Active Solar Array Thermal Control System for the Solar Probe Plus Spacecraft

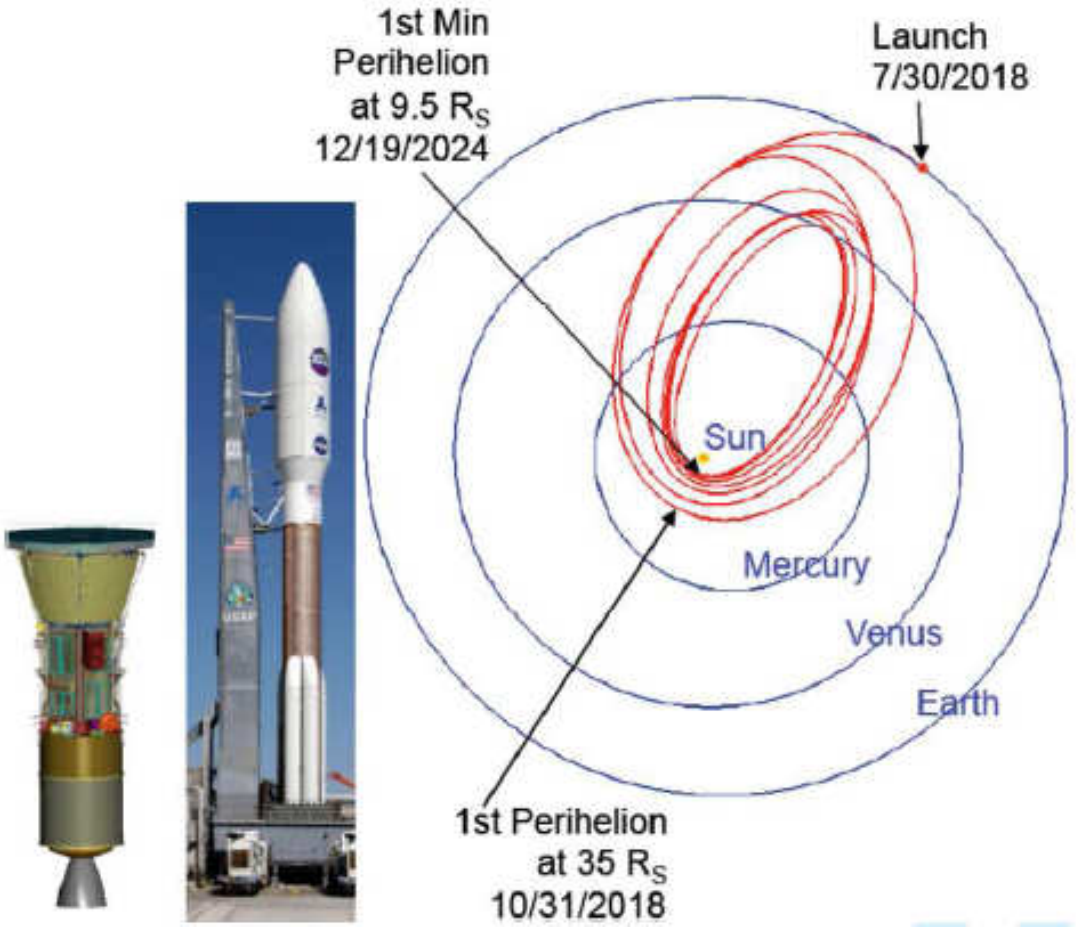
Carl J. Ercol
Johns Hopkins University Applied Physics

Greg Guyette, and Wei-Lin Cho
Hamilton Sundstrand Space Systems

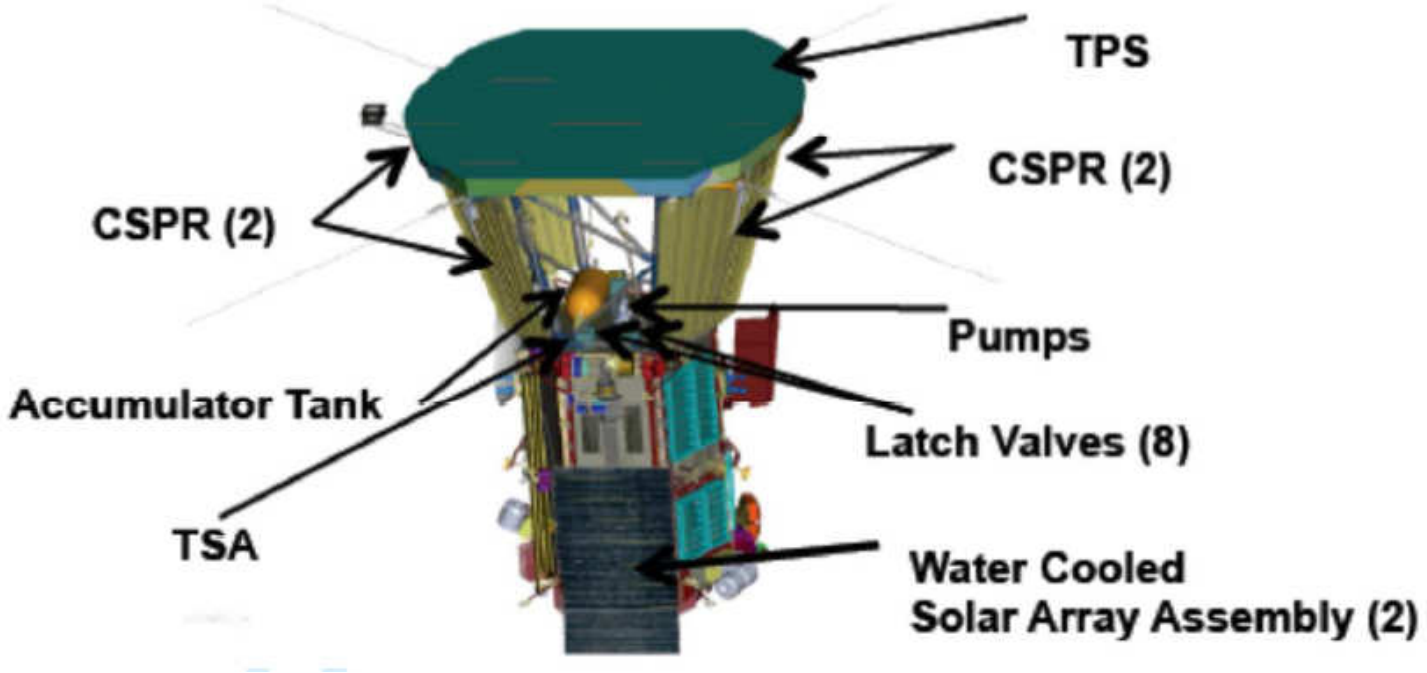
Hamilton Sundstrand
A United Technologies Company

Thermal and Fluids Analysis Workshop
August 13-17, 2012
Pasadena, California

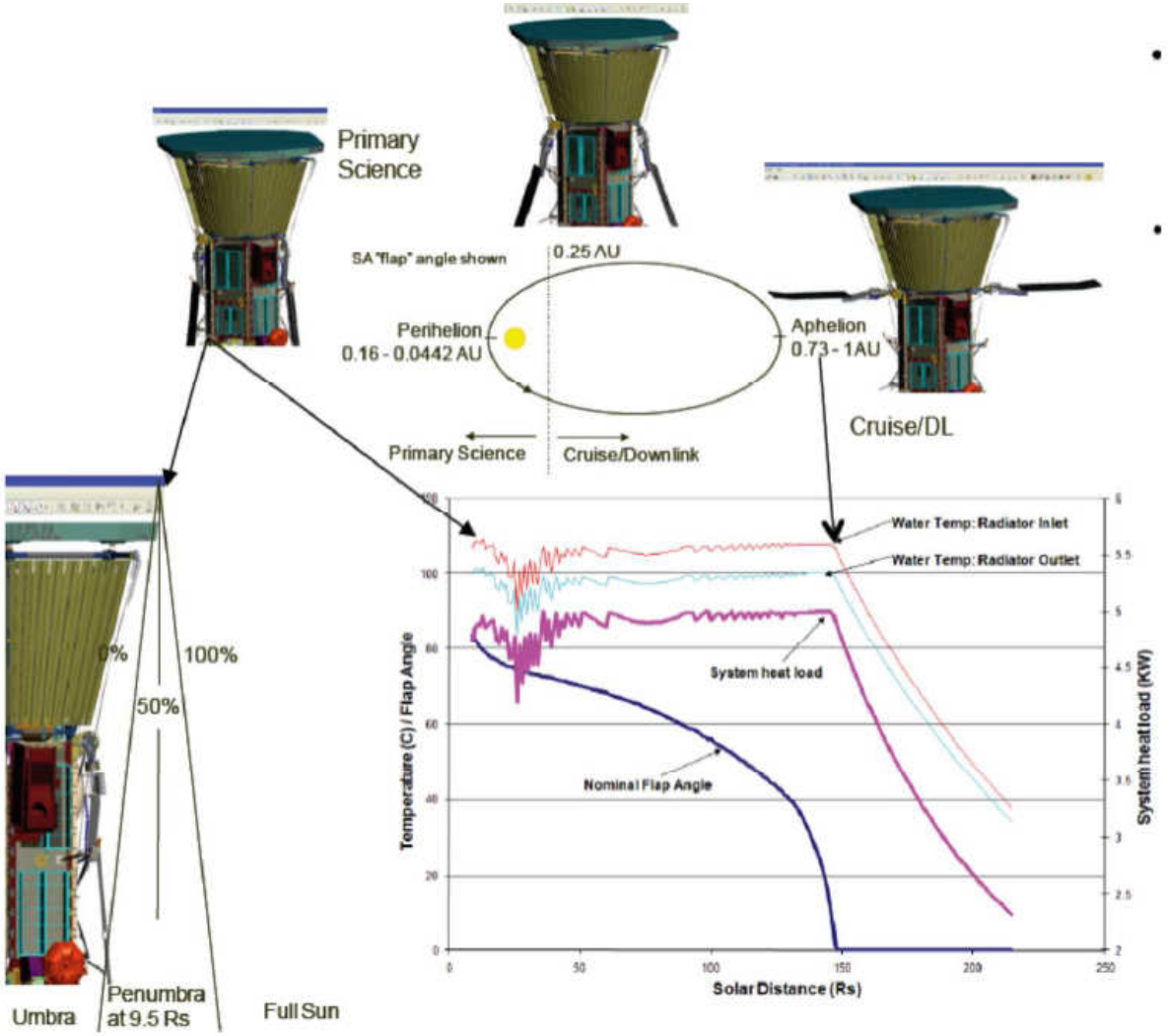
Solar Probe Plus Mission Profile



Space Craft


TPS
CSPR (2)
CSPR (2)
Pumps
Accumulator Tank
Latch Valves (8)
TSA
Water Cooled
Solar Array Assembly (2)

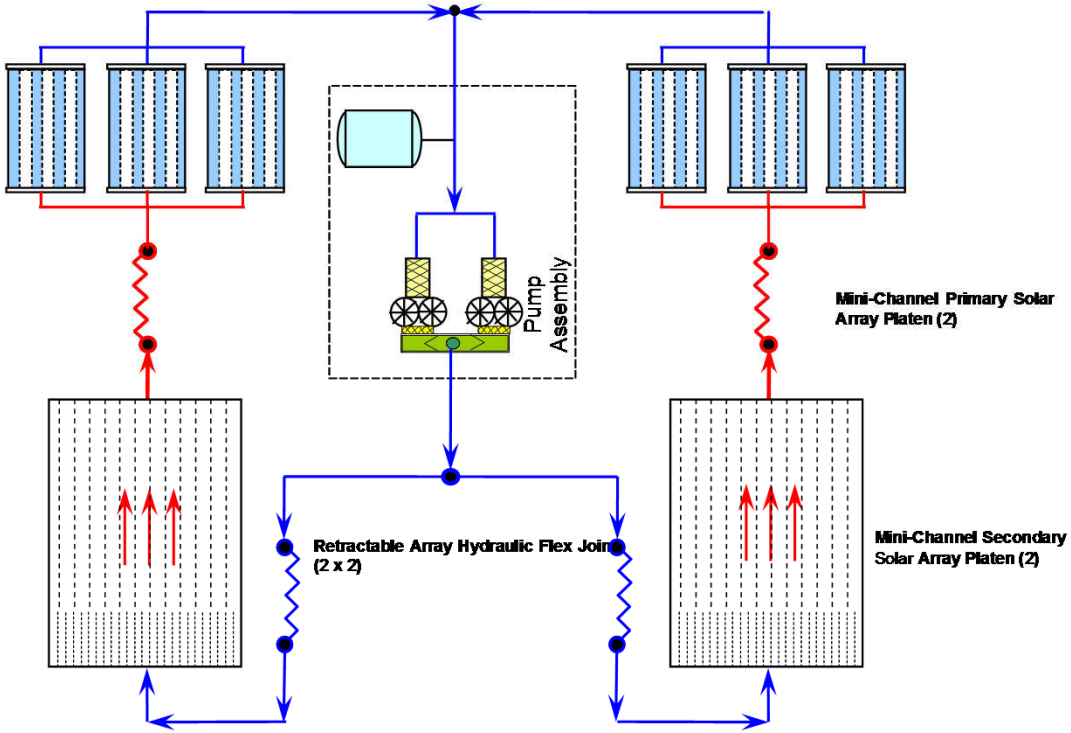
System Operation



Solar Array Thermal Control System Requirements

- Maximum solar array interface temperature: 150 ° C
- Worst-case hot heat load per solar array: 3,000 W
- Must Maintain a cold system operating temp of 10 ° C to prevent freezing
- Maximum TCS mass: 65 kg
- Maximum TCS operating power: 60 W
- Maximum TCS survival temperature: 200 ° C
- Maximum temperature difference in solar cell string direction: 10 ° C

Phase A Thermal Control Schematic



Phase A Tasks

- Increase the Technology Readiness level of the TCS Components to a TRL 5
- Build a 1/6 Scale Bread Board
  - 1 Full Scale Radiator
  - 1/3 Scale Cold plate
- Test the breadboard during major portions of the mission
  - Aphelion, Perihelion, Venus Fly By and near earth orbit
- Evolve the flight design of the TCS system
  - Develop 4 radiator vs. 6 radiator concept
  - Work on valving approach for filling of the system after launch

Phase A Thermal Breadboard Development

Full Size Radiator

1/3 Scale width Cold plate

Breadboard Assembly

Radiator Acoustic Testing

Thermal Performance Test Summary

- Post Launch Warm up and Backfill
  - Objectives
    - Determine the amount of time it takes to warm up the radiator from -150° C to 20° C, and the cold plate from -80° C to 20° C at different heat loads.
    - Demonstrate Backfill of the system
  - Results
    - All warm up times were consistent with modeling results
    - System Backfill was demonstrated successfully

Thermal Performance Test Summary

- **Near Earth Orbit Steady State**
  - Objectives
    - Determine the TCS steady state operating temp in Near Earth Orbit
    - Determine minimum cold plate heat load to maintain radiator outlet temp at 10° C
  - Results
    - With 390W of heat load applied to the cold plate using a combination of Kapton and Ceramic heaters the maximum cold plate interface temperature is 41° C.
    - The minimum heat load needed to maintain 10° C is 270W

Thermal Performance Test Summary

- Venus Orbit Hot Slew Steady State and Eclipse
  - Objectives
    - Determine the TCS steady state operating temp in the Venus Orbit
    - Determine the time for the TCS to cool down to 10° C during the eclipse
  - Results
    - The system survived a Venus Eclipse and was able to maintain temperature for a minimum of 11 minutes.
    - Surface temps on all components of the TCS were never below 0° C

Thermal Performance Test Summary

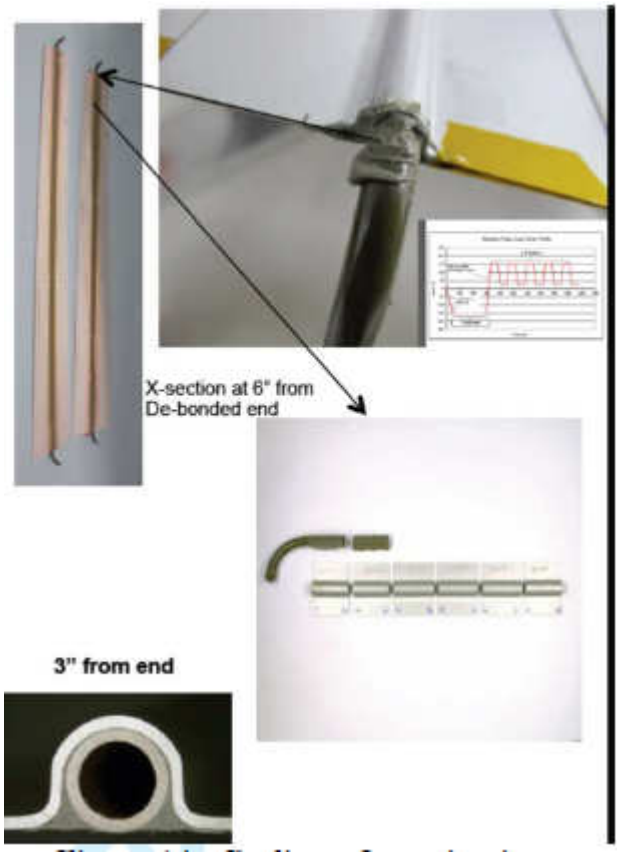
- Perihelion Steady State
  - Objectives
    - Determine the TCS steady state operating temp during perihelion
    - Determine maximum cold plate interface temperature
  - Results
    - The maximum cold plate interface temperature did not exceed 150° C during the perihelion case
    - All results during this testing were consistent with modeling results

Radiator Vibration, Acoustic testing

- Vibration and Acoustic test results were benign in that performance matched closely with predicted results.

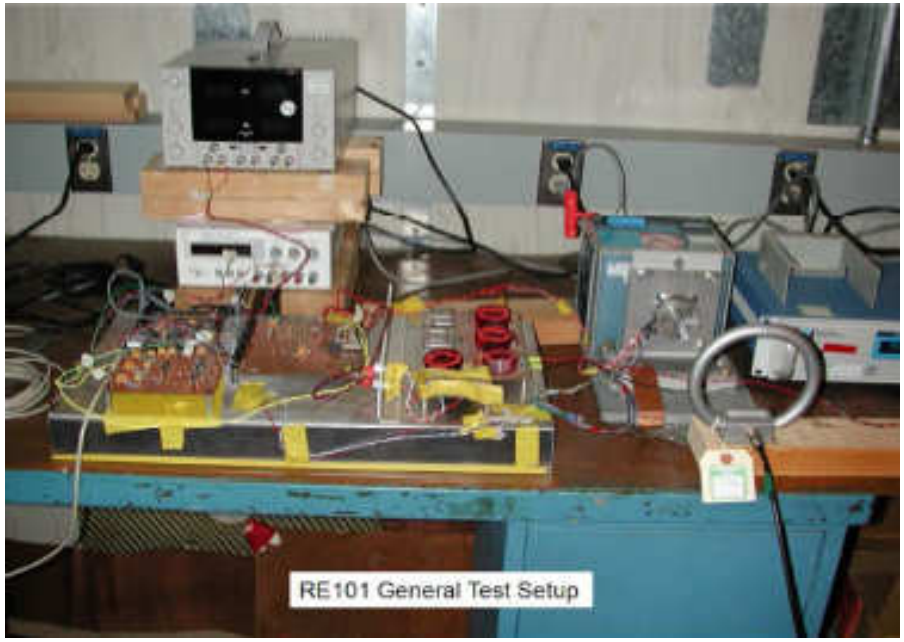
Thermal Cycling

- Thermal Cycling Testing resulted in a separation of the bond material in the radiator and the its associated tubes



Sensor less Motor Controller

- Traditional means of HED motor Control will not work in the Solar Probe Spacecraft because of temperature and Radiation Environments.
- A Sensor less Motor Controller Breadboard was built and tested with excellent results including EMI testing.



Forward Work/Phase B

- Continue to Evolve to Flight Design
- Develop an Alternate Radiator configuration to make it more robust.
- Vibration and thermal testing of the new radiator
- Test a Half System to demonstrate TRL 6
- Pump Development Testing
- Micro Meteoroid Susceptibility
- Reliability and Fault Detection

Conclusion

- Phase A of the Solar Probe Plus Space Craft Program was successful
  - Independent review board recommended to proceed to phase B
  - TRL of all components were at TRL 5 or better at the end of Phase A