

USING SPACECLAIM/TD DIRECT FOR MODELING COMPONENTS WITH COMPLEX GEOMETRIES FOR THE THERMAL DESKTOP-BASED ADVANCED STIRLING RADIOISOTOPE GENERATOR MODEL

William A. Fabanich, Jr.

NASA John H. Glenn Research Center – Cleveland, OH

ABSTRACT

SpaceClaim/TD Direct has been used extensively in the development of the Advanced Stirling Radioisotope Generator (ASRG) thermal model. This paper outlines the workflow for that aspect of the task and includes proposed best practices and lessons learned. The ASRG thermal model was developed to predict component temperatures and power output and to provide insight into the prime contractor's thermal modeling efforts. The insulation blocks, heat collectors, and cold side adapter flanges (CSAFs) were modeled with this approach.

The model was constructed using mostly TD finite difference (FD) surfaces/solids. However, some complex geometry could not be reproduced with TD primitives while maintaining the desired degree of geometric fidelity. Using SpaceClaim permitted the import of original CAD files and enabled the defeaturing/repair of those geometries. TD Direct (a SpaceClaim add-on from CRTech) adds features that allowed the “mark-up” of that geometry.

These so-called “mark-ups” control how finite element (FE) meshes are to be generated through the “tagging” of features (e.g. edges, solids, surfaces). These tags represent parameters that include: submodels, material properties, material orienters, optical properties, and radiation analysis groups. TD aliases were used for most tags to allow analysis to be performed with a variety of parameter values. “Domain-tags” were also attached to individual and groups of surfaces and solids to allow them to be used later within TD to populate objects like, for example, heaters and contactors. These tools allow the user to make changes to the geometry in SpaceClaim and then easily synchronize the mesh in TD without having to redefine the objects each time as one would if using TDMesher.

The use of SpaceClaim/TD Direct helps simplify the process for importing existing geometries and in the creation of high fidelity FE meshes to represent complex parts. It also saves time and effort in the subsequent analysis.

INTRODUCTION

The Advanced Stirling Radioisotope Generator (ASRG) (Figure 1) is a high efficiency power source designed to meet multi-mission requirements for deep space missions. Its development was motivated by the increasing power needs of mission planners and an assumed waning supply of plutonium 238 which made the currently used power systems (i.e. MMRTG) insufficient and potentially unavailable.

The ASRG differs from previous systems in that it is a dynamic power source – it has moving parts. It is built around the Advanced Stirling Converter (ASC) developed by Sunpower, Inc. for the NASA Glenn Research Center (GRC). This device, which consists of a free-piston Stirling engine integrated with a linear alternator, converts heat generated by the nuclear decay of plutonium into electricity.

A detailed overview of the design and function of the ASRG is not presented in this document. For more information, please refer to *Development of Advanced Stirling Radioisotope Generator for Space Exploration* [Ref. 1].



Figure 1. ASRG Engineering Unit Test Rig at GRC Stirling Lab.

The ASRG thermal model was constructed using mostly Thermal Desktop (TD) finite difference (FD) surfaces/solids. However, some complex geometry could not be reproduced with TD primitives and still maintain the desired degree of geometric fidelity. Using SpaceClaim permitted the import of original CAD files, which were a combination of Pro/Engineer and SolidWorks files, and allowed the defeaturing/repair of those geometries. TD Direct (a SpaceClaim add-on from CRTech) adds features that allow the thermal-related “mark-ups” of that geometry for subsequent import directly into the TD drawing file.

Three components/assemblies were imported and meshed using SpaceClaim and CRTech TD Direct. These included: the heat collector, a component for conducting heat from the general purpose heat source (GPHS) to the Advanced Stirling Converter (ASC); the cold side adapter flange (CSAF), a complex assembly providing a conductive heat path from the ASC to the housing (radiator); an insulation block, an assembly of eight components that insulate the GPHS.

Below, Figure 2 shows the basic internal arrangement of these components.

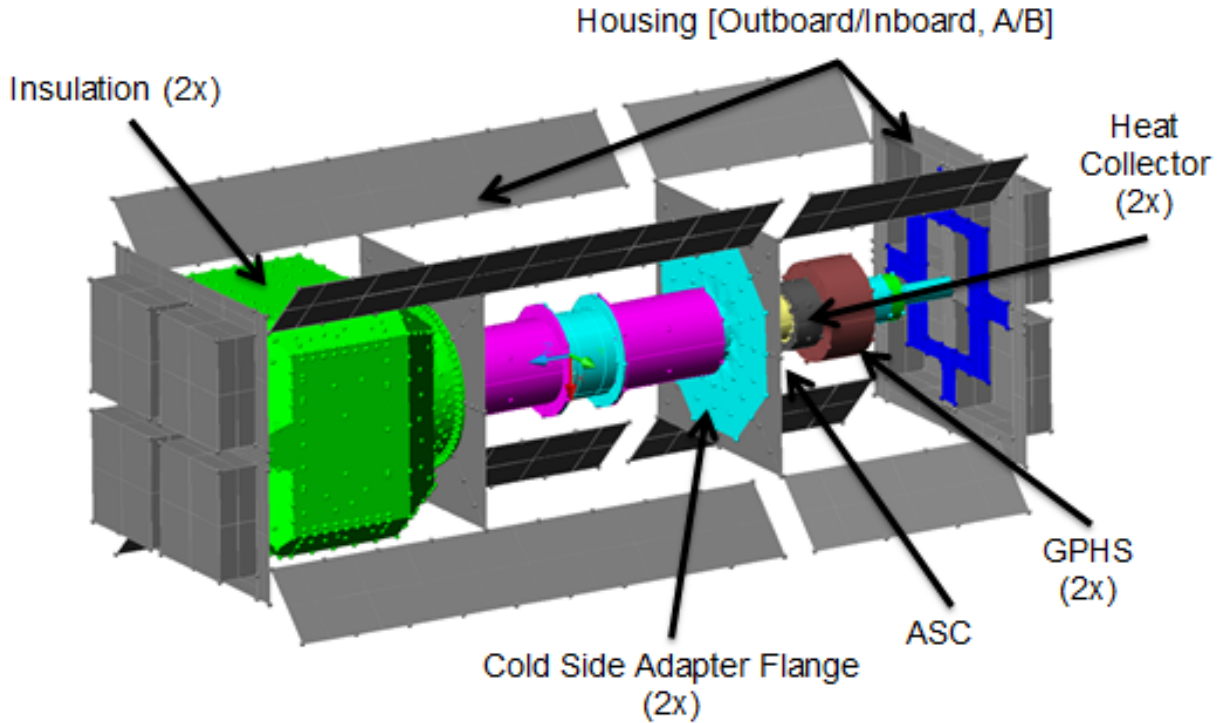


Figure 2. ASRG Thermal Desktop Model Cutaway.

SOFTWARE

The Thermal Desktop (TD) and Systems Improved Numerical Differencing Analyzer (SINDA) thermal modeling tools were selected for developing the ASRG thermal model. Both are widely used at NASA and within the aerospace industry for spacecraft, payload, subsystem, and component level thermal modeling. Additionally, SpaceClaim was used for geometry import, modification, repair, and defeaturing for parts and assemblies where high geometric fidelity was to be preserved. CRTech TD Direct, an add-on to SpaceClaim, provides the capability to mesh and integrate these parts and assemblies into a TD model.

Thermal Desktop

Thermal Desktop (TD) provides a graphical user interface for creating SINDA thermal models. To facilitate this, TD runs in the AutoCAD environment. Here, the user has access to the features of AutoCAD for creation or import of geometries which can be used for generating solids and surfaces for a TD thermal model. Additional tools for directly creating finite difference (FD) nodes, surfaces, and solids or for converting AutoCAD natives are available with the TD installation.

Broadly used within the NASA and aerospace thermal community, additional information about TD and its features can be found in *Thermal Desktop User's Manual* [Ref. 2].

SpaceClaim Engineer & TD Direct

Often it is desirable to import an existing CAD geometry into TD and convert it to a FD solid/surface or to use it as a scaffolding to lay down TD generated geometries on top. This can accelerate the process of generating a model (as opposed to starting from scratch) or help to maintain some level geometric fidelity with the actual hardware. In addition to these techniques, TD possesses a native FE mesher called TDMesh.

TDMesh is an integrated feature of TD. It is a tri/tet object-level mesher that can be used for creating FE meshes when greater geometric fidelity is required. However, as outlined in Ref. 2, its capabilities are limited when meshing assemblies, automatically updating meshes after their initial creation, or having control over local mesh features and specifying different element types.

Due to the inherent limitations of this tool in some situations, SpaceClaim Engineer and CRTech TD Direct are offered.

SpaceClaim is a direct modeling tool used to natively produce geometries or to import geometries from other modeling software (e.g. Pro/E) for repair and defeaturing/simplification prior to export into TD. With the addition of the SpaceClaim add-on CRTech TD Direct (formerly known as CRTech Thermal Adaptor), there are additional features that allow the thermal analyst to mark-up geometries (edges, faces, solids) with Thermal Desktop information (tags) prior to export and meshing in a the TD model. This process uses the TD Direct FE mesher – SCMesh – which overcomes the shortcoming of TDMesh as described above.

PROCESS OVERVIEW

Often a thermal analyst is provided CAD models, in various formats, for information about the hardware to be modeled. Some of the challenges in this include: the thermal analyst being unable to open a particular format because they lack that software, the inclusion of thermally irrelevant details, and not receiving the most up-to-date versions of the CAD.

The CAD might be used for information only: the analyst can use the data gleaned from the CAD to produce from scratch a model consisting of AutoCAD/Thermal Desktop generated geometries. The CAD can also be imported in some cases (if your version of AutoCAD can open that format) directly into the model drawing file. If so, this imported geometry can be used in two ways: as a scaffolding to lay down TD FD surfaces or solids or use TDMesh to directly mesh the geometry. Typically, a process of simplification and preparation of an imported geometry is needed before utilizing TDMesh (e.g. the removal of small holes, fillets).

With the addition of SpaceClaim Engineer and the CRTech TD Direct add-on to the workflow, additional capabilities to import and repair/simplify/defeature geometries, and generate and customize FE meshes within the TD environment are available. Based on the author's experience of employing these new tools in the modeling of the ASRG, three major benefits were realized. One, this process affords gains in speed and ease of import of existing geometries over the more traditional methods described above as well as adding additional capabilities for preparing those geometries that were previously too difficult or impossible to work with for meshing. Second,

due to the additional features of SCMesh, it is possible to maintain high geometric fidelity in areas of interest while having better control over the total node/element count. Lastly, the ability to update FE meshes in TD without losing and having to redefine network objects is added (this also includes being able to alter the CAD in SpaceClaim and automatically update and remesh its representation in TD.)

Below, the basic process for using SpaceClaim and CRTech TD Direct for TD thermal modeling is outlined followed in the next section by ASRG specific examples.

Additional information on the traditional techniques and the new SpaceClaim-based methods can be found in *Thermal Desktop Advanced Modeling Guide* [Ref. 3].

Importing into SpaceClaim

As mentioned before, a thermal analyst typically has to deal with receiving CAD files in a multitude of formats. SpaceClaim has the ability to open a number of commonly used formats natively. In addition, there are two 'Data Exchange' packages available to increase the number of compatible formats. (A complete list can currently be found on the SpaceClaim website.)

The non-SpaceClaim CAD document is imported into an open SpaceClaim document. There are various options available and these are accessible through an 'Options' button found on the 'Open' dialog box. It is recommended based on the author's experience that users also select the 'Check Geometry' check box also located on the 'Open' dialog box. This helps simplify the import process and allows the software to automatically deal with any issues that arise during import. The software will alert the user to any problems with the imported geometry that the user will have to address manually before tagging and meshing can be done.

'Import Options' allow the user to select (or deselect) the types of features to be imported, include hidden features, and can break assemblies into multiple SpaceClaim documents (among other options.) Many are very useful and the user should familiarize themselves with these capabilities.

There were instances when better results (of the import process) were obtained by converting, for example, a specific Pro/E file to a STEP file *then* importing it into SpaceClaim. In this example, the Pro/E file was still able to be imported into SpaceClaim, however it required additional repair prior to tagging and meshing into TD. However, the STEP file version of the same geometry did not require the additional preparation. Hard and fast rules are difficult to establish, but with a little experimentation and experience the user can establish their own best practices to save themselves time and effort.

The *CRTech TD Direct User's Guide* [Ref. 4] provides a complete overview.

Repair & Defeaturing/Simplification

This step is greatly simplified by the direct modeling capabilities of SpaceClaim. It should be noted that most CAD packages that users will be familiar with are referred to as ‘parametric modelers’. With parametric modeling software (e.g. Pro/E, SolidWorks) geometries are created by steps that build up the components of the model. This approach, also referred to as history-based modeling, yields components that are tied to constraints, relations, and other dependencies. Such models are hard to modify without changing (usually) many of these rules. This also requires a certain level of mastery of the software. With direct modeling, or history-less modeling, a user can change geometries and features on the fly.

It is this nature that makes this type of software very appealing for a thermal analysis. Not only can it accommodate CAD files from many different packages, but most users find the tools highly intuitive. This reduces the need to invest a large amount of time and effort learning multiple software packages and allows the analyst to make modifications quickly and easily without having to understand how the original CAD was produced, or its ‘design intent’.

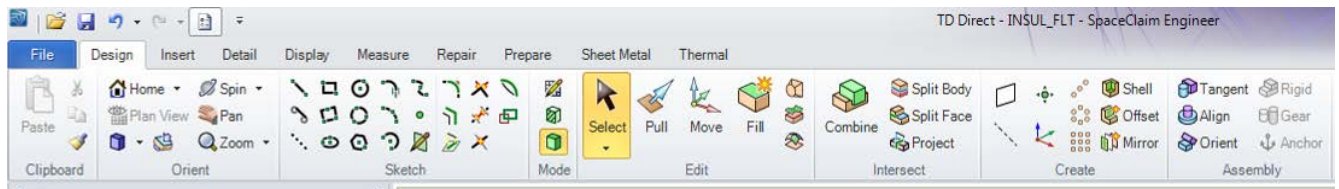


Figure 3. Design tools used to modify geometry.

As suggested by the design tool bar (Figure 3), tools are simple and intuitive. For tools with additional features, context sensitive buttons appear in the work space once the primary tool is selected and a complete description of the functionality of the additional features will appear by hovering the pointer over each button.

In the author’s experience, many features could be adequately modified with just the ‘PULL’ tool. This tool allows, as is typically required for preparing a thermal model, holes and fillets to be selected and deleted without affecting any other aspect the geometry (or your ability to change it).

For geometries that require additional modifications or for assemblies the analyst would like to create for import into TD, other SpaceClaim tools are useful. The ribbons shown in Figure 4 show the types of tools available. A complete description on their use can be found in Ref. 4.

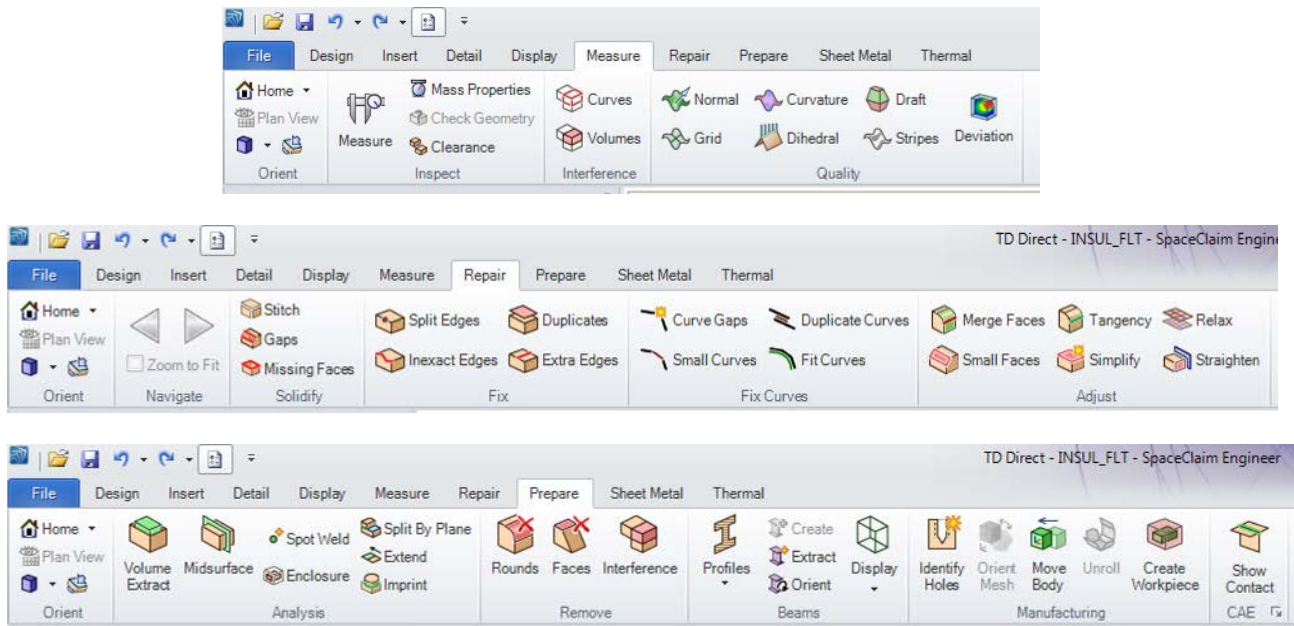


Figure 4. Toolbars used to repair, defeature, and simplify geometries.

Many of these tools are useful for repairing small edges, slivers, missing surfaces and gaps that might be present that would ultimately cause the mesher to fail. Also, these tools can help make adjustments to assemblies to ensure that there is no overlap or interference that would also be problematic for the mesher or cause issues during thermal analysis in TD (especially radiation analysis.)

Tagging

Tagging is the process by which information is added to features of the geometry for eventual use by TD or by the mesher during the process that exports the component/assembly to TD. These tags include submodel names, domains, thermophysical and optical property names (or aliases), radiation analysis group names, thickness (of a surface), orienters, and mesh controls. This ability is part of the functionality of CRTEch TD Direct.

Tags are further differentiated into two categories: thermal and mesh. Thermal tags can be assigned to surfaces, solids, and individual faces of solids. These tags are carried over to TD for, for example, solid bodies that have a thermophysical property name (or alias) tag for a given property, then have the specifics of that property as it exists in that model's thermophysical property database assigned to the features with that tag. Note that tags can be updated in SpaceClaim, the geometry re-exported to TD, and then the new thermal tag will replace the previous one.

Another type of thermal tag that is useful is the 'domain' tag. These can be applied to a collection of edges, faces, surfaces, or solids. A good example of their utility is grouping faces in domain tag sets that can be later used in forms for, for example, heat loads or contactors. The domain tag sets would act as a place holders for the TO and FROM surfaces in these network objects forms.

This is useful because the TO and FROM surfaces are now (post meshing) made up of a large number of 2D surface elements. It is also useful because, should the user want to modify the geometry in SpaceClaim or make changes to the mesh parameters (hence having the mesh regenerated and the previous elements deleted and regenerated with new elements and ID's), the network objects will now persist in TD with the domain tag set names still anchoring the object. Previously, using TDMesh, changing a mesh would result in loss of the elements populating the TO and FROM fields (even if you had collected them in an AutoCAD group) and if a TO and/or FROM field was left unpopulated then the network object would cease to exist.

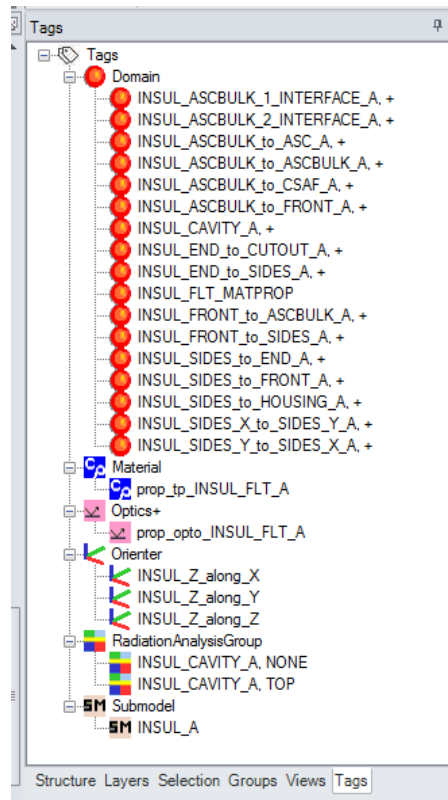


Figure 5. Example of tags applied to outboard insulation block.

The other type is a mesh tag. These may be global/default or local. Local mesh tags will override whatever the global settings is for a given edge, surface, solid, or face of a solid.

SCMesh provides far more options for controlling the generation of FE meshes than TD's native TDMesh. Mesh controls that are available include:

- Mesh Size (absolute or relative)
- Mesh Size Scaling (X, Y, and Z directions)
- Surface Mesh Type (Triangular or Quad Dominant)
- Curvature Refinement & Lower Limits on Mesh Size of the Curve (absolute or relative)

- Ignore Small Features and Max Number of Nodes
- Mesh type for contacting Geometry (merged, independent, and matched)

Additionally, for local mesh controls, there is:

- Surface Mesh Type (quadrilateral)
- Swept Mesh
- Merge if imprinted (for contacting geometries)

Figure 5 (above) shows the tags that were created for a single insulation block. Addition details on this process can be found in Ref. 4.

Meshing/Exporting to Thermal Desktop

Once the appropriate and desired tags have been added to the geometry in SpaceClaim, a TD Direct Imported must be created within Thermal Desktop. This is done from inside TD under 'TD Direct>Create Link' on the 'Thermal' pull-down menu. Here the user specifies the SpaceClaim file for the geometry of interest (it can still be open in SpaceClaim). A TD model can have multiple importers defined. They may be for multiple instances of the same geometry. They may be for completely different components prepped in SpaceClaim.

Once the initial synchronization takes place, the importer (a dynamic link between SpaceClaim and Thermal Desktop) may be moved to any location and any orientation in the TD thermal model. With each change made on the SpaceClaim side (geometry, tags) and subsequent re-synch of the importer, a new mesh replaces the previous mesh at the location of the importer.

Note that when an importer and its associated mesh are created there are layers created in TD for 2D elements, 3D elements, the mesh controller (which appears and functions like those created for TDMesh), and the TD Direct Importer. An additional layer will be created should the user chose the option of including to import the solid model into the TD file. (This is thermally irrelevant, but sometimes is useful to import in to TD for the purpose of aligning geometries – a virtual “fit check”.) The user may find it useful to change the visibility of these layers to facilitate different views during modification of the model or for post-processing purposes.

It is the synching of the TD Direct Importer that creates the mesh. The mesh is not present in the SpaceClaim file and cannot be viewed from there. Only the mesh control tags are readable in SpaceClaim, which provides the 'instructions' on how the mesh should be created in TD.

ASRG-BASED EXAMPLE

The ASRG thermal model is a system level model. However, due to the fact that this model is used for assisting in the evaluation of the design and performance of hardware that is in the

development phase, there are a number of details that researchers desired to have at a high fidelity. These include the heat collector, the cold-side adapter flange (CSAF), and the insulation block.

Dimensions of the ASRG components were based primarily on a Lockheed Martin created Pro/E solid model of the ASRG. Many components were easily modeled with TD FD primitives. Early versions of the model used such primitives to model the heat collector and the CSAF, and a TDMesh generated FE mesh was used for the insulation block but eventually all were replaced with SpaceClaim/TD Direct generated FE meshes.

Heat Collector

The heat collector is the component that connects and provides a conductive heat path from each GPHS to the heater head (hot end) of the adjacent ASC.

Shown below in Figure 6 is the raw CAD geometry. Also included is an image of how TD FD primitives were initially used to model this component.

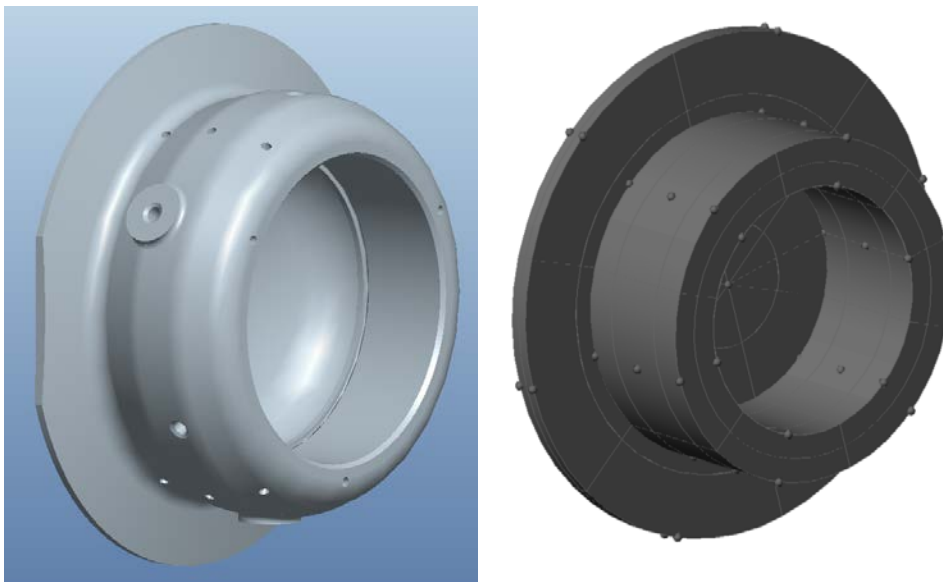


Figure 6. (left) Pro/Engineer CAD, (right) TD FD version of Heat Collector.

Using the Pro/E design geometry, the component was defeatured in SpaceClaim. Thermally irrelevant features such as small holes, channels, and notches were removed (Figure 7). Such features would likely be difficult or impossible to mesh.



Figure 7. Defeatured in SpaceClaim.

This component is actually manufactured as two pieces: the body and the plate. In SpaceClaim, the single CAD geometry solid was split into two different but contacting pieces to allow assigning of two different material properties.

The plate and a body were meshed as two separate bodies. The mesh along their interface was matched and merged; in the actual hardware these components are brazed together. In the ASRG engineering unit, both of these subcomponents are made of the same material. In the flight unit, the plate and body are made from dissimilar materials. The ability to split the body, match and merge the nodes on the interface, and assigned different properties was made possible by SpaceClaim/TD Direct.

Additional tags were set to identify contact areas, material properties, and surface properties for when the part is meshed and exported to TD. (Again, this preparation of the component allows the part to be geometrically modified and/or re-meshed at will without having to make any changes to the model in TD. Changes will be automatically updated in TD once the user synchs the SpaceClaim/TD Direct link.)

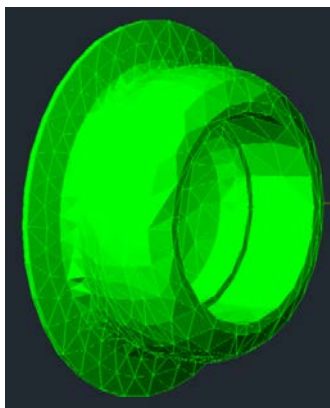


Figure 8. Meshed Heat Collector.

Once this updated component was fully integrated into the ASRG model, analysis runs were made to compare with the results of the original TD FD heat collector. This run produced

identical result. The simple TD FD heat collector performed at the system level the same as the TD Direct FE version. However, it was noted that the higher fidelity version likely showed higher fidelity temperature gradients more representative of those experienced by the actual hardware.

The increased geometric fidelity also helped create a higher degree of confidence and buy-in from the researchers than the simplified TD FD heat collector did, which is an important consideration. In addition to that, the author found this relatively simple component an easy way to establish a process and work out the bugs before attempting the far more complex geometries of the CSAF and the insulation block.

CSAF

The purpose of the CSAF is to provide a highly efficient heat path from the rejection side of the ASC to the housing/radiator. The CSAF consists of a copper-based exterior and an interior consisting of a dissimilar material.

Prior to the availability of SpaceClaim, one difficulty in modeling this geometry is that it is not possible to make a surface with a round hole in the TD environment (with a FD surface.) Instead, the design geometry was reduced to a thermal geometry of a 2D octagonal flange and a 3D FD cylindrical hub. AutoCAD polygons were created and polar arrayed to create the octagon. Using the 'Convert AutoCAD surfaces to node/elements' feature, a 2D FD mesh was created. A 3D FD cylinder was added to account for the hub of the CSAF. Overlapping nodes between adjacent 2D FD polygons were merged to complete the flange. Then nearby nodes on the inner circumference of the flange and the outer circumference of the hub were merged to complete the CSAF geometry.

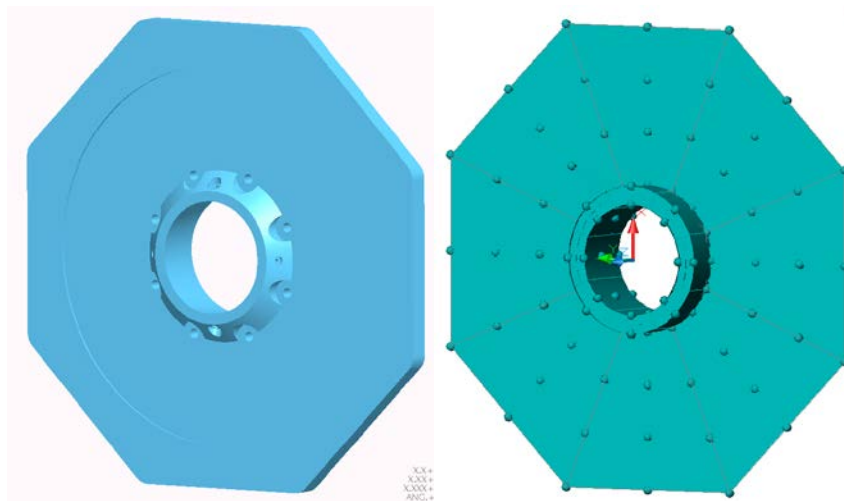


Figure 9. (left) Pro/Engineer CAD model, (right) TD FD CSAF.

However, this solution to the modeling of the CSAF geometry leads to a second difficulty. The lack of a modeled interior did not allow for a way to account for the 'compound' thermal

conductivity of the CSAF. Therefore, a simplifying assumption was made. The thermal conductivity of the interior and the exterior parts of the CSAF were assigned to the flange (octagonal) and the hub (cylinder) geometries, respectively.

To replace this with a much higher fidelity SpaceClaim/TD Direct FE mesh, as in the previous section describing the heat collector, the original Pro/Engineer design geometry of the CSAF was imported, defeatured, tagged in SpaceClaim and then meshed and linked to the TD model. The SpaceClaim FE meshed (SCMesh) component replaced the previous TD FD CSAF (Figures 10, 11).

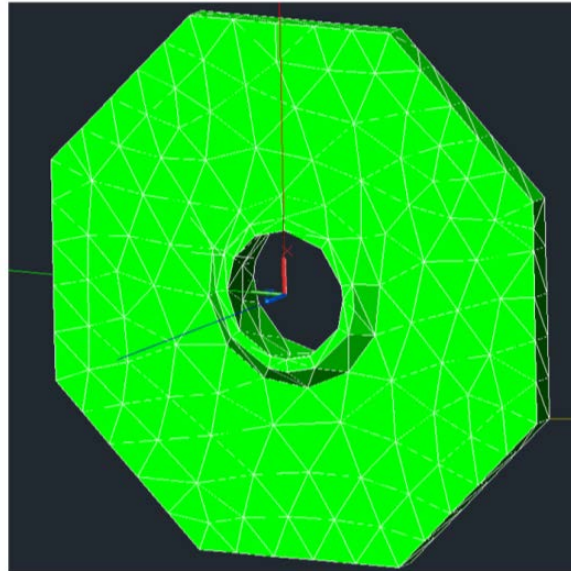


Figure 10. (left) Exterior mesh – CSAF.

Steady-state analysis was rerun to identify any differences in the thermal behavior of the remodeled component with the previous version. A much better view of how heat was conducted through this complex geometry was established. Also, the ability to trade different material properties or to study the effect of the contact conductance between the interior and the rest of the flange was now possible.

Insulation Block

The insulation package surrounds hardware from the heat source support to the heater head of the ASC. Simply, its purpose is to minimize heat loss from the GPHS to the other hardware and the environment and to maximize heat available to the ASC.

For the ASRG engineering unit, the insulation package consists of eight separate pieces (per end) with five unique pieces (for the ASRG flight unit, 10 separate pieces, and five unique). Due to the geometric complexity of each piece and the many interfaces (contact areas) between them, a separate FE mesh was generated for each piece with TDmesh (see Figure 12). This proved

extremely time-consuming and in the end replete with errors that caused the radiation analysis group for the interior cavity to miscalculate the radiative heat exchange.

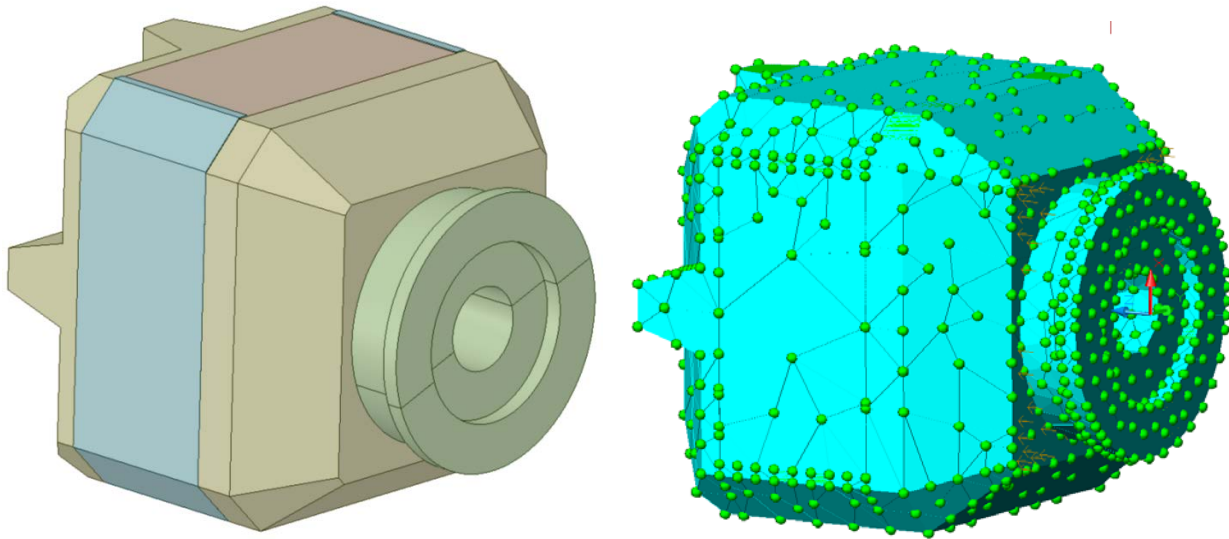


Figure 11. (left) CAD and (right) TDMesh generated insulation block.

Later, using SpaceClaim/TD Direct, this geometry was revised to model heat transfer through the assembly and to provide better information about the temperature gradients across the insulation pieces.

The complexity of the insulation block required the use of SpaceClaim/TD Direct to work with assemblies and multiple instances. (Actually, both the heat collector and the CSAF have two instances in the ASRG thermal model. The following description of using this capability to import multiple instances of a component or assembly into TD can be extrapolated to those two previous cases.)

Each piece was individually imported into SpaceClaim from its native CAD file. This resulted in having five unique SpaceClaim documents from which to assemble one insulation block. These pieces are then inserted by the user in to a new SpaceClaim file and aligned using the assembly tools on the design tab.

Any components inserted into another file retain a dependency on the original SpaceClaim file. Should a change be made in the original file, then that is propagated down into the documents that piece was inserted into. This dependency can be broken. Here, once a single assembly consisting of all eight parts was completed and reviewed for alignment and relative positioning, the dependency to the higher level documents was broken. The assembly file was now independent.

As there are two instances of the insulation block in the ASRG, mesh control tags and thermal tags common to both instances were added to this “mother” file. Two new empty SpaceClaim

documents were created. The assembly was inserted into each of the new files. From there the geometry in each file was marked-up with additional tags specific to the each instance.

Dependence is maintained between the mother assemble and its two instances. This allowed for changes to be made in the mother file that would then propagate to both instances. Later, after import into TD, changes in one file could easily find their way into the meshed geometries in the TD model by simply synchronizing each TD Direct Importer. (Note that each instance of the geometry will have its own TD Direct Importer placed in the appropriate location and orientation in the TD thermal model by the user. See Figure 12.

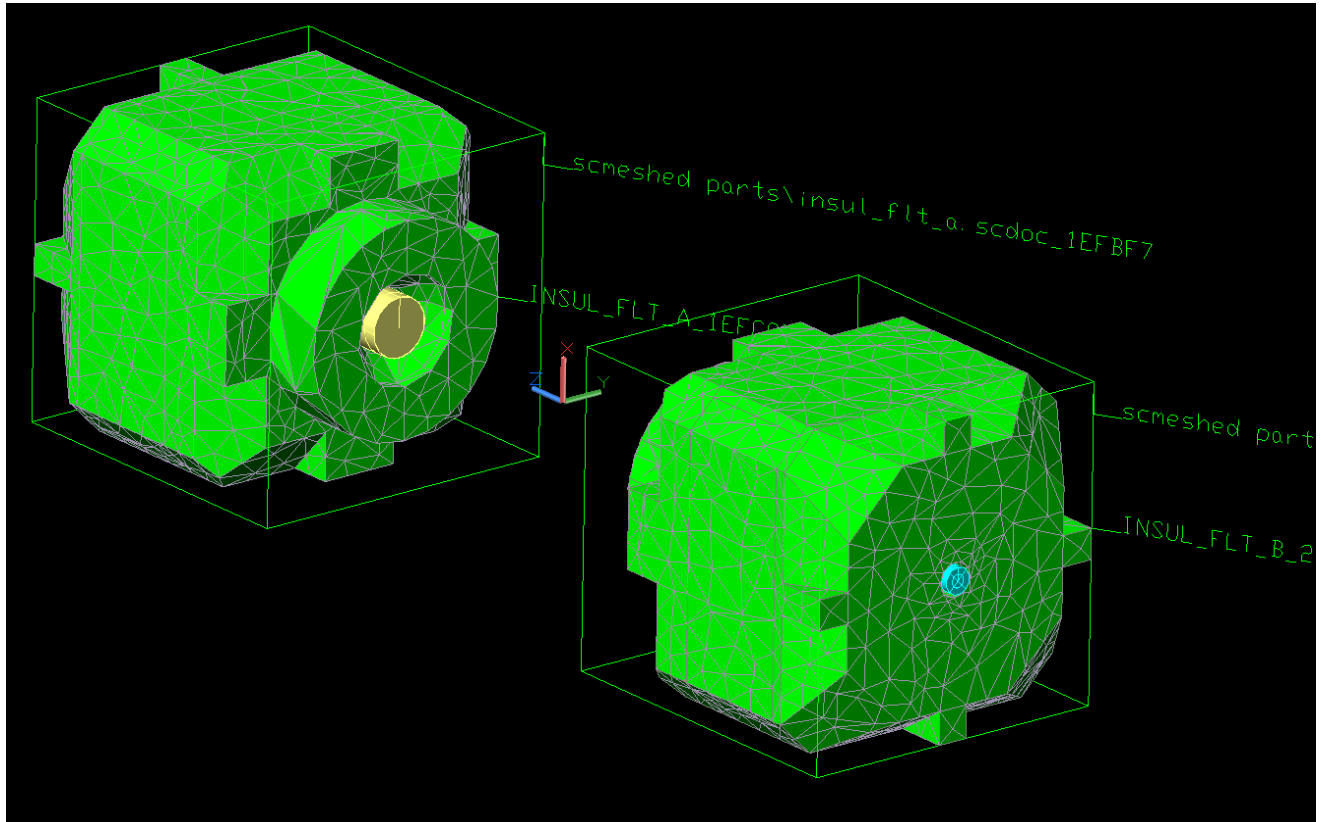


Figure 12. Two instances of the TD Direct generated FE meshes of the insulation block in TD

In the case of the ASRG engineering unit, since the insulation block is an assembly of eight components, each piece comes into contact with two to six other pieces. Therefore, there are multitudes of contacting surfaces *within* the assembly. Contactors for these surfaces require that domain tag sets be generated that contain the faces to be used for each interface. With a little work (and a methodical naming convention) domain tag sets can be generated with SpaceClaim/TD Direct that will be available in TD for populating the TO and FROM fields in the contactor form. See Figure 13 for an example of some of these interfaces and their associated contactors.

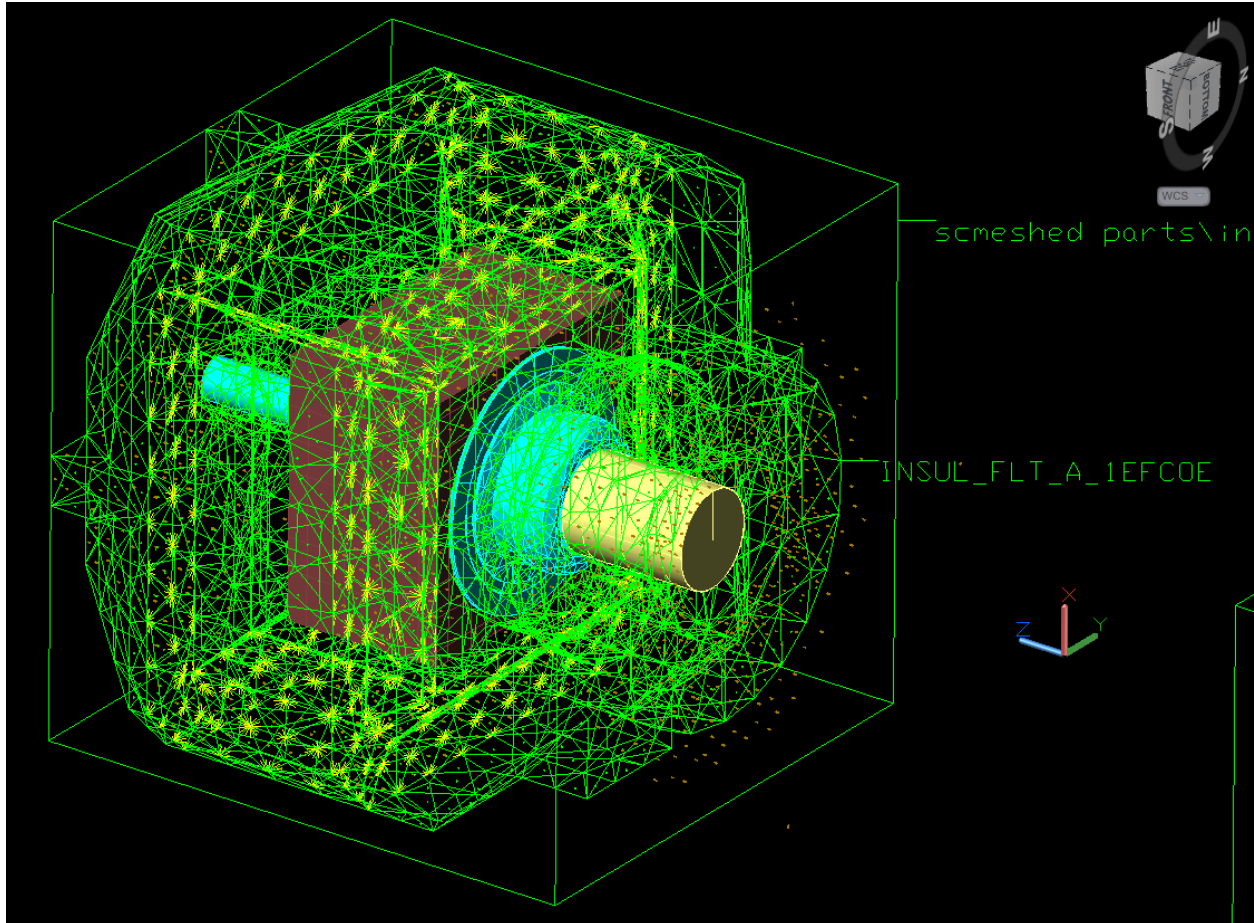


Figure 13. Contactors w/ many interfacing surfaces can be defined with Domain Tag Sets.

BEST PRACTICES/LESSONS LEARNED

The previous sections contain a number of approaches, comments, and suggestions for employing SpaceClaim and TD Direct in your thermal Desktop modeling. No doubt many will find better processes or ways that better suit their task at hand. Ref.'s 2-4 provide a great deal of insight into the basic use of these software packages and a number of helpful examples that are more than enough to get anyone started.

However, the author can offer a few more suggestions to help a potential user move quickly along the learning curve.

- While studying the manuals, learn the terminology or 'lingo'. The author has suffered by too often creating his own and this only added to the challenges in learning a new software tool. (Bad habits are hard to break.)
- Go to the SpaceClaim website and go through the basic and intermediate tutorials. Most are less than five minutes. It is sufficient to use them as one needs them and not sit down and try to review them all before jumping into SpaceClaim with both feet.

- Go to the CRTech website and review the examples they have included as part of their marketing material. They are very basic but they do a good job of familiarizing the user with many of the capabilities and potential uses for the software.
- Stay organized. For each thermal model, create a sensible file/part naming scheme to allow the user to efficiently manage files for components, assemblies, and multiple instances of assemblies. This will be very useful should you start having multiple versions of the components/assemblies.
- Make sure you understand how SpaceClaim documents handle dependency between documents and how you can internalize or make external. (This discussion is beyond the scope of this document. See Ref. 4)
- The author uses a folder, kept at the same level as the .dwg file, for keeping all the SpaceClaim documents associated with that thermal model. Should one have to relocate a model (e.g. share it on another computer) then there will be no worries about paths changing. (When a TD Direct Importer is created, it is attached to a specific file at a specific location and can't be changed.) This is similar to the issue that many TD users have experienced when optical and thermophysical property files are in a separate folder, the model is moved, and then they can't be found by the program.
- Before taking on complex geometries, try simplified sample models that capture the essential features of the geometry you are attempting to work with. This can also be useful when sharing models with CRTech Tech Support for clarity and in some cases to avoid sharing proprietary or restricted information.
- Don't be afraid to pose question to CRTech support. Additionally, utilize their support forum on their website. At the moment there are few SpaceClaim related posts. It would be nice to see more questions and answers accumulate there as a resource for the community.
- Consider using SpaceClaim for new geometry creation. Unless you have a specific reason for wanting to use TD FD primitives, FE meshes are quick and easy to generate and later modify especially for complex models. SpaceClaim is also handy for importing and cleaning up geometries that you can then export to TD (via a TD Direct Importer) without generating a FE mesh. The resulting "geometry-only" import into TD can then be used as scaffolding for TD FD primitives.
- Share you experiences and get others in your organization to use and value this tool. No tool is a panacea, but SpaceClaim/TD Direct does a lot to enhance thermal model creation and analysis in Thermal Desktop. If utilized to its full extend it should be able to help the analyst increase their productivity and lessen their headaches. Helping to build a bigger user base can only improve everyone's experience and encourage CRTech to continue improving and enhancing the capabilities of this tool.

CONCLUSIONS

The use of SpaceClaim/TD Direct provides a thermal analyst with the ability to work faster and, hopefully, easier given the additional tools now available for import, defeaturing/simplification, and meshing. In some cases the results of a thermal model might not be any different than using the previous approach. But in many cases the analyst will be able to provide those analyses quicker and more efficiently.

For some modeling efforts, like the ASRG, the ability to easily maintain high fidelity with the original CAD model allows finer details of heat flow and temperature gradients to be resolved than would be in a more lumped model. In this particular case, researchers were interested in heat flow in a complex geometry of just a few watts.

As always, it is up to the analyst to understand the capabilities and limitations of the tools available. It is also up to them to judge how best to use those tools in an efficient manner to provide answers to the questions being asked through the analysis.

This overview of how SpaceClaim/CRTech TD Direct was employed in creating the ASRG thermal model is far from an extensive review of the capabilities of these tools. Nor is it likely a very sophisticated use of the capabilities. Many more features not employed in these examples, like the ability to parametrically drive dimensions of the CAD geometry as TD symbols and have an automatic regeneration of the mesh based on those changes, are available. One can see how these can better automate the model generation and analysis processes.

Despite the ease of use and intuitive nature of the software, it is still advanced enough to create any geometry one would create in a parametric modeler. SpaceClaim is a full-featured 3D CAD software package; CRTech TD Direct is an add-on that allows for addition preparation, meshing, and provides a dynamic link to Thermal Desktop.

This software fills a need in the Thermal Desktop environment for import of non-native CAD files, the repair/defeaturing/simplification of those geometries, and the creation of far more sophisticated FE meshes than is possible with TDMesh for preserving high levels of geometric fidelity. In the more than two years the author has used these tools, additional features have come online that promise to extend the capabilities of the software and increase the efficiency of the analysis done with Thermal Desktop.

ACKNOWLEDGEMENTS

The author wishes to thank Xiao-Yen Wang and Paul Schmitz of GRC for their support and collaboration in developing this model and Duane Beach of GRC for his advice and support during this work. He would also like to thank those at Cullimore and Ring Technologies (CRTech) for their outstanding technical support, especially the efforts of (and the many virtual lessons from) Tim Panczak.

NOMENCLATURE, ACRONYMS, ABBREVIATIONS

| | |
|--------|---|
| ASC | Advanced Stirling Converter |
| ASRG | Advanced Stirling Radioisotope Generator |
| CAD | Computer aided design |
| CRTech | Cullimore & Ring Technologies |
| CSAF | Cold Side Adapter Flange |
| FE | Finite Element |
| FD | Finite Difference |
| GPHS | General Purpose Heat Source |
| GRC | NASA John H. Glenn Research Center |
| NASA | National Aeronautics and Space Administration |
| Pro/E | Pro/Engineer (CAD/Modeling software) |
| TD | Thermal Desktop |
| TDMesh | Thermal Desktop Mesher (a simple, TD-native FE mesher.) |
| SCMesh | TD Direct FE mesher incorporated into SpaceClaim Engineer |
| SINDA | Systems Improved Numerical Differencing Analyzer |
| ... | |

REFERENCES

1. Chan, Jack, J. Gary Wood and Jeffrey G. Schreiber. Development of Advanced Stirling Radioisotope Generator for Space Exploration. NASA/TM-2007-214806. Cleveland, OH: NASA Glenn Research Center, 2007.
2. Cullimore and Ring Technologies. Thermal Desktop User's Manual. Version 5.6. 2013.
3. Cullimore and Ring Technologies. Thermal Desktop Advanced Modeling Guide. Version 5.6. 2013.
4. Cullimore and Ring Technologies. CRTech TD Direct User's Guide. Version 5.6. 2013.