NASA ISS PTCS Model Check-out

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Presented By

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Introduction

- ISS PTCS performs review/check-out of thermal models planned for distribution to other ISS participants
  - For example, ISS payloads to be launched via a SpaceX or JAXA vehicle
- NASA PTCS responsibilities
  - Maintain database of received models
  - Conduct check out of the models received
  - Preparation of a check-out report
  - Interaction with the model developer to make modifications as needed
  - Delivery of the model to the next destination
- A model check-out process was developed based on an existing NASA reviewed Boeing processes
- A NASA-built template was prepared
  - Streamline check-out process
  - Guide to future model reviewers
  - Ensure consistency from one check-out to the next

Payload Check-Out Process

- The payload model is delivered to NASA PTCS from the payload developer
- The model is reviewed by NASA PTCS
- NASA PTCS provides model check-out findings to developer
- NASA PTCS works with developer for clarification
- Developer makes appropriate modification
- Modified model delivered to NASA PTCS
- NASA PTCS spot checks changed areas (receiving confirmation that nothing else was changed)
- NASA PTCS delivery of complete model including all files with documentation
  - Boeing
  - Transportation Integration Office (NASA-JSC-ON) for delivery to commercial provider (Space-X)
  - Delivery to other final receiving party

Model Heritage

- Receive Model from Developer
  - Plus Critical Nodes List and Benchmark case if possible
- Fill in initial section of the model configuration form:
  - Payload Name
  - Payload Overview (one-two sentence)
  - Report Prepared By
  - Checkout Conducted By
  - Received By
  - Received From
  - Received Date
  - Developer
  - Model Version
  - Files Received
  - Critical Nodes Received (Y/N)
    - Files Received
  - Benchmark Case Received (Y/N)
  - Additional References
- Model Storage
  - If necessary, create a folder within the ISS_PTCS/PTCS Configuration Control folder
  - If necessary, within this folder create a folder for the received model version
  - Place files in this folder
  - Fill in corresponding section on model configuration form

Level Designation

- Perform cursory review to determine model level
  - Model complexity
  - Future determined use
- Suggested guidelines for model review level determination
  - Level 1
    - Simple models of hardware with no intended future use, or negligible impacts to the ISS
  - Level 2
    - Mid-level complexity
    - Typically simple payloads or smaller Orbital Replacement Unit (ORU) level models

Level Designation

- Level 3
  - complex models or models with many include files
  - models from International Partners (IP)
  - larger models of ORUs integrated with Flight Support Equipment (FSE)
  - any model developed by multiple vendors
  - any model with significant impact to ISS, regardless of complexity
    - For example, potential for constraint on unpowered transfer time to ISS installation site
    - At minimum, priority is placed on verification of credible, unpowered transfer times through mass, surface treatment, insulation, and critical node/limit checks

Model Check-Out

- Level 1 Model Review
  - Document model heritage, model level, and rationale
  - Save within model folder
- Level 2 Model Review
  - Document model heritage, model level, and rationale
  - Model Summary
    - Number of Nodes
      - TD/RC Nodes
      - User Nodes
      - MLI (Non-graphical nodes)
      - Total Nodes
    - Number of planar elements
    - Compare to suggested count: 500 nodes and 500 planar elements

Model Check-Out

- Review SINDA submodel nomenclature
  - Alphanumeric characters, no more than six (TRASYS compatibility)
  - Cargo identifying prefix (Space X suggested)
    - To avoid duplication of submodel names during integration (Ex. Submodel named PLATE)
    - Example: XXXnam10 (where “XXX” is a payload identifier)
- Document and assess model elements
  - Optical and Thermophysical Material Properties
  - Symbols
  - Heaters
  - Include Files
- Level 2 Documentation saved to model folder

Model Check-Out

- Level 3
  - All contents in Level 2
  - Set up model to run and conduct a test run
    - Compare test run to benchmark case (if provided)
    - Spot Check: Assess calculated values compared to critical node list values (if provided)
  - Generate Record Files
    - Contactor and Conductor Record File, list of conductors and image of connections (excluding external radk's),
    - Capacitance Record File (Submodel max/min, detailed record in Appendix)
    - Mass Record File (by submodel, detailed node record in Appendix)
    - Surface Record File (colormap of solar absorptivity (α), IR emmisivity (ε), α/ε, Radiation analysis groups)
    - Temperatures/min-max (by submodel, detailed record in Appendix)
    - Image of interface (CEPA)

Model Check-Out

– Level 3 (cont.)
  - Review/Screen and Document Record Files for gross errors and any values out-of-family
  - Prepare model check-out report using model template
  - Check-out ends here.
  - Save files in the appropriate model folder

Example Model Check-Out

- Payload: TFAWS KSC Payload (TKP)
  - TKP is not an actual payload, but the following points were pulled from examples of real check-outs
- Payload Overview
  - The TKP is a propulsion experiment using a high specific impulse (ISP) and a non-toxic monopropellant.
  - Transport Vehicle: SpX4 flight
  - Destination: Columbus module on ISS
- Files Received (saved in appropriate folder in the database)
  - TKP_Thermal_model_rev2.dwg
  - RcOptics.rco
  - TdThermo.tdp
  - TKP_Analysis_Model.pdf

Example Model Check-Out

- Model Heritage
  - Final Report Prepared By: L. Carrillo
  - Check-out Completed by: L. Carrillo
  - Received From: T. Faws
  - Received Date: 7/1/2013
  - Received By: L. Carrillo
  - Model Developer: K. Space
  - Model Version: TKP_Thermal_model_rev2.dwg
  - Critical node list to date was received. It is contained in TKP_Analysis_Model.pdf

Example Model Check-Out

- Model Level
  - Level 3 model
  - Rationale: This is a complex model with a lower integrated Flight Releasable Attachment Mechanism (FRAM) built by a different developer with potential impacts to the ISS.
- Thermal Desktop model summary
  - Model Nodes (not including Dragon and Fram submodels)
    - 391 TD/RC nodes
    - 4 User Nodes
    - 56 MLI (non-graphical nodes)
    - Total: 451 total nodes
  - Planar Elements: 132
  - The number of nodes and surfaces fall below the suggested value of 500.

Example Model Check-Out

- SINDA Submodel Names
  - TKPIN
    - Under 6 characters
    - All alpha-numeric characters
    - Unique payload designation does not duplicate Dragon submodels
  - TKP_Outer_Shell#2
    - The guidelines are not met
    - Over 6 characters
    - Not all alpha-numeric characters
- Duplicate Nodes
  - There are no duplicate nodes in the payload submodels.
- Optical Properties (one chosen for example purposes)
  - TKP_Beta_Cloth
    - ALPHA: 0.45
    - EMISS: 0.8
    - Kriegbaum's Optical Property Database, Points to: Aeroassist Flight Experiment Carrier Thermal Data Book, MSFC-DOC-1609, June 1990
  - Correct naming convention ensures that optical properties are not duplicated with Dragon or other payloads (prefix payload designator)

Example Model Check-Out

- Thermophysical Properties (one chosen for example purposes)
  - TKP_MLI:
    - Conductivity: 0 Btu/hr/ft/F
    - Specific Heat: 0.22 Btu/lbm/F (921 J/kg/K)
    - Density: 34 lbm/ft^3 (544 kg/m^3)
    - Estar: 0.09 (cold case), 0.024 (hot case)
    - MLI surfaces are modeled with diffusion nodes
      - Demonstrates importance of model check-out. Actual nodes were changed to arithmetic nodes prior to final delivery.
  - Correct naming convention ensures that optical properties are not duplicated with Dragon or other payloads
    - Prefix payload designator

Example Model Check-Out

- Symbols
  - TKP_COLD _DenCon_Bap = 0.27
    - Multiplier for density and conductivity of base plate
    - The multiplier accounts for the removed iso-grid material since the actual thickness is used.
  - TKP_Fire_1.5_psi = 0, TKP_Fire_150_psi = 0, TKP_Fire_15_psi = 0, TKP_Fire_450_psi = 0
    - Heat load inside the nozzle
    - All Disabled for Cold Case
    - These symbols are used for firing analysis only. A brief description is given in the documentation.
  - TKP_t_XPU = 0.313
    - In.
    - Thickness of XPU
    - 0.026 ft

Originally had a mix of inches and feet. Documented as a comment in the model check-out report. Payload developer updated this such that all plate thicknesses using this symbol were in inches.

Example Model Check-Out

- Heaters
  - PTM1 Heater
    - Disabled
  - Tank Heater
    - On Temp: 0F (-17.8C)
    - Off Temp: 10F (-12.2C)
    - Power: 204.7 Btu/hr (60W)
    - Register String: _TANK
  - Camera Electronics Heater
    - On Temp: 0F (-17.8C)
    - Off Temp: 10F (-12.2C)
    - Power: 204.7 Btu/hr (60W)
    - Register String: _CAMELEC

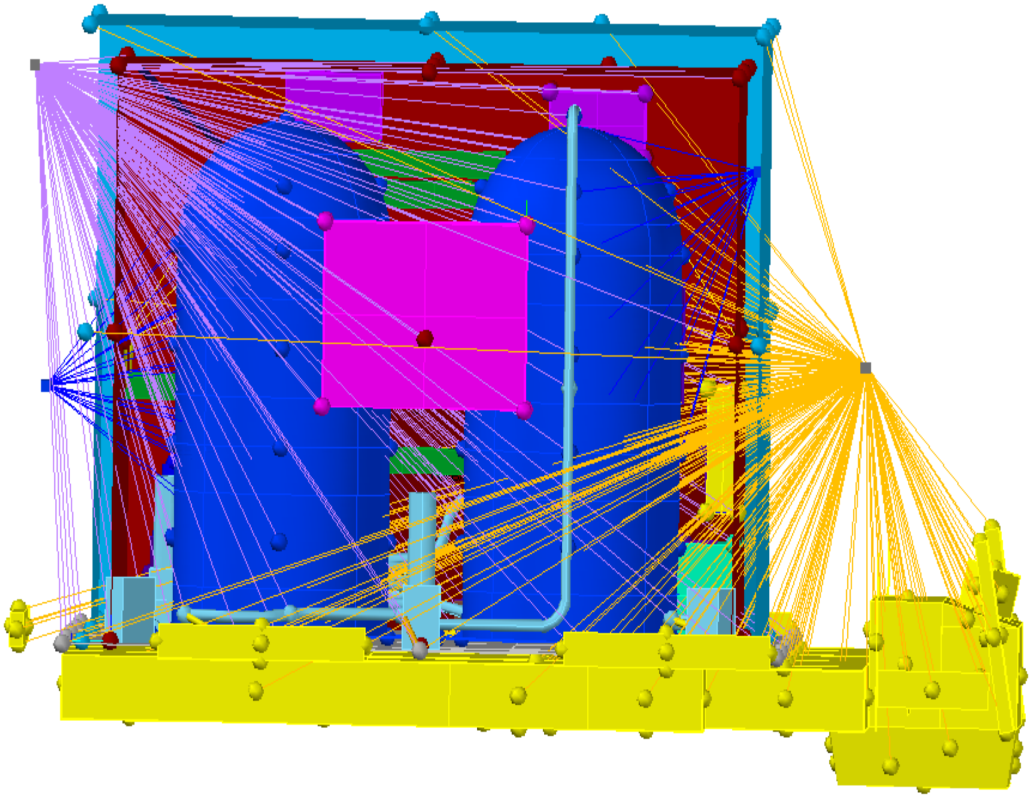
These register strings are documented to make it easier for SpaceX or other receivier to pull out the heater data.

Example Model Check-Out

- Include Files
  - No include files are brought into the case run manager beyond .inp and .cc generated by TD
- Test case
  - TKP_only (Ran 7/4/2013)
    - Only one case set-up in the case set manager. The purpose of the model is purely for integration
    - Generated TKP_only.cc and TKP_only.inp
  - Errors generated
    - TKP_t_XPU = 0.313 symbol used a mixture of ft/in. This was corrected by the model developer.
    - Heating errors indicate dimensionless values for certain heaters. This was expected since these heaters are disabled and used for TKP team internal purposes only.

Example Model Check-Out

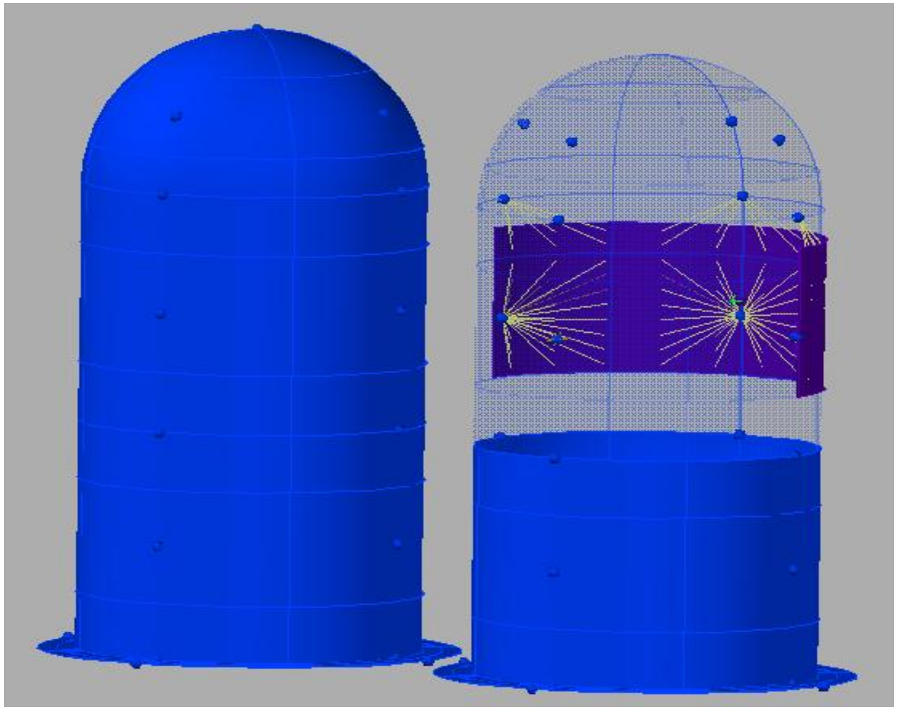
- Contactors
  - Internal Convection
    - Purple
    - 1e-5 Btu/hr/sq. ft/F,
  - External Convection
    - Orange
    - 1e-5 Btu/hr/sq. ft/F
  - Fluid to tank
    - Blue
    - 1.89563 Btu/hr/F.



External nodes are added per the Space-X IDD. Note that the value of these is small. This is addressed in the documentation of the TKP model.

Example Model Check-Out

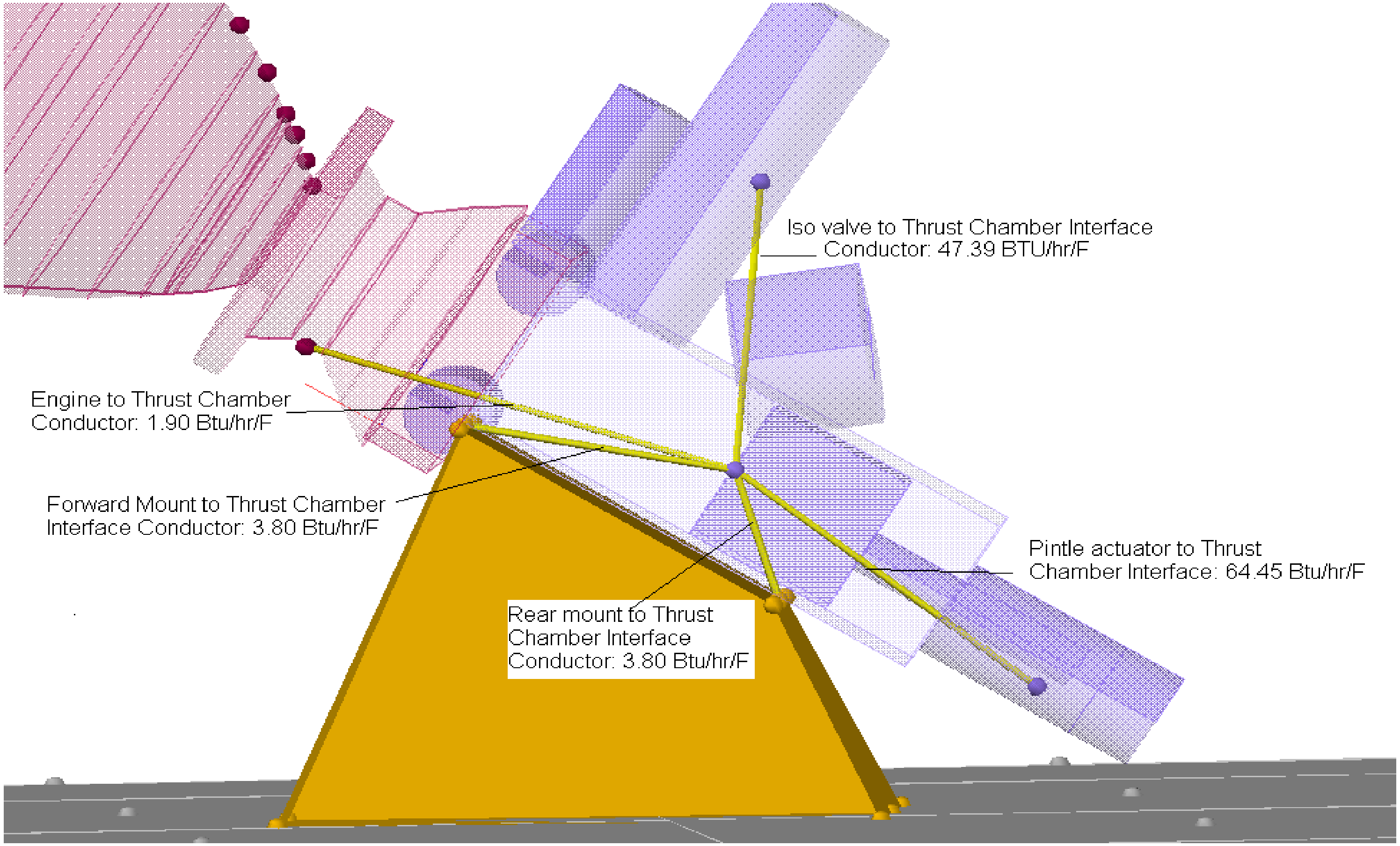
- Contactors
  - Heater tank contactor per area
  - TKP_Tra-Bond_2151
  - Thickness of 0.0005 ft



Surface connections look good. The contactor and conductor graphical checks are important. Many model developers overlook checking this. Often this check uncovers incorrect connections.

Current Model Check-Out

Conductors



Capacitance Data

NODE	TYPE	CAPACITANCE (ENERGY/DEG)	NODE	TYPE	CAPACITANCE (ENERGY/DEG)	NODE	TYPE	CAPACITANCE (ENERGY/DEG)
1000	DIFF	0.132199	2100	DIFF	0.155127	3200	DIFF	0.46874
1001	DIFF	0.264399	2101	DIFF	0.155163	3201	DIFF	0.886884
1002	DIFF	0.264399	2102	DIFF	0.155127	3202	DIFF	1.09821
1003	DIFF	0.264399	2103	DIFF	0.155163	3203	DIFF	0.503395
1004	DIFF	0.132199	2104	DIFF	0.155126	3204	DIFF	0.561122
1005	DIFF	0.264399	2105	DIFF	0.155162	3205	DIFF	0.531867
1006	DIFF	0.528798	2106	DIFF	0.155162	3206	DIFF	0.289162
1007	DIFF	0.528798	2107	DIFF	0.155126	3207	DIFF	0.235535
1008	DIFF	0.528798	2200	DIFF	0.125518	3208	DIFF	0.338628
1009	DIFF	0.264399	2201	DIFF	0.125518	3209	DIFF	0.63167
1010	DIFF	0.264399	2202	DIFF	0.125654	3210	DIFF	0.718519
1011	DIFF	0.528798	2203	DIFF	0.125654	3211	DIFF	0.382297

Capacitance data for each node is documented in an Appendix of the model check-out report.

Example Model Check-Out

Detailed Mass Record, lbm

Node Name	Mass
TKPIN.1000	0.57
TKPIN.1001	1.15
TKPIN.1002	1.15
TKPIN.1003	1.15
TKPIN.1004	0.57
TKPIN.1005	2.3
TKPIN.1006	2.3

Mass associated with each node is documented in an Appendix of the model check-out report.

Submodel, Surface/Solid Mass, Insulation Mass, lbm

TKP, 399.51515, 15.93714
(only one submodel in this case)

Total Mass For Surfaces/Solids = 399.5 lbm

Total Insulation Mass For Surfaces and Solids = 15.9 lbm

Total Sum of Surfaces/Nodes/Insulation is 415.4 lbm

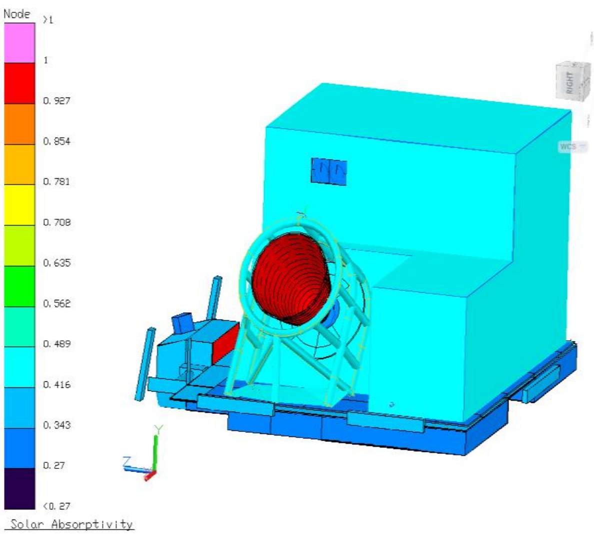
All nodes written to NodeSummary.xls

The total actual mass of TKP: 430 lbs.

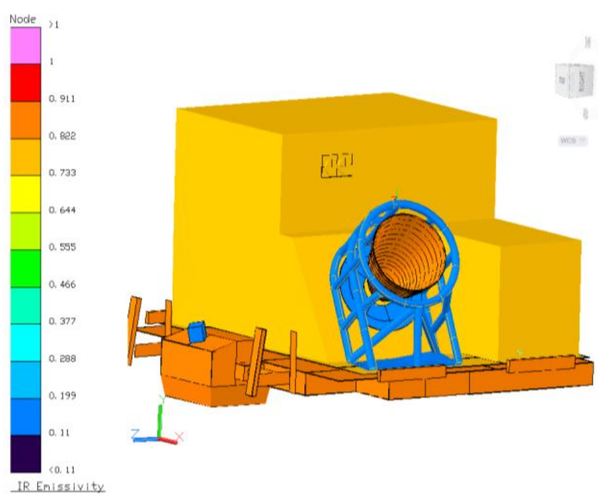
The total mass is in the range of the actual total mass of the hardware.

Example Model Check-Out

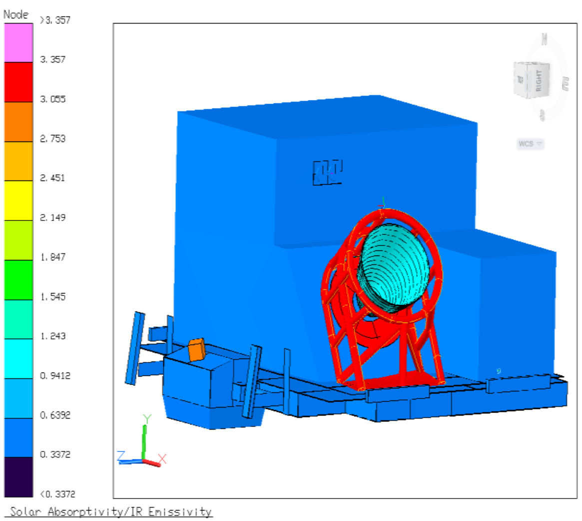
Optical Property Screening



Solar Absorptivity

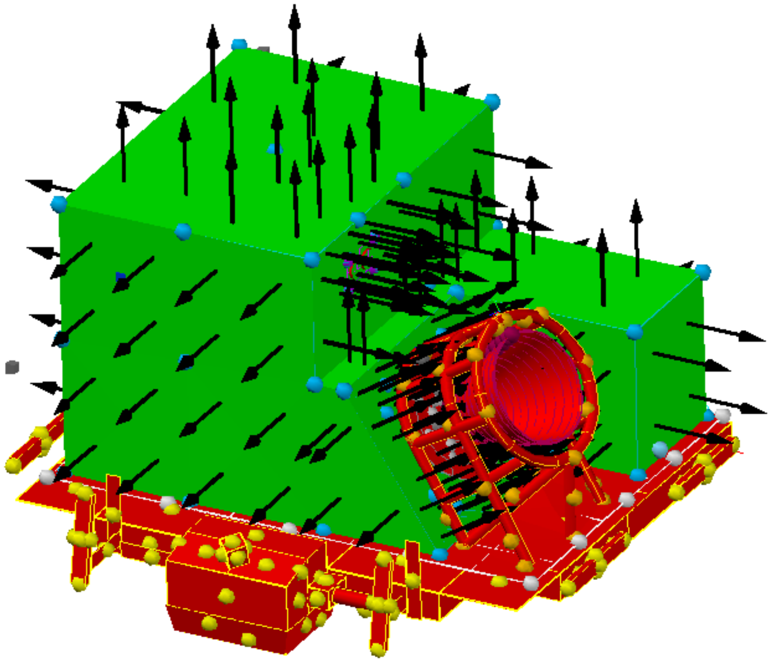


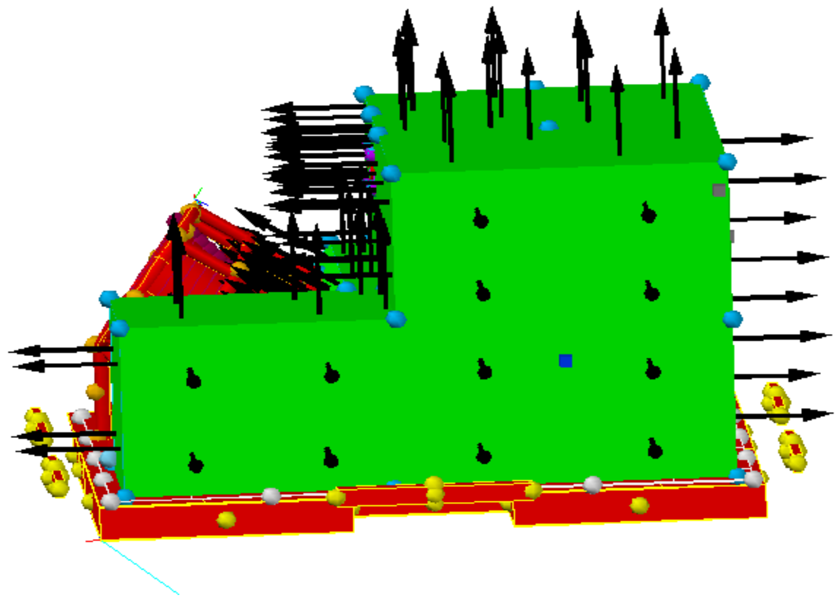
IR Emissivity



Solar Absorptivity/ IR Emissivity

MLI Surface Screening

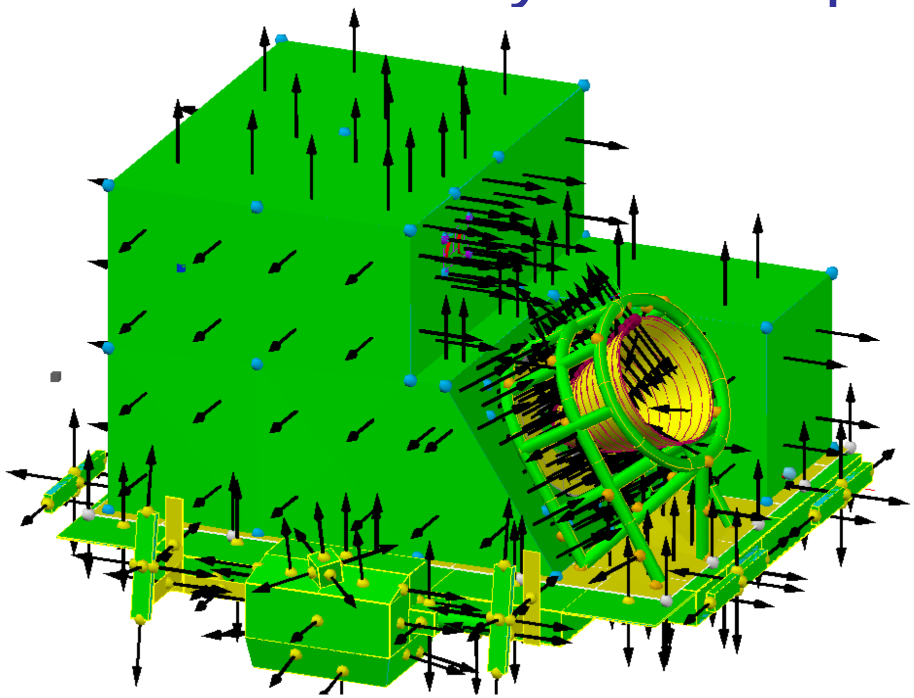




This is screening that model developers also overlook. With this check, it is easy to see a missing surface of MLI. This particular payload did not have this issue.

Example Model Check-Out

Radiation Analysis Group



This is screening that model developers also overlook. With this check, it is easy to see a surface that is missing from a radiation analysis group. This particular payload did not have this issue.

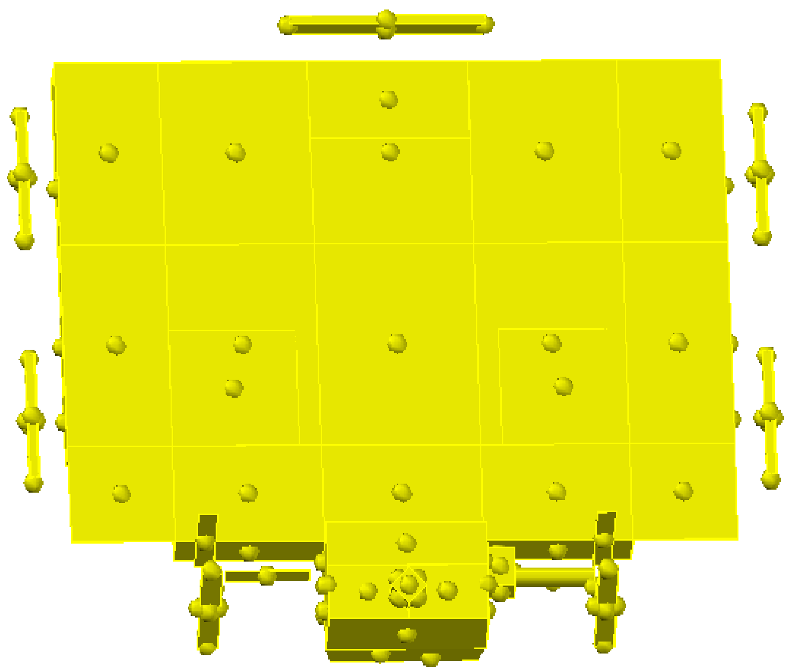
Example Model Check-Out

- Conductor Screens
  - Small Range Conductors Sampling
    - Conductor 16, CEPA.815 TKPIN.9000, 1.1e-6
    - Conductor, 113, TKPIN.1002, TKPIN.9001, 3.3e-6
  - Large Range Conductor Sampling
    - Conductor 42, CEPA.1006, TKPIN.1023, 97.5
    - Conductor 37, CEPA.1003, TKPIN.1024, 94.8

Note: Negative conductor values in some conductors are due to the implementation of Finite Element. These are not of concern.

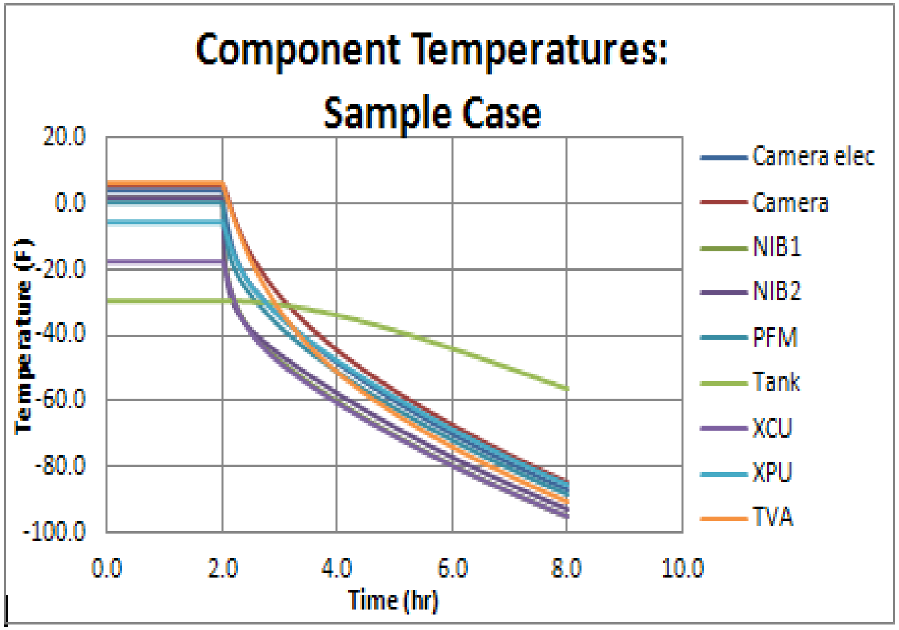
Example Model Check-Out

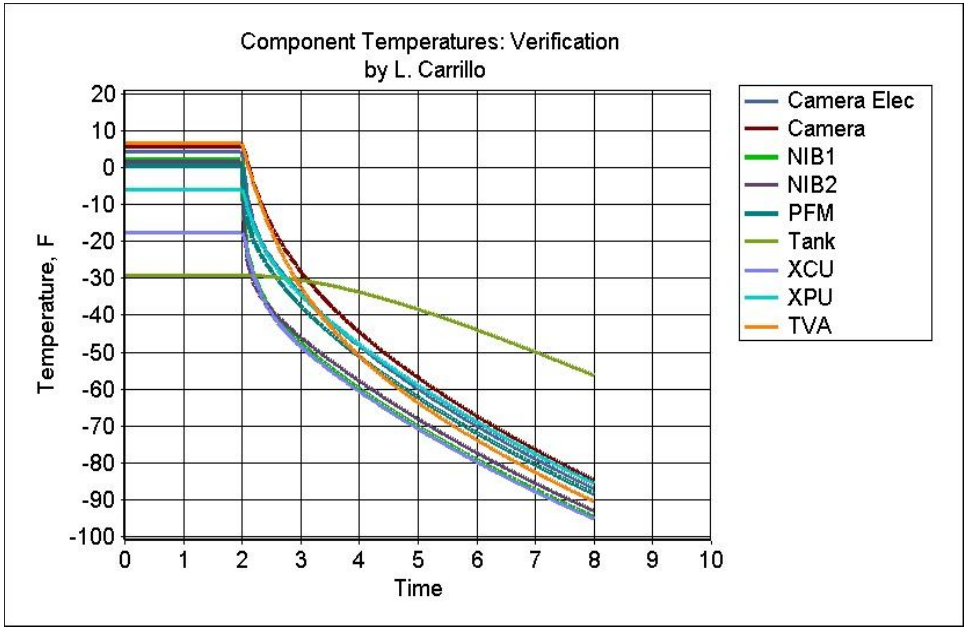
- Interfaces: CEPA
  - The CEPA is a model provided by Boeing
  - In the past, payload developers have sometimes built their on plate. This would need to be updated prior to final model delivery
  - CEPA is modeled as follows with/without MLI facing the payload
  - This model is



Example Model Check-Out

Benchmark Case Comparison





Benchmark Case Provided

Generated for Verification

Submodel Max/Min Data:

Max	7.403527	TKPIN.8011
Min	-228.1396	TKPIN.4119

Unique Challenges

- Tight schedule
  - Exacerbated when the model is received late in the delivery cycle to ISS participant
  - Pressure to approve the model even if accuracy is compromised
    - At minimum, priority is placed on verification of credible, unpowered transfer times through mass, surface treatment, insulation, and critical node/limit checks
- Request for an additional updated model check-out once the model check-out has begun or is complete
- Payload developer resistance
  - Discussion on check-out findings
  - Implement modifications
- Limited resources

Conclusion

- ISS PTCS has the responsibility to review ISS thermal models
- The level designation is based on complexity and future model use
- An established step-by-step check-out process exists for the model reviewer
- A NASA-built template is used to create the results report
  - Model details
  - Review of the model elements (mass, conductor, optical properties…)
  - These steps as illustrated in the example can be followed to minimize error