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New Frontiers in CAE Interoperability

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Introduction

- Data Exchange Integrity
- Issue of Meshability
- Geometry Reasoning
- Geometry Reasoning Applications
- Conclusions

ITI TranscenData Europe Overview

- CAE and CAD background
- Meshing pioneer and research in the 1960's
- FEGS Ltd formed in 1978
  - Original focus on CAE pre- and post-processing
    - 1st generation - ***FEMGEN*** & ***FEMVIEW***
    - 2nd generation - ***FAM*** 'Field Analysis Modeller'
  - Re-focussed on key role of CAE geometry in 1996
    - 3rd generation - ***CADfix***
- European subsidiary of ITI TranscenData in 1998
  - Leading provider of CAD/CAM/CAE/PDM interoperability solutions

F E G S

FAM 4

CADfix®

ITI TranscenData

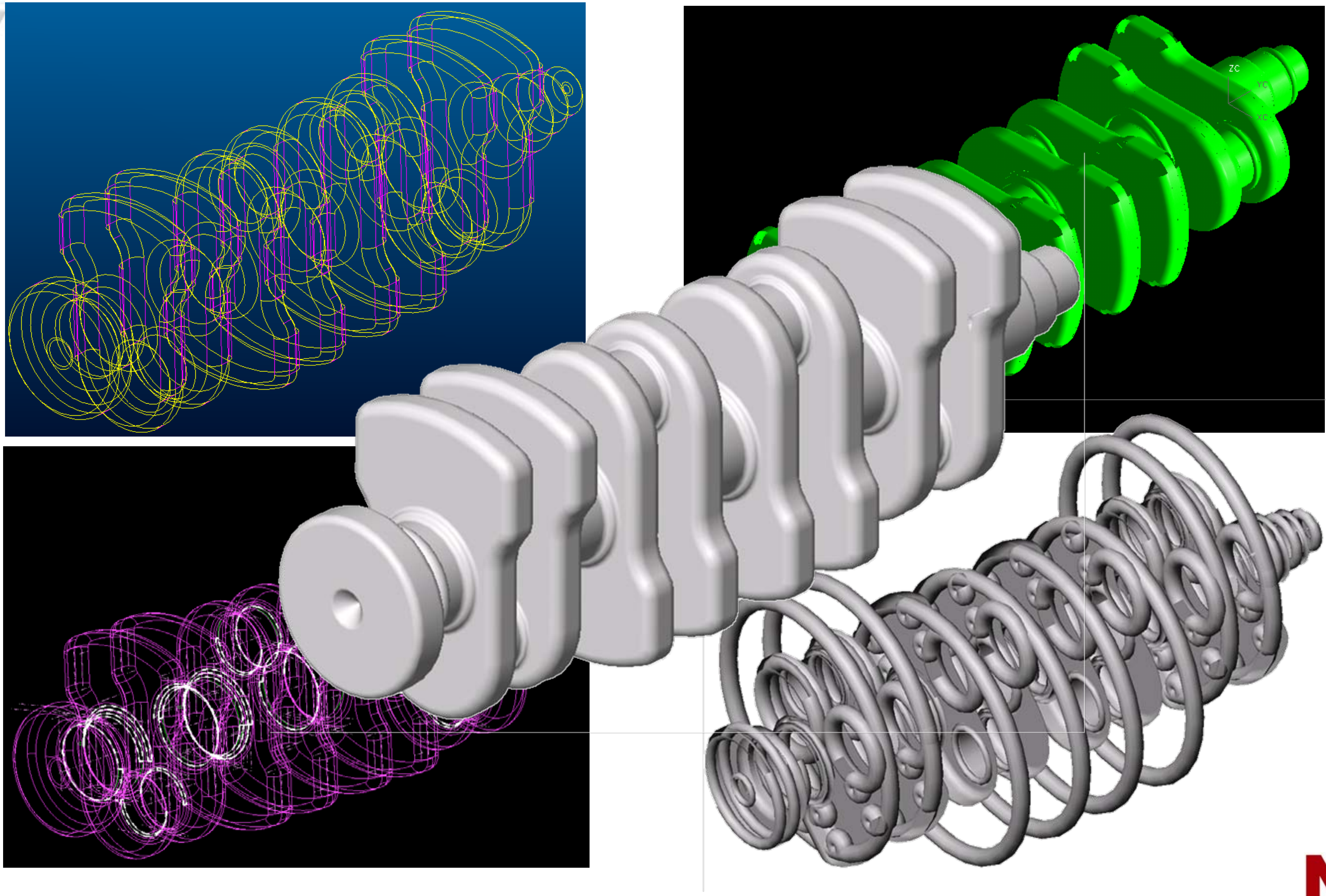
www.transcendata.com

- Focus on the critical role of CAD geometry in engineering processes, particularly CAD to CAE and process automation

Data Exchange Integrity

- Requirements
  - Valid solids and well connected shells
  - Seamless interface with little or no rework requirement
- Frequently not as straightforward as it should be!
  - Different tolerances between systems
  - System dependant geometrical and topological representations
  - Poor implementations or adoption of standards e.g. IGES and STEP
  - Different levels of complexity supported across diverse systems
  - Data exchange is not the core business of a CAD or CAE system vendor and is often seen as an unwanted distraction

Data Exchange Integrity Example

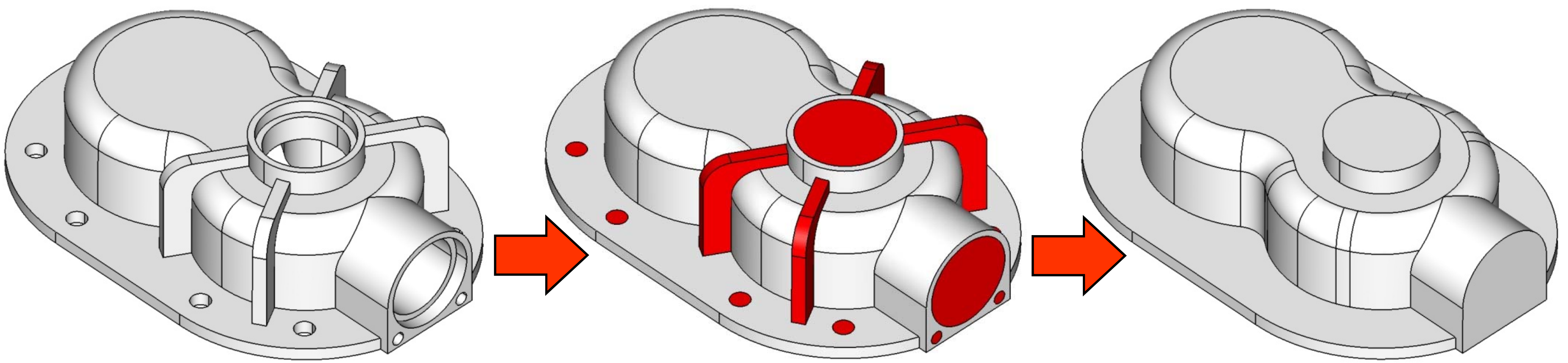


Data Exchange Integrity Improvements

- There have been significant advances and improvements
- CAD system evolution, translator development and standards
  - IGES translators fixed, STEP matured, translator support improved
  - Kernels, e.g. Parasolid, more widely used as basis for CAD/CAE applications
  - New native CAD translators
- Specialist and CAD data exchange and repair tools now available
- CAD and CAE System Integration
  - Corporate CAD/CAE acquisitions for more integration and less translation
  - Rationalisation of CAD systems and underlying geometry kernels
- Communication, awareness, modelling procedures and training

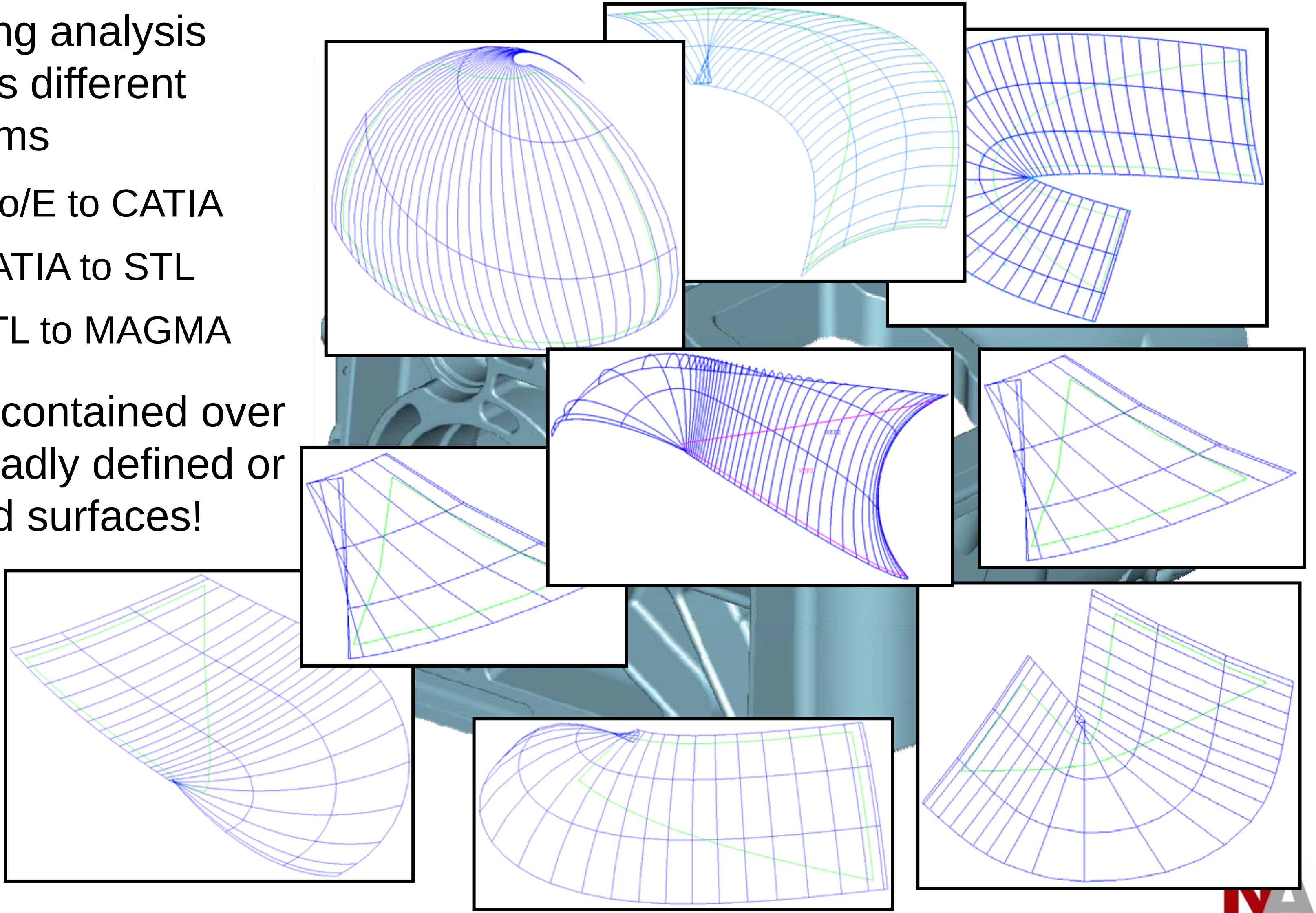
Meshability

- High integrity basic data exchange is not enough for CAE
- Need to consider the ***Meshability*** of the model
  - Underlying geometrical definitions appropriate for meshing
  - Appropriate level of detail required by the CAE process
  - Simplest representation to reduce Degrees of Freedom and run time whilst maintaining design intent



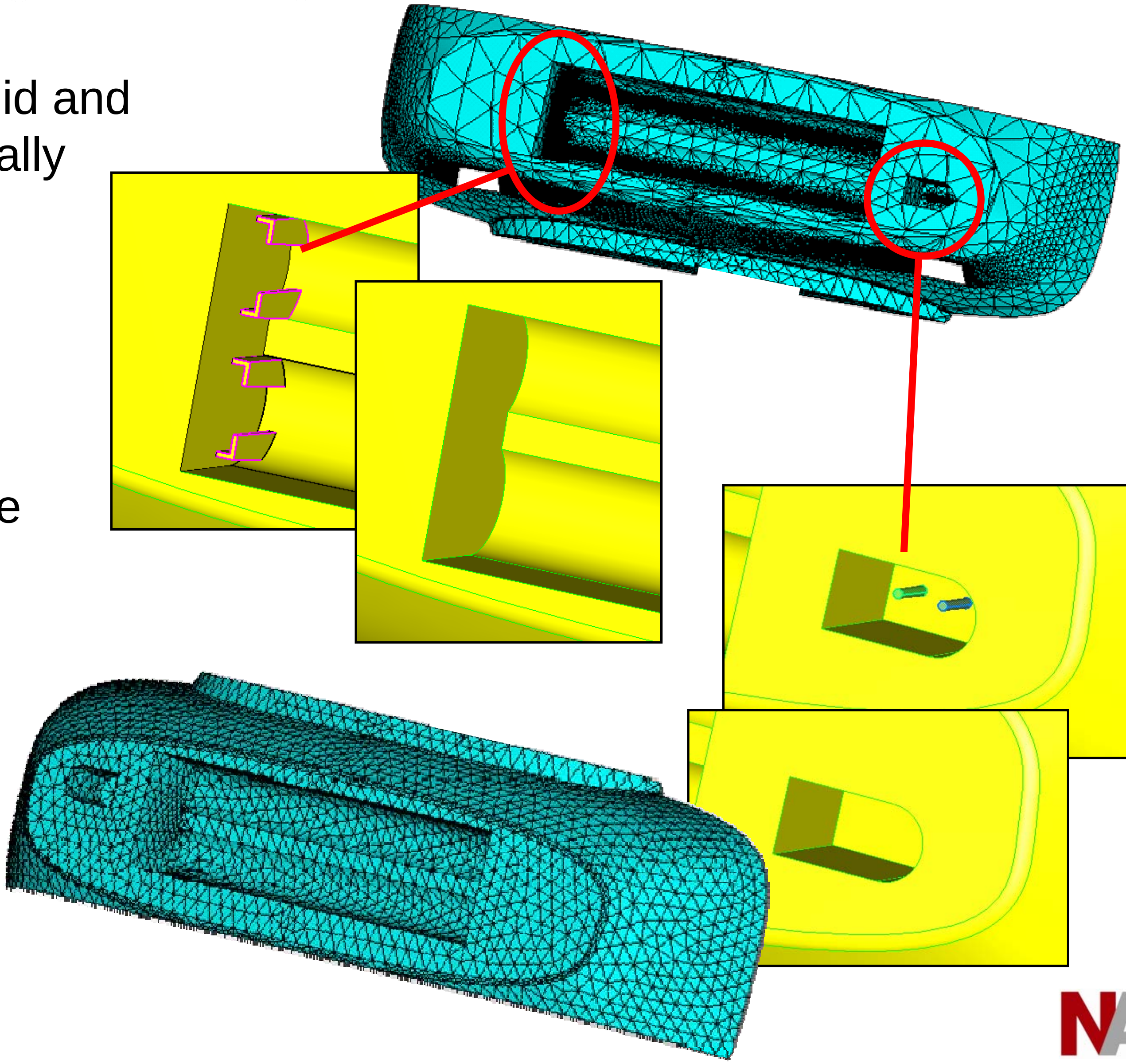
Meshability Example - Invalid Surfaces

- Casting analysis across different systems
  - Pro/E to CATIA
  - CATIA to STL
  - STL to MAGMA
- Solid contained over 300 badly defined or invalid surfaces!



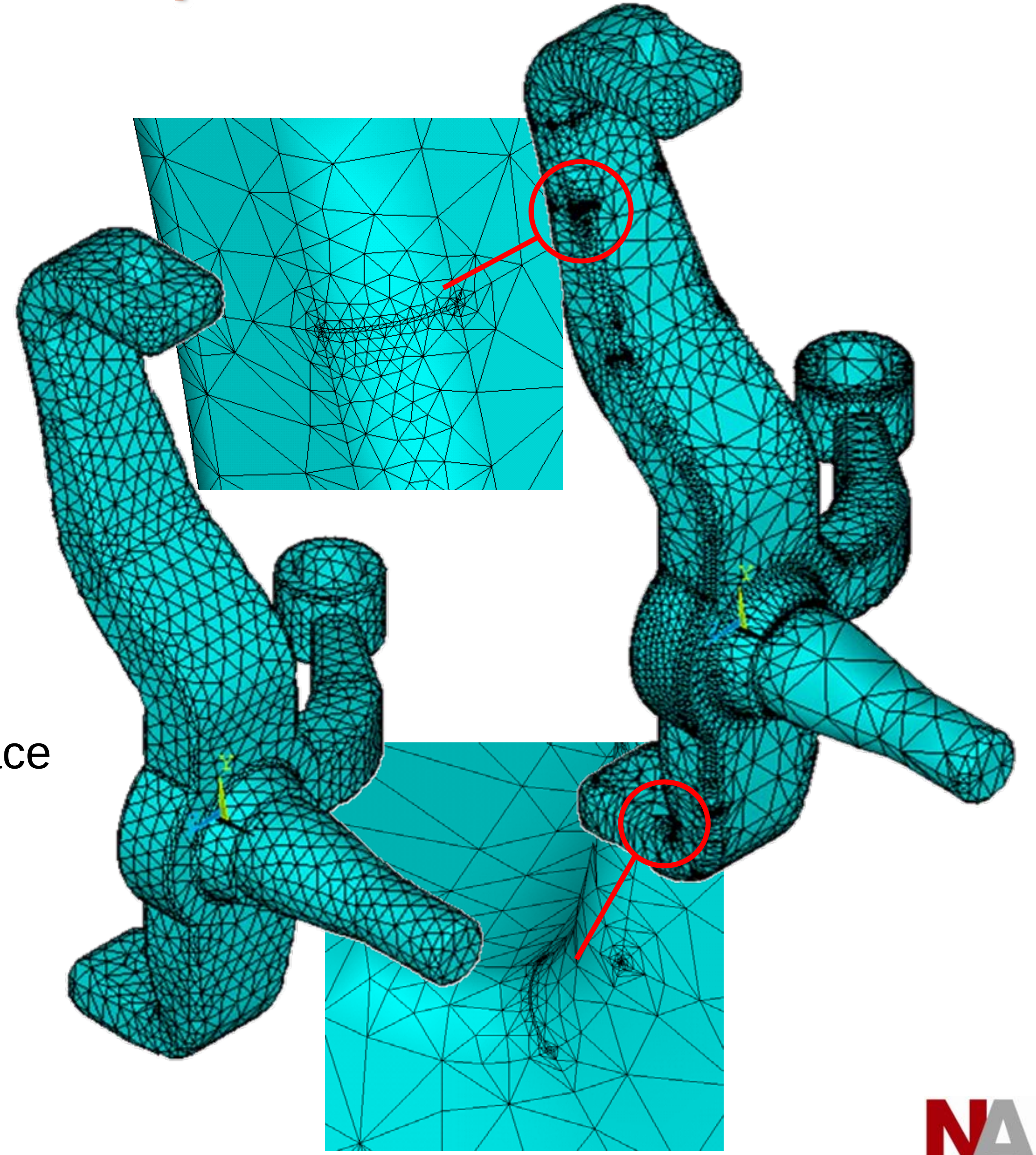
Meshability Example - Design Features

- Part imports as solid and meshes automatically
  - 57,100 elements
  - 112,976 nodes
- Unwanted design features result in complex and dense mesh
- Simplified Model
  - 15,360 elements
  - 30,823 nodes



Meshability Example - CAD Artefacts

- Part imports as solid and meshes automatically
  - 107,344 elements
  - 160,001 nodes
- Unwanted small features result in complex and dense mesh
- Simplified Model
  - Short edge removal, small face collapse, Face joining
  - 22,113 elements
  - 35,057 nodes



Meshability Improvements

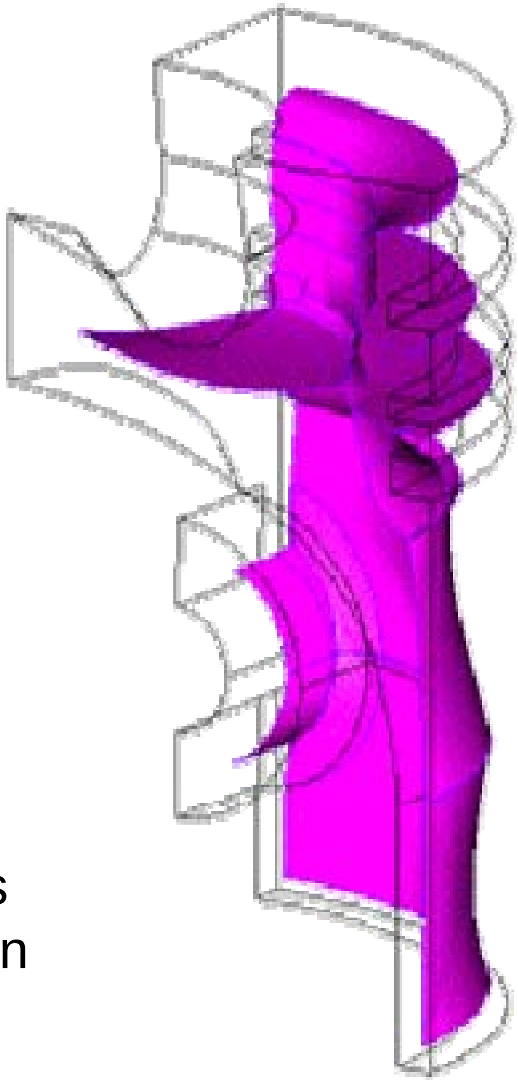
- Short edges and small faces are less of an issue today
  - ***But not for everyone***
- Software
  - Some meshers now suppress and mesh over topology constraints
  - Data exchange tools developed to offer defeaturing capabilities
- Hardware
  - Faster machines cope with larger problems
  - ***But still DoF and time limitations (e.g. optimisation runs)***
- System Integration
  - Single geometry PLM model allows for CAD feature suppression
  - ***But don't always have native CAD access with history tree***

Advanced Applications and Automation

- Still more advanced geometry idealisation issues
  - De-featuring - difference between intended and unwanted features
  - Dimensional reduction - thin model to shell elements
  - Domain partitioning - hex meshing or CFD block gridding
- Different considerations for different disciplines
  - FEA stress raisers, CFD vortex inducers, CEM spark gaps
- Still mostly interactive and dependent on judgement
  - e.g. When is a ‘rib’ not a ‘rib’?
- Idealisation for CAE is difficult to automate and whilst the CAD BREP serves it’s intended purpose well, it doesn’t provide what is required to make intelligent CAE decisions

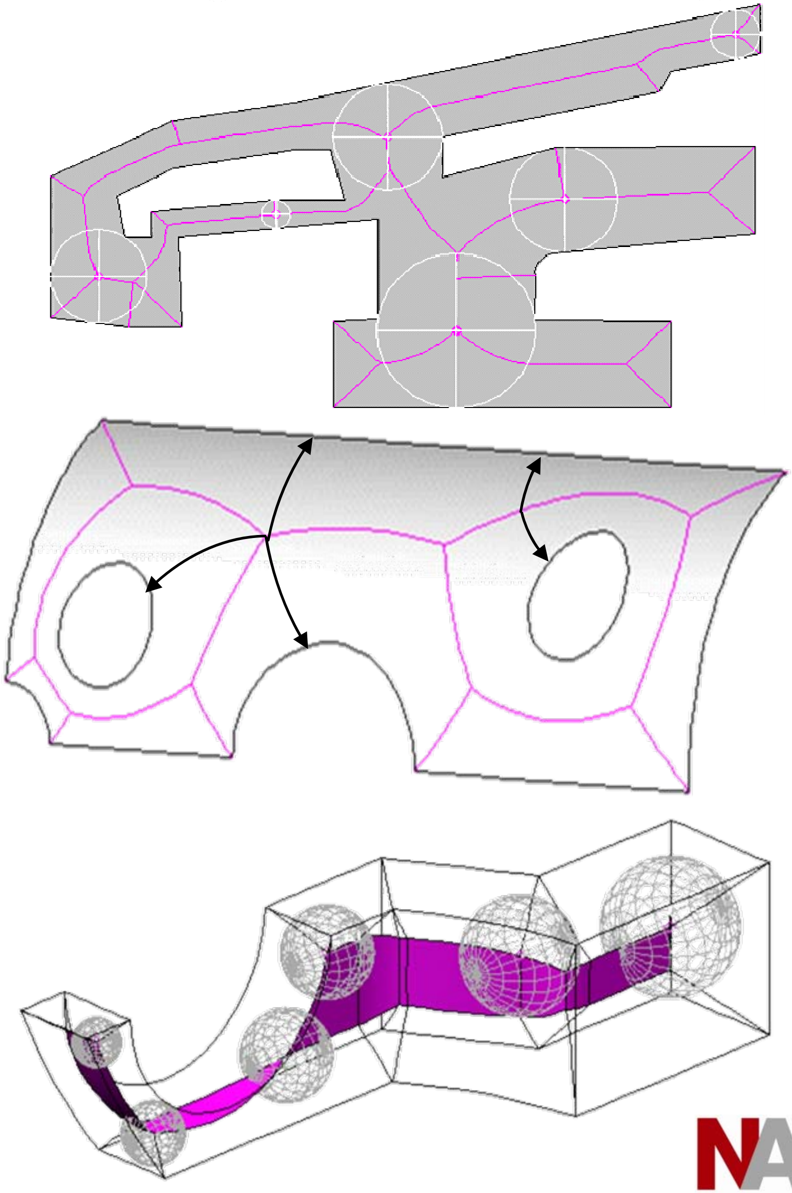
Geometry Reasoning

- A more intelligent use of a CAD model beyond what a BREP offers is needed
- TranscenData has developed an application to ‘walk around’ the inside of an object, deducing properties
  - Proximity
  - Aspect ratio
  - Thinnest
  - Thickest
- Geometric Reasoning (GR) of the CAD model
- GR technology is key to future CAD-CAE process automation and will lead to major breakthroughs in engineering analysis applications



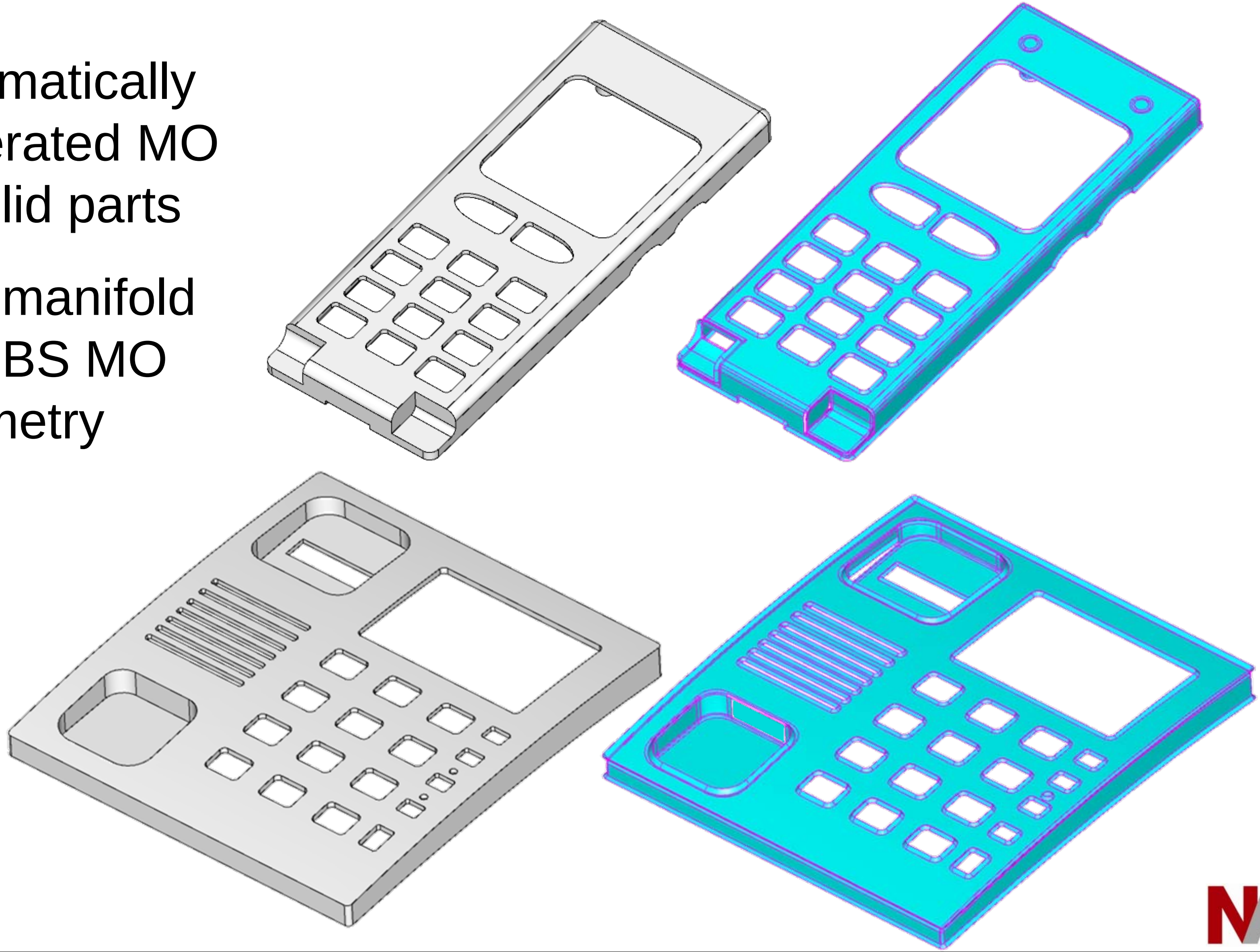
Medial Object and Geometry Reasoning

- Geometric Reasoning based on the Medial Object (MO) - or Medial Axis Transform
- MO is formed by rolling a maximal diameter disc inside a face, or a sphere inside a volume
  - Path of the center of the disc or sphere describes the MO geometry
- MO populated with attributes
  - Radius function = distance to boundary
  - Parent geometry = geometrical entities that the medial object relates to
- Accurate, robust and complete 3D MO generation is not easy!
  - Several years research and development at TranscenData and Queens University



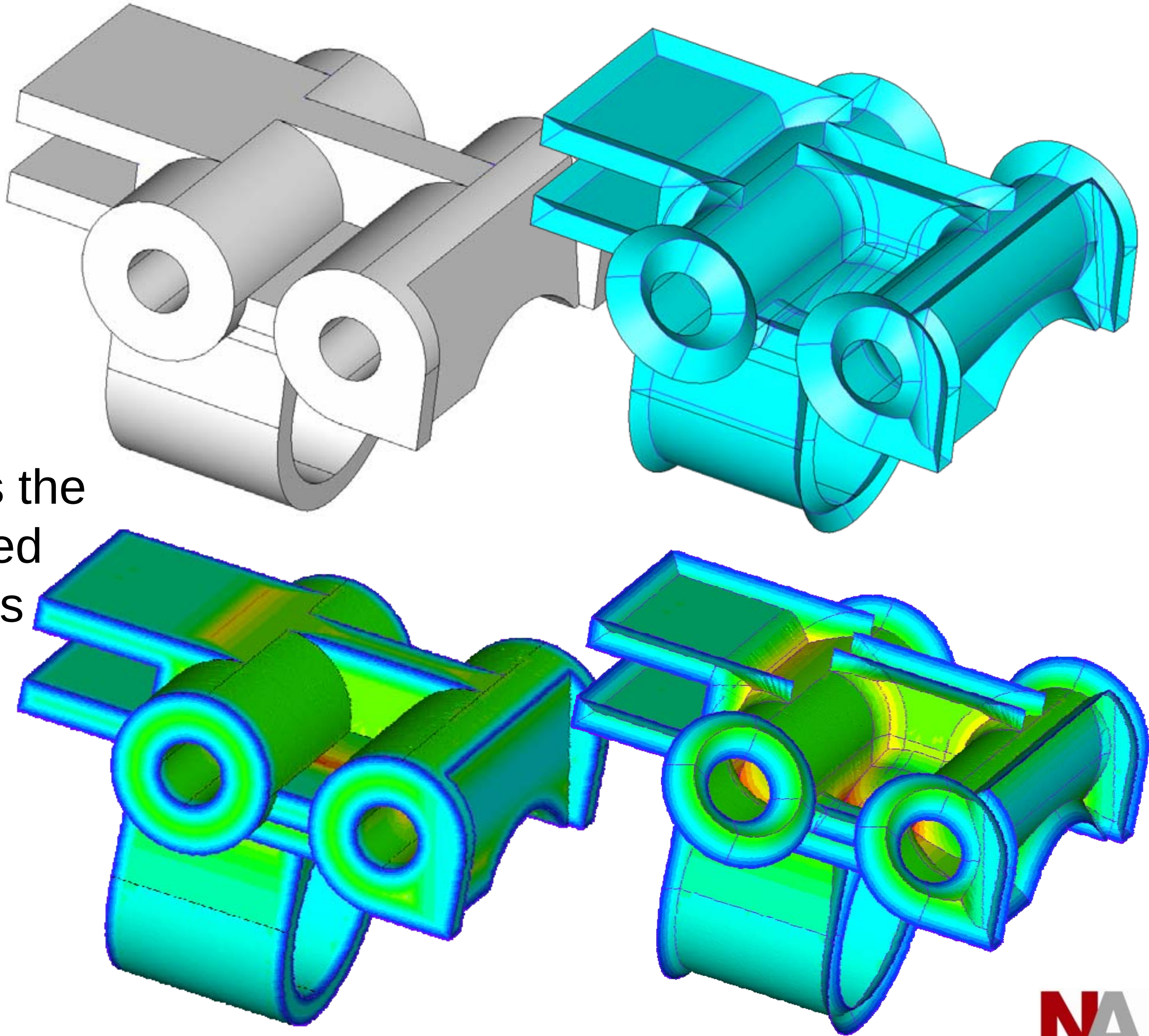
3D Medial Object Examples

- Automatically generated MO of solid parts
- Non-manifold NURBS MO geometry



3D Medial Object Attributes

- MO is rich with 3D attributes and properties
  - Radius function
  - Parent geometry
- MO geometry and attributes available as the basis to build advanced CAD-CAE applications
- Contours of medial radius shown on MO geometry and parent geometry

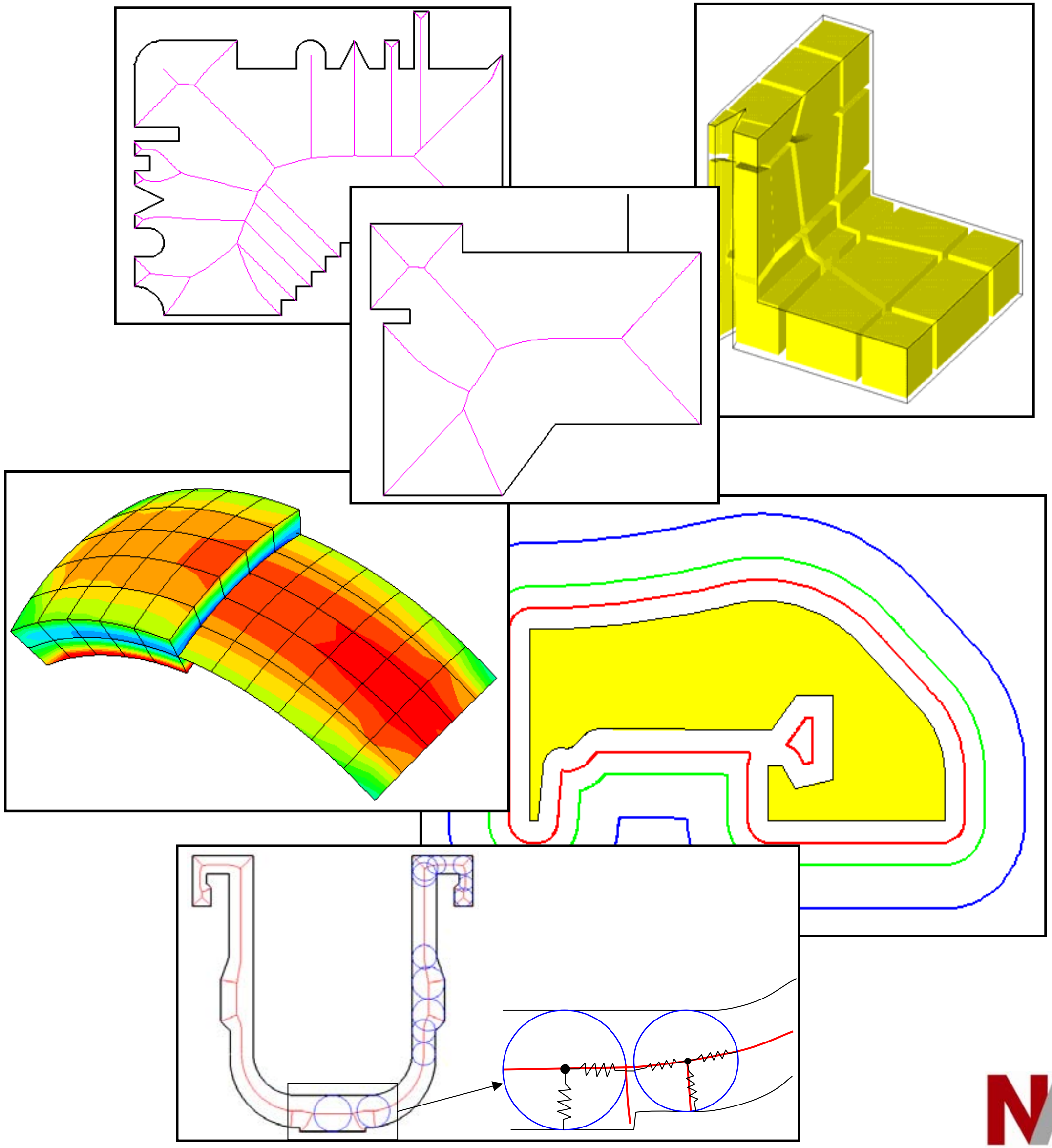


MO Demonstration

- Medial Object generation and interrogation

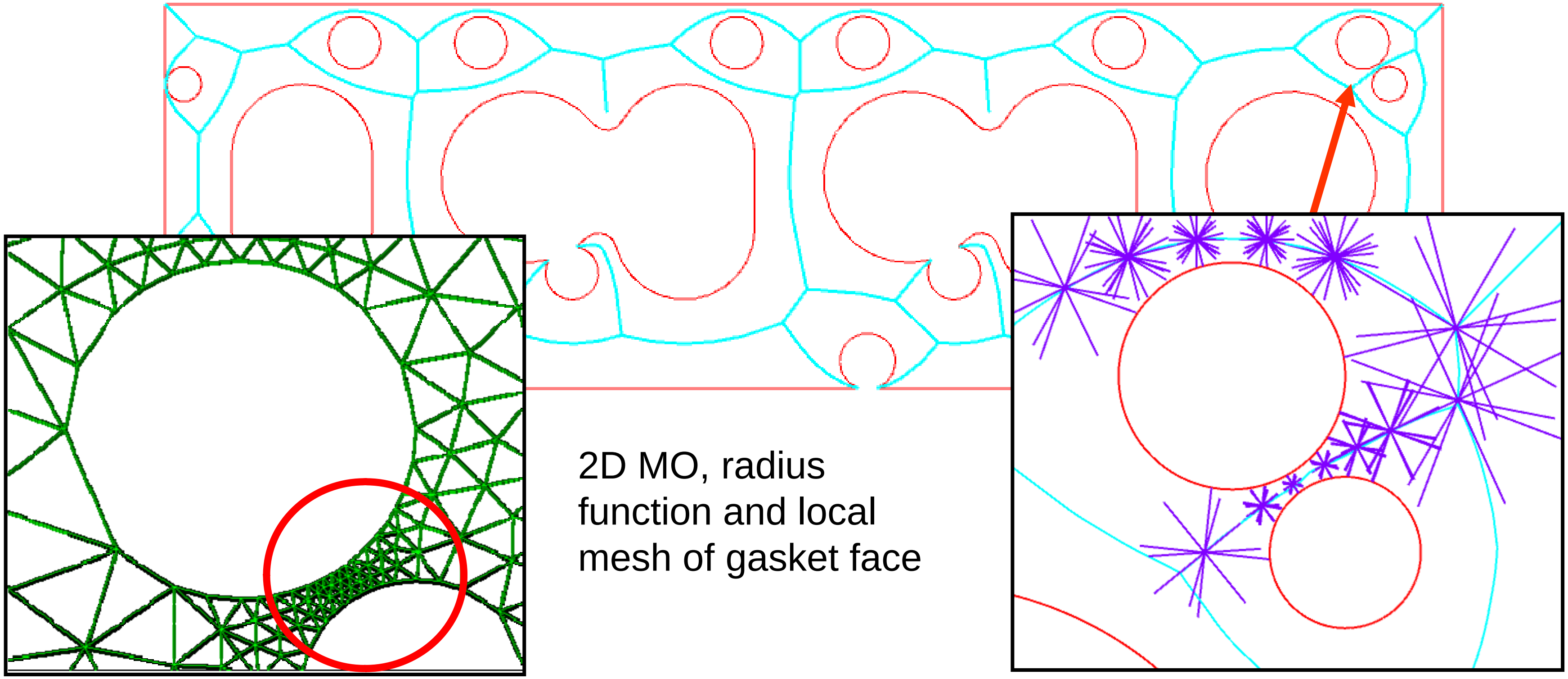
Geometry Reasoning Applications

- Many GR applications
  - Feature recognition
  - Spatial partitioning
  - Dimensional reduction
  - Mid-surfacing
  - Shelling
  - Manufacturability
- GR is key to future CAD-CAE integration



Proximity Tools for Meshing

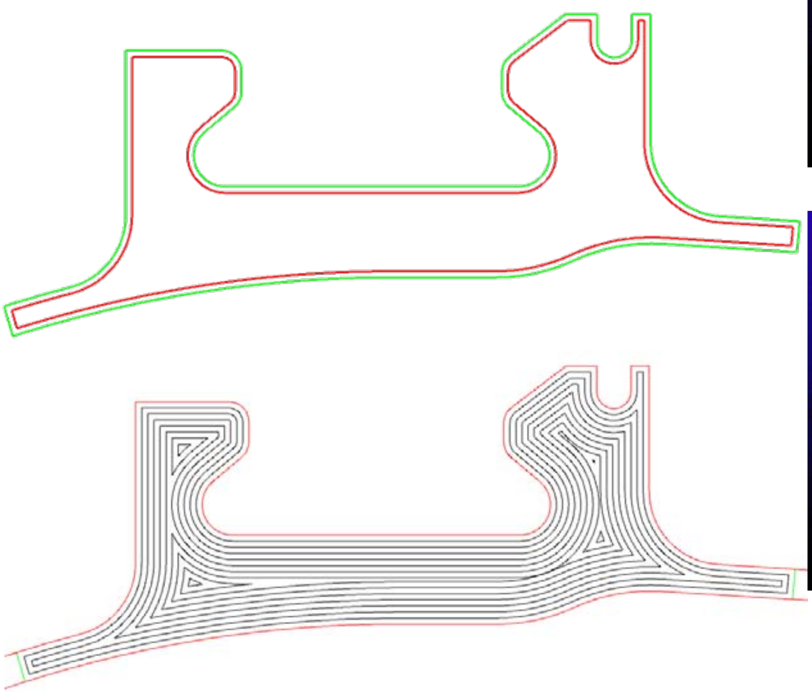
- Challenge to automatically determine optimum element sizes
  - GR offers a means to rapidly extract reliable proximity information
  - Automatic edge-to-edge proximity within a face available today
  - Promise of full 3D proximity inside and outside an object

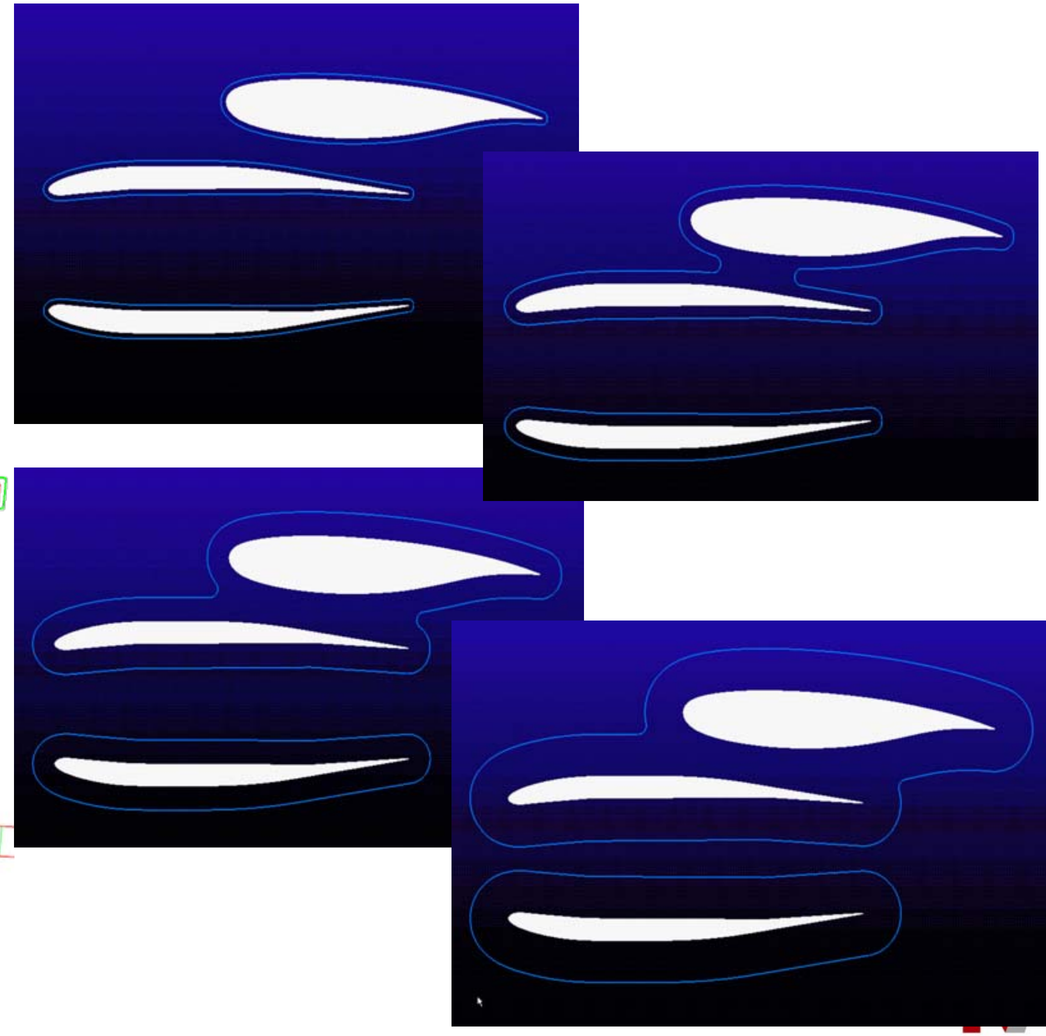


2D MO, radius function and local mesh of gasket face

Robust Offsetting and Shelling

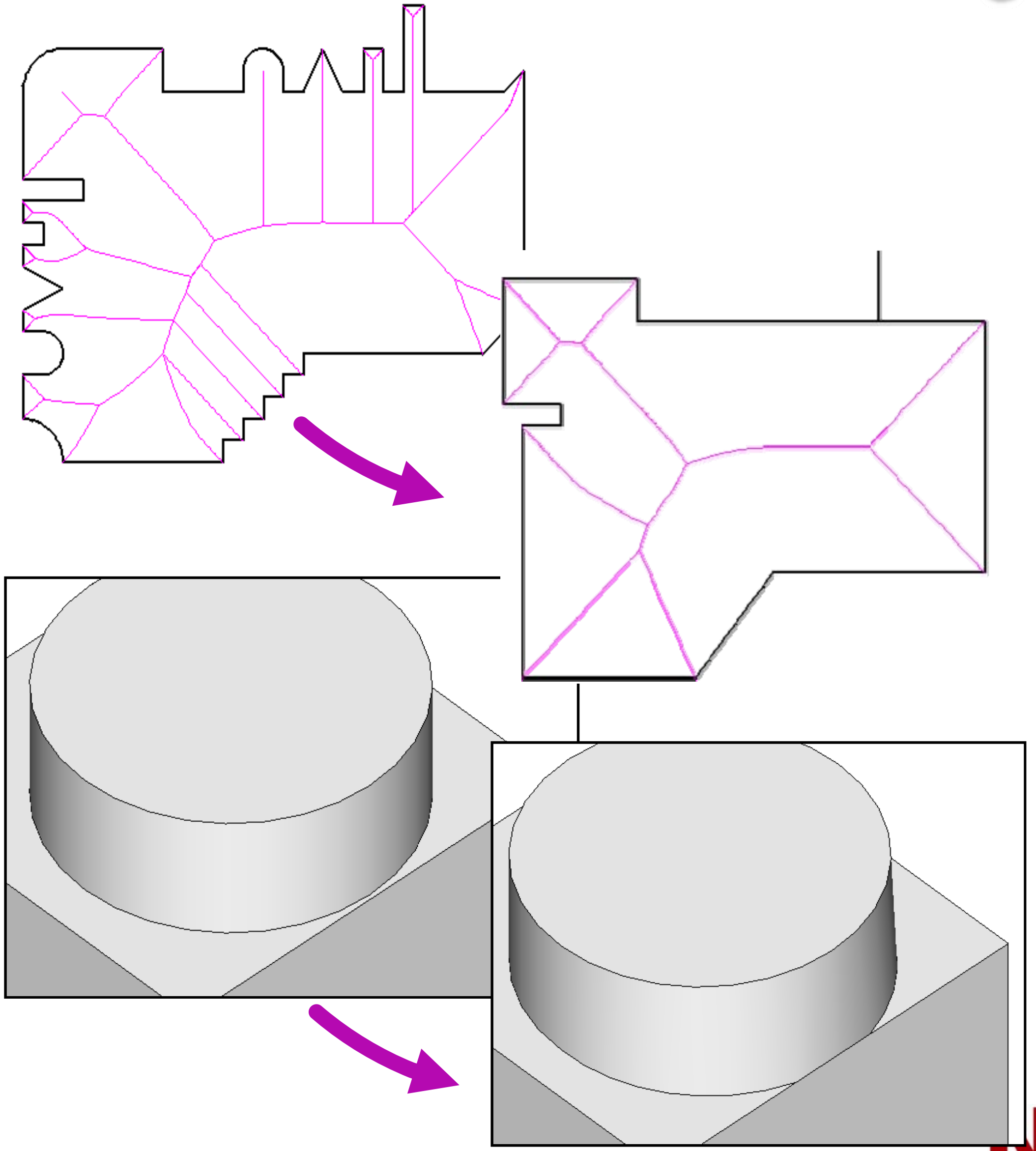
- GR used for robust and accurate offset and shelling
  - Boundary layers
  - Shrinkage
  - Domain partitioning





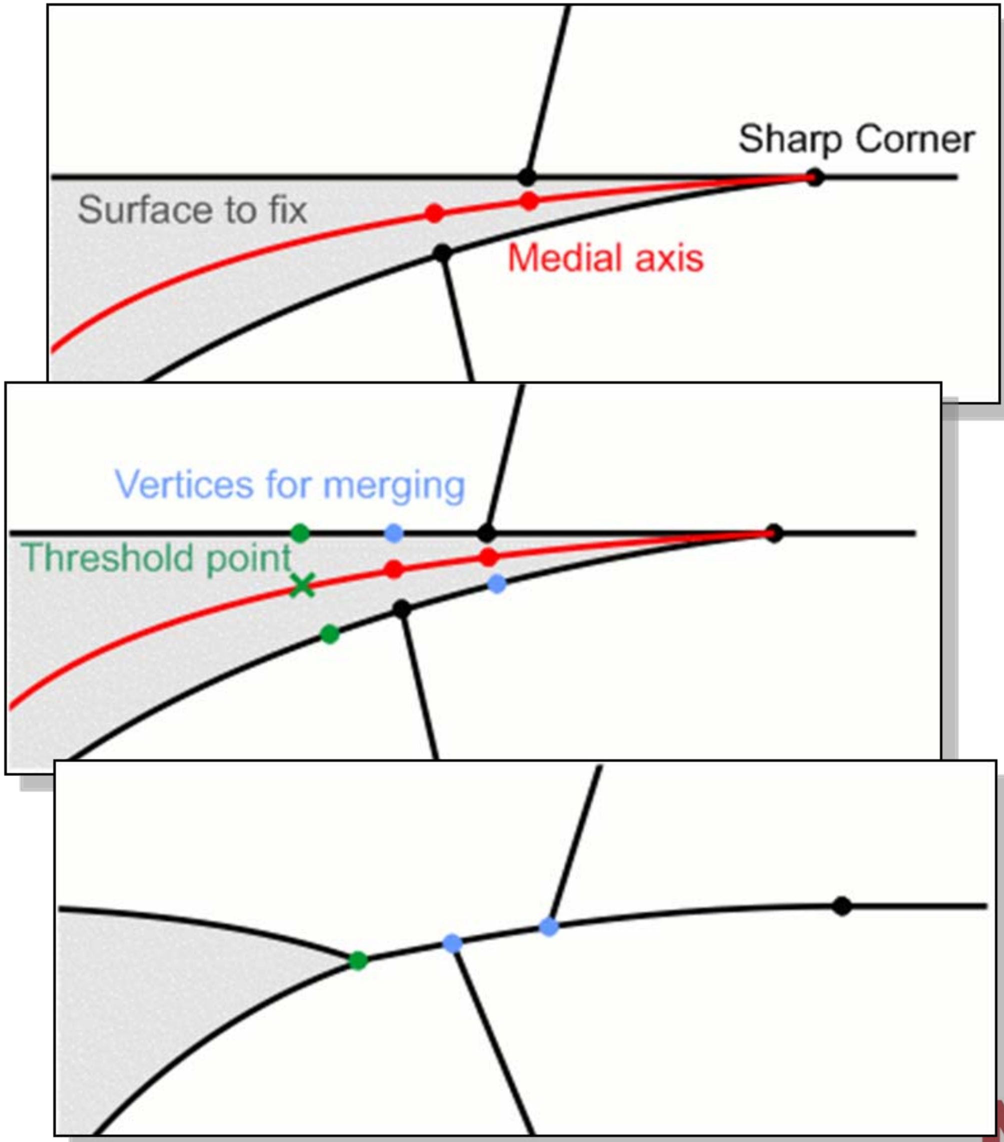
Automatic Defeaturing

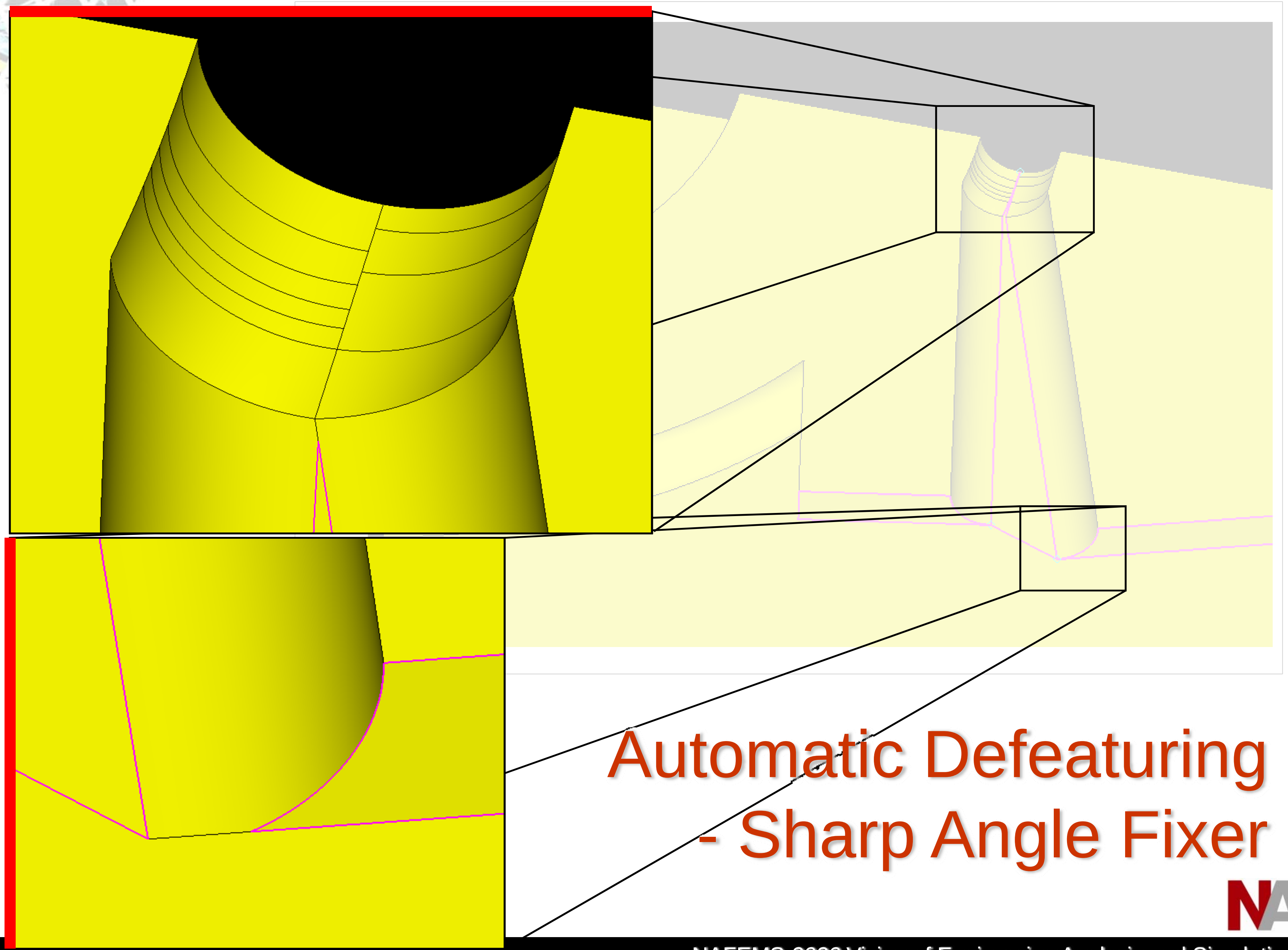
- Recognition of features defined by proximity and relative size
  - Constrictions, pockets, through holes, voids
  - Necks, slots, steps, tangencies, spikes, shoulders
  - Protrusions, pockets
- Identifying features for simplification or automatic removal



Automatic 2D Defeaturing

- 2D MO used to identify and fix potential problem areas for meshing
  - Narrow regions
  - Tangential conditions
  - Sharp edge angles
- User control of process
  - Threshold distance
  - Merge position
  - Truncate or merge to fix
- Intelligent automation

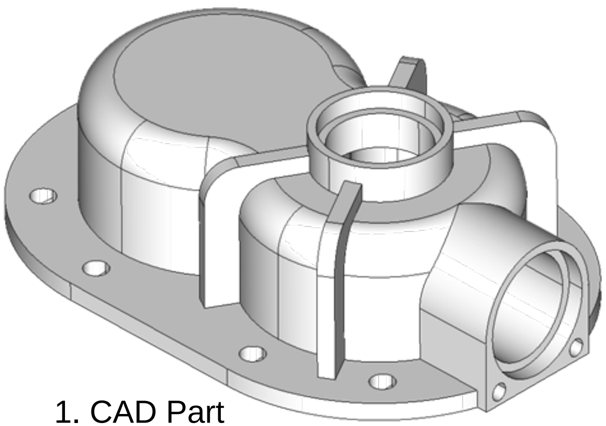




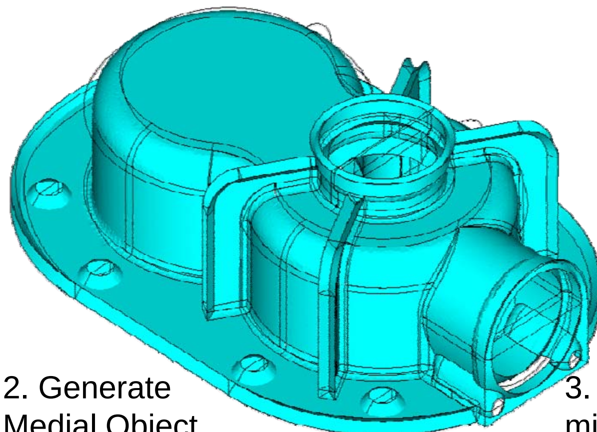
Automatic Defeaturing - Sharp Angle Fixer

Automatic 3D Defeaturing

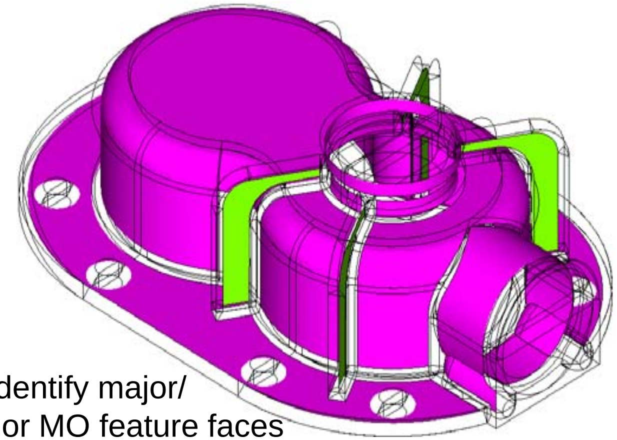
- 3D MO offers the promise of intelligent 3D model defeaturing for analysis



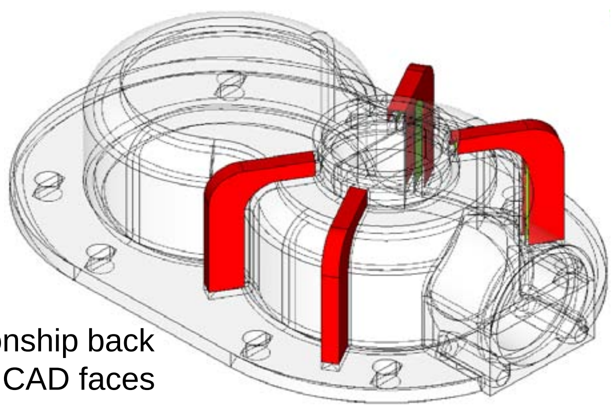
1. CAD Part



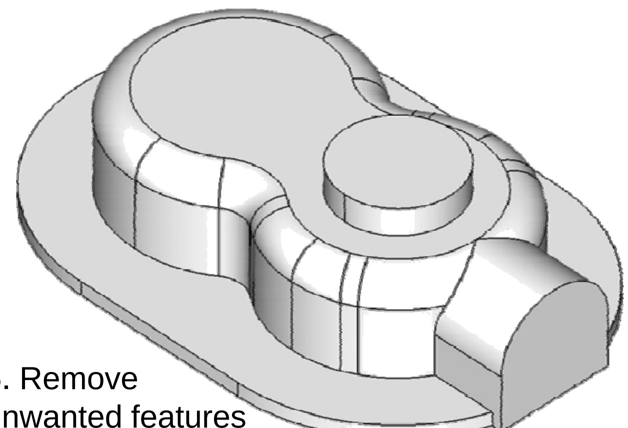
2. Generate Medial Object



3. Identify major/ minor MO feature faces



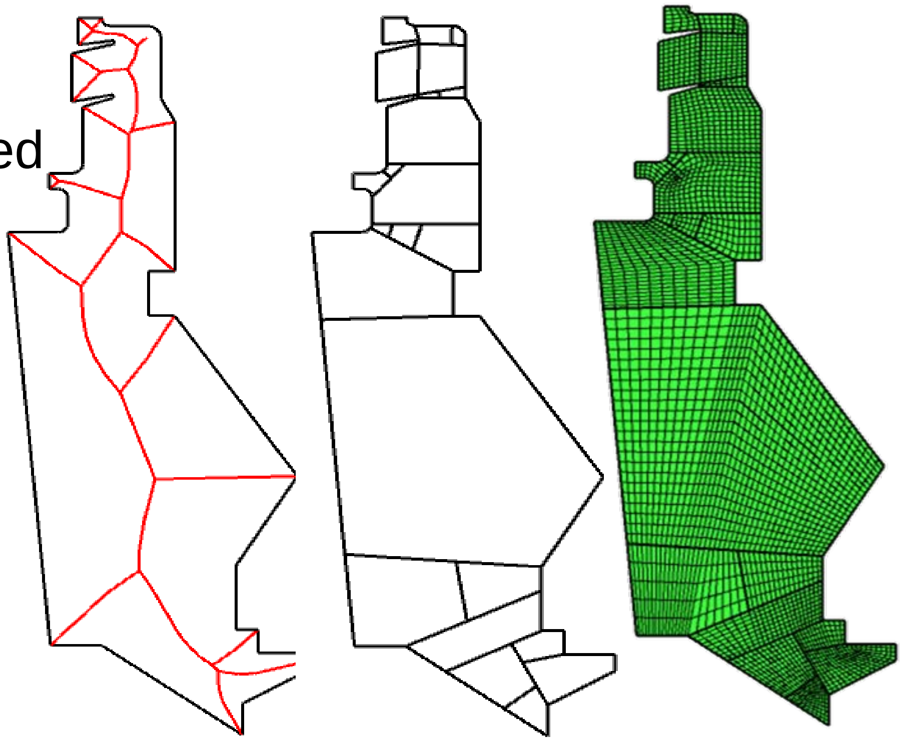
4. Relationship back to parent CAD faces



5. Remove unwanted features

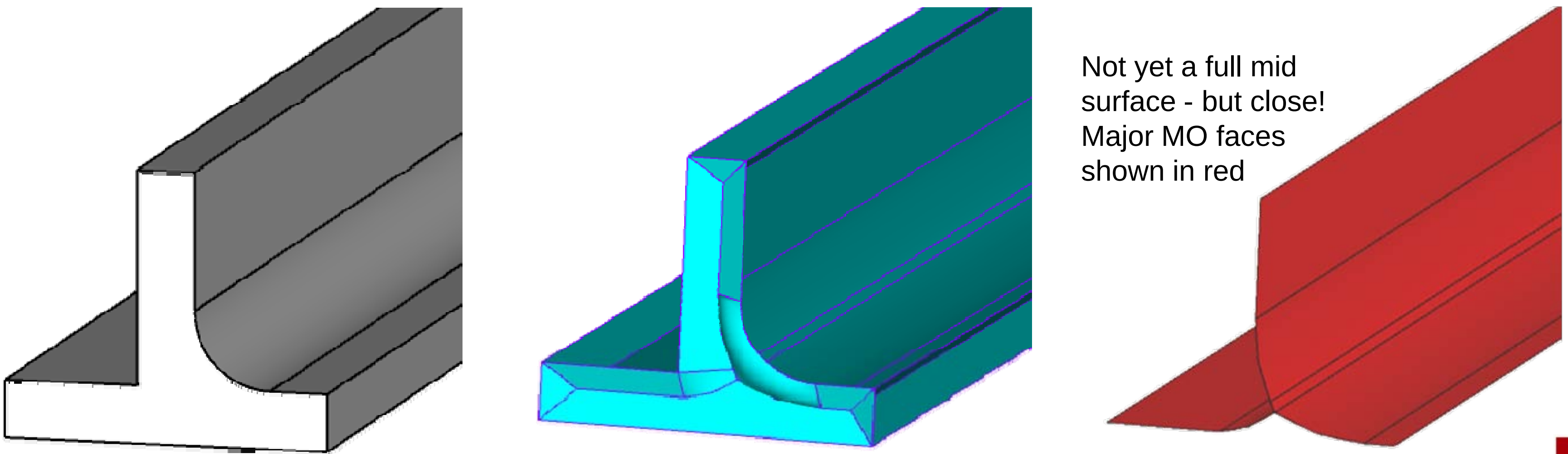
Spatial Partitioning / Subdivision

- GR using MO enables a geometry model to be traversed systematically in order to subdivide it into regions with limited complexity
- Automatic 2D subdivision for mapped meshing is an established method
- Potential for 3D GR subdivision
  - 3D subdivision for Hex dominant meshing
  - 3D subdivision for CFD body-fitted grids
  - Thin-thick subdivision for mixed dimensional modeling



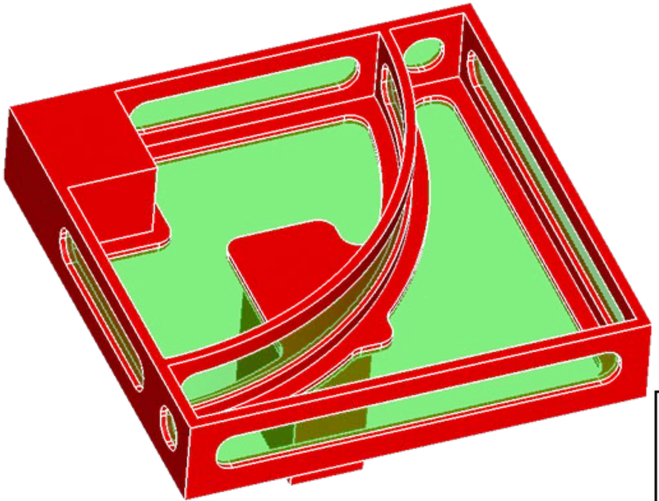
Mid Surface Extraction

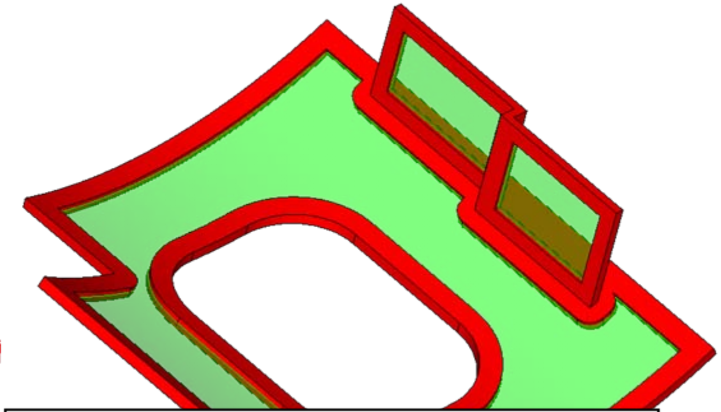
- Automatic extraction of well connected and accurate mid surface models
- MO is close to a full mid surface - but not quite!
  - Need to deal with intersections, edge conditions, thick regions
- Configurable GR application for accurate mid surfacing
  - 100% theoretical sharp intersections
  - Influence of features on shape of mid surface (effect of fillets etc)

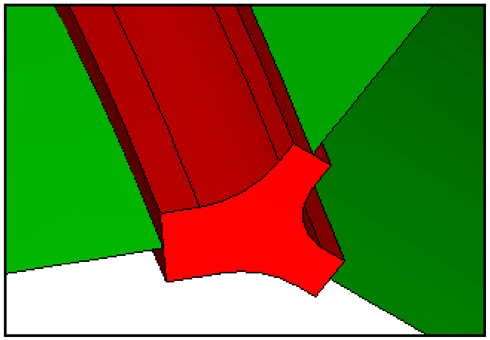


Thin-Thick Subdivision

- Subdivision of a model into thin and thick regions
  - Exploit theory of bending
  - Mixed dimensional solid and shell mesh and analysis
  - Significant degree of freedom reduction
  - Potential for massive time savings for iterative optimisation analysis
- What is needed to make this a realistic application?
  - Automatic process to derive a well connected, mixed dimensional model
  - Facility to manage solid-shell interface in downstream analysis







Potential for an analysis time reduction by a factor of 10-100

VIVACE Project

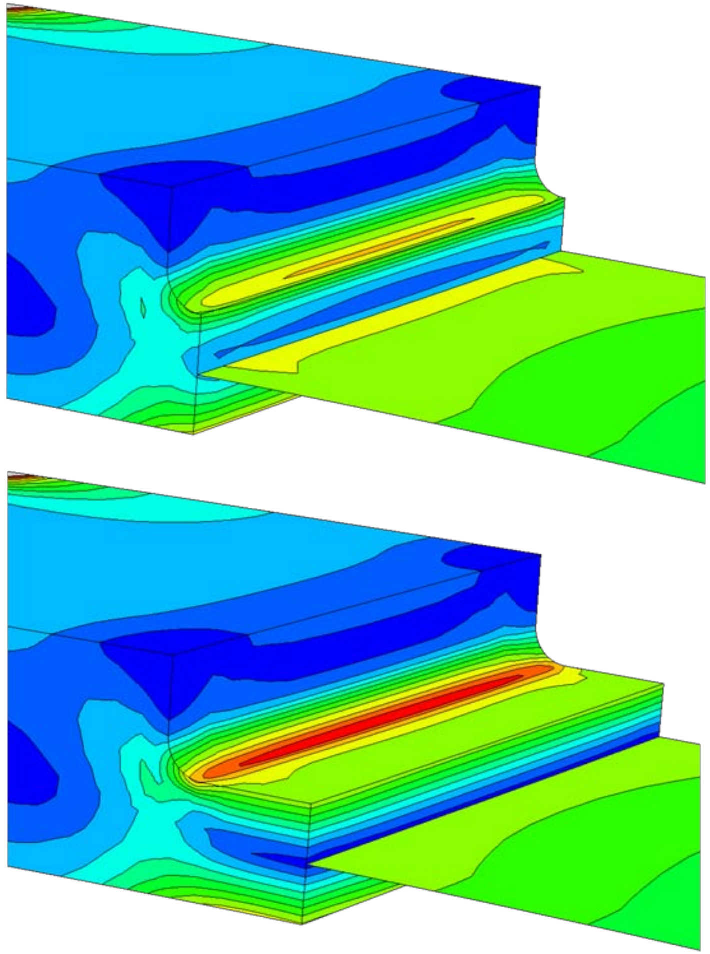
- Thin-Thick subdivision and mixed dimensional modelling was developed as part of the European VIVACE project involving aerospace companies, their suppliers, Universities and research institutes and software vendors
- A mixed-dimensional modelling methodology was researched and shown as a viable option for aero engine dynamics studies (Queens University)
- Automatic derivation of 3D thin-thick model from CAD (TranscenData)
- Demonstrated in a commercial analysis environment (Aero engine OEM)
- Tet mesh and analysis of engine component compared to that for a dimensionally reduced model
  - **Degrees of Freedom reduced from 9e6 to 7e5**
  - **Analysis time reduced by two orders of magnitude**
  - **Acceptable error and mass deviation**

http://www.vivaceproject.com/

http://www.vivaceproject.com/content/forum2/4-2.pdf

Implementation of Thin-Thick Subdivision

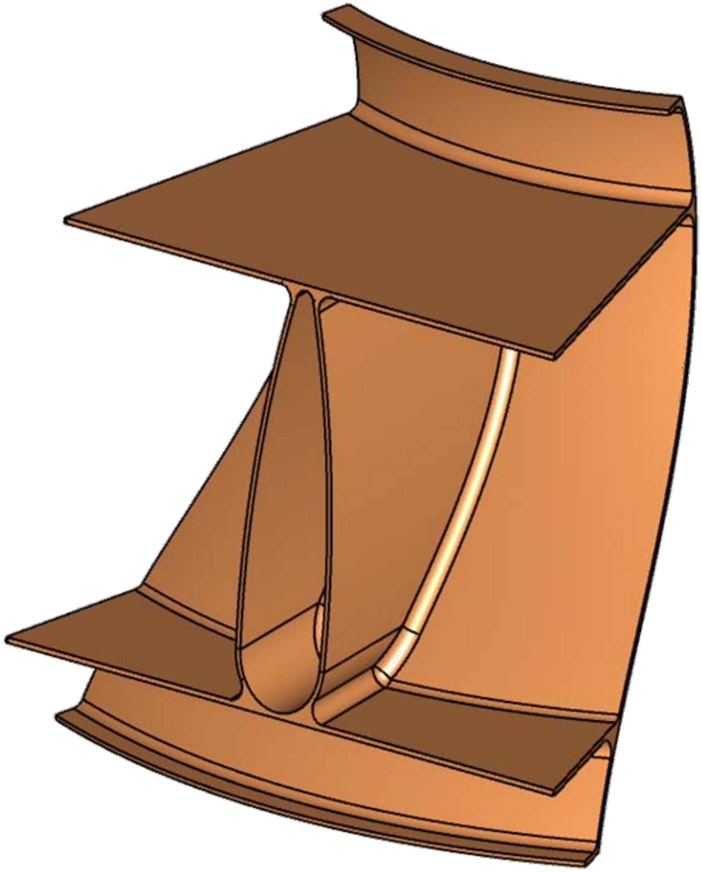
- Implementation based on MO/GR with user controls for:
  - Aspect ratio
  - Setback factor
  - Stay-thick tags
  - Leave thick border on sheets
  - Split into thin/thick solids
- Stress concentrations at shell edges (solution is 3D)
- Need to extend solids into shell region to capture stress concentrations
- “Set Back” Factor ensures valid stress pattern for shell elements and the application of bending theory

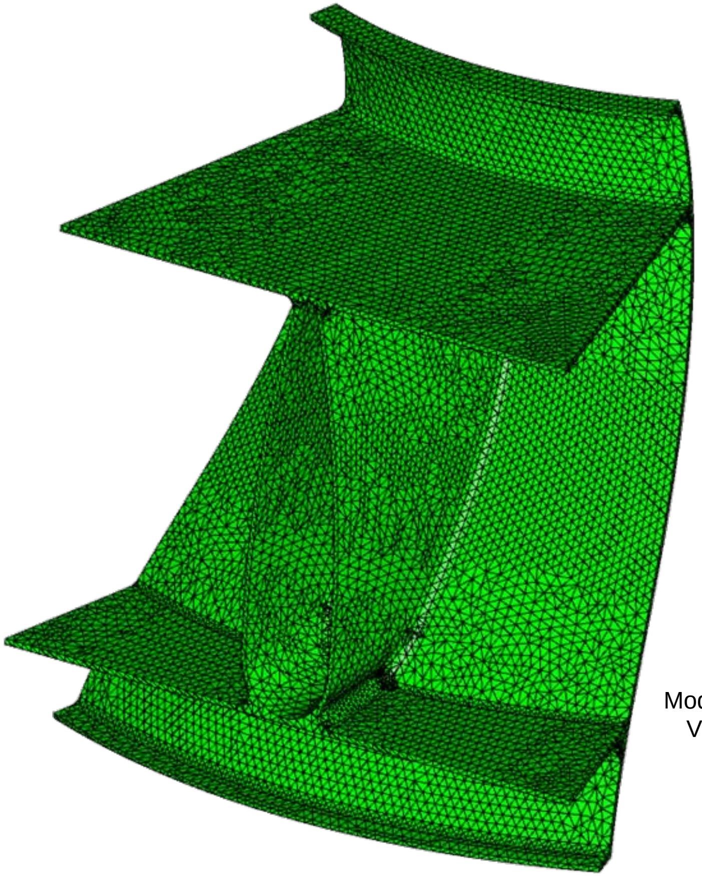


Images courtesy of Queens University and VIVACE project

Thin-Thick Subdivision Example

- Original CAD part
  - Full Tetrahedral mesh of section with too many DOF for iterative optimisation analysis

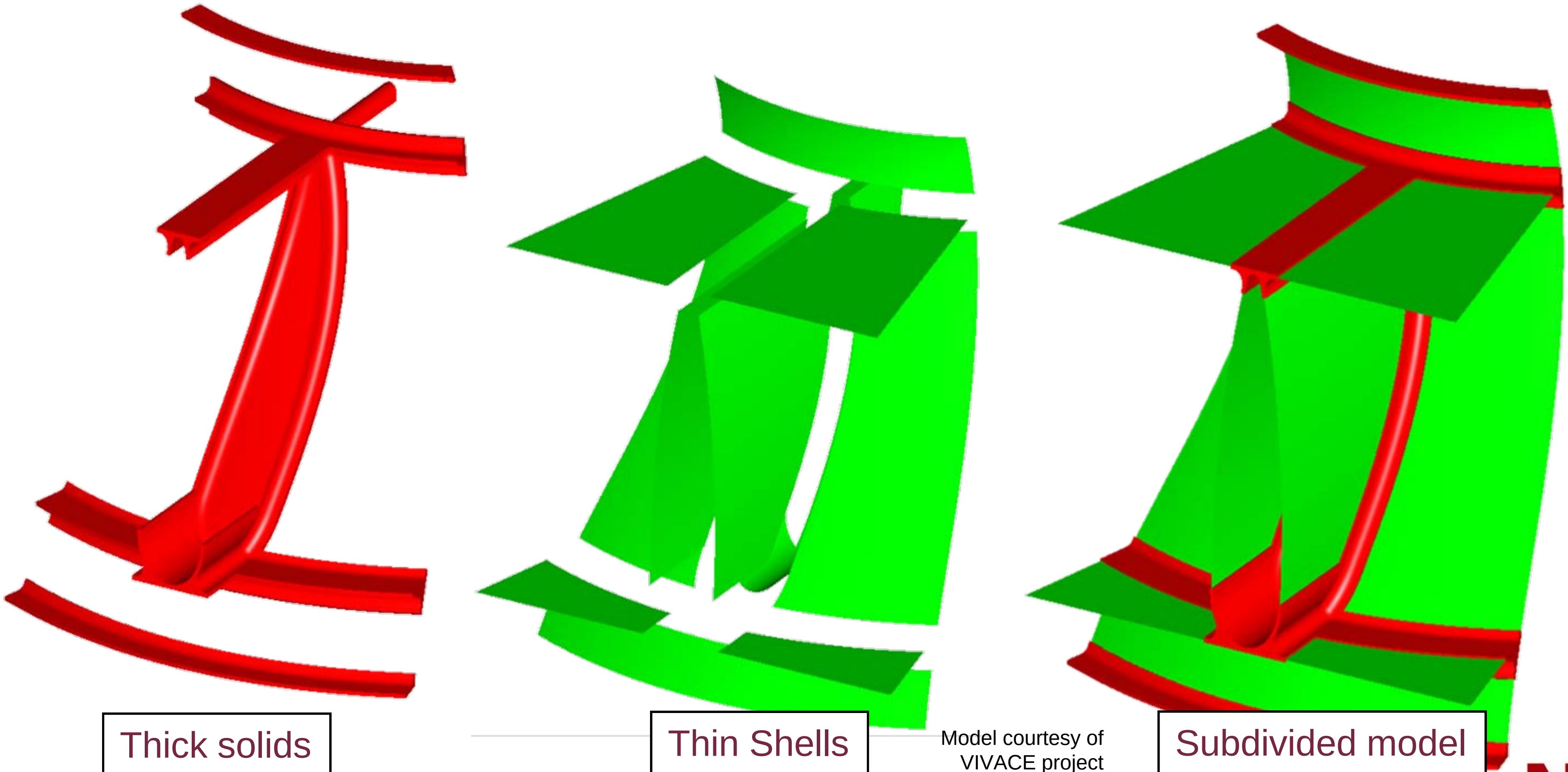




Model courtesy of
VIVACE project

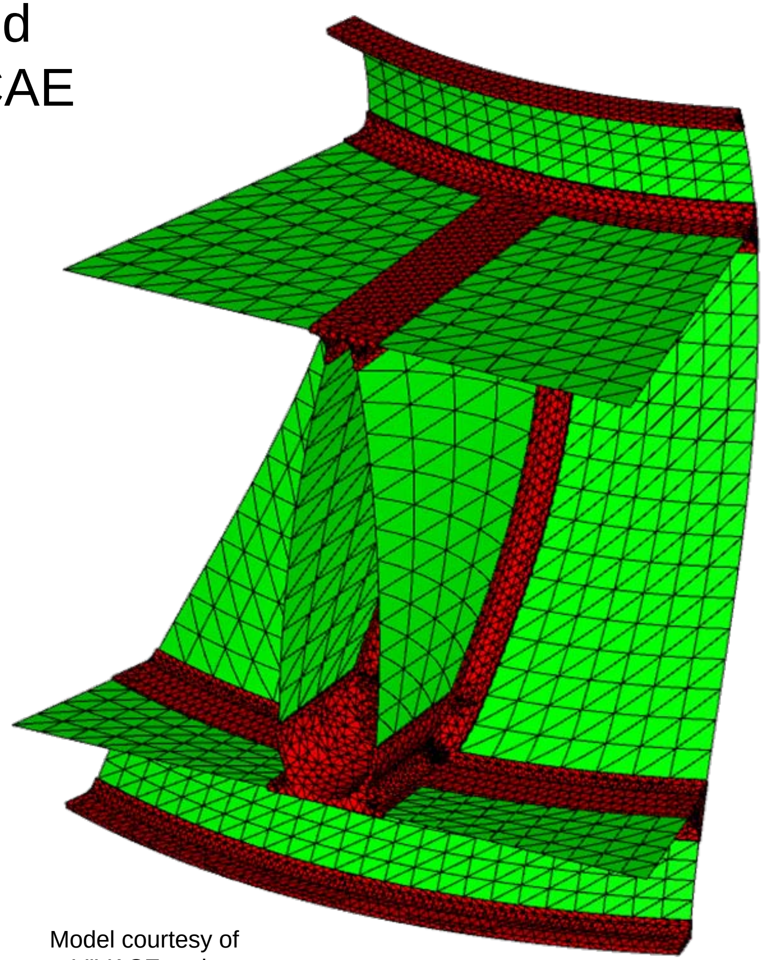
Thin-Thick Subdivision Example

- Utilise MO geometry and attributes for Geometry Reasoning and automatically derive Thin-Thick subdivided model



Thin-Thick Subdivision Example

- Export subdivided model with required shell-solid connectivity attributes to CAE system for meshing and analysis
- Shell-solid connectivity achieved downstream with MPCs
  - Auto generation possible using connectivity and mappings exported with mixed shell-solid geometry model
- Mixed tet and shell mesh with significant DoF saving



Model courtesy of VIVACE project

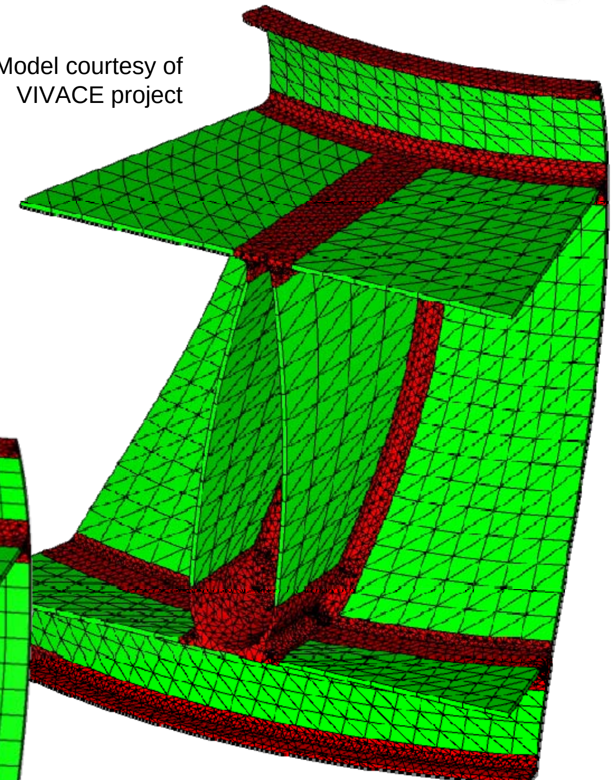
Thin-Thick Subdivision Demonstration

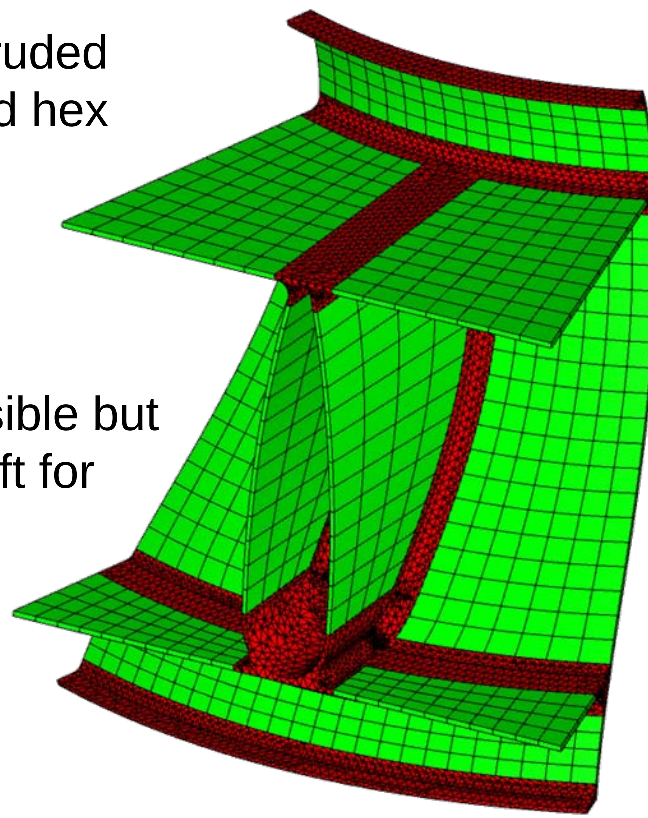
- GR application to automatically subdivide a CAD model into thin and thick regions

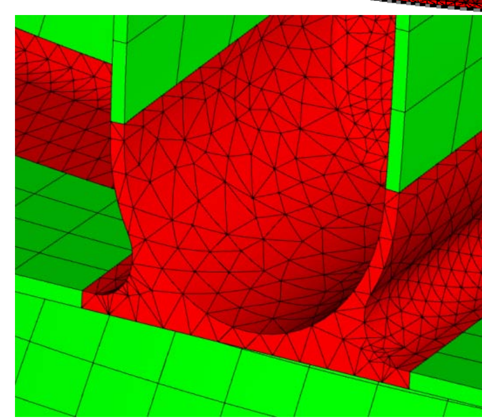
Wedge and Hex Dominant Meshing

- Extrude surface mesh using MO proximity data (thickness map)
  - Tri mesh extruded for mixed tet and wedge mesh
  - Quad mesh extruded for mixed tet and hex mesh
- Subdivision for hex dominant meshing
  - Hex where possible but some regions left for tet meshing

Model courtesy of
VIVACE project



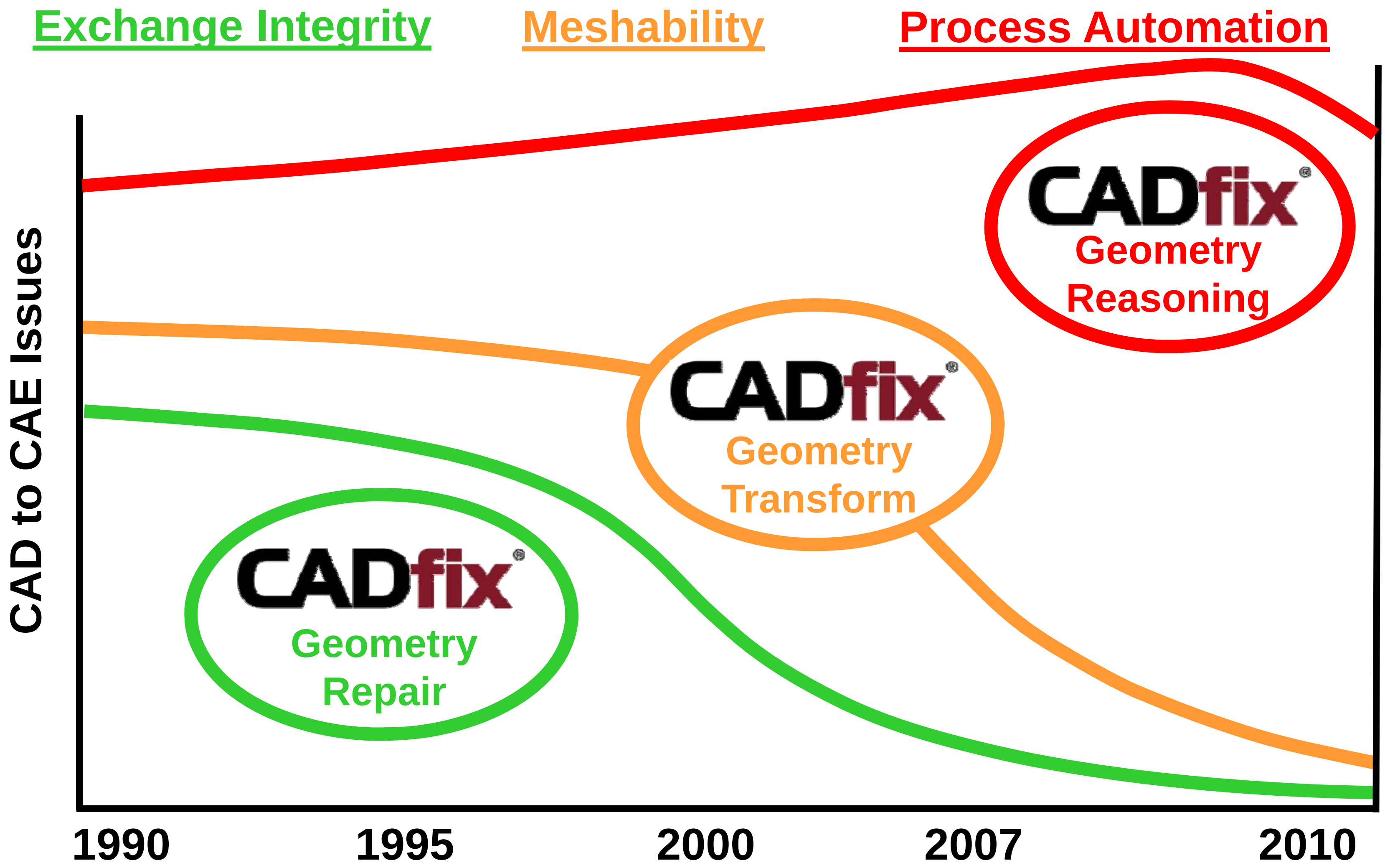




Conclusions

- Geometry is fundamental to future CAD-CAE processes
  - Data exchange integrity and meshability has improved
- Demanding requirements for specialist CAE applications and process automation
  - Automatic and intelligent defeaturing
  - Automatic subdivision - 2D, Thin-Thick, Hex dominant, Fully Hex
  - Mid surface extraction
  - Shelling
- Geometric Reasoning technology is unique with significant potential
- GR is key to future CAD-CAE integration and automation

CADfix Developments for CAE



New Frontiers in CAE Interoperability

Thank you

Any questions?

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