SAND2008-2838P

MESHING and GEOMETRY RESEARCH and DEVELOPMENT

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Computational Modeling Sciences

CIS External Panel Review
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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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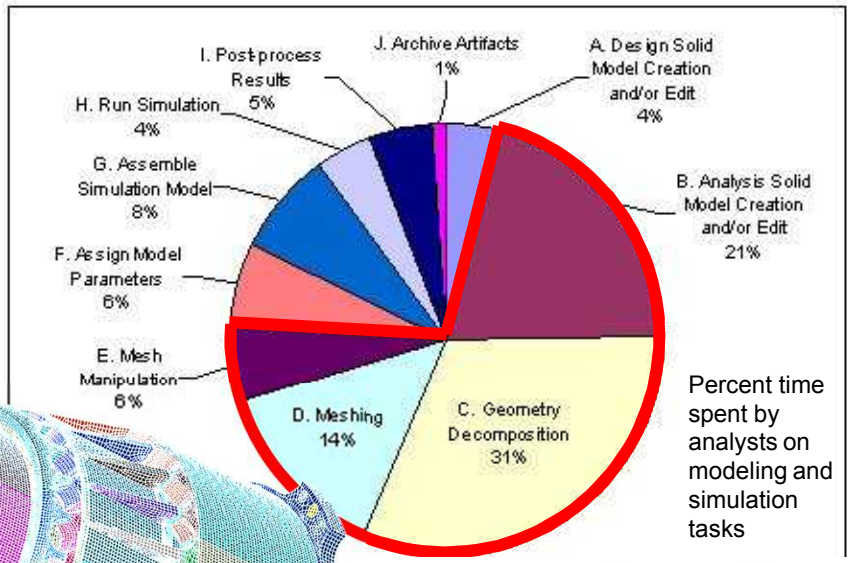
Meshing and Geometry: Critical Technologies for Sandia

Motivation

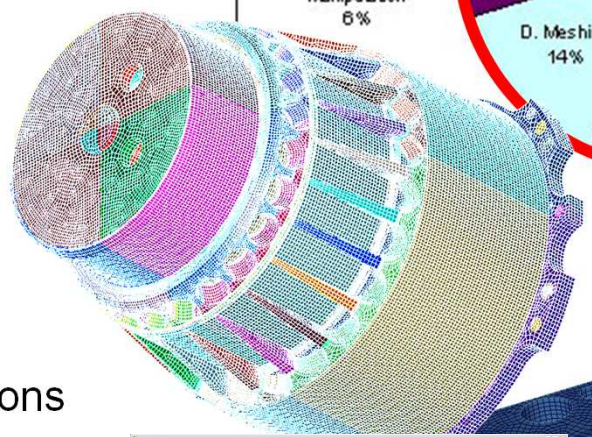
- Required by almost all SNL FEA codes
- Most time consuming aspect of simulation
- Sandia designers demand all-hex meshes

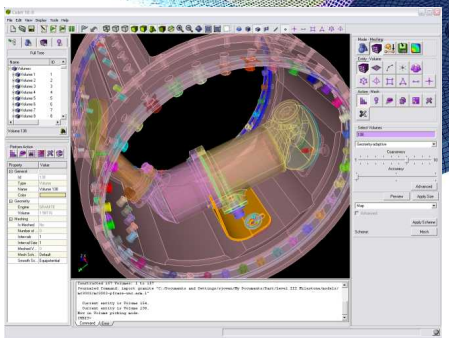
Sandia's Impact

- Definitive leader in hex meshing research
- Sponsor of annual International Meshing Roundtable
- Winner of 2 R&D-100 awards
- Numerous patents and publications
- CUBIT Geometry and Meshing Toolkit – over 400 users per month
- Goodyear and Caterpillar corporate meshing solution

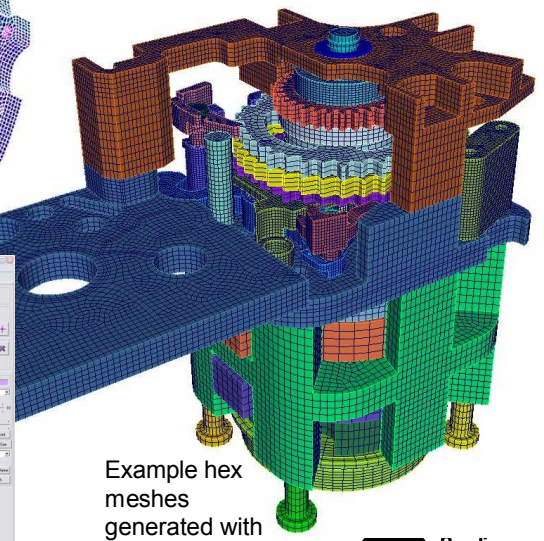


Percent time spent by analysts on modeling and simulation tasks





CUBIT Geometry and Meshing Toolkit



Example hex meshes generated with CUBIT

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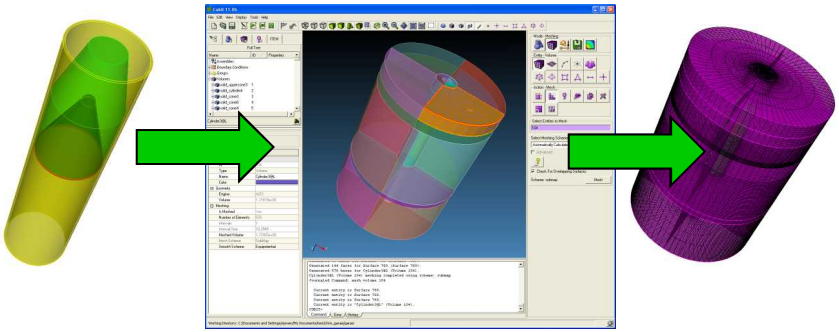
Geometry and Mesh Generation Toolkit

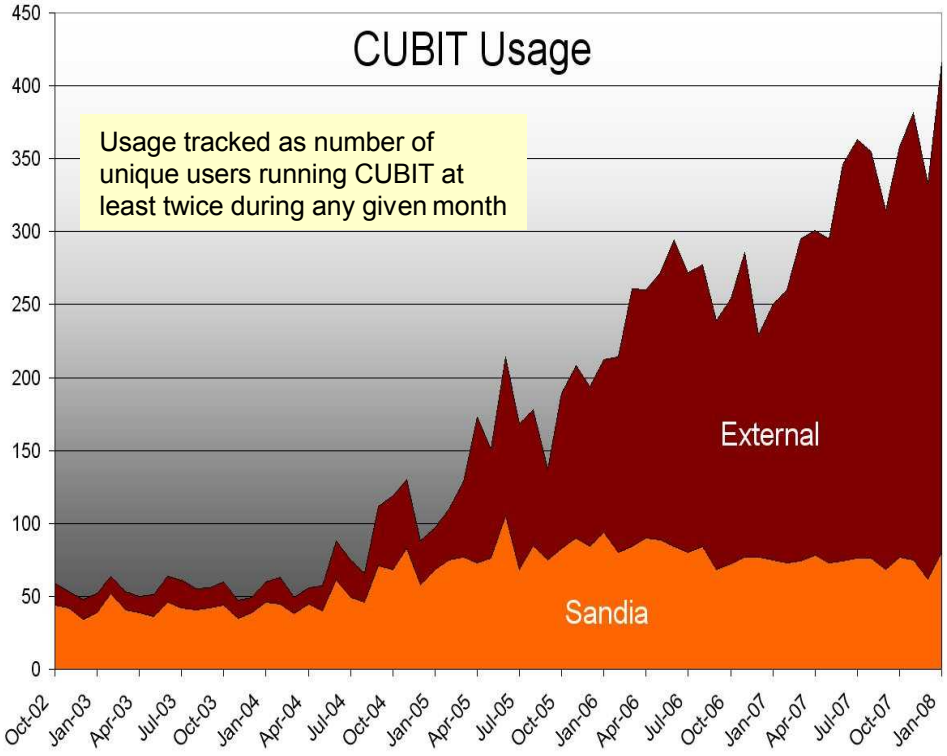


CAD Model | CUBIT | Mesh

CUBIT accepts a CAD model as input, and exports a finite element mesh ready for analysis

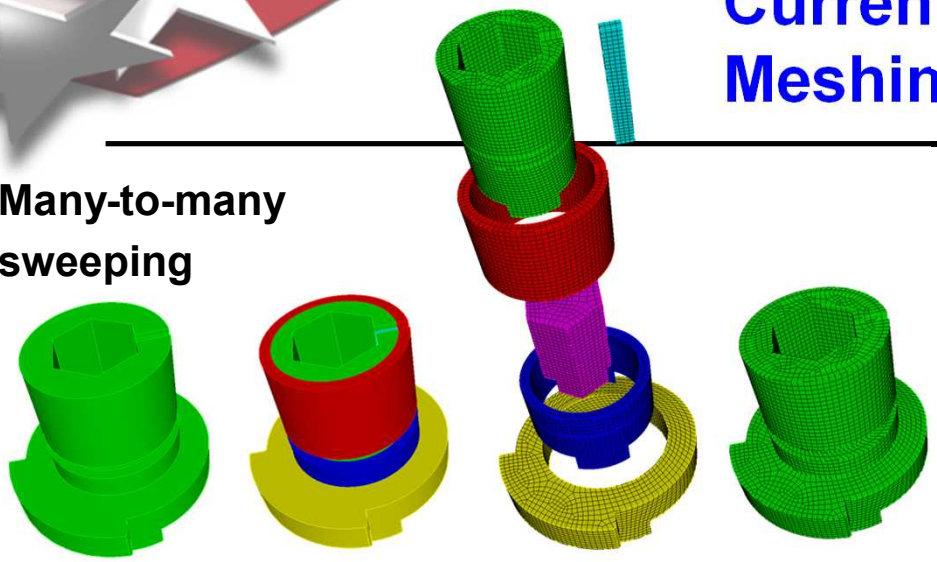
CAD-Based Meshing Toolkit

- Specializes in all-hex meshes for complex assemblies
- CAD Geometry diagnostics, clean-up and decomposition tools
- Automatic Hex, tet, quad, tri meshing schemes
- Includes wizard-based workflow for model prep.
- Element quality diagnostics and mesh improvement
- Professional cross-platform GUI
- Command/script driven interface
- Supports multiple CAD and mesh formats



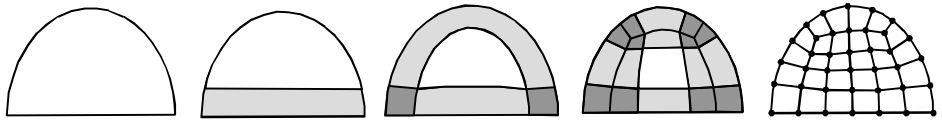
Current Hexahedral Meshing Strategies

Many-to-many sweeping

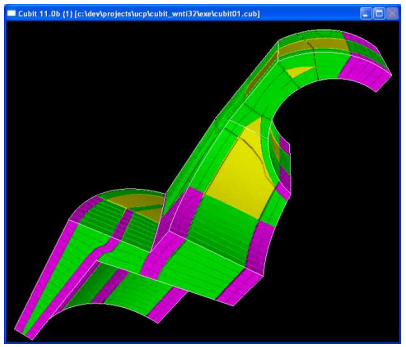


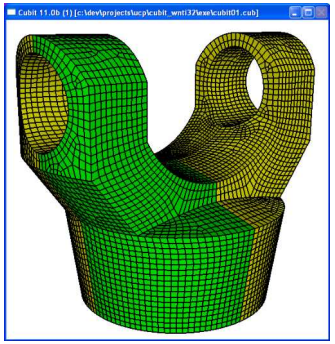
Decomposition technique for single axis sweepable parts.
Released as part of CUBIT 11.0, Nov. 2007

Unconstrained Plastering



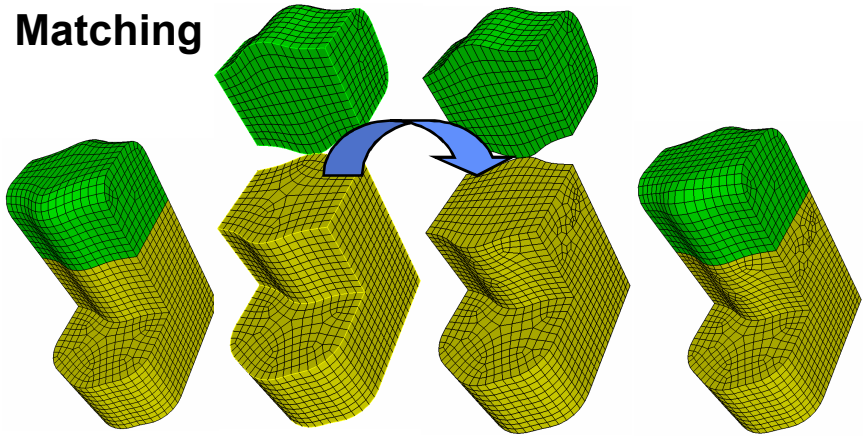
Decomposition technique that advances geometric layers through the solid model to define simplified mappable and sweepable regions





3D UCP research progressing, but on hold. Matt Staten on DSP

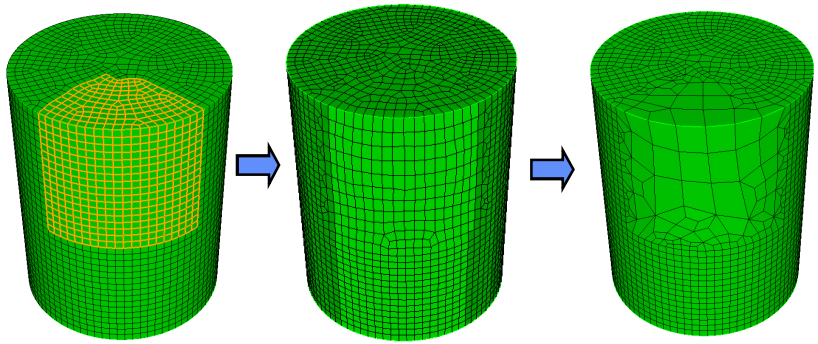
Mesh Matching



Forces a conforming mesh between coincident pats through local hexahedral transformation operations. Paper submitted

Hexahedral Refinement and Coarsening

New robust technique for local conformal refinement released.
Conformal coarsening algorithms progressing. Patent submitted.

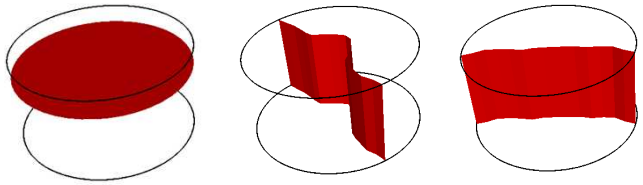


3D conformal hex coarsening example.

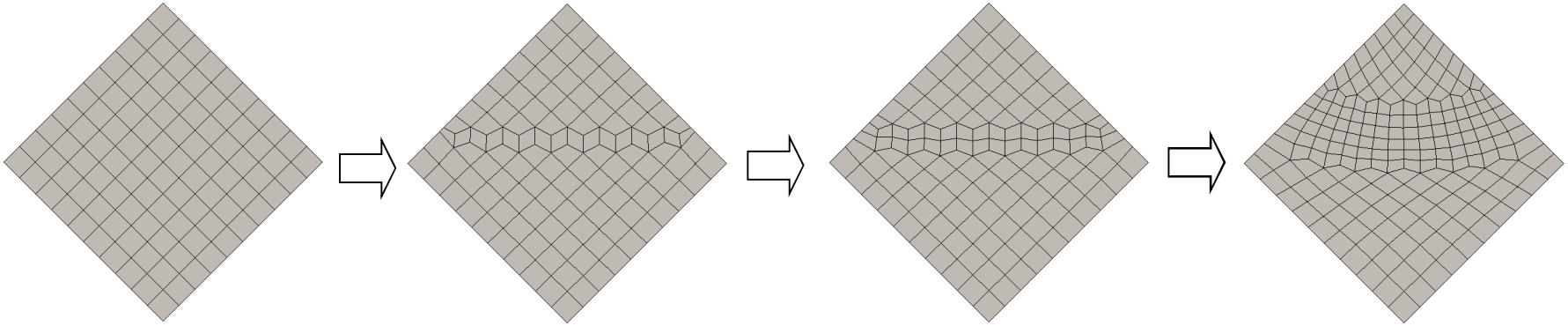
Sheet Insertion: A new a strategy for all-hex mesh generation

Jason Shepherd

- Hexahedral meshes are composed of layers of hexahedral elements.
  - **(These layers can also be thought of as manifold surfaces, referred to as sheets.)**



- New layers can be inserted into existing meshes using sheet insertion techniques (i.e., pillowing, dicing, grafting, meshcutting, etc.)



- The goal, then, is to
  1. define minimal sets of layers that must be present to capture the geometric object,
  2. constrain the topology and geometry of the layers to satisfy analytic, quality, and topologic constraints for the final hexahedral mesh, and
  3. automate the process.

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Automation of the sheet insertion procedure

Automatic Sheet Insertion Procedure

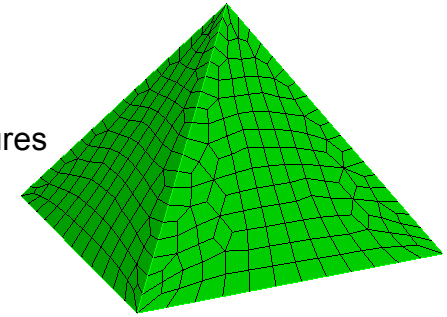
- Embed geometry in a base hexahedral mesh
- Recover geometry and topology from the base mesh by inserting “sheets” of hexes
- Improve mesh

Sheet Insertion Impact

- Potential for all-hex meshing for arbitrary geometry
- Major improvement over current grid-based procedures

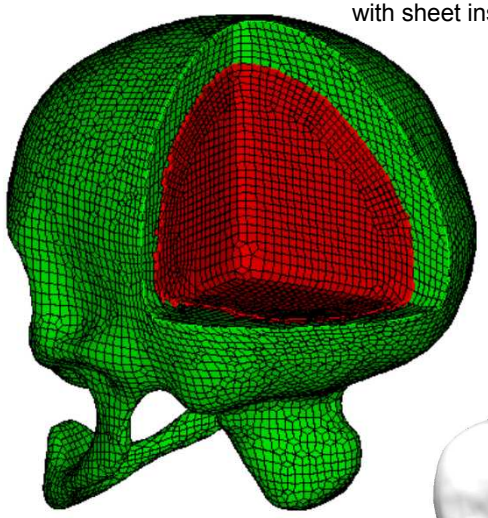
Sheet Insertion Status/Challenges

- Robust recovery of topology from mesh
- Full and robust automation of sheet insertion
- Automation of single parts by Q4 FY08

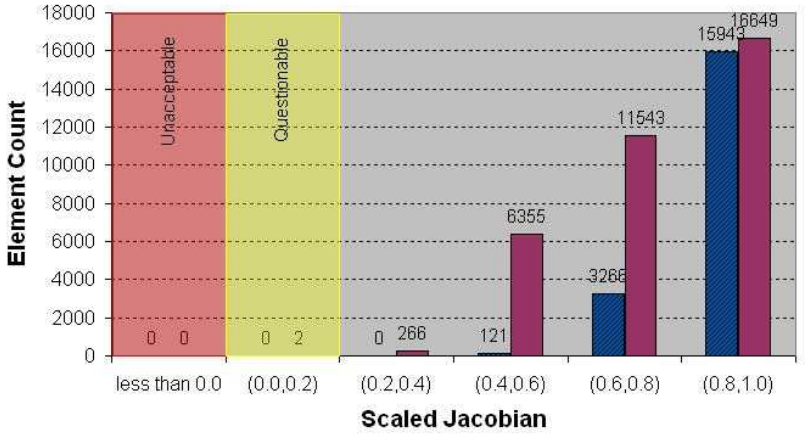


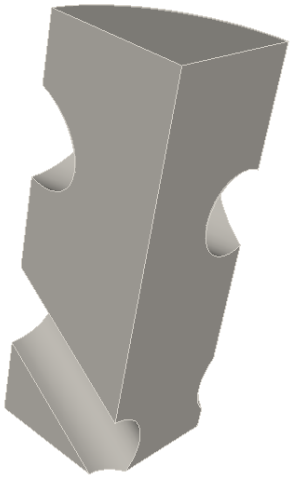
Example automatic sheet insertion procedure

Skull hex model generated with sheet insertion

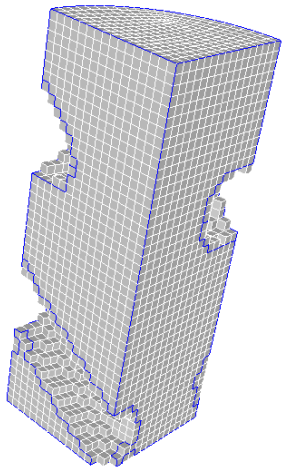


Skull Element Quality Distribution

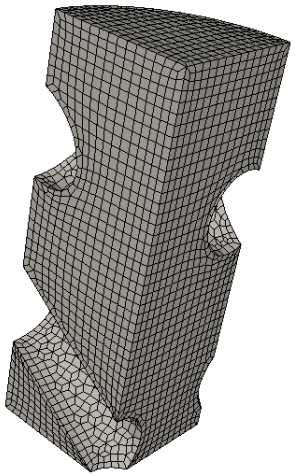




Original CAD model



CAD topology embedded in hex mesh



Final mesh

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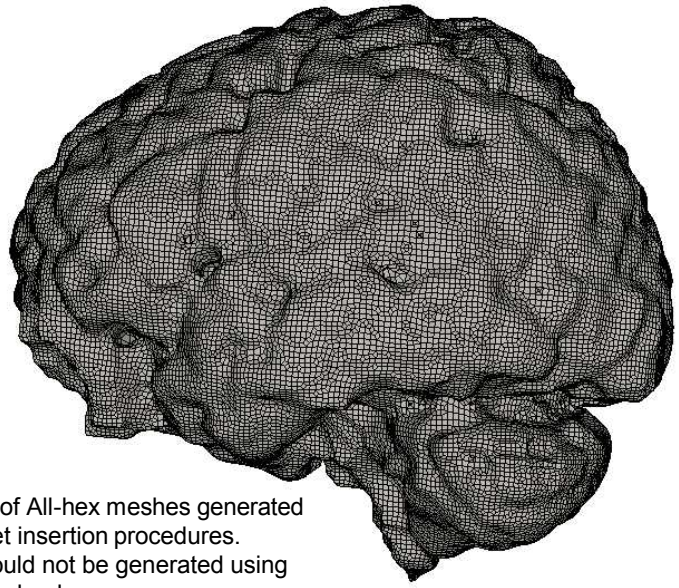
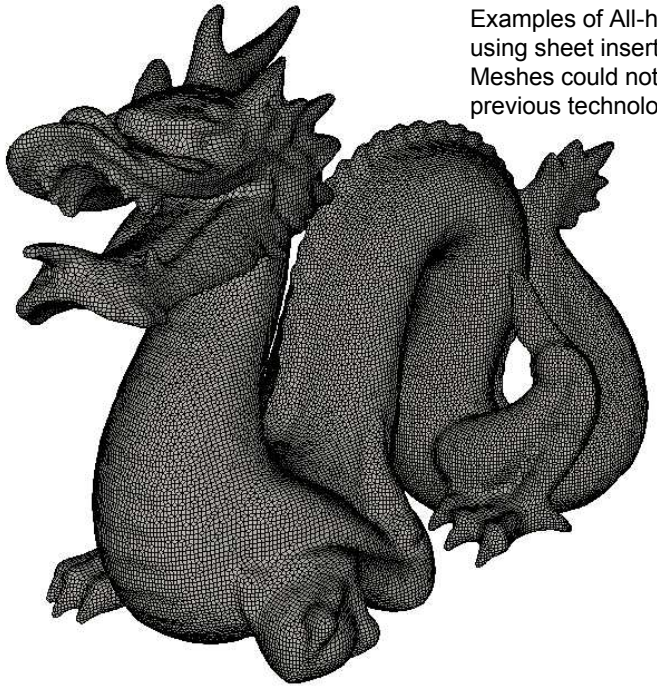
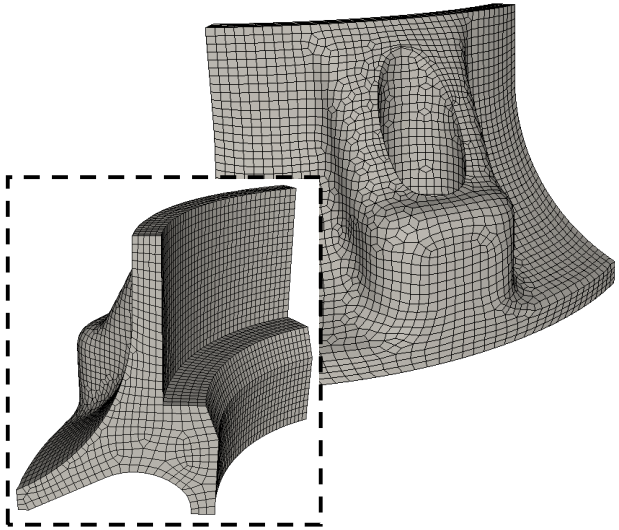
Sheet Insertion Examples



Examples of All-hex meshes generated using sheet insertion procedures. Meshes could not be generated using previous technology

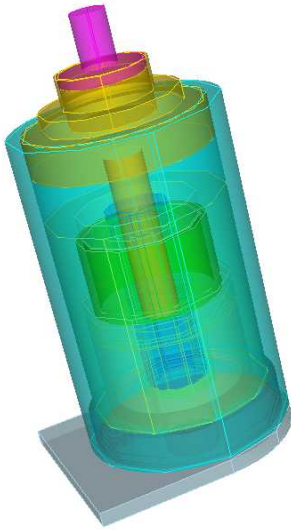




AF&F: Example Sandia model. Eventual objective of fully automatic hex meshing

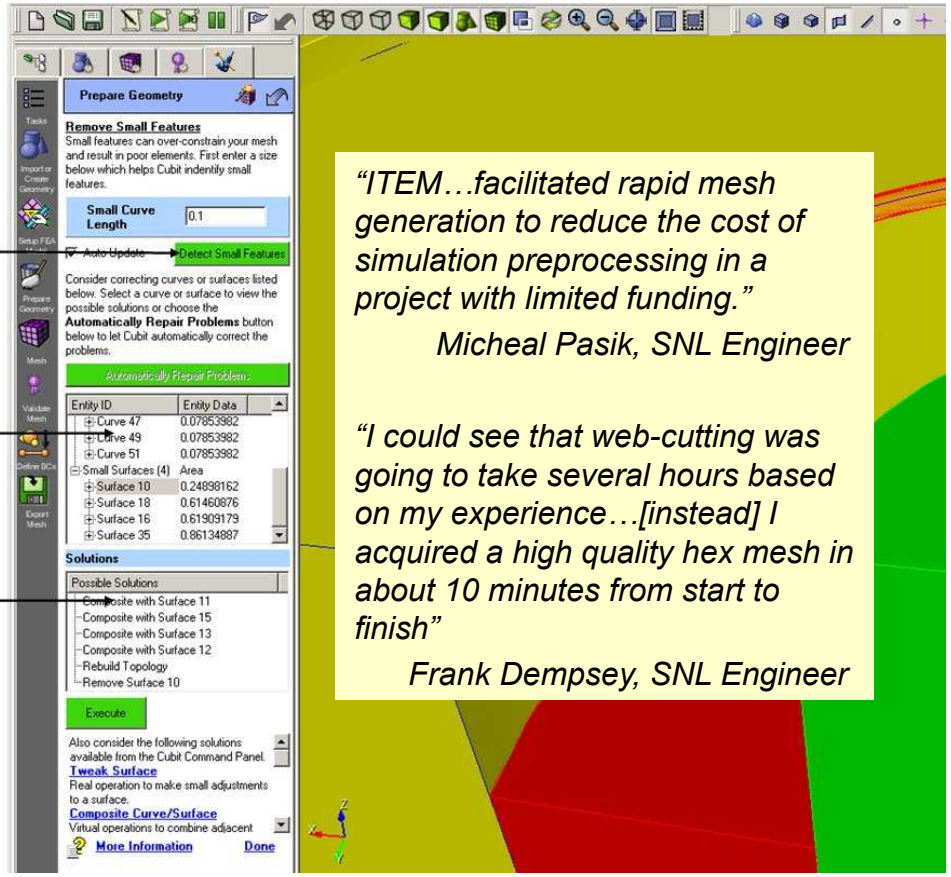
Simplifying the CAD to Mesh Process with ITEM

ASC Level 2 Milestone 2007



CAD Model

1. Diagnostic
2. Problems Detected
3. Solutions

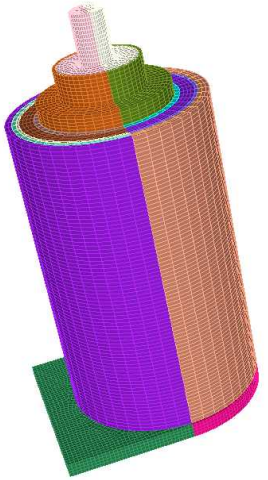


"ITEM…facilitated rapid mesh generation to reduce the cost of simulation preprocessing in a project with limited funding."

Micheal Pasik, SNL Engineer

"I could see that web-cutting was going to take several hours based on my experience…[instead] I acquired a high quality hex mesh in about 10 minutes from start to finish"

Frank Dempsey, SNL Engineer



Mesh

ITEM: Immersive Topology Environment for Meshing

Uses a diagnostic solution approach in a wizard-like environment to guide the user through the geometry preparation and meshing process

R&D 100 Nominee

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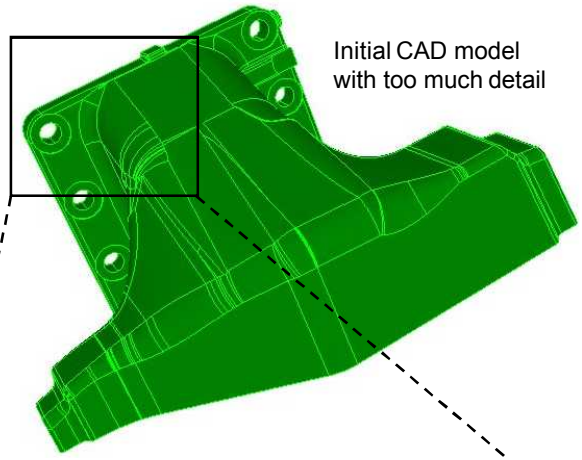
Geometry tolerant meshing eliminates need for tedious geometry repair

ASC Level 2 Milestone 2008

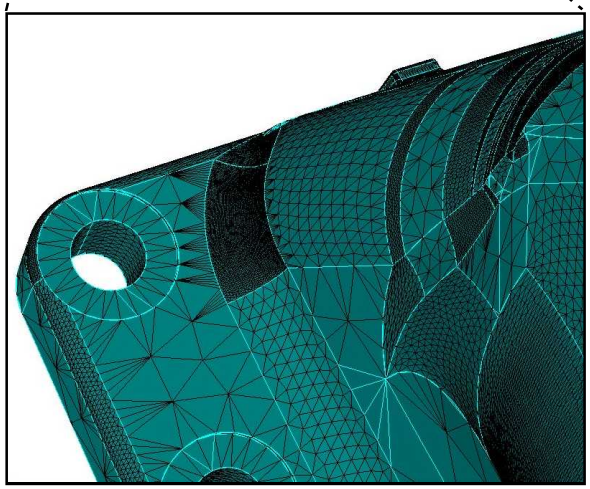


Geometry Tolerant Meshing Procedure

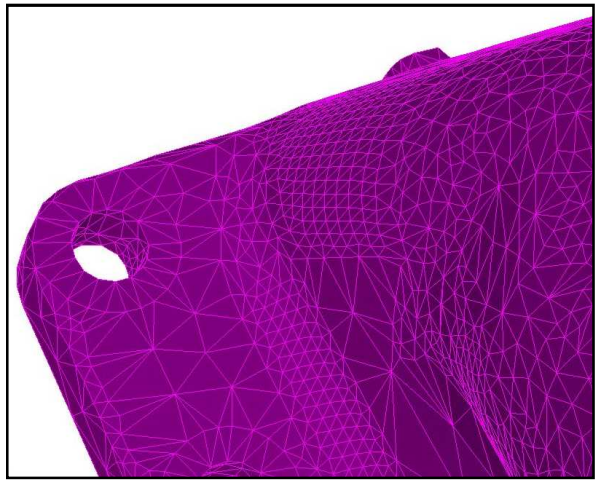
- Use ITEM to resolve imprint and merge issues
- Build a facet-based representation of the model
- Modify facets to suppress unwanted features by collapsing triangles
- Use existing triangle and quad algorithms to mesh over facets

Impact

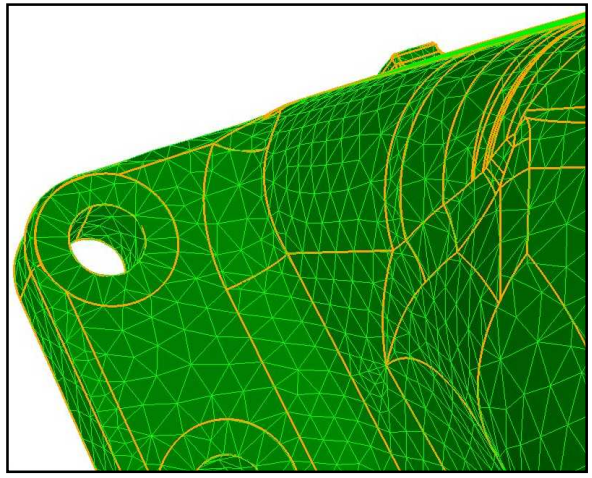
- Dramatically reduce time to mesh
- Increase throughput and design iterations



Triangle facets are extracted from the geometry kernel for each surface and stitched together



Triangle facets are adjusted by collapsing small edges to eliminate small features



Mesh is generated over modified triangle facets resulting in tolerant mesh

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