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TEXAS TECH UNIVERSITY

Passive Thermal Control for the Low Density Supersonic Decelerator (LDSD) Test Vehicle Spin Motors Sub-System

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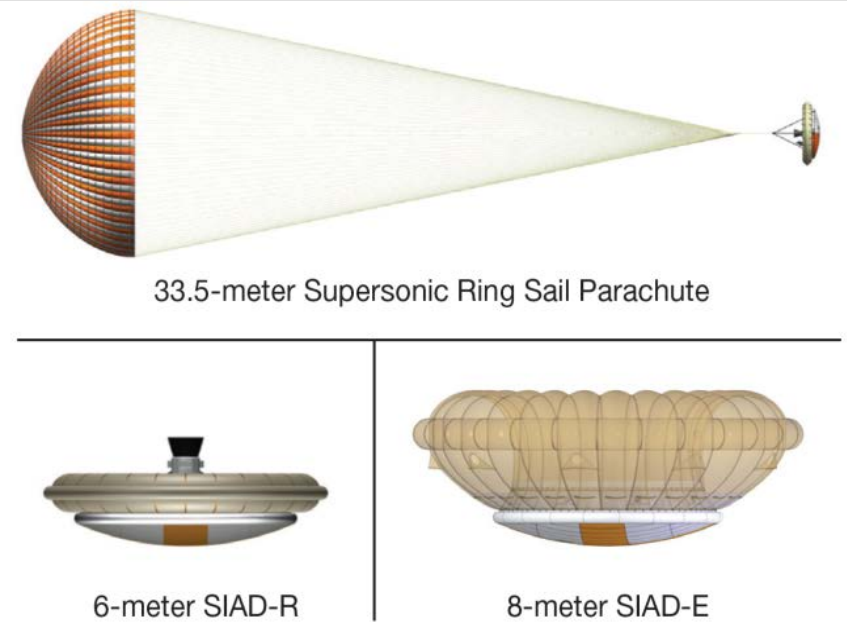
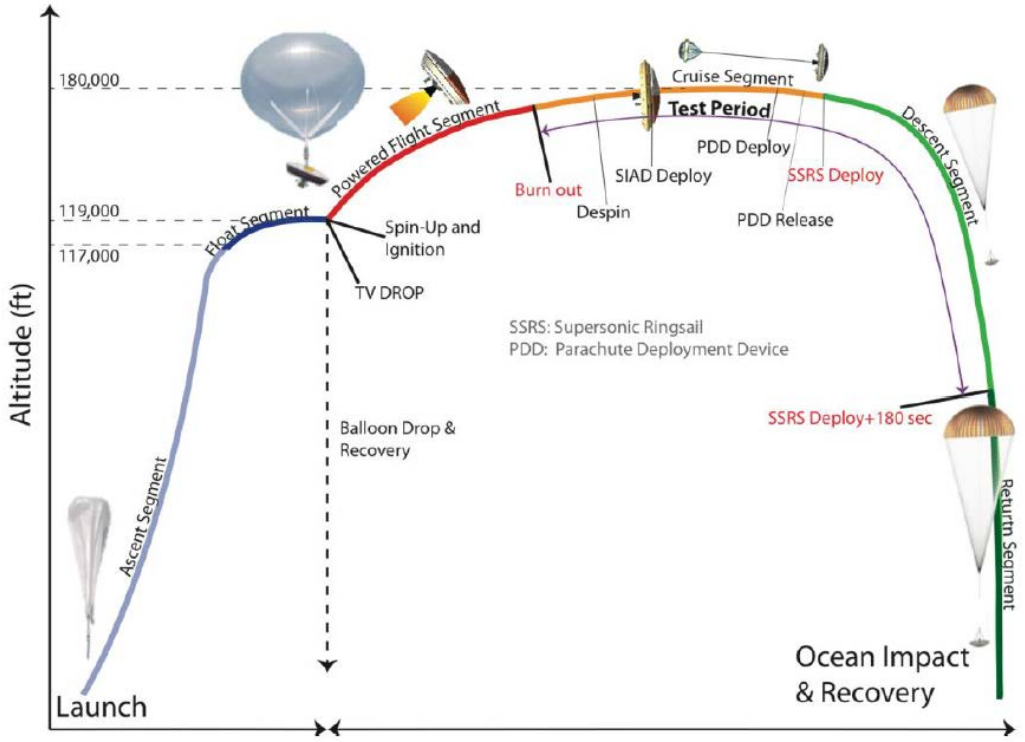
Introduction

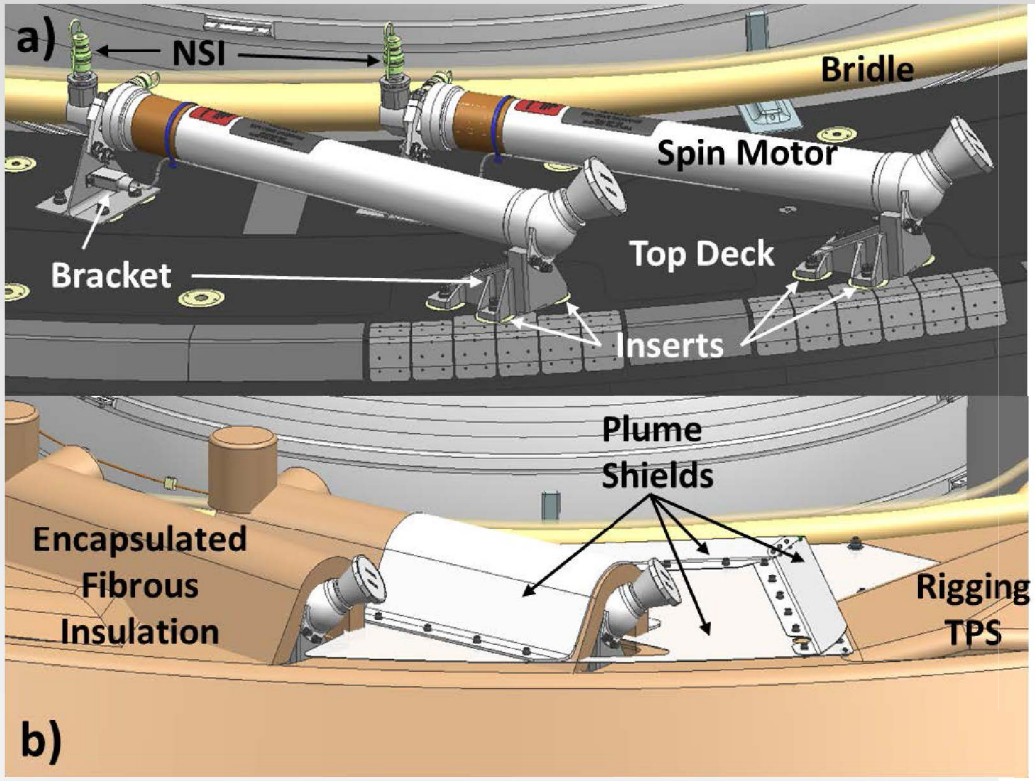


Decelerators tested in the test program[1]

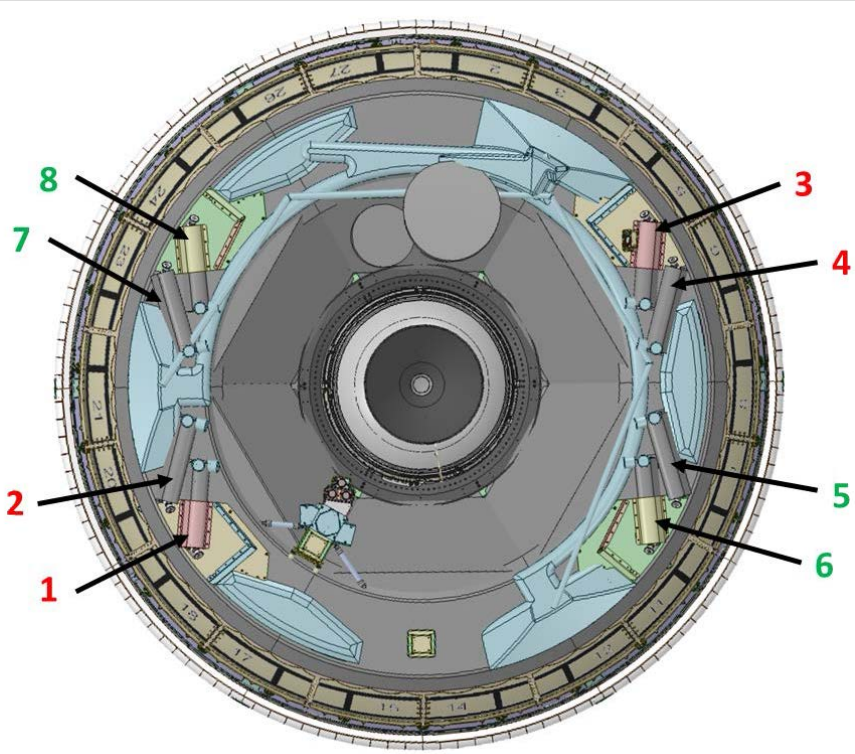


Summary of the flight profile[2]

Sub-System Overview



Sub-System a) without TPS b) with TPS



Spin motor numbering on the test vehicle

Sub-System Requirements

- The temperature difference between two spin motors in a spin motor pair shall be 8 C or less at spin motor firing.

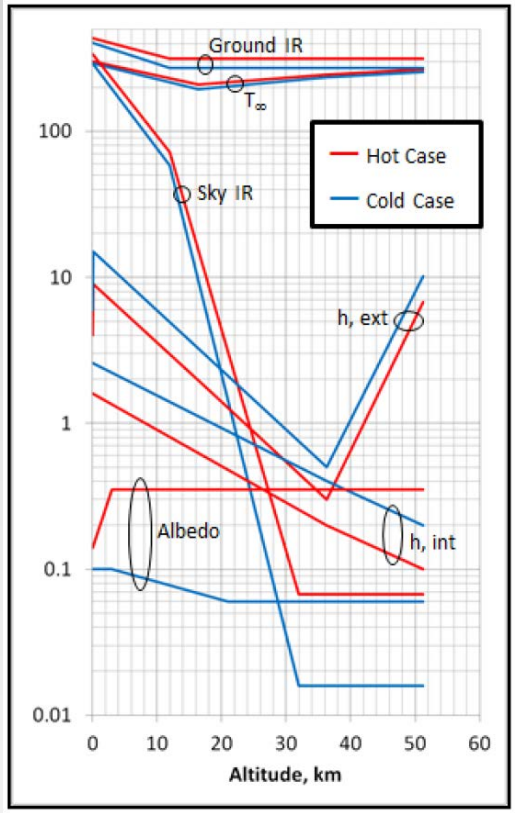
- Note: The hardware may be capable of operating at more extreme temperatures, but its performance may not be verified.

Summary of the temperature requirements for the spin motor sub-system:

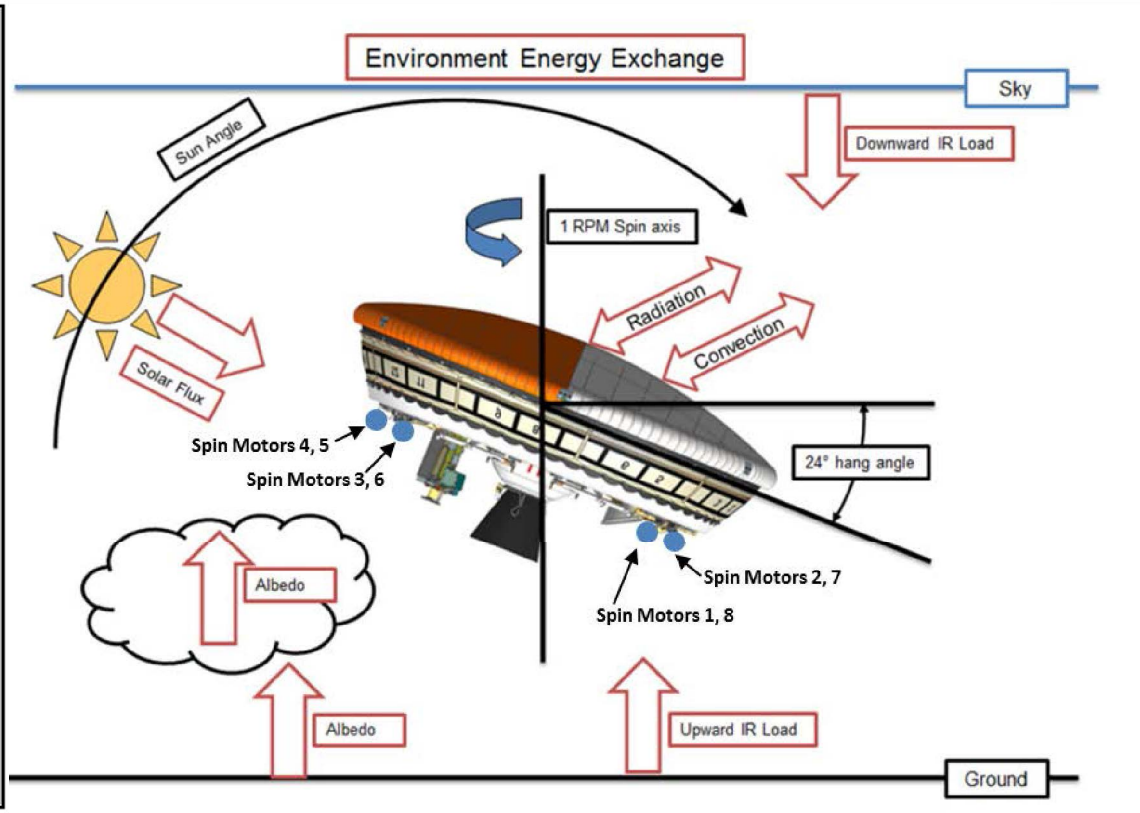
	Allowable Flight Temperature (°C)				Qualification Temperature (°C)			
	Operational		Nonoperational		Operational		Nonoperational	
Component	Min	Max	Min	Max	Min	Max	Min	Max
Spin Motor	-39	54	-39	54	-54	74	-54	74
Top Deck	-43	64	-43	88	-58	84	-58	108
Fibrous Insulation	-45	730	-45	730	-60	750	-60	750
Insulation Encapsulant	-45	730	-45	730	-60	750	-60	750

Thermal Environment

Vertical Axis Units:
Ground IR: W/m²
Sky IR: W/m²
T_∞: K
h, ext, int: W/m²K
Albedo: none



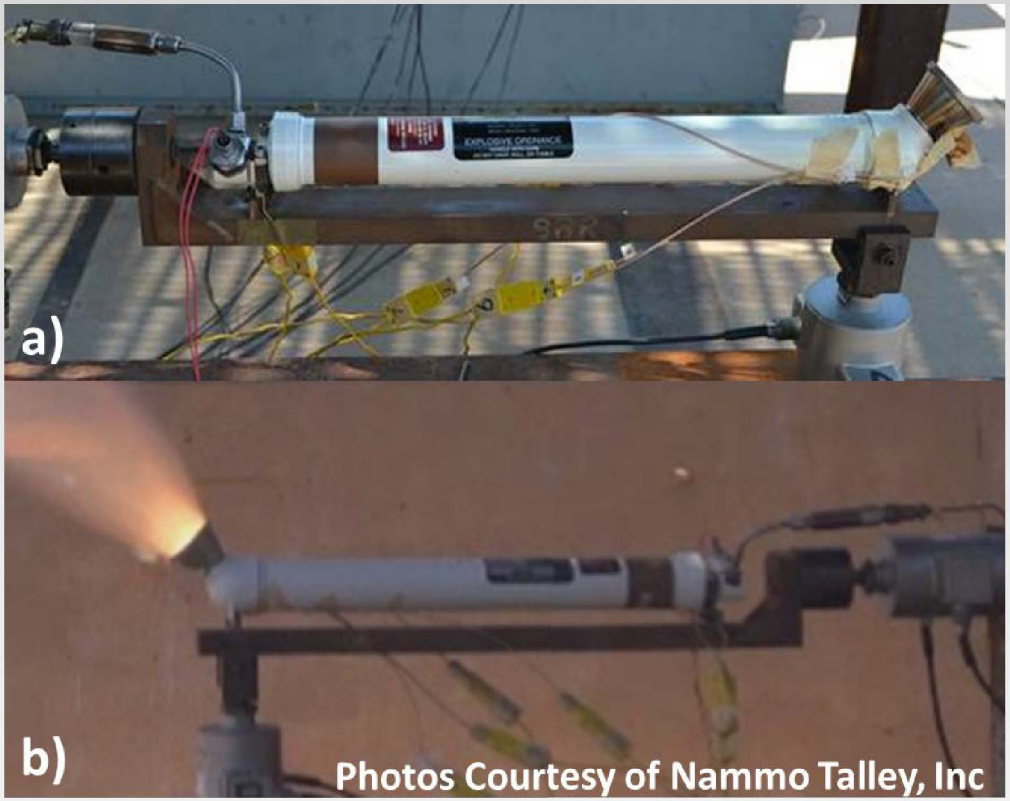
Vehicle thermal environments relative to spin motors[3]



Vehicle thermal environments relative to spin motors

Ground Testing

- Ground testing was performed by the spin motor supplier.
- Spin motors were chilled overnight prior to testing.
- Spin motors were instrumented with thermocouples.

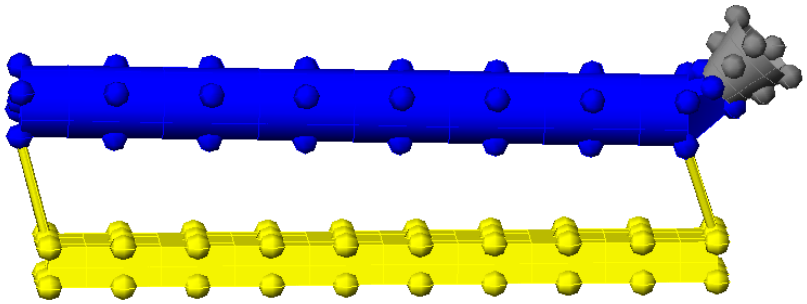


**Spin motor test setup: a) before firing
b) during firing**

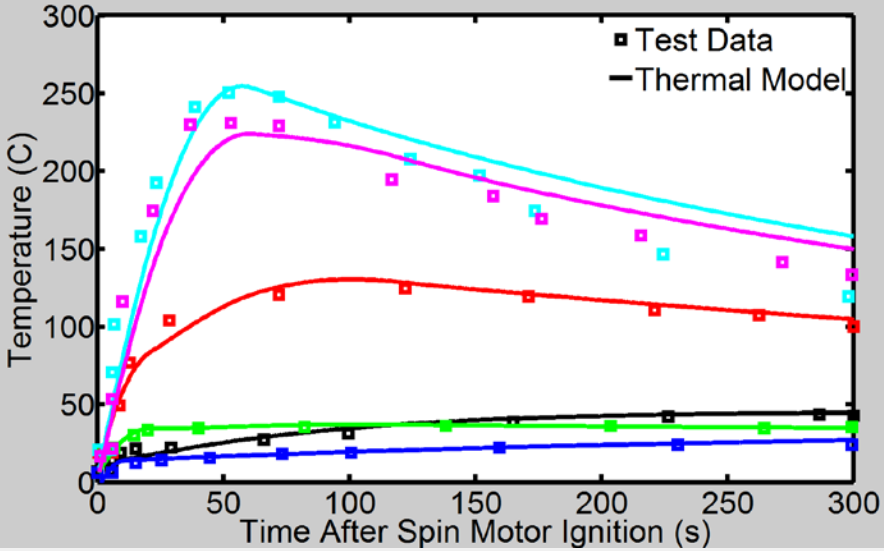
Model Calibration

- 5 time-varying heat loads are applied to different segments of the thermal model and calibrated so that the modeled temperature response matched the test firing data as closely as possible.

- Conduction, convection, and radiation are modeled.



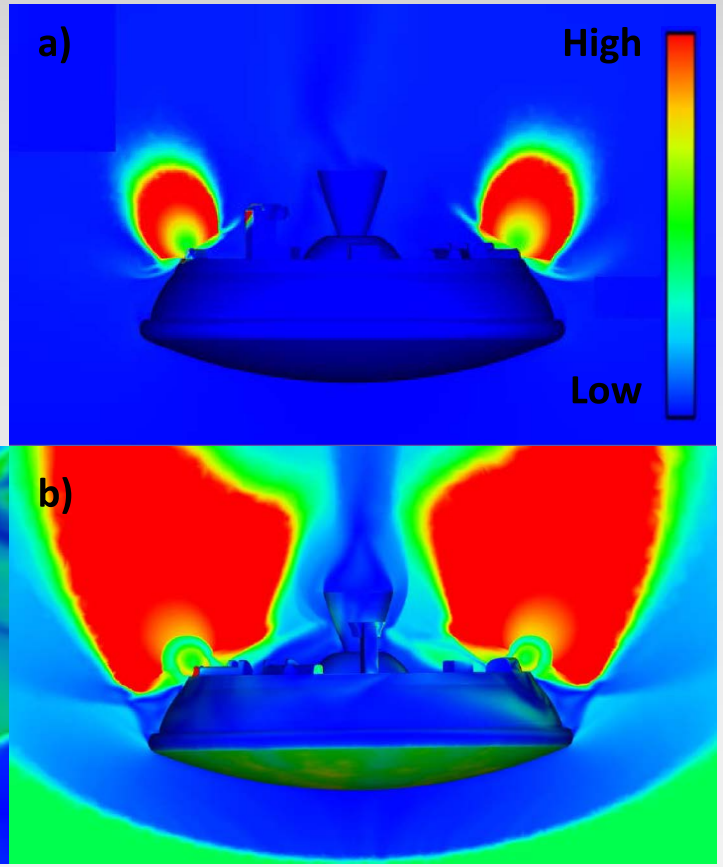
Thermal model of the spin motor test setup



Temperature response of six discrete locations on the thermal model in comparison to the test data.

Plume Heating Predictions

- The CFD code Loci-Chem 3.2 was used to model the plume impingement flow field and for both spin up and spin down motors.



Selected CFD simulation results: a) mach contour for the spin up plumes b) mach contour for the spin down motor plumes c) heat flux contour on the spin motor case, bridle, and top deck.

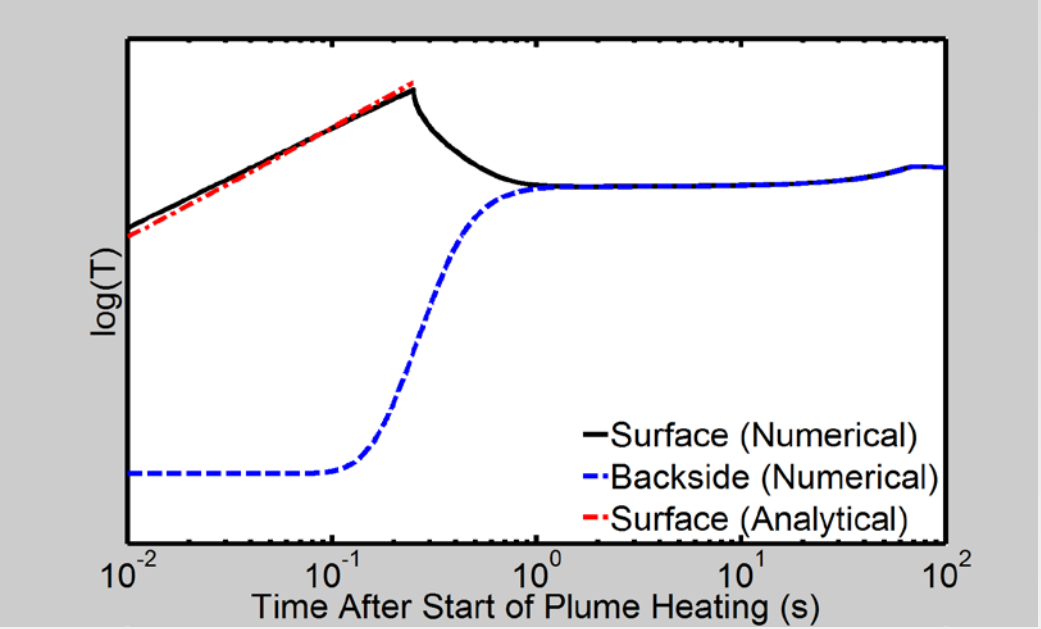
TPS Temperature Response

- Simple textbook equations can be used to predict peak surface temperature of the fibrous insulation and metallic plume sheilds.
  - Steady state energy balance

$$T = (q"/\sigma\varepsilon)^{0.25}$$

  - Semi-infinite body with a constant heat flux

$$T(t) = T_i + 2q" \sqrt{\frac{t}{\pi k \rho c_p}}$$



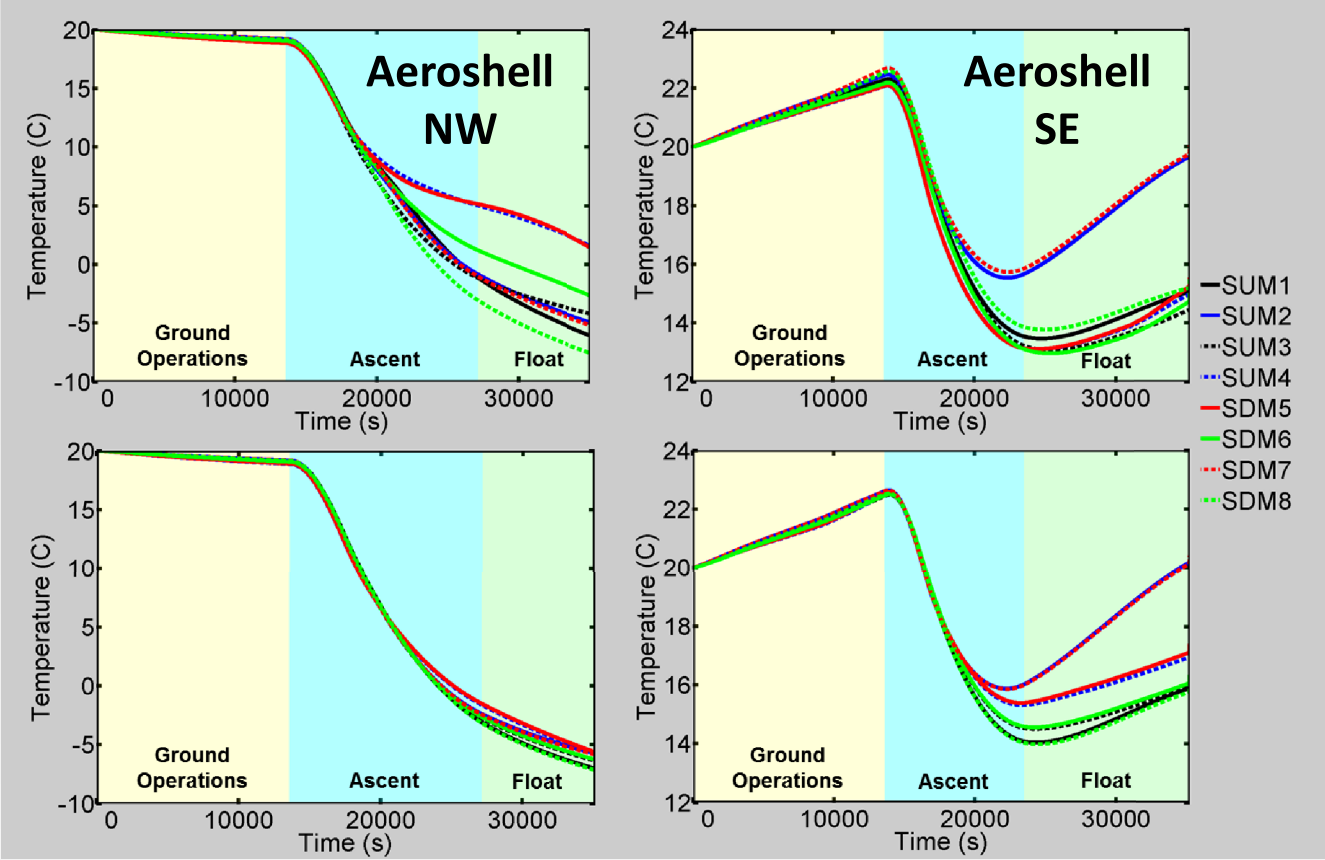
Predicted plume shield temperatures using numerical and analytical methods

Predicted Flight Temperatures

WCC **WCH**

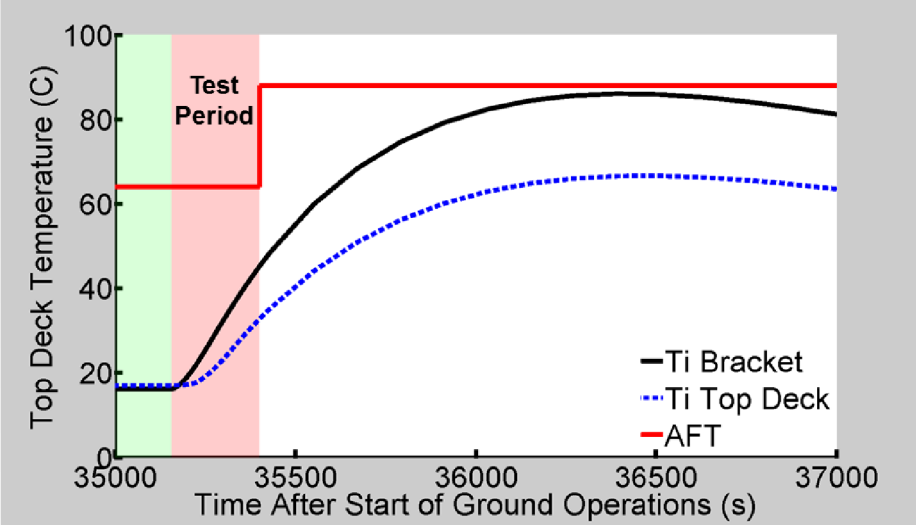
30° Hang Angle, No Spin

24° Hang Angle, Spinning

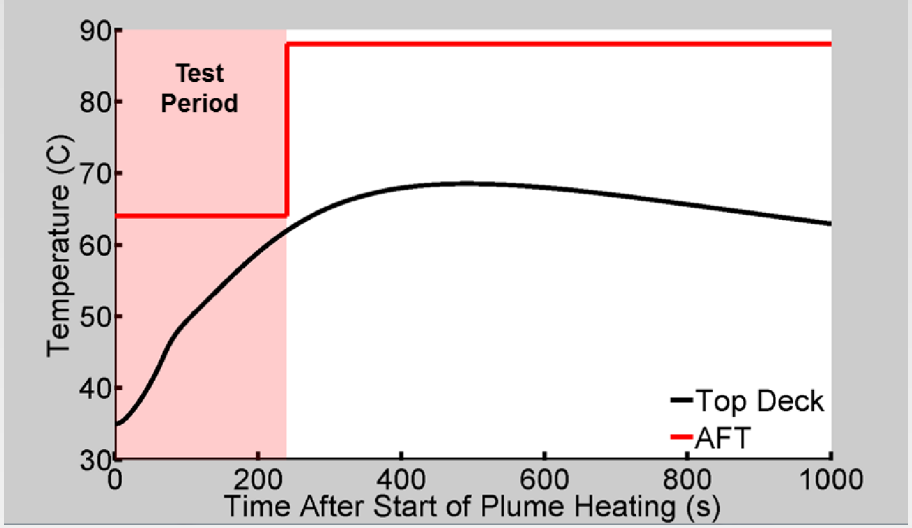


Soak Back Predictions

- The primary concern was that motor soak back might cause the top deck to exceed its AFT.



The WCH predicted temperature of the top deck and spin motor brackets



The WCH predicted temperature of the top deck underneath the titanium stand-offs.

Conclusion

- All components are predicted to meet their temperature requirements.
- Test data from the first test flight indicates that the components met or exceeded thermal requirements in the first flight.

References

[1]NASA, "Fact Sheet: Low Density Supersonic Decelerators," 26 March 2013. [Online]. Available: http://www.nasa.gov/pdf/737628main_Final_LDSD_Fact_Sheet_3-26-13.pdf. [Accessed 20 January 2014].

[2]Cook, B.T., Blando, G., Kennett, A., Heydt, M.V., Wolff, J.L., and Yerdon, M., "High Altitude Supersonic Decelerator Test Vehicle," in AIAA Aerodynamic Decelerator Systems Conference, Daytona Beach, FL, 2013.

[3]A. J. Mastropietro, M. Pauken, E. Sunada and S. Gray, "Thermal Design and Analysis of the Supersonic Flight Dynamics Test Vehicle for the Low Density Supersonic Decelerator Project," in International Conference on Environmental Systems, Vail, CO, 2013.

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