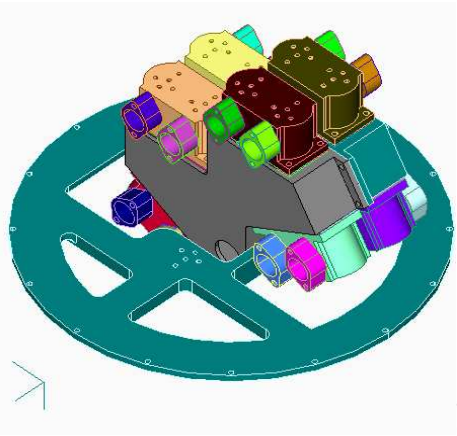
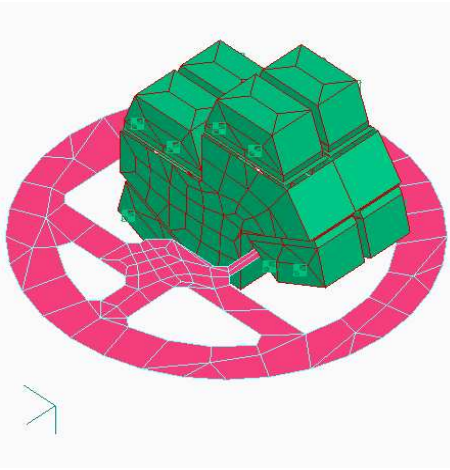
Innovations in Using Finite Element Modelers for Spacecraft Thermal Design



October 21st, 2003

Ron Behee
Network Analysis Inc



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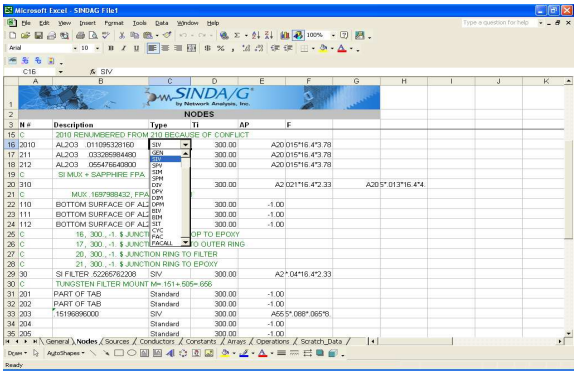
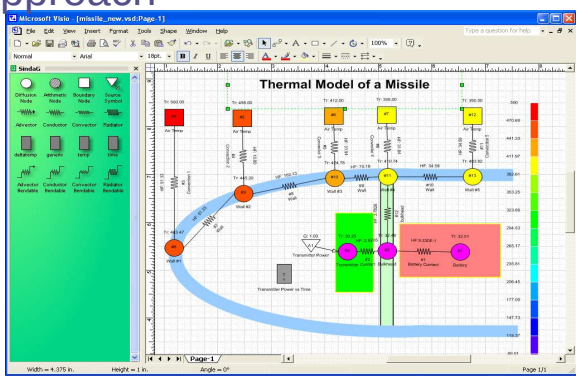
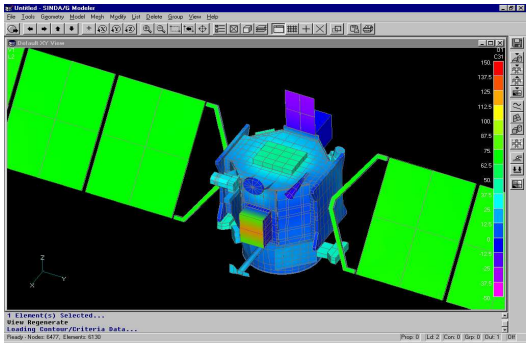
Two Basic Approaches for building Thermal Models in SINDA or ESATAN

Network Approach





Geometric Approach



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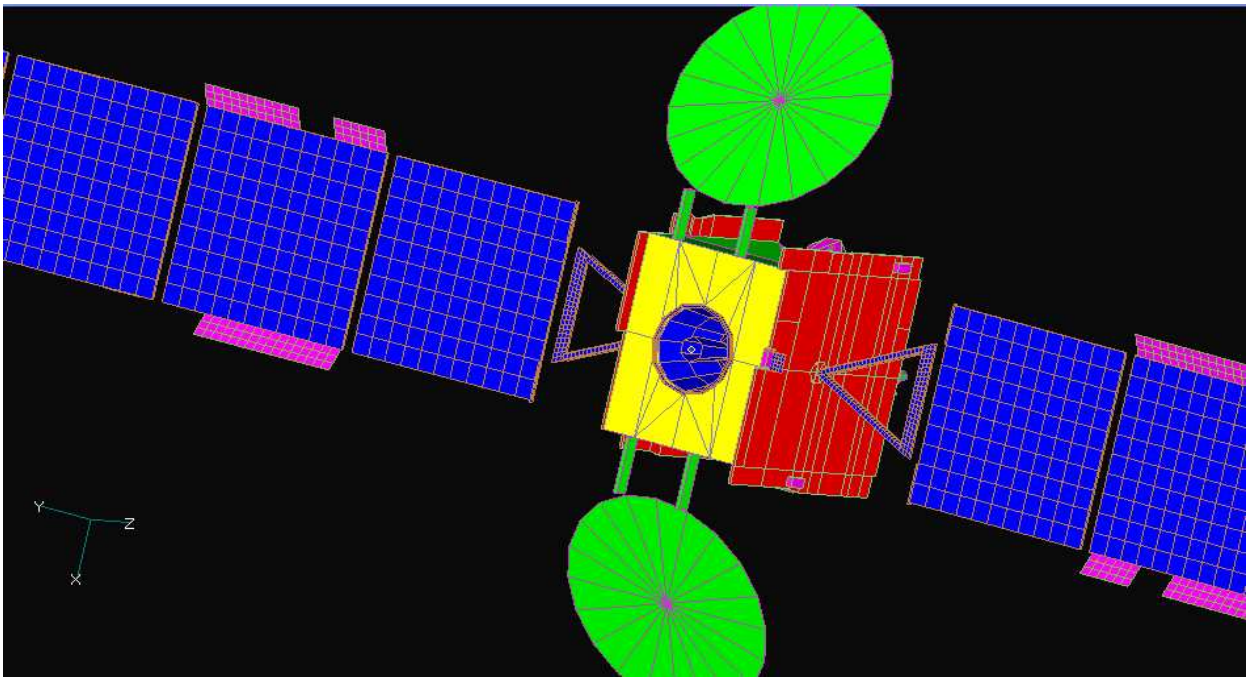
Geometric Thermal Model of Telecommunication Satellite

Mostly planer surfaces



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Geometric Approach has been Implemented in Modelers Using Two Different Technologies

- FEA Meshing Based Model Builders
  - Create 3D solid geometry or import from CAD and divide geometry into finite elements using FEA meshers.
  - These model builders are general purpose and are frequently used by many different analyzers (thermal, structural, CFD).
- Radiation Shape Based Model Builder
  - Create model using several geometric shapes that are supported by the thermal radiation code.
  - These model builders are usually tied to one thermal radiation code, and will not easily work with another.

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Commercially Available Geometric Modelers for *SINDA/G*

Shape Model Builder	Meshing Model Builder
THERMICA	SINDA/G For MSC.Patran
TSS	SINDA/G for FEMAP
ESARAD	MSC.Patran Thermal
NEVADA (SPARKS)	TMG for I-DEAS or FEMAP
Thermal Desktop	

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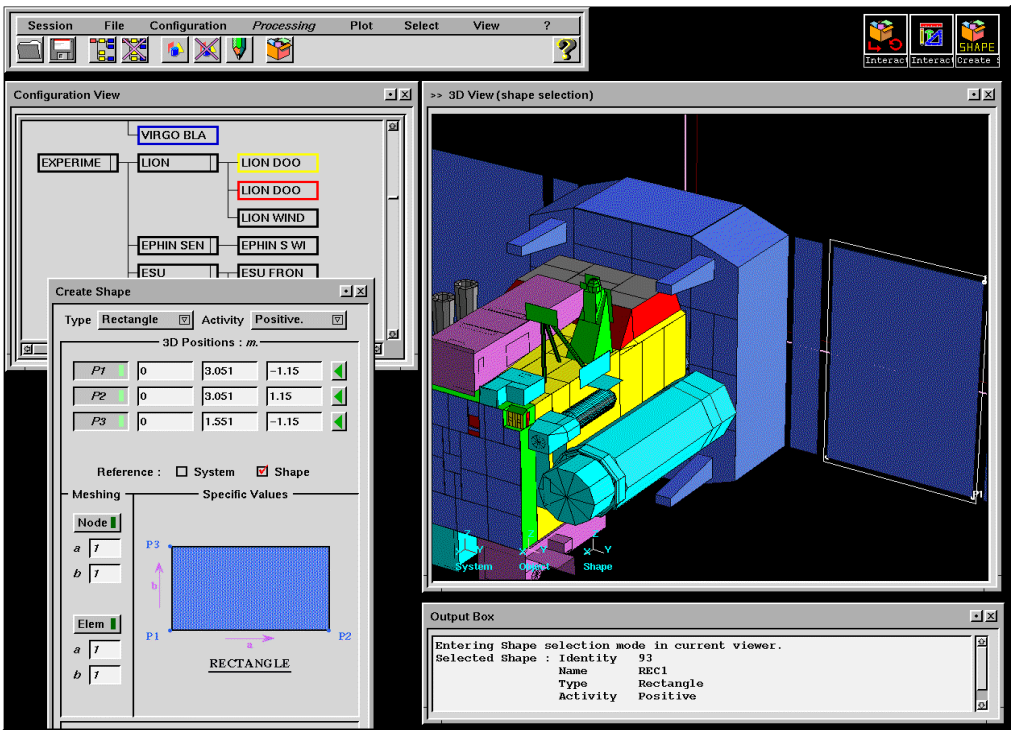
Geometric Approach

Radiation Shape Based Model Builders



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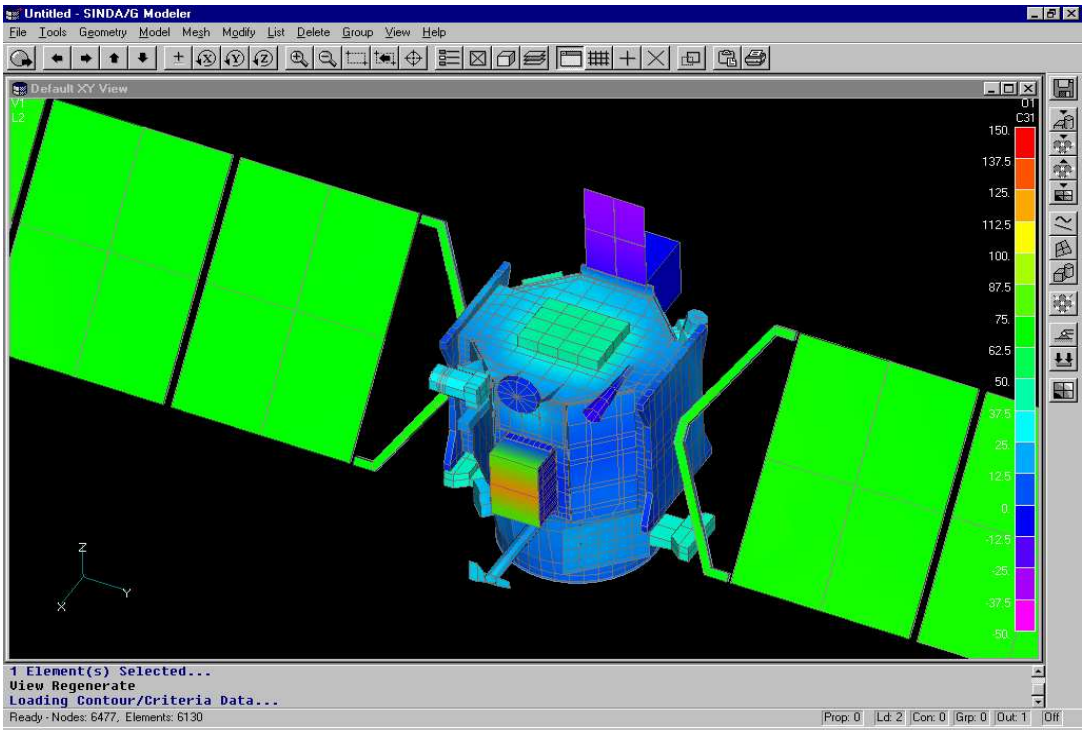
Geometric Approach

FEA Meshing Based Model Builders



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Advantages and Disadvantages of the Two Types of Geometric Modelers

- FEA Meshing Based Model Builders
  - Good connection to CAD
  - Good connection to FEA structural/fluid programs
  - Typically have flat plat connection to radiation/orbital heating programs
  - Models solids, orthotropic materials and laminate materials
  - Thermal models with complex shapes work well.
- Radiation Shape Based Model builders
  - Poor connection to CAD
  - Poor connection to FEA programs
  - Excellent-full shape connection to radiation/orbital heating programs
  - Usually only models surfaces and use isotropic materials
  - Some Geometries are difficult to model and thermal models may contain inaccuracies in the conduction network.

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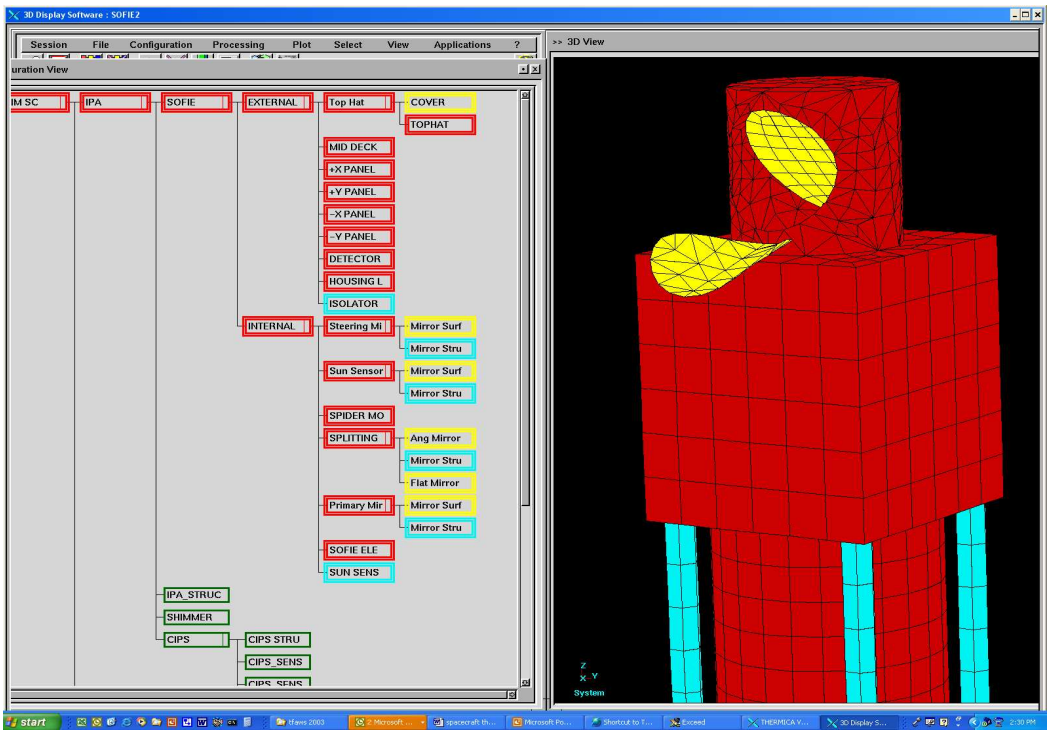
Example of Difficult Geometry for Shape Based Modelers



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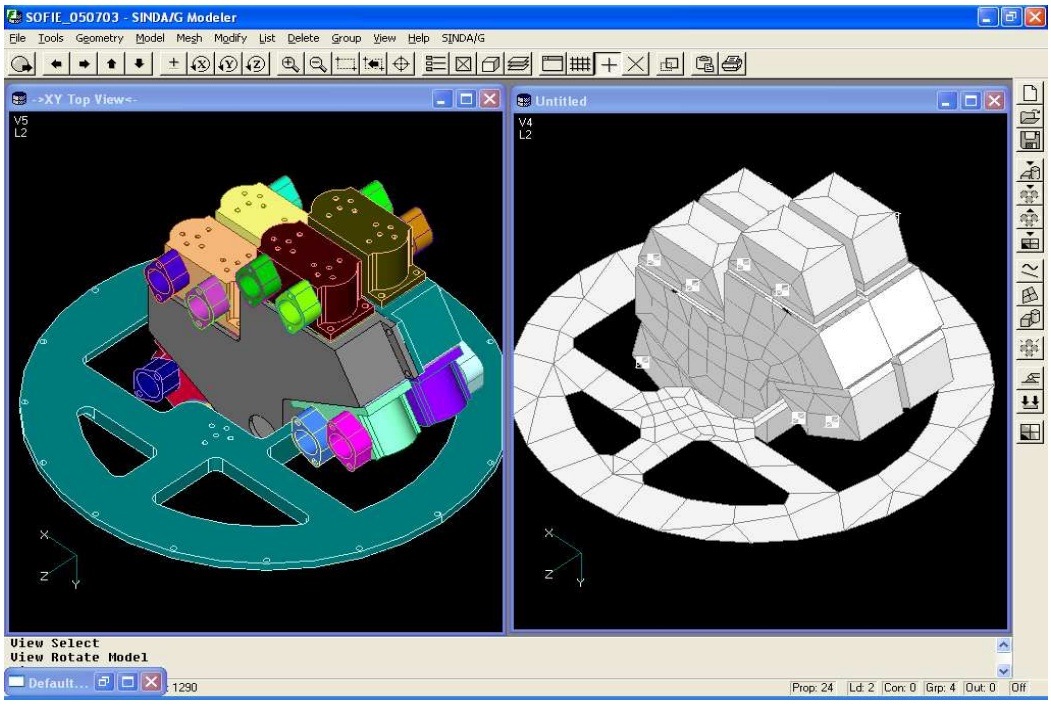
CAD Interface

FEA Meshing Type Model Builders



CAD geometry can be simplified

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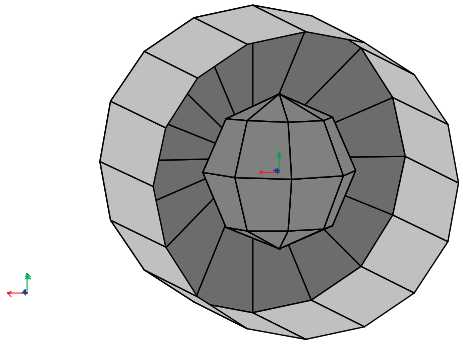
Biggest Problem of FEA Meshing Based Model Builders

Radiation Model Consists of Multiple Small Flat Plates

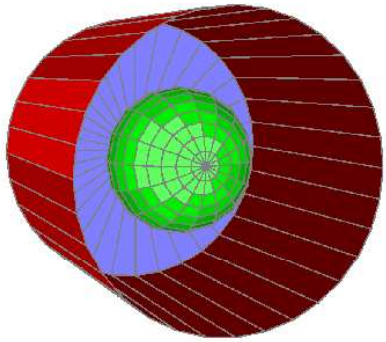
FEA Mesher Based Model Builder



Hydrazine Tank Modeled with 112 Flat Plates

Produces 6000+ radiation conductors

Radiation Shaped Based Modeler



Hydrazine Tank Modeled with 4 True Geometric Surfaces

Produces 6 radiation conductors

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How to Combine the Best of Both Types of Geometry Modelers

- Use FEA Advantages
  - Good connection to CAD
  - Good connection to FEA
  - Can model complex shapes
  - Supports solids, plates, and complex conduction models
- Use Shape Advantages
  - Support full radiation shapes

Various Approaches Different Software Companies Have Taken

- Radiation shaped based approaches
  - ESA – Complex surfaces and Boolean operations on shapes in ESARAD
  - Astrium – Ability to create shapes on top of CAD geometry and Boolean operations on shapes
- FEA meshing based approaches
  - TMG – Directly use 10,000 to 100,000 small shapes (including Quad 8 curved shapes) and have a faster radiation code (hemicube method). Also supporting shapes from FEA mesher but the shapes are not integrated into the FEA modeler.

Conclusions

Radiation Shape Based Model Builders

Shape-based radiation models offer quick solutions that are helpful in performing trade studies and optimization analyses. During the early stages of satellite and instrument development programs, the thermal engineer will need to explore various surface coatings and geometry combinations. Shape-based models allow the thermal engineer to quickly change geometry and surface properties without having to re-work intricate meshes.

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Example of Combining Both Technologies

As the design matures, many odd shapes will begin to appear in the spacecraft or instrument geometry that are not easily modeled with *primitive shapes*. However, the native shapes should not be eliminated altogether. For example, the conceptual design of the SOFIE instrument onboard the AIM spacecraft, the SOFIE instrument is modeled with high-fidelity using finite elements. The remaining items in the model, such as the spacecraft and other instruments, are approximated by large single-element surfaces or primitive surfaces.

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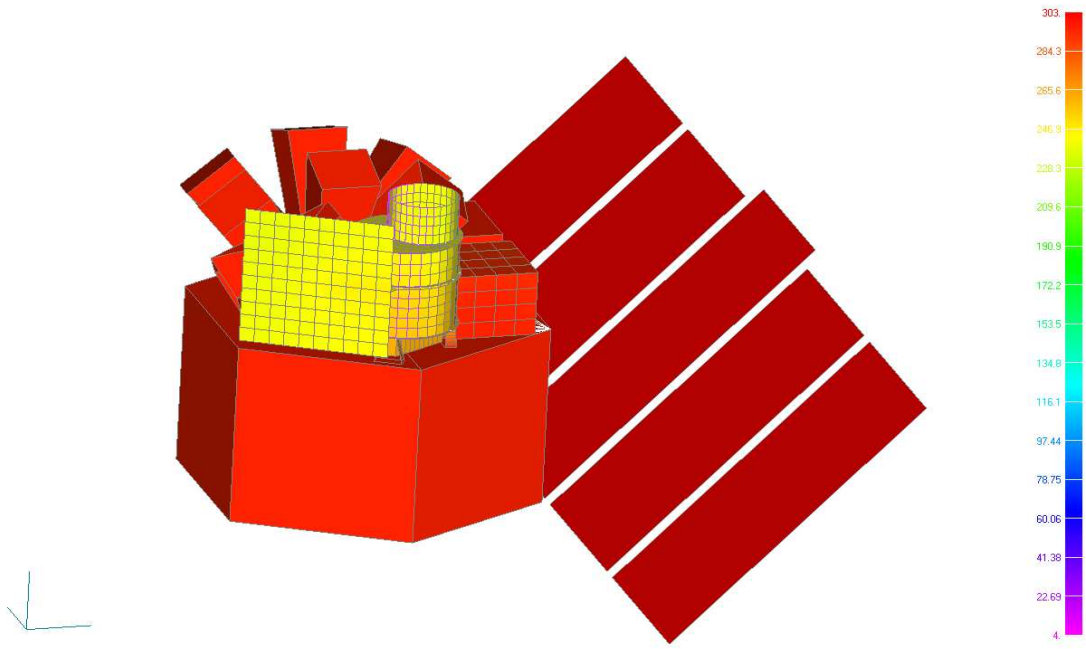
Detailed Payload and Simplified Spacecraft Using Both Technologies



SOFIE instrument aboard the AIM spacecraft

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Conclusions

Possible Best Solution

- Start with FEA model builder that has excellent connection to CAD, and supports FEA flat and curved elements for radiation.
- Add curved plate elements to the radiation code to minimize the faceted errors and reduce the number of elements to model curved surfaces
- Add the ability to create common radiation shapes such as a cylinder, sphere or disk.
- It also should also have the ability to group smaller FEA type elements into larger radiation shapes to reduce the number of Radiation Exchange Factors (REF's).

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NAI's New Product Development

NASA Phase II SBIR Contract

- Use the most widely accepted FEA model builder MSC.Patran (used by MSC.Nastran).
- Have MSC add common radiation shapes to MSC.Patran.
- Have at lease one radiation code developer add a curved *element type* shapes to their radiation code.
  - Quad 8 elements, Quad 16 elements (unique to Patran) or more complex surface.
- Create radiation "super elements" that group a fine conduction mesh into a larger radiation mesh

NAI will be working on these concepts during the next 2 years under a NASA research contract and we invite you to share with us your feedback, experiences and needs.