Thermal Modeling Method Improvements for SAGE III on ISS

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Outline

• Background
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  – Model Development

• Method Improvements
  – Inclusion of TVAC chambers and GSE
  – Use of assemblies for Dragon model updates
  – Creation of time-varying orbital parameters
  – Setting model parameters using case definition
  – Incorporation of a convection submodel
  – Approach for case grouping

• Summary
SAGE III on ISS Background

- SAGE III is an ISS-mounted science payload, to be launched on Falcon vehicle/Dragon capsule in 2016
- 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
Dragon and ISS Configuration

Dragon Unpressurized Cargo Module

Instrument Payload (IP)

Nadir Viewing Platform (NVP)

S3 Truss Payload Attachment System-4 Site (PAS-4)

Passive FRAM Adapter Plate Site 3 (PFAP-3)

ExPRESS Logistics Carrier-4 (ELC-4)

Dragon Unpressurized Cargo Module
Model Development Background

• Developed in Thermal Desktop® beginning in 2011
• Includes ISS and Dragon capsule
• Shared between several NASA engineers, contractors, and Italian payload partners
• Versioned: Current version 55f
  – Number represents major model change (number of nodes, sav file no longer valid), letter represents minor tweak
• Initial development of efficient modeling methods was presented at TFAWS 2013

~8500 nodes
Inclusion of TVAC Chambers and GSE

• SAGE III thermal vacuum (TVAC) testing has occurred in two chambers at NASA LaRC
  – 6’x6’ chamber has 3 independently-controlled temperature zones
    (GN$_2$-controlled shroud and two LN$_2$/heater controlled platens)
  – 8’x15’ chamber has an LN2-controlled shroud and quartz lamps separated into 6 zones

• Representations of each chamber have been included in the system-level model (same model with ISS)
  – 6’x6’ model includes two platens and a node to represent the shroud temperature
  – 8’x15’ model includes an accurate representation of the full chamber geometry

• SAGE III Ground Support Equipment (GSE), primarily heater plates, has also been included in each chamber model
Method

- Chambers are turned on/off using flags
- 8’x15’ chamber position is adjusted to match the positioning in the chamber only for cases where that chamber is on
  - Symbols were created for X/Y/Z translation and rotation, controlled via logic (i.e., (Flag_IP_Tvac == 1)? 90:0)
- Symbols are used to set zone temperatures
- In addition to chamber controls, SAGE III utilizes heater plates to achieve subsystem temperature targets
  - Heater plate GSE is included in the chamber models and turned on/off using the same flags
Benefits

• Accurate pre-test predictions are useful for verifying that targets can be achieved and estimating test time
• Having the chamber models in place prior to testing expedites correlation of the model to TVAC test data
• Including the chambers in the system-level model, rather than creating TVAC-specific versions, prevents the TVAC model from falling behind when the system-level model is updated
• Chamber models can be shared with future payloads
Use of Assemblies for Dragon Model Updates

- Orbits in the Dragon model v3r1 are substantially different from those defined in v2r1
- Assemblies were used to change the orientation of the Dragon, IP, and NVP submodels
  - Prevents having to re-orient the SAGE III model in a fixed way
  - Allows for easy incorporation of future Dragon orbits
Creation of Time-Varying Orbital Parameters

- Per ISS requirements, SAGE III implemented time-varying orbital parameters (albedo and Earth IR)
  - First time this has been done in a payload developer’s thermal model

Example of Time-Varying Parameters from SSP 57003-ELC Rev D
Method

- Arrays were created to represent the timeline and changing values for both parameters in each of the ISS-defined cases
  - ISS defines “A” and “B” cases for hot and cold, also broken down into “nominal” and “extreme” cases
- The interp function was used to create symbols for each parameter (albedo and Earth IR) for each of the ISS-defined cases
  - Ex: interp(albedo_times_hot, albedo_values_hot_extreme_B, hrTime)
  - A total of 8 timelines was created for each parameter
- Code has been made available to all NASA Centers on the Agency-wide share drive
Setting Model Parameters with Case Definition

- Model includes a small set of registers that fully control case definition
  - Parameters such as initial temperature, heater voltage, power dissipation
  - Type of case such as payload location, flight scenario (science event type), TVAC case (balance or functional), special scenarios (plume heating, parked ISS trackers, etc.)

- Flags are used in case sets, logic blocks, and enable blocks to set up the desired scenarios
  - Case_def (values 0, 1, 2, and 3) is used to represent cold, nominal and hot cases; controls boundary conditions and component power dissipations
  - Flag_NVP_MOV and Flag_SAGE_MOV are used to define the position of the payload (Dragon, EOTP, ELC)
  - Flag_voltage sets voltage to minimum or nominal
  - Flag_IP_TVAC and Flag_TVAC_6x6 are used to specify TVAC cases
  - Flag_survival and Flag_transfer are used to define scenarios with survival heater power only or no power during transfer from one location to another
  - Flag_plume_heat and Flag_park_port_SARG define special scenarios

- Allows many different scenarios to be run by simply defining a few flags in the case set
Examples of Case Definition

Flight Hot Op Case on ELC

Flight Cold Survival Case on EOTP

IP TVAC Case

Logic Based on Case Definition Flags
Incorporation of Convection Submodel

- Addition of a convection submodel that is only built for certain cases has proved useful for several situations
  - Submodel includes air nodes and convection conductors which are not built for flight cases; activated by flags
- One component underwent testing in both air and vacuum
  - Incorporating air convection allowed for correlation of all cases to occur in a single model
- Following completion of payload integration, several functional tests were completed in a clean room environment
  - Incorporating air convection allowed for early quick-look correlation work to be completed prior to TVAC testing
- Air convection model was used to show that the EMI setup with the payload bagged would not result in limit exceedences
Approach for Case Grouping

- The current SAGE III system-level model contains ~250 cases
- Run directories are defined by model version, payload location, and hot/cold case (i.e. v55_runs\ELC_hot, v55_runs\EOTP_cold)
  - Keeps the cases organized in a way that's easy for multiple users to understand
- Each group of cases has a common run directory
  - Makes it easy to update the run directories when the model version is changed
  - Minimizes the necessity to re-run radk cases for new analysis runs
- TVAC cases are grouped separately from flight cases
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
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