Thermal Analysis of Mars Orbiting Sample Subsystem (OSS) for Sample Retrieval Lander

Lina Maricic, ATA Engineering
Jennifer Miller, Jet Propulsion Laboratory,
California Institute of Technology

Presented By
Lina Maricic

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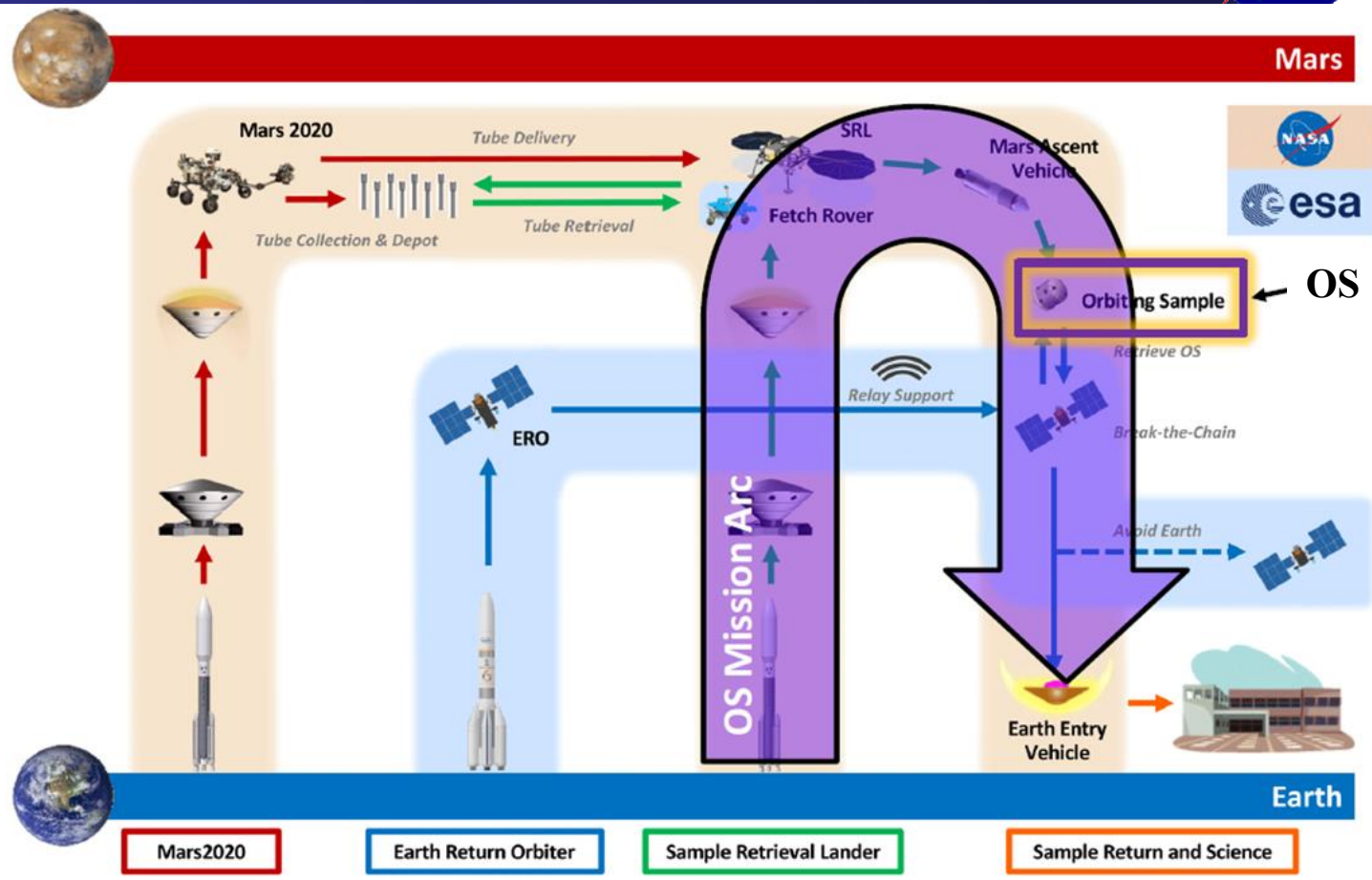
Outline

- Mars Sample Return (MSR) / Sample Retrieval Lander (SRL) Overview
- OSS Thermal Responsibilities
- Requirements
- Boundary Conditions
- Model Overview and Assumptions
- Temperature Predictions for Select Cases
- Select Sensitivities
- Conclusions

High Level MSR/SRL Planning Overview[1]

- The Mars Sample Return (MSR) campaign would potentially return the first ever samples from Mars to Earth
- The Orbiting Sample (OS), is the container which would carry the Mars 2020 Returnable Sample Tube Assemblies (RSTAs) with Martian rock and soil samples back to earth.
- The OS is the keystone component of the campaign that is transferred between the Sample Retrieval Lander (SRL) and Earth Return Orbiter (ERO) missions.
- OS would be deposited in Martian orbit by SRL
- OS would be detected and captured by ERO
- This presentation focuses on early thermal analysis of OS on Mars surface, Mars launch and on-orbit before OS captured by ERO (see OS Mission Arc on the right)
  - As the design of the OS is continuing to evolve, the results presented here within are subject to change.
  - The decision to implement Mars Sample Return will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.



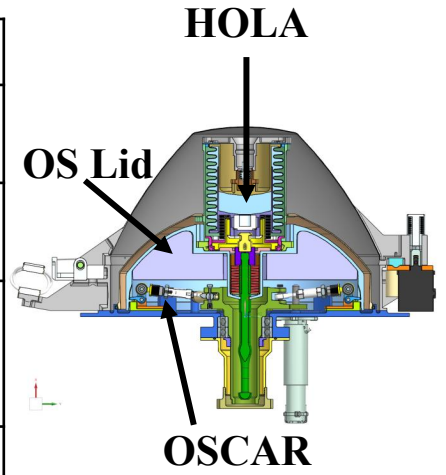
Project	M2020	ERO	SRL	Science
Key Interfaces	• Returnable Sample Tube Assemblies (RSTA)	• Rendezvous System • Capture, Containment, and Return System (CCRS)	• Mars Ascent System (MAS) • Sample Transfer System (STS)	• Martian Sample Handling Facility

Ref. 1: OS Concept Review.pdf (JPL)

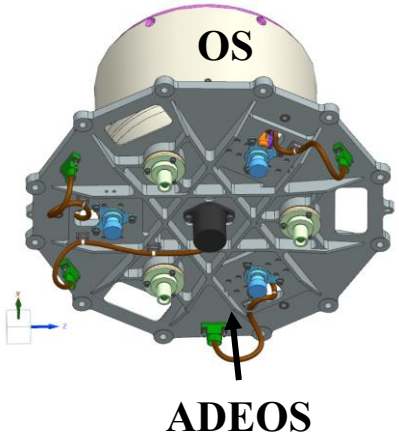
OSS Thermal Responsibilities for SRL

- SRL OSS (Orbiting Sample Subsystem) team is responsible for the thermal design/delivery of:
  - OS that contains the sample tubes (RSTA) once on Mars
  - OSCAR (Orbiting Sample lid Containment and Release)
  - HOLA (Handling of the OS and Lid Assembly)
  - ADEOS (Assembly to holD and Eject the OS) – Predicts reference only
- Analysis matrix includes five mission phases and 10 different environments:
  - Earth to Mars Cruise – TBD, no samples in OS
  - Mars Entry, Descent and Landing (EDL) – TBD, no samples in OS
  - Mars Surface
  - Mars Ascent
  - Mars Orbit
- Only select cases presented here
- Worst case assumptions were used in analysis, and temperature predictions include no margins

Environment /Case ID	Configuration	Boundaries
1. Cruise	OS Open/Lander Closed	TBD
2. Mars EDL	OS Open/Lander Closed	TBD
3. Surface	OS Open/Lander Closed	WCH Non-op WCC Non-op
4. Surface	All Closed	WCH Non-op WCC Non-op
5. Surface	All Open	WCH Non-op WCC Non-op
6. Surface	All Open – Oscar Op	WCC Non-op
7. Surface	All Closed	WCH Op WCC Op
8. Surface	All Closed	MAV DOL
9. Ascent	-	MAV ascent
10. Orbit	-	WCH, no spin



On Mars surface, OS Lid inside OSCAR, with HOLA attached to OS Lid



Temperature Requirements

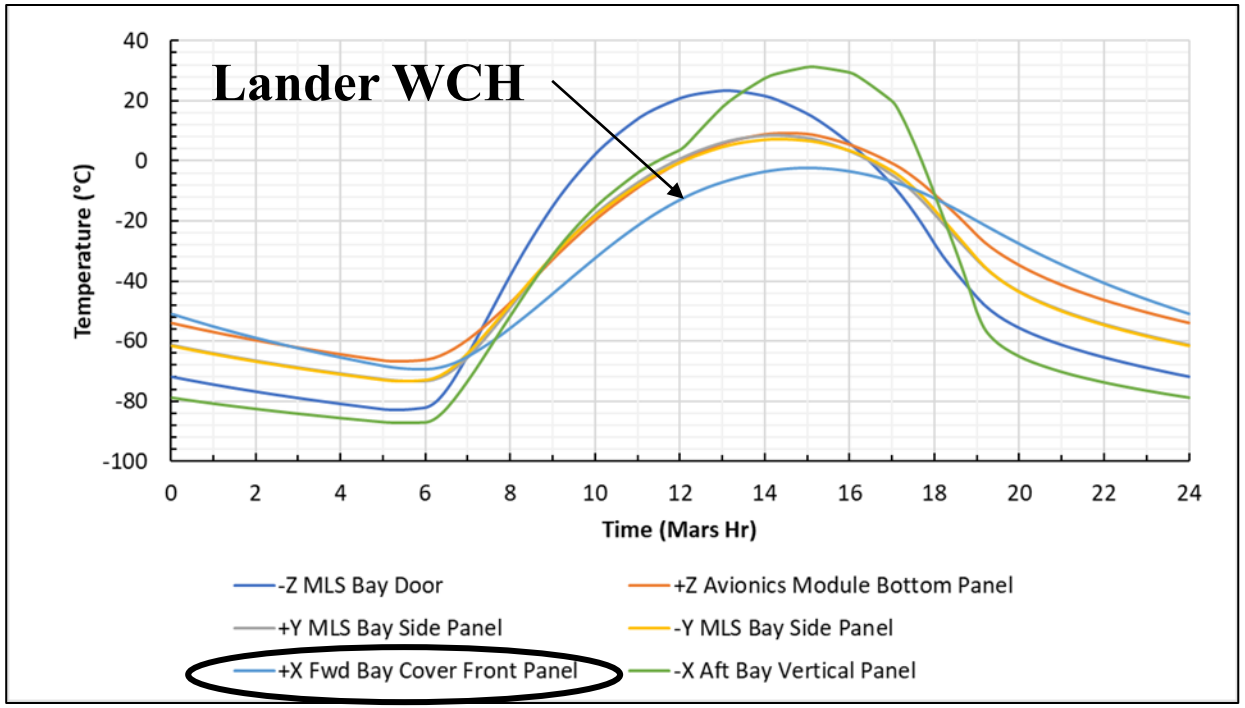
- MSR SRL TRT contains the OSS temperature requirements (subject to change)

Hardware	Allowable Flight Temperature (AFT), ºC			
	Operational		Non-Operational	
	Min	Max	Min	Max
RSTAs	N/A	30	N/A	-20
ADEOS Components	-50	50	-75	50
HOLA	-75	50	-105	50
OSCAR Components	-50	50	-105	50

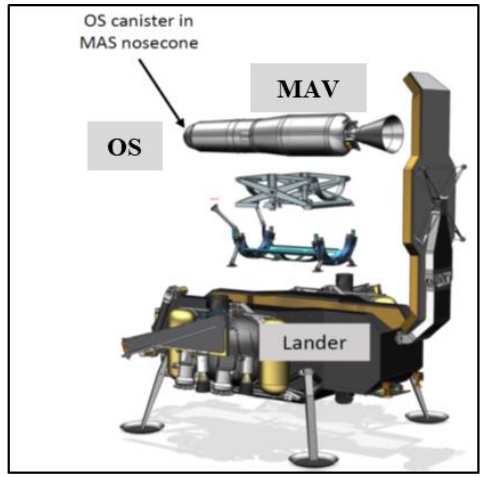
- SRL shall maintain the external temperature of the RSTAs below an Allowable Flight Temperature (AFT) of -20C except for periods of unavoidable operational transients for which the AFT is +30C.

OSS Boundary Temperatures on Mars Surface

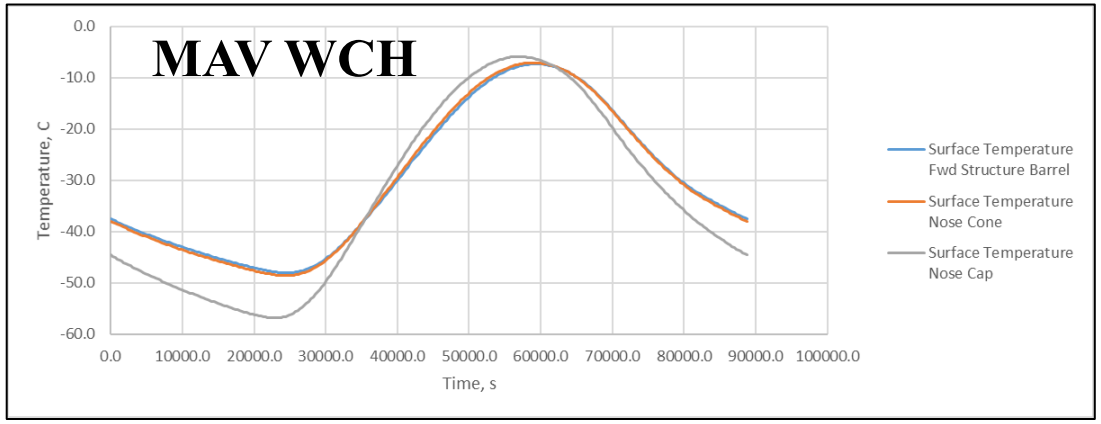
- Example WCH boundary conditions – note that OSS predictions follow the boundaries
- OSS temperatures highly driven by boundary temperatures



OS view of Lander +X Fwd Bay Cover at -90C to 0C



Configuration while on SRL Lander

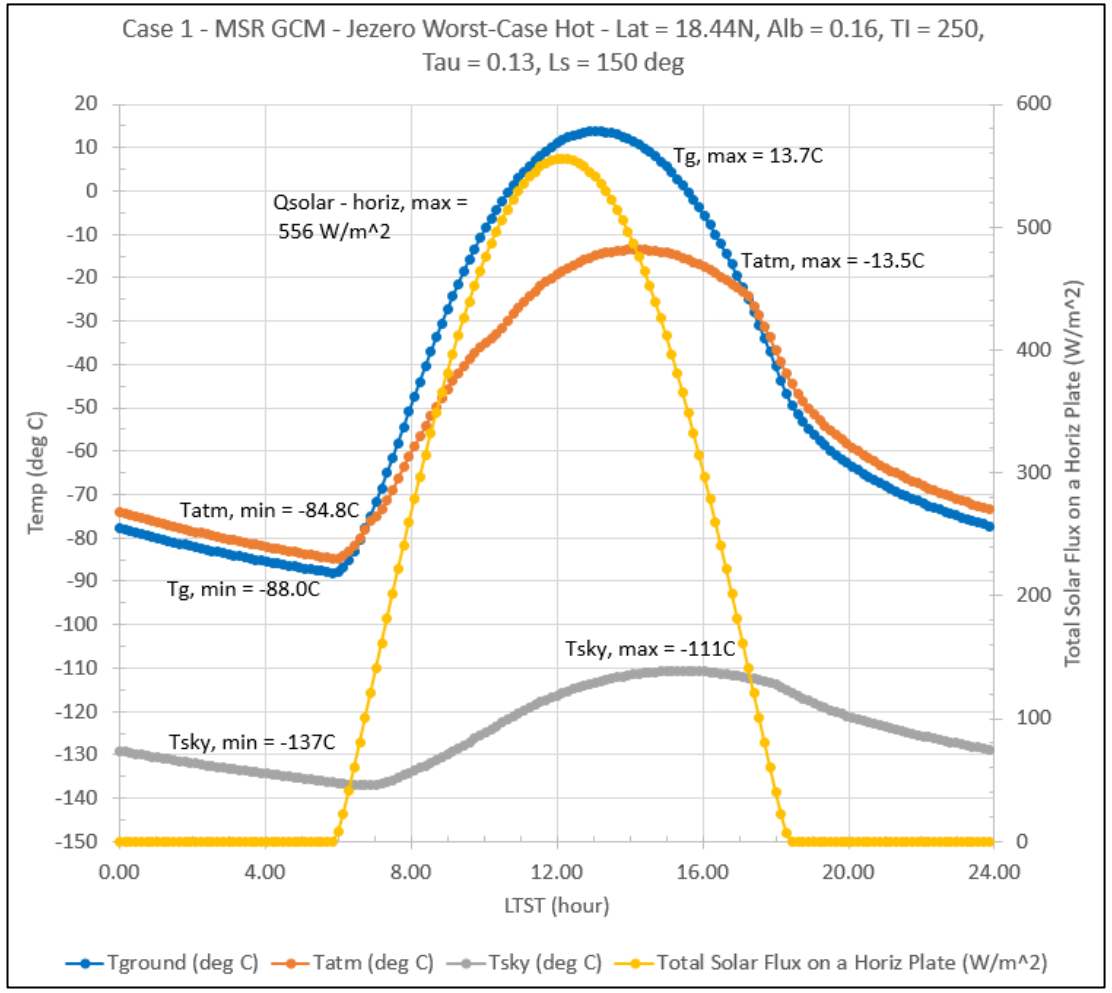


OS view of MAV at -60C to -5C

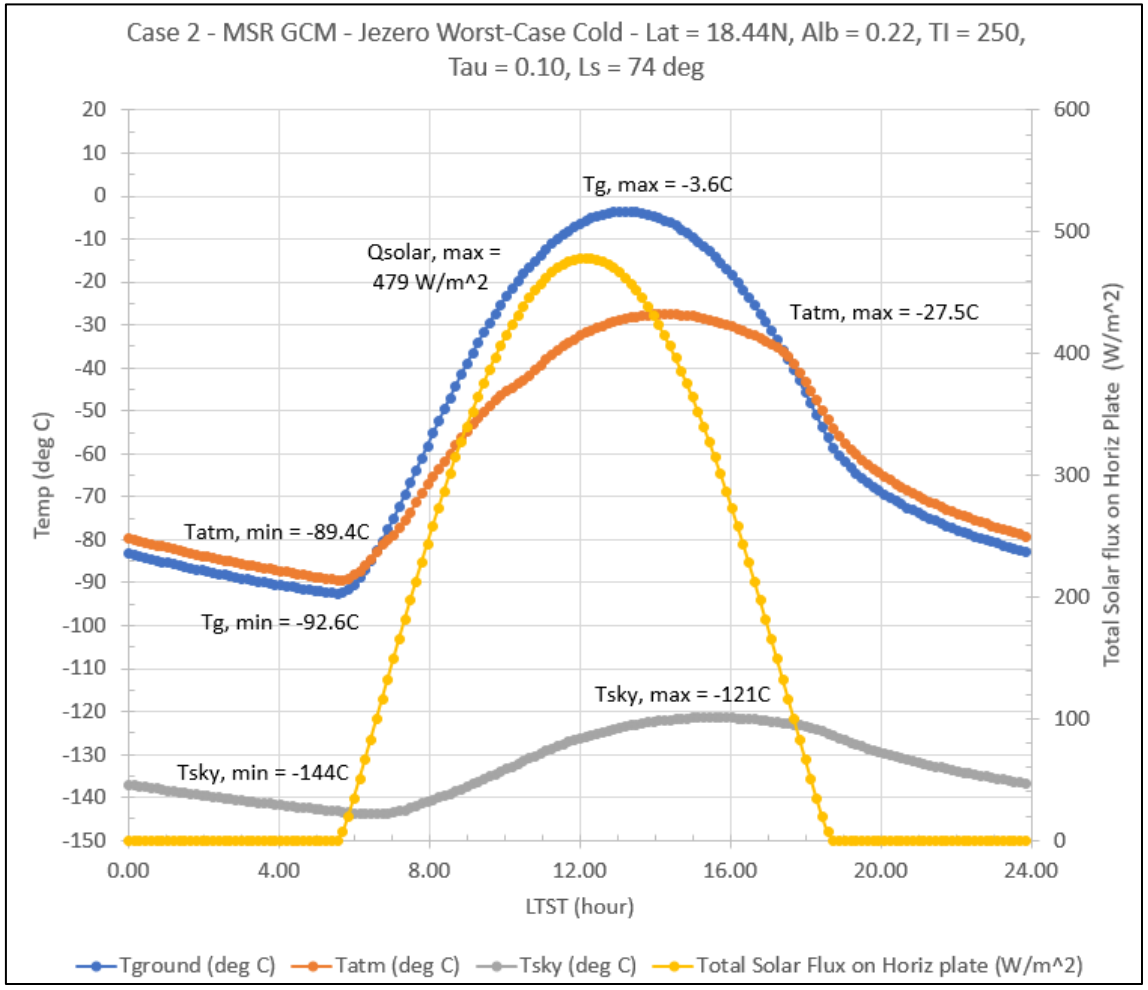
OSS Environments on Mars Surface Jezero Crater Site

- Environments include solar flux, atmosphere, ground, and sky temperatures
- OSS temperatures highly affected by environment temperatures

WCH

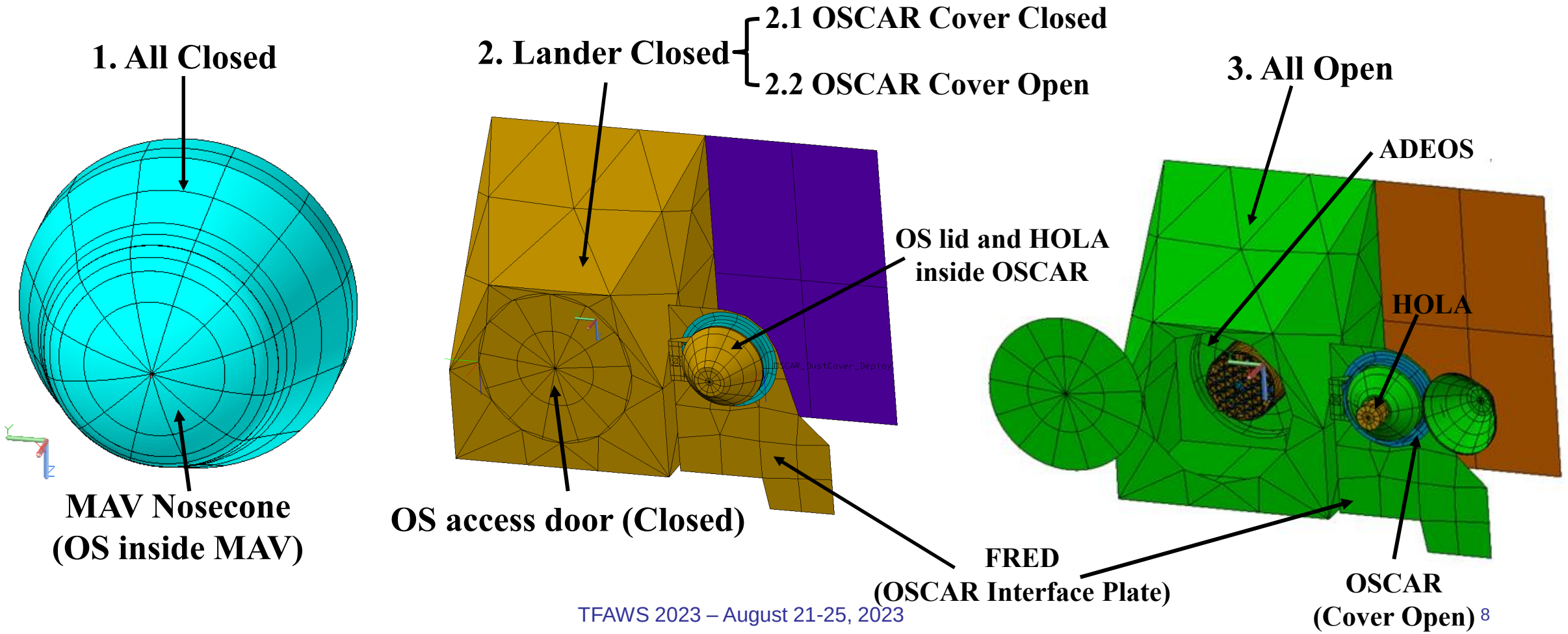


WCC



Mars Surface Model Configurations

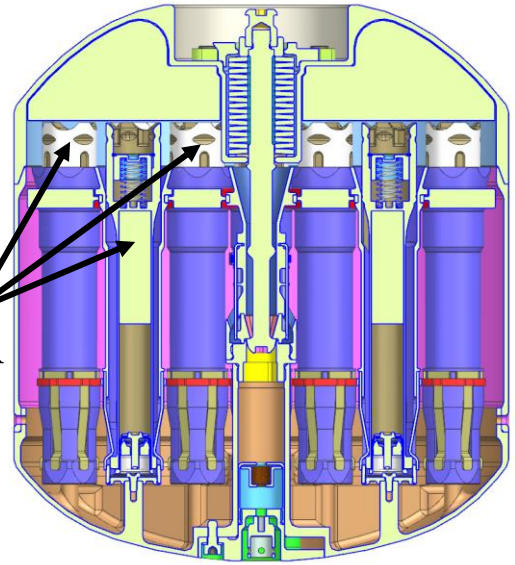
1. All Closed: OS inside MAV; MAV nosecone, OS lid, lander OS access door all closed
2. Lander Closed: MAV nosecone open, OS lid open, lander OS access door closed (OS Lid/OSCAR/HOLA on FRED)
3. All Open: MAV nosecone open, OS lid open, lander OS access door open (OS Lid/OSCAR/HOLA on FRED)



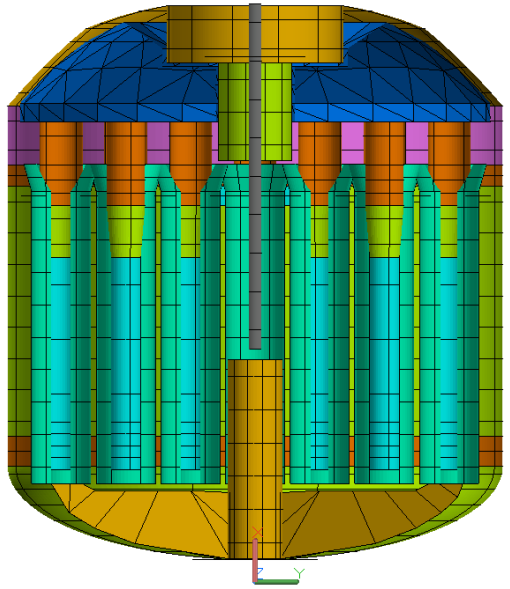
OSS Thermal Desktop (TD) Models Overview

- OS: 6.1 Kg, assume 30 empty RSTA tubes
- OSCAR: 2.2 Kg
- HOLA: 0.7 Kg
- Model uses temperature dependent properties
  - Majority components use Titanium (Ti)

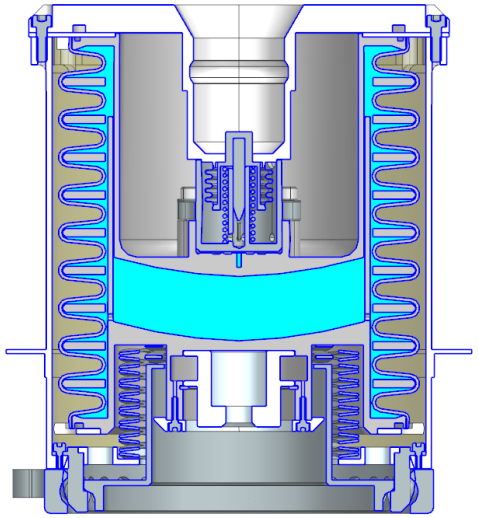
OS CAD (10-12-2022)



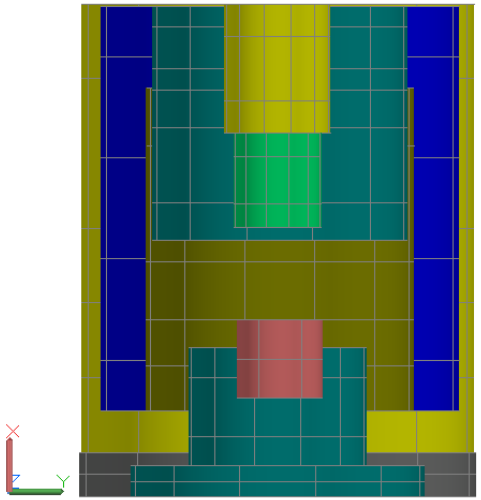
OS Model (Section View)



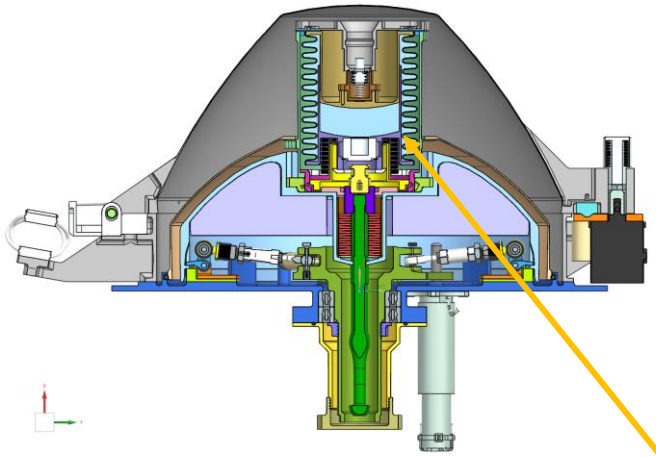
CAD (04-20-2023)



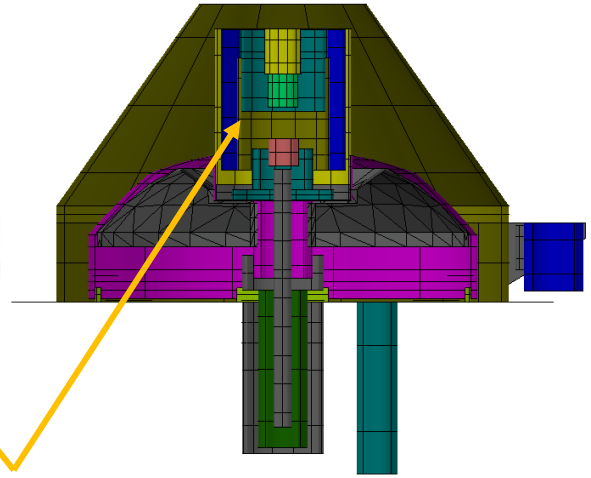
HOLA Model



OSCAR CAD (03-10-2023)



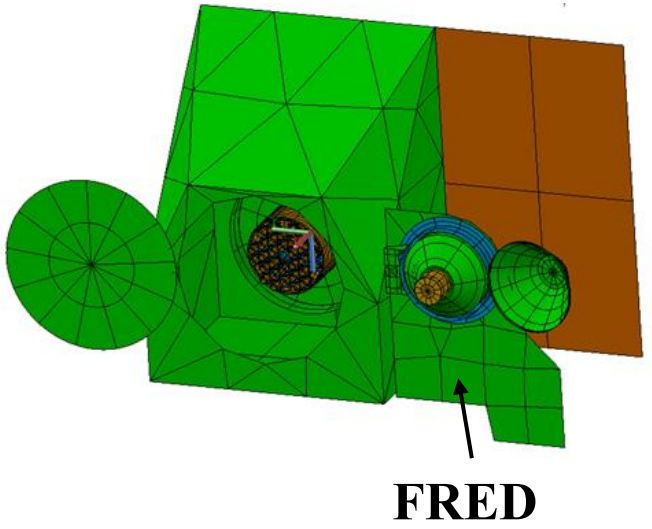
OSCAR Model (Section View)

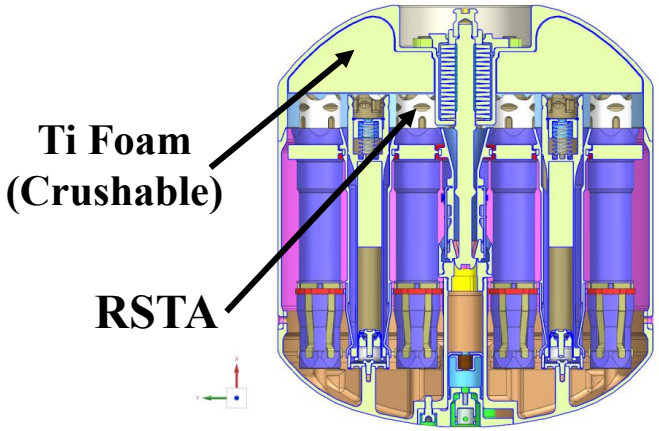


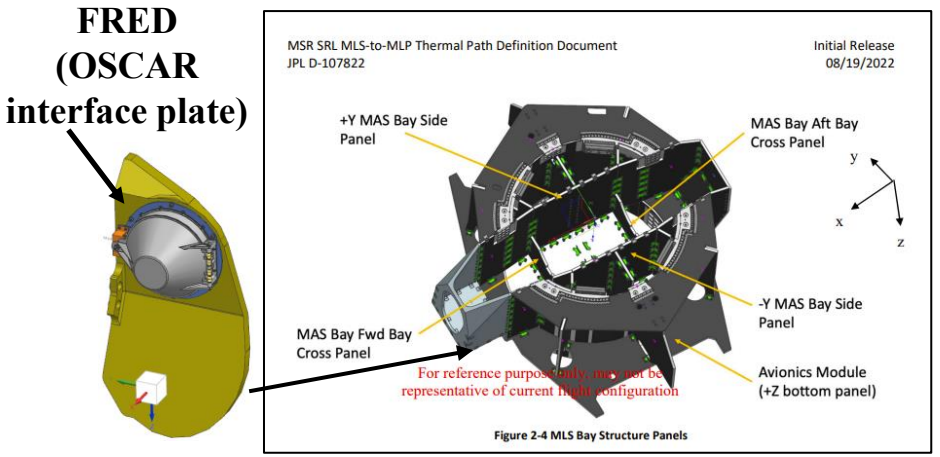
HOLA attached to OS Lid

Key Assumptions

- OS external Sealed Ceranovis white paint (EOL α/ε = 0.34, BOL α/ε = 0.20)
- In WCH, solar absorptivity considers dust coverage
- In WCC, bare metal optical property
- Static gap between RSTA and Ti foam (G = 0 W/C), unless noted otherwise
- Wind convection heat transfer coefficient (h) when lander door open
  - WCH: h = 0.4 W/m²-K
  - WCC: h = 4 W/m²-K
- OSCAR interface plate (Forward Retrieval Equipment Deck, FRED) assumed to the same temperature as SRL forward bay +X panel



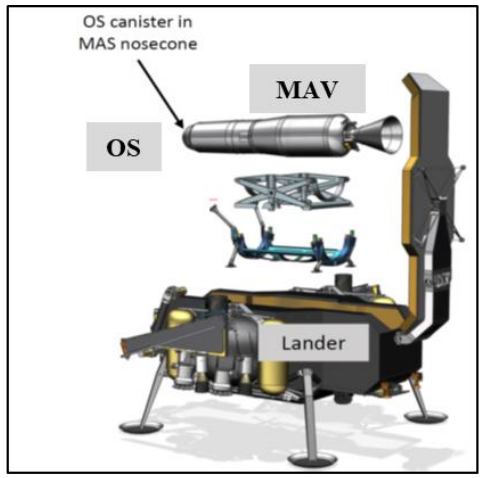




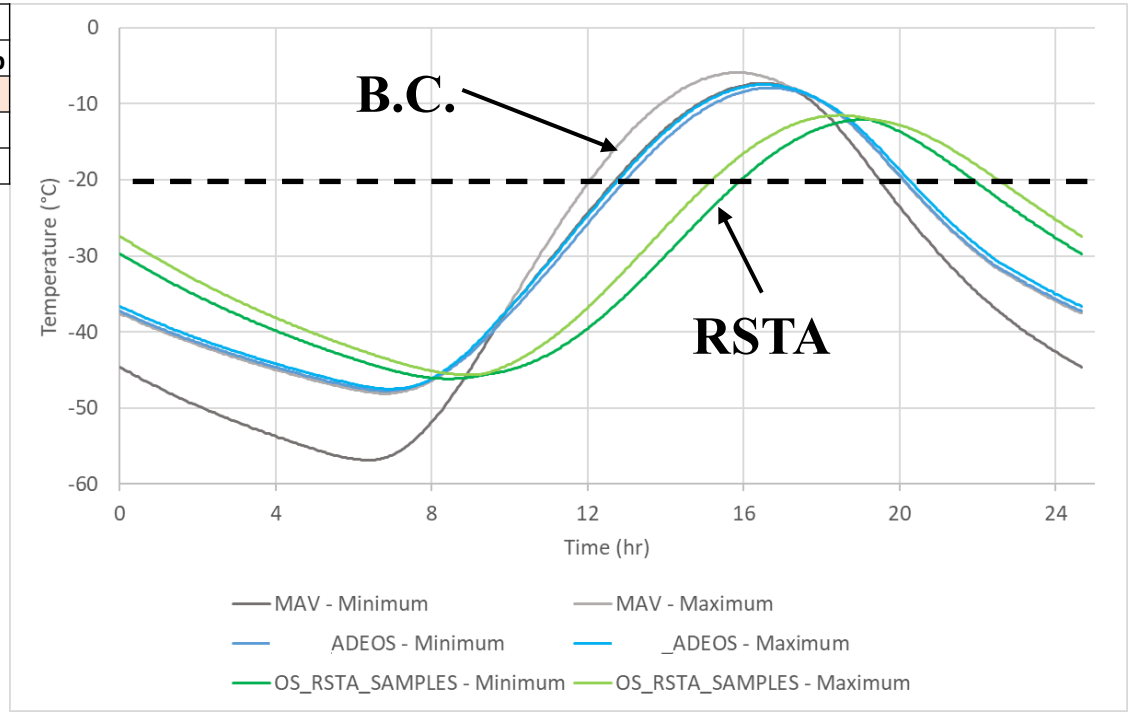
Case 7. Mars Surface, Config 1, All Closed, WCH Op

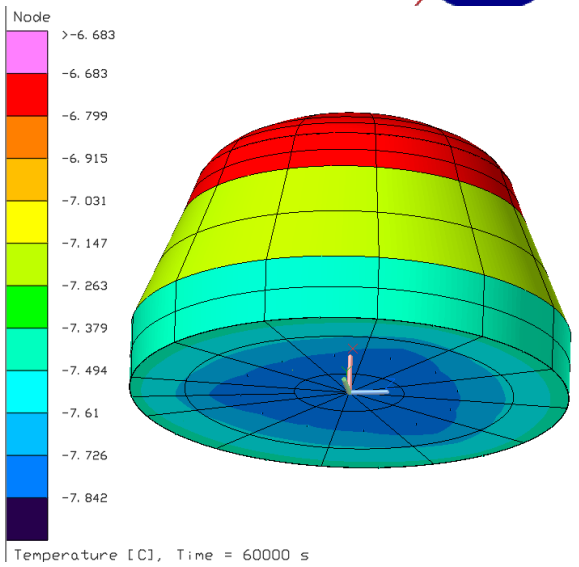
- RSTA lags behind boundary temperatures with muted response
- RSTA -11C maximum with 7 hours of the day above -20C
- ADEOS predicts are for reference only

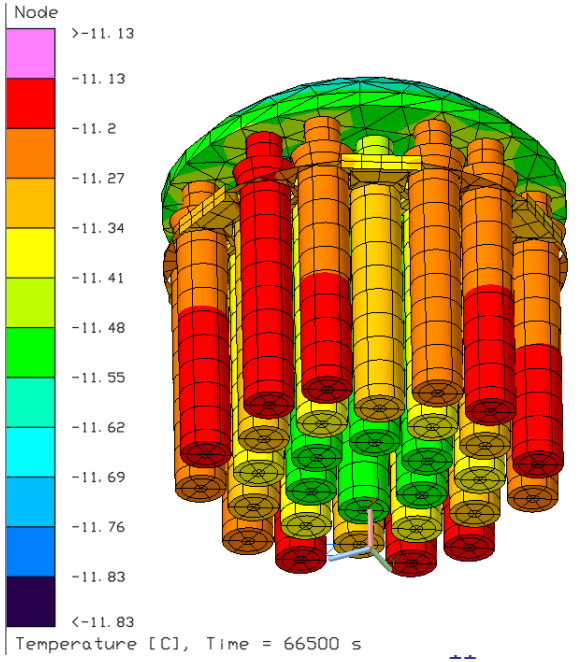
Temperature [°C]	TRT AFT Op		Mars Surface Case 7, all closed, WCH, Op	
Submodel	Min	Max	Min	Max
ADEOS	-105	50	-48.1	-7.4
OS_RSTA_SAMPLES	n/a	30	-46.2	-11.5



Configuration while on SRL Lander



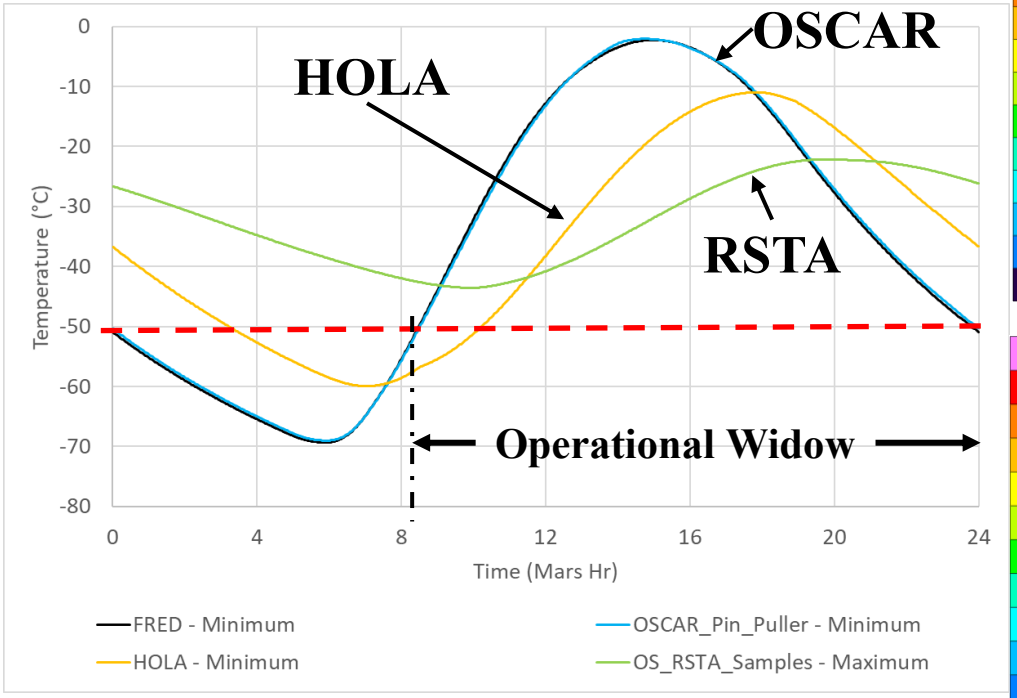


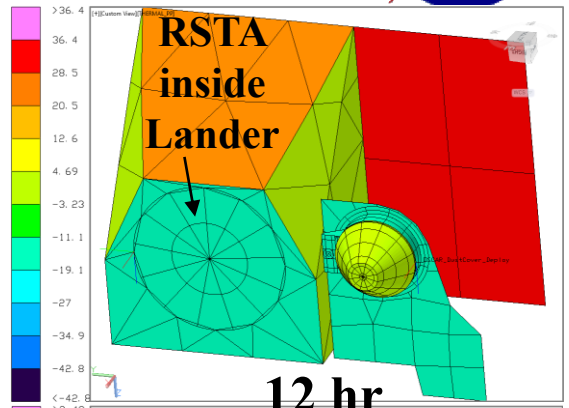


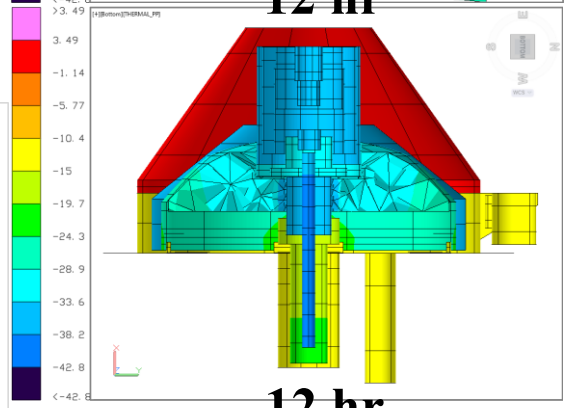
Case 3. Mars Surface, Config 2.2, Lander Closed, OSCAR Cover Closed, WCH

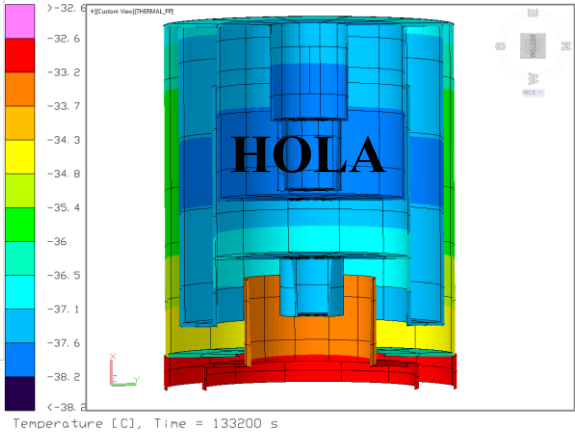
- RSTA (inside lander) -22C maximum
- OSCAR follows boundary FRED's temperature closely
  - OSCAR is above -50C min Op for 15.5 hours of the day (from 8.5 to 24 hr) and requires flight rule to control Op time
- HOLA follows (and bounded by) OSCAR's temperatures with delayed response
  - Non-op min limit of -105C provides HOLA +45C of margin

Temperature [°C]	TRT AFT Op		V13b, WCH, Lander Close, OSCAR Cover Closed 10% Dust Coverage, Low G	
Group	Min	Max	Min	Max
OS_RSTA_Samples	n/a	30	-43.79	-22.14
OSCAR_Min/Max	-50	50	-69.24	-1.87
HOLA	-75	50	-59.95	-9.55





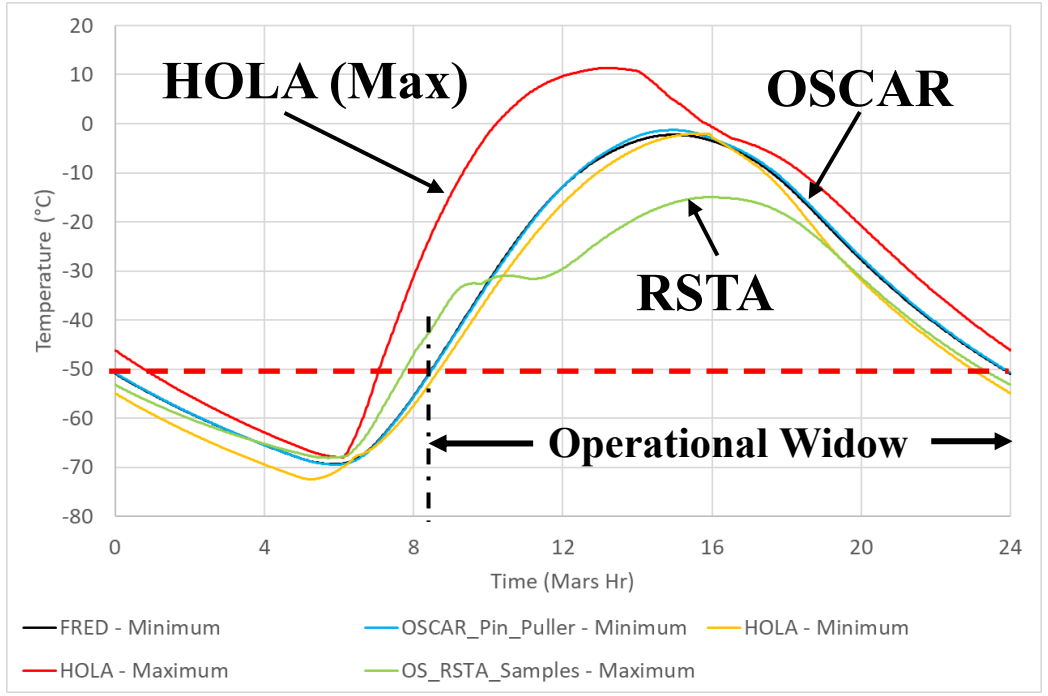


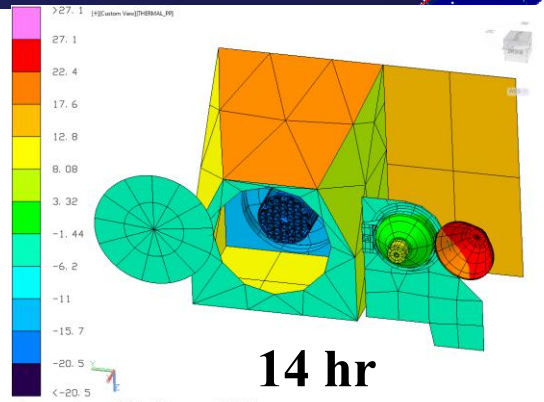


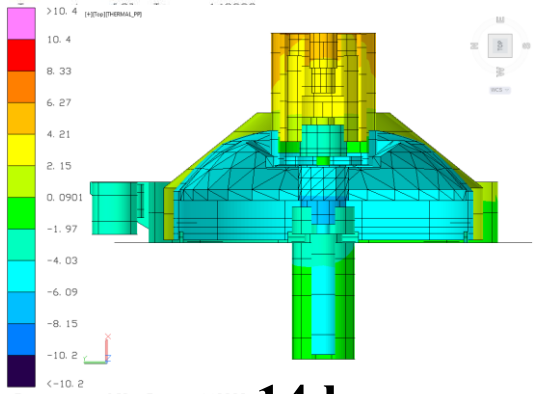
Case 5. Mars Surface, Config 3, All Open, WCH

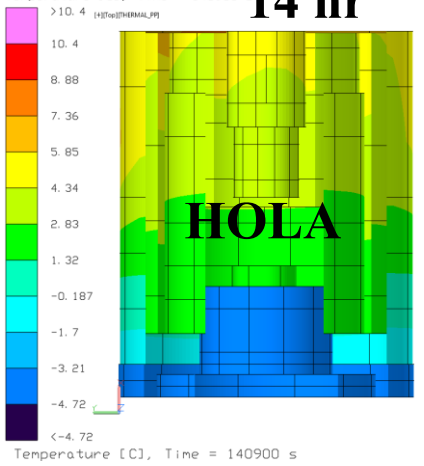
- RSTA -15C maximum with 4 hours above -20C
- OSCAR follows boundary FRED's temperature closely
  - OSCAR is above -50C Op temp for 15.5 hours of the day (from 8.5 to 24 hr) and requires flight rule to control Op time
- HOLA experiences more extreme temperatures due to diurnal change of Mars surface environment
  - Non-op min limit of -105C provides HOLA +33C of margin

Temperature [°C]	TRT AFT Op		V13c, WCH, All Open 10% dust	
Group	Min	Max	Min	Max
OS_RSTA_Samples	n/a	30	-70.06	-14.98
OSCAR_Min/Max	-50	60	-69.49	1.29
HOLA	-75	50	-72.40	11.34





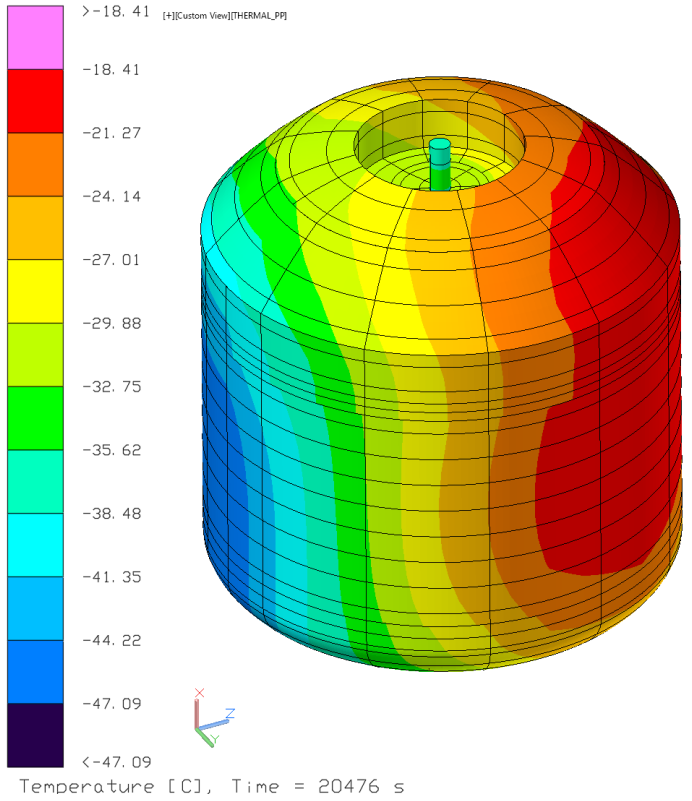


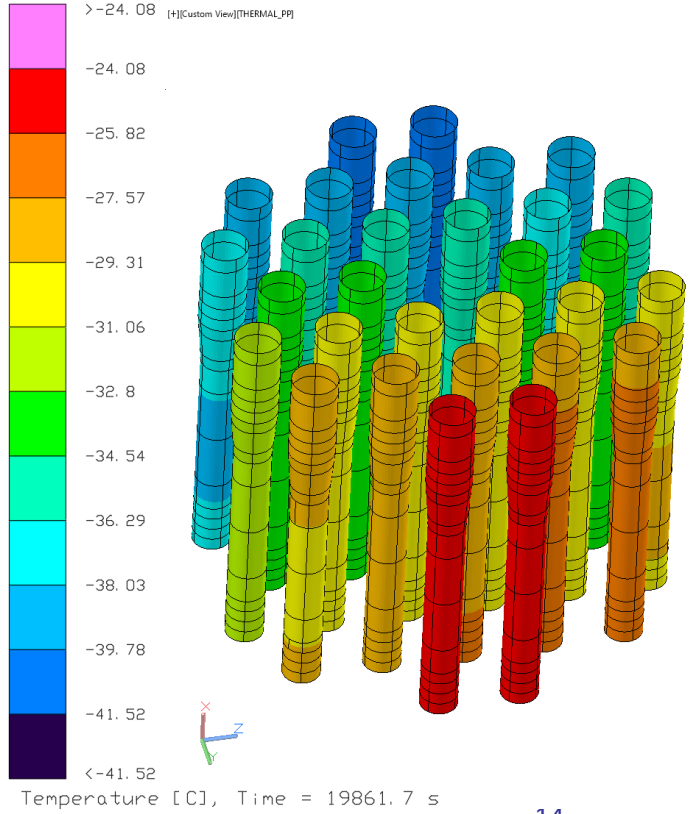


Case 10. Mars Orbit WCH Sun +Y β = 55° (No Spin)

- OS external surface α/e (EOL) = 0.34 (sealed white Ceranovis V-14ACF)
- Spin requirement is < 40 rpm (WCH is 0 rpm with sun on cylinder side)
- Solar flux = 717 W/m², Mars IR = 470 W/m², Albedo = 0.29
- RSTA -24C maximum, within AFT limit of -20C

Temperature [°C]	TRT AFT Non-Op		V11, WCH6, Beta55, Sun+Y OS a/e=0.34, RSTA2Foam 0W/C	
Submodel	Min	Max	Min	Max
OS_RSTA_SAMPLES	n/a	-20	-41.57	-24.08





Select Sensitivities

- RSTA to Foam conductance highly sensitive to large energy inputs into the OS lid
- Mars orbit spin rate of > 0.1 rpm helps reduce RSTA temperatures by 8 – 13C in Mars orbit
- Mars dust 3% area coverage results in 1C temperature increase in RSTA in WCH Mars orbit
- RSTA temperatures in Mars orbit highly sensitive to OS external coating a/e ratio. Higher a/e ratio than 0.4 could cause violations in RSTA temperatures in Mars orbit case w/o spin
- Assumption of 1 RSTA vs 30 RSTAs results in 3C increase in All Open configuration on Mars surface
- Lander azimuth and landing orientation angles (<16-deg) on Mars surface do not have large impact on OSS temperatures

Conclusions

- Analyzed OS on Mars surface, ascent and on-orbit, and captured appropriate environments and configurations
- OSS follow MAV or lander's boundary temperatures when attached to MAV or lander
- RSTAs meet temperature requirements in above mentioned environments with current external coatings
- OSCAR and HOLA show compliance with TRT AFTs. Flight rules are required to control Op time
- High temperature and gradients identified in OS hardware during ascent without MAV nose cone. Require further analysis
- RSTA could potentially violate temperature requirements if external optical a/e ratio is larger than a threshold

- Future Work
  - Further refine ascent inputs and predictions
  - Further identification of OS external optical coating
  - Continue model updates as OSS design evolves
  - Further define test campaign and hardware requirements
  - Provide gradients to mechanical team as needed
  - Update temperature requirements as needed

Acknowledgements

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Backup

Acronyms

- MSR = Mars Sample Return
- SRL = Sample Retrieval Lander
- MAV = Mars Ascent Vehicle
- OS = Orbiting Sample
- OSS = Orbiting Sample Subsystem
- RSTA = Returnable Sample Tube Assembly
- ERO = Earth Return Orbiter
- OSCAR = Orbiting Sample lid Containment and Release
- HOLA = Handling of the OS and Lid Assembly
- ADEOS = Assembly to holD and Eject the OS
- FRED = Forward Retrieval Equipment Deck
- AFT = Allowable Flight Temperature