Near-Real Time Thermal Model Correlation of an External Shuttle Payload

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StarNav I

- StarNav I is a pathfinder project for the Commercial Space Center for Engineering (CSCE) and is expected to validate CSCE’s capabilities to monitor and predict thermal variation for external payloads on the Shuttle or ISS.
- The objective of the StarNav I flight experiment is to validate Lost In Space Algorithm (LISA) for determining precise spacecraft attitude without prior knowledge of position.
- StarNav I is a COTS startracker payload to be flown on the inaugural flight of SPACEHAB’s Quick External Science Tray (QUEST). The QUEST will fly on STS-107 to be launched in September or December 2002.
- StarNav I is a device entirely designed and built at Texas A&M University.

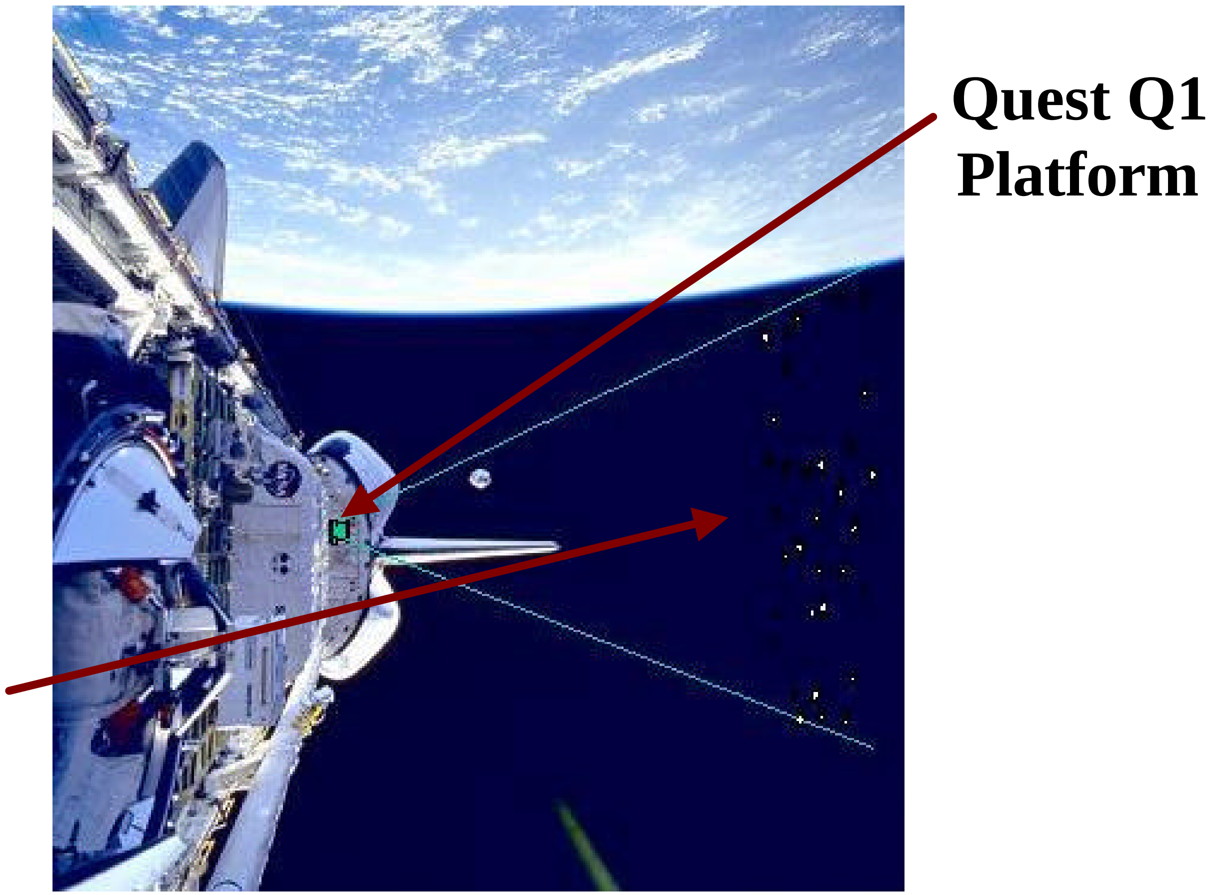
StarNav Contests

- A successful demonstration of LISA will also provide an opportunity for students and other contestants to learn about navigation with stars and general astronomy topics.
- Three StarNav contests will be held via a website during the mission in which contestants would:
  - Analyze the images obtained from StarNav I and use basic star pattern techniques to identify the labeled stars.
  - Use the tables and a star image provided to identify the stars on the picture.
  - Use the table and star images to apply the Lost In Space Algorithm.

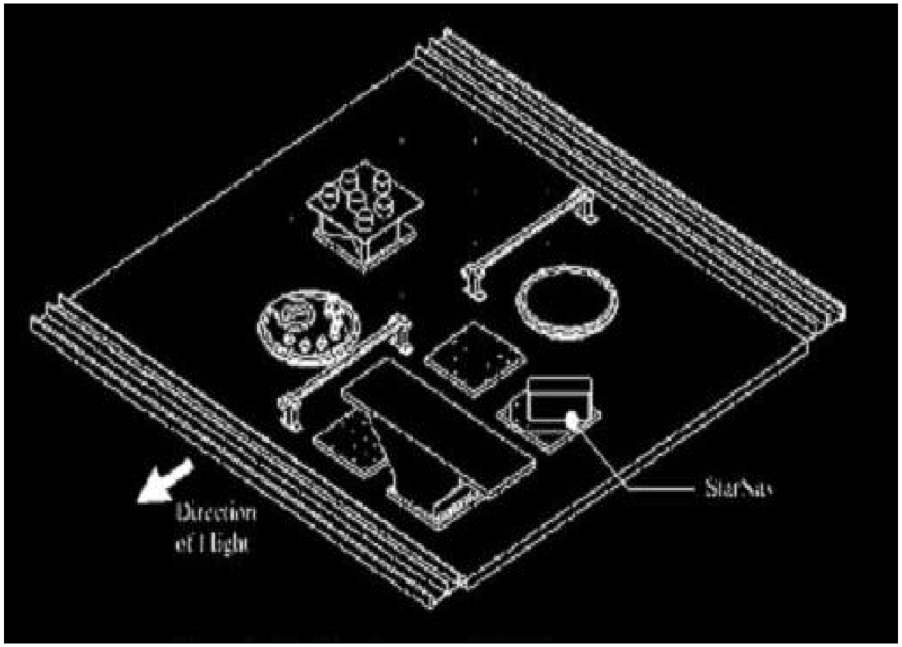
StarNav Contests (Contd.)

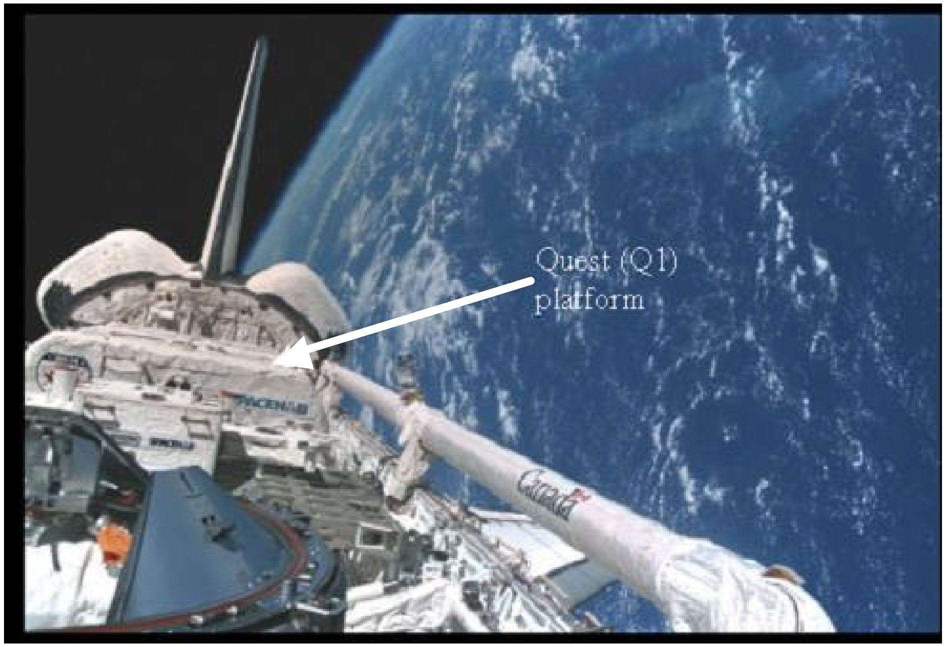
- The contests will vary in complexity dependent on the contestants (from high school students to the general public) and will be broadcast on the web during the mission.

StarNav I Location



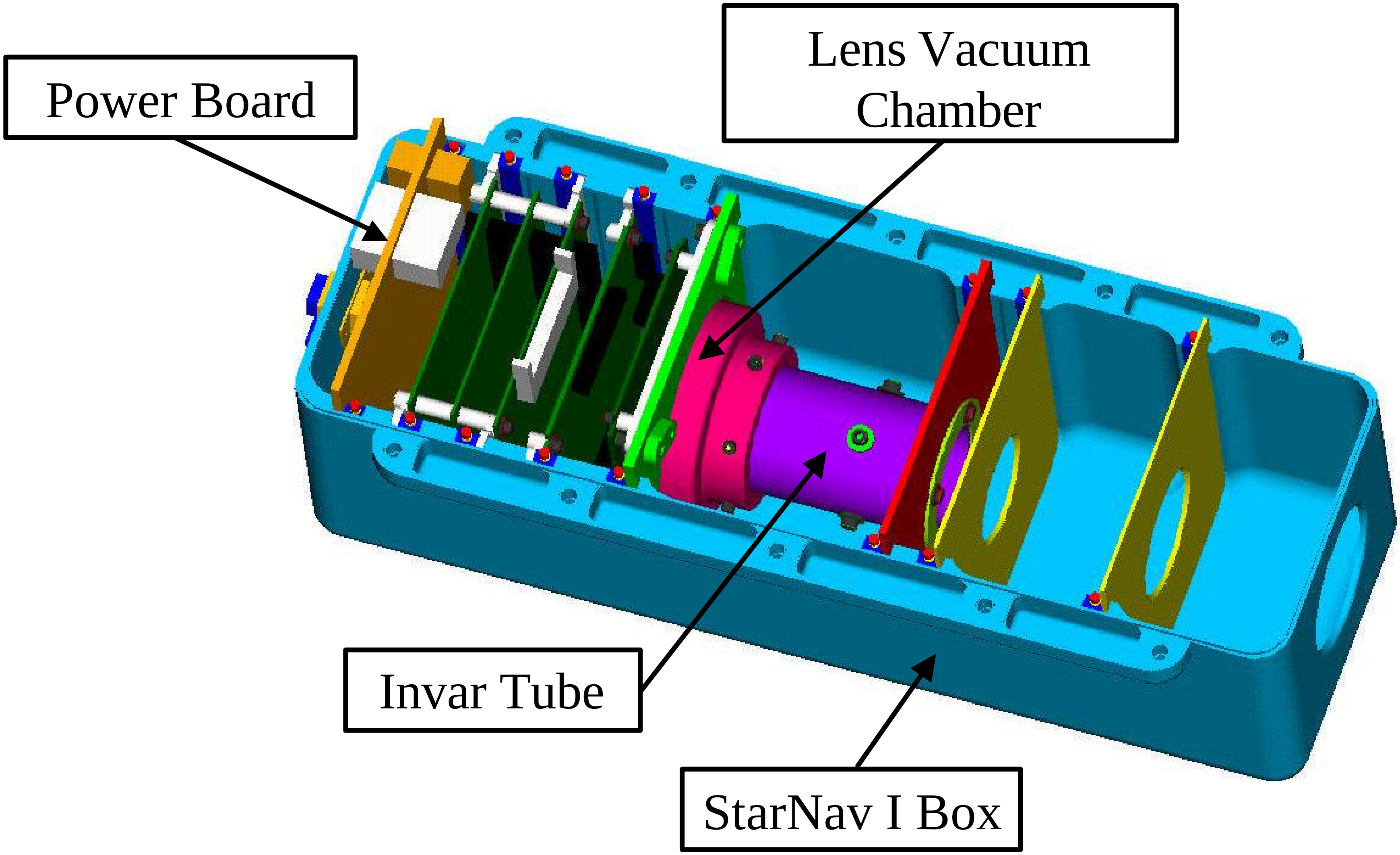
StarNav I Location (Contd.)





StarNav I layout on QUEST **Location of QUEST platform**

StarNav I Solid Model – Inside View



StarNav I Parameters

- Heat Load = 50W
- Mass = 5kg
- Dimensions
  - Length = 0.11m
  - Height = 0.4m
  - Width = 0.4m
- Material of Casing = Aluminum
- Optical Coating = Silver Coated Teflon tape

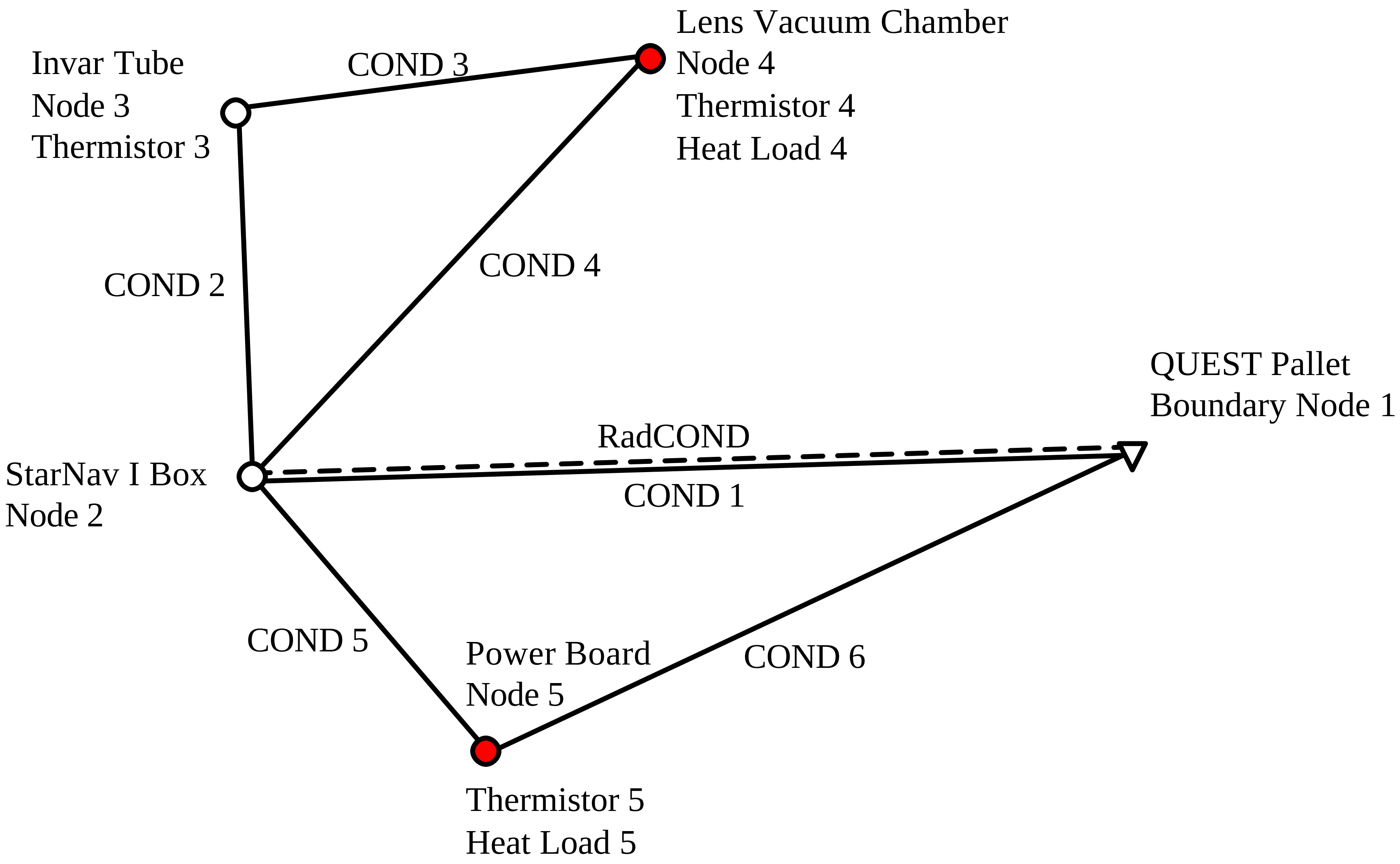
Simplified Model Approach

- In order to provide operational support for this payload during the STS-107 mission, the thermal team has created a simplified thermal model capable of quickly answering potential questions from JSC Operations.
- This presentation will show the different models developed in support of this flight. We will also show our approach to a real time thermal model correction based on data to be gathered from the flight.
- Because of the delay in shuttle flights, no on-orbit test data was available for demonstration of correlation methods.

Testing Summary

- Test Data Correlation was based on four tests carried out under different conditions. These are summarized as follows:
  - J&T (May 01)
    - Involved external and internal thermistors on StarNav I
    - Carried out in vacuum with varying temperatures of surrounding walls from 205K to 315K
    - Involved different starting conditions for the camera, i.e. at hot and at cold temperatures.
  - CSCE (Dec 01)
    - Involved longest operation cycle of StarNav I of two and a half hours in vacuum at room temperature.
  - CSCE (Jan 02)
    - Involved testing of StarNav I after implementing thermal solutions. This test was also carried out in identical conditions to CSCE (Dec 01).
  - KSC IVT Testing (March 02)
    - Involved recording temperature for internal thermistors after installation of StarNav I on QUEST pallet of SPACEHAB module.
    - Test performed in a convective environment to estimate contact conductance with SpaceHab module and QUEST.

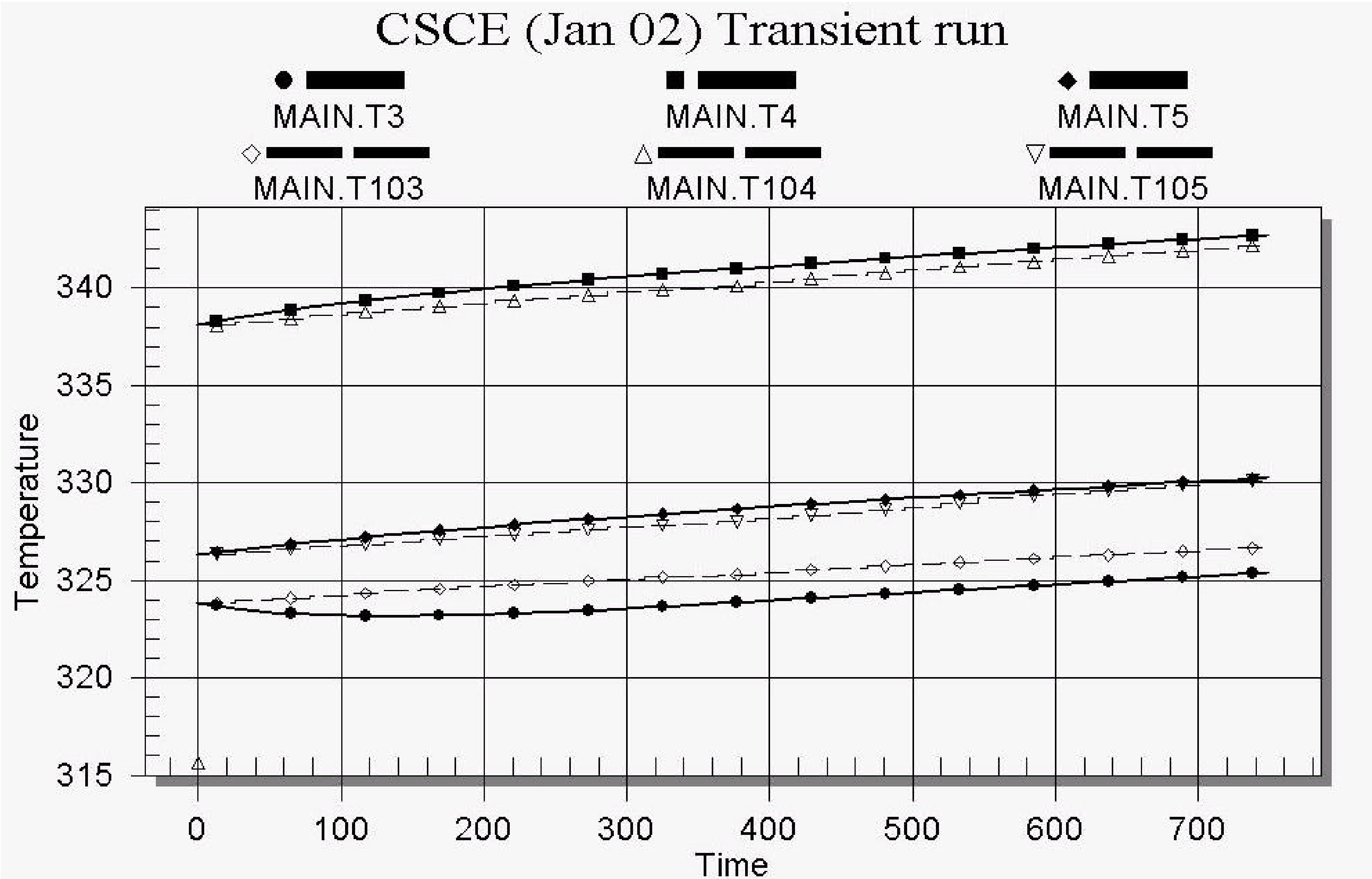
Test Data Correlation Model



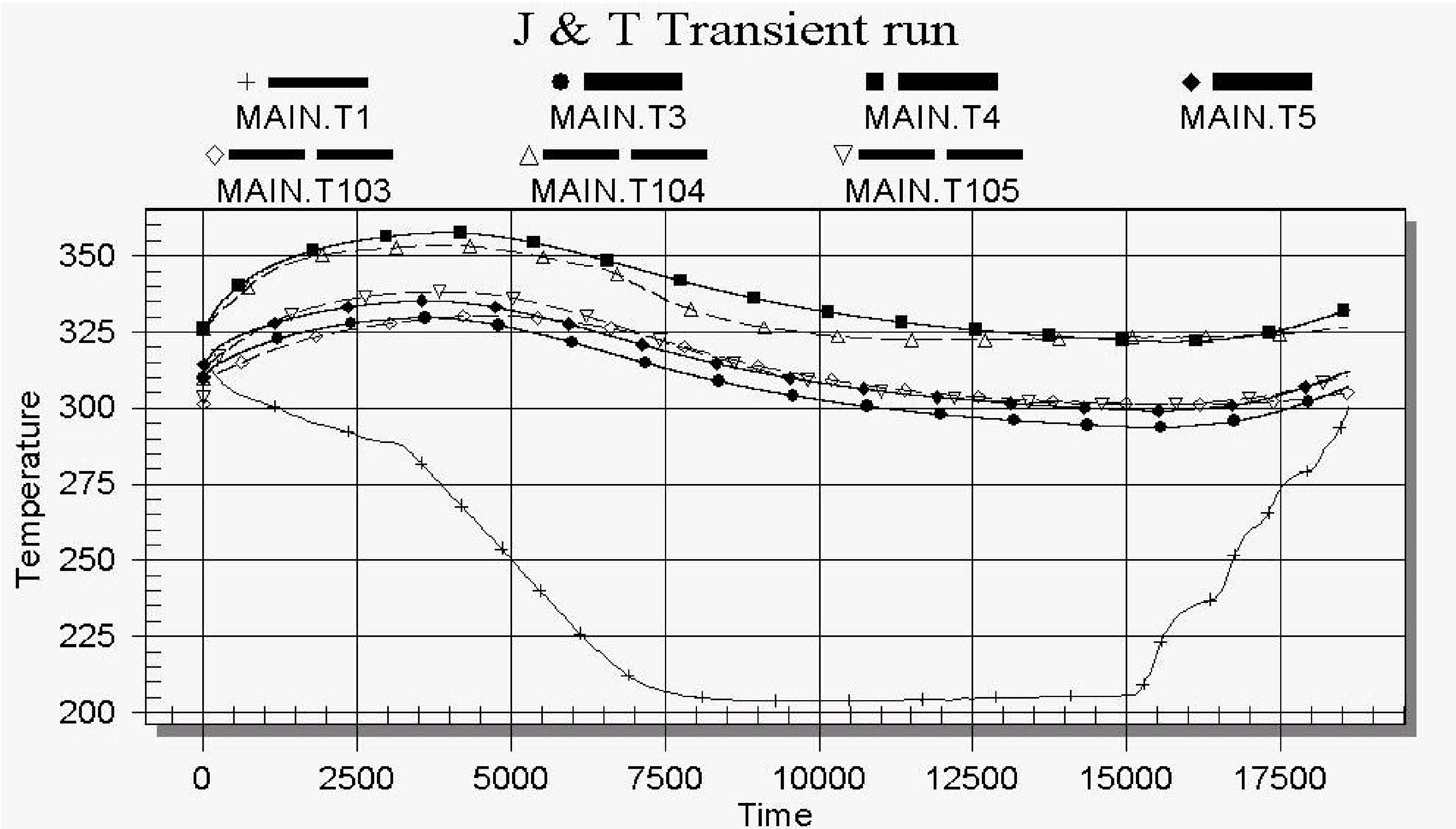
Test Data Correlation Methods

- Used Thermal Desktop® version 4.4 and SINDA version 4.4
- Included nodes for major thermal masses only
- Estimated conductances and created a network of conductors between nodes
- Assigned symbols to conductors, thermal masses, heat loads in Symbol Manager
- Designated ‘Design’ variables and placed upper and lower limits on the symbols representing them
- Constrained total thermal mass and total heater power to within upper estimates and/or known test conditions
- Solver optimization used to minimize sum of RMS errors between test data points and calculated temperatures by varying symbol values
- Plotted test data and calculated temperatures on the same graph and compared the two
- Solver optimization also included a constraint on the slope of temperature curves

Test Data Correlation Results 1/2

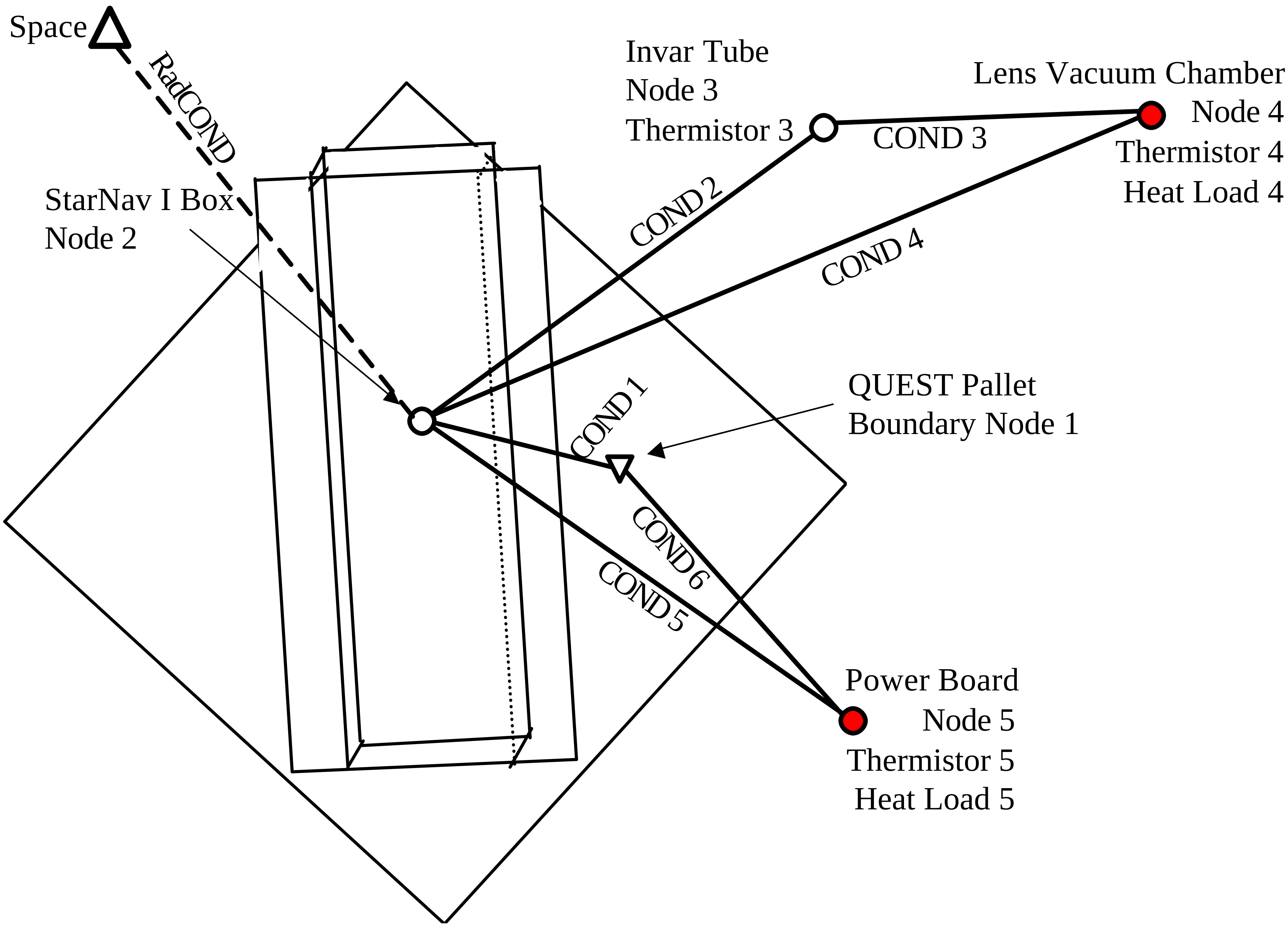


Test Data Correlation Results 2/2



Note: Node "MAIN. T1" is used to indicate the range of temperature we put our equipment under and is not to be correlated.

On-Orbit Predictive Model



On-Orbit Predictive Model's Unknown Parameters

The current unknown parameters in the on-orbit model are:

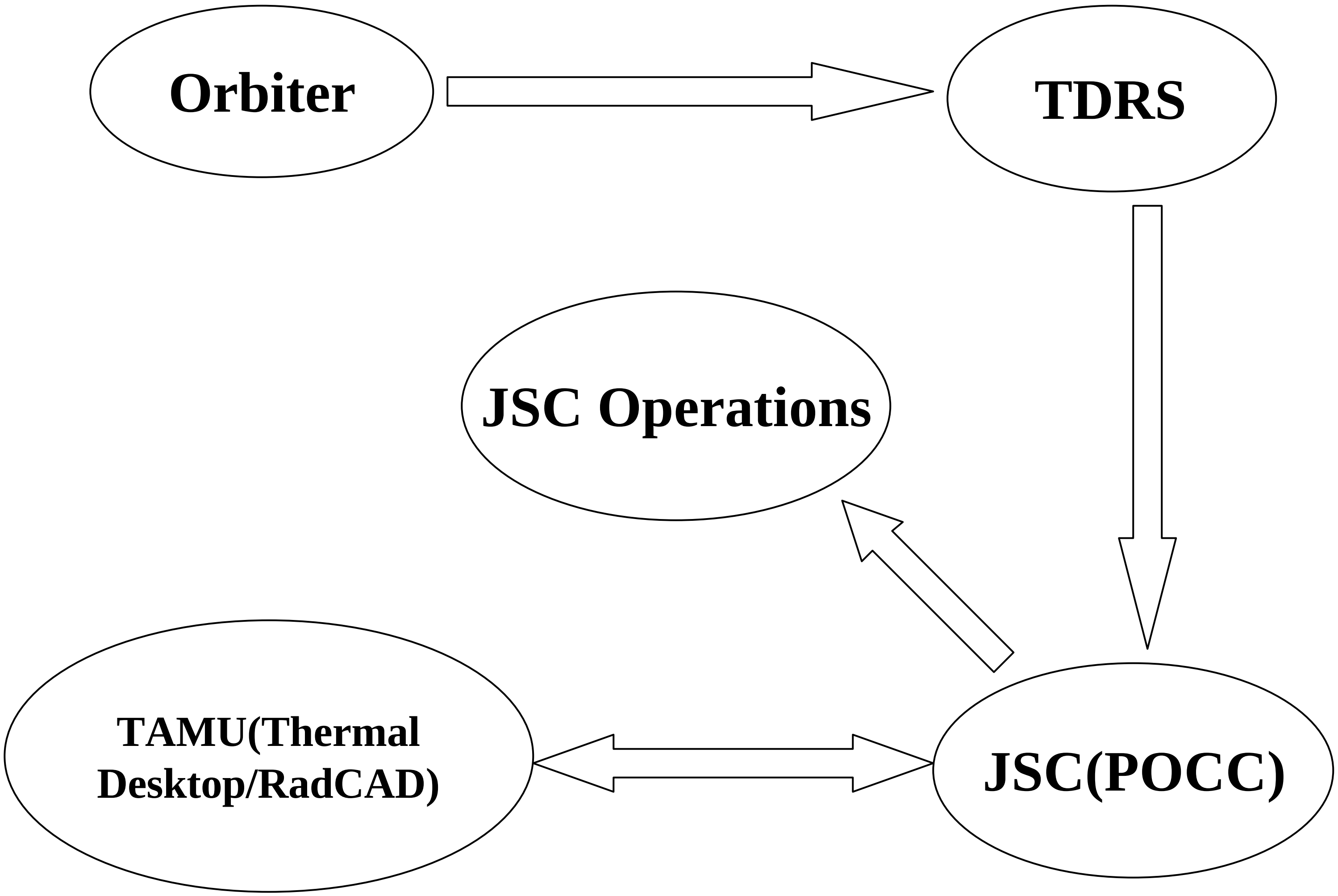
- Actual heat flux as a function of time
- Attitude as a function of time
- Actual conductance to the spacehab module
- Actual absorptivity (currently estimated from vendor specifications) of the outside silver coated teflon tape
- The timeline for shuttle attitude can be changed during the mission
- Also, the timing of when StarNav I is turned on may change. It is slated for 20 iterations of 30 minutes activity during the mission. It is turned off during the rest of the mission

On-Orbit Predictive Methods

- Obtain initial temperatures, proposed attitude timeline, orbital information, and StarNav I duty timeline from JSC
- Incorporate attitude timeline in terms of roll, pitch, yaw into Thermal Desktop through ‘Dynamic SINDA’
- Assign initial temperatures to nodes
- Apply orbital information to RadCAD Keplerian orbit with date/time for calculating sun angle
- Apply StarNav I duty timeline to create time dependent heat loads to simulate on/off of StarNav I
- Run a transient case to predict StarNav I temperatures for defined conditions
- Derived a program to download temperature data from the orbiter at a location close to the experiment (longeron payload bay)

On-Orbit Predictive Methods

Flow of data



On-Orbit Correlation Methods

- Obtain temperature readouts from StarNav I thermistors, QUEST temperature, orbital timeline, attitude timeline
- Read StarNav I temperatures into on-orbit model as test data
- Apply QUEST temperature to boundary node (can be time varying)
- Set RadCAD orbital parameters to values at $t = 0$
- Set roll, pitch, yaw symbols in model to orbiter attitude
- Re-run ‘Solver’ optimization code for new temperature data and calculated on-orbit heating conditions
- Update values of conductors, thermal masses, and especially optical properties

Conclusions

- Near real time parameter estimation will be performed on a thermal model of an external payload during STS-107.
- STS-107 is currently expected to fly in December 2002.
- On-orbit predictive model would enable us to answer the potential questions by JSC Operations during the STS – 107 mission.
- With the current unknowns in the on-orbit predictive model, more work is needed to make it more precise.

Compliance with Safety Requirements

- From previous tests and model, it was estimated that the experiment would not reach upper value of touch temperature for the duration of the flight.

- Shuttle timeline was taken into account for model evaluation leading to a satisfactory StarNav I cold restart.

Acknowledgements

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