NA Regional Summit 2008 NAFEMS
2020 Vision of Engineering Analysis and Simulation
October 29 - 31, 2008 | Hampton, Virginia

Modeling Bolted Connections

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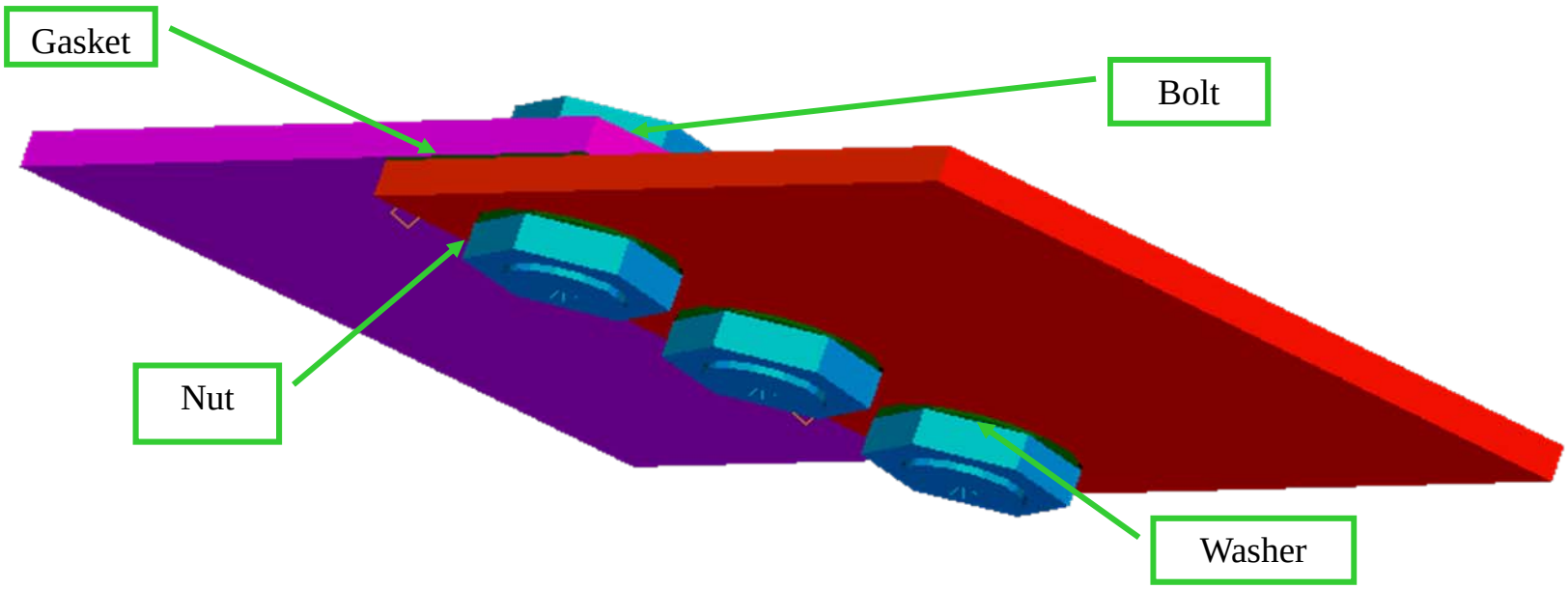
Overview

- Bolted Connection
- Engineering Judgment
- Modeling Options
- Summary

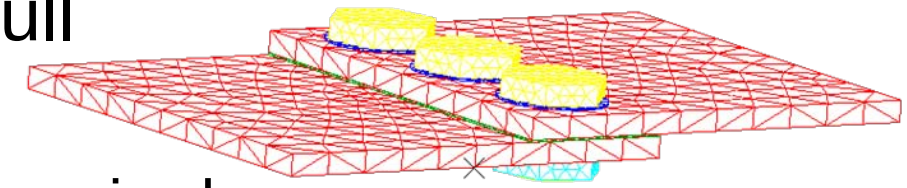
Typical Bolted Connection



- Technology has advanced in modeling, meshing and solving
- The connections maybe the critical path
- The model must represent the physical behavior within the functionality of FEA

Engineering Judgment

- The ability to model the full joint is available
  - The computer resources required may be prohibitive
  - The user may get more information then required or needed
  - The time required for data reduction may be more then the model preparation time



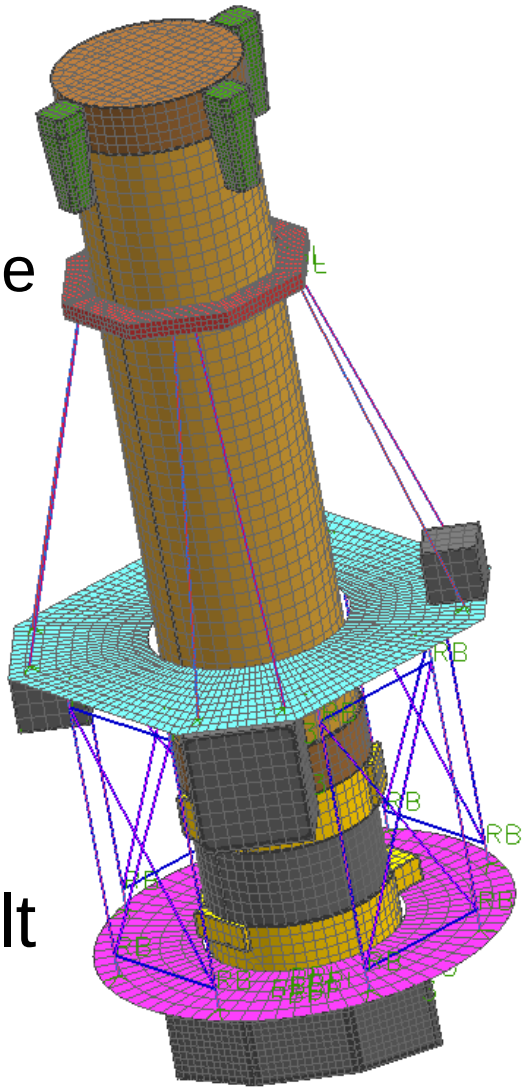
1609 Elements

7341 Nodes

29 Contact Pairs

Engineering Judgment

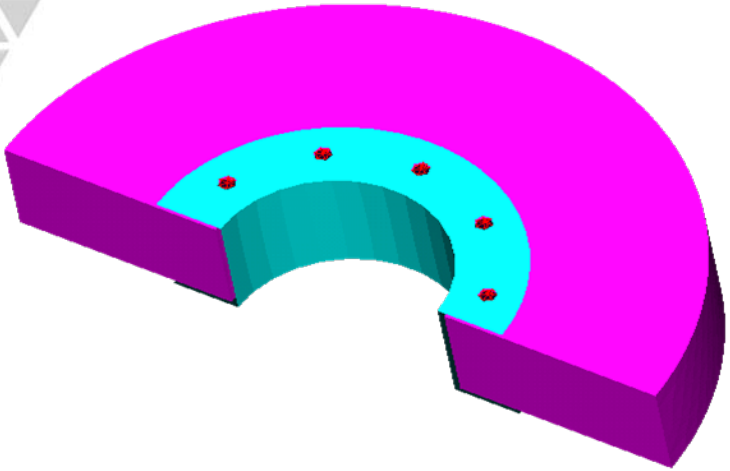
- What information is needed
  - Where is the product in the design cycle
- What resources are available to perform the analysis
- Is a full system model required
- Is a detailed simulation including bolt preload needed

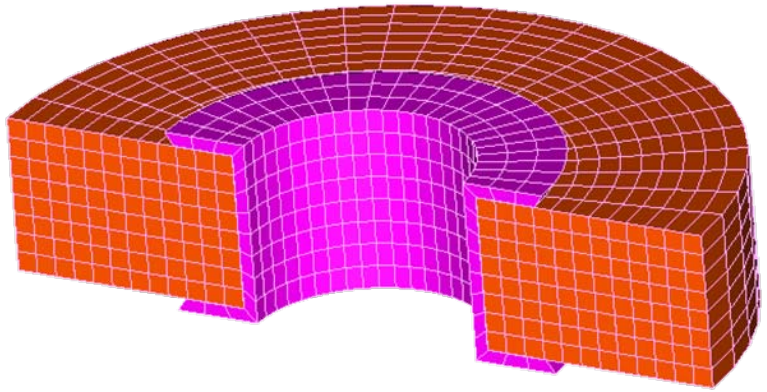


Modeling Options

- Selection of the connection model depends on the element type that is used for the structure
- The model may or may not include the hole
- Connection Modeling Options
  - Merge Nodes
  - Rigid Elements
  - Spring Elements
  - Beam Elements

Merge Nodes

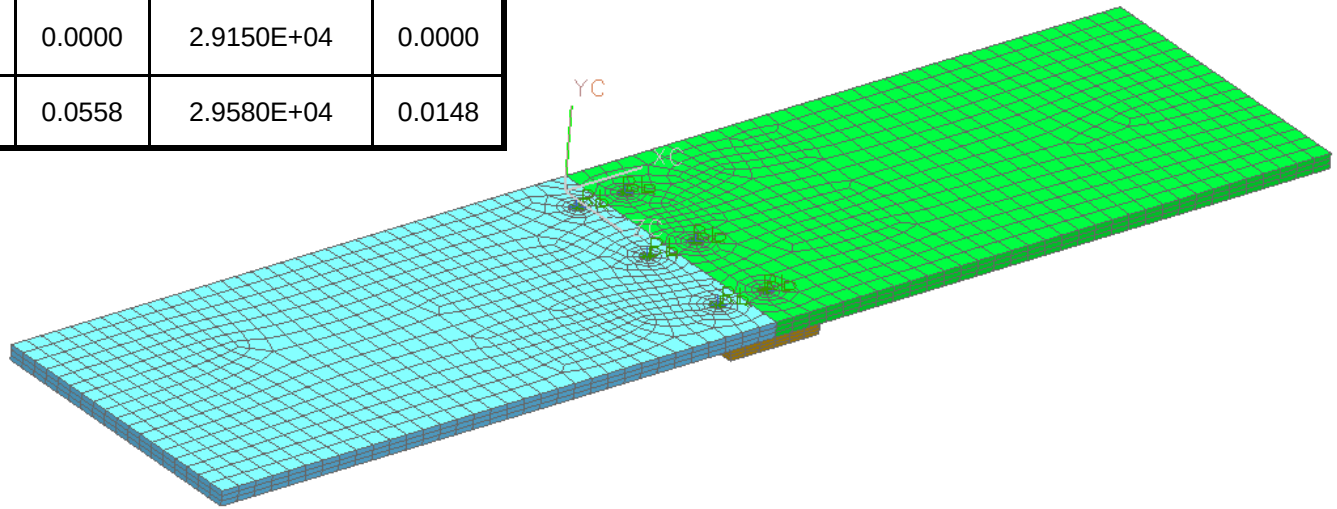




- Holes may be included
- Bolt locations or surface can be merged
- Contact should be included when only bolt locations nodes are merged
- Shell models will not have coincident nodes
- Matching nodes is an additional task
- Joint forces not available

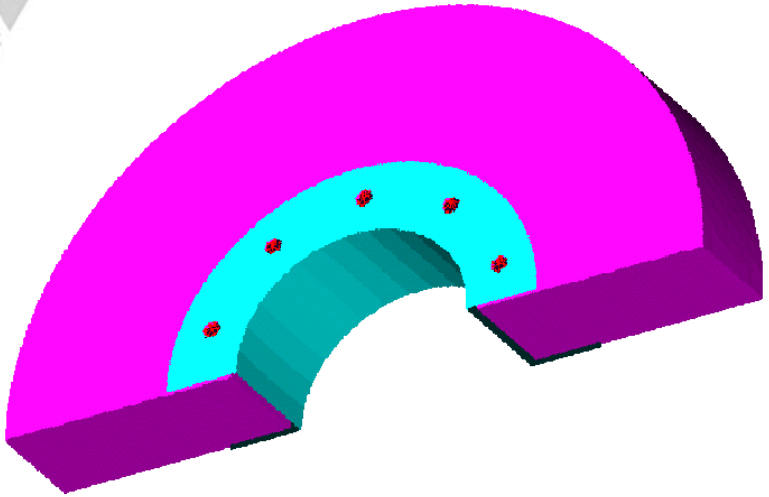
Merge Nodes

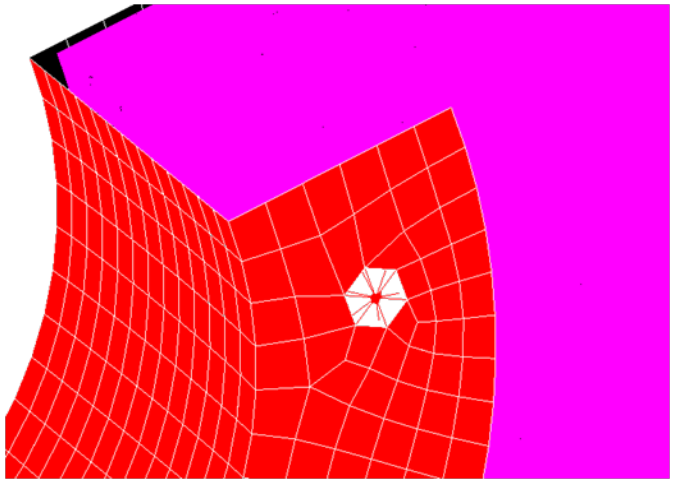
Mating	Disp	Diff	vM Stress	Diff
Contact	0.1541	0.0000	2.9150E+04	0.0000
Contact	0.1627	0.0558	2.9580E+04	0.0148



- Contact must be accounted for between all bodies if only the nodes at the bolt locations are merged
- The glue option on NX Nastran can be used
- The nodes between all bodies can be merged
  - Matching the meshes may require additional effort

Rigid Elements

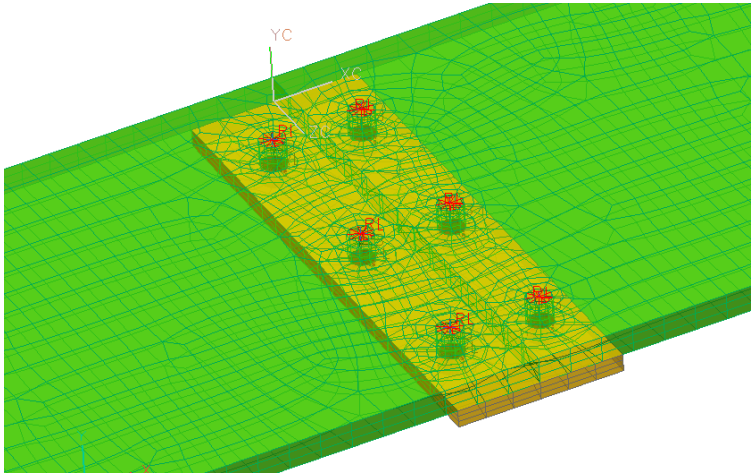




- Holes may be included
  - Maintains the hole's shape
  - May add numeric stiffness around the hole
  - Can be extended to include head area
- Joint Forces can be recovered
- If the nodes are not coincident, a moment will be induced

Rigid Elements

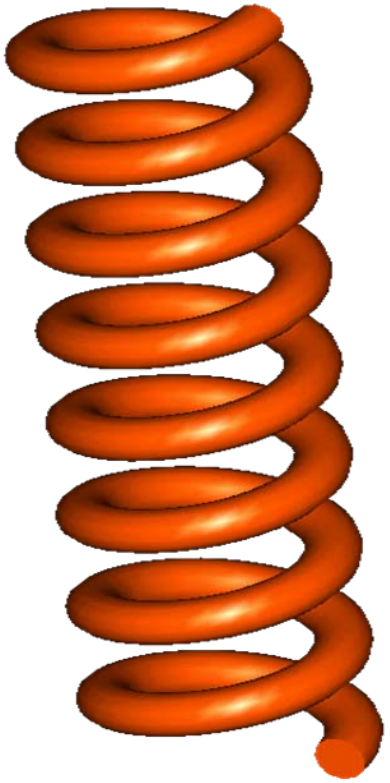
Model	Disp	Diff	vM Stress	Diff
No Hole	0.1541	-0.0504	2.9150E+04	-0.0048
Hole	0.1467	0.0000	2.9010E+04	0.0000



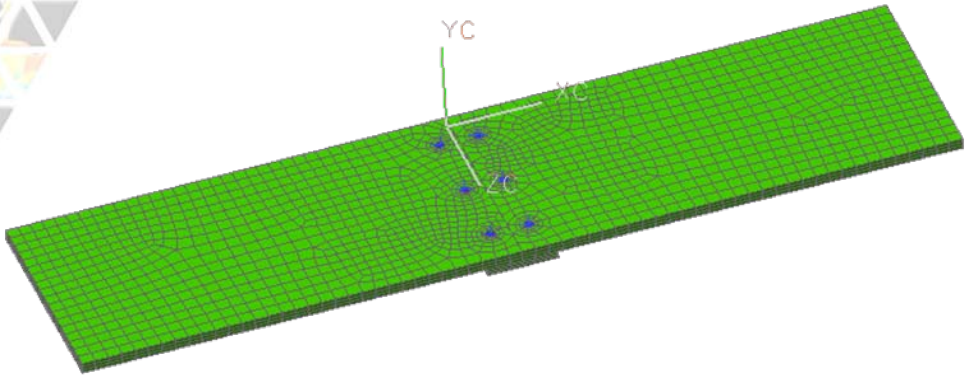
- Multiple options with rigid elements
  - Spider to model the hole
  - A spider may extend to represent the head
  - Rigid bars may be used for the bolt
  - May be connected through the thickness of the model or only at the contacting surfaces
  - May be used in combination of other element types
- Contact is needed between bodies

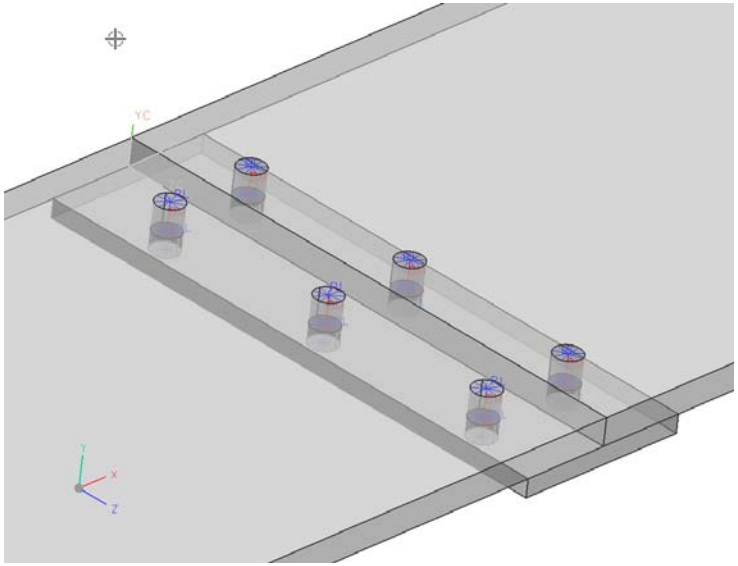
Spring Elements

- Holes may be included
  - Connection to the hole edge would require a connection element (rigid or constraint)
- Joint forces can be recovered
- Requires a hand calculation to determine the equivalent stiffness for each direction
  - An axial behavior could be modeled with a rod (truss) element
  - Stiffness in 3 directions could be modeled with a beam element

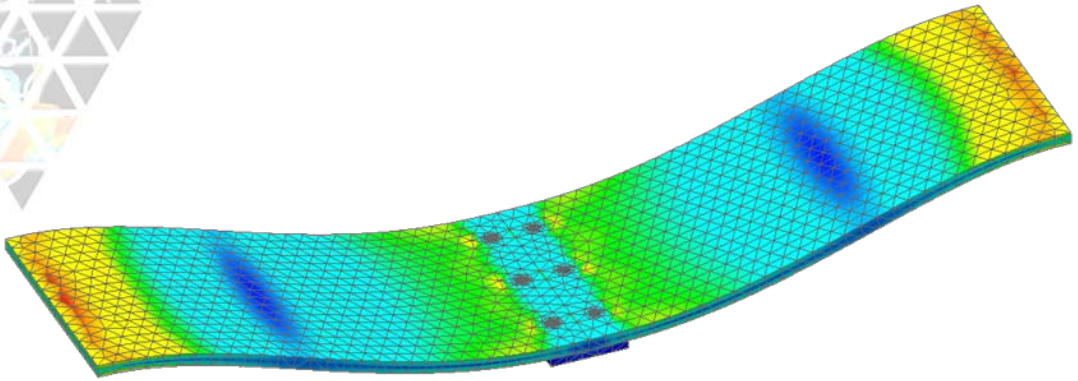


Beam Elements





- Holes may be included
- Recovers joint forces
- A connection element from the beam to the hole edge is required
  - Rigid elements model the volume of the bolt
  - Spider elements can be extended to represent the bolt head
- Preload can be easily included



Beam Elements

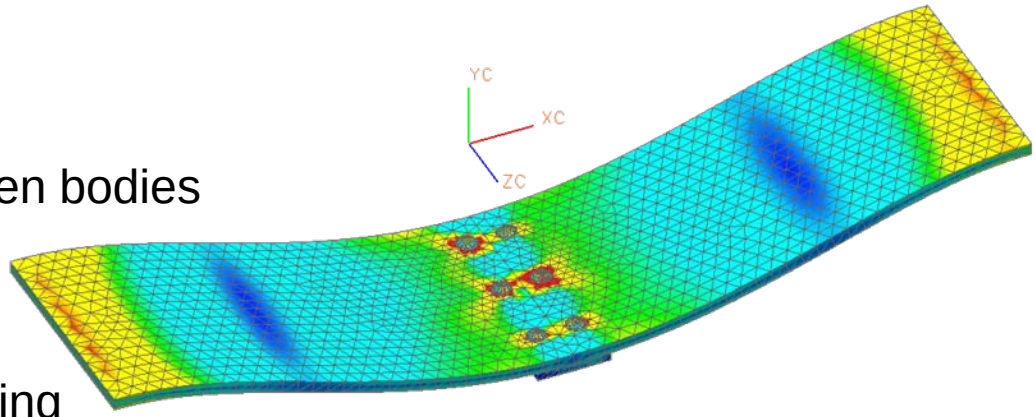
Mesh	Displacement	vonMises Stress		Axial Force	Shear Force
		Maximum	At Hole		
Hole	0.1467	2.6990E+04	2.4281E+04	232.8310	388.3210
Head	0.1426	2.7890E+04	4.1420E+03	23.2720	302.8240
P = 1000	0.1426	2.7435E+04	4.7570E+03	1000.0000	304.0890
P = 9000	0.1426	2.8410E+04	2.2169E+04	9000.0000	312.4500

- Including the head area will effect the local behavior
- Preload effects the results

No Abstraction

Geometry	Mesh	Bolts	Displacement	Diff	vonMises Stress	Diff
Hole with Head	Tet	Tet	0.1542	0.000	2.8133E+04	0.000
No Hole	Hex	Beam	0.1549	-0.005	2.9210E+04	-0.038
	Tet	Beam	0.1537	0.003	2.8110E+04	0.001
Holes	Hex	Beam	0.1467	0.049	2.8983E+04	-0.030
	Tet	Beam	0.1467	0.049	2.6990E+04	0.041
Hole with Head	Tet	Beam	0.1426	0.075	2.7890E+04	0.009

- Requires solid elements
  - Large number of elements
  - Surface contact required between bodies
- Predicts localized behavior
  - Breakout or substructure modeling
- Bolt Preload requires external calculation



No Abstraction

Geometry	Mesh	Bolts	Axial Force	Diff	Shear Force	Diff
Hole with Head	Tet	Tet	566.3270	-1.566	465.4950	0.001
			220.7170	0.000	466.1930	0.000
No Hole	Hex	Beam	237.4910	-0.076	243.9420	0.477
	Tet	Beam	226.6160	-0.027	279.0120	0.402
Holes	Hex	Beam	164.5750	0.254	243.5470	0.478
	Tet	Beam	232.8310	-0.055	388.3210	0.167
Hole with Head	Tet	Beam	23.2720	0.895	302.8240	0.350

- Joint forces require additional effort to determine
  - Use grid forces or contact forces
- Joint forces are easier from beam element models

Summary

Geometry	Mesh	Bolts	Displacement	Diff	vonMises Stress	Diff
Hole with Head	Tet	Tet	0.1542	0.000	2.8133E+04	0.000
Midsurfaces	Shell	n/a	0.1568	-0.017	2.8920E+04	-0.028

- Many options are available
- Best practice is based
  - Analysis objectives
  - Results required
  - Available resources
- Within the functionality of FEA, reasonable results can be generated using good modeling techniques