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Thermal Modeling Method Improvements for SAGE III on ISS

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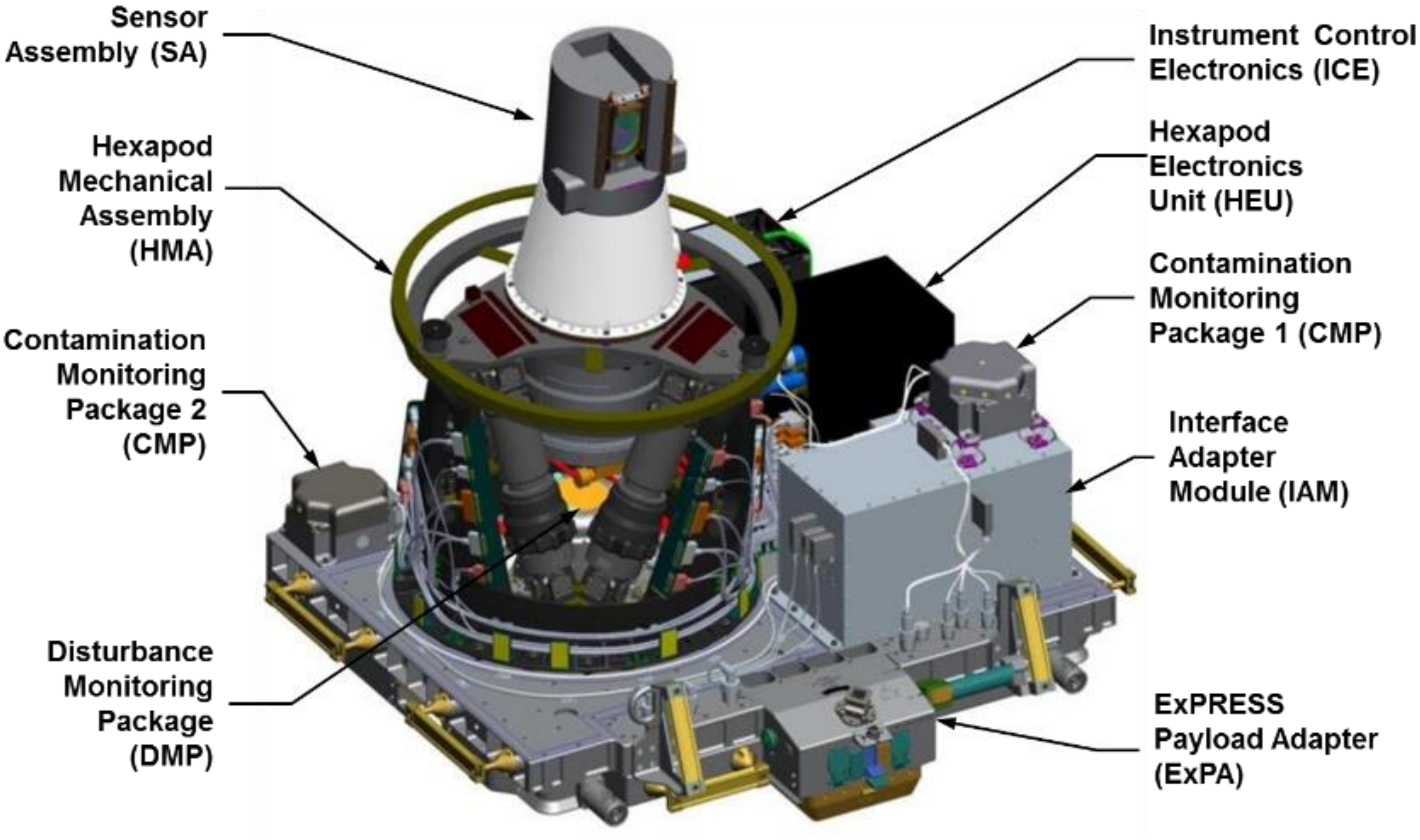
Outline

- Background
  - SAGE III on ISS
  - 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

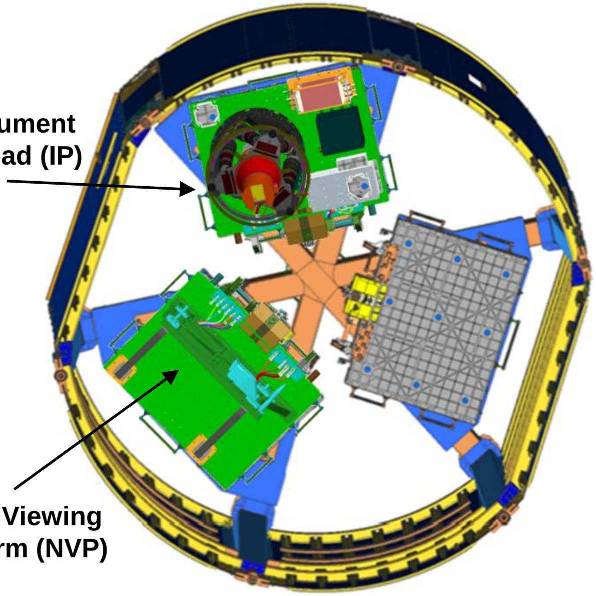
- SAGE III is an ISS-mounted science payload, to be launched on Falcon vehicle/Dragon capsule in 2016
- Three year minimum lifetime on ISS
- Monitors aerosols and other gases in stratosphere
- Thermal analyses are being completed for launch vehicle and all ISS scenarios
- Instrument Payload (IP) mounted on Nadir Viewing Platform (NVP)
- Several subsystems built in 1990’s and placed in storage
  - Text legacy thermal models

Instrument Payload



Dragon and ISS Configuration

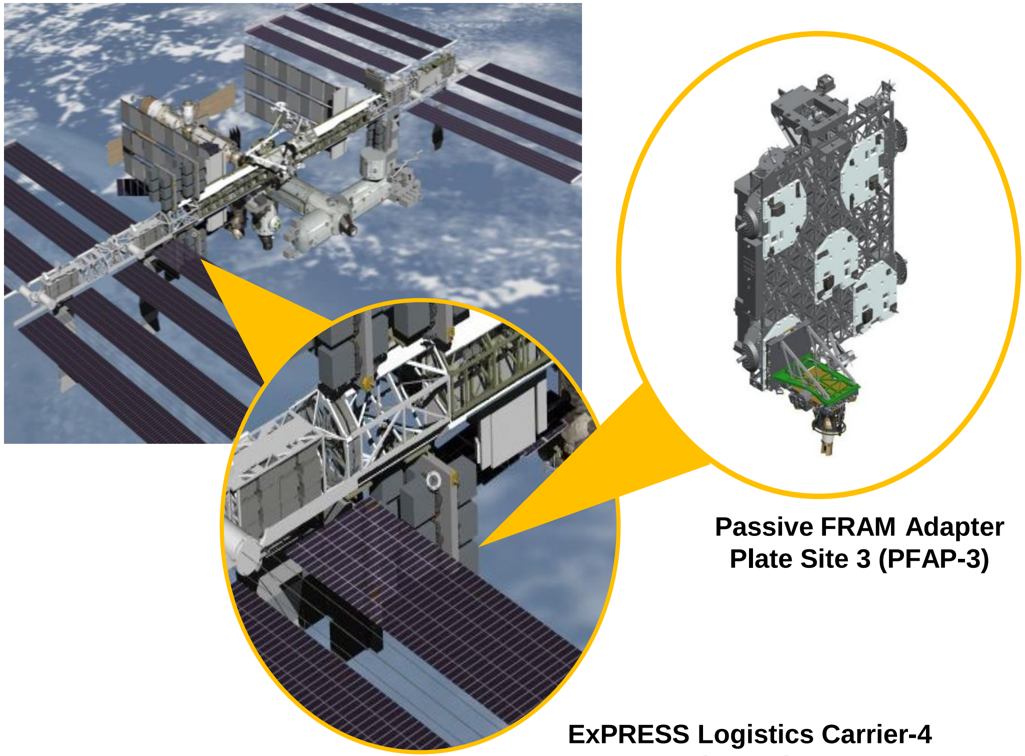
Dragon Unpressurized Cargo Module



Instrument Payload (IP)

Nadir Viewing Platform (NVP)

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

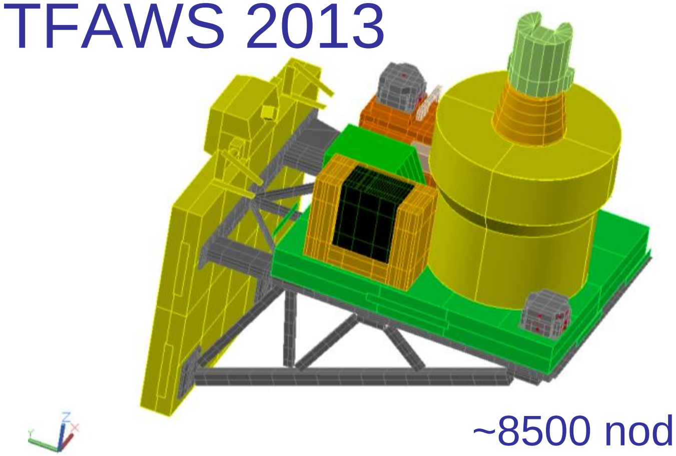


Passive FRAM Adapter Plate Site 3 (PFAP-3)

ExPRESS Logistics Carrier-4 (ELC-4)

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  - Number represents major model change (number of nodes, sav file no longer valid), letter represents minor tweak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

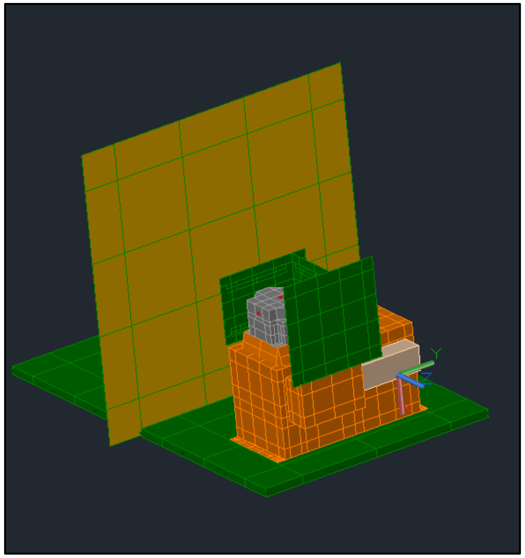
Method

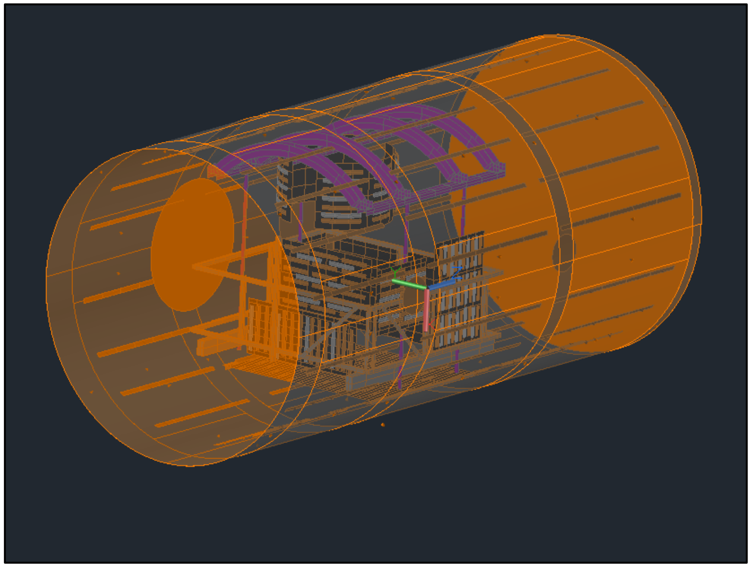
- Chambers are turned on/off using flags
- 8’x15’ chamber position is adjusted to match the positioning in the chamber only for cases where that chamber is on
    - Symbols were created for X/Y/Z translation and rotation, controlled via logic (i.e., (Flag_IP_Tvac == 1)? 90:0)
- Symbols are used to set 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

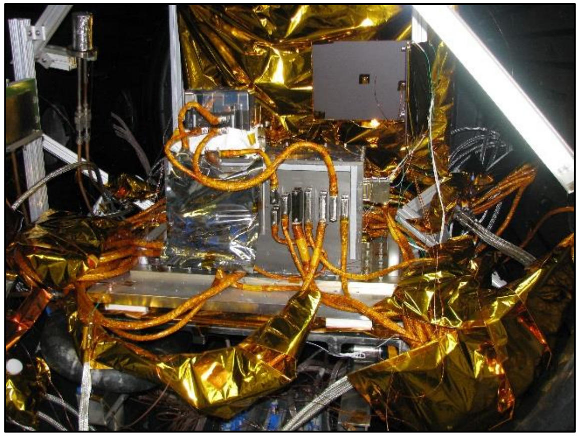
Photos and Model Images

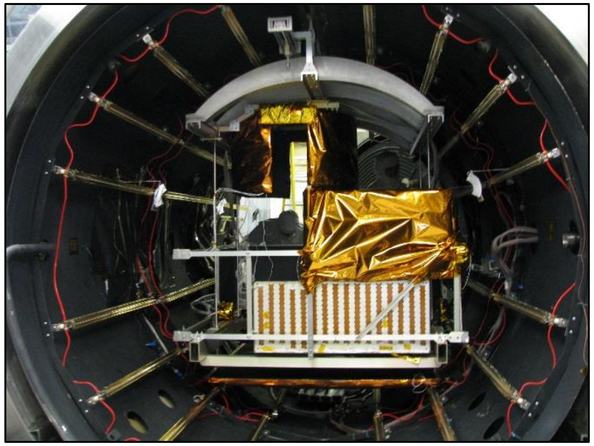
6’ x 6’ Chamber

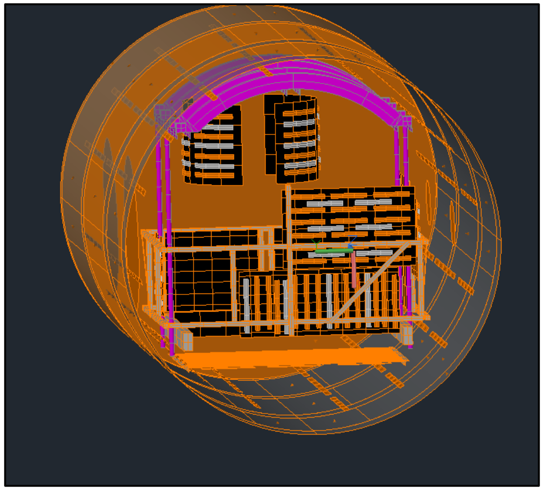
8’x15’ Chamber









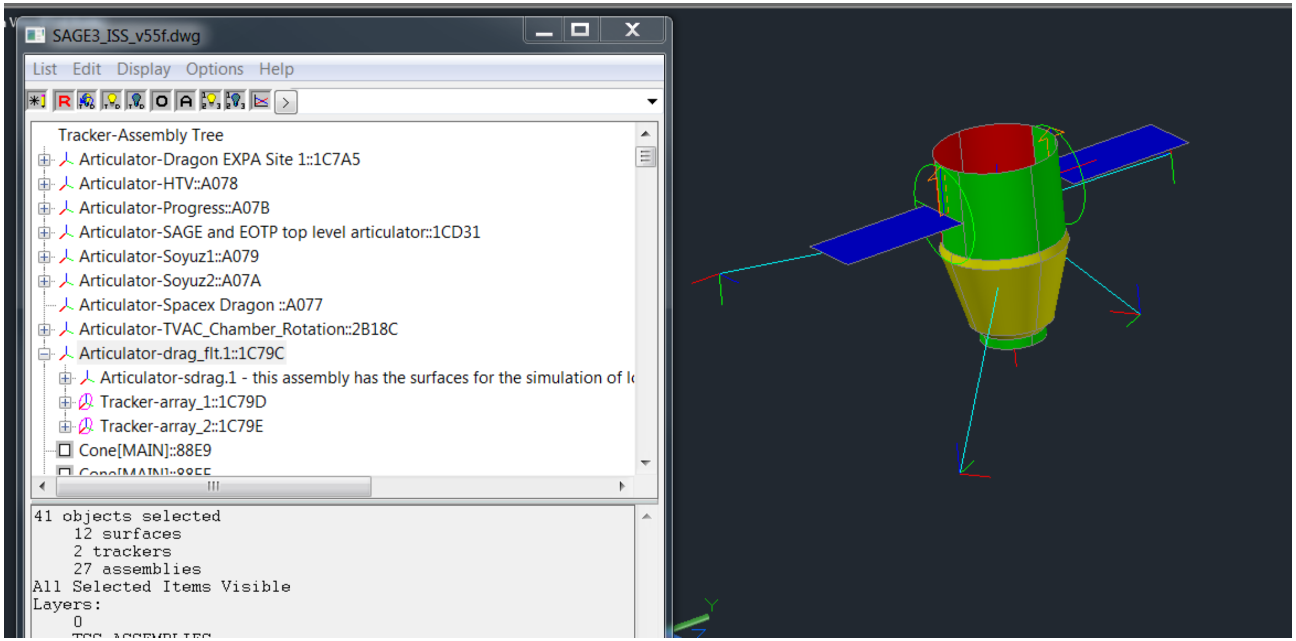


Benefits

- 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

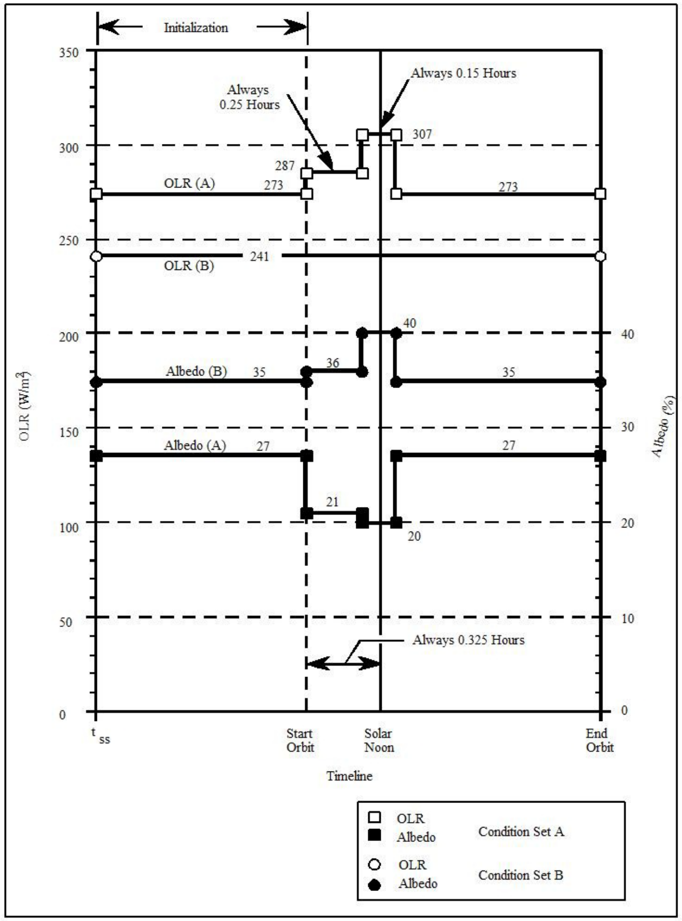


Tracker-Assembly Tree
- Articulator-Dragon EXPA Site 1::1C7A5
- Articulator-HTV::A078
- Articulator-Progress::A07B
- Articulator-SAGE and EOTP top level articulator::1CD31
- Articulator-Soyuz1::A079
- Articulator-Soyuz2::A07A
- Articulator-Spacex Dragon ::A077
- Articulator-TVAC_Chamber_Rotation::2B18C
- Articulator-drag_flt.1::1C79C
  - Articulator-sdrag.1 - this assembly has the surfaces for the simulation of
  - Tracker-array_1::1C79D
  - Tracker-array_2::1C79E
- Cone[MAIN]::88E9

```
41 objects selected
    12 surfaces
    2 trackers
    27 assemblies
All Selected Items Visible
Layers:
    0
```

Creation of Time-Varying Orbital Parameters

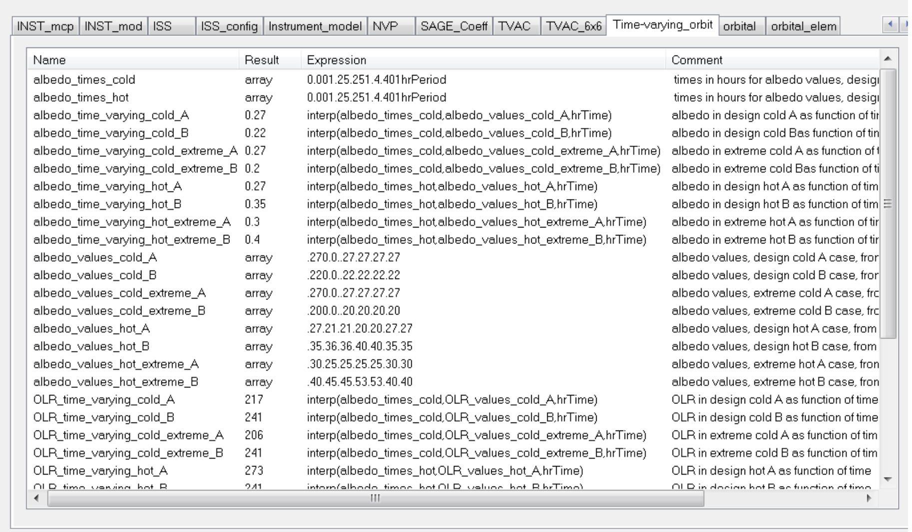
- Per ISS requirements, SAGE III implemented time-varying orbital parameters (albedo and Earth IR)
  - First time this has been done in a payload developer’s thermal model



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



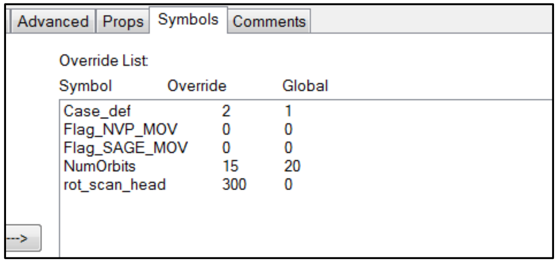
Name	Result	Expression	Comment
albedo_times_cold	array	0.001.25.251.4.401hrPeriod	times in hours for albedo values, desig
albedo_times_hot	array	0.001.25.251.4.401hrPeriod	times in hours for albedo values, desig
albedo_time_varying_cold_A	0.27	interp(albedo_times_cold,albedo_values_cold_A,hrTime)	albedo in design cold A as function of ti
albedo_time_varying_cold_B	0.22	interp(albedo_times_cold,albedo_values_cold_B,hrTime)	albedo in design cold Bas function of tin
albedo_time_varying_cold_extreme_A	0.27	interp(albedo_times_cold,albedo_values_cold_extreme_A,hrTime)	albedo in extreme cold A as function of
albedo_time_varying_cold_extreme_B	0.2	interp(albedo_times_cold,albedo_values_cold_extreme_B,hrTime)	albedo in extreme cold Bas function of ti
albedo_time_varying_hot_A	0.27	interp(albedo_times_hot,albedo_values_hot_A,hrTime)	albedo in design hot A as function of tim
albedo_time_varying_hot_B	0.35	interp(albedo_times_hot,albedo_values_hot_B,hrTime)	albedo in design hot B as function of tim
albedo_time_varying_hot_extreme_A	0.3	interp(albedo_times_hot,albedo_values_hot_extreme_A,hrTime)	albedo in extreme hot A as function of ti
albedo_time_varying_hot_extreme_B	0.4	interp(albedo_times_hot,albedo_values_hot_extreme_B,hrTime)	albedo in extreme hot B as function of ti
albedo_values_cold_A	array	.270.0..27.27.27.27	albedo values, design cold A case, fro
albedo_values_cold_B	array	.220.0..22.22.22.22	albedo values, design cold B case, fro
albedo_values_cold_extreme_A	array	.270.0..27.27.27.27	albedo values, extreme cold A case, fr
albedo_values_cold_extreme_B	array	.200.0..20.20.20.20	albedo values, extreme cold B case, fr
albedo_values_hot_A	array	.27.21.21.20.20.27.27	albedo values, design hot A case, from
albedo_values_hot_B	array	.35.36.36.40.40.35.35	albedo values, design hot B case, from
albedo_values_hot_extreme_A	array	.30.25.25.25.25.30.30	albedo values, extreme hot A case, fron
albedo_values_hot_extreme_B	array	.40.45.45.53.53.40.40	albedo values, extreme hot B case, fron
OLR_time_varying_cold_A	217	interp(albedo_times_cold,OLR_values_cold_A,hrTime)	OLR in design cold A as function of time
OLR_time_varying_cold_B	241	interp(albedo_times_cold,OLR_values_cold_B,hrTime)	OLR in design cold B as function of time
OLR_time_varying_cold_extreme_A	206	interp(albedo_times_cold,OLR_values_cold_extreme_A,hrTime)	OLR in extreme cold A as function of tim
OLR_time_varying_cold_extreme_B	241	interp(albedo_times_cold,OLR_values_cold_extreme_B,hrTime)	OLR in extreme cold B as function of tim
OLR_time_varying_hot_A	273	interp(albedo_times_hot,OLR_values_hot_A,hrTime)	OLR in design hot A as function of time
OLR_time_varying_hot_B	241	interp(albedo_times_hot,OLR_values_hot_B,hrTime)	OLR in design hot B as function of time

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

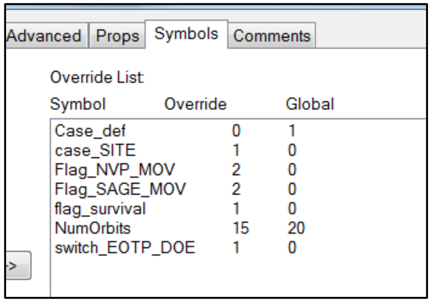
Flight Hot Op Case on ELC



Override List

Symbol	Override	Global
Case_def	2	1
Flag_NVP_MOV	0	0
Flag_SAGE_MOV	0	0
NumOrbits	15	20
rot_scan_head	300	0

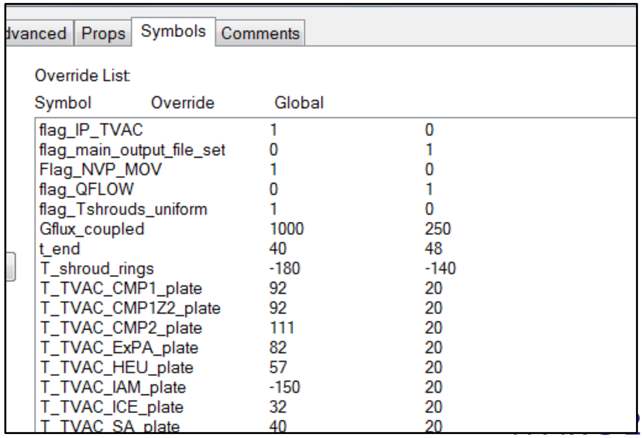
Flight Cold Survival Case on EOTP



Override List

Symbol	Override	Global
Case_def	0	1
case_SITE	1	0
Flag_NVP_MOV	2	0
Flag_SAGE_MOV	2	0
flag_survival	1	0
NumOrbits	15	20
switch_EOTP_DOE	1	0

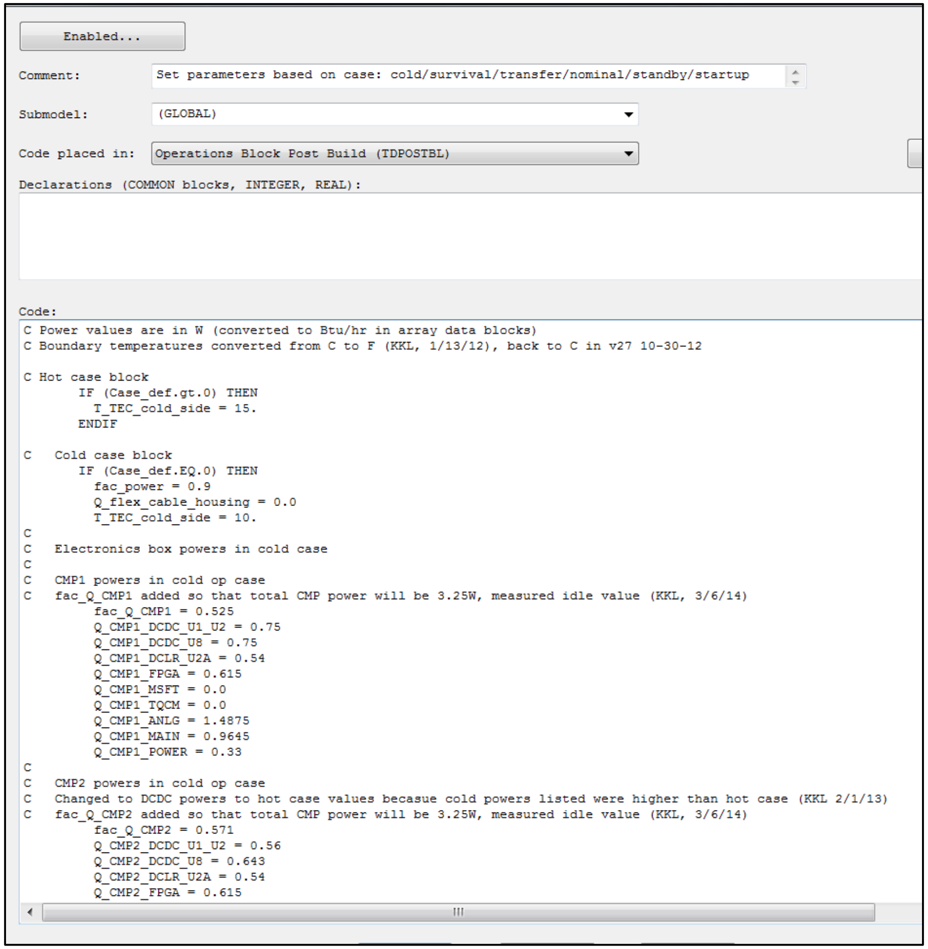
IP TVAC Case



Override List

Symbol	Override	Global
flag_IP_TVAC	1	0
flag_main_output_file_set	0	1
Flag_NVP_MOV	1	0
flag_QFLOW	0	1
flag_Tshrouds_uniform	1	0
Gflux_coupled	1000	250
t_end	40	48
T_shroud_rings	-180	-140
T_TVAC_CMP1_plate	92	20
T_TVAC_CMP1Z2_plate	92	20
T_TVAC_CMP2_plate	111	20
T_TVAC_ExPA_plate	82	20
T_TVAC_HEU_plate	57	20
T_TVAC_IAM_plate	-150	20
T_TVAC_ICE_plate	32	20
T_TVAC_SA_plate	40	20

Logic Based on Case Definition Flags



Comment: Set parameters based on case: cold/survival/transfer/nominal/standby/startup

Submodel: (GLOBAL)

Code placed in: Operations Block Post Build (TDPOSTBL)

Declarations (COMMON blocks, INTEGER, REAL):

Code:

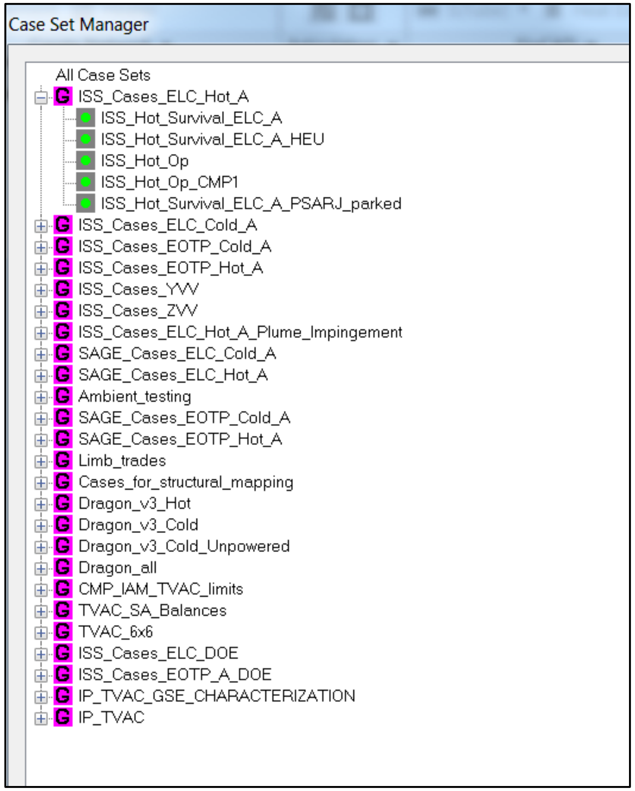
```
C Power values are in W (converted to Btu/hr in array data blocks)
C Boundary temperatures converted from C to F (KKL, 1/13/12), back to C in v27 10-30-12

C Hot case block
       IF (Case_def.gt.0) THEN
         T_TEC_cold_side = 15.
       ENDIF

C   Cold case block
       IF (Case_def.EQ.0) THEN
         fac_power = 0.9
         Q_flex_cable_housing = 0.0
         T_TEC_cold_side = 10.
C
C   Electronics box powers in cold case
C
C   CMP1 powers in cold op case
C   fac_Q_CMP1 added so that total CMP power will be 3.25W, measured idle value (KKL, 3/6/14)
         fac_Q_CMP1 = 0.525
         Q_CMP1_DCDC_U1_U2 = 0.75
         Q_CMP1_DCDC_U8 = 0.75
         Q_CMP1_DCLR_U2A = 0.54
         Q_CMP1_FPGA = 0.615
         Q_CMP1_MSFT = 0.0
         Q_CMP1_TQCM = 0.0
         Q_CMP1_ANLG = 1.4875
         Q_CMP1_MAIN = 0.9645
         Q_CMP1_POWER = 0.33
C
C   CMP2 powers in cold op case
C   Changed to DCDC powers to hot case values becasue cold powers listed were higher than hot case (KKL 2/1/13)
C   fac_Q_CMP2 added so that total CMP power will be 3.25W, measured idle value (KKL, 3/6/14)
         fac_Q_CMP2 = 0.571
         Q_CMP2_DCDC_U1_U2 = 0.56
         Q_CMP2_DCDC_U8 = 0.643
         Q_CMP2_DCLR_U2A = 0.54
         Q_CMP2_FPGA = 0.615
```

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



Case Set Manager

All Case Sets
- G ISS_Cases_ELC_Hot_A
  - ISS_Hot_Survival_ELC_A
  - ISS_Hot_Survival_ELC_A_HEU
  - ISS_Hot_Op
  - ISS_Hot_Op_CMP1
  - ISS_Hot_Survival_ELC_A_PSARJ_parked
- G ISS_Cases_ELC_Cold_A
- G ISS_Cases_EOTP_Cold_A
- G ISS_Cases_EOTP_Hot_A
- G ISS_Cases_YVV
- G ISS_Cases_ZVV
- G ISS_Cases_ELC_Hot_A_Plume_Impingement
- G SAGE_Cases_ELC_Cold_A
- G SAGE_Cases_ELC_Hot_A
- G Ambient_testing
- G SAGE_Cases_EOTP_Cold_A
- G SAGE_Cases_EOTP_Hot_A
- G Limb_trades
- G Cases_for_structural_mapping
- G Dragon_v3_Hot
- G Dragon_v3_Cold
- G Dragon_v3_Cold_Unpowered
- G Dragon_all
- G CMP_IAM_TVAC_limits
- G TVAC_SA_Balances
- G TVAC_6x6
- G ISS_Cases_ELC_DOE
- G ISS_Cases_EOTP_A_DOE
- G IP_TVAC_GSE_CHARACTERIZATION
- G IP_TVAC

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

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