Title: Heat Analysis Manager (HAM), a Thermal Desktop API based Heat Map Generation Software

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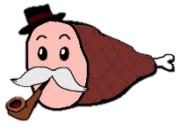
Thermal engineers often create custom heat maps to analyze their thermal model. However, generating a heat map is difficult because thermal simulation only readily provide attributes of simulated nodes such as temperature, capacitance, heat generation, and a network of conductances. Heat flow values are a derived quantity from the nodal attributes, and the data processing and management of heat flow between nodes quickly become difficult for large models. Deriving a network of heat flow values requires vast amount of calculations and data handling, heat map generation process generally suffers from processing speed, loss of accuracy, and/or presentation of data in a useful format. Heat Analysis Manager (HAM) is a Thermal Desktop (TD) based free multi-purpose tool developed to aid thermal engineers in analyzing their thermal model, including a heat map generation functionality. HAM's heat map generator retains accuracy and fast processing speed by utilizing TD's application programming interface (API) and built-in TD's "Qflow from Results." Furthermore, HAM's heat map output is presented in an easily customizable format in Excel, allowing users to create various custom visual heat maps. A full description of how HAM utilizes TD's API to create a customizable heat map is provided. A simple model demonstration is included along with step-by-step procedures on creating custom heat maps. HAM's heat map result has been verified against TD's and other heat map generation software, and verification methods are also included.

TFAWS Software Demo



Heat Analysis Manager

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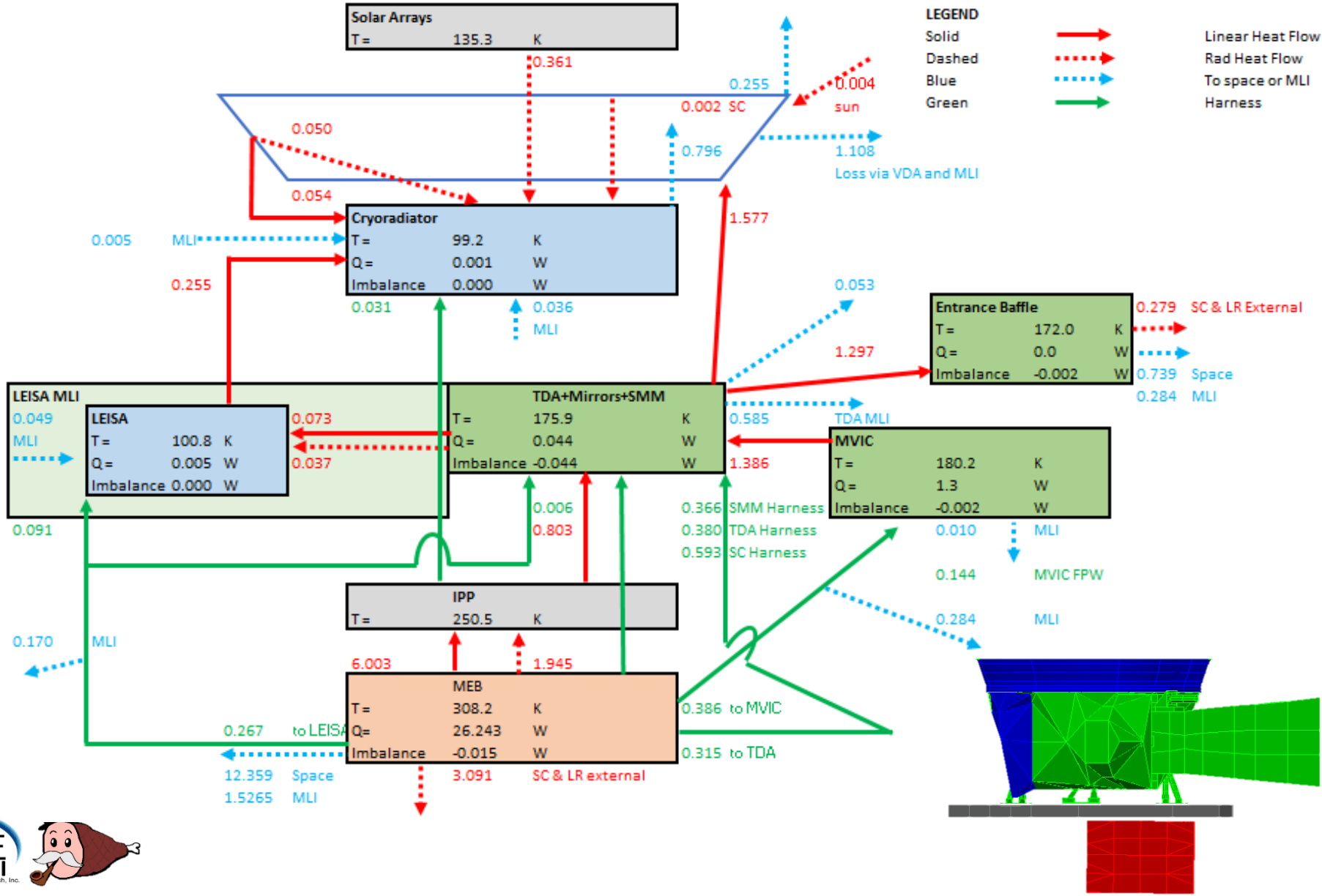
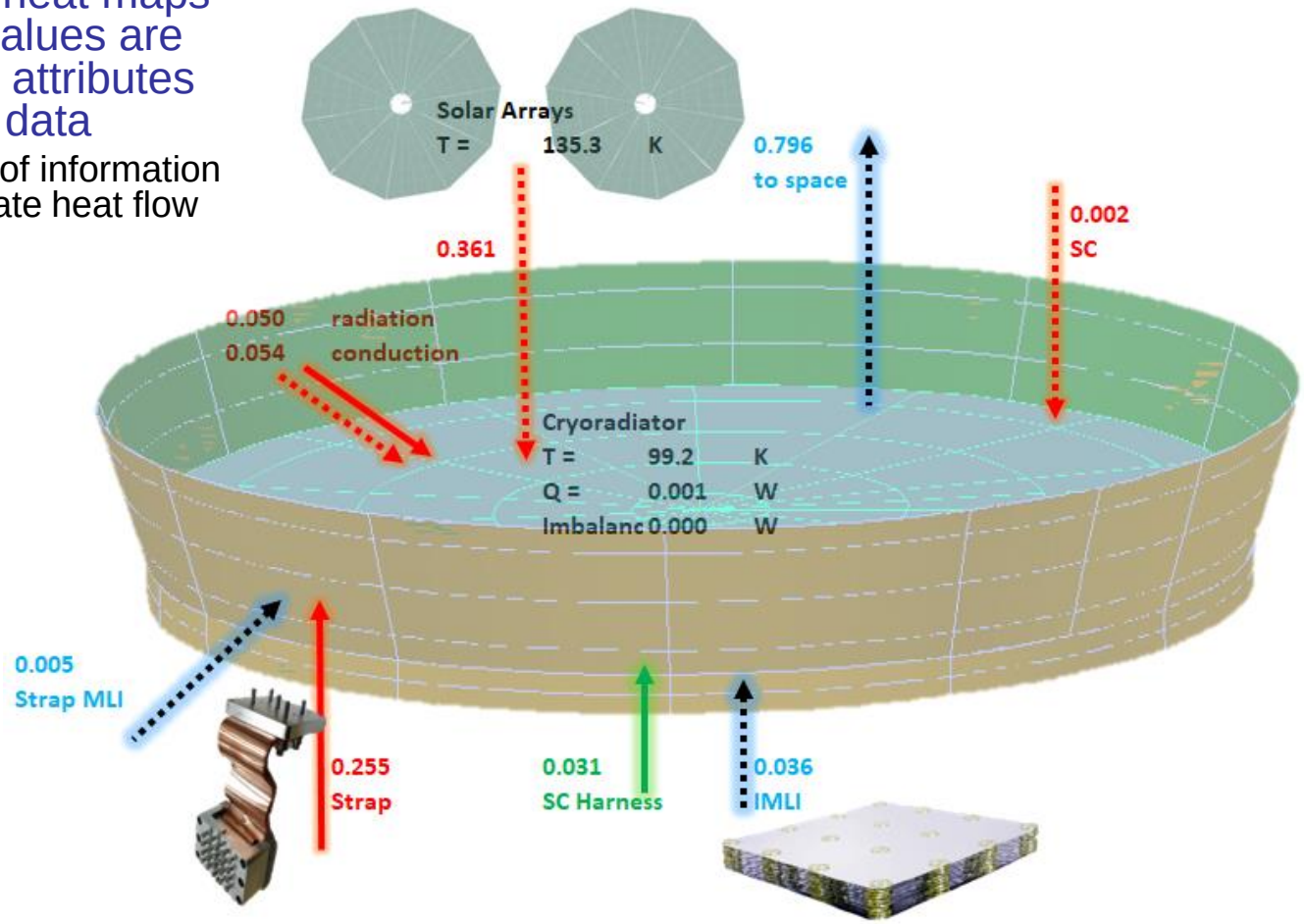
What is a Heat Map?



Purpose of a Heat Map

- Heat maps are extremely useful for understanding the TCS and the thermal model

- Difficult to generate heat maps because heat flow values are not readily available attributes but rather a derived data
  - Significant amount of information is needed to calculate heat flow values



Current Methods for Heat Map Generation

- SINDA routines: QMAP
  - Manually look at QMAP data in .out (or user defined) file then figure out connections
  - QMAP file size can be huge and difficult to process output data
  - Difficult to process transient heat map
- Conduction Network
  - Create a conduction network from .out/.sav/CSR then generate complete nodal heat flow map
  - Will take a long time to process data due to recalculation of heat flows
  - Accuracy losses due to external reprocessing of data
- TD's built in "QFLOW between Submodels" and SINDA's QFLOW subroutine
  - Returns heat flow between submodels via "Model Browser"
  - No easy way to obtain subset or superset of submodel's heat flow information

Motivation and Need

Heat map generation needs/wants:

- Accuracy
  - heat flow value should match TD's output
- Usability
  - amount of user input should be minimized
- Graphical Processing
  - creating graphical heat map should be simple and guided
- Customizability of node groups
  - user should be able to group up nodes how ever they see fit
- Transient data processing
  - all data types should be able to be processed
- Fast processing
  - heat flow calculations should be fast (time for calculation AND for data manipulation/presentation)
  - For L'Ralph, a single heat map generation would easily take an hour or more with current methods

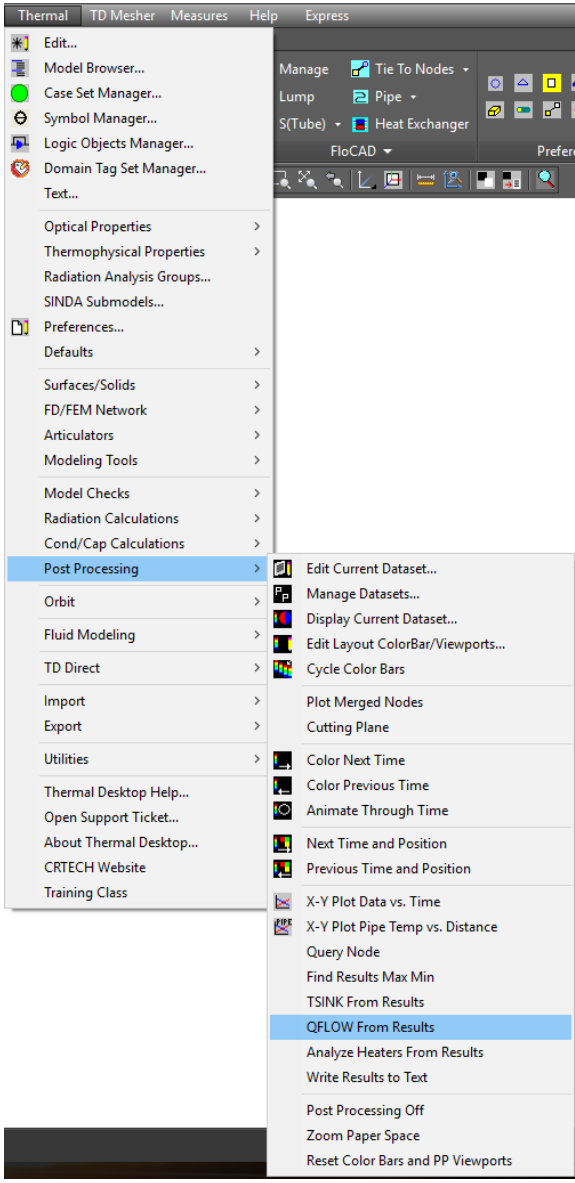
Solution: HAM

- HAM: **H**eat **A**nalysis **M**anager
  - Collection of useful features for thermal analysis
    - Only heat map and extracting data from .sav/_csr so far
  - Heat map functionality uses TD's built-in "QFLOW from results"
    - Heat flow between any group of nodes to another from a .sav /_csr file
    - Has import/export functionality: allows HAM to "talk" with TD
- Attributes
  - Accuracy: TD does the calculations so results are as accurate as TD
  - Usability: Standalone .exe with GUI to facilitate work flow
  - Graphical Processing: Saves data to a macro-enabled excel template file, which can be customized, saved, and reused
  - Customizability of node groups: simple customizable .txt file
  - Transient data processing: "If QFLOW from results can do it, so can HAM"
  - Fast processing: HAM and QFLOW from results is FAST
    - Entire heat map generation process takes <5 min with HAM for L'Ralph

QFLOW from Results

- Calculates heat flow between any group of nodes/submodels to another
  - Uses .sav/_csr file
    - .sav /_csr file must have T, C, G, Q data in order for QFlow from results / HAM to work
- Gives four separate heat flow values:
  - Total, Conductive, Radiative, and Fluid Tie
- Heat map is nothing more than a collection of heat flow values
  - We just have to tell TD to calculate which heat flow values we need in order to generate a full heat map

QFlowOutputFile



HAM DEMO

- General HAM heat map process flow
  1. HAM: Create/Customize group file and Qflow import file
     - This can be skipped if the model or the group file didn't change from a previous Qflow run
  2. TD: Calculate heat flows based on the Qflow import file
  3. HAM: Post process TD Qflow results and generate excel file
  4. EXCEL: Initialize workbook and customize
- Simple model demo
- Complex model demo – L'Ralph
- Additional feature demo – if time

Potential New Features?

- Separation of environmental heating loads vs heat load/heater imposed load
- Limit checker
  - Assign limits to groups
- General improvements to heatmap visualization
  - Excel portion
  - Standalone HAM's heatmap visualization
- GUI implementation of group file customization
- Implementation of using QFLOW SINDA subroutine
- Automation of HAM heat map generation steps via TD 6.2 API
- Other helpful features (not necessarily related to heat map)
  - Extract TCQ only on a subset of nodes, not on full file
  - Built in plotter in HAM (TD 6.2)
  - MLI estar predictor (based on temperature dependent behavior)
  - Bolted conductance calculator (similar to TAGUP)
- Suggestions?

APPENDIX

HAM Assumptions and Caveats

- Prerequisites:
  - TD license needed to run QFLOW form results
  - .sav/_csr file needs to have T,C,Q,G saved for the times you want heat map
    - TD's default .sav output setting should be fine
  - In Excel, must have "Trust access to the VBA project object model" must be checked in Excel's option "Trust Center"
- Assumes there are no one way conductors between groups
  - If user have one way conductors, we can add in a checkbox to allow one way conductors; TD just has to do double the amount of calculations to capture impact of all the one way conductors
- Fluid tie heat flow values are backwards for TD 5.8 and earlier versions of TD 6.0
  - Investigated with CRTech and they fixed it in later versions of TD 6.0
- Recommendation: Do not run HAM's heat map on a transient .sav file that has high output frequency with "Output T, G, C, Q" options all checked
  - Qflow from results will take a long time since it will try to perform heat map for EVERYSINGLE time step
  - *TD 6.1 allows time selection for Qflow from results, which will bypass this issue*