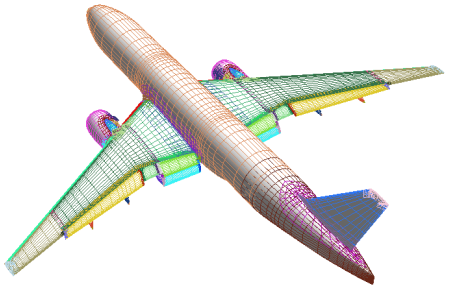
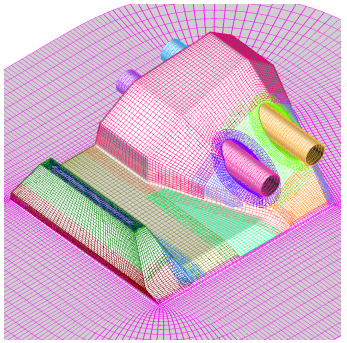
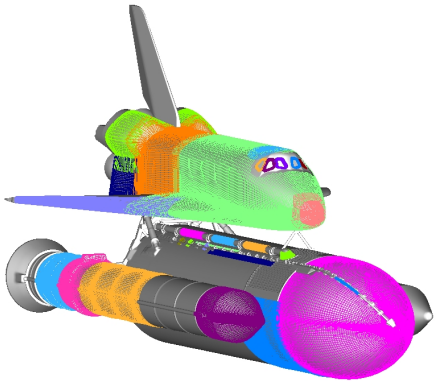
Ames Research Center



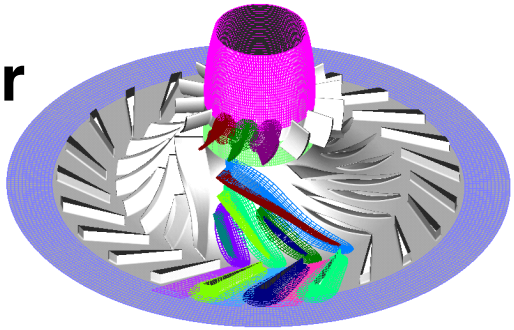
CHIMERA GRID TOOLS TUTORIAL



William M. Chan and Shishir A. Pandya



NASA Ames Research Center



12th Symposium on Overset Composite Grids and Solution Technology,
Atlanta, Georgia, October 6 - 9, 2014

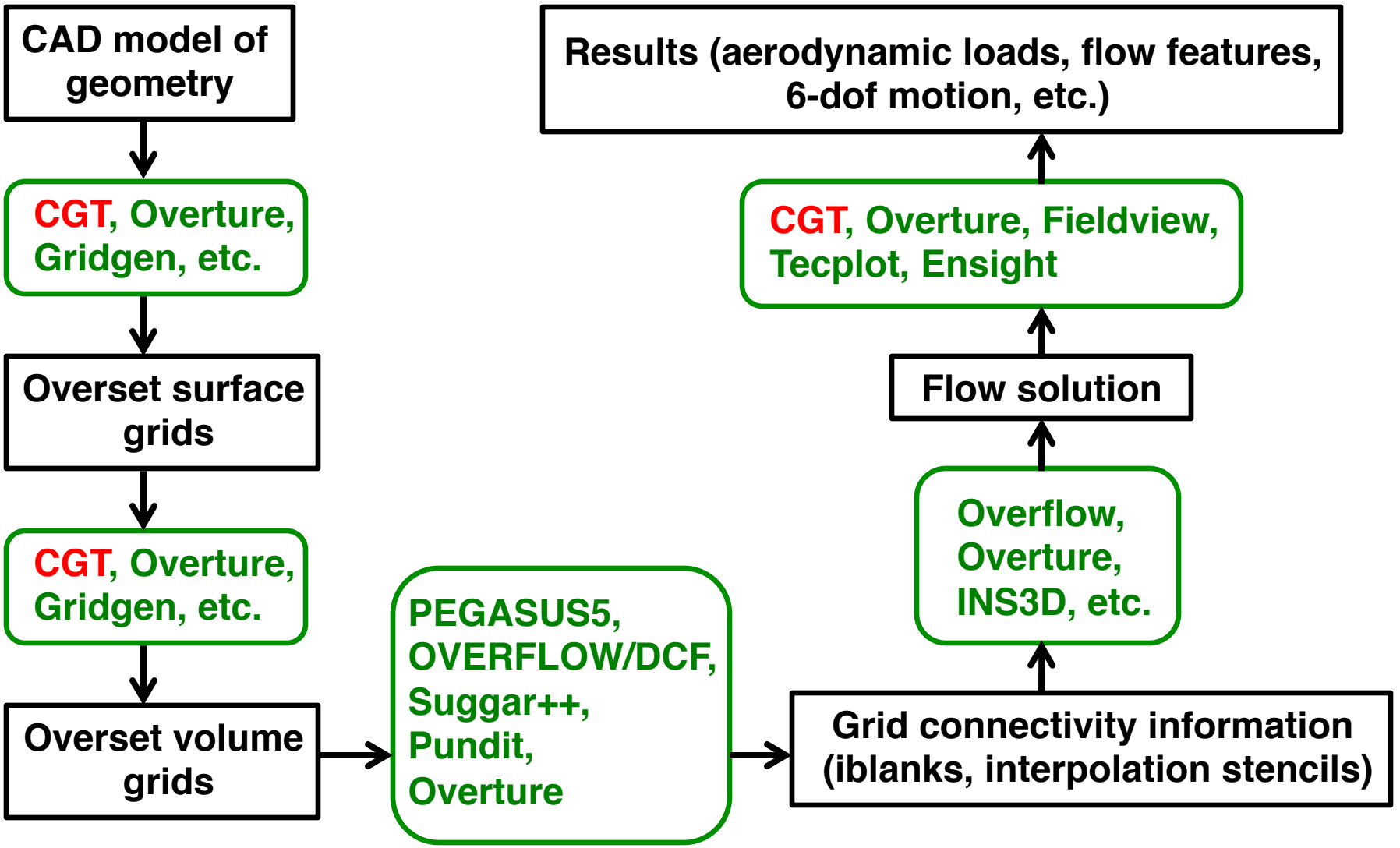
OVERVIEW

- Chimera Grid Tools (CGT)
  - Introduction
  - Pre-processing
  - Post-processing

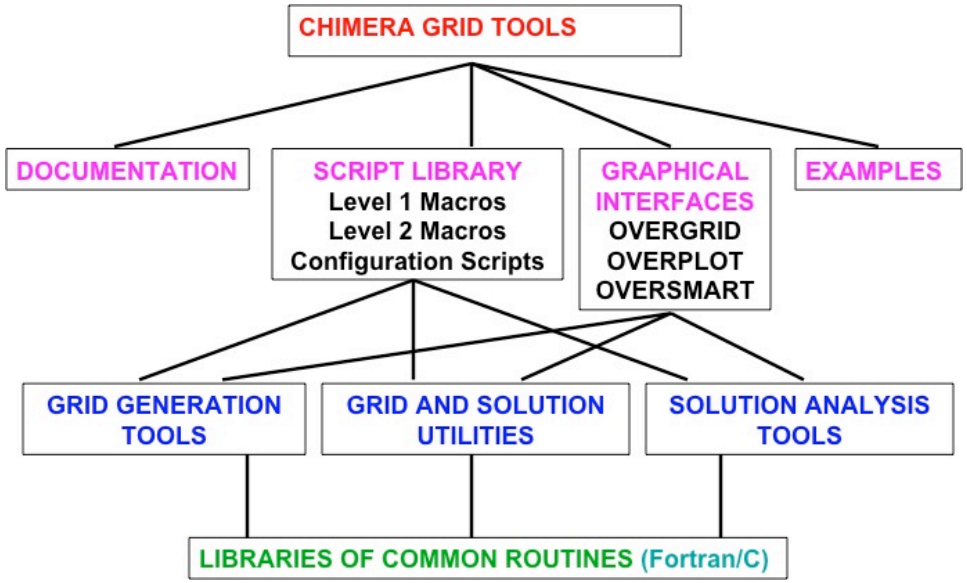
- Demos
  - OVERGRID (brief overview, grid generation utilities, grid connectivity diagnostics, solution viewer)
  - Pre-processing script creation (rocket example)
  - TRILOAD line loads integration tool

A more detailed OVERGRID demo is available at:
The OVERGRID Graphical User Interface in Chimera Grid Tools (Parts 1, 2, 3)
http://www.nas.nasa.gov/publications/ams/2014/05-13-14.html
http://www.nas.nasa.gov/publications/ams/2014/05-20-14.html
http://www.nas.nasa.gov/publications/ams/2014/05-29-14.html

TYPICAL MODELING AND SIMULATION PROCESS USING OVERSET GRIDS



CHIMERA GRID TOOLS (CGT) Version 2.1



What is CGT

- A collection of software tools for pre- and post-processing of overset grid CFD computations

Authors

- William Chan, Stuart Rogers, Shishir Pandya, David Kao, Pieter Buning, Robert Meakin, David Boger, Steve Nash

Availability

- U.S. citizens/permanent residents working under U.S. organization in the U.S.
- Fill out and return Software Usage Agreement form
- Source (Linux, Unix, Mac OS-X)
- Executables (Mac 10.5, Windows-XP)
- Version 2.1+ available for use by authors' associated projects

INSTALLATION, DOCUMENTATION, TUTORIALS

Installation software requirements

- Fortran 90 compiler (ifort, pgf90, gfortran 4.4+)
- C compiler (gcc, icc, pgcc)
- OpenGL, X11, Tcl/Tk libraries (OVERGRID)
  Tcl/Tk 8.5.8 or earlier for CGT 2.1
  Tcl/Tk 8.6.2 or earlier for CGT 2.1+
- Python, swig, matplotlib package or gnuplot (OVERSMART)
- Tcl wish, xmgrace or gnuplot (OVERPLOT)

Installation instructions

- chimera2.1/doc/{INSTALLATION.html, overgrid.html}

Documentation

- chimera2.1/doc/man.html

Recommended tutorials

- chimera2.1/gui/tutorial/* (OVERGRID)
- chimera2.1/examples/scriptlib/* (CGT script library)

EXECUTABLES

Run configure script to generate Makefiles

configure -- help **(get list of options)**

Executables
- **single precision**
- **double precision**
- **og (overgrid executable)**
- **smart.so (oversmart shared library)**

Big/little Endian
- **controlled by compiler flag (pgf90)**
- **controlled by environment variable (ifort, gfortran)**
- **conversion using p3dConvert or overConvert**

OVERGRID can auto-detect single/double precision, big/little endian

PRE-PROCESSING STEPS AND BEST PRACTICE

Task: Given complex geometry definition, create input files needed for overset grid CFD analysis

- Grid file containing overset volume grids and iblanks
- Connectivity file containing fringe points, donor stencils, interpolation coefficients
- Flow solver input file with boundary conditions for each grid
- Input file for performing forces and moments integration on components of interest
- Input files for coupled physics
  - Prescribed/6-DOF input files for relative motion problems
  - Species convection
  - Structural deformation

Best practice:

- Develop pre-processing script to create all input files needed above
- Use CGT's OVERGRID to check and visualize individual steps
- Use CGT's Script Library to record steps into script

PRE-PROCESSING USING CGT

Geometry Creation and Manipulation

Surface Grid Generation

- on triangulation or CAD
- algebraic, hyperbolic

Volume Grid Generation

- near-body curvilinear (hyperbolic)
- off-body Cartesian

Domain Connectivity Inputs

- Xray map creation and hole-cut instructions
- PEGASUS5

Flow Solver Inputs (OVERFLOW)

- boundary conditions
- component hierarchy and prescribed/6-DOF dynamics
- prescribed dynamics animation (overgrid)

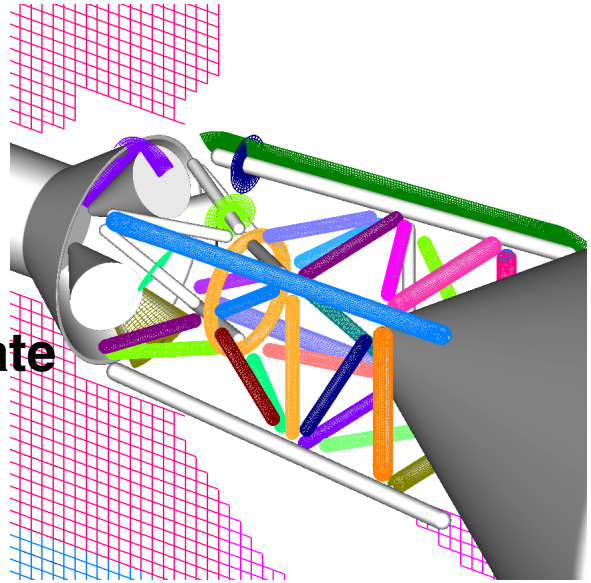
GEOMETRY CREATION

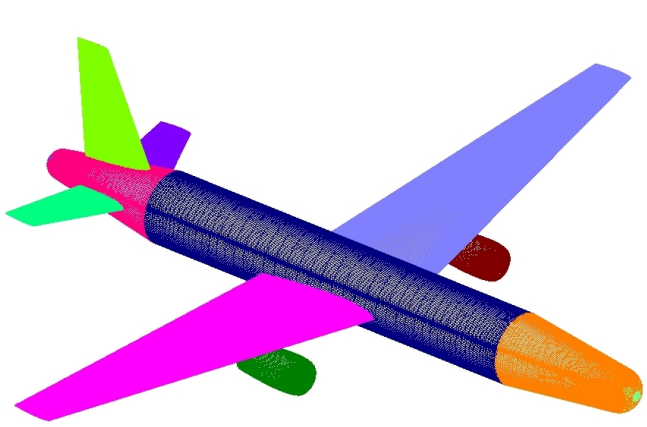
Script Library has macros to create

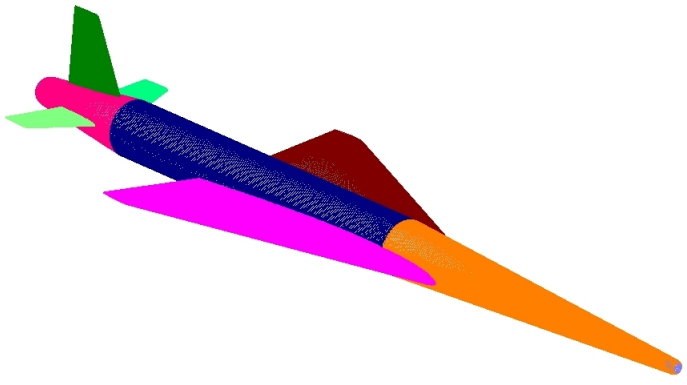
- Points
- Straight lines
- Analytic curves
- Cylinders
- Frustums
- Cartesian boxes
- Airfoil shapes
- > NACA 4 and 5 digit series
- > PARSEC (CGT 2.1+)

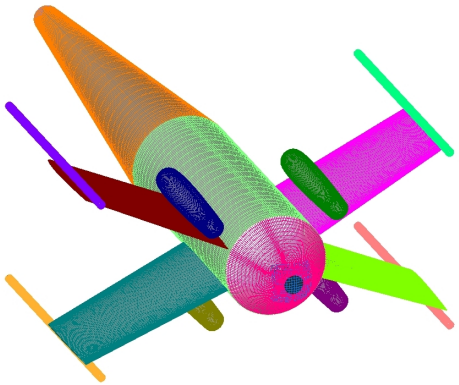
Combine with basic macros to generate more complex shapes

- Translate
- Scale
- Rotate
- Mirror
- Extract
- Concatenate
- Revolve
- Duplicate









GEOMETRY INPUT

Native CAD (Pro-E, Catia V5, Parasolid, OpenCASCADE, SolidWorks, UniGraphics, FELISA, STEP)

- Use CAPRI library (CADNexus) as interface to convert native CAD parts into surface triangulations
- Need CAD license and CAPRI users license
- CGT surface grid generator has option to project back to original CAD but usually a fine surface triangulation is sufficient

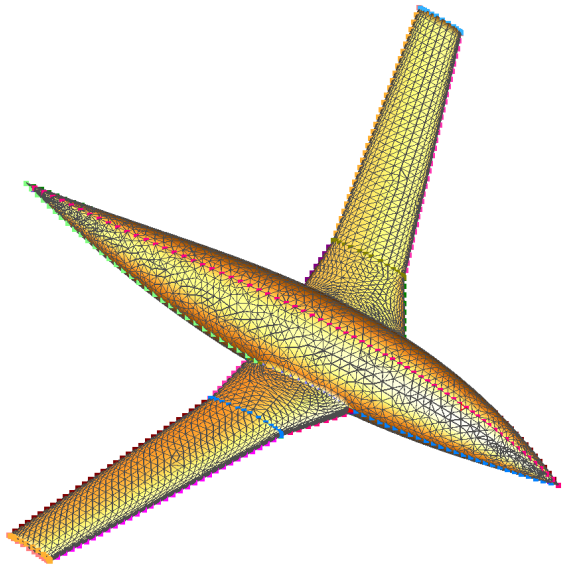
STEP, IGES

- Solids can be converted to BRep, then use CAPRI as interface to convert to surface triangulations

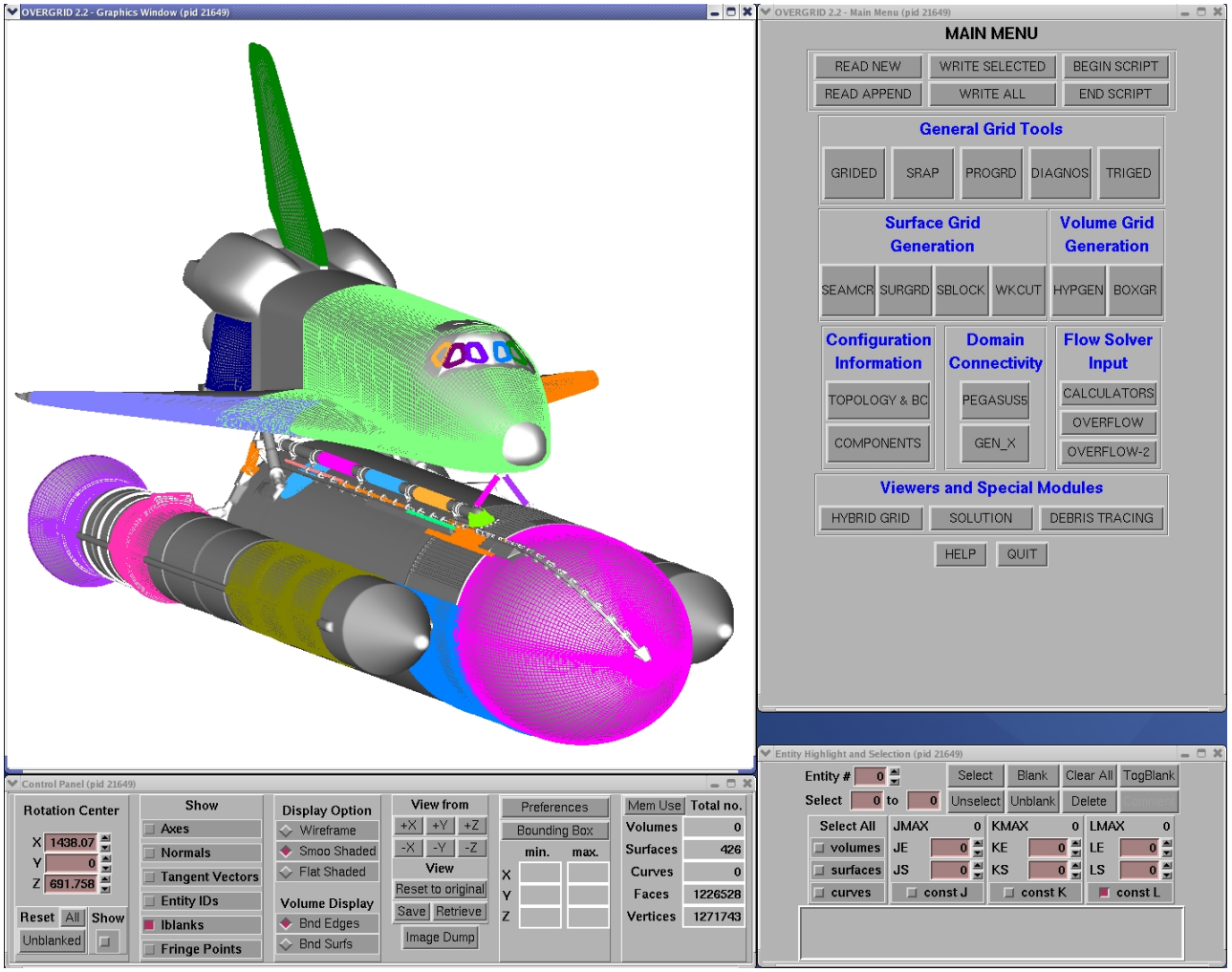
Surface Triangulation

- CART3D (.tri, .triq) (.trix in CGT 2.1+)
- UCD (.ucd)
- FAST (.fst)
- STL (.stl), FRO (.fro) (CGT 2.1+)

Structured Surface Grids (PLOT3D format)



OVERGRID



- CAD interface via CAPRI
- Geometry/grid processing (structured quads, triangulations)
- Grid processing, redistribution, projection
- Surface and volume grid generation (TFI, hyperbolic, Cartesian)
- Hole cutter generation
- Grid diagnostics
- Flow solver inputs and b.c. preparation
- Multi-component dynamics input/animation
- Standard atmosphere, mass properties, 6-dof input calculators
- Simple solution viewer
- Debris trajectory inputs
- Strand/AMR Cartesian grid viewer

Supported platforms – Linux, Mac OS-X,Windows-XP

CGT SCRIPT LIBRARY

Tcl macros -10x more compact scripts, > 3x faster development time

Low – Mid Level

- File manipulation (e.g., combine files, format conversion,…)
- Geometry creation (e.g., points, lines, analytic curves, cylinders,...)
- Grid information (e.g., interrogate grid dimensions, coordinates, arc lengths, formats,…)
- Grid editing (e.g., extract, concatenate, split, duplicate, swap/ reverse indices, scale, translate, rotate, mirror, revolve, …)
- Grid redistribution
- Surface grid generation (TFI and hyperbolic)
- Volume grid generation (hyperbolic and Cartesian)
- X-ray hole cutter generation and hole cut instructions creation
- Pegasus5 input preparation
- Force/moments computation inputs
- OVERFLOW boundary conditions inputs and namelist i/o

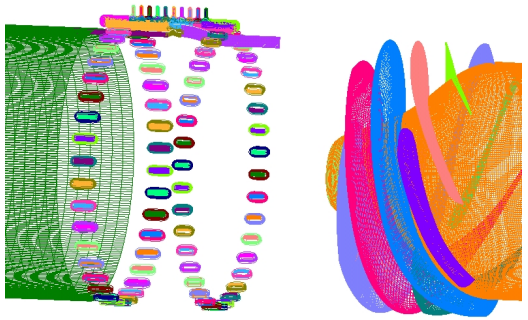
Top Level

- Grid-based approach (Configuration Management Scripts, peg5)
- Component-based approach (duplicated/moving comp., X-rays)

PRE-PROCESSING STRATEGY USING SCRIPTS

Scripting approach

- rapid replay of all steps
- easy to parameterize inputs (e.g., grid stretching, spacings, etc.)
- easy to make small changes
- recommended even for one-of-a-kind cases
- modification needed if surface topology changes



Surface Grid Generation

- generate grids from
  - surface triangulation (from CAD, or supplied)
  - surface feature curves (from CAD, supplied, or manually created)

Volume Grid Generation

- near-body hyperbolic grids, off-body Cartesian grids

Domain Connectivity, Force/Moments Computation, Flow Solver Inputs

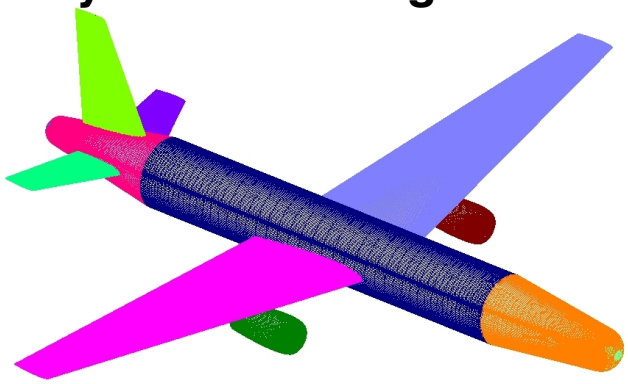
- construct and store common database in script
  (boundary conditions, component definitions, etc.)

DISTRIBUTED TEAM-BASED SCRIPT DEVELOPMENT

- Identify components of a complex configuration

- A component is a geometric part and may be modeled by one or more grids

- Create stand-alone script for each component
  - generation of surface and volume grids
  - domain connectivity inputs (X-ray maps)
  - solver boundary conditions
  - forces and moments integration inputs



- Each component script can be created by different developers

- Use file repository system to update script so that each team member can get most up-to-date version of each script

- Share global parameters file (e.g., wall spacing, global spacing, str. ratio, etc.)

- Each developer is responsible for grid connectivity of individual component

- Create master script to call component scripts, assemble final grid system, generate input files for domain connectivity, force/ moment integration, flow solver

POST-PROCESSING USING CGT

Forces and Moments Computation (mixsur/overint, usurp)

Solution Convergence Analysis

- solution/turb. model residuals, forces/moments
- one page overview (oversmart)
- individual plots (overplot)

Flow Visualization (overgrid)

- scalar and vector functions
- turb. model dependent variables, species partial densities
- unsteady 2-D movies

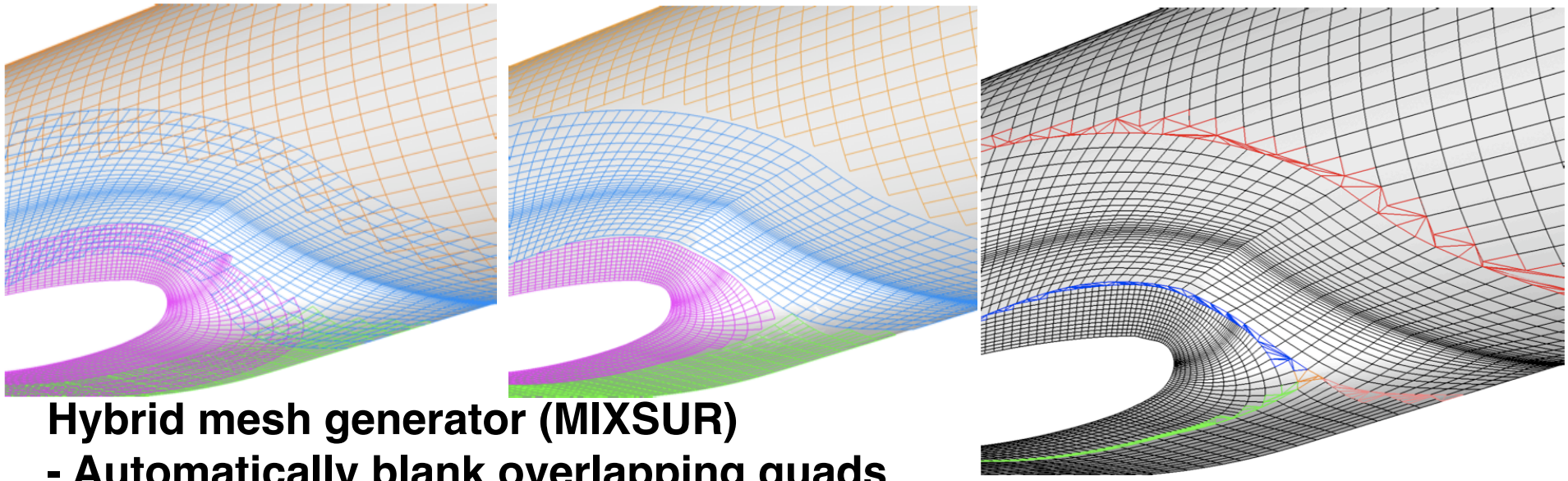
Component Line Loads (triload)

- cumulative line loads
- sectional Cp

Dynamics Animation (overgrid)

- 6-DOF dynamics output from flow solver

FORCES/MOMENTS INTEGRATION APPROACH 1 – INTEGRATE ON HYBRID SURFACE MESH
CGT Modules: MIXSUR, OVERINT



Hybrid mesh generator (MIXSUR)
- **Automatically blank overlapping quads**
- **Automatically fill narrow gap with triangles**
- **Very fast but may sometimes contain a few bad triangles (200 surface grids, 2 million+ surface pts, 22 sec., 1 proc.)**

Integration tool (OVERINT)
- **Integrates on non-overlapping quads and triangles**
- **Integrates linear function exactly**

Chan, W. M., Enhancements to the Hybrid Mesh Approach to Surface Loads Integration On Overset Structured Grids, AIAA Paper 2009-3990

OVERINT OUTPUT FILES (RECENT DEVELOPMENTS)

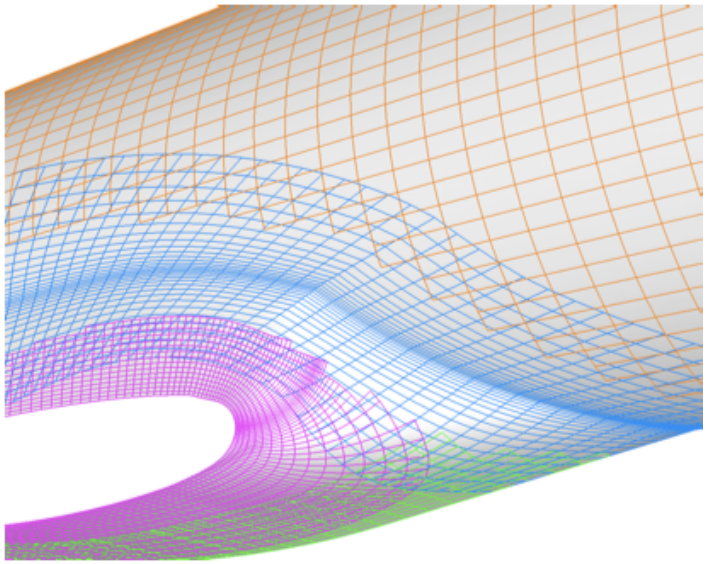
- Surface distributions of local forces and moments

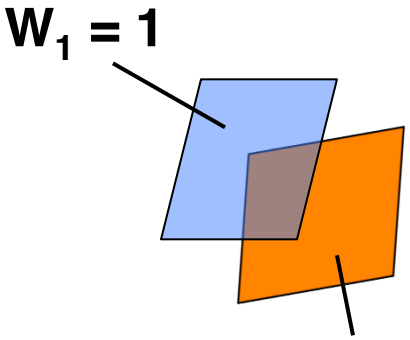
- Four unstructured surface triangulation files, each with cell-centered scalar variables (extended CART3D .i.tri format)

  (1) Cell ΔF
  (2) Cell ΔF / Cell area
  (3) Cell ΔM
  (4) Cell ΔM / Cell area

- Scalars: X, Y, Z components of forces/moments
  total magnitude, pressure, viscous, momentum contributions
  local cell area

FORCES/MOMENTS INTEGRATION APPROACH 2 – INTEGRATE ON WEIGHTED QUADS
CGT Module: USURP





Polygon subtraction in 3-D

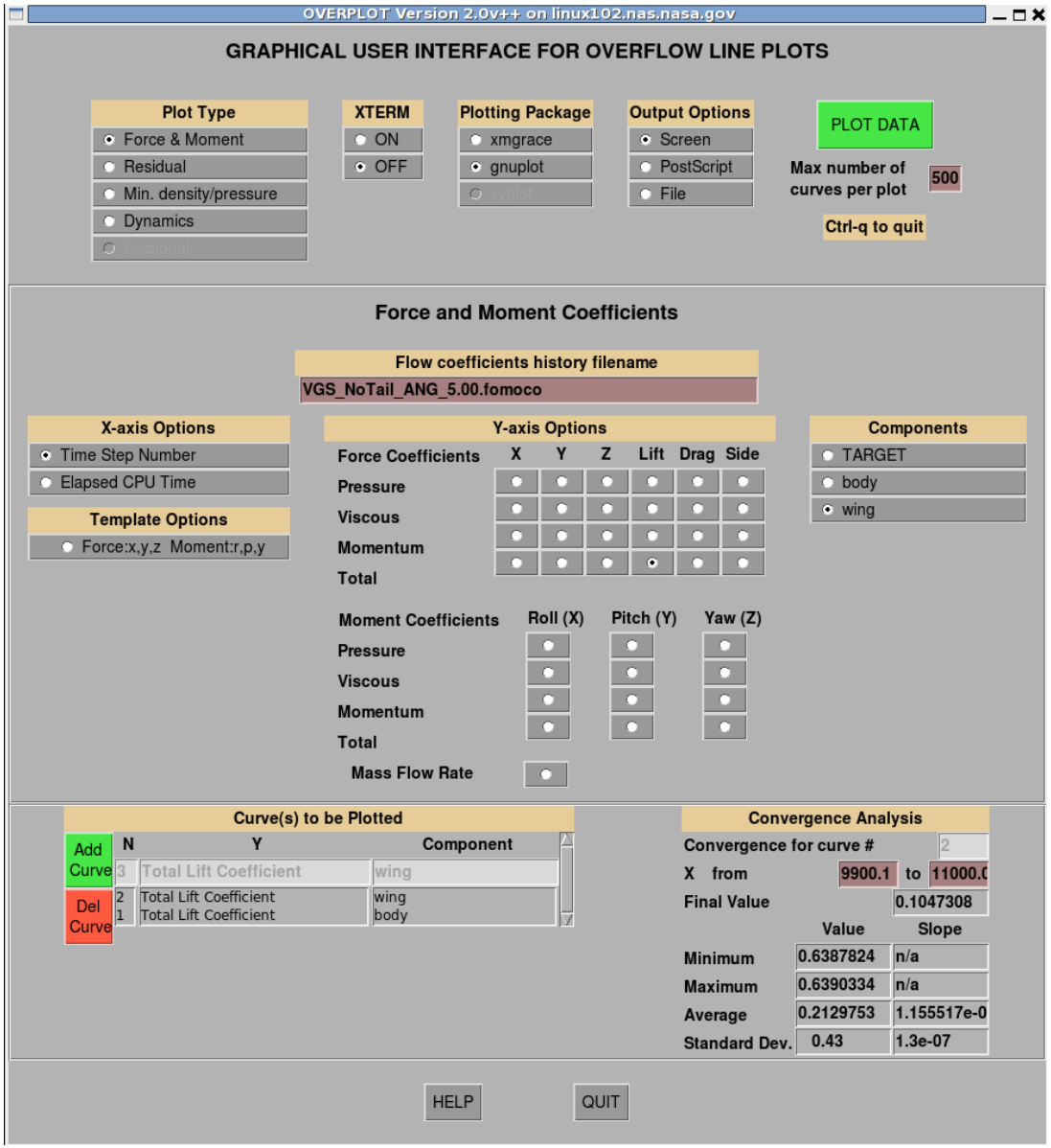
$W_2 = (A_Q - A_{OV})/A_Q$

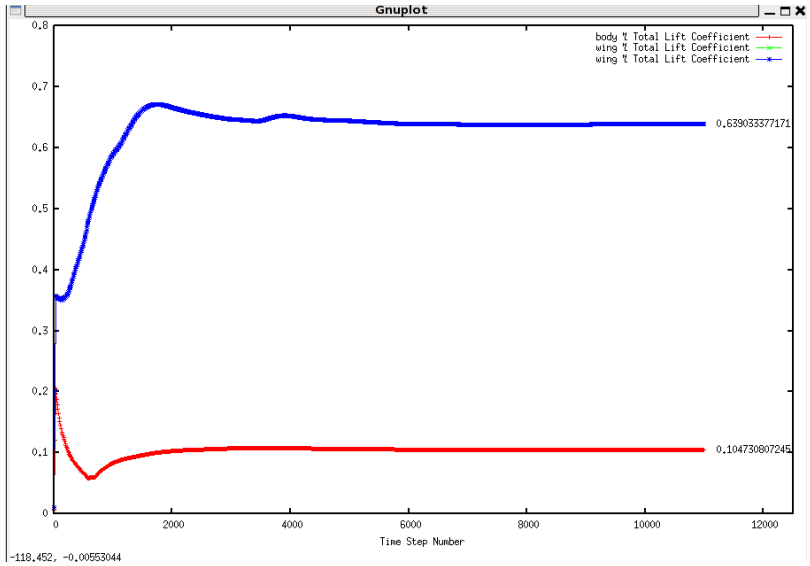
A_Q = Area of quadrilateral
A_{OV} = Area of overlap

Quad panel weights calculator and integrator (USURP)
- Automatically computes panel weight for each quad
- Always returns a result by integrating over all quads
- No hybrid mesh => no visual checks
- Does not integrate linear function exactly
- Also has standalone and OVERFLOW modes

Boger, D. and Dreyer, J., Prediction of Hydrodynamic Forces and Moments for Underwater Vehicles Using Overset Grids, AIAA Paper 2006-1148

SOLUTION CONVERGENCE ANALYSIS: OVERPLOT
Forces/Moments Panel (.fomoco)

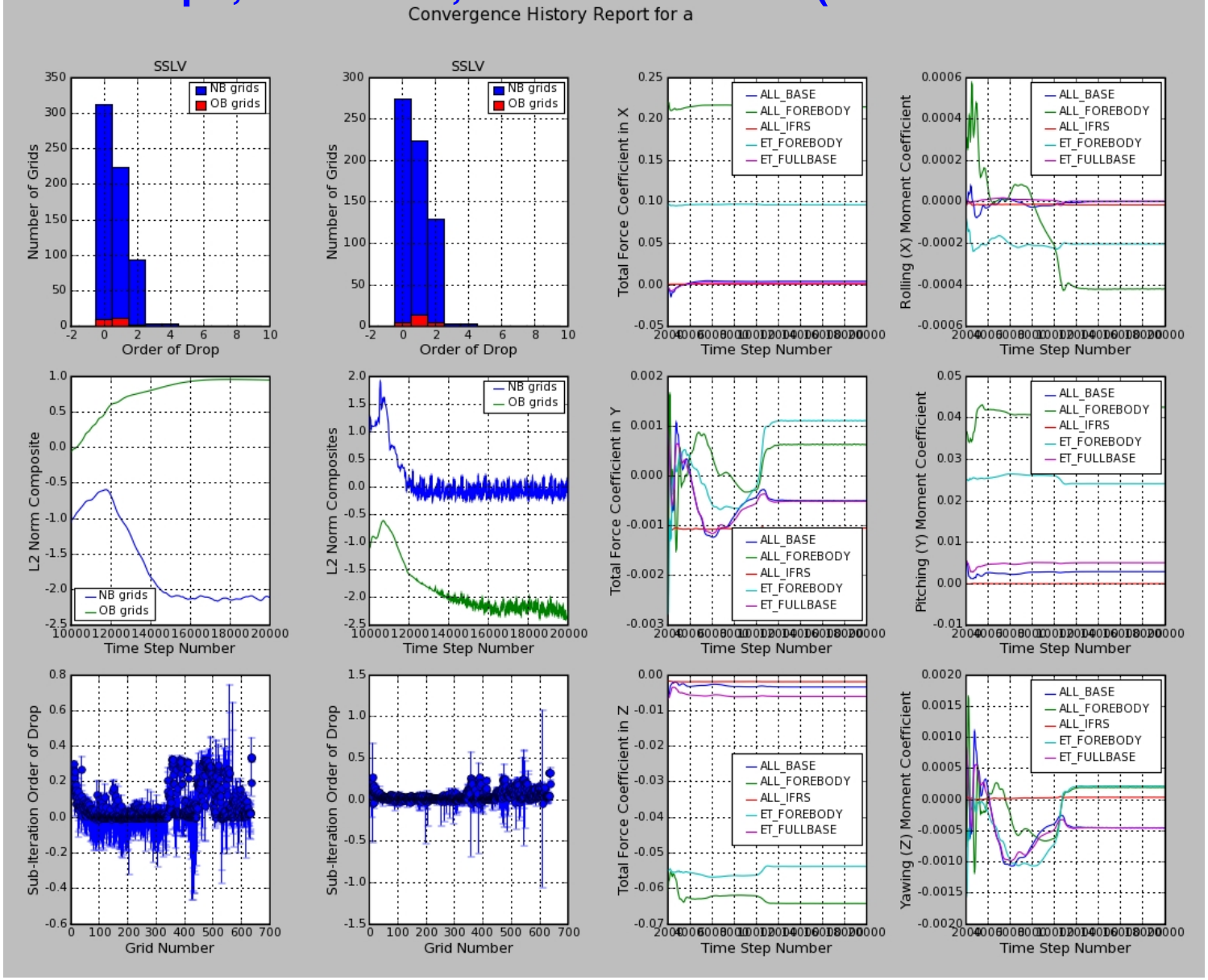




- **Single coef. plot with option to add more coefs.**

- **Six coef. matrix plot (Fx, Fy, Fz, Mx, My, Mz)**

SOLUTION CONVERGENCE ANALYSIS: OVERSMART SUMMARY PAGE
Space Shuttle Launch Vehicle
10,000 Time Steps, 636 Grids, 3-Sub-iterations (resid file: 19 million lines)



SOLUTION VISUALIZATION

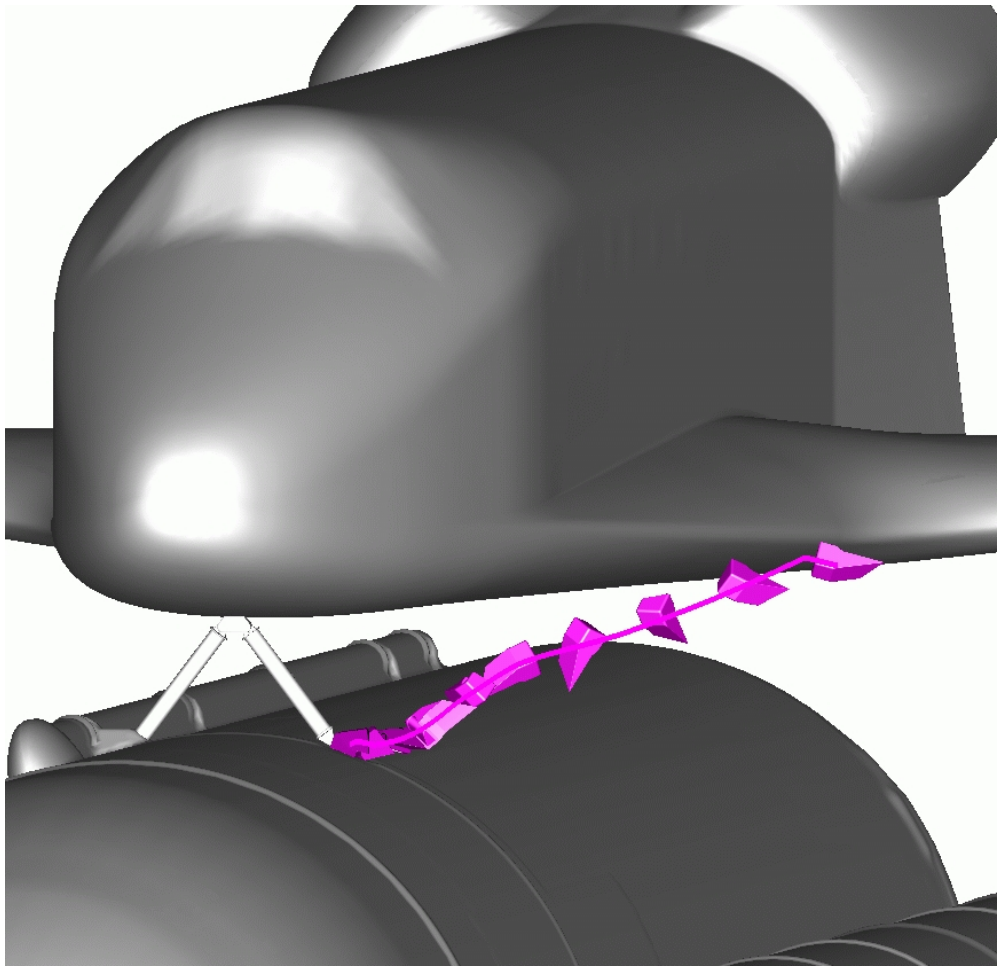
- 6-DOF component trajectories

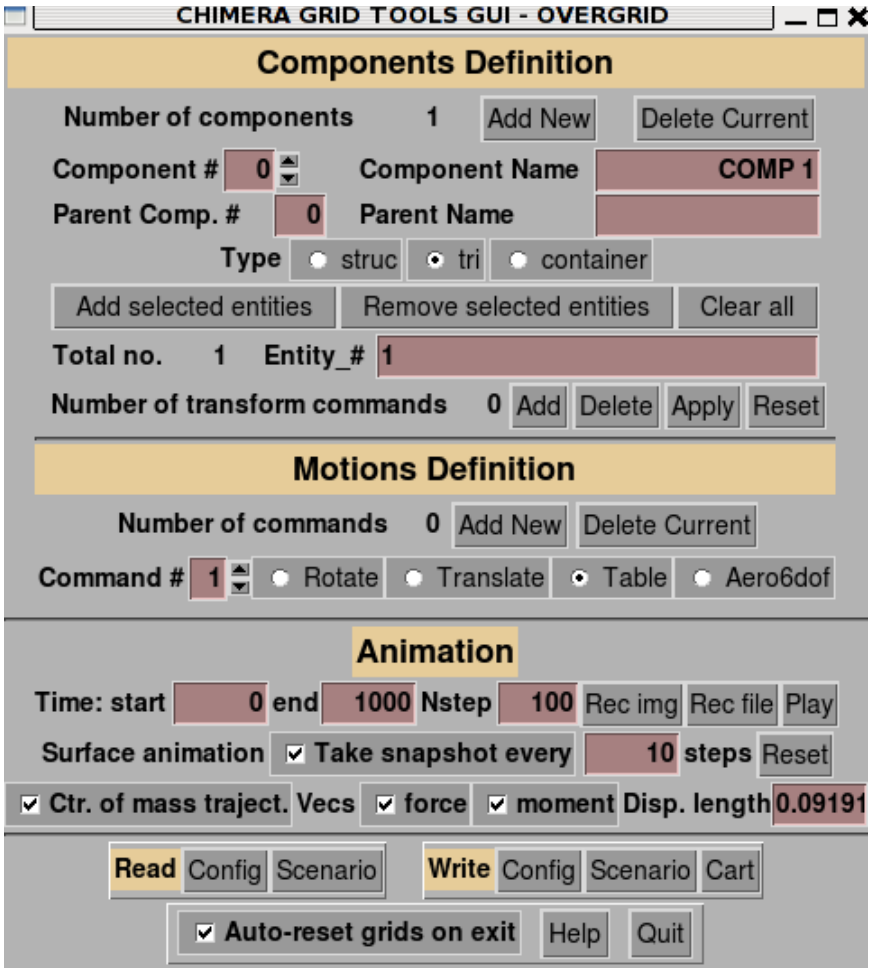
- Flow variables

  - Surface triangulations
    - vertex and cell-centered scalars

  - Overset structured surface and volume grids
    - steady (scalars and vectors)
    - unsteady (scalars)
    - 2-D moving body with adaptive grids (scalars)

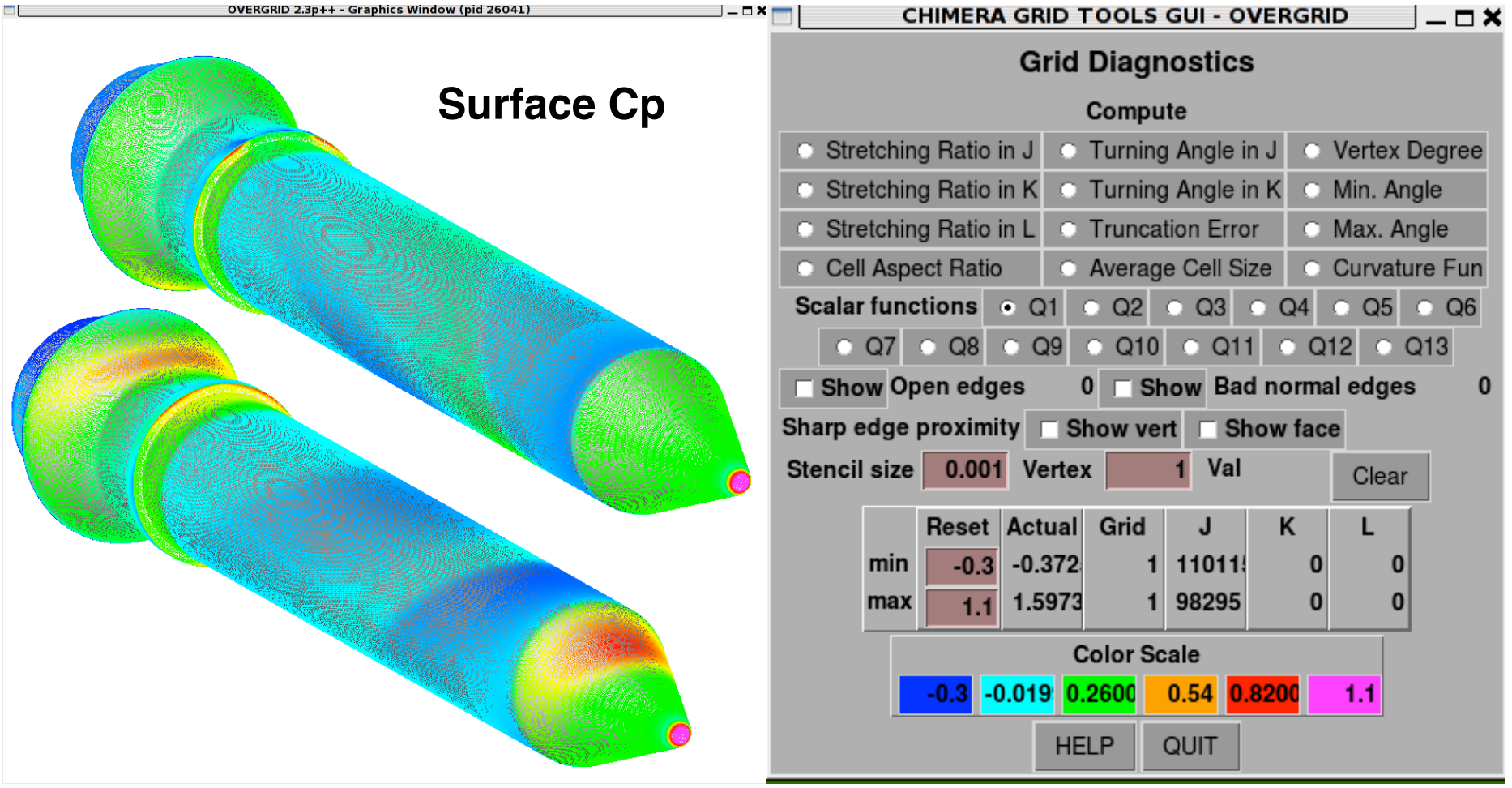
COMPONENT TRAJECTORIES VISUALIZATION FROM SIX-DOF COMPUTATIONS (OVERGRID module)





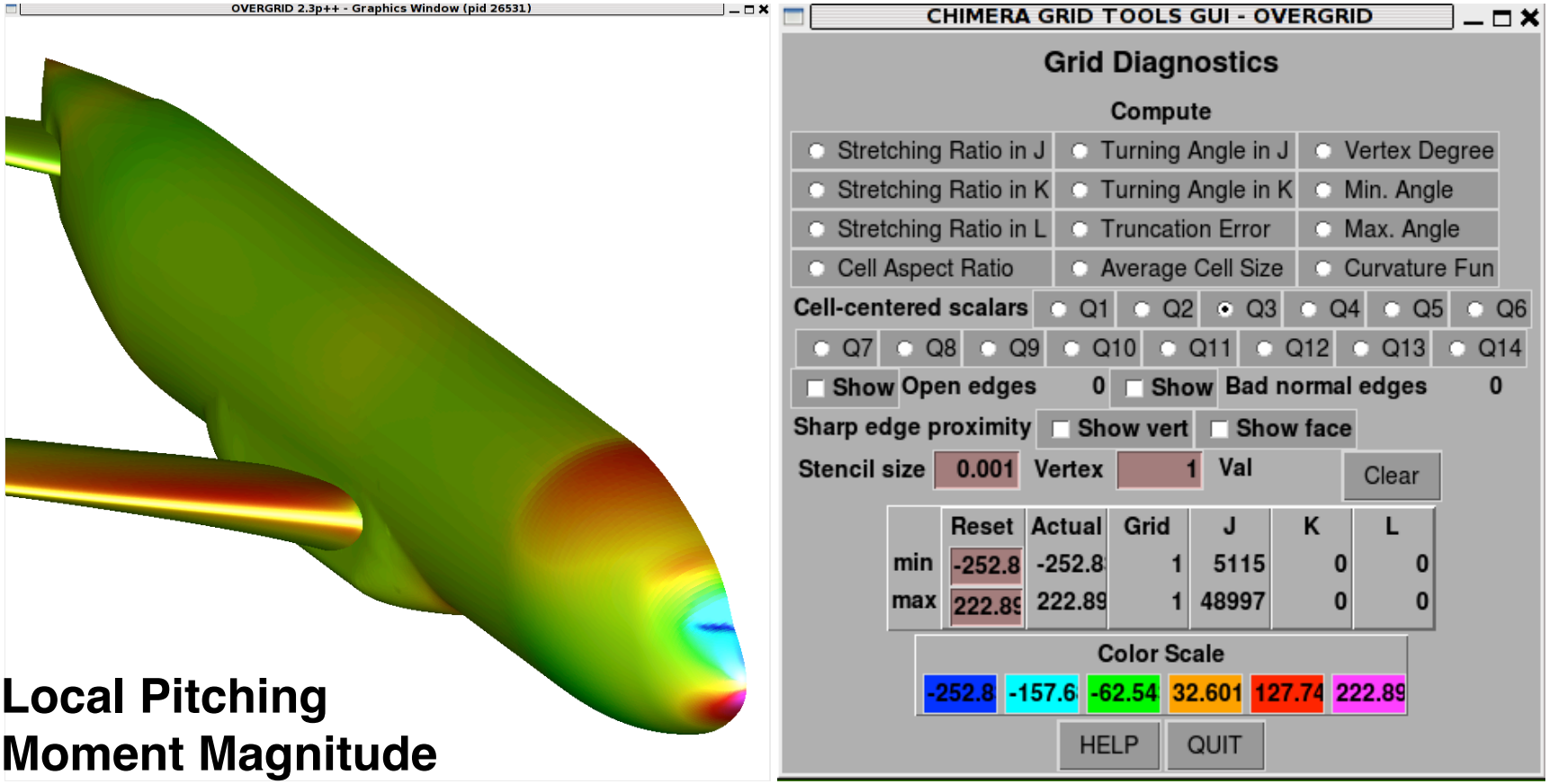
VISUALIZATION OF VERTEX-CENTERED DATA ON SURFACE TRIANGULATIONS

Standard CART3D triq file



VISUALIZATION OF CELL-CENTERED DATA ON SURFACE TRIANGULATIONS

Recent addition: Extended CART3D tri file with cell-centered scalars
Local forces/moments tri file output from OVERINT



Writing Grid Scripts in CGT

Shishir Pandya, William Chan

Geometry Preparation

STEP 1: Obtain surface representation

CGT Tool: cad2srf (CAPRI Library required)

Input: CAD, Output: Surface Triangulation

STEP 2: Obtain seam curves

- Aircraft
  - Leading and trailing edges
  - wing/body junction
  - tail/body junction
- Rocket
  - Axisymmetric body definition
  - protuberance junctions
  - Sharp features

CGT Tool: cad2srf

Input: CAD; Output: Curves

CGT Tool: seamcr, Isect

Input: Structured patches; Output: Curves

CGT Tool: seamcrt

Input: Surface Triangulation; Output: Curves

CGT Scriptlib Tools: CreateSeamCur

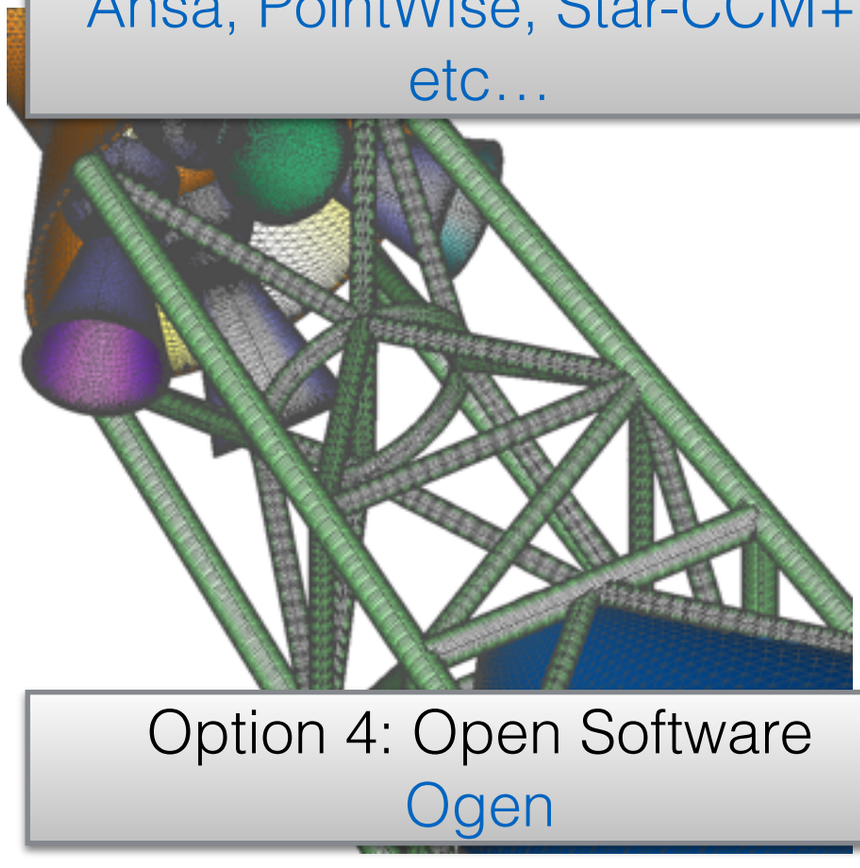
Input: Structured patches, Triangulation; Output: Curves

Option 2: DIY

CGT Scriptlib Tools: CreateLine, CreateCurve, CreateAirfoilComponent, CreateParsecFoil, CreateCylGrids, CreateFrustumGrids

Option 3: Commercial Tools

Ansa, PointWise, Star-CCM+, etc…



Option 4: Open Software

Ogen

Configuration or Component?

Configuration:

- Grid-centric
- Written for static geometries

- Rules must be followed
  - Set root names
  - Define input variables, defaults
  - Surface files: *.srf
  - Volume files: *.vol
  - Each file contains 1 grid

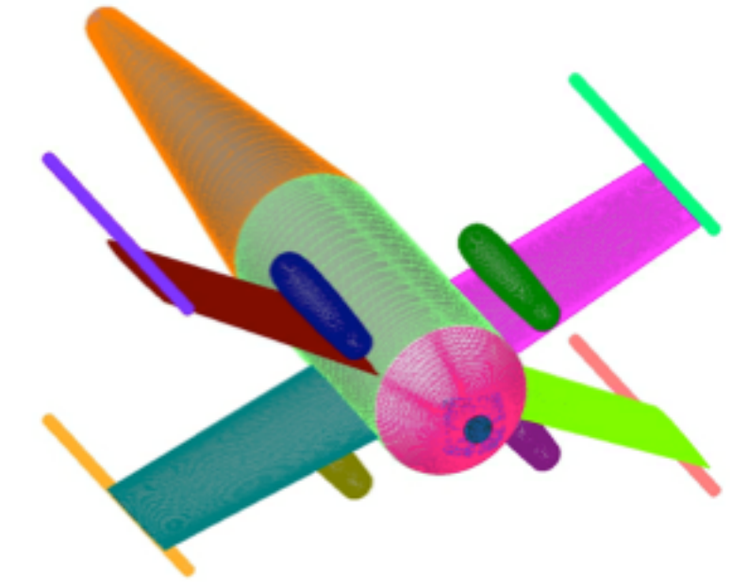
- Framework provided
- Short main script
  - BuildSurf
  - BuildVol
  - BuildPeg5i
- Peg5, X-rays supported
-

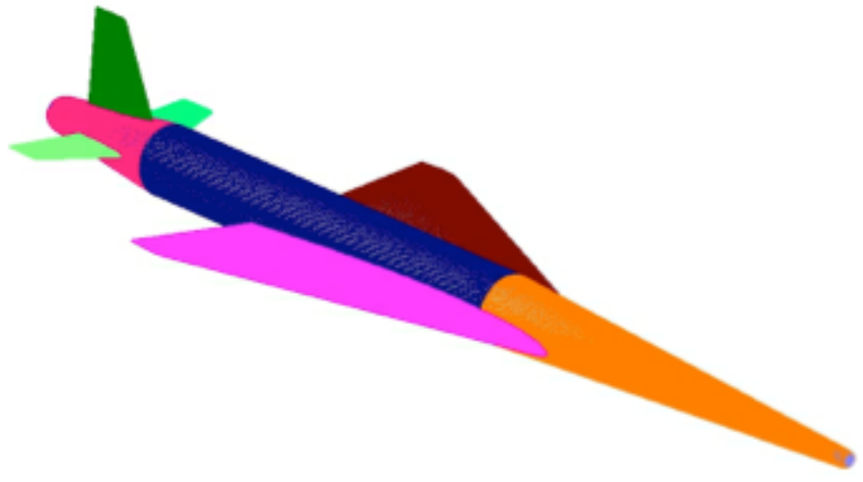
Component:

- Component-centric
- Written for repeated components and moving-body cases
- Rules must be developed by each user
  - Best practice:
    - Define input variables
    - Flexible filenames: *.sur, *.cut
    - Fixed names: *.vol, *.xry
    - Each file contains 1 component (Any number of grids)
- Framework contained in a main script
- Longer main script
  - Contains all calls for surface, volume, and connectivity according to user's choice.
- Supports X-rays (Overflow)
  - Basic support for Peg5, and c3p.

Surface Mesh Generation

- Curve Manipulation
- TFI grids
- Hyperbolically marched grids
  - Collar grids
- Assure proper surface coverage





Curve Manipulation

STEP 1: Identify curves that can be concatenated

CGT Tool: grided

Input: Curves, Grids; Output: Curves, Grids

CGT Scriptlib Tools: ConcatGrids, ConcatGrids2, ConcatGridsn, AutoConcateGrids

Input: Curves, Grids; Output: Curves, Grids

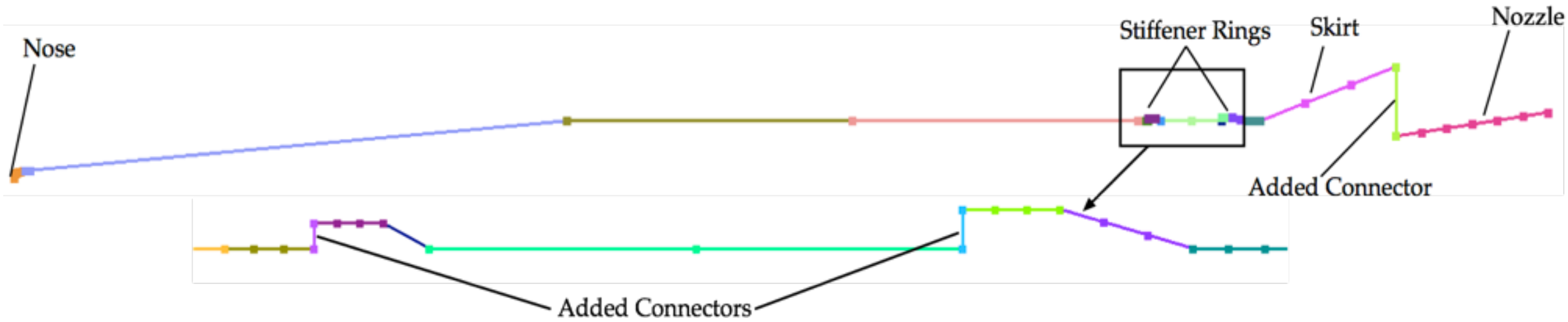
STEP 2: Identify curves that need to be split

CGT Tool: grided

Input: Curves, Grids; Output: Curves, Grids

CGT Scriptlib Tools: ExtractSubs, ExtractGrids, GedSplitJkl, GedSplitXyz

Input: Curves, Grids; Output: Curves, Grids



Curve Manipulation (cont.)

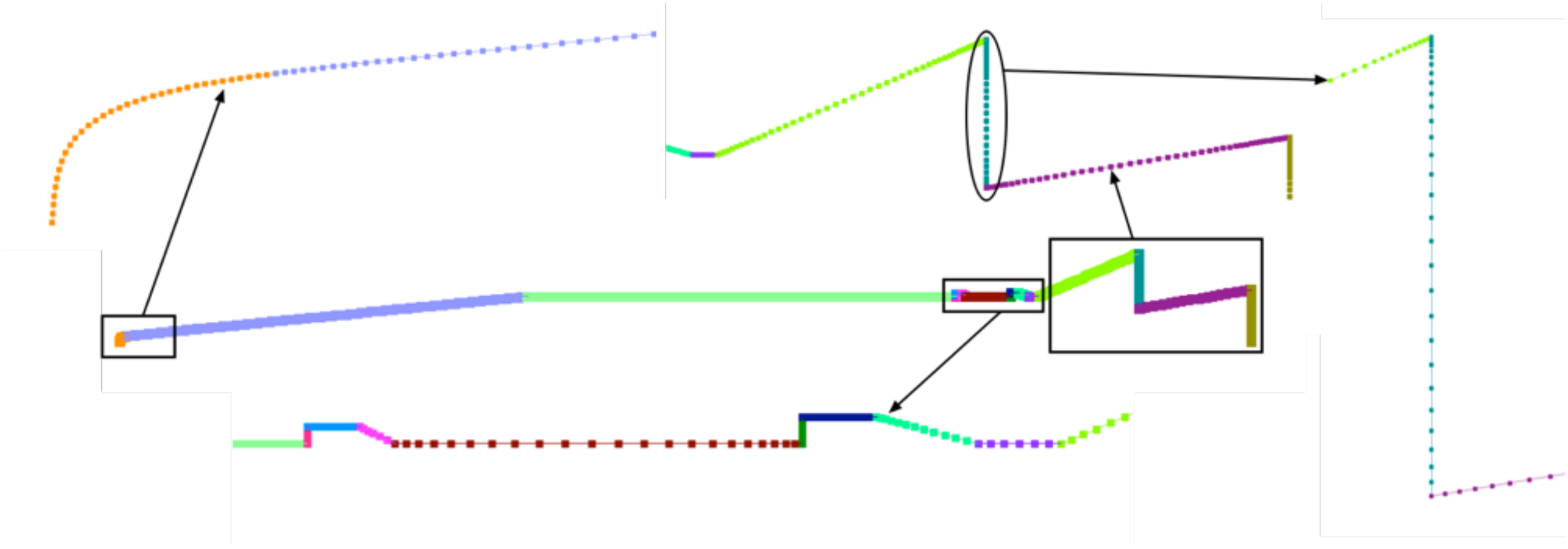
STEP 3: Redistribute

CGT Tool: srap

Input: Curves, Grids; Output: Curves, Grids

CGT Scriptlib Tools: SrapRedist

Input: Curves, Grids; Output: Curves, Grids



TFI Patches

STEP 1: Identify TFI patch curves

- Aircraft
  - LE, TE, Root, Tip
- Rocket
  - Portions of protuberances

CGT Tool: OVERGRID

Input: Ref. Surface, Curves; Output: Grid

CGT ScriptLib Tool: CombineGrids

Input: Curves, Grids in multiple files; Output: Curves,Grids in one file

STEP 2: Create TFI patches

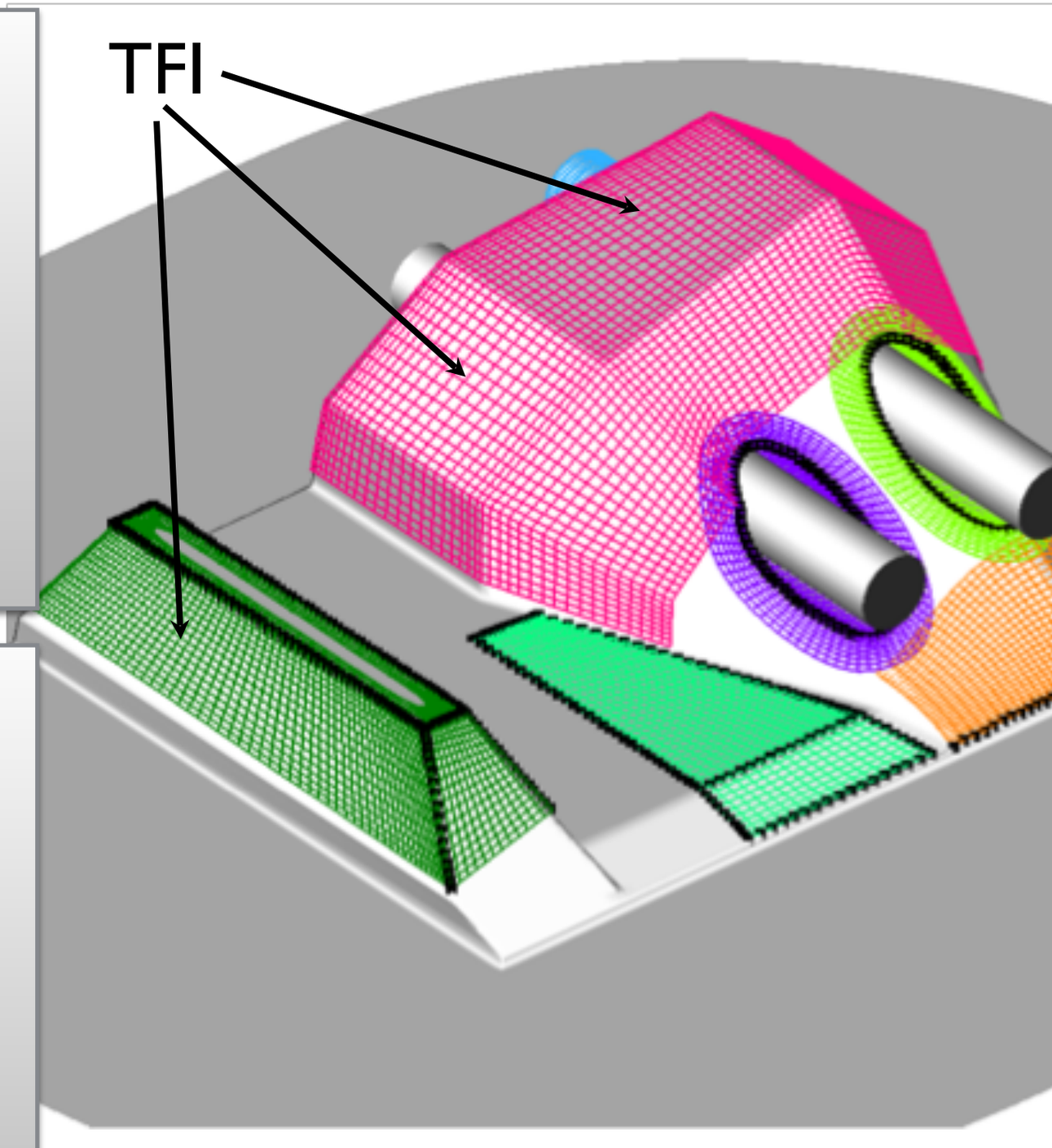
- Aircraft
  - Top of wing, Bottom of wing
  - Portions of other parts
- Rocket
  - Portions of protuberances

CGT Tool: surgrd

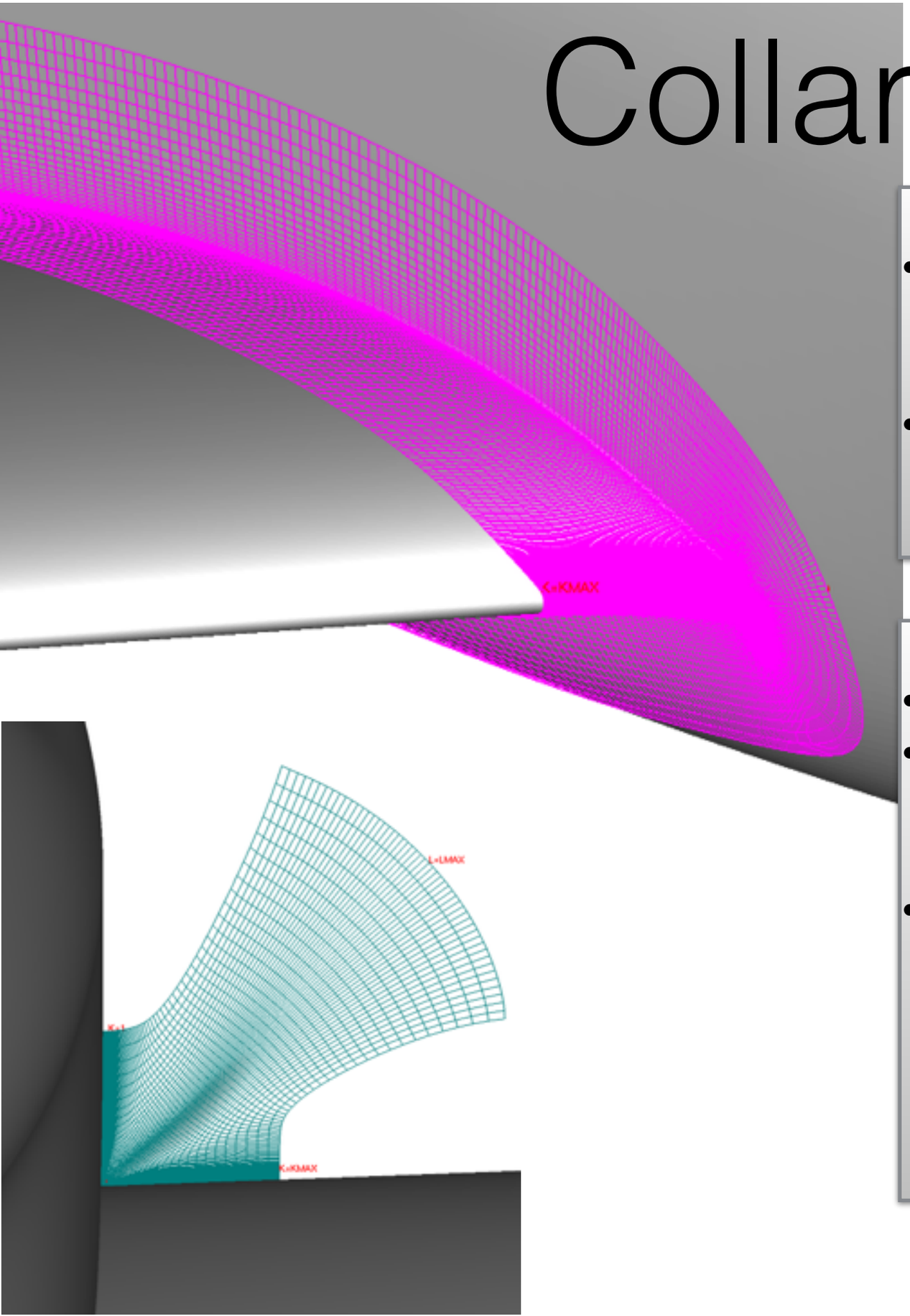
Input: Ref. Surface, Curves; Output: Grid

CGT ScriptLib Tool: GenTFI

Input: Ref. Surface, Curves; Output: Grid



Collar Grids



STEP 1: Identify Starting curves

- Aircraft
  - Wing/Body junction
  - Tail/Body junction
- Rocket
  - Protuberances/Stack junction

CGT Tool: OVERGRID

STEP 2: Create collar grids

- Identify Starting curves
- Aircraft
  - Wing/Body junction
  - Tail/Body junction
- Rocket
  - Protuberances/Stack junction

CGT Tool: surgrd

Input: Ref. Surface, Curves; Output: Grid

CGT ScriptLib Tool: GenHypSurGrids

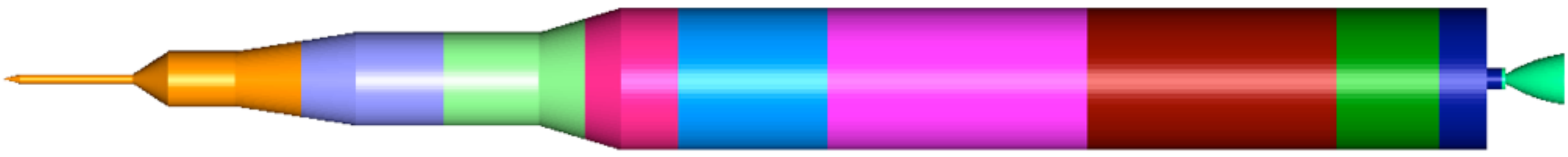
Input: Ref. Surface, Curves; Output: Grid

Concatenate, Break-up Grids

STEP 1: Identify grids that can be concatenated, or need to be split
CGT Tool: OVERGRID

STEP 2: Concatenate grids
CGT Tool: grided
Input: Ref. Surface, Curves; Output: Grid
CGT ScriptLib Tool: ConcatGrids, ConcatGrids2, ConcatGridsn, AutoConcateGrids
Input: Ref. Surface, Curves; Output: Grid

STEP 3: Split grids
CGT Tool: grided
Input: Ref. Surface, Curves; Output: Grid
CGT ScriptLib Tool: ExtractGrids,GedSplitJkl, GedSplitXyz, ExtractSubs, SplitToNGrids
Input: Ref. Surface, Curves; Output: Grid



Assure Complete Surface Coverage

STEP 1: Identify gaps, improper overlaps

CGT Tool: OVERGRID

STEP 2: Identify/Create Curves

CGT Tool: seamcr, seamcrt

Input: Ref. Surface; Output: Curves

CGT ScriptLib Tool: CreateSeamCurs

Input: Ref. Surface, Curves; Output: Grid

STEP 3: Fill gaps

- TFI
- Hperbolic surface marching

CGT Tool: surgrd

Input: Ref. Surface, Curves; Output: Grid

CGT ScriptLib Tool: GenTFI, GenHypSurGrids

Input: Ref. Surface, Curves; Output: Grid

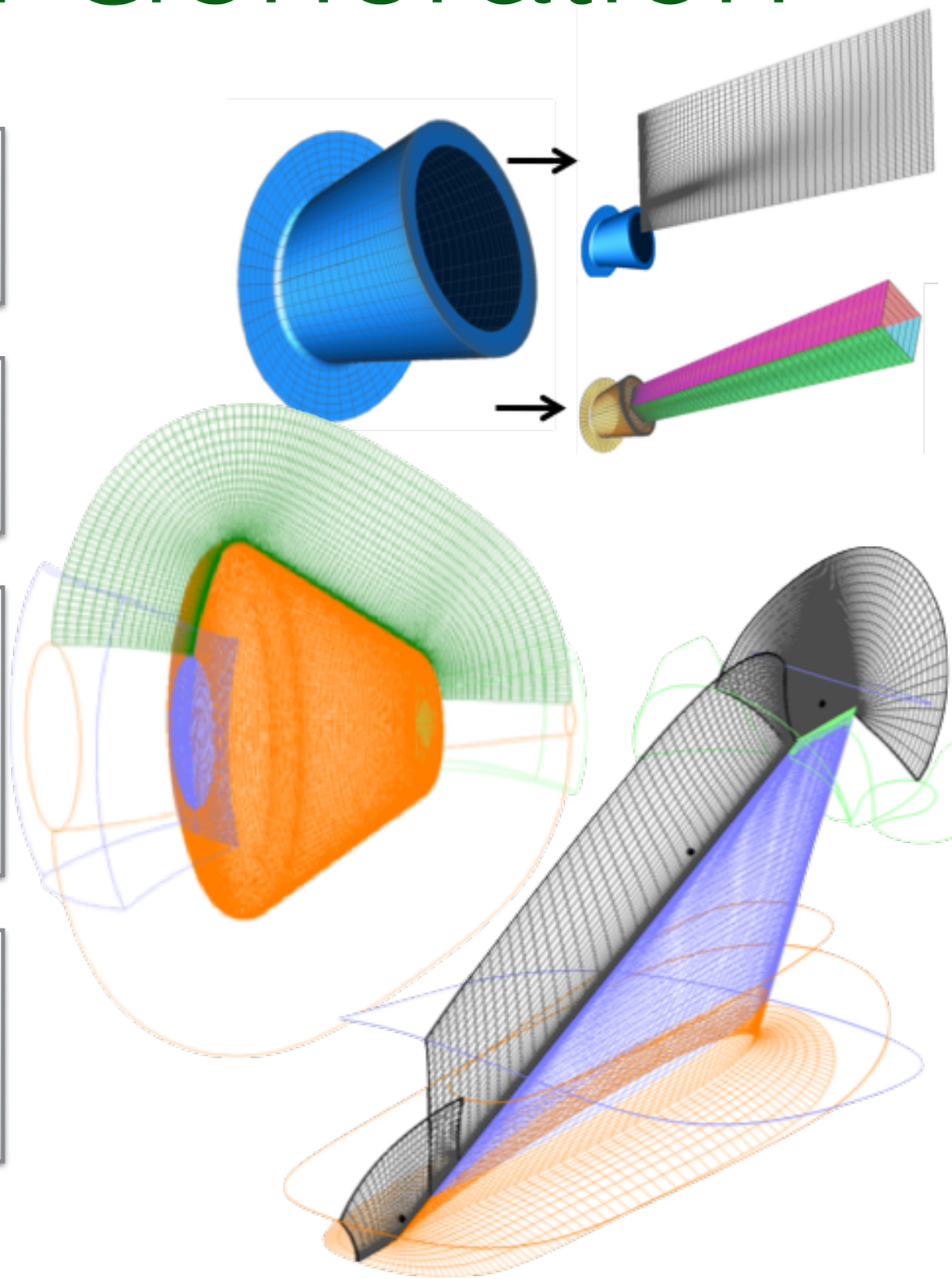
Volume Mesh Generation

Option 1: Interactively
CGT Tool: hypgen
Input: Surface grid; Output: Volume grid

Option 2: Configuration scripts
CGT Scriptbin Tool: BuildVols
Input: Surface grid; Output: Volume grid

Option 3: Component scripts
CGT Scriptlib Tool: GenHypVolGrids, GenUniformBox, GenStretchedBox, CreateCore, BuildGeneralPlumeGrids, …
Input: Surface grid; Output: Volume grid

Option 4: Higher-level component scripts
CGT Scriptlib Tool: BuildAxisymGrids
Input: Axisym. curve or Surface grid; Output: Volume grid with caps



Connectivity

Step 1: Write connectivity inputs to file

Option 1: Manual

Option 2: Configuration scripts
CGT Scriptbin Tool: BuildPeg5i
Input: Volume grid; Output: Grid Connectivity

Option 3: Component scripts
CGT Scriptlib Tool: AddCutterID, SetCutterCutee, WriteOvr2InpFile
Output: OVERFLOW input

Step 3: Run connectivity code

Option 1: Manual
Tools: DCF/OVERFLOW, Pegasus5, etc.
Input: Volume grid; Output: Connectivity

Option 2: Component scripts
CGT Scriptlib Tool: RunConnectivityCode
Input: Volume grid; Output: Connectivity

Step 2: Create x-rays
DCF/OVERFLOW only
CGT Scriptlib Tool: CreateXrayMap
Input: Cutter, Output: X-ray

Step 4: Remove orphans
CGT Tool: OVERGRID
Diagnose Module

Boundary Conditions

Step 1: Setup BCs

Option 1: Manual

Option 2: Configuration scripts
CGT Scriptbin Tool: WriteOvfi
Output: Grid BC file

Option 3: Component scripts
CGT Scriptlib Tool: AddGridNames, AddBCInfo, WriteBCInfo
Output: Component BC file

Step 2: Process and write Overflow input file

Option 1: Manual

Option 2: Configuration scripts
CGT Scriptbin Tool: BuildOveri
Input: Grid BC files; Output: Overflow inputs

Option 3: Component scripts
CGT Scriptlib Tool: ProcessBCInfo, WriteOvr2InpFile
Input: Component BC files; Output: OVERFLOW input

FOMOCO Inputs

Step 1: Setup integration surfaces

Option 1: Manual

Option 2: Configuration scripts
CGT Scriptbin Tool: WriteOvfi
Output: Grid BC file

Option 3: Component scripts
CGT Scriptlib Tool: AddFomocoSubset, AddFomocoMegaComp, WriteFomoInfo
Output: Component Fomo file

Step 2: Process and write FOMOCO input file

Option 1: Manual

Option 2: Configuration scripts
CGT Scriptbin Tool: BuildOveri
Input: Grid BC files; Output: Overflow inputs

Option 3: Component scripts
CGT Scriptlib Tool: ProcessFomoInfo, WriteOvr2InpFile
Input: Component Fomo files; Output: OVERFLOW input