TFAWS Passive Thermal Paper Session

DEVELOPMENT AND IMPLEMENTATION OF EFFICIENCY-IMPROVING ANALYSIS METHODS FOR THE SAGE III ON ISS THERMAL MODEL

Kaitlin Liles, Ruth Amundsen, Warren Davis, and Salvatore Scola
NASA Langley Research Center (LaRC)

Steven Tobin, Northrop Grumman

Shawn McLeod, Analytical Mechanics Associates (AMA)

Sergio Mannu and Corrado Guglielmo, Thales Alenia Space-Italy (TAS-I)

Timothy Moeller
Georgia Institute of Technology/National Institute of Aerospace (GT/NIA)

Presented By

Ruth M. Amundsen

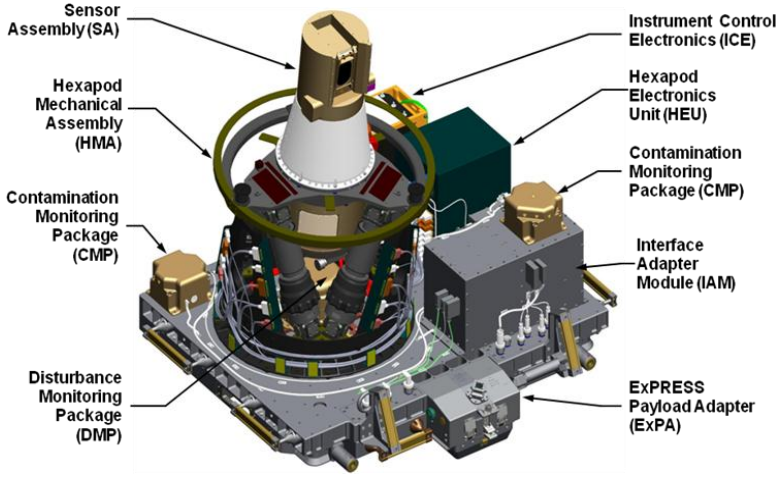
Thermal & Fluids Analysis Workshop
TFAWS 2013
July 29-August 2, 2013
Kennedy Space Center
KSC, FL

Outline

- Background
- Model Development
  - Assemblies
  - DoE methods
  - Incorporation of legacy models
  - Units flexibility
  - Case-based logic
  - Mapping to structural models
  - Streamlined results processing
- Summary

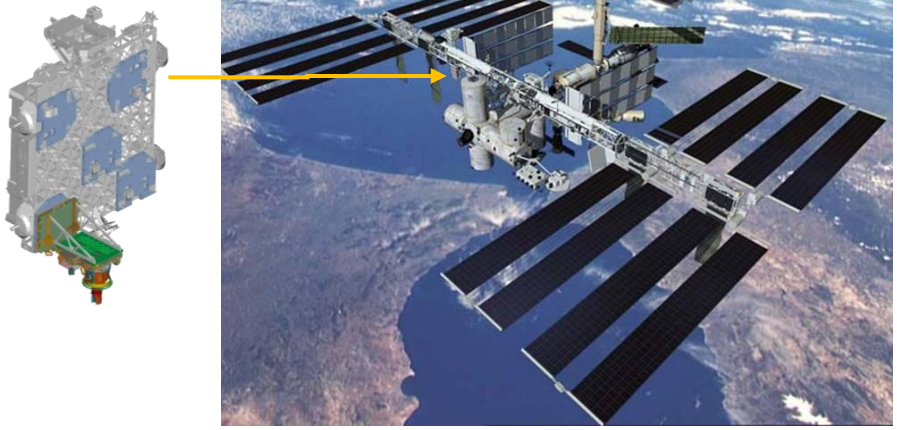
Background

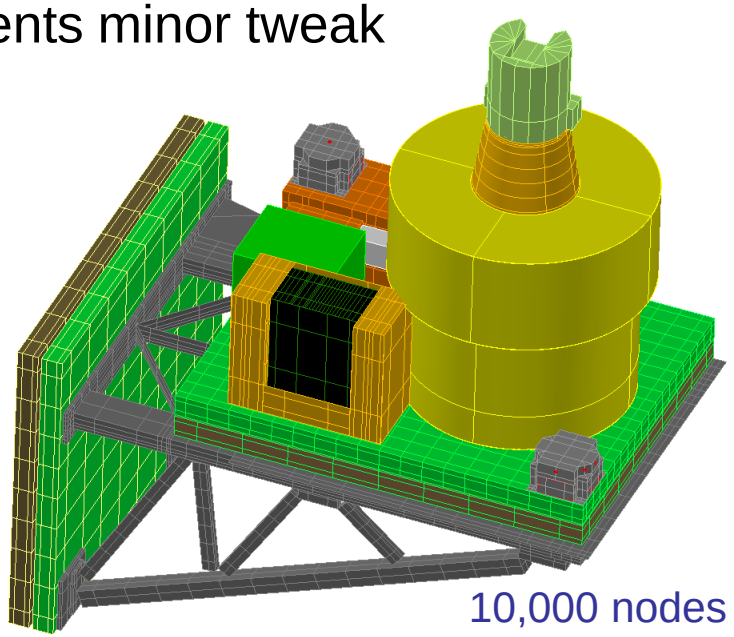
- SAGE III is an ISS-mounted science payload, to be launched on Falcon vehicle/Dragon capsule in 2015
- Three year minimum lifetime on ISS
- Monitors aerosols and other gases in stratosphere
- Thermal analyses are being completed for launch vehicle and all ISS scenarios
- Instrument Payload (IP) mounted on Nadir Viewing Platform (NVP)
- Several subsystems built in 1990's and placed in storage
  - Text legacy thermal models
- CCD sensor kept at temperature by TEC



Model Development

- Developed in Thermal Desktop®
- Includes ISS and Dragon capsule
- Shared between several NASA engineers, contractors, and Italian payload partners
- Versioned: Current version 40c
  - Number represents major model change (number of nodes, sav file no longer valid), letter represents minor tweak



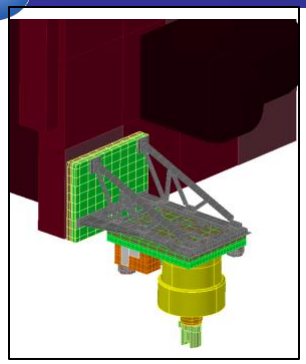


10,000 nodes

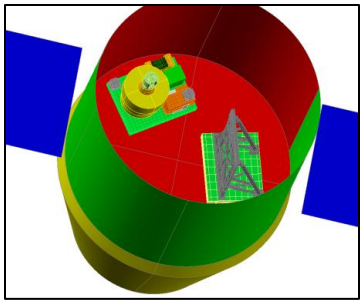
Assemblies Used for Configuration Change

- SAGE III Analysis Configurations
  - Free-flying on Dragon capsule: ~100 cases
  - Dragon Berthed on ISS: ~30 cases
  - Enhanced Operational Transfer Platform (EOTP): 7 cases
  - SAGE on ELC-4, final location: 15 cases
  - Design of Experiments for EOTP and ELC-4 orbit determination: ~400 cases
- All configurations contained in single model
  - Avoids duplication and model re-work
- Configuration change achieved with assemblies / case logic
  - Single variable defines payload position
  - Used to turn submodels on and off, and determine payload positions and orientations
  - Used to determine voltage ranges corresponding to available power at each location

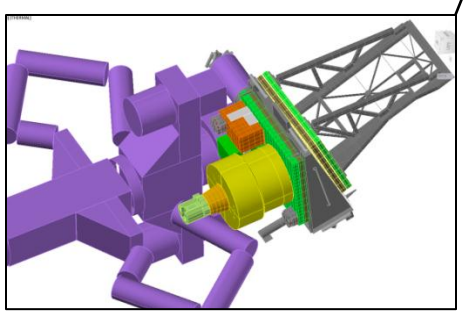
Configurations



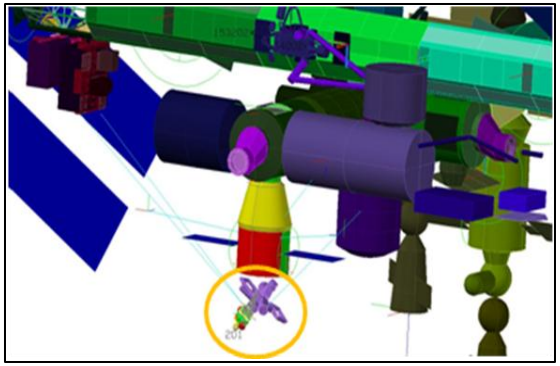
ELC-4 (MOV flag = 0)



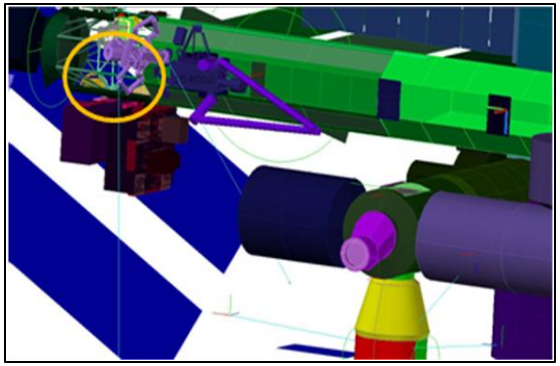
Dragon (MOV flag = 1)



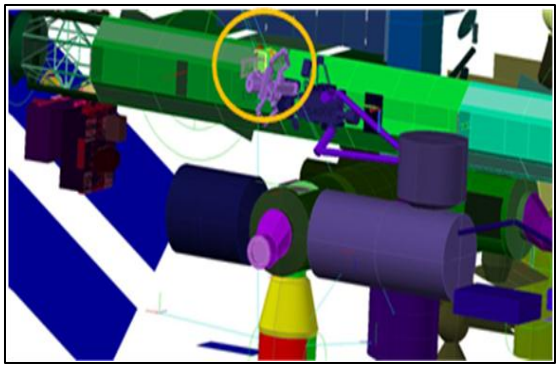
EOTP (MOV flag = 2-5)



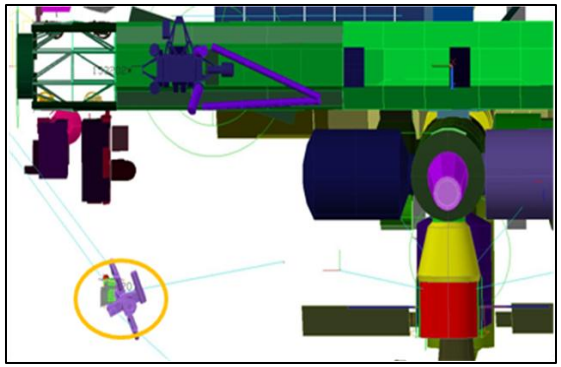
MOV flag = 2 (Outside Dragon)



MOV flag = 4 (Docked at W-2)



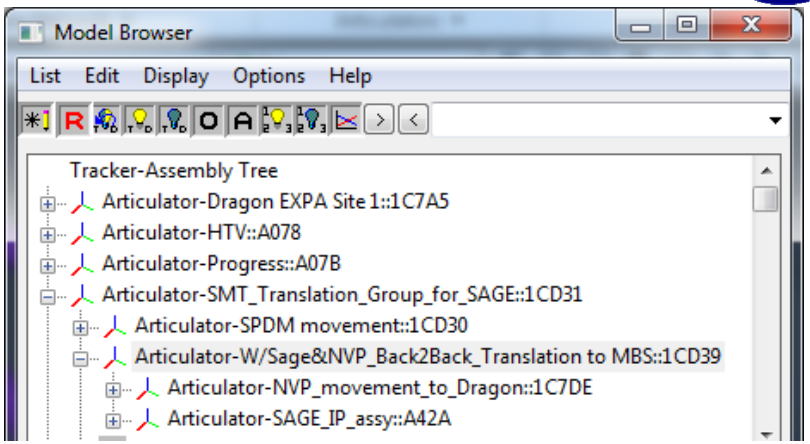
MOV flag = 3 (Docked at W-5)



MOV flag = 5 (Prior to ELC-4 attachment)

Method

- Nested articulators
  - Motion of NVP/IP
  - Motion of EOTP
  - Motion of Dragon
- NVP and SAGE IP separate



- Single variable for position of each

  0 = On ELC4, 1 = In Dragon, 2 = outside Dragon on EOTP, 3 = at w-5 on EOTP, 4 = at w-2 on EOTP, 5 = EOTP near ELC-4

- Logic in articulator translation and rotation blocks

  E.g.: (Flag_Sage_Mov == 0) ? 0 : ((Flag_Sage_Mov == 1) ||(Flag_Sage_Mov == 2)||(Flag_Sage_Mov == 3)||(Flag_Sage_Mov == 4)||(Flag_Sage_Mov == 5)) ? 33.2 : 0

Design of Experiment Methods

- Design of Experiment (DoE) methods used to select worst case orbits
- ISS orbits: varying beta angle, roll, pitch, yaw and altitude
  - SAGE III science orbits restricted to beta +/-60°
- DoE run sets generated to determine worst case hot and cold conditions
  - 6 sets of runs: Locations ELC-4, EOTP w-2 and w-5, SAGE III mission success and ISS extreme cases
  - Each set has 64 cases, except mission success with SAGE science-only beta cases has 79
  - With multi-processor machine, each set takes 3-4 days to run

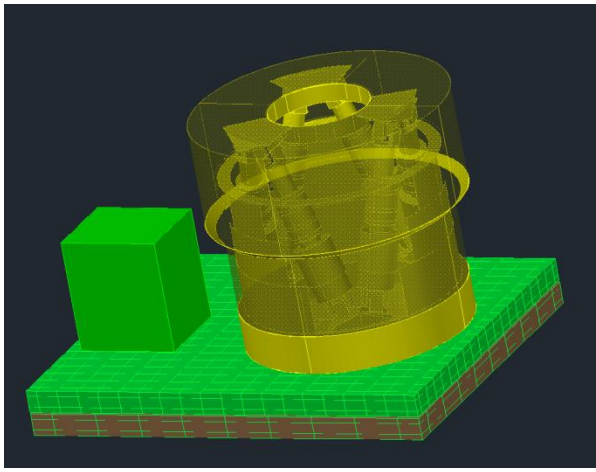
	Beta (°)		Yaw (°)		Pitch (°)		Roll (°)	
	Min	Max	Min	Max	Min	Max	Min	Max
SAGE Mission Success	-75	75	-9	-3	-12	-2	0.5	1
ISS Extreme	-75	75	-15	15	-20	15	-15	15

Method

- Run sets accomplished through feature in TD 5.5 that allows symbol load from Excel spreadsheet
  - All runs in set accomplished with one case in Case Set Mgr
  - Steady-state rather than transient runs saves computational time
- Results evaluated with feature ‘Find Tsave Min Max’
  - Critical nodes evaluated over entire set of runs and worst cases identified
  - Can also use Scola’s FilePlottingTools (described later)
- Allows quick exploration of entire design space without 1000’s of runs that would be needed for full factorial

Text Submodel Incorporation

- Several text models included in overall model
  - ISS and Dragon models in text logic blocks
  - Hexapod model in text (from ESATAN/ESARAD)
- ISS model: 128 logic blocks
  - Original model modified to include registers for initial temp, boundary temps
  - Blocks for automated build of submodels based on case
  - Blocks for different temperature units
- Hexapod model: 26 logic blocks
  - Define nodes, conductors, power, heaters, operational logic
  - Complex internal structure
  - Radiative nodes corresponded to thermal nodes



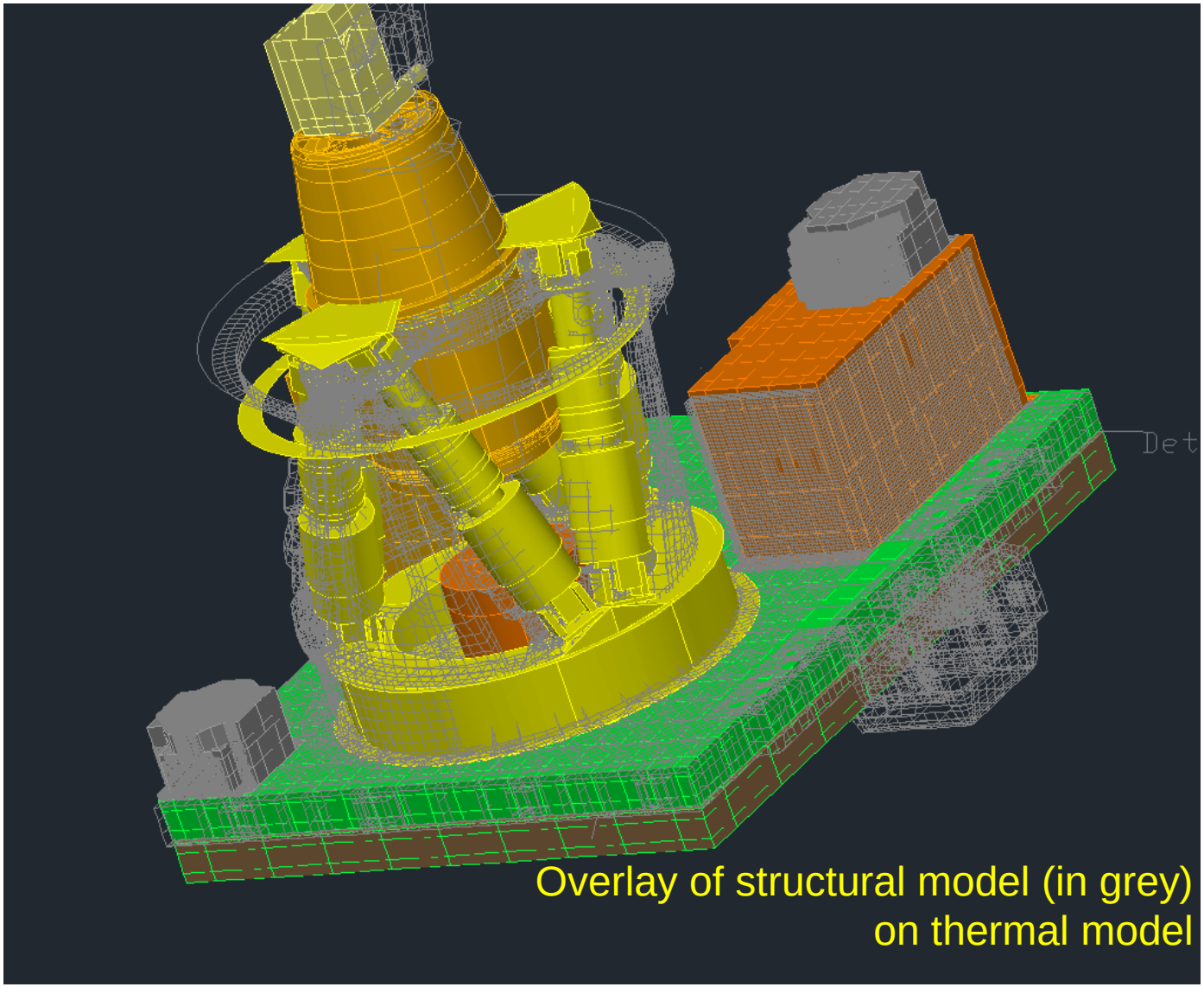
Units Flexibility

- Original model all metric (W, s, m, °C) including ISS model
- Requirement to deliver model in English, as well as incorporation of new ISS model version, led to change to all British (Btu, hr, ft, °F)
- Preference of science, testing and thermal personnel for degrees C led to change to flexible unit model
- Model currently can be run in either °F or °C units
- Single register used to define temperature set
  - switch_temp_units: 0 for °C and 1 for °F
- All logic blocks using units are built dual, one for each setting of switch
- Model can be run in °C, then delivered in °F

Case-Based Logic

- Register flags used to define scenario
  - Hot/cold/nominal, operation/survival, voltage range, etc.
- Register flags used:
  - In Enable blocks to turn powers & contact on/off
  - In logic to define heater & power values based on voltage, operational scenario, MLI conductance, operational timeline, etc.
- Multiple arrays defined for instrument science timeline
  - In Excel; too complex for register-only action
  - Different arrays activated by flags
- Allows many different scenarios to be run by simply defining 2 or 3 flags in the case set

Mapping Thermal Results to Structural



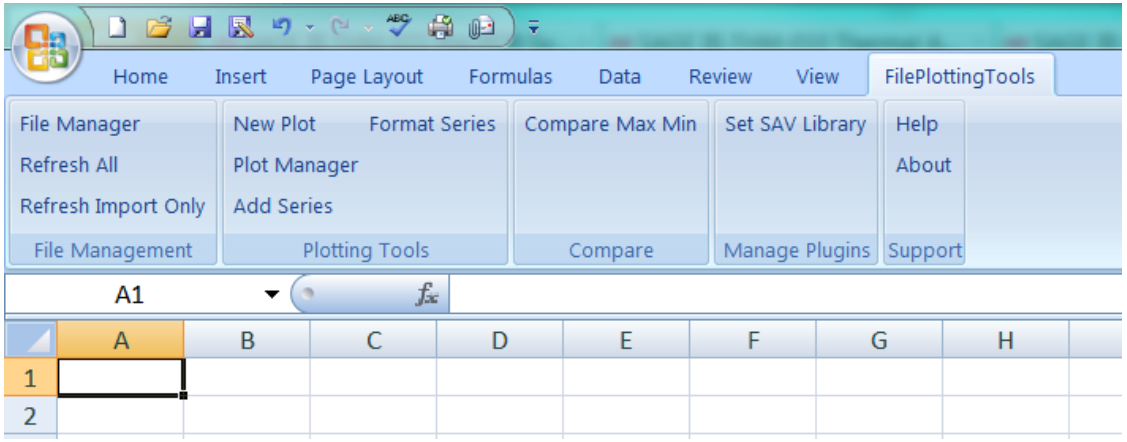
Overlay of structural model (in grey)
on thermal model

Thermal to Structural Tips

- Import and map using TD PP Mapper function
- Multiple structural models to be mapped to
  - Many are huge (>50 GB)
  - Several use different co-ordinate systems
  - If maintained in model, unwieldy model size
  - Multiple imports very time-consuming due to need for alignment
  - Mapping each transient time point creates HUGE files (>500 GB)
- Create unique use coordinate system for each structural model (use separate models for thermal interfaces)
  - Allows simple re-import into exact location
  - Maintains small model size
- Create registers for gradient along each axis of part
  - Peak in register defines time point for worst case stress

Streamlined Results Processing

- Hundreds of transient cases run
  - Loading and evaluating each file separately in TD Excel Plotter very time-consuming
- Tory Scola at NASA LaRC solved this with custom-built Excel module
  - FilePlottingTools, http://fileplottingtools.larc.nasa.gov/
  - Works within Excel
  - Imports and compares large number of text or .sav files rapidly
  - Simple drag-and-drop operation



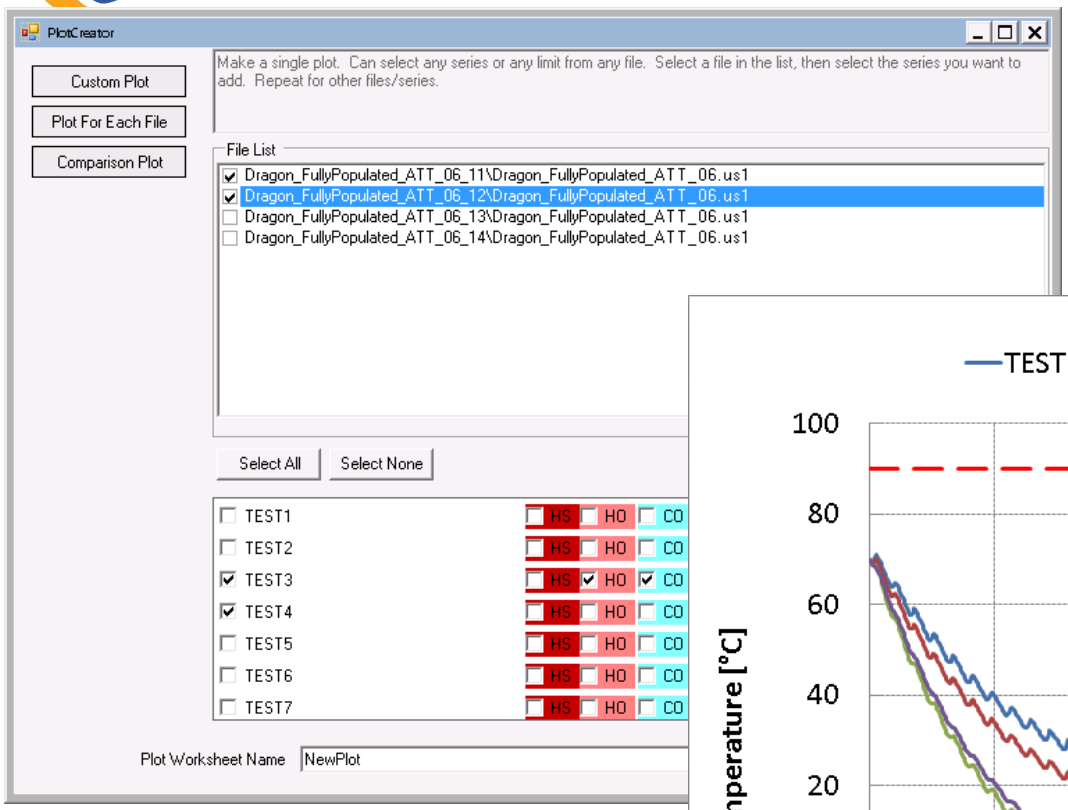
FilePlottingTools Functionality

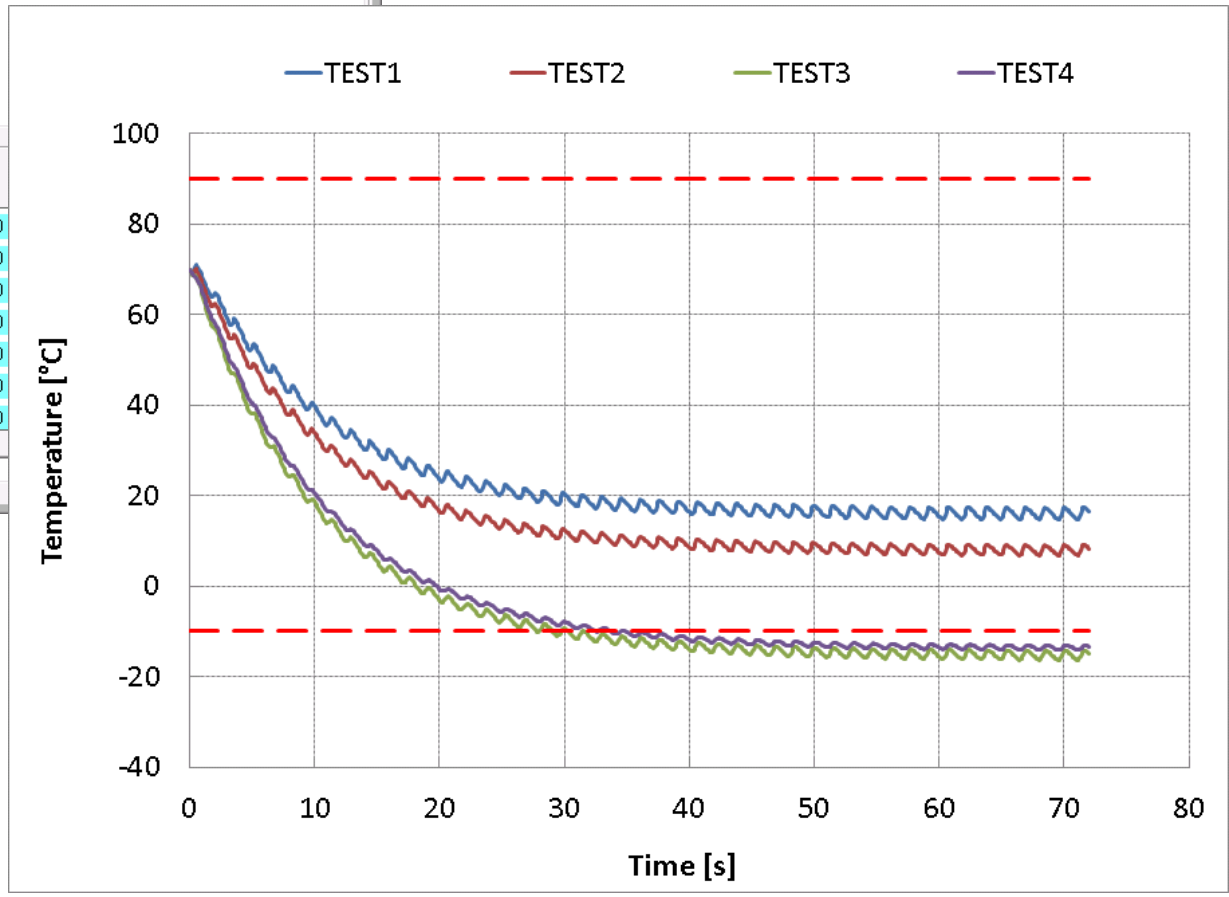
- Computes max and min over transient for selected nodes and registers
  - Can do hundreds of files with multiple nodes simultaneously
- Determines worst case file run for each node
- Compares max/min to limits for each node and run
- Highlights extremes and worst case out of all cases
- Calculates Time-To-Limit (TTL) for each node
- Standardized plot creation using any selection of nodes and files
  - Plots refreshed when imported files refreshed
- Specialized routine also available to plot standard 128 cases run for Dragon in required format

FilePlottingTools Examples

Component Description	T1	T2	T3	T4	T5
Node Number	0	0	0	0	0
Non-Op Max	65	65	65	65	65
Op Max	55	56	85	18	65
Op Min	-10	-40	-55	-55	-30
Non-Op Min	-15	-55	-55	-55	-30
OVERALL MAX	19.5	19.1	17.1	18.1	20.0
OVERALL MIN	-19.7	-36.2	-36.6	-35.7	-11.6
MAXIMUM TEMPERATURES					
Case1.us2	18.99	18.49	15.17	16.42	19.95
Case2.us2	18.99	18.49	15.17	16.42	19.95
Case3.us2	19.46	19.12	17.05	18.03	19.97
Case4.us2	19.50	19.09	16.82	18.13	19.98
Case5.us2	19.32	18.79	16.03	17.42	19.96
Case6.us2	19.32	18.91	16.42	17.46	19.96
MINIMUM TEMPERATURES					
Case1.us2	-19.74	-36.20	-36.61	-35.74	-11.42
Case2.us2	-19.72	-36.19	-36.60	-35.73	-11.42
Case3.us2	-8.21	-23.33	-25.46	-22.99	-8.56
Case4.us2	-8.02	-24.94	-27.82	-27.32	-11.61
Case5.us2	-12.10	-28.30	-28.95	-30.06	-11.59
Case6.us2	-8.85	-26.11	-29.02	-28.31	-11.59

FilePlottingTools Plotting Examples





Summary

- Methods developed have made SAGE III analysis quicker, more accurate, and more flexible
- Up-front time investment has paid off in faster analyses
- Methods shared with other programs and Centers
- Other payloads, particularly ISS and Dragon, may find these methods useful

Acknowledgements

- Thanks to all co-authors for their work in developing and perfecting these processes
  - Kaitlin Liles, Ruth Amundsen, Warren Davis, and Salvatore Scola, NASA Langley Research Center (LaRC)
  - Steven Tobin, Northrop Grumman
  - Shawn McLeod, Analytical Mechanics Associates (AMA)
  - Sergio Mannu and Corrado Guglielmo, Thales Alenia Space-Italy (TAS-I)
  - Timothy Moeller, Georgia Institute of Technology/National Institute of Aerospace (GT/NIA)
- Thanks to C&R staff for outstanding technical support
- Thanks to branch management for support in time and funding for state-of-the-art computer hardware and software