



TARDIS TVAC Heat Switch Design & Function

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Presented By
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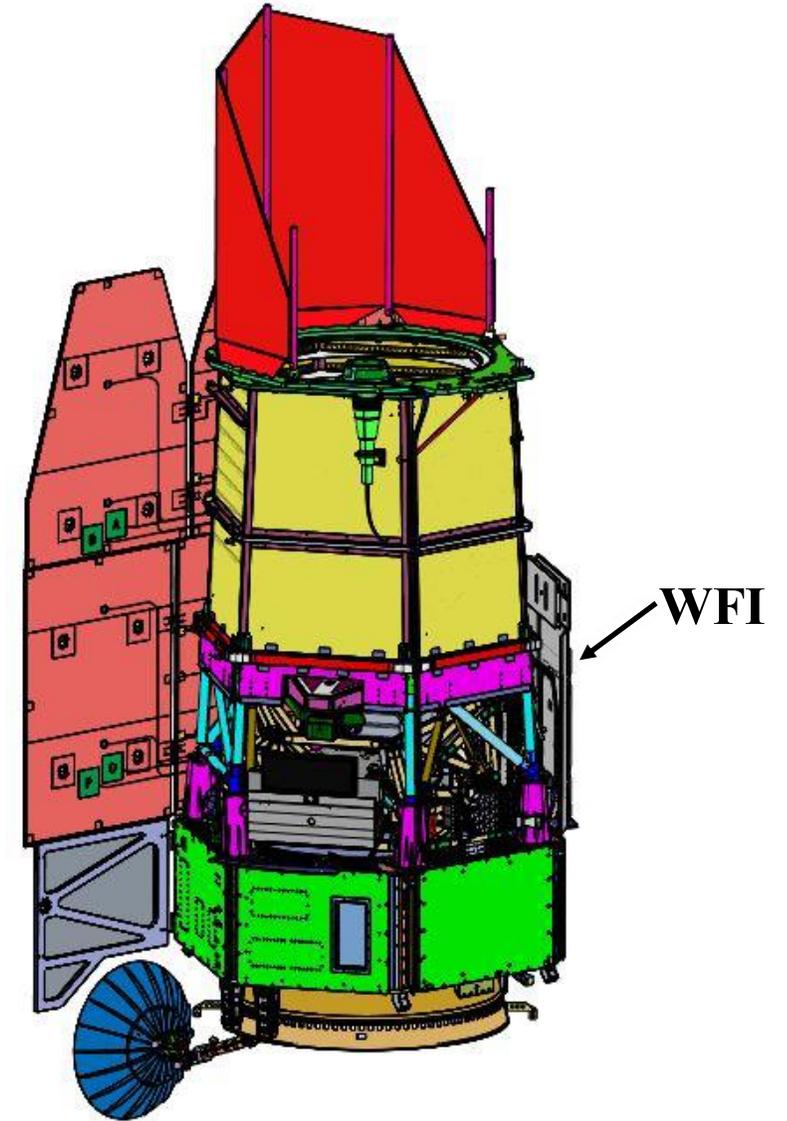


Agenda

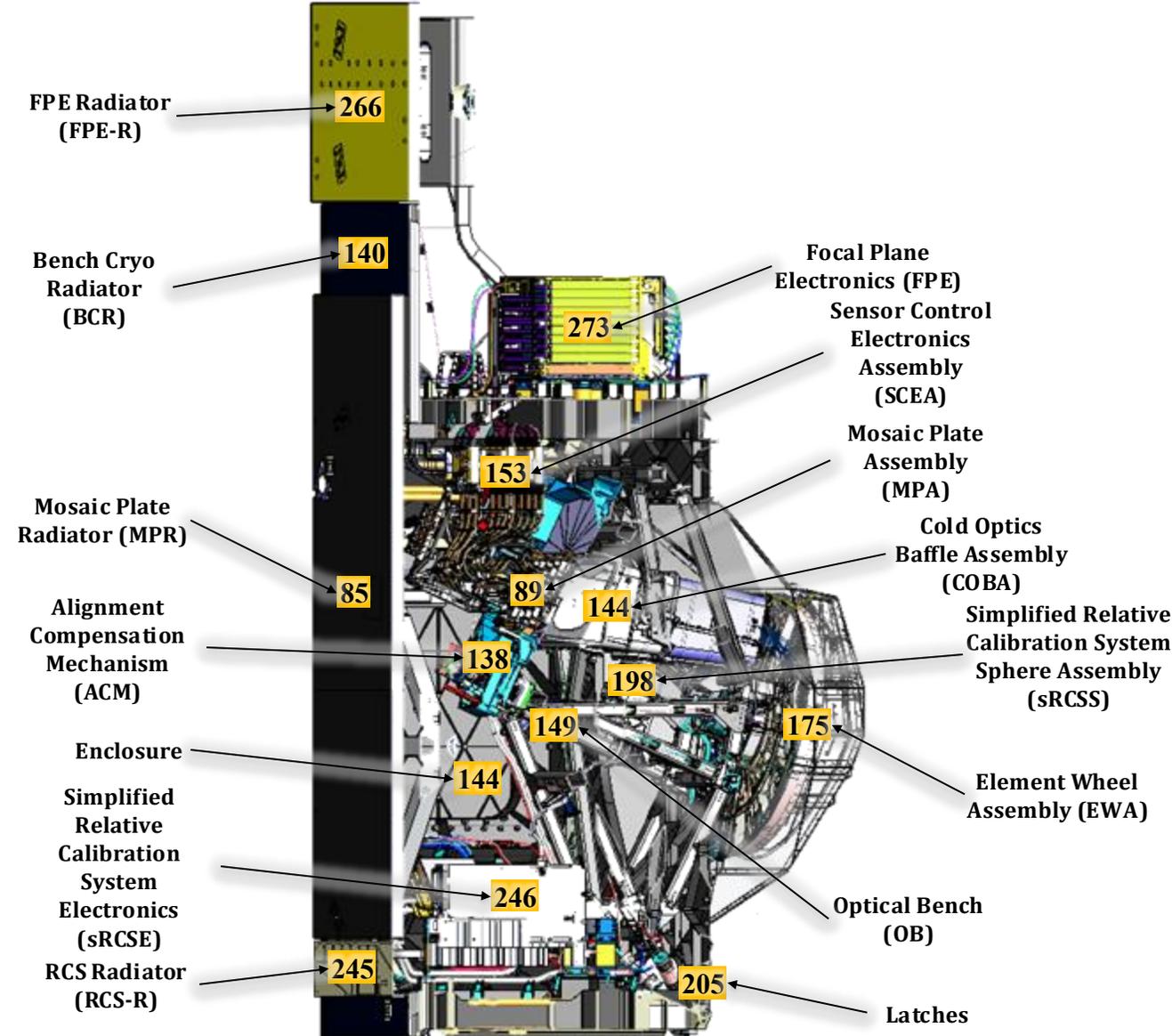


- Introduction
- Background
- TARDIS Design & Overview
- TARDIS Performance in WFI TVAC Campaign
- Future Applications
- Conclusion

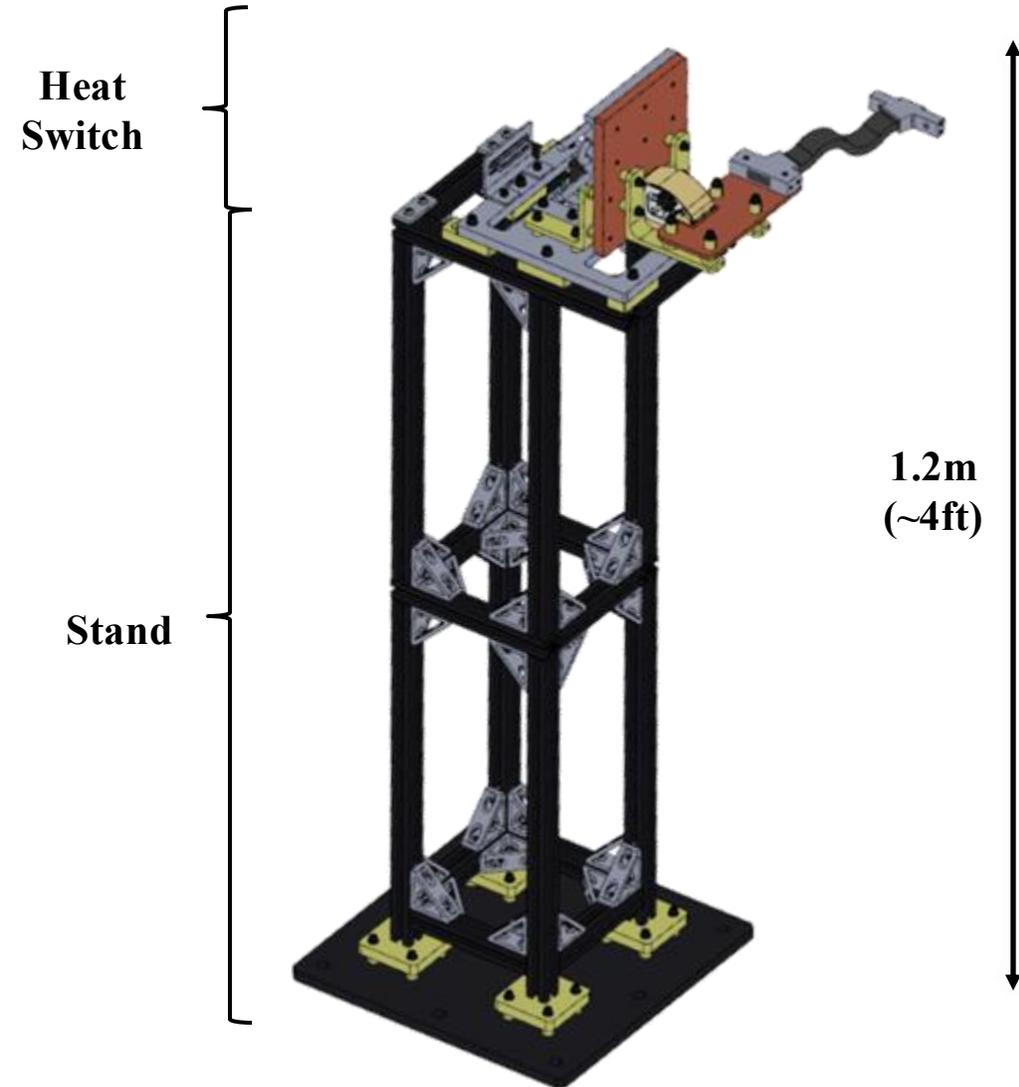
- Wide Field Instrument (WFI)
 - Cryogenic IR instrument on Roman Space Telescope (RST)
 - Underwent instrument-level TVAC testing at Ball Aerospace/BAE Systems in Colorado
 - Temperatures range from room temperature to 85K
- TVAC Transitions
 - Significant transition times during TVAC, especially for cryogenic instruments
 - Transitions via radiation heat transfer are very slow at cryogenic temperatures due to T^4 relation



- WFI has four radiators that cool different parts of the instrument
 - BCR: Cools enclosure, OB, COBA, SCEA, ACM, EWA
 - MPR: Cools MPA
 - FPE-R: Cools FPE
 - RCS-R: Cools sRCS
- EWA, ACM, and COBA inside the enclosure are thermally isolated from the rest of the BCR-cooled system
 - Drives transition times (especially cooldowns) to be very long
- Wanted GSE heat switch to connect to enclosure to help cool internally isolated components as fast as possible to save schedule

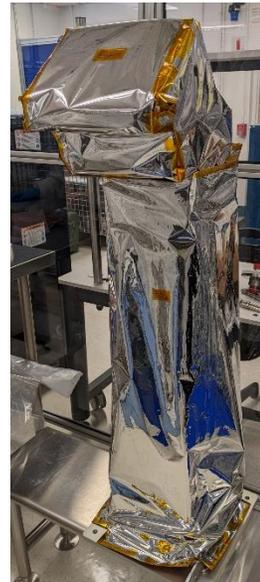
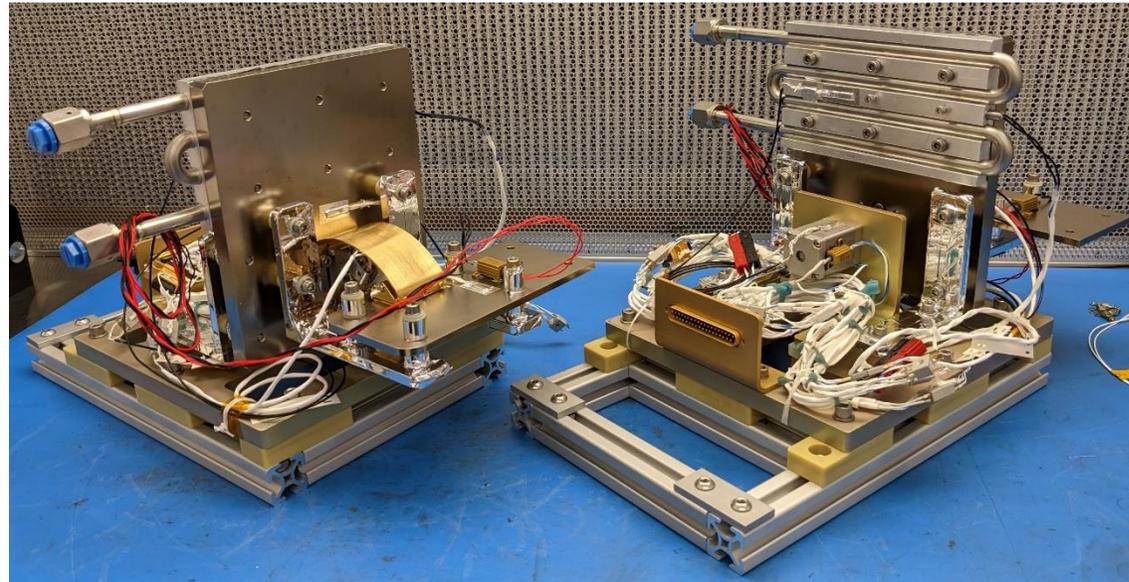
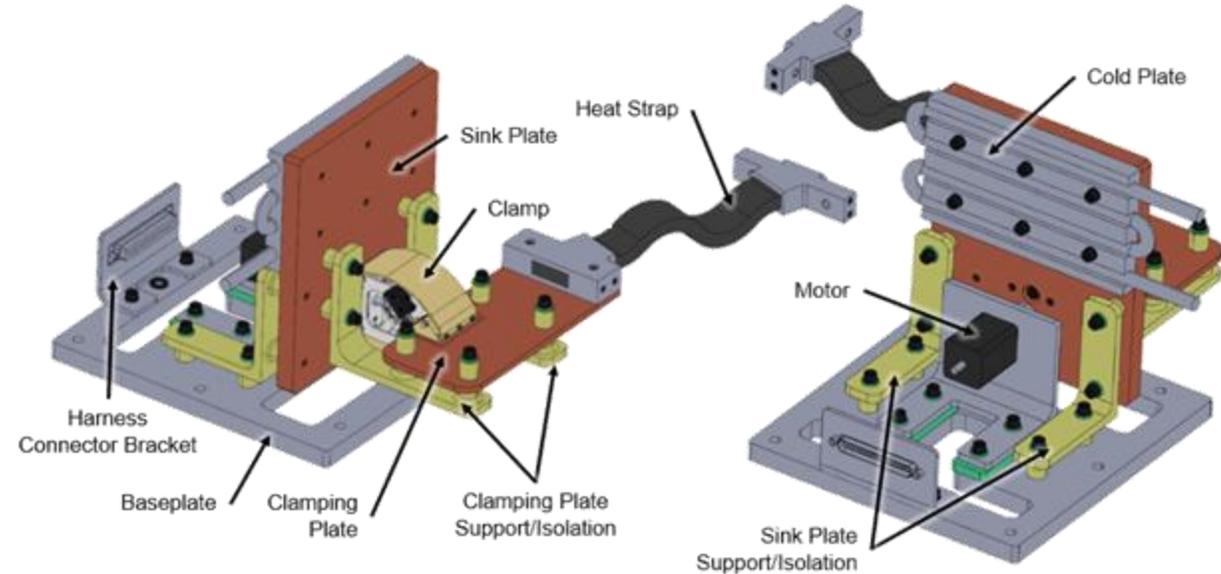


- TARDIS: Thermal Acceleration Rate Device for Integrated Systems
 - TVAC GSE heat switch based off Lucy L'Ralph AZQ (Active Zero-Q) Heat Switch Design
- Purpose
 - Decrease WFI TVAC transition times during WFI TVAC campaign while also allowing for thermal balances
 - Need for high conductance
 - Allows TARDIS to drive WFI temperatures cold/hot for transitions
 - Need for low conductance
 - Reduces TARDIS thermal influence for WFI testing and balances
 - Allows for Zero-Q operation



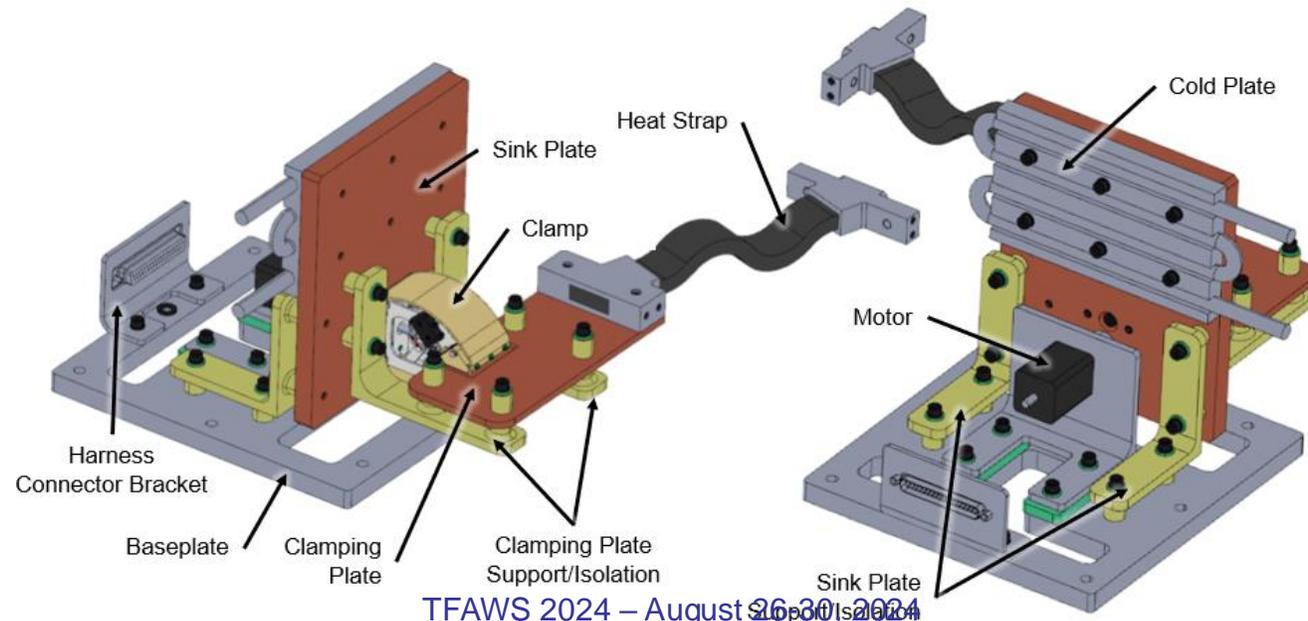
TARDIS CAD Model

- Pyrolytic Graphite thermal strap is attached to WFI structure
- Thermal strap attached to the clamping plate w/ e-Graf
- Clamping plate is thermally isolated from the rest of TARDIS w/ Ultem supports
- When engaged, the clamp thermally connects the clamping plate with the controllable cold plate



TARDIS Operating Modes

	Engaged	Disengaged	Disengaged Zero-Q
WFI TVAC Stage	WFI Transitions	WFI Testing Plateaus	WFI Balances
Vice Clamp	Engaged	Disengaged	
Cold Plate	On: Set hot/cold depending on transition (controlled with LN2/GN2 and/or heater)	Off: Temperature allowed to float	On: Set to measured WFI temperature to maintain Zero-Q



- Temperature Sensors

- 5 PRTs
 - Read by Lakeshore 336

- Heaters

- Cold plate Heater
 - 50 W cartridge heater
 - PID controlled by Lakeshore 336 from a PRT
- Motor Survival Heater
 - 10 W Vishay Dale-Ohm heater (two 15 Ω in series)
 - PID controlled by Lakeshore 336 from a PRT

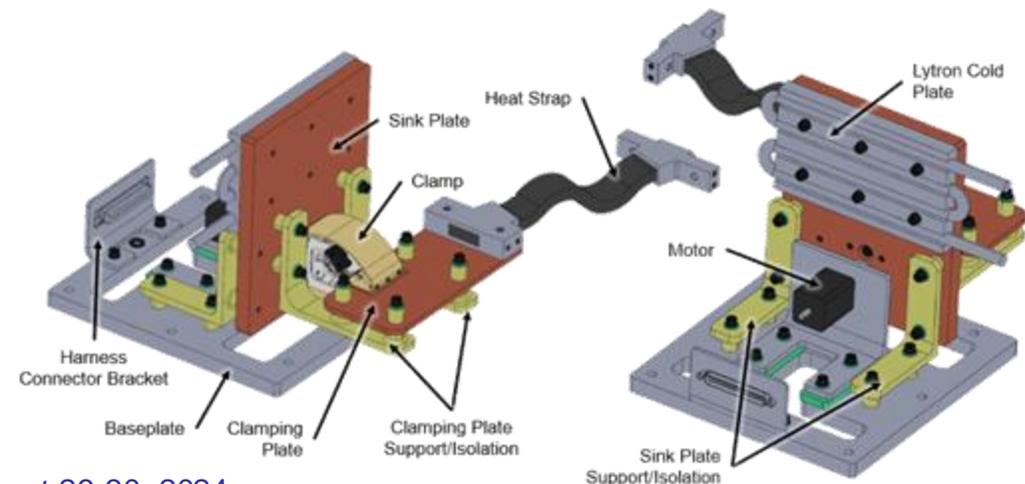
- Cold Plate

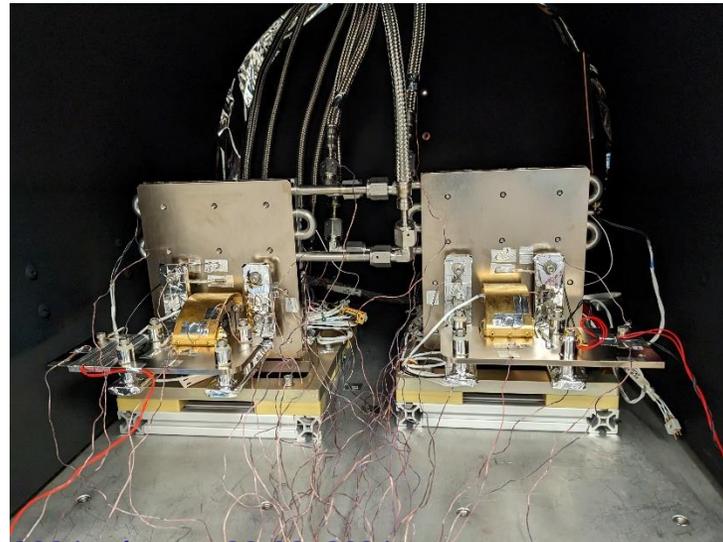
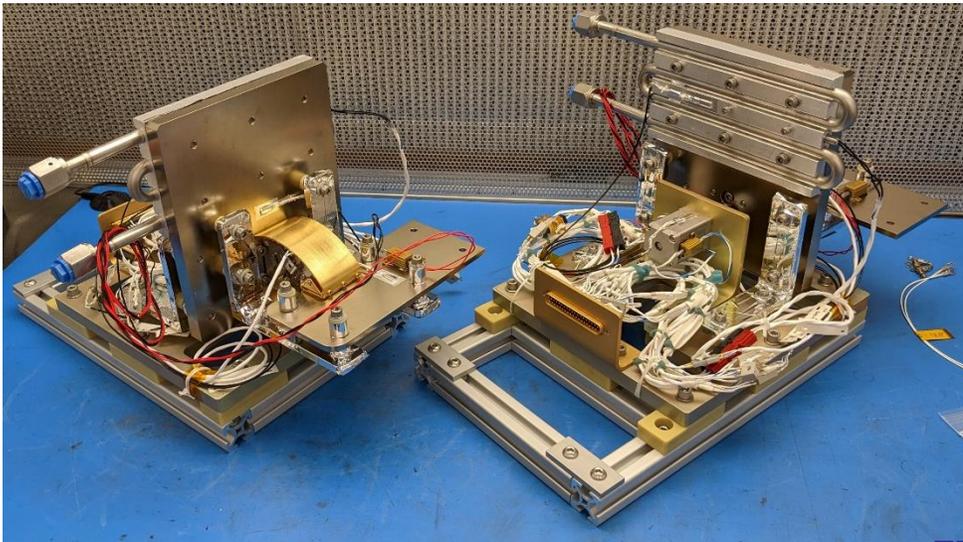
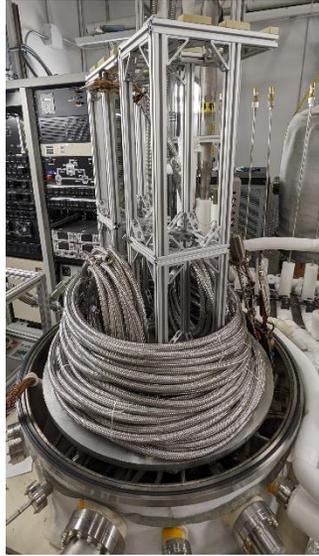
- 3/8" OD VCR fitted Lytron cold plate

- 40' and 60' flex hoses
- Solenoids controlled from Lakeshores

- Control

- Lakeshore 336 (3 total for both TARDIS units)
- Computer & controllers for motors







GSFC TVAC - TARDIS Performance



- Averaged Performance (TVAC measured data from clamping plate to cold plate)
 - Engaged: 0.3068 W/K
 - Disengaged: 0.0026 W/K
 - Turndown Ratio: 117:1

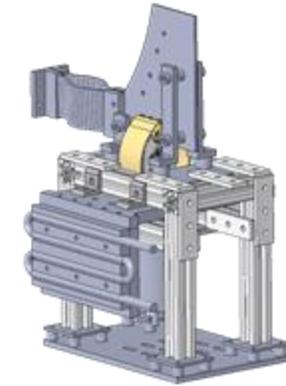
		Disengaged		Engaged	
		Cold	Hot	Cold	Hot
TARDIS 1	Test Heater [W]	0.10	0.10	5.00	5.00
	Clamping Plate [K]	174.20	225.07	126.17	212.30
	Cold Plate [K]	108.39	199.35	107.70	197.85
	Conductance [W/K]	0.0015	0.0039	0.2707	0.3459
	Average Conductance [W/K]	0.0027		0.3083	
	Turndown Ratio	114 : 1			
TARDIS 2	Test Heater [W]	0.10	0.10	5.00	5.00
	Clamping Plate [K]	176.68	227.27	125.12	212.39
	Cold Plate [K]	108.14	199.24	107.59	197.01
	Conductance [W/K]	0.0015	0.0036	0.2853	0.3251
	Average Conductance [W/K]	0.0025		0.3052	
	Turndown Ratio	121 : 1			

TARDIS vs L'Ralph AZQ* Heat Switch

	TARDIS	L'Ralph AZQ*
Approximate Height	1.2m	0.4m
QTY in TVAC	2	1
Motor Survival Temp	253 K	77 K
TVAC Interface Temperature	> Payload	< Payload
Heat Strap	Pyrolytic Graphite x1	Braided Copper x2
Clamping Plate Orientation	Horizontal	Vertical
Engaged Conductance	0.3068 W/K	0.416 W/K
Disengaged Conductance	0.0026 W/K	0.0008 W/K
Turndown Ratio	117	520



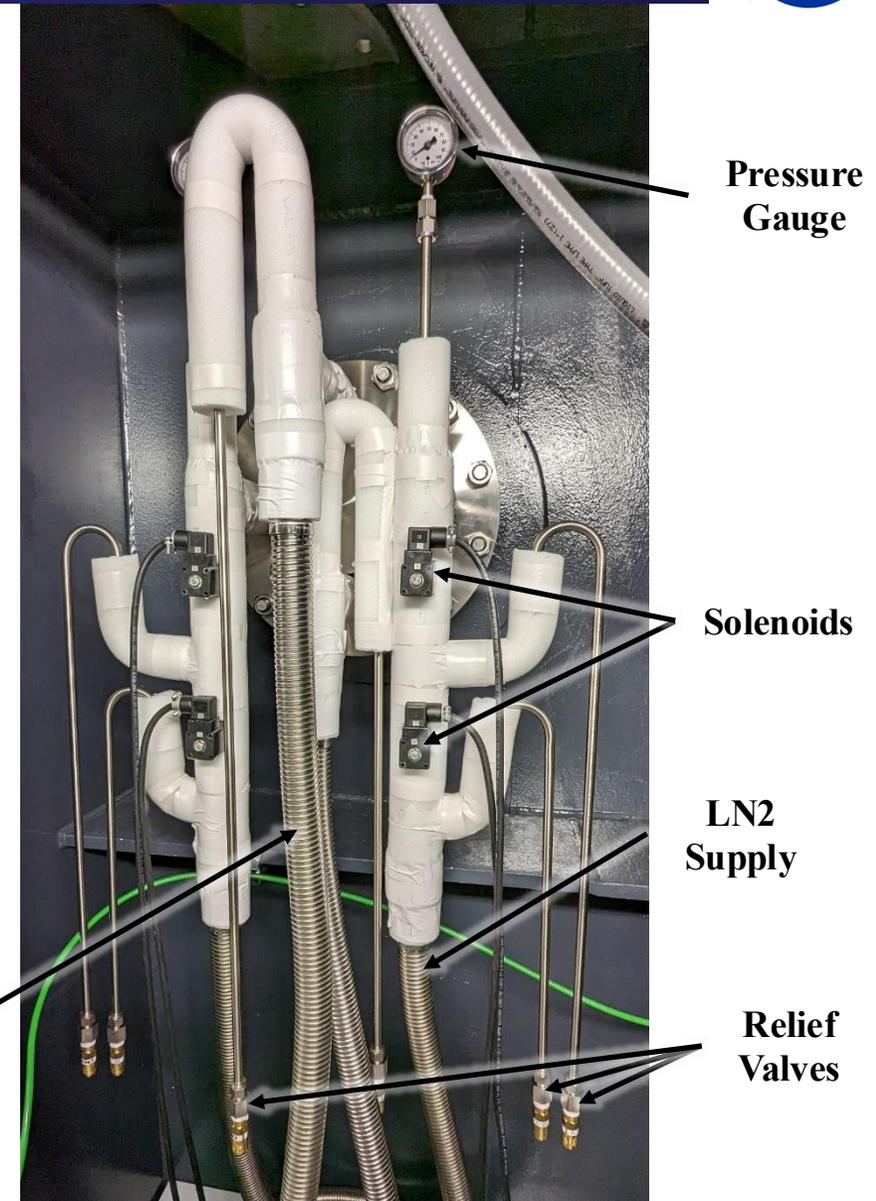
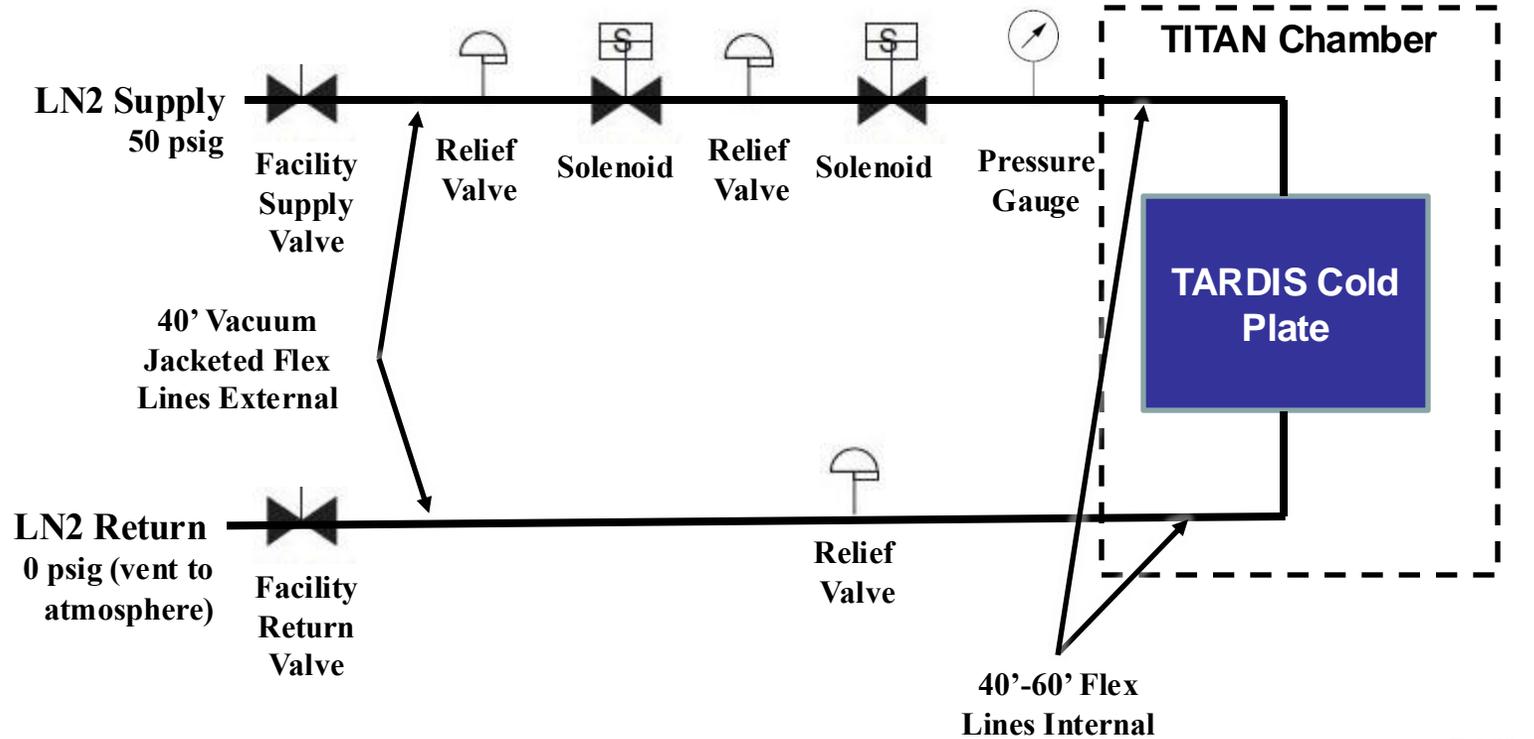
TARDIS



L'Ralph AZQ

**J. Rodriguez-Ruiz, and D. Bae, "Use of Mechanical Heat Switch to Speed up TVAC Transitions on Flight Hardware Below 200K," presented at the International Conference on Environmental Systems, 2021, 52.*

LN2 Control System (per TARDIS)



Thanks to Frank Robinson for designing, assembling, and installing this hardware!



TARDIS User Interface



mydesc Console - RST - TARDIS [myhost.adm.2995027]

Console Help

Devices Graphs Listings Figures Pages Limits Alerts Derived Scripts Utilities Debug Streams

- Tardis Master
 - Tardis Control 1
 - Tardis Control 2
 - Motor Control 1
 - Motor Control 2
 - Power Supply 1
 - Web Switch 1
 - Web Switch 2

TARDIS 1 (South)

Power: ● ON OFF

PS1.VOLTAGE: 19.991
PS1.CURRENT: 0.164
States : 0 1

Home Motor Control

Engage Disengage

Turn + Turn -

MOT1.CMD: o1400 Limit: 0

Motor Heater

PRT_105: 292.429
LS3_HTR1_P: 0.000

Setpoint 280.00 On Off

Lytron

PRT_101: 0.000 Heat Strap
PRT_102: 292.000 Clamp Plate
PRT_103: 291.969 Sink Plate
PRT_104: 291.947 Cold Plate

Setpoint Power (On) (Off)

200.00 0.000

Flow1 Flow2

On On

LN2 Setpoint 202.500

Flow 0 0

Ctrl: De- Activate

TARDIS 2 (North)

Power: ● ON OFF

PS1.VOLTAGE: 19.991
PS1.CURRENT: 0.164
States : 0 1

Home Motor Control

Engage Disengage

Turn + Turn -

MOT2.CMD: Empty Limit: 0

Motor Heater

PRT_205: 292.974
LS3_HTR2_P: 0.000

Setpoint 280.00 On Off

Lytron

PRT_201: 0.000 Heat Strap
PRT_202: 291.882 Clamp Plate
PRT_203: 291.848 Sink Plate
PRT_204: 291.812 Cold Plate

Setpoint Power (On) (Off)

300.00 0.000

Flow1 Flow2

On On

LN2 Setpoint 310.000

Flow 0 0

Ctrl: De- Activate

Export Screen as a PNG... Dynamic Mode Static Mode... Dynamic Mode

Advanced Options

Duplicate Screen Rename Screen... Delete Screen

Move Screen Up Move Screen Down

Edit Mode Save Screen Export Screen...

CONTROL DATA

LS1 LS2 LS3 VS1 VS2 MOT1 MOT2 PS1

gs448thermal@gs448... mydesc Console - RST - ...

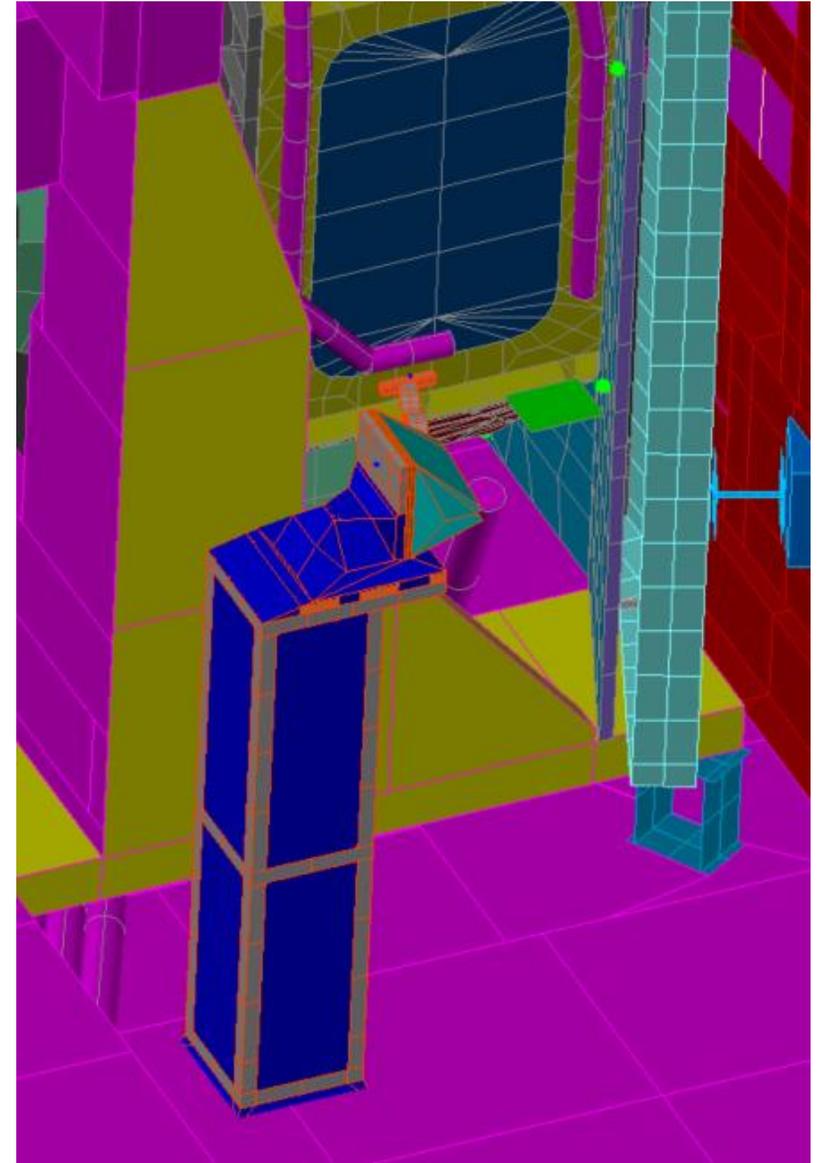
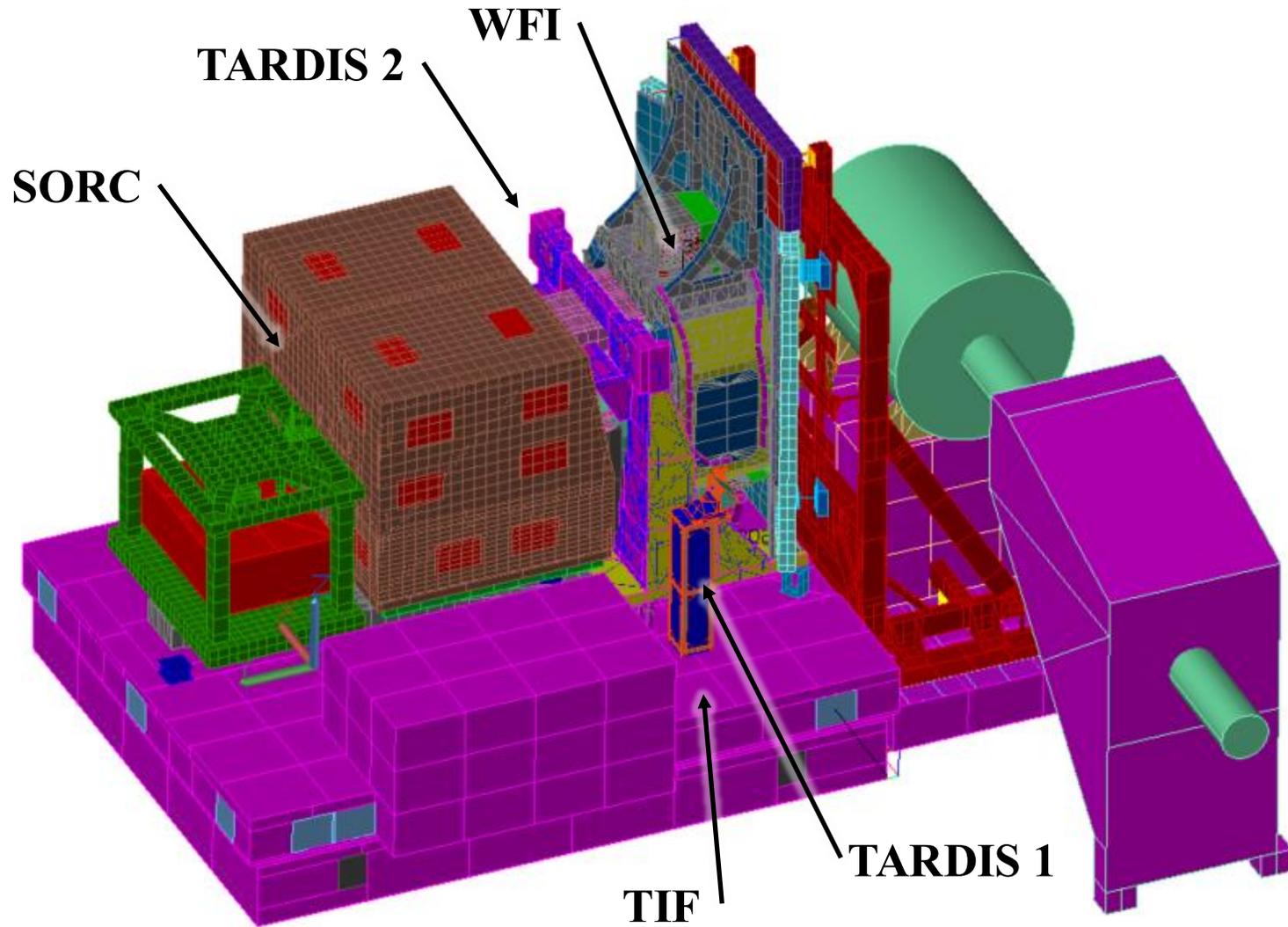
Thanks to Allen Lunsford for setting up the motor & software!

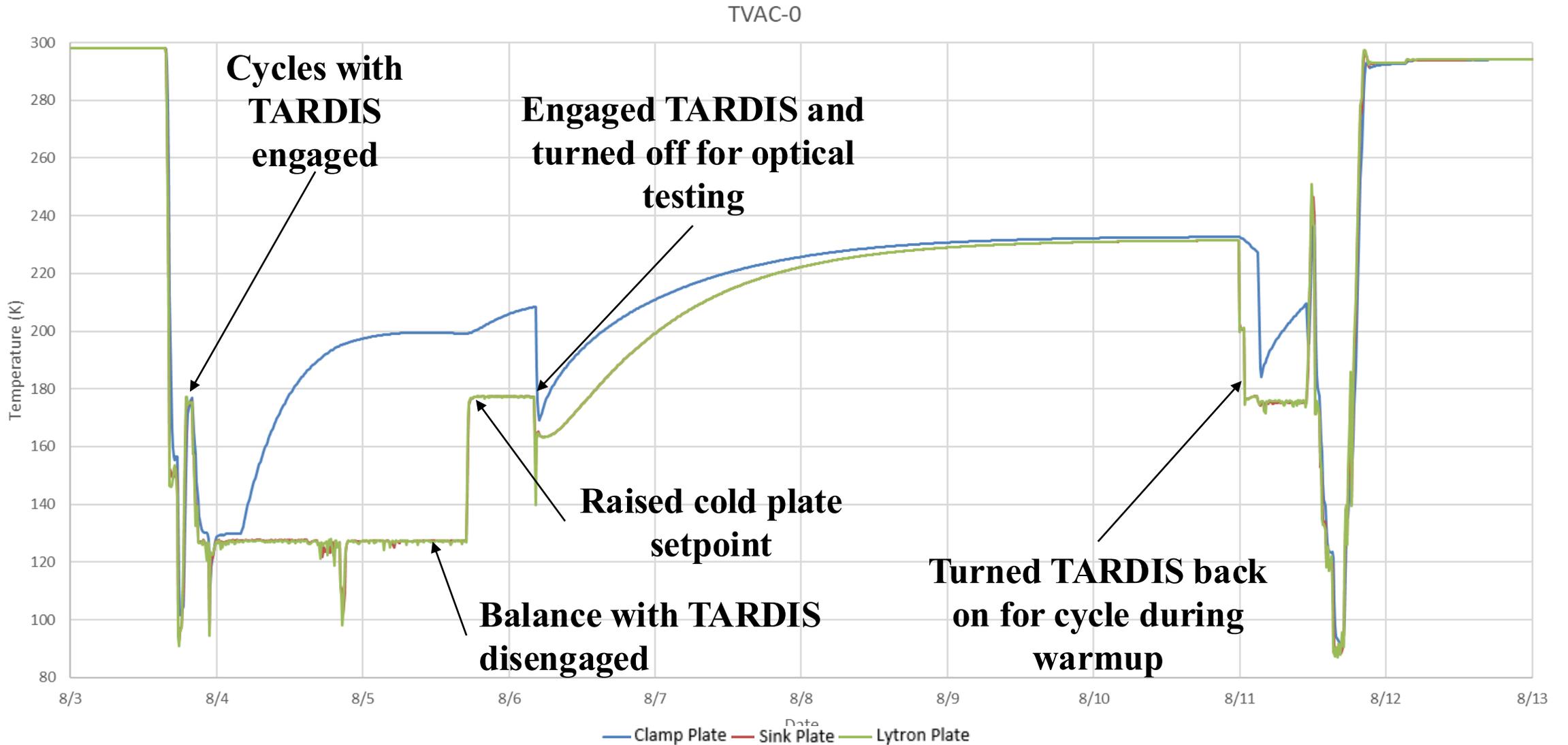


TVAC at Ball/BAE Overview

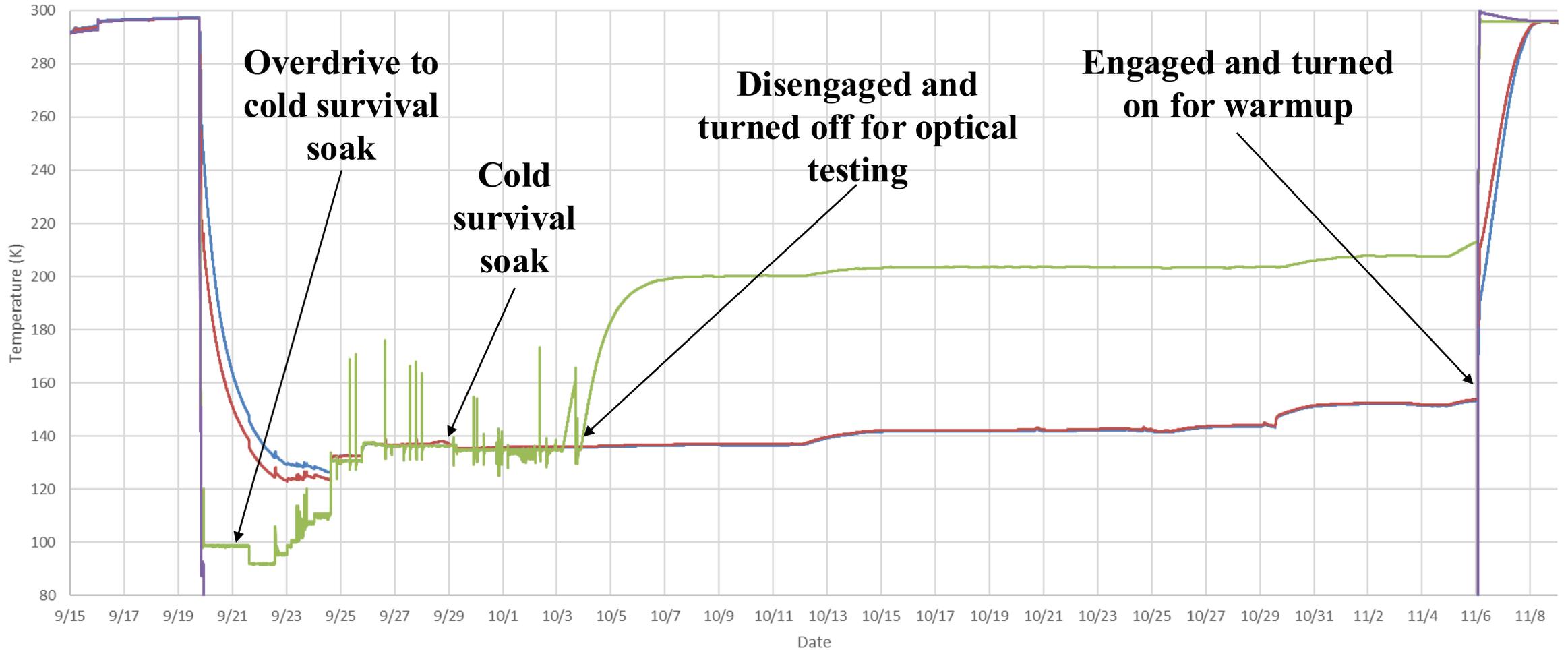


- TARDIS was included in three TVAC tests in BAE Titan Chamber in Boulder, CO
- Project wanted TARDIS LN2 flow disabled during all optical testing to prevent potential jitter
- TVAC-0 (7/23/23 – 8/13/23): GSE only, no flight hardware
 - TARDIS thermal straps not installed since they had no WFI to connect to
 - PRT-203 (TARDIS-2 sink plate) stopped working while cold, didn't come back during warmup
- TVAC-1 (9/10/23 – 11/9/23): Baseline performance test of WFI
 - First test of TARDIS while connected to WFI
 - TARDIS used to drive cooldown/warmup and zero-Q for cold qual balance
 - PRT-104 (TARDIS-1 cold plate) stopped working while cold, came back during warmup
- TVAC-2 (3/13/24 – 5/16/24): Post-vibe/acoustics WFI performance test
 - TARDIS used to drive two cooldowns/warmups and zero-Q for cold survival balance



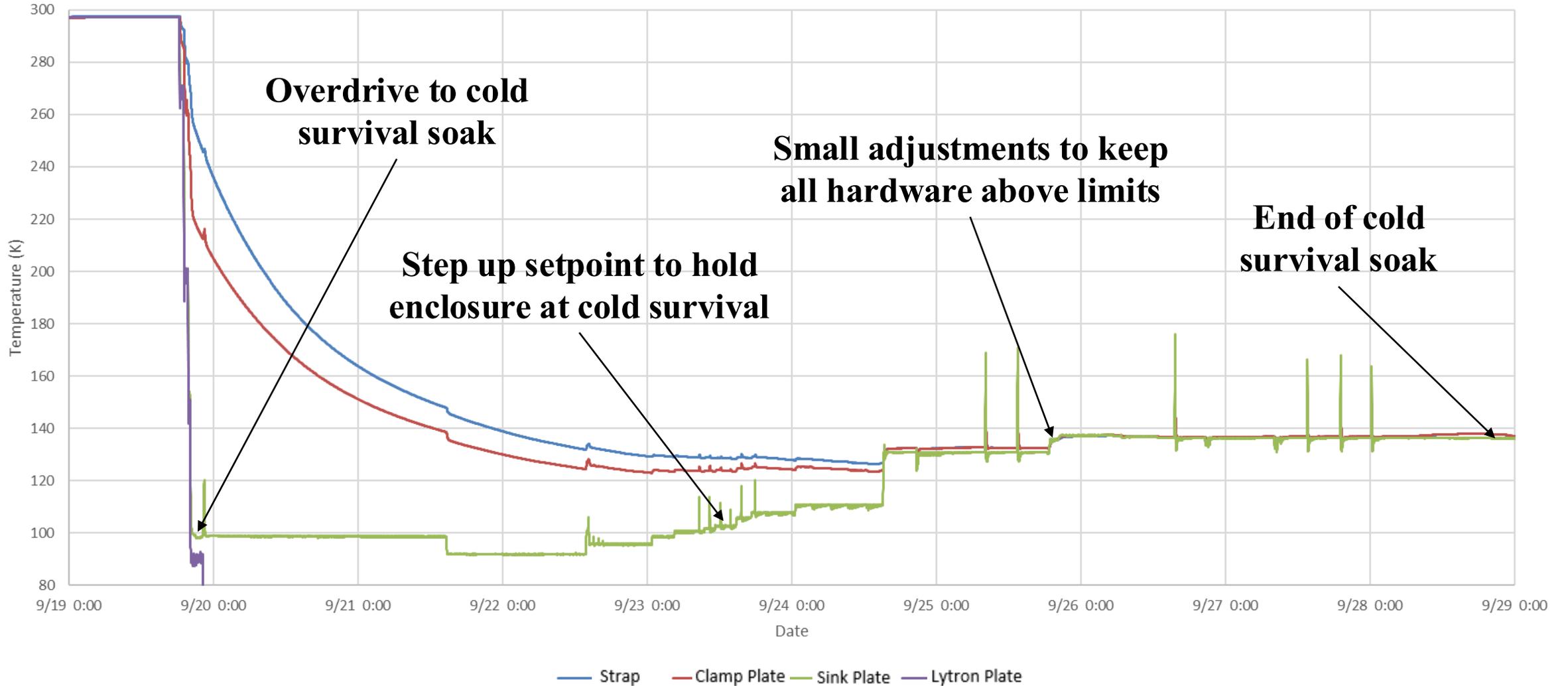


TVAC-1

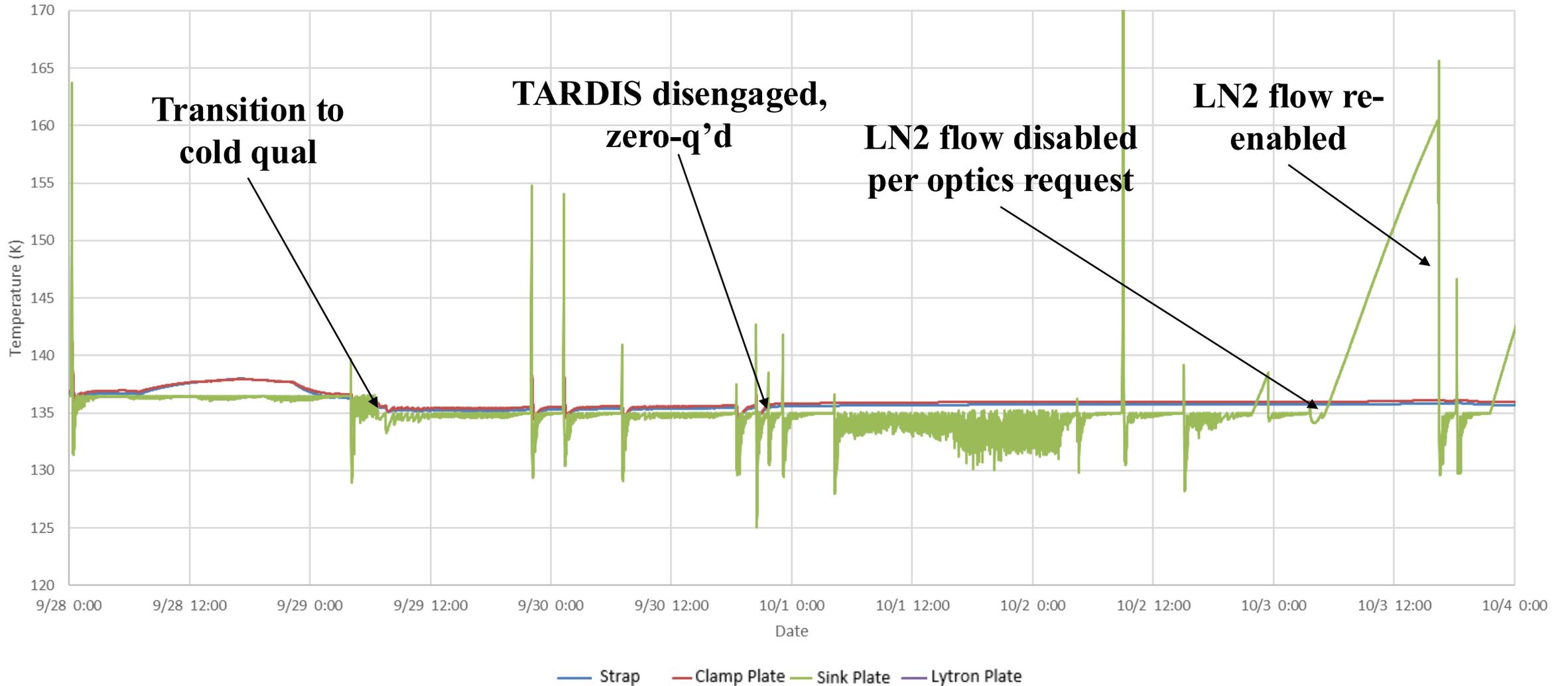


— Strap — Clamp Plate — Sink Plate — Lytron Plate

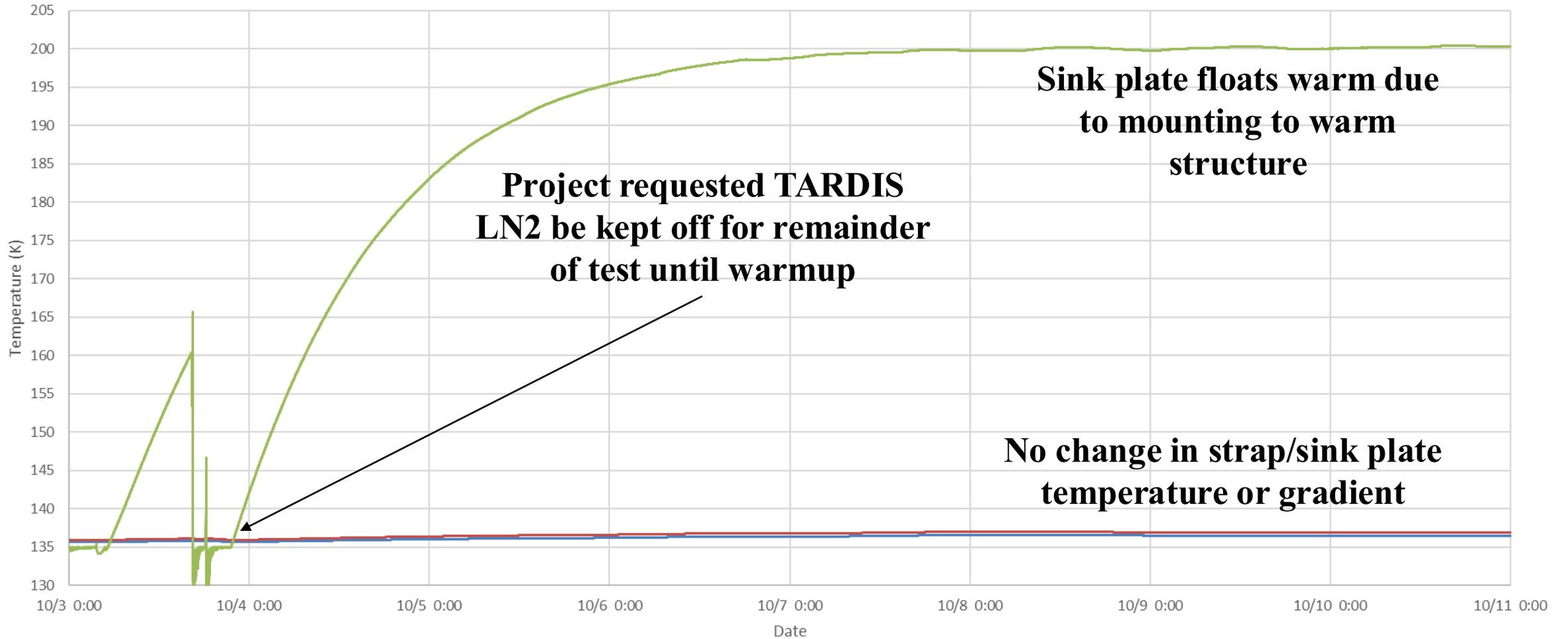
TVAC-1



TVAC-1



TVAC-1



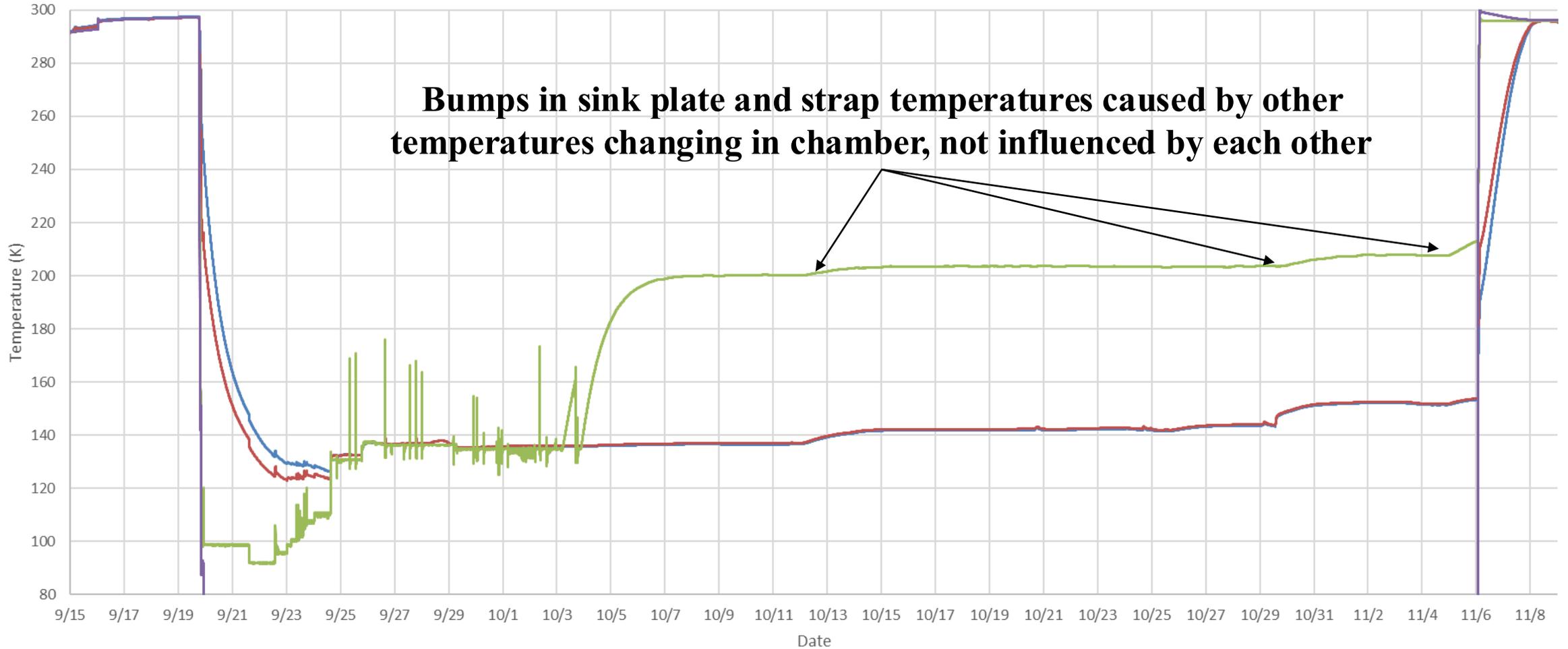
Project requested TARDIS LN2 be kept off for remainder of test until warmup

Sink plate floats warm due to mounting to warm structure

No change in strap/sink plate temperature or gradient

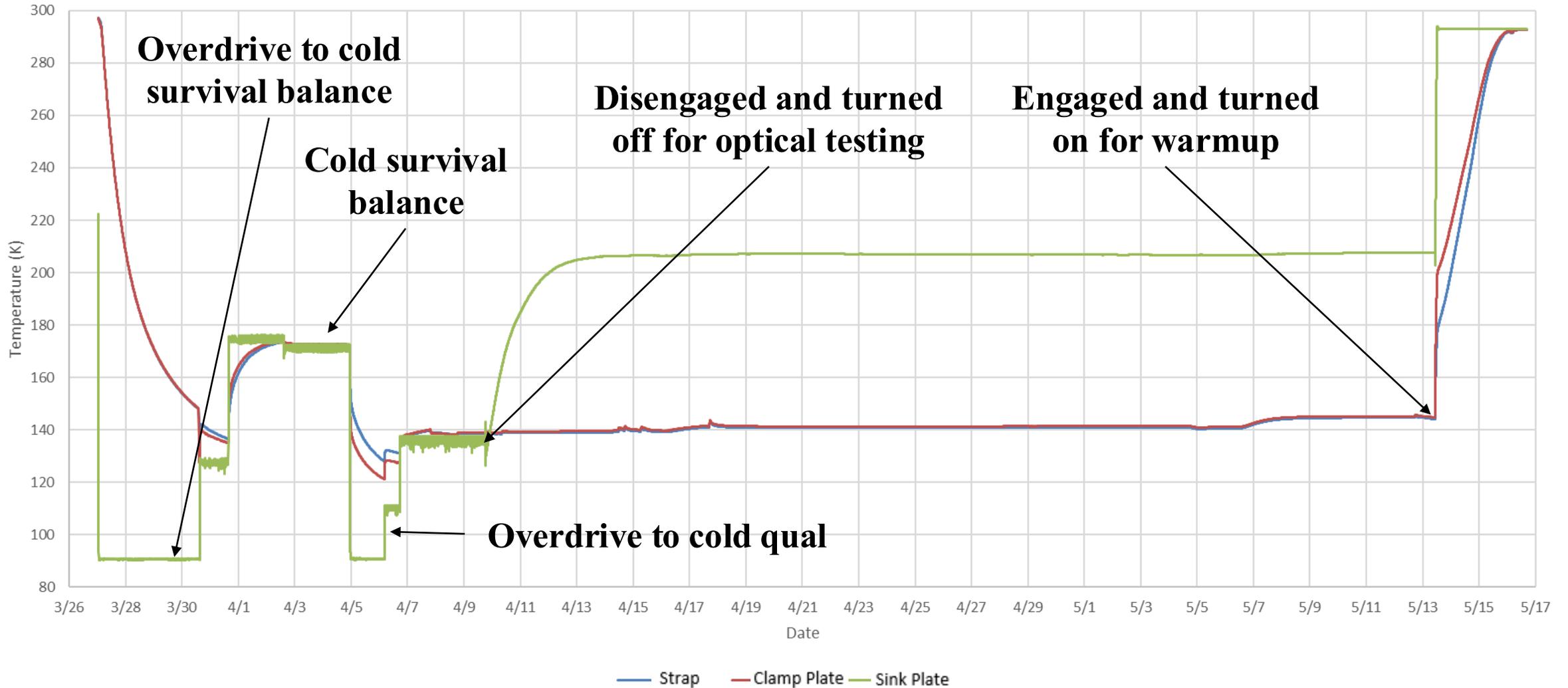
— Strap — Clamp Plate — Sink Plate — Lytron Plate

TVAC-1

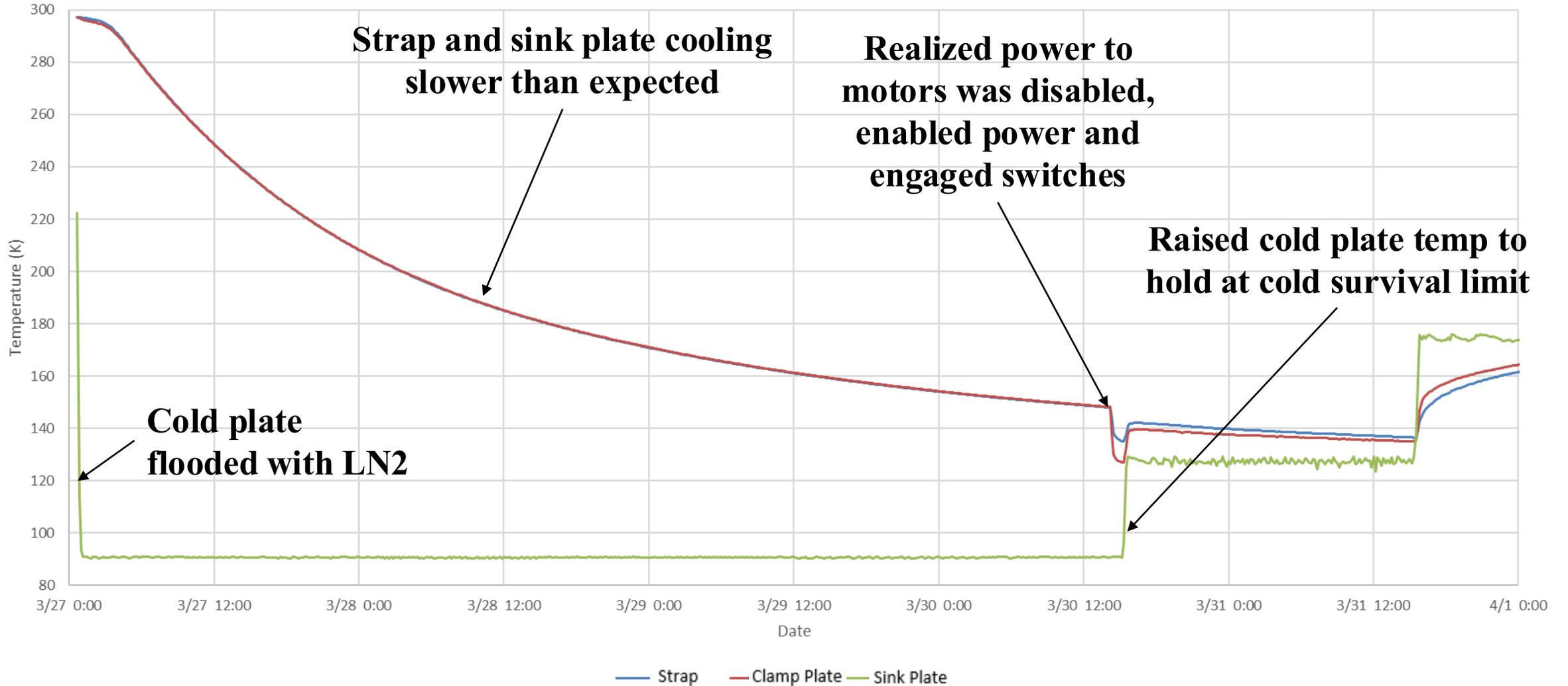


— Strap — Clamp Plate — Sink Plate — Lytron Plate

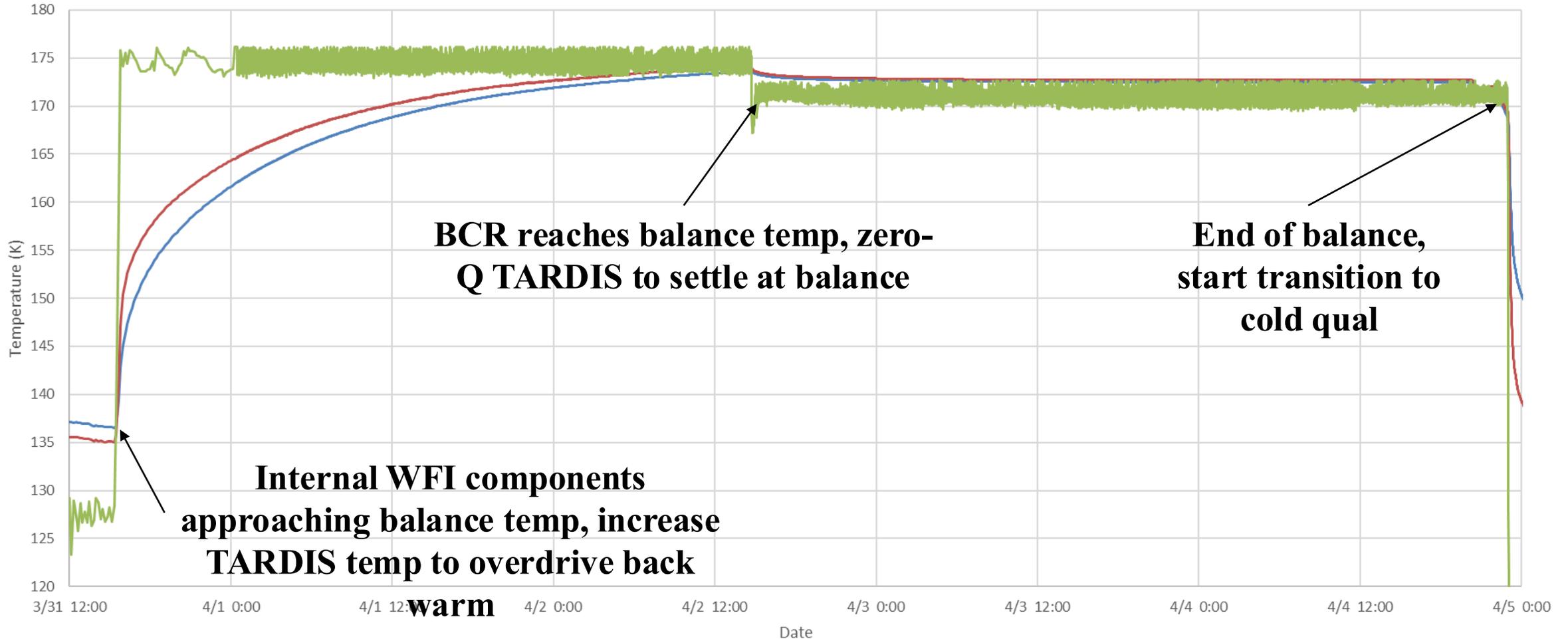
TVAC-2



TVAC-2

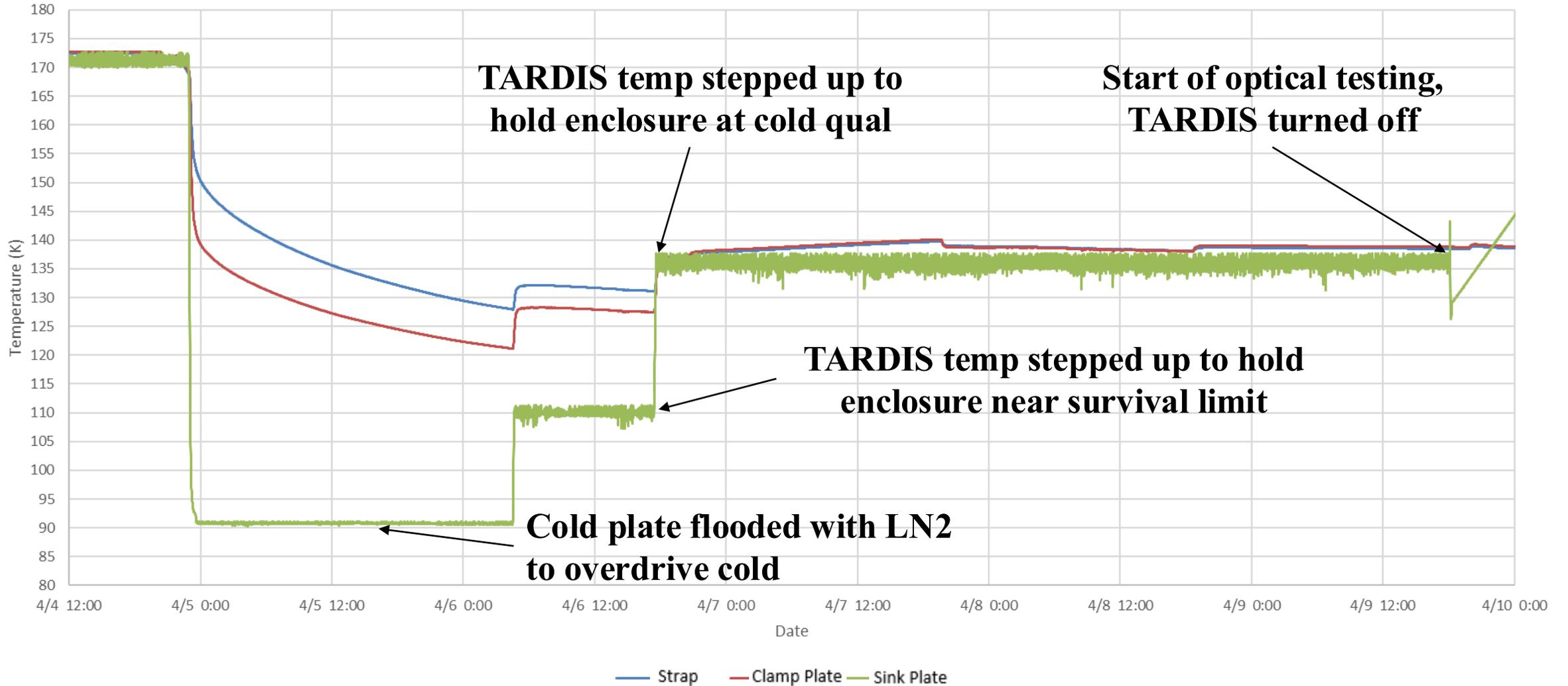


TVAC-2

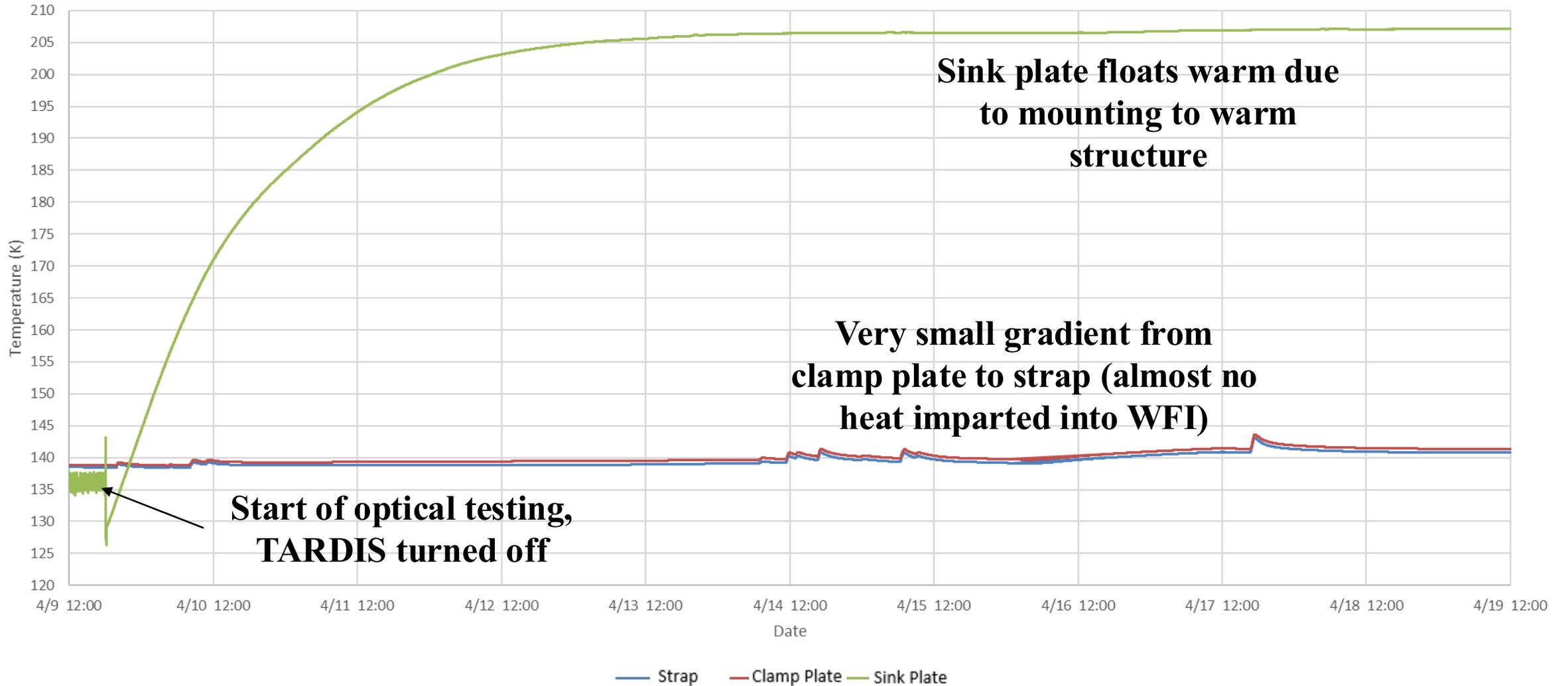


— Strap — Clamp Plate — Sink Plate

TVAC-2



TVAC-2



**Start of optical testing,
TARDIS turned off**

**Sink plate floats warm due
to mounting to warm
structure**

**Very small gradient from
clamp plate to strap (almost no
heat imparted into WFI)**



Lessons Learned



- **Control System Instability**

- Occasional spikes in the sink plate temperature, possibly due to warm GN2 flowing through the cold plate instead of LN2.

- **PRT Failures**

- Lost sensors 104 & 203 (20% of all sensors!)
- Even though lost sensors, had enough redundancy in similar temperature zones (and on the other TARDIS) to maintain stability.
- Able to change control sensor on the fly

- **Blanket Install**

- MLI was installed at the very end. Not a lot of room to maneuver with other GSE/hardware in the way

- Didn't have a blanket tech available to install

- **Engage/Disengage Indicator**

- Not a great way to reliably say if TARDIS is engaged or disengaged. Software bug allowed to send engage command and receive "Engaged" confirmation even though motor controller was unpowered.

- **Configuration Management**

- TARDIS treated as "Critical GSE". Needed certified techs with certified torque wrenches, QA, etc.
- Arguably more oversight than strictly required for GSE.

- TARDIS is ready to use in your next TVAC campaign!
 - Modifications needed for your use
 - New stand/fixture to fit your hardware
 - Heat strap or adapter to fit your hardware
 - MLI modifications for new stand & heat strap
 - LN2 line & harness feedthroughs
 - Recommended Upgrades
 - Swap out PRTs
 - Software updates
 - Cryogenic motor
- Currently working on modifications for lunar surface application



Contact Bryan Matonak or Seth Abramczyk for your FREE consultation to see if TARDIS is right for you!



Acknowledgements



- TARDIS

- Bryan Matonak
- Ben Abresch
- Allen Lunsford
- Mark Klappenberger
- Minhee Kim
- Seth Abramczyk

- WFI

- Bryan Matonak
- John Lanza

- Lucy L'Ralph AZQ

- Juan Rodriguez-Ruiz
- Daniel Bae

- T2D2

- Frank Robinson
- Colton Cohill
- Elliot Schwartz
- Mike Chapman



Backup

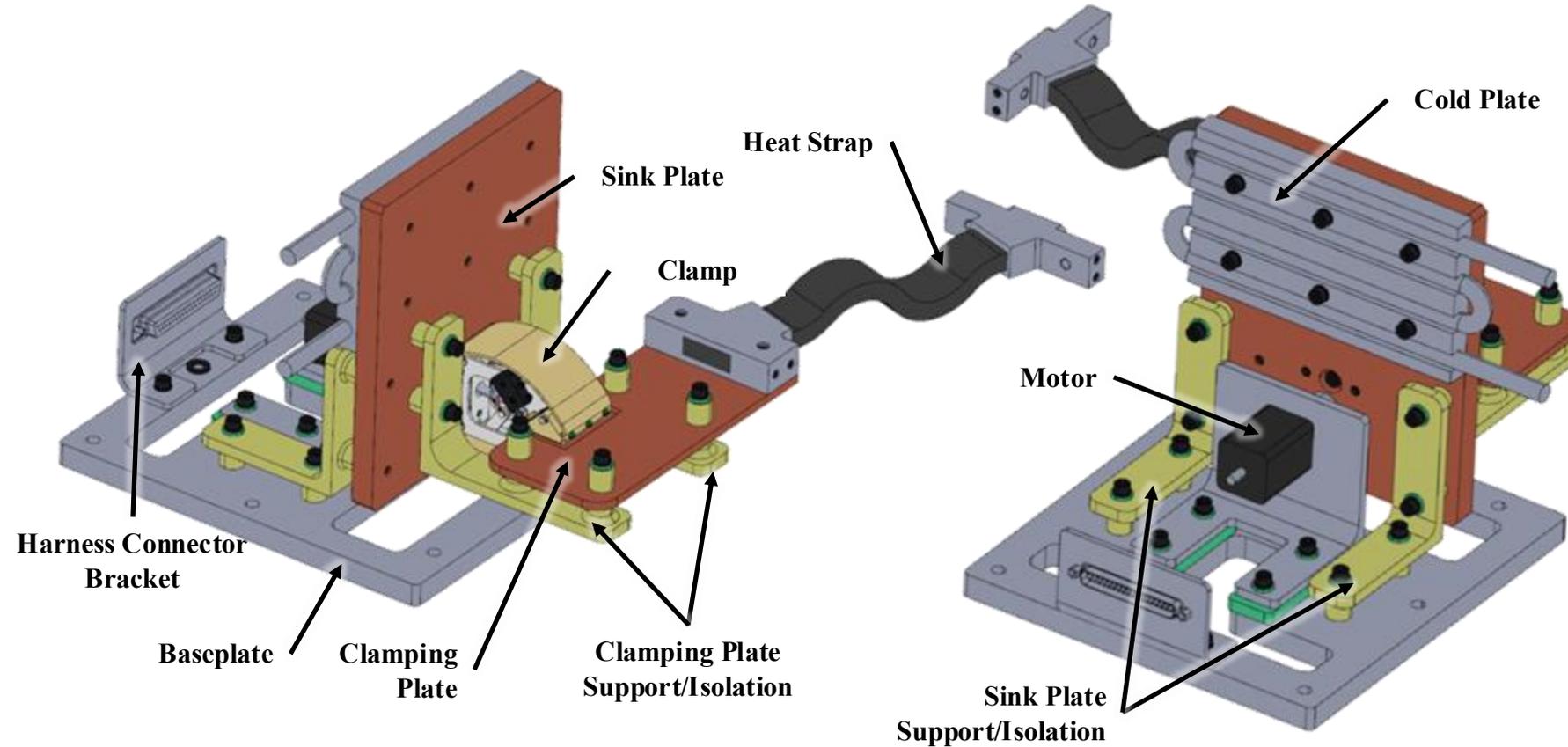


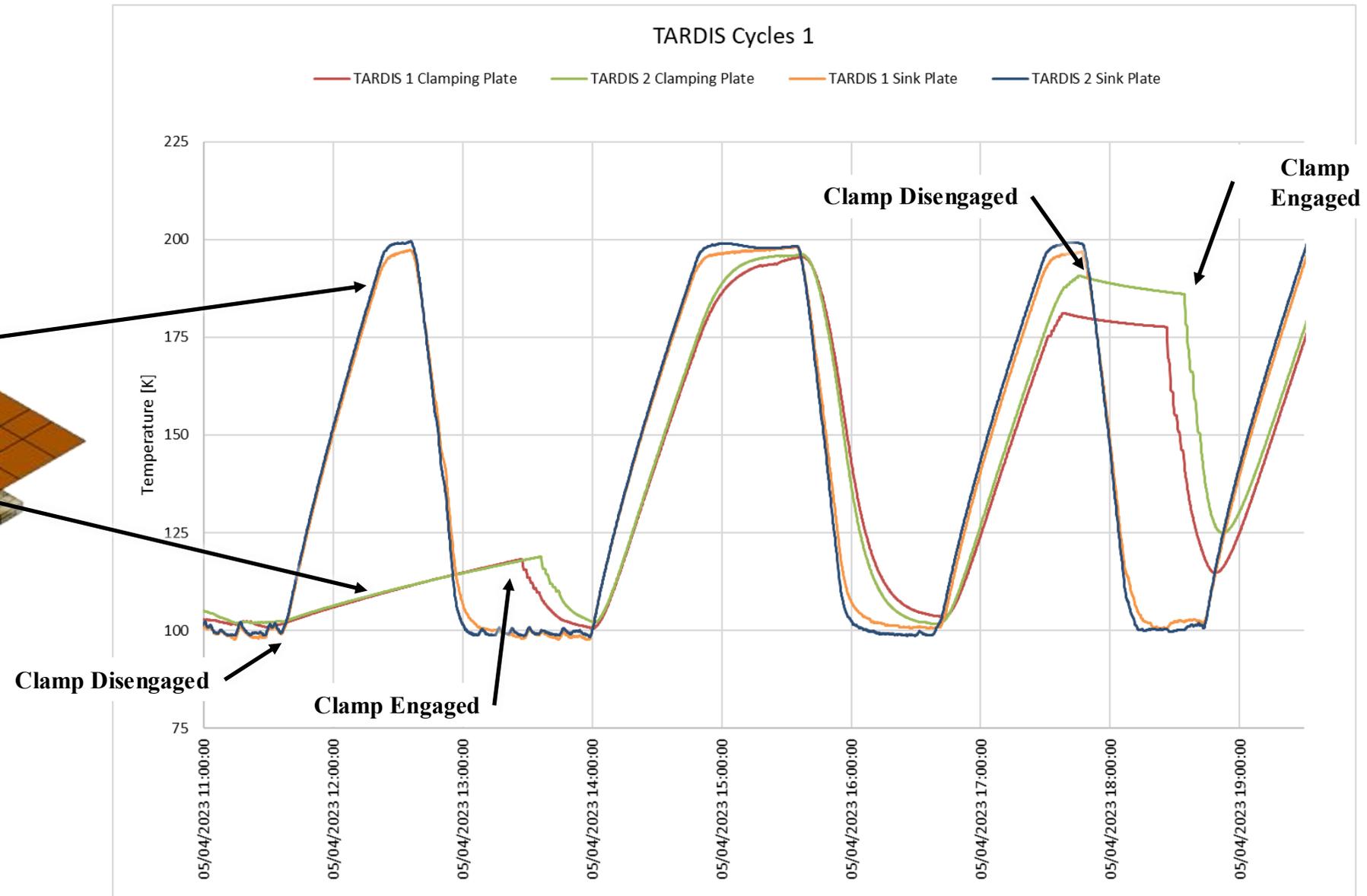
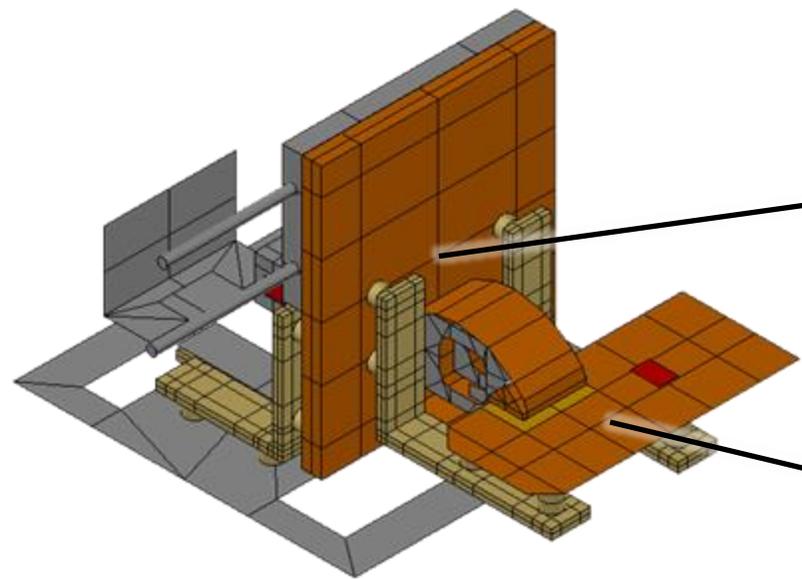
Acronyms



AZQ	Active Zero-Q
CSM	Cold Sensing Module
GN2	Gaseous Nitrogen
GSFC	Goddard Space Flight Center
ICES	International Conference on Environmental Systems
JSC	Johnson Space Center
LN2	Liquid Nitrogen
PG	Paralytic Graphite
PRT	Platinum Resistance Thermometer
RST	Roman Space Telescope
TARDIS	Thermal Acceleration Rate Device for Integrated Systems
TC	Thermocouple
TFAWS	Thermal & Fluids Analysis Workshop
TVAC	Thermal-Vacuum
WFI	Wide Field Instrument

TARDIS Components





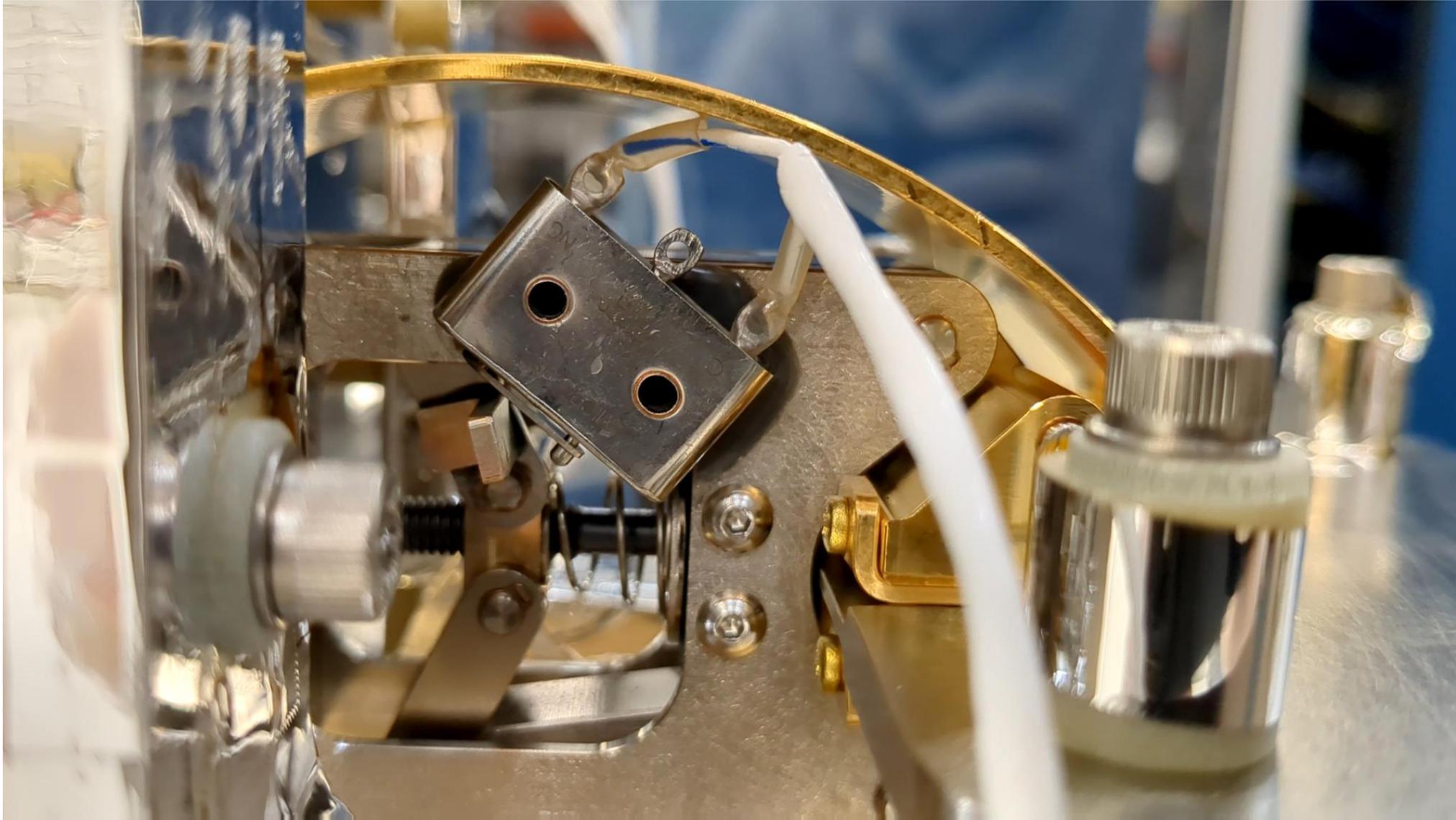
TARDIS Rack

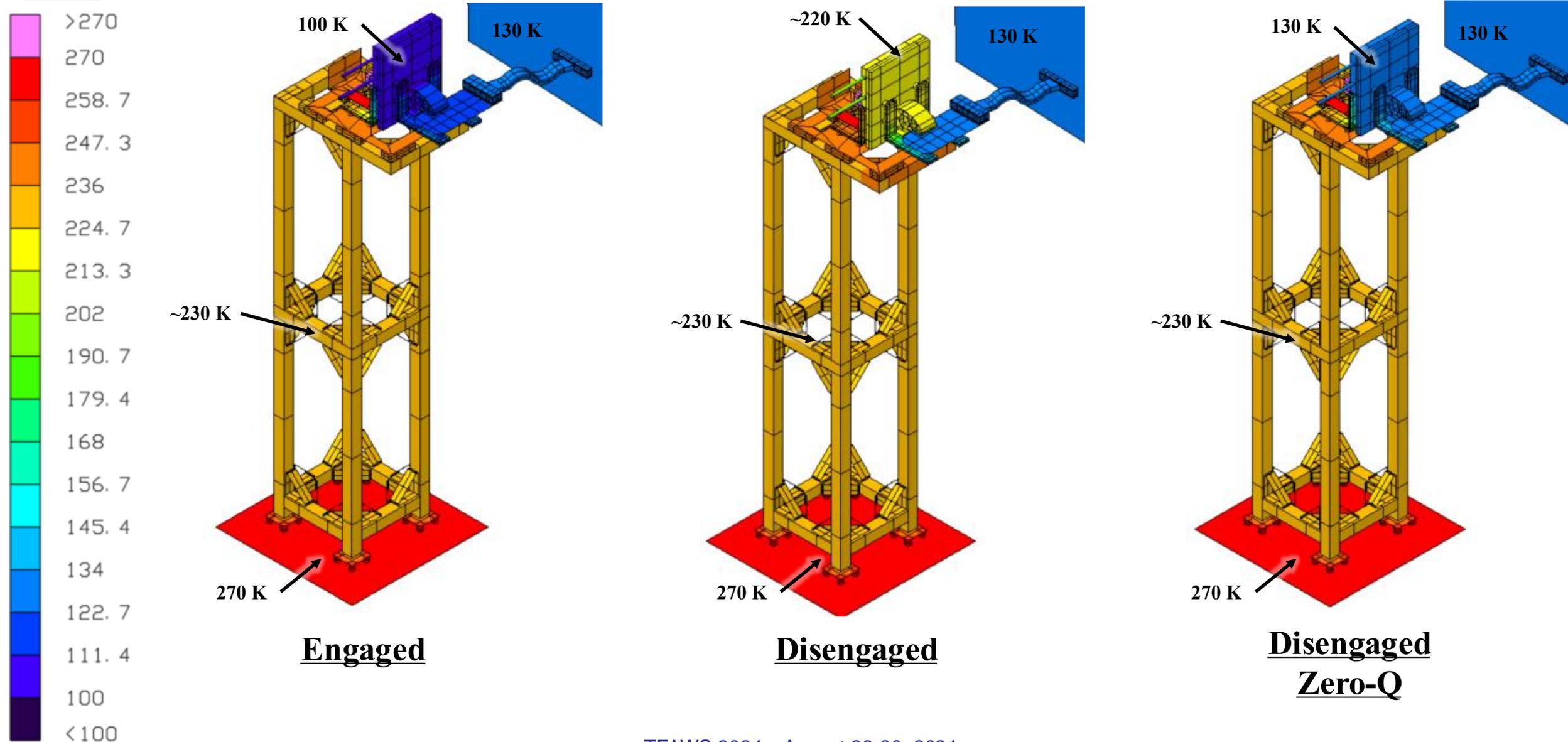


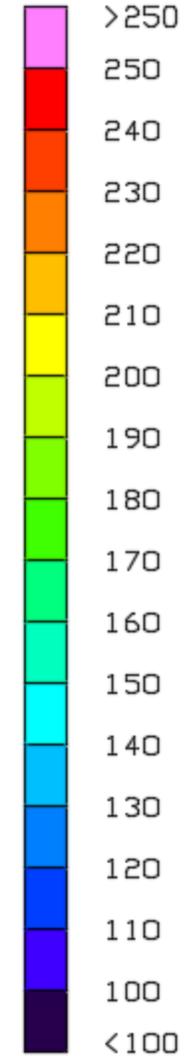
Lakeshore 336 (x3)

UPS

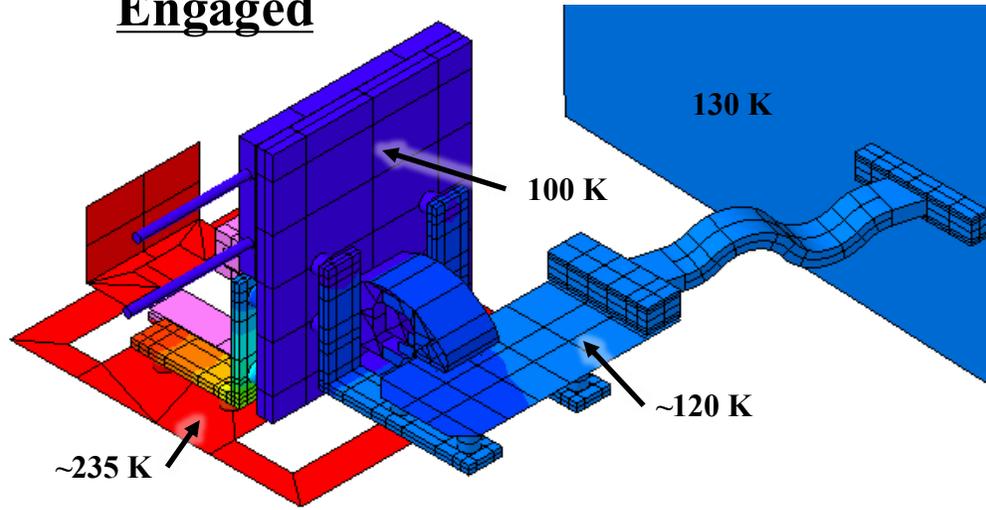
Clamp Indicator



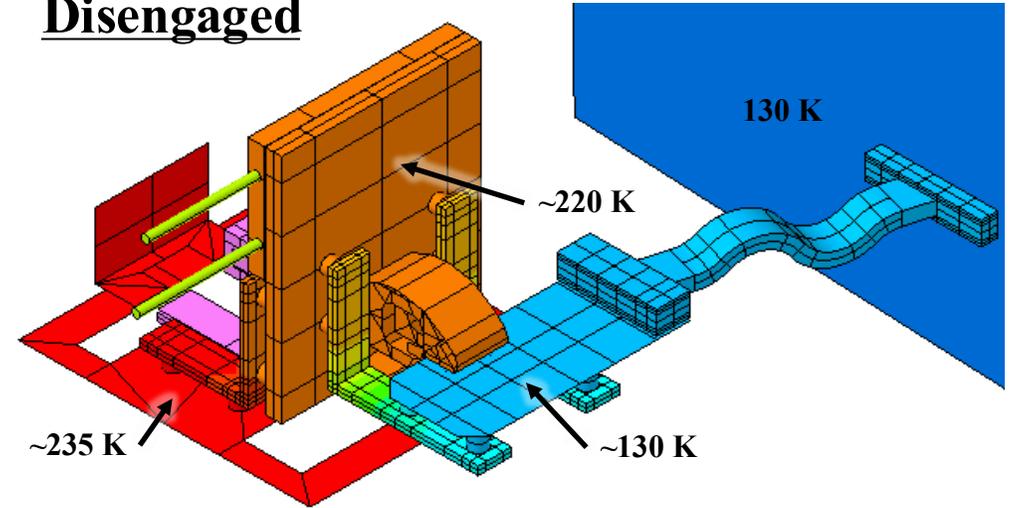




Engaged



Disengaged



**Disengaged
Zero-Q**

