Thermal Design of the Earth Surface Mineral Dust Source Investigation (EMIT)

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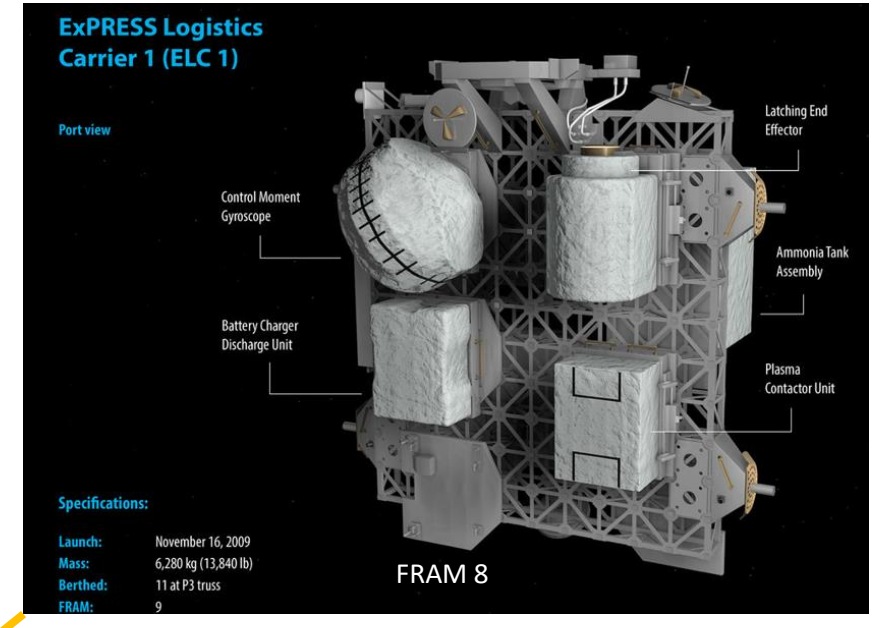
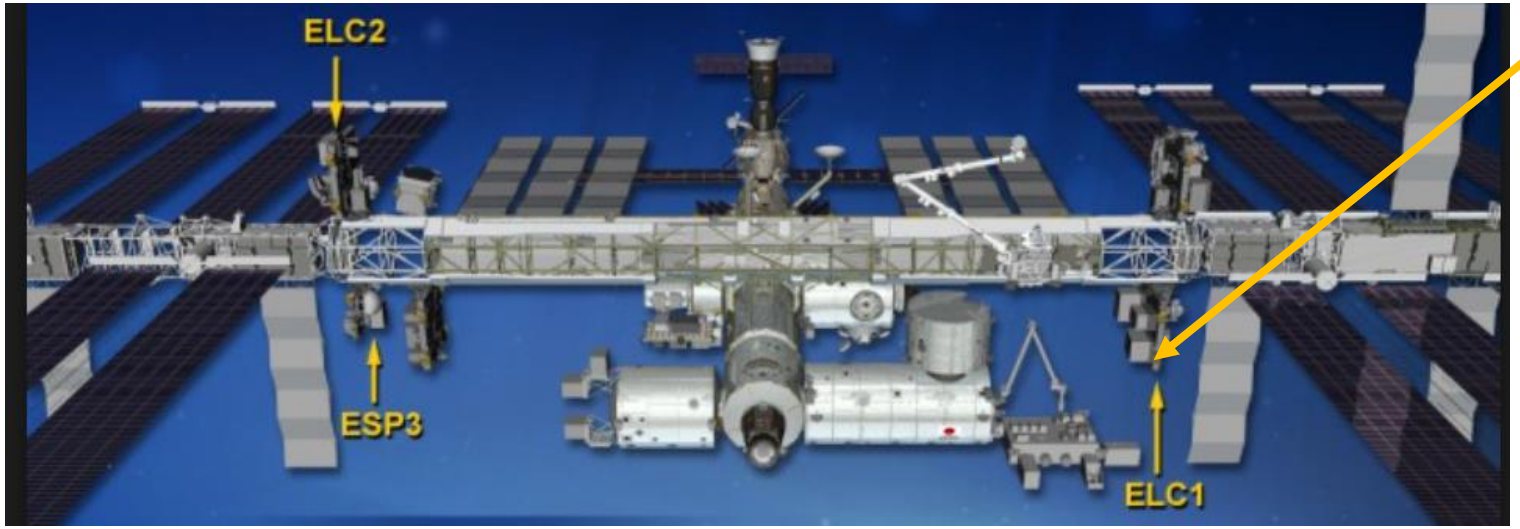
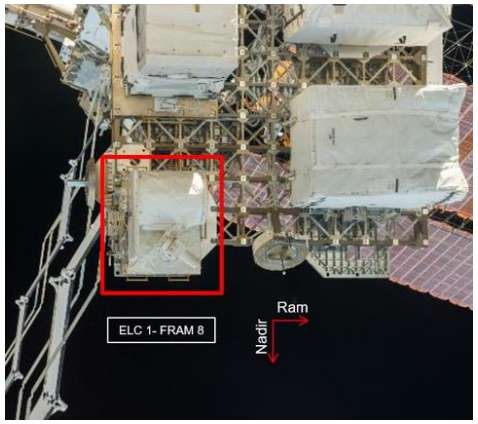
EMIT Project Overview

EMIT is an Earth Venture Instrument-4 on ISS

- Earth Surface Mineral Dust Source Investigation (EMIT)
  - Map the surface mineralogy of arid dust source regions via imaging spectroscopy (VSWIR)
- Planned for launch in 2022
- CRS-2 Launch Vehicle: SpX Falcon 9
- CRS-2 De-orbit Vehicle: SpX, Dream Chaser, H-II Transfer Vehicle (HTV)
- Deployed on ISS at ELC1/FRAM 8
- Operational life: 1 year after 30 days in-orbit checkout



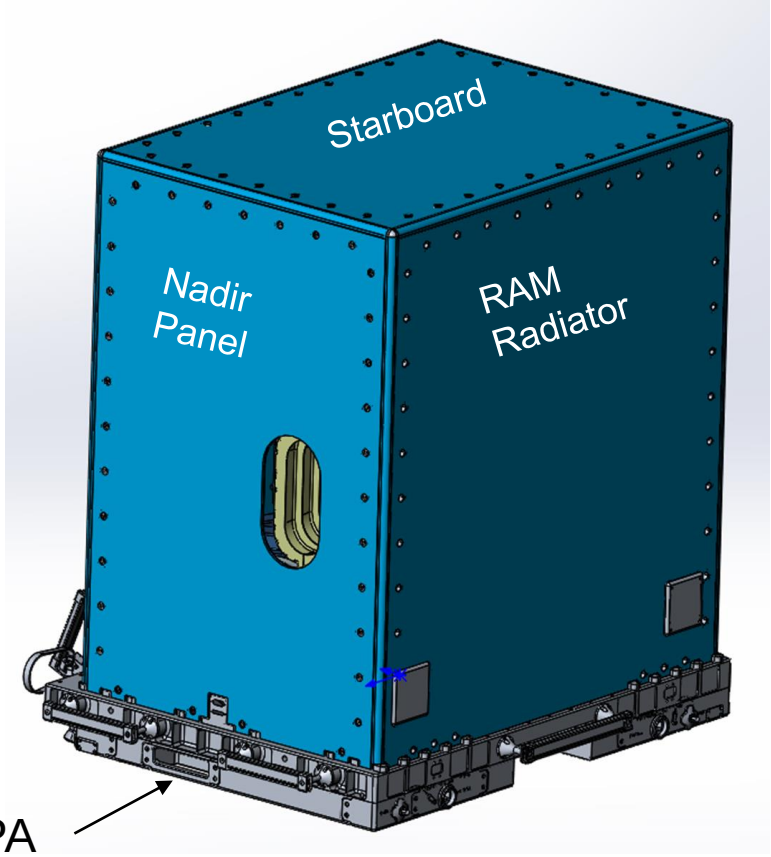




Thermal Control System (TCS) Overview

- TCS consists of a combination of active and passive components
- Active thermal control systems include mechanical cryocooler (one cooler, one cooler electronics, and variable conductance heat pipes)
- Passive thermal control systems include radiators, heat pipes, HX clamp, multi-layer and single layer insulations, and flexible thermal straps
- FPA and Spectrometer are cooled to 155 +/- 5K and 240K+/- 2K, respectively, and temperature controlled by means of split stirling pulse tube cryocooler (Thales LPT 9310) powered by IRIS HP-LCCE2 and operational heater
- The cryocooler heritage of ECOSTRESS used in this TCS

  (Compressor **TRL9** and Expander **TRL6**)
- Heat Rejection System is comprised of electronics mounting plate, heat pipes, and cross-strapped radiators



The TCS is designed to handle Payload CBE power plus contingency totaling 225W and maintain payload within Allowable Flight Temperature limits

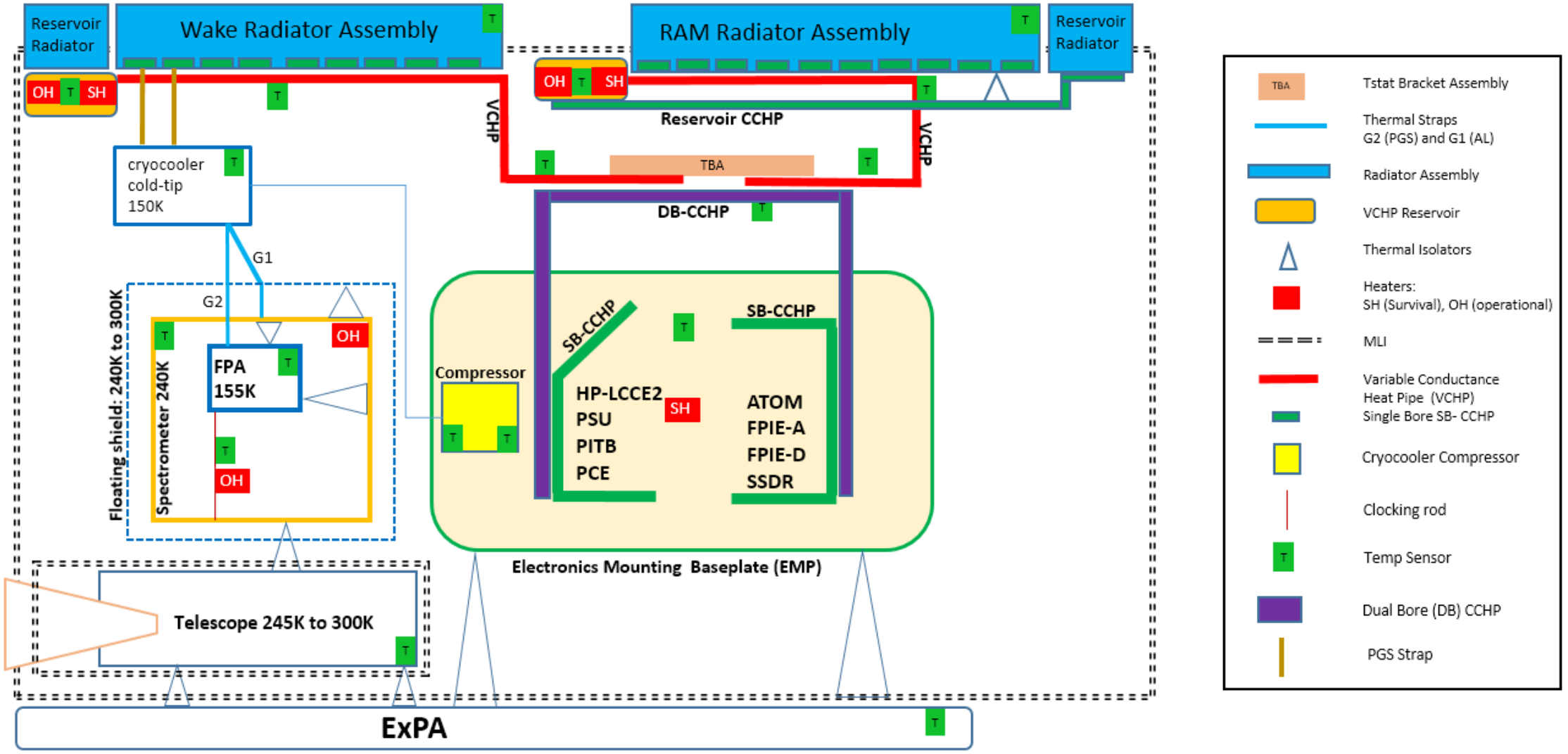
Thermal Requirements and Key Design Drivers

	Allowable Flight Temperature (°C)	
Instrument	**Operating**	**Non-Operating**
FPA	150K to 160K	145K to 303K
Spectrometer	238K to 242K	200K to 303K
Electronics/Cryo compressor	-15 to 40	-40 to 40
Cryo Expander	-25 to 40	-65 to 40
FPIE-D	-15 to 35	-40 to 40
Telescope	-28 to 27	-60 to 40
HRS		
Radiator CCHPs	-55 to 40	-72 to 60
EMP	-20 to 40	-55 to 60
VCHPs	-15 to 30	-72 to 50
Enclosure	-70 to 60	-75 to 60
GFE		
FRAM (ExPA)	-92.8 to 126.7	-92.8 to 126.7

Description	**Requirement**
EMIT ERD compliance	Compliant
Spectrometer spatial gradient	<6.5K
Telescope spatial gradient	<2.5K
Unpowered transfer survivability	6 hours in any orientation all possible beta angles
FPA stability	100mK RMS over any 260s interval (sun-lit)
Spectrometer	240±2K
Telescope	245-300K
Cryocooler electrical power	≤70W
Survival power	66W in SpX Dragon 80W at ELC1
Temperature maintenance	Maintain op and non-op AFTs for 13 months
Op heat rejection capability	Up to 225W at ELC1

HRS: Heat Rejection System
GFE: Government Furnished Equipment

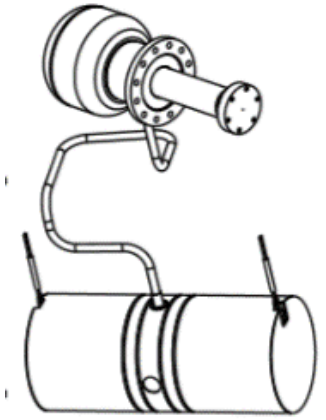
Thermal Architecture



Cryocooler Overview

- Thales LPT9310
  - Compressor (TRL 9)
    - ECOSTRESS
  - Expander (TRL 6)
- Past JPL qualification tests
  - Random vibration
    - PF levels: 0.7 g^2/Hz (peak)
    - 150 gram supported mass
  - Thermal cycling
    - Non-op: -55°C to 65°C
    - Op: -30°C to 50°C
  - Non-op cold limit
    - Tested expander to -80°C at JPL

EMIT cooler



Capability

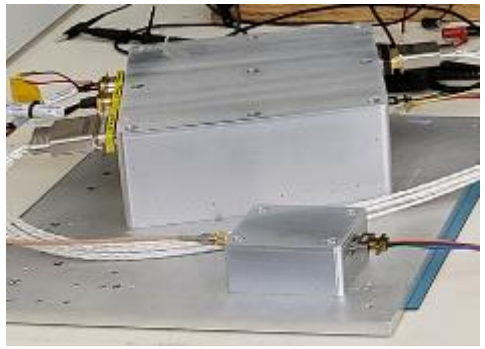
- Baseline MTTF: **90000 hrs**
- Compressor dimensions: **90 mm × 204 mm**
- Cold finger / approx. dewar bore: **24 mm**
- Mass [DNG 865742]: **7.0 kg**
- Cooling power @ 80K/23°C (Typical): **5100 mW**
- Input power: **< 180 W**
- Operating temperature range: **-40/71 °C**
- Input voltage: **28 V_{AC}**

GEVS		EMIT Comp Axial		EMIT Comp Lateral		EMIT Cooler Coldhead	
Freq	PF/Qual	Freq	PF/Qual	Freq	PF/Qual	Freq	PF/Qual
	G^2/Hz		G^2/Hz		G^2/Hz		G^2/Hz
20	0.026	20	0.08	20	0.02	20	0.08
50	0.16	130	0.2	45	0.03	50	0.08
800	0.16	160	0.7	70	0.5	70	5
2000	0.026	250	0.7	150	0.5	110	5
		300	0.04	250	0.04	150	0.25
		500	0.04	500	0.04	375	0.25
		2000	0.01	2000	0.01	2000	0.02
Grms	14.14	Grms	11.77	Grms	10.02	Grms	21.2

EMIT RV levels are higher than PF GEVS especially at lower frequencies. For expander overall Grms is 21.1. As part of risk mitigation activity performed random vibe tests on COTS cooler at JPL and flight cooler at Thales and both coolers successfully survived this very challenging EMIT RV levels.

HP-LCCE2

- Iris Technology High-Power Low Cost Control Electronics (HP-LCCE2)
  - Main function: convert DC bus voltage to AC voltage to supply the cryocooler motors
- TRL: 6
- Two physical boxes
  - Main module
    - Bus voltage, output to cooler, temperature feedback, serial communication
  - Signal conditioner unit (SCU)
    - Accelerometer charge amp
    - Converts charge to voltage

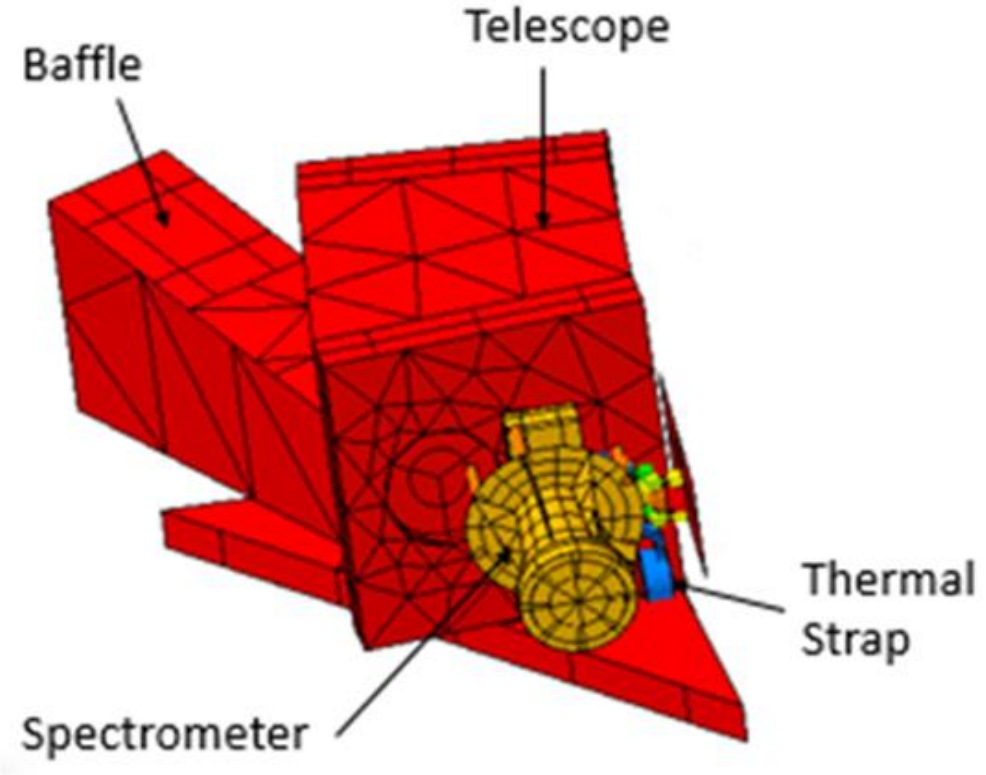


GEVs		HP-LCCE axial		HP-LCCE Lateral	
Freq	PF/Qual	Freq	PF/Qual	Freq	PF/Qual
	G^2/Hz		G^2/Hz		G^2/Hz
20	0.026	20	0.08	20	0.02
50	0.16	100	0.08	50	0.02
800	0.16	200	0.3	80	0.5
2000	0.026	300	0.3	150	0.5
		2000	0.02	250	0.08
				500	0.08
				2000	0.02
Grms	**14.14**	**Grms**	**13.09**	**Grms**	**11.79**

EMIT RV levels are higher than PF GEVS especially at lower frequencies. Structural analyses was performed and results showed sufficient technical margins

Thermal Model

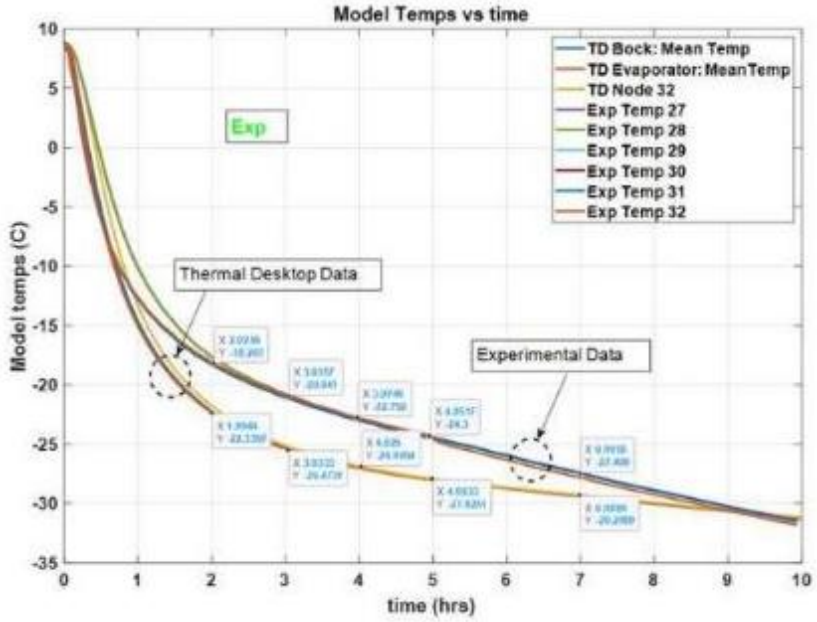
- The EMIT thermal models were built in Thermal Desktop (TD) 6.1
- The telescope assembly was modelled using planar surfaces to represent the aluminum outer housing of the telescope, the baffle, and the optical mirrors
- The thermal model was used to predict
  - absolute temperatures
  - Gradients
  - temperature stability
  - heater power use for a range of orbit beta angles



6-hr Unpowered Transfer Simulation Test and VCHP Model Correlation

- Performed risk reduction test on VCHP to confirm passive shutoff capability
- Passive shutdown of VCHP was successfully demonstrated at JPL with no reservoir heater power. This confirmed that EMIT can successfully meet the 6 hr unpowered transfer requirement with ~ **$3m^2$** radiator at -80C sink temperature
- Successfully correlated VCHP model to test data and model accurately predicts gas front location during unpowered transfer and op and non-op conditions.

EMP Simulator Model Vs Exp Comparison: Uncorrelated



Requirement: maintain EMP above -40C for 6 hrs without survival power

EMP Simulator Thermal Desktop vs Exp: Correlated

Surviving 6 hr unpowered transfer with ~$3m^2$ radiator at -80C sink temp is very challenging. Using VCHP passive shutoff capability EMIT was able to meet this requirement.

Summary and Conclusions

- A thermal control system has been successfully designed to meet the challenging EMIT thermal requirements.
- A combination of active and passive thermal control systems was employed to maintain the components within the AFT limits.
- TCS design shows positive technical margins on all requirements
- Performed random vibe test on COTS LPT9310 cooler to levels exceeding PF GEVS at JPL and Thales.
- Both coolers successfully survived and post vibe cooler performance data showed no degradation in performance
- Structural analysis performed on HP-LCCE2 with higher RV levels showed sufficient technical margins.
- Both LPT 9310 and HP-LCCE2 mechanical design performance exceeded their design specifications
- Successfully verified VCHP passive shufoff capability at JPL
- EMIT TCS is meeting the challenging the 6 hr unpowered transfer requirement
- Thermal control system design will be verified in Instrument TVAC which is planned for 3Q 2021.

Acknowledgements

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