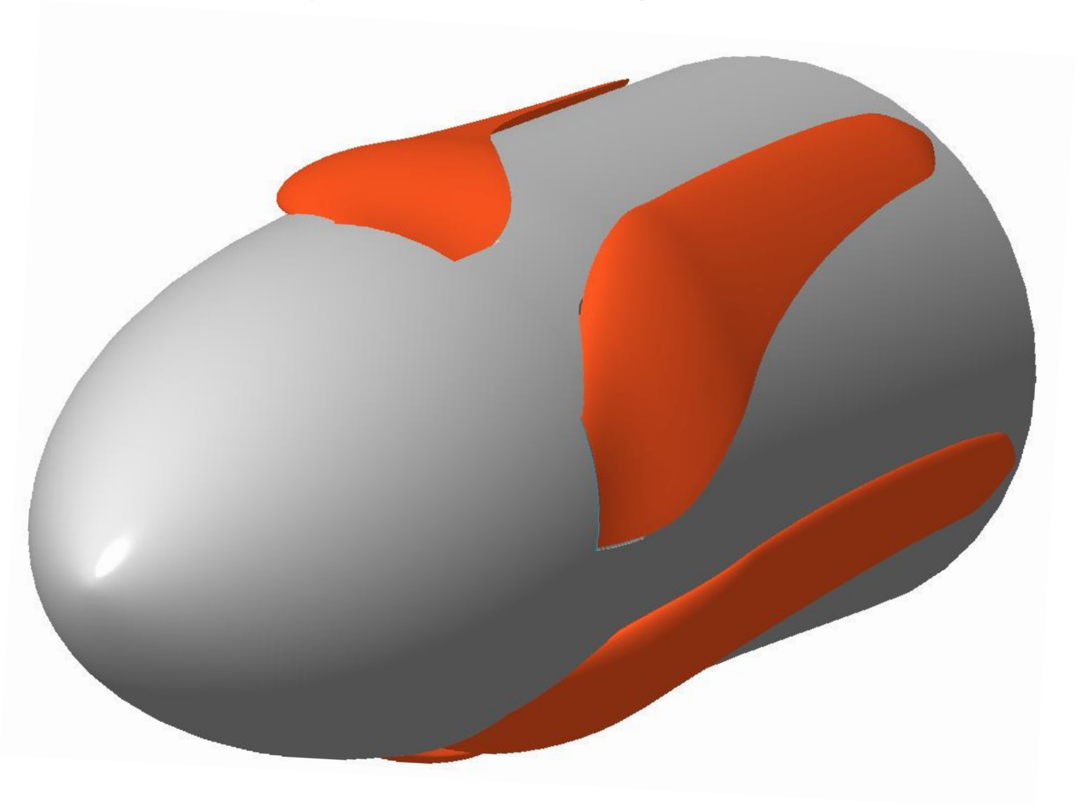
Starting from a parametric model, …



Tool Interaction

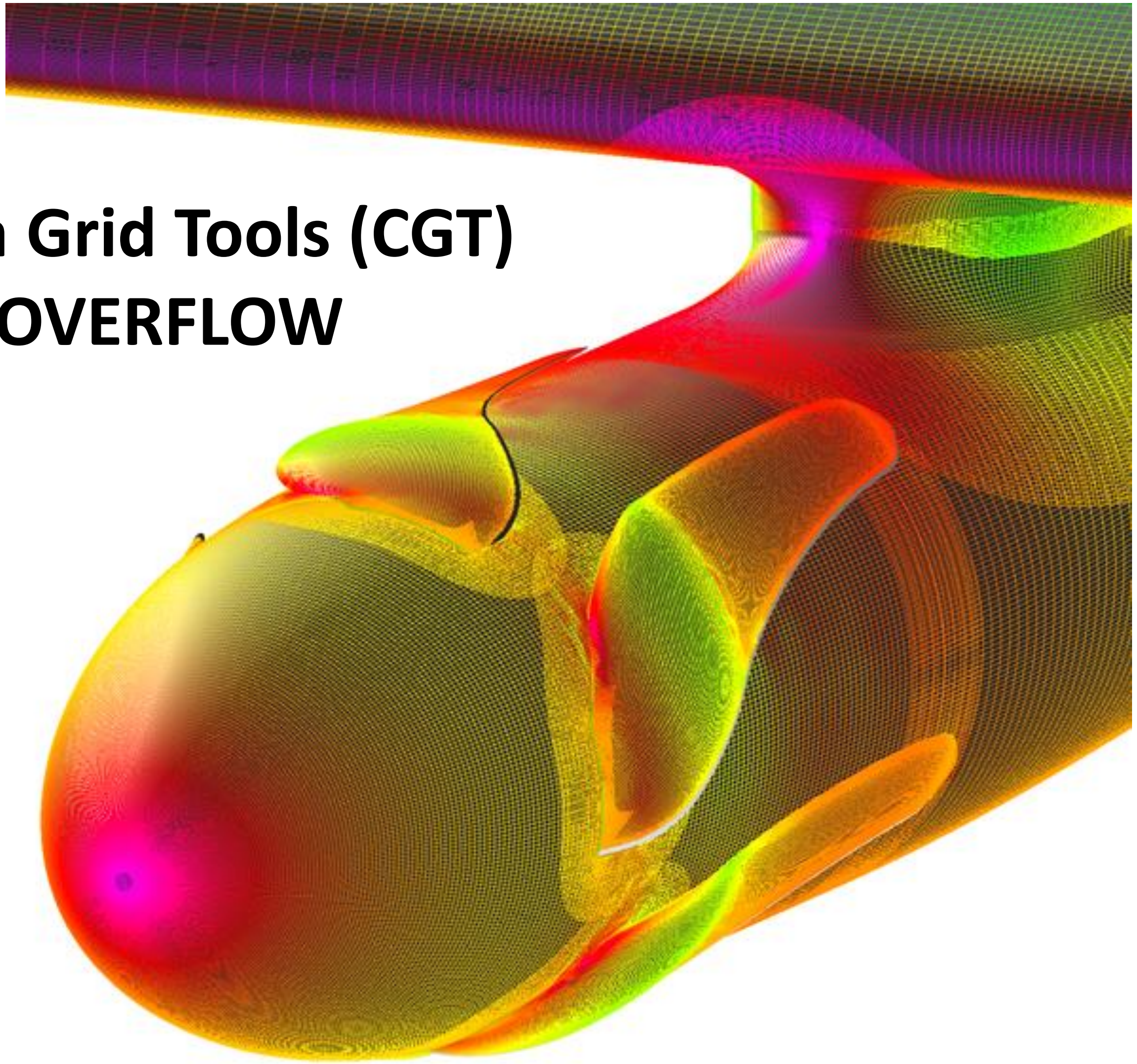
Computer-Aided Design (CAD) Software

… adding details in CAD, …



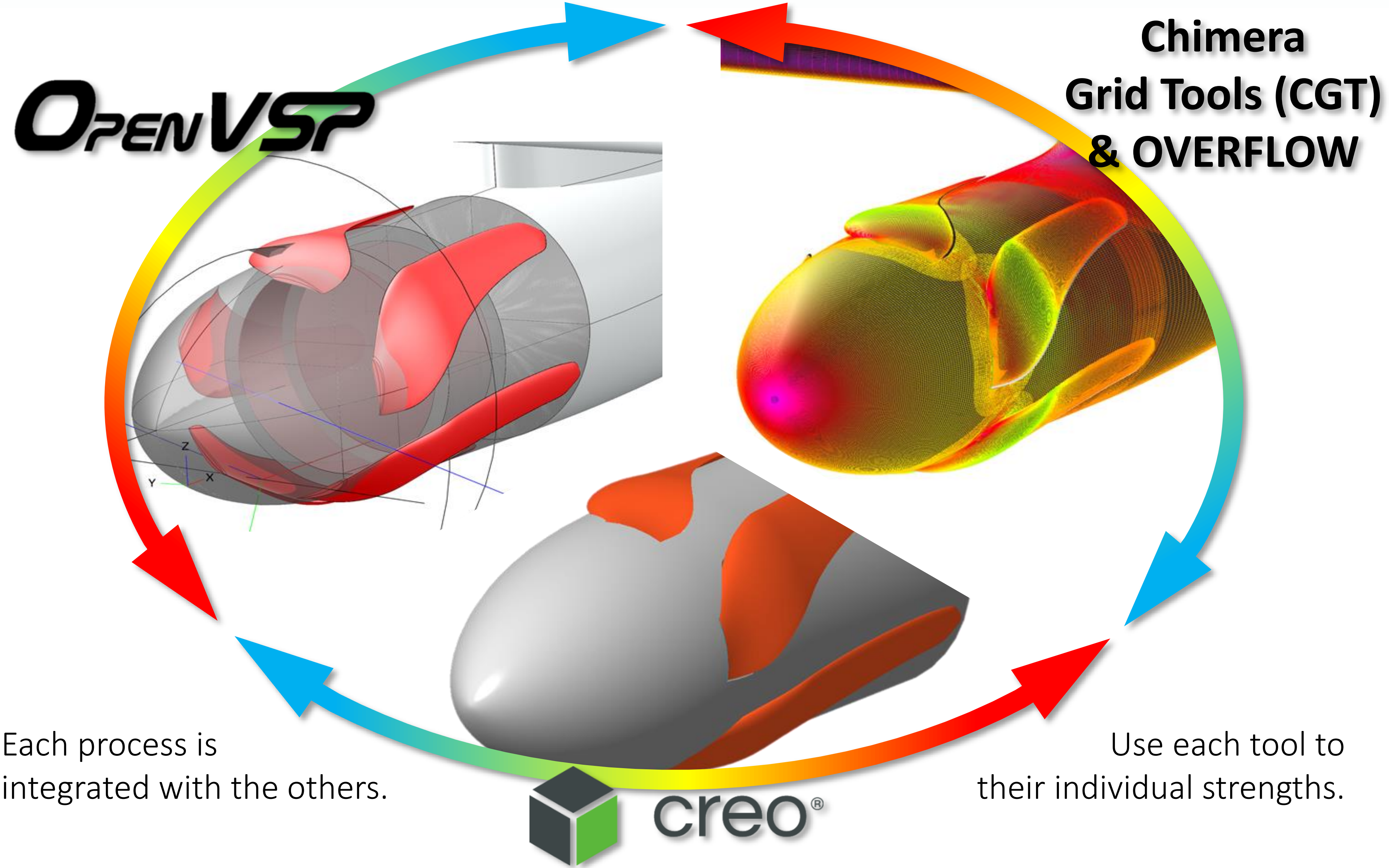
Tool Interaction

Chimera Grid Tools (CGT)
& OVERFLOW



… and generating grids
for CFD solvers.

Tool Interaction



Each process is
integrated with the others.

Use each tool to
their individual strengths.

OpenVSP

VSP Surface Resolution

- Exporting as a grid *reference surface* requires very high tessellation. The grids will grow and project onto this surface so make sure that it is a “true” representation.
  - Projecting a good grid onto a bad surface will still cause issues.
- When using the VSP surface itself as the *solver model*, set tessellation and grouping according to your needs.
  - Increase tess. and grouping where large gradients are expected.
- Exporting for 3-D printing requires very high tessellation.
- Beware using airfoil files with excessively clustered points.
  - Can cause issues with surface export.
  - Usually between 100-200 foil points is “good”.
  - Avoid too many points at the LE or TE. Causes VSP and others to “ring” while attempting to fit.

VSP Surface Resolution

- Typical model setup for export to gridding:
  - Saves some effort in the gridding process by starting with grids close to the final arrangement.
  - Attempt to have a maximum growth ratio of 1.1 to 1.2.
  - Wing-type settings:
    - Num_W = 201, Total Num U ~ 80-100
    - LE/TE Clustering = 0.1, Tip Clustering = 0.1
  - Body-type settings:
    - Num_W = 361 (1°/section), Num U/Num_U as needed

VSP Model Units

- When exporting to grids, ensure that the model is in the solver units. VSP surface export (PLOT3D or TRI) seem insensitive to model units and remain accurate.
- When exporting to CAD via IGES/STEP:
  - Improved CAD export processes have made this unit agnostic.
  - Set tolerance such that the surfaces import with your software well.
  - Determine if you need trimmed or untrimmed CAD.

VSP File Formats

VSP Formats	
Import	Export
Stereolith (STL)	Stereolith (STL)
Cart3D (TRI)	IGES
Points (PTS)	STEP
	Cart3D (TRI)
	PLOT3D (P3D)
	Drawing (DXF)

CAD Formats	
Import	Export
IGES	IGES
STEP	STEP
Stereolith (STL)	Stereolith (STL)
Drawing (DXF)	
Points (PTS)	

CFD Grid Formats	
Import	Export
PLOT3D (P3D)	PLOT3D (P3D)
Cart3D (TRI)	Cart3D (TRI, I.TRI)
IGES > EGADS2SRF	
STEP > EGADS2SRF	

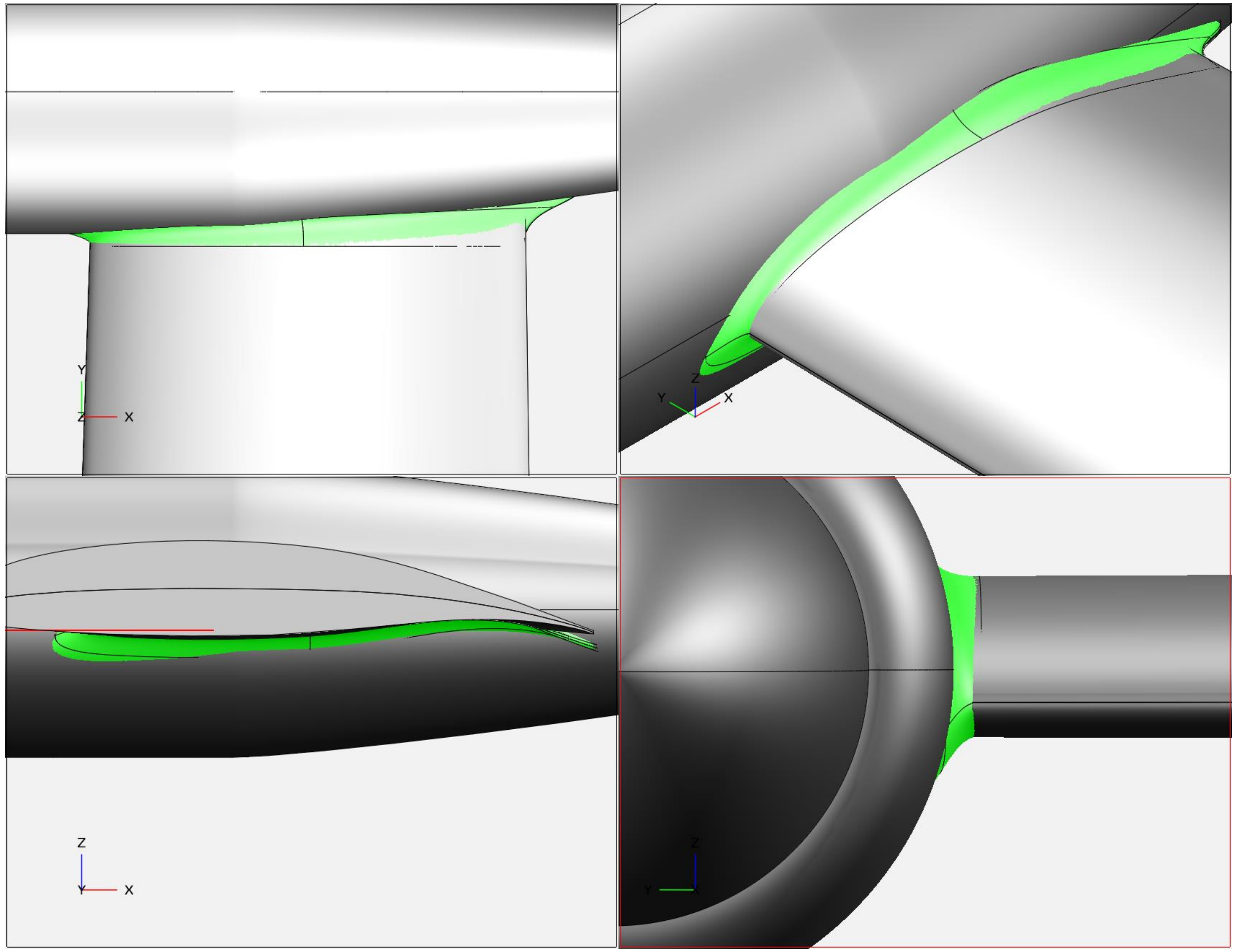
Advanced VSP Techniques

- Strakes and Fillets
- Cutter Components
- Hinges
- Scripting
- Trimmed Surface

VSP Strakes/Fillets

- Initially tried to use Fuselage/Stack component and VSP-generated or user-defined airfoils to achieve desired shape.
  - Filled in wing-nacelle intersection.
  - Adjusted surface with Skinning.
  - No true control over fillet“radius” or shape between surfaces
  - Trying to match a 2-D section to a 3-D surface is problematic…
- Conclusion: Not quite...

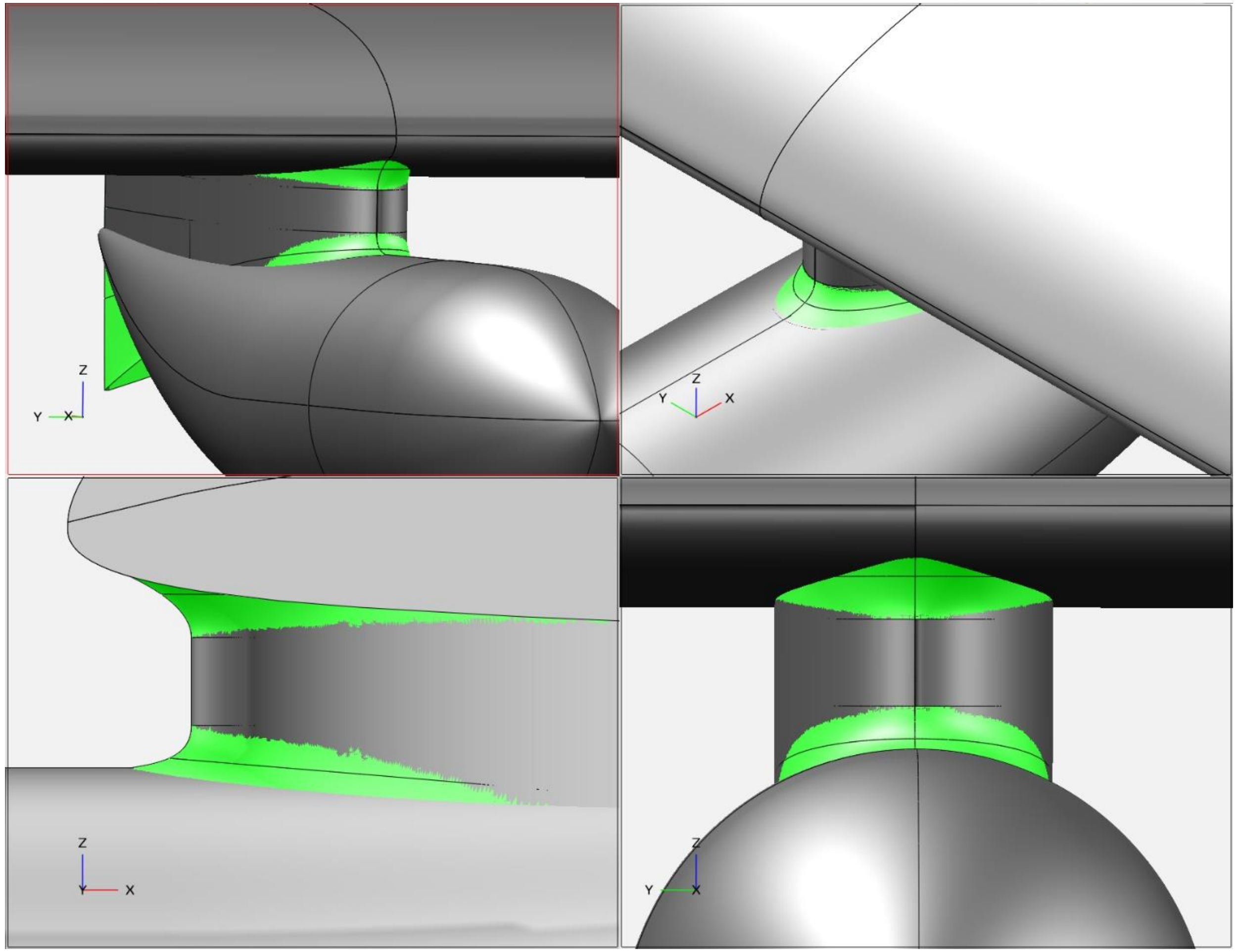
Wing-Nacelle Junction Fillet



VSP Strakes/Fillets

- Initially tried to use Fuselage/Stack component and VSP-generated or user-defined airfoils to achieve desired shape.
    - Filled in nacelle and pylon intersections
    - Adjusted surface with Skinning. Attempted to make intersections tangent at strake LE.
    - No true control over strake “radius” or shape between surfaces
    - Trying to match a 2-D section to a 3-D surface is problematic…
    - Easily matches to normal cross-sections. Could be useful for blending between successive wing sections if Blending feature will not work.
- Conclusion: Almost there...

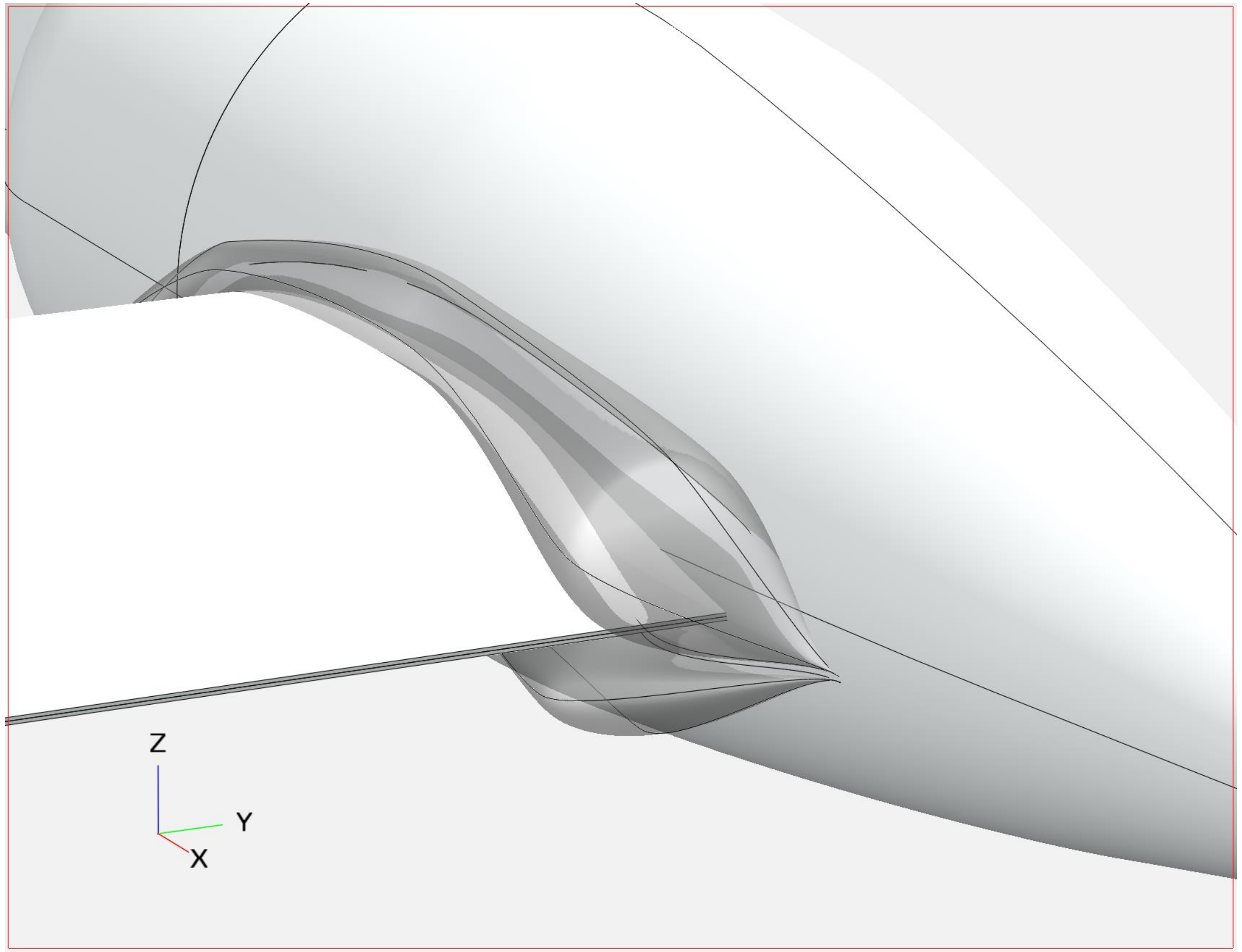
Wing-Pylon & Pylon-Nacelle Junction Strakes



VSP Strakes/Fillets

- Realized that gridding/CAD software doesn't care about the VSP surface normal.
- Can use the INSIDE of a component as the blending surface.
- Fuselage part allows for fine control of cross-section shape, size, and placement.
- Skinning allows some control over the intersection curves. Not perfect.
- Must manually place the cross-sections along the intersecting bodies. Process improvements underway.

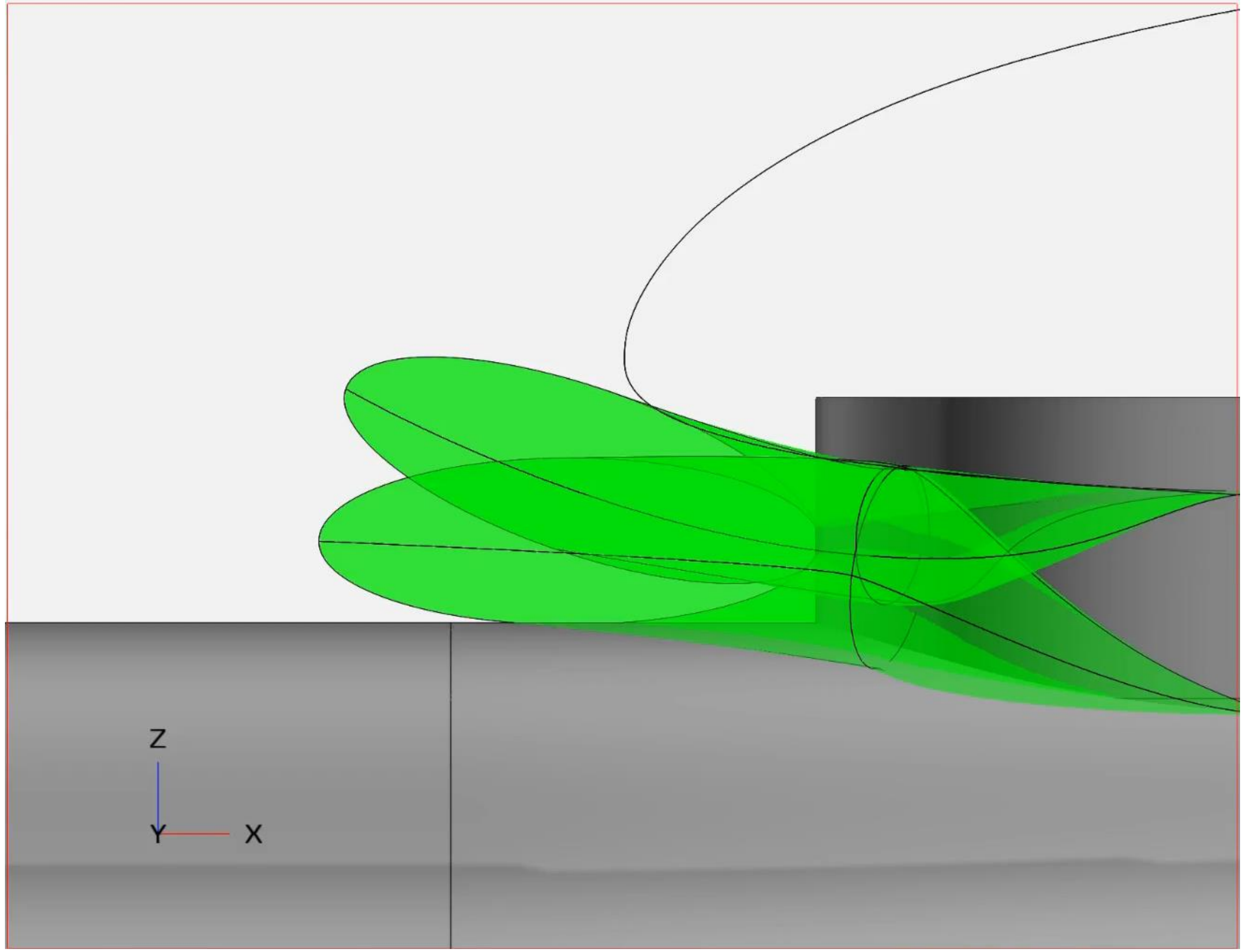
Wing-Nacelle Junction Fillet



VSP Strakes/Fillets

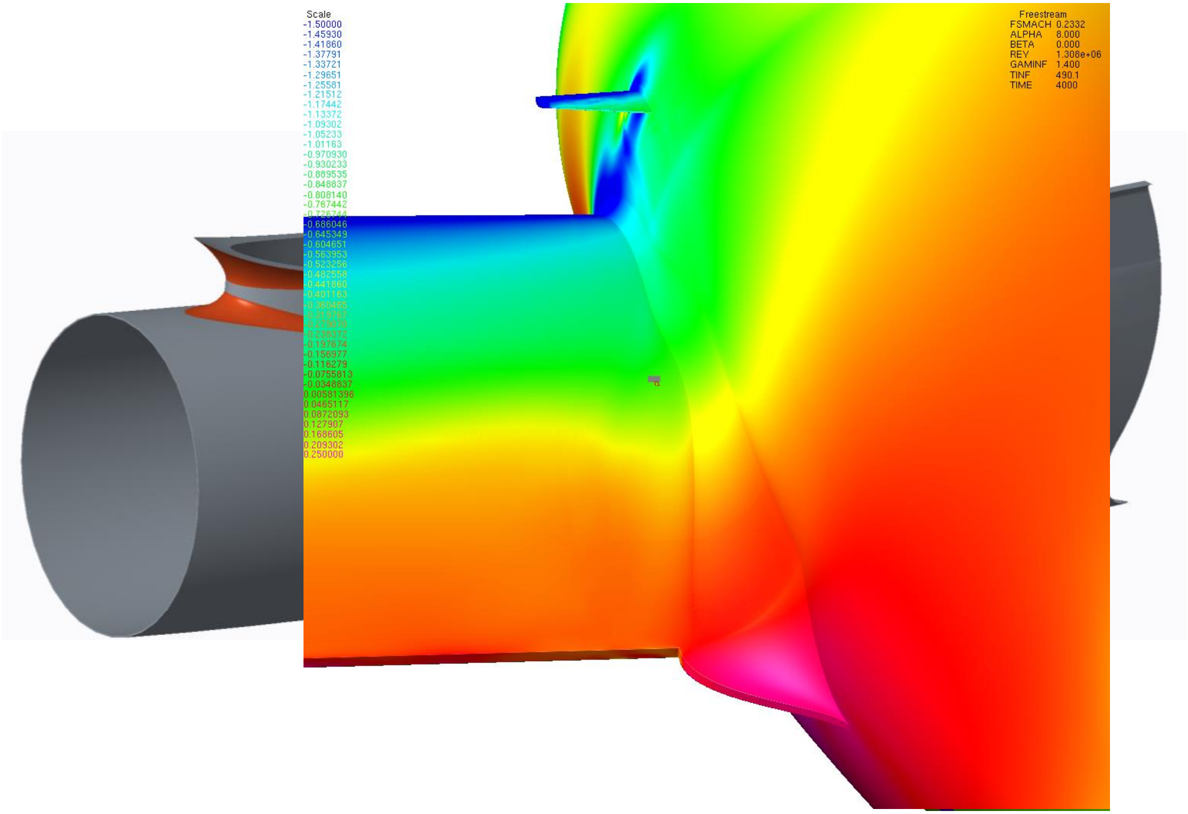
- Building strakes onto pylons is easier with planes of symmetry.
  - Only half of the sections defined.
- Still required to determine cross-section placement, angles, etc.
- MUST ensure that the blending component intersects both bodies.
  - Improperly intersected parts will not have well-defined intersection curves.
  - Requires the user to manually interpolate curve points along surface.
  - Cannot cleanly project the blending curve back onto the original surface.
    - Projection will “jump” between blending and body surfaces.

Wing-Pylon & Pylon-Nacelle Junction Strakes



VSP Strakes/Fillets

- STEP/IGES files exported to CAD serve as a guide for features.
    - Can extract curves or surfaces and smooth any imperfections.
- Part3D files exported directly to gridding software.
    - Extract intersection curves between surfaces.
    - Build blending surface across bodies.
    - Grid system assembled in MUCH less time than having CAD in the loop.
    - VSP features are currently limited in their fidelity and need to be improved to capture true fillet geometry.



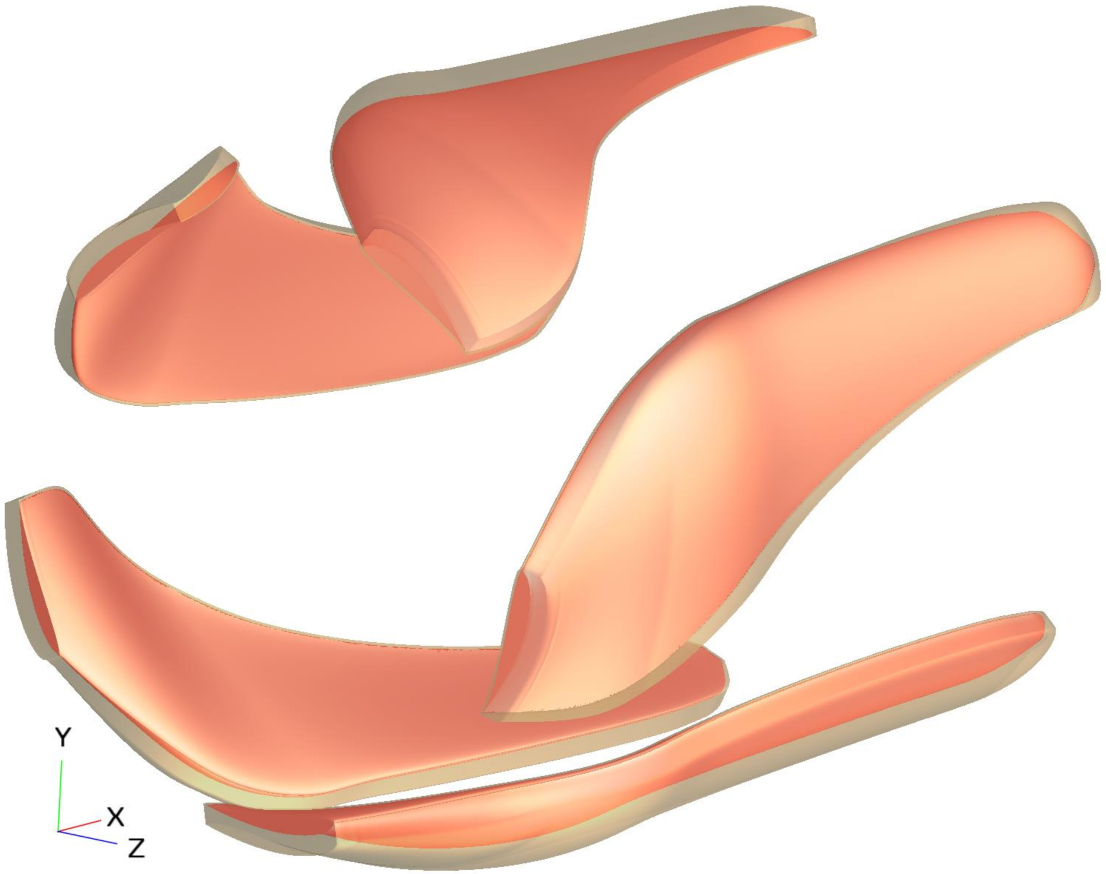
Strakes/Fillets Summary

- OpenVSP components can be used to blend between parts in a model.
  - The current process can be tedious, depending on the required accuracy of the geometry approximation.
  - Blending between parallel slices e.g., wing-to-wing, is much easier and only requires two sections.
  - Process improvement is underway.
- Blending components can be directly exported to CAD/Grid software.
  - Drastically reduces the time required to build features.
  - Improves communication of design intent to CAD or CFD groups.
  - Allows for rapid evaluation of multiple designs to determine the “best” geometry.
- Existing designs can be approximated in VSP by importing STL geometry from CAD and fitting cross-sections and skinning by hand or Fit Model.

VSP Cutters

Using VSP components to remove material from CAD parts.

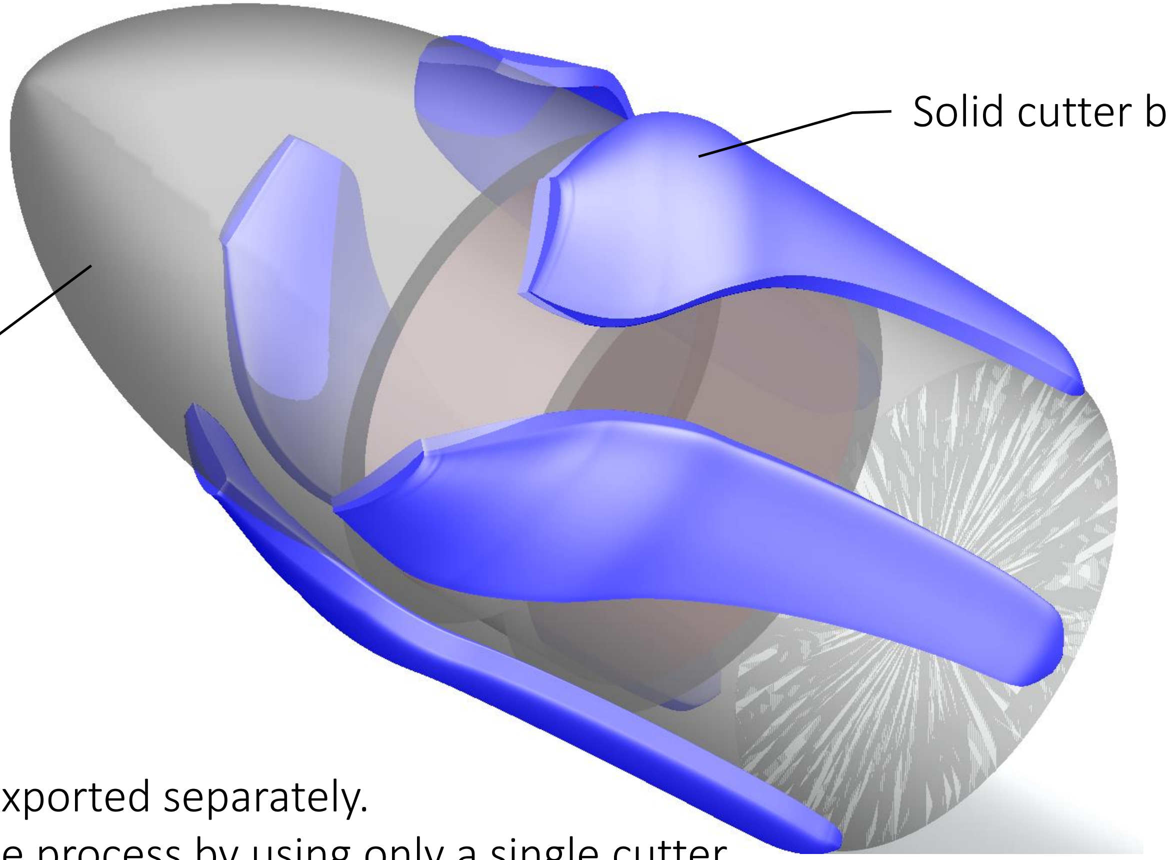
In this example, a modified Prop component (gold) is designed to surround the folded propeller blades (red) and used to clear material from the nacelle.



VSP Model

VSP Cutters

Transparent materials allow viewing the cut region.

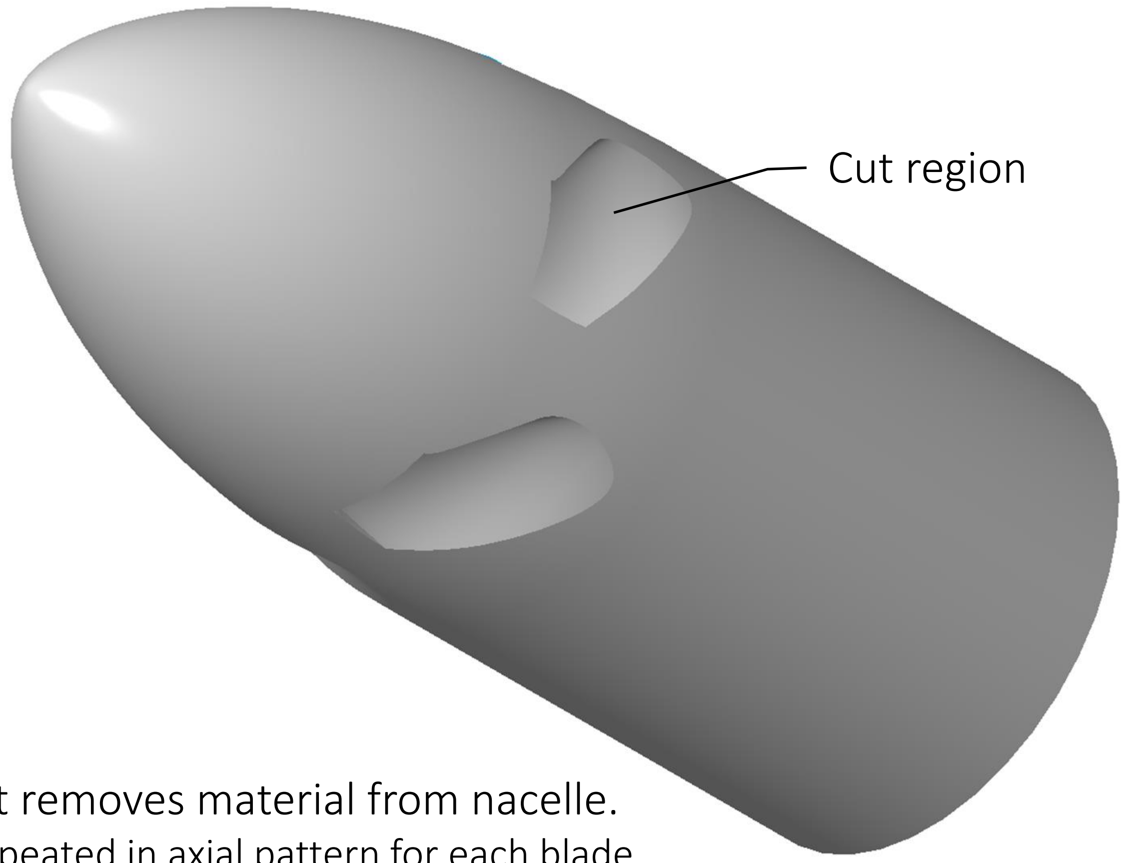


- Parts are exported separately.
- Simplify the process by using only a single cutter.
    - Axial pattern created in CAD.

VSP Model

VSP Cutters

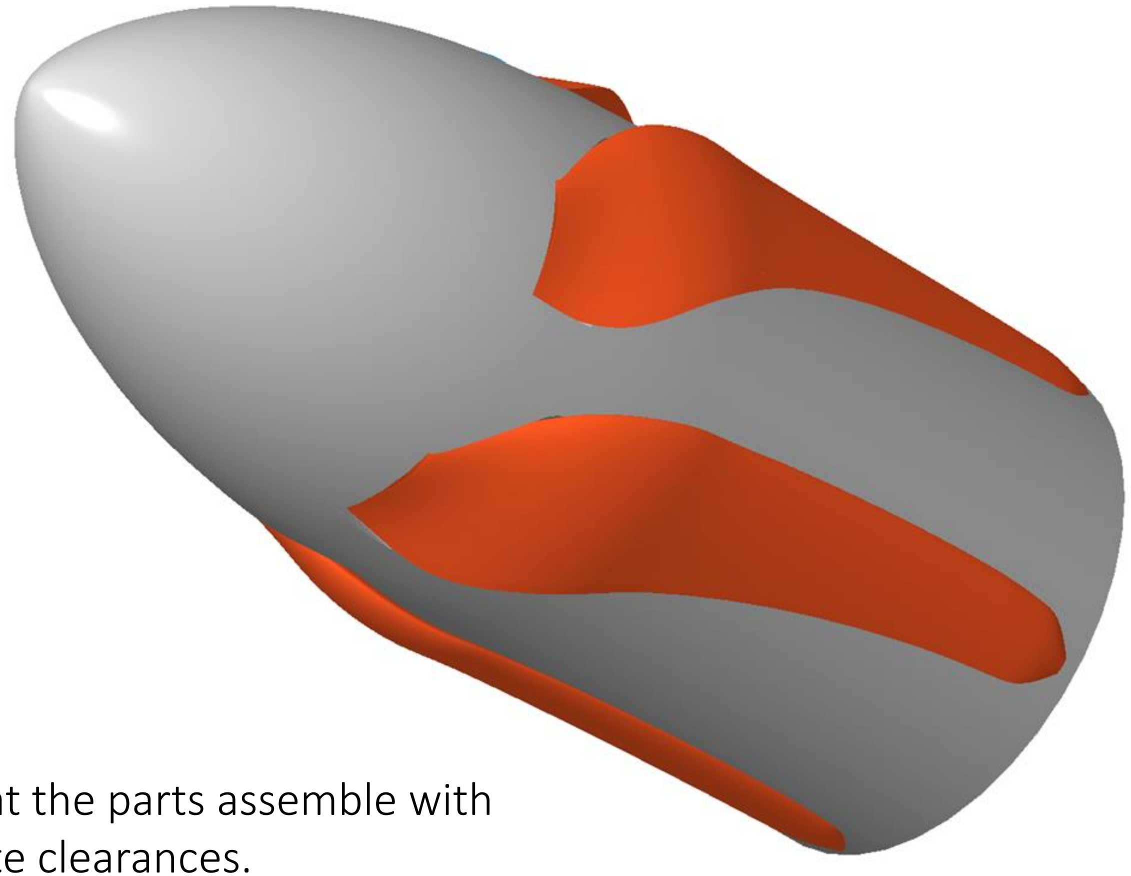
Import into CAD and repair surfaces as needed.



- Cutter part removes material from nacelle.
  - Cut repeated in axial pattern for each blade.
- Adjust additional features to improve gridding.
  - Avoid sharp corners and multi-directional bends.
  - Adjust surfaces to allow grids to grow easily.

CAD Model

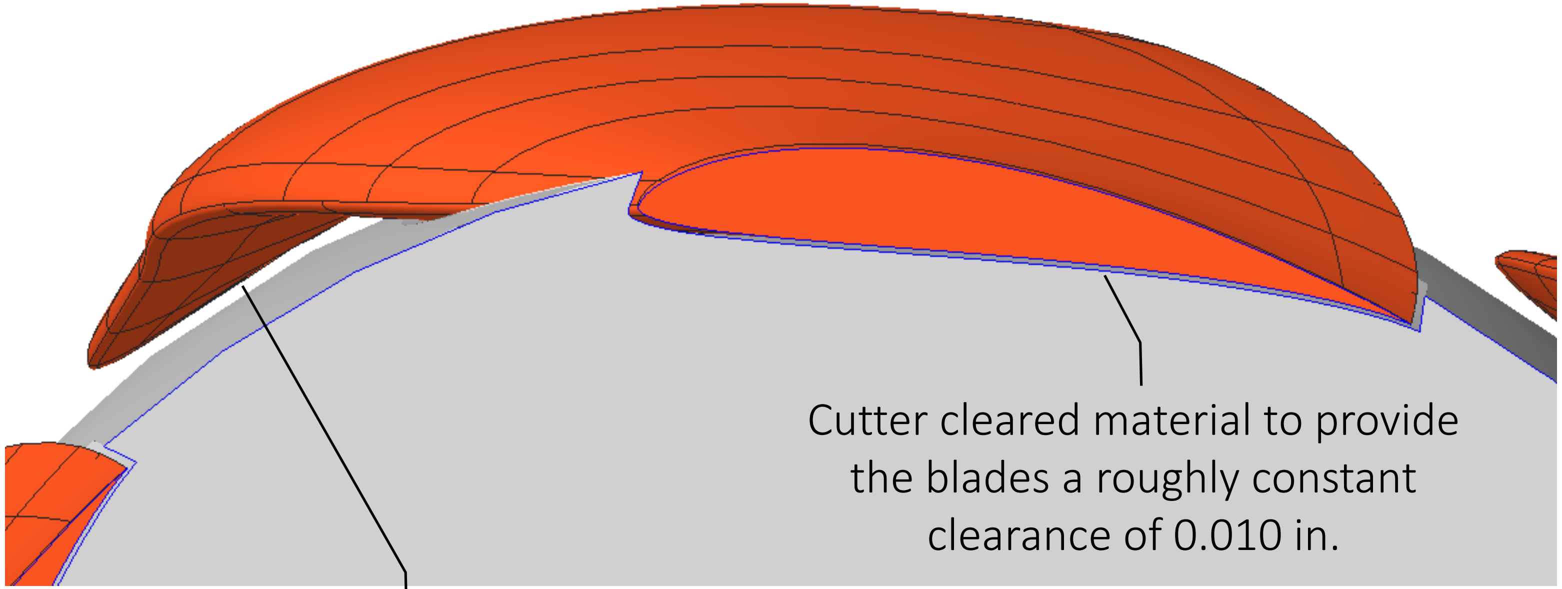
VSP Cutters



- Ensure that the parts assemble with appropriate clearances.
- Prep for export to gridding or assembly.

CAD Model

VSP Cutters



Cutter cleared material to provide the blades a roughly constant clearance of 0.010 in.

Blades intentionally designed to maintain a 0.030 in. clearance to the outer nacelle surface.

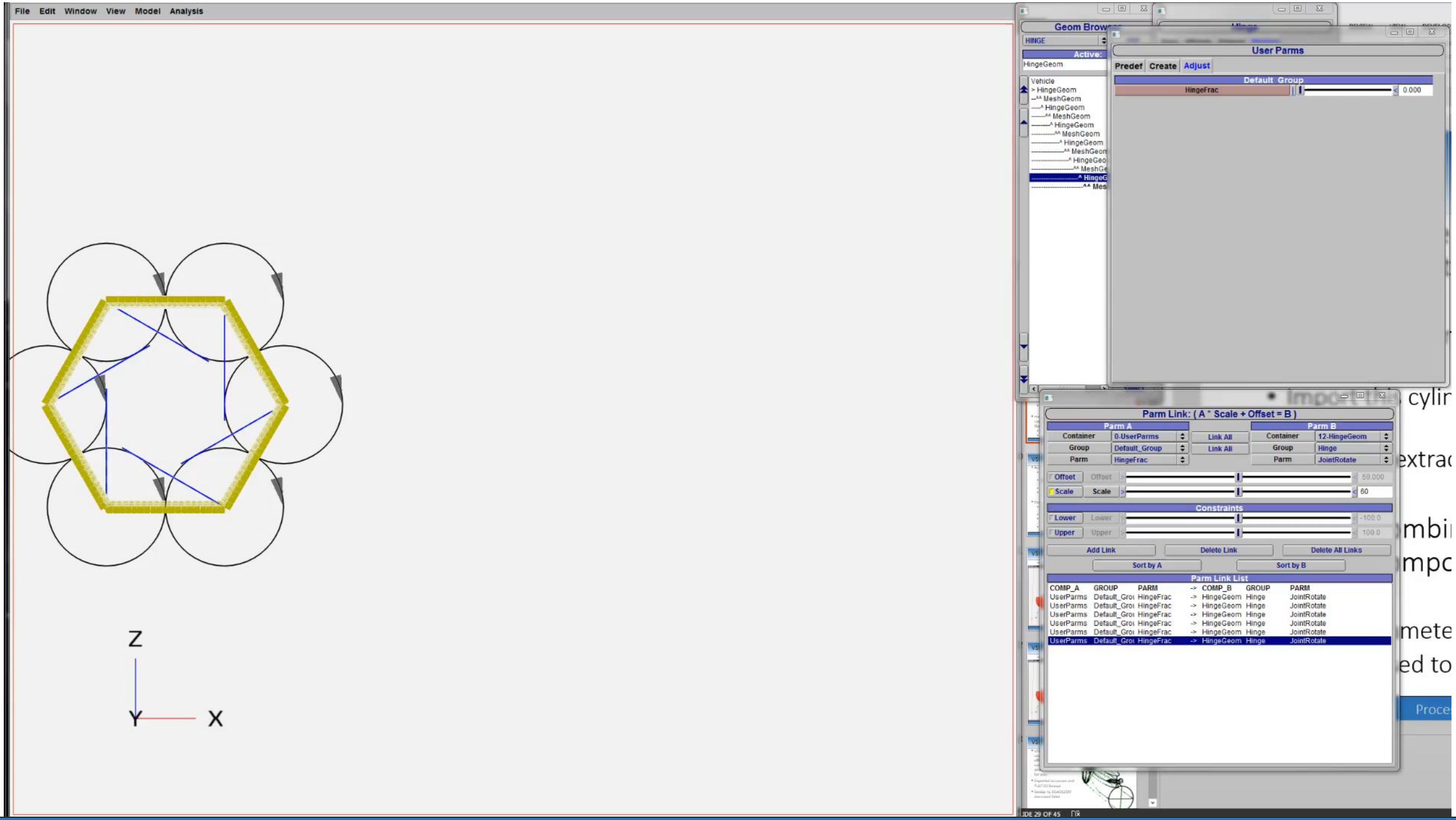
CAD Model

VSP Hinges

- If you've modeled Hinges or pins in your VSP model, you can easily export those axes and locations using simple cylinders.
  - Attach a VSP pin to the rotation center and extend along the rotation axis.
  - Import this cylinder into CAD and use to define axis and hole locations.
  - Useful for extracting control surface deflection axes for detailed modeling.
- Hinges or Combination Hinges provide more realistic control of component kinematics than simply combining Blanks.
  - Hinge parameters such as Rotate and Translate can be linked.
  - Hinge is used to define pin, cylinder, slide, etc. joints.

Combination Hinge Example

Six-Level Jointed Hinge, all hinges driven by single fraction

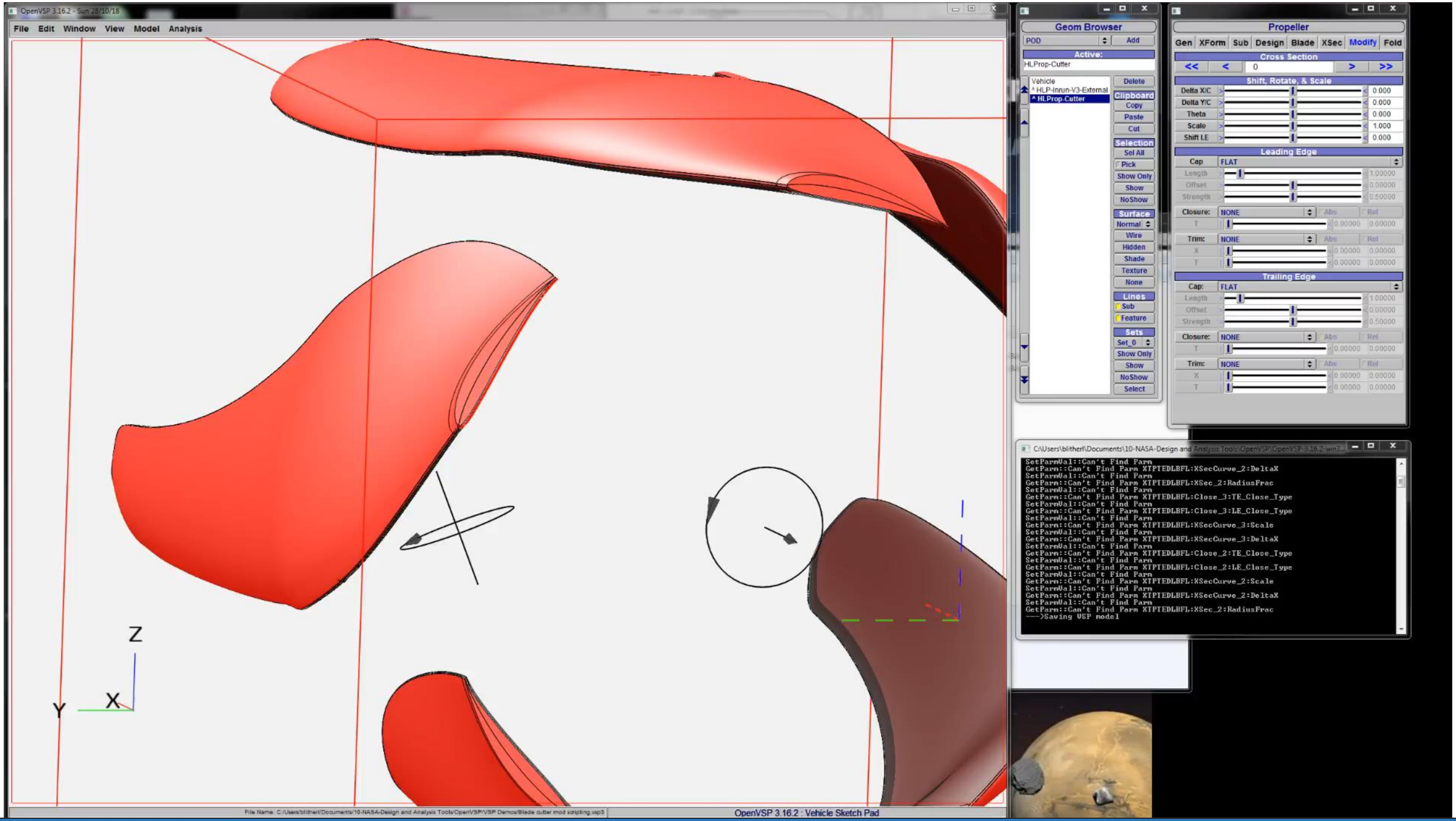


VSP Scripting

- Automatic component generation and modification
  - Rapidly alter configurations by changing chosen parameters and inputs.
  - **Drastically** reduces the time involved in modifying components by hand.
  - Ensures repeatable and accurate models are created.
  - Enables tightly controlled tolerances for creating CAD-ready geometries.
- Example case is the VSP Conformal Blades and Cutters:
  - Each Prop blade is defined by between 40 and 80 radial stations, depending on the inputs.
  - VSP struggles to update after each manual change.
  - Manually updating each propeller configuration would have been infeasible.
  - Scripting enabled the rapid generation of a family of prototype designs intended to reduce cost and save time.

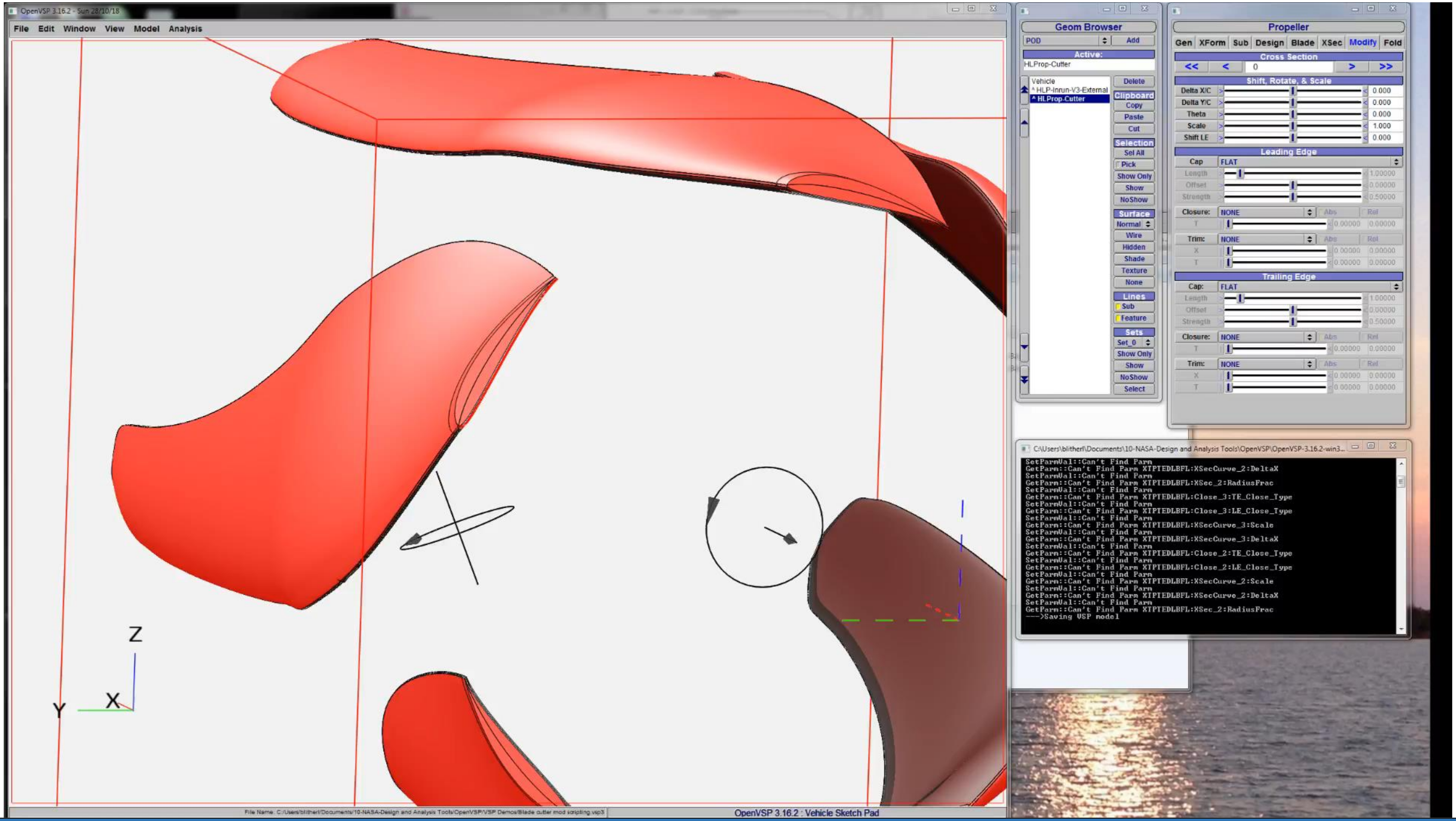
VSP Scripting - Comparison

High-Lift Propeller, 80 stations, 4 XSec Single Section Modify Example (~45 sec)



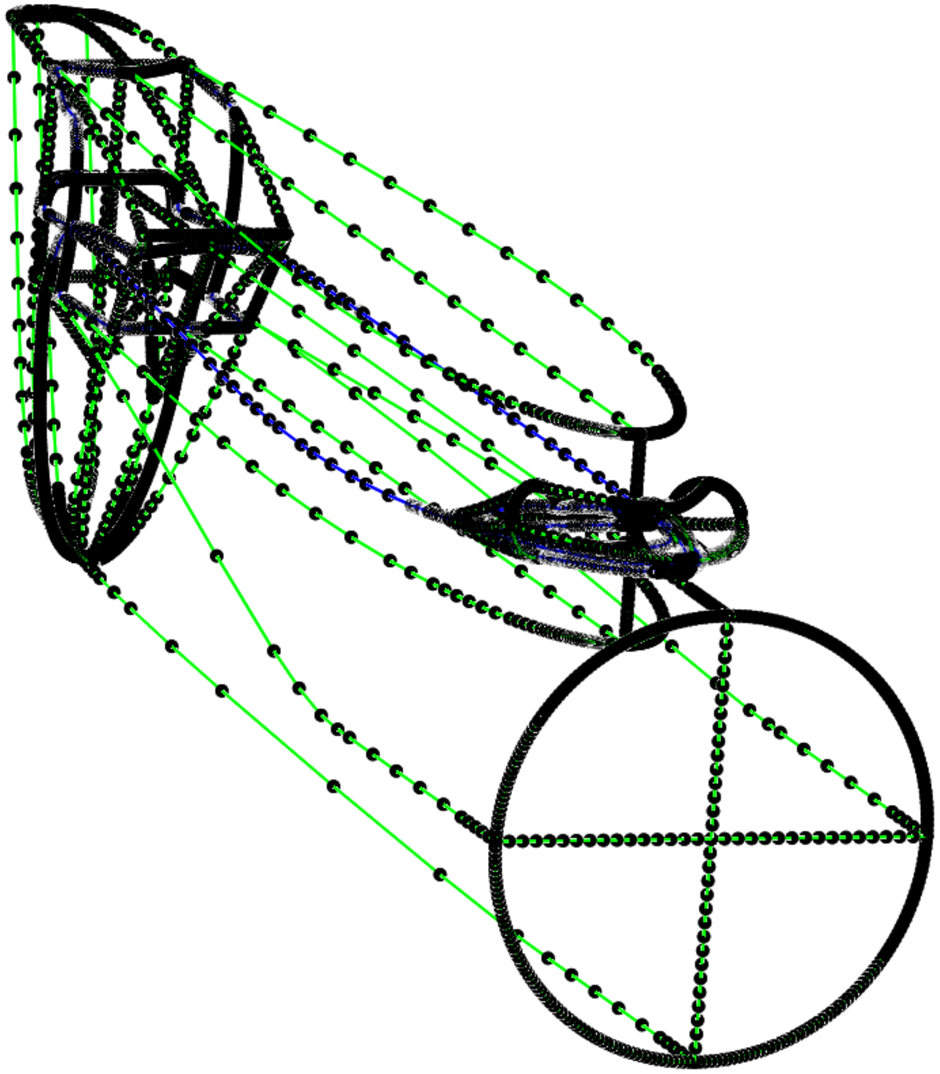
VSP Scripting - Comparison

High-Lift Propeller, 80 stations, 4 XSec   Scripted Blade Modify Example (~22 sec)



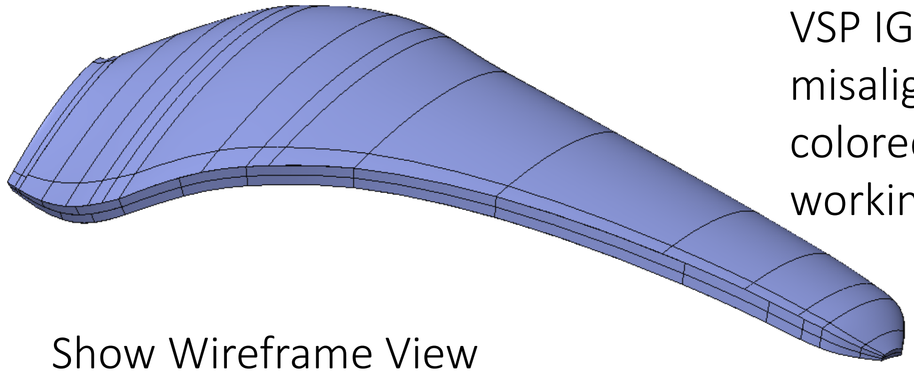
VSP Trimmed Surfaces

- VSP Analysis > Trimmed Surfaces saves some gridding effort by evaluating the surface intersections and trimmed surfaces for you.
- Exported as curves and PLOT3D format.
- Exported as trimmed CAD in IGS or STP.
- Similar to EGADS2SRF discussed later.



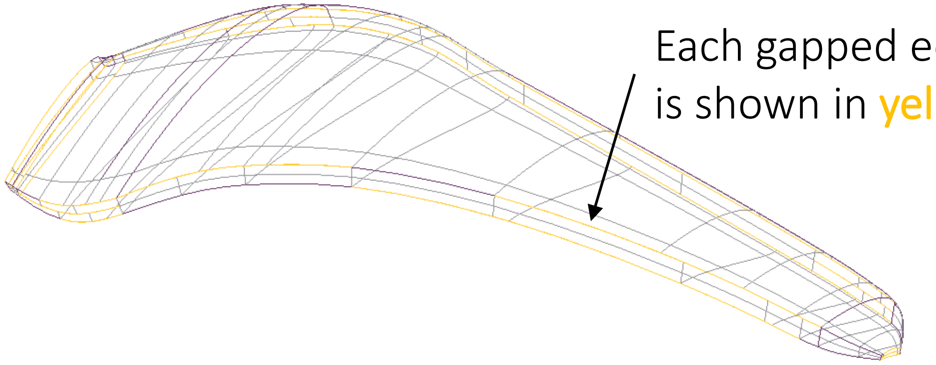
CAD

CAD: Healing Imported Surfaces



VSP IGES file may not import as a solid due to misaligned edges. In Creo, non-solid surfaces are colored blue by default. This is common even when working between different CAD programs.

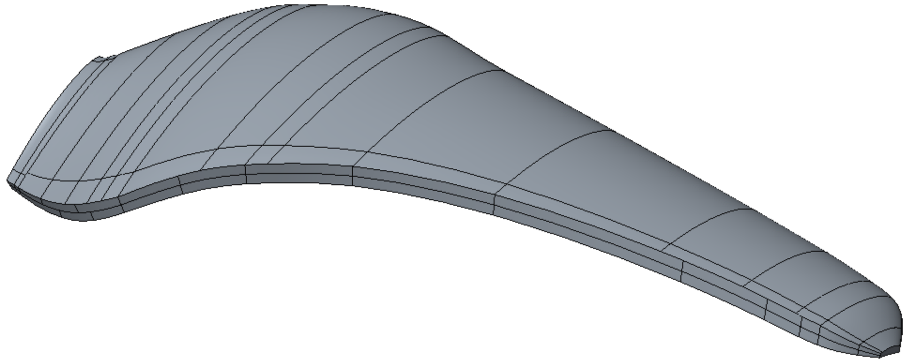
Show Wireframe View



Each gapped edge is shown in yellow.

Use CAD import repair tools to close these gaps and make the model watertight.

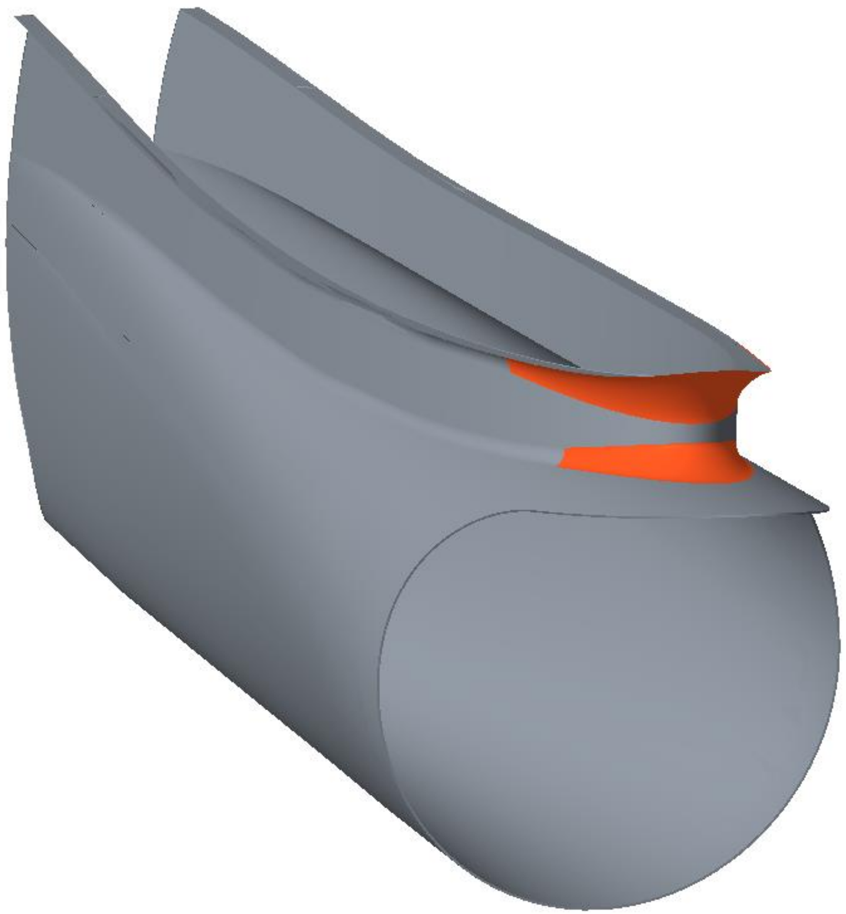
Creo: Import Data Doctor
SolidWorks: Import Diagnostics
NX: Examine/Heal Geometry
Autodesk: Heal Errors



Once the model is watertight, the surfaces are merged into a single, solid part. Creo will automatically color the part grey when solidified.

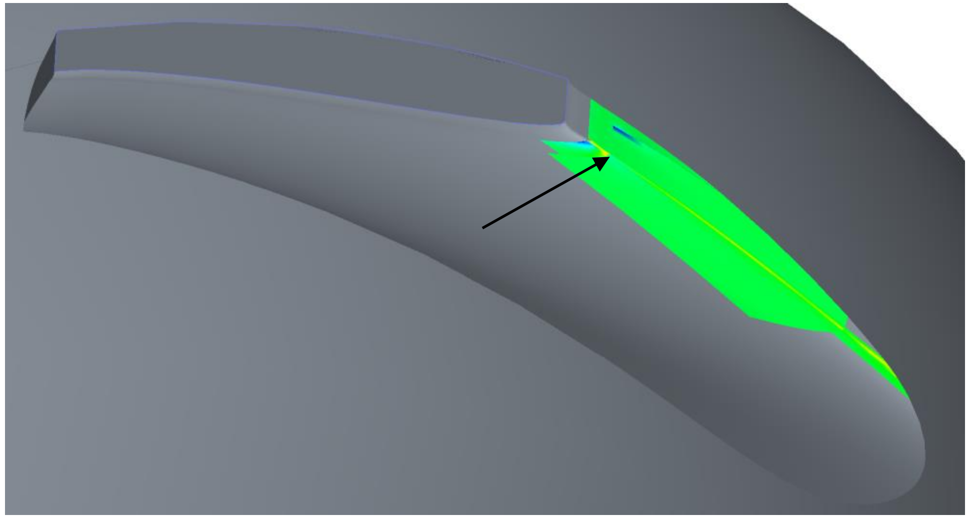
CAD: Adding Features

- Once the imported parts are solidified you can:
  - Add rounds and chamfers to more closely match the final intended design.
  - Blend surfaces together to adapt the model for easier grid generation.
  - Remove material as needed to resemble the machined part.



Exporting CAD for Gridding

- Beware of high-curvature surfaces and “pinched” regions.
  - These are difficult to detect but can sometimes be located by examining surface shading shadows.
  - Good practice is to perform a curvature analysis on the surfaces and look for twisted, pinched, or overlapping areas.



- Check your model accuracy and units prior to export.
- Most gridding tools will accept IGES/STEP as import.

GRIDS

EGADS2SRF

- Automatic grid generation from IGES/STEP
- Using Open-source MIT EGADS to interface CGT
  - Engineering Geometry Aircraft Design System as part of Engineering Sketch Pad (Haimes, Dannenhoffer)
- Manual location: https://www.nas.nasa.gov/publications/software/docs/chimera/pages/egads2srf.html
- Can be used with VSP IGES export but intended for CAD.
- Need to build in addition to CGT install.
- There are currently some issues with translation scaling when reading units other than millimeter.
  - For best results, scale the CAD model or VSP model to mm before exporting to IGES/STEP.
  - Resulting curves and surfaces are scaled back to original units in gridding tools.

EGADS2SRF

This tool is used to generate discrete surface representations of IGS, STEP, and EGADS/OpenCascade files using the open source EGADS Libray from MIT.

For each body in the geometry, the following files are generated:
rootname.i.tri - an unstructured surface triangulation.

rootname.triq - an unstructured surface triangulation with u,v parameter values at vertices of each CAD face.

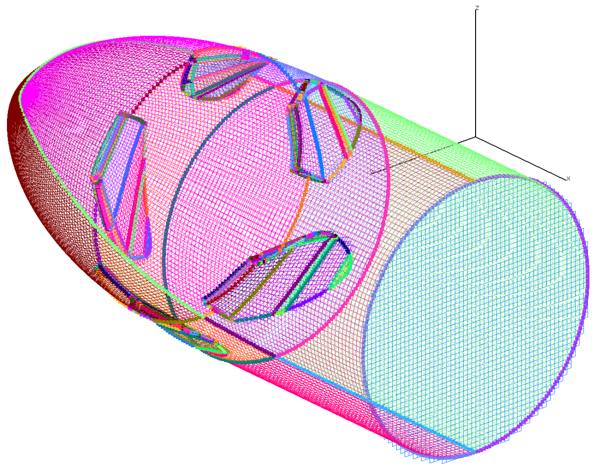
rootname.uvx - a set of structured surface patches.

rootname.uv - PLOT3D function file containing u,v values for vertices in rootname.uvx.

rootname.cur - CAD edges on geometry.

rootname.cuv - PLOT3D function file containing edge vertex u,v values for each edge

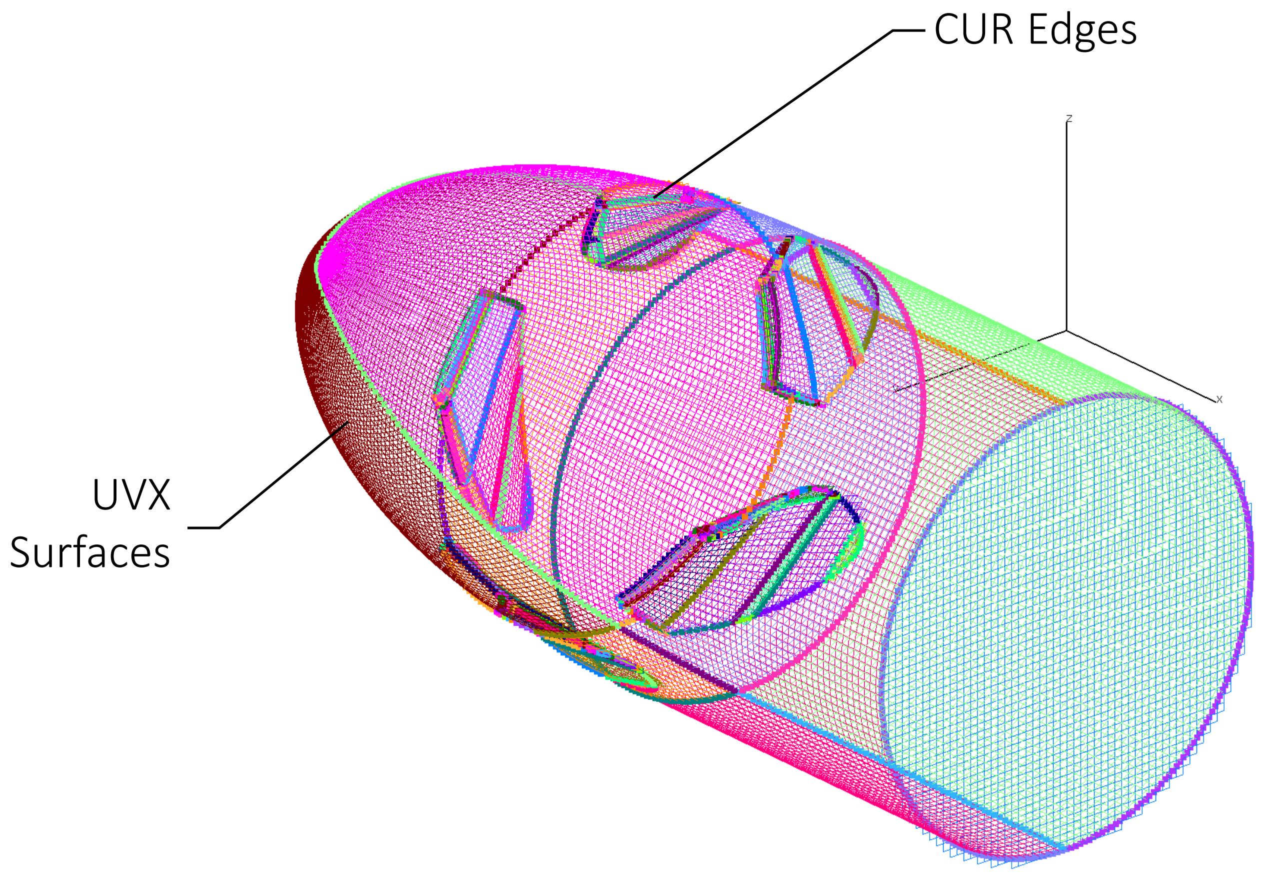
rootname.topo - ASCII text file containing topological information for faces and edges



See backup slides for details and use.

EGADS2SRF

CAD detail features brought into CGT using EGADS2SRF

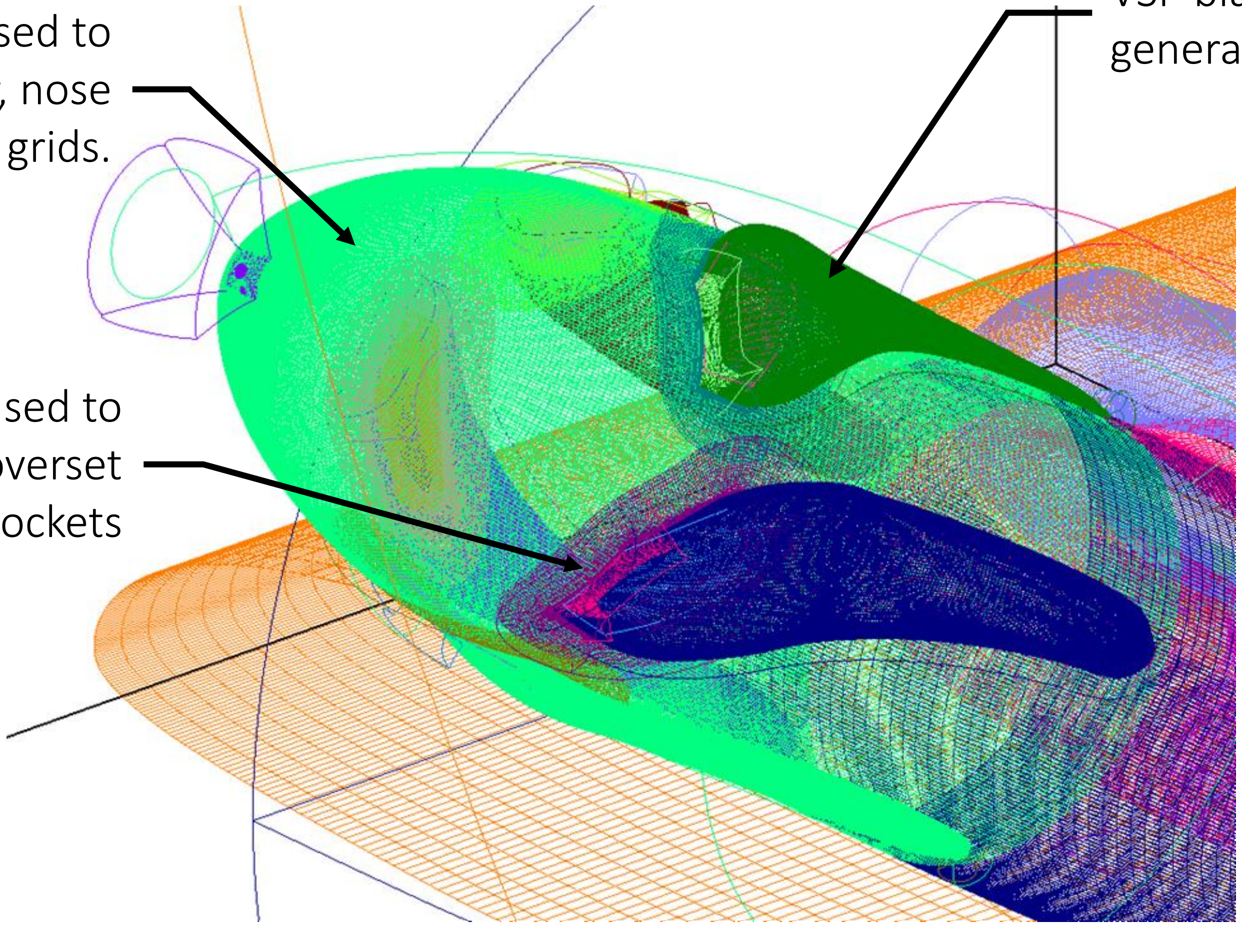


Resulting Grid System

End result is a combination of various sources.

VSP nacelle used to create spinner, nose cap, and nacelle grids.

UVX surfaces used to grow and project overset grids into pockets



VSP blades used to generate blade grids

Because VSP was the original source, all of these parts integrate seamlessly!

Other Tips/Tricks

- VSPAERO flow field query
  - https://groups.google.com/forum/#!topic/openvsp/8TF3DCy7BWA
  - Add the following to the vspaero file and run from command
  - NumberofSurveyPoints = n

```
1  x1  y1  z1
2  x2  y2  z2
3  x3  y3  z3
4  x4  y4  z4
...
n  xn  yn  zn
```

Other Tips/Tricks

- New Prop feature allows representing as Disk
  - Can change Prop parms while in disk mode without updating surface.
  - Much faster control and parm entry.
  - Return to Prop mode to display changes.

Thank you!

Questions?

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EGADS2SRF

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For each body in the geometry, the following files are generated:

rootname.i.tri - an unstructured surface triangulation.
(one entity in intersected CART3D.i.tri format)

rootname.triq - an unstructured surface triangulation with u,v parameter values at vertices of each CAD face.
(NFACE entities in CART3D .triq format)

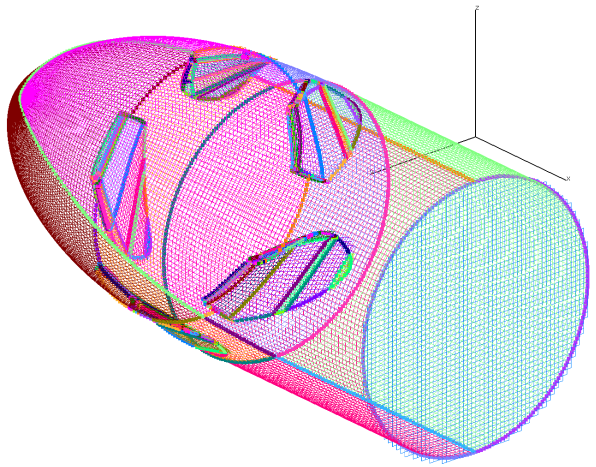
rootname.uvx - a set of structured surface patches from forward evaluation of auto-determined parameter space locations driven by max dihedral angle, max cell size, and max chordal deviation inputs. Iblanks at vertices are used to indicate trimmed regions while partially trimmed cells are retained.
(NFACE surface grids in PLOT3D format)

rootname.uv - PLOT3D function file containing u,v values for vertices in rootname.uvx.
(fun 1 = u value, fun 2 = v value)

rootname.cur - CAD edges on geometry.
(NEDGE surface curves in PLOT3D format)

rootname.cuv - PLOT3D function file containing edge vertex u,v values for each edge
(fun 1,2 = u,v on face 1 associated with edge,
fun 3,4 = u,v on face 2 associated with edge,
u=v=0 if face 2 is empty as on open boundary)

rootname.topo - ASCII text file containing topological information for faces and edges



EGADS2SRF

Usage:

egads2srf [-i ifile] [-maxa maxang] [-maxc maxchord] [-maxe maxedge] [-smedge smalledge] [-epst epstd] [-u units] [-help]

All arguments are optional. If omitted, the defaults in the following table are used. A log file called "egads2srf.log" is automatically generated that contains the most recent command line arguments.

Argument	Description	Default
ifile	input file containing geometry (igs or step)	(not read)
maxang	Max allowed dihedral angle in degrees	10.0
maxchord	Max allowed chordal deviation (> 0 take value as input; < 0 take absolute value times global bounding box diagonal arc length as input)	-0.001
maxedge	Max allowed arc length of triangle edge or structured mesh spacing (> 0 take value as input; < 0 take absolute value times global bounding box diagonal arc length as input)	-0.025
smalledge	Remove edges smaller than smalledge	0.0
epst	Extend uv bounding box of triangles by epst * triangle bounding box diagonal (increase this parameter slightly to unblank more points on uv structured patches)	0.01
units	Convert output grid files to different unit assuming input geometry has been interpreted in mm. Use this option only if egads2srf could not determine units from input geometry file (in/ft/m/cm)	(no conversion)