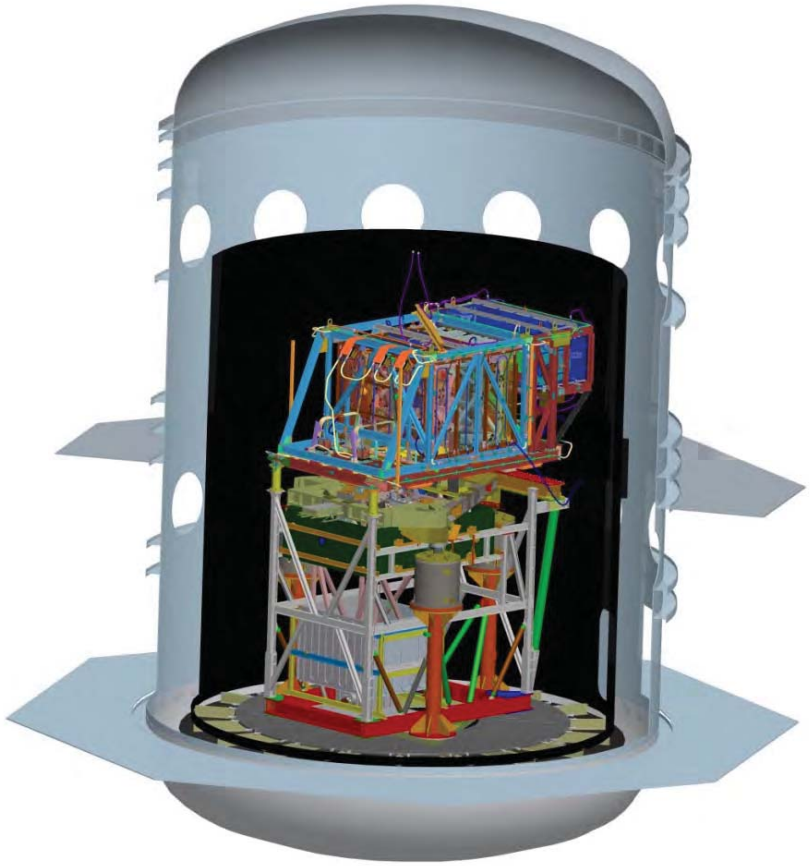
James Webb Space Telescope (JWST) Integrated Science Instruments Module (ISIM) Cryo-Vacuum (CV) Testing at GSFC

Calinda Yew

28th Space Simulation Conference

NASA Goddard Space Flight Center (GSFC)



Topics

- JWST Mission Overview
- ISIM CV Test Campaign at GSFC
- Test Configuration
- CV1 Test Summary
- CV1 Chamber Performance
- Improvements in Path Forward to CV2 & CV3
- Summary

JWST Mission Overview

Mission Objective

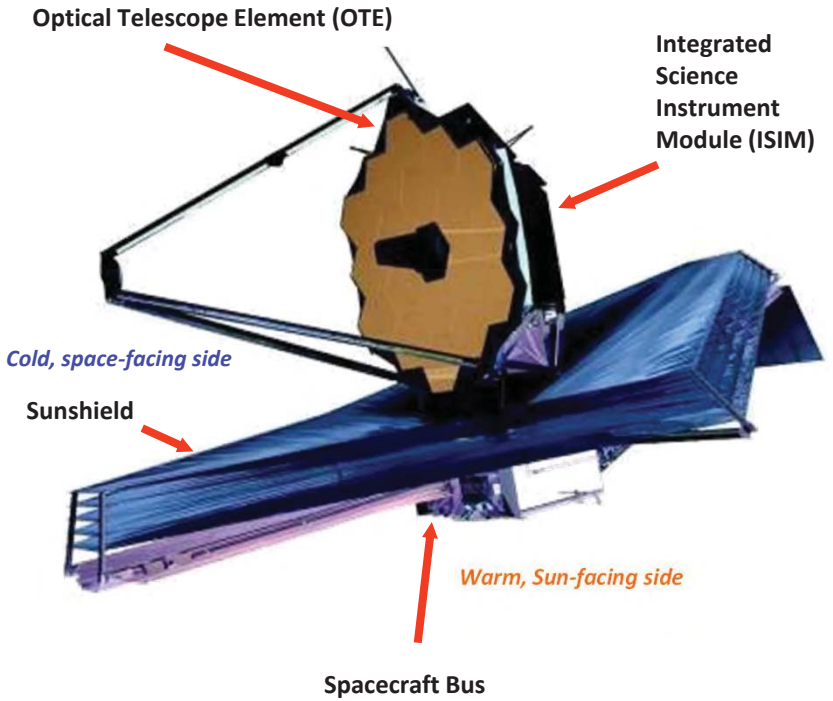
- Study the origin and evolution of galaxies, stars & planetary systems: *Optimized for infrared observations (0.6 – 28 μm)*

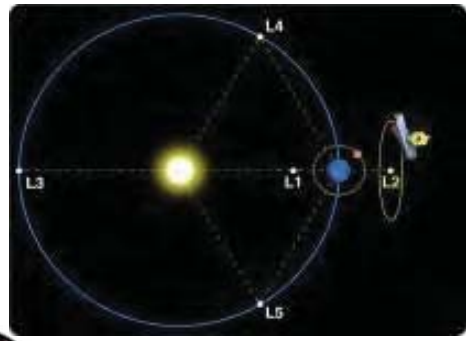
Organization

- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Space Technology
- Instruments:


  - Near Infrared Camera (NIRCam) – Univ. of AZ
  - Near Infrared Spectrograph (NIRSpec) – ESA


  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - Fine Guidance Sensor (FGS) – CSA





Description

- Deployable telescope w/ 6.5m dia segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch Oct 2018 on ESA-supplied Ariane 5 ECA rocket to Sun-Earth L2
- 5-year science mission + 2 years of data analysis

ISIM CV Test Campaign at GSFC

FGS 

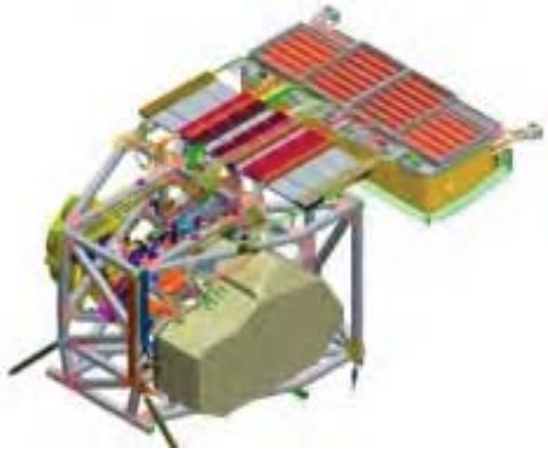
MIRI 

NIRCam 

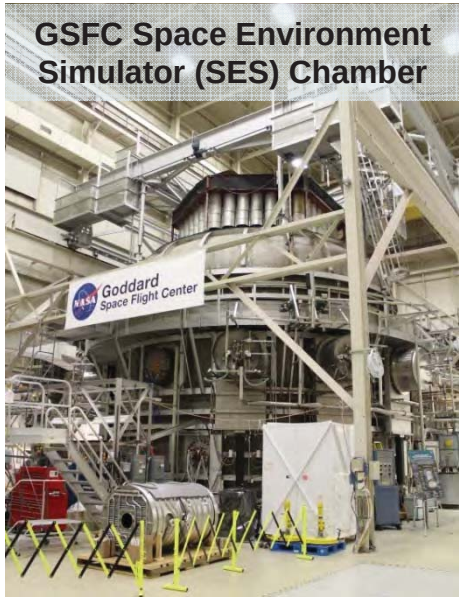
NIRSpec 

ISIM CV #1
Aug – Nov 2013

ISIM CV #2 & 3
June 2014 & Aug 2015



ISIM CV Overall Test Configuration



GSFC Space Environment Simulator (SES) Chamber

Chamber specifications

Volume: 27’ dia x 40’ high

Pumping speed

- 7 cryopumps: 2.1 x 10^5 l/s
- Turbomolecular pump: 6,000 l/s

Payload support: 40,000 lbs

Nitrogen shroud

Helium shroud

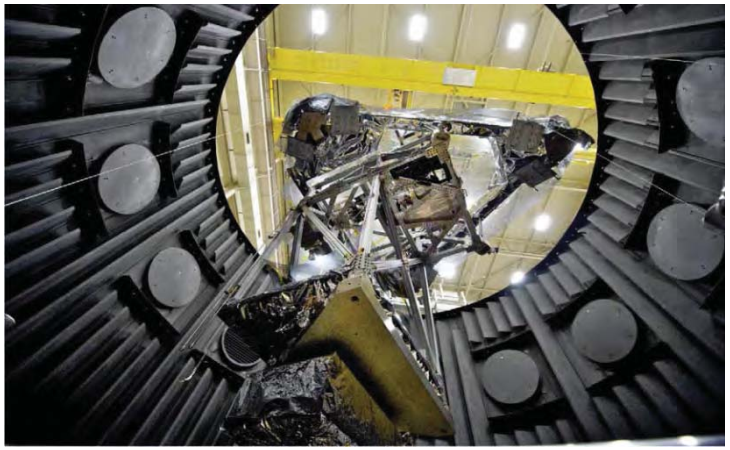
ISIM hardware & support frames

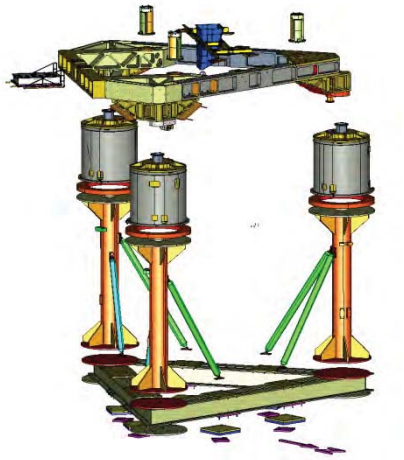
JWST OTE Simulator (OSIM)

Vibration isolators

Upper and Lower Supports Assembly

Nitrogen Volume Test Configuration





N_2 Volume Support Hardware Components

GSFC Equipment Support Hardware Assembly (GESHA): triangular Al structure to alleviate motion between two aligned systems

- Upper GESHA held at around 90K (-183°C)
- Lower GESHA: held at ambient temperatures to alleviate CTE induced strains

Vibration Isolators System (VIS): pneumatic system isolates test articles from chamber induced jitter sources

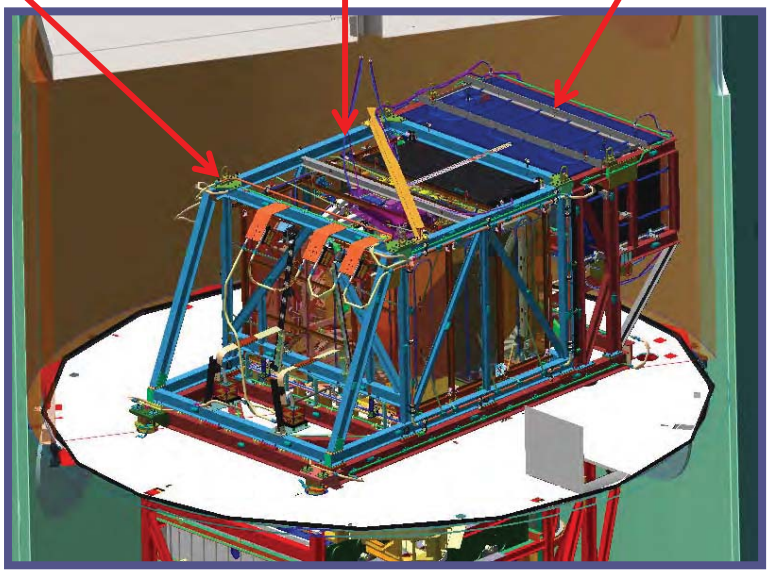
- Chamber vibration measured amplitudes of 1 milli-G in all axes at 20 Hz – VIS provides minimum attenuation of 40 dB to these levels
- VIS vertical natural frequency is 1.0-1.3 Hz
- VIS horizontal natural frequency is 0.4-0.6 Hz

Helium Volume Test Configuration

SIF & STMS Frame

HR Shroud (HR)

IEC Shroud (IEC LN_2 Panel)



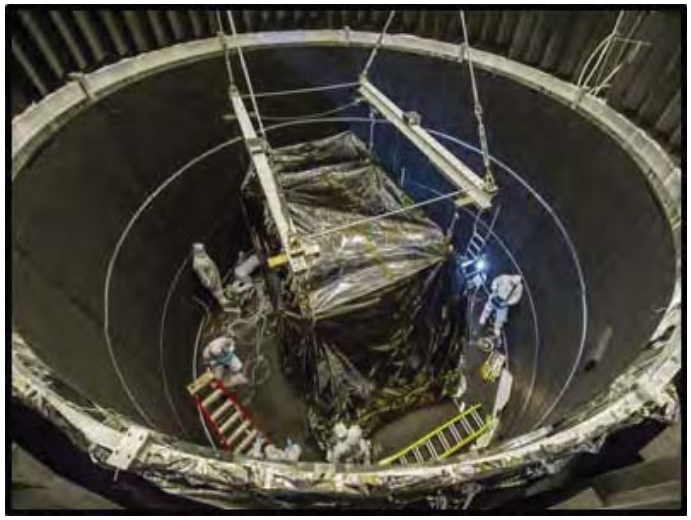
SIF = SES Integration Frame
STMS = Surrogate Thermal Management System
IEC = Instruments Electronics Module

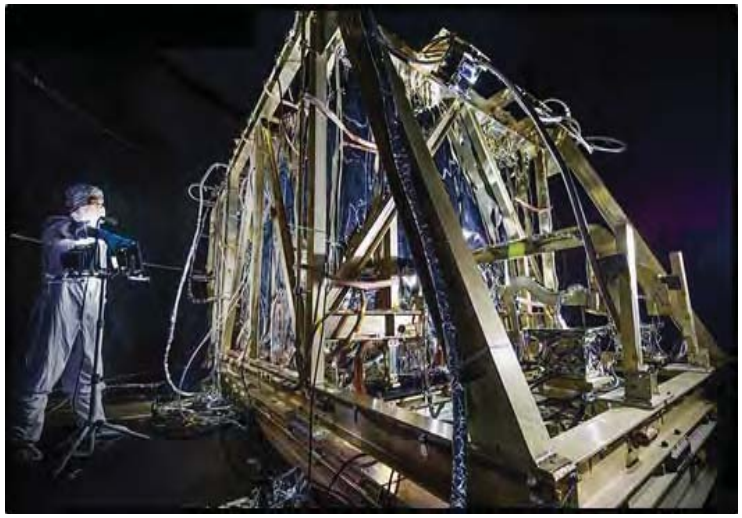
HR = Harness Radiator
DSR = Deep Space Radiator

He Shroud Specifications

- Dimensions 26’ dia x 15’ tall
- Provide 1000 W cooling capacity
- Cooling between 80K (-193°C) and 20K (-253°C)
- Five independently controlled shroud zones
- The other five helium zones are allocated to various parts of ISIM structure

ISIM CV1 Test Summary

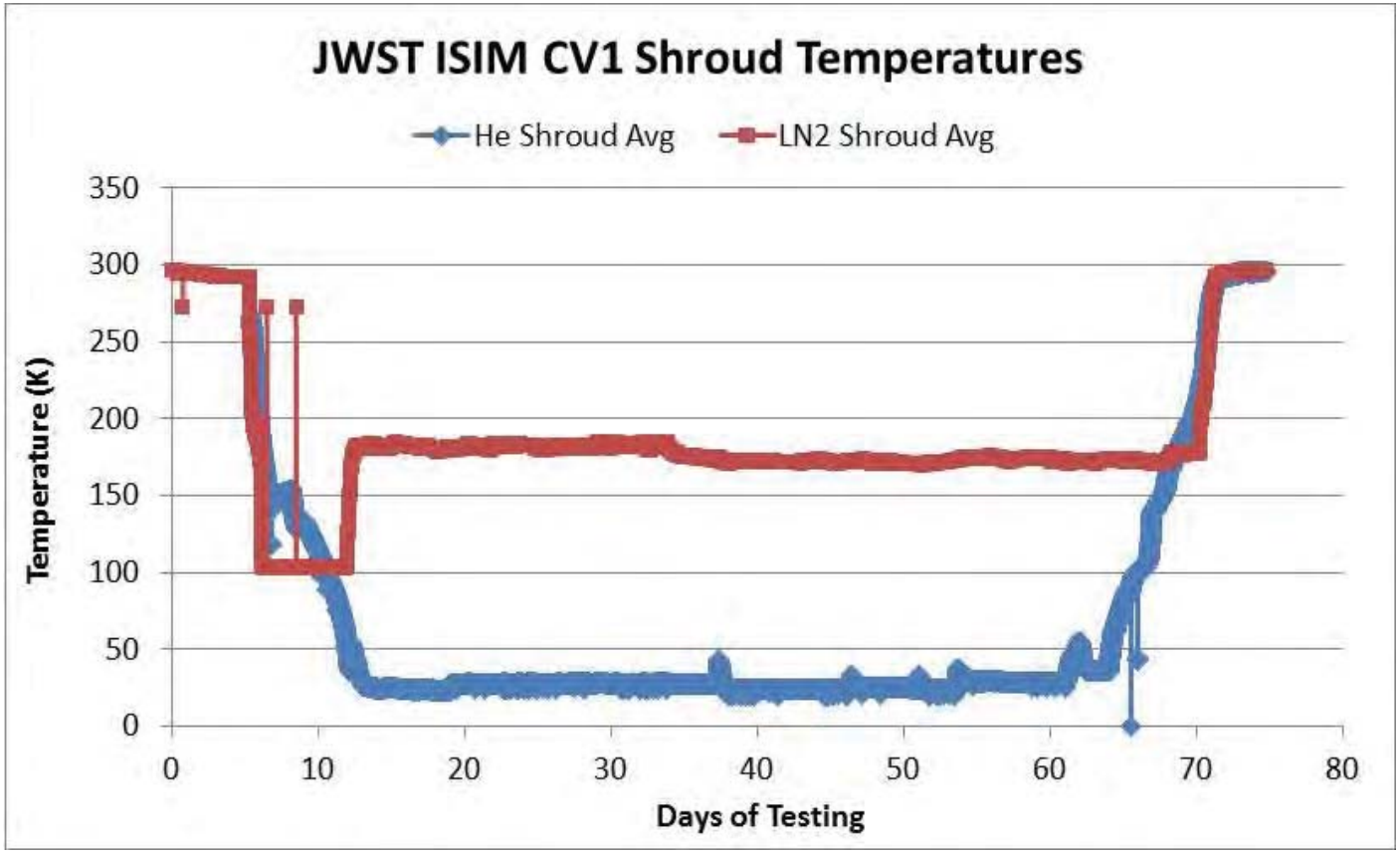




- Pump-down: 08/29/2013 ~21:00
- Warm-up: 10/29/2013
- Open chamber: 11/11/13
- Total days under vacuum = 73 days
- Total consumables
  - LN_2 = 520K gallons
  - Helium = 20 bottles

Shrouds Temperature Performance

At steady state: Helium shroud achieved 24K ±1K
LN2 shroud maintained 182K ±3K (switched LN2 to GN2 Day 11: 9/10/13)



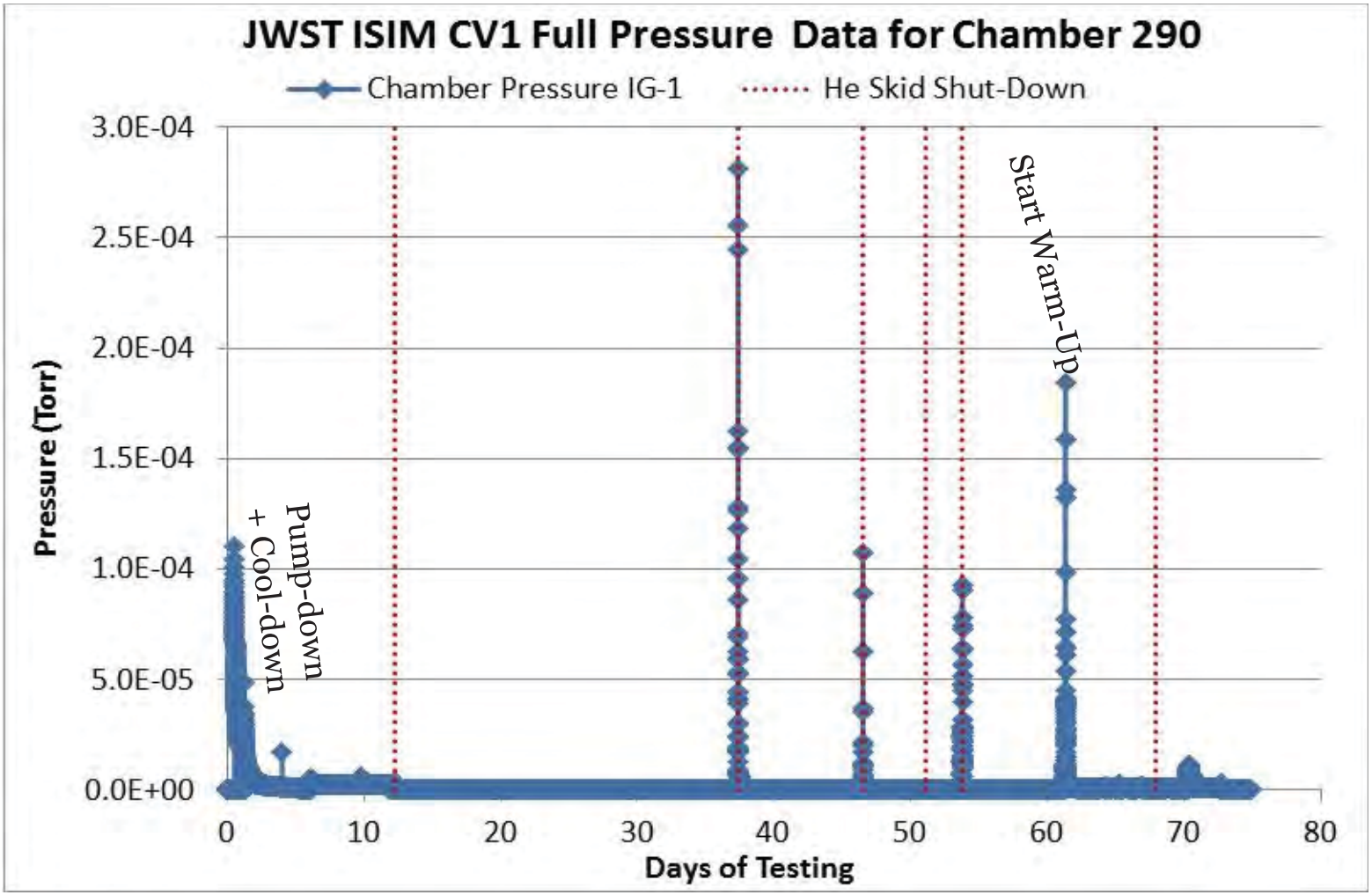
Chamber Vacuum Performance

- High vacuum was achieved using:
  - (qty 6) 65000 liter/sec cryopumps
  - (qty 1) 5000 liter/sec turbopump
- 1 (of 6) cryopumps left in reserve at all times

Pressure (Torr)	Time since start
5.0 x 10-5	29 hrs (1.2 days)
1.0 x 10-5	35 hrs (1.5 days)
5.0 x 10-6	46 hrs (1.9 days)
1.0 x 10-6	108 hrs (4.5 days)
5.0 x 10-7	128 hrs (5.3 days)

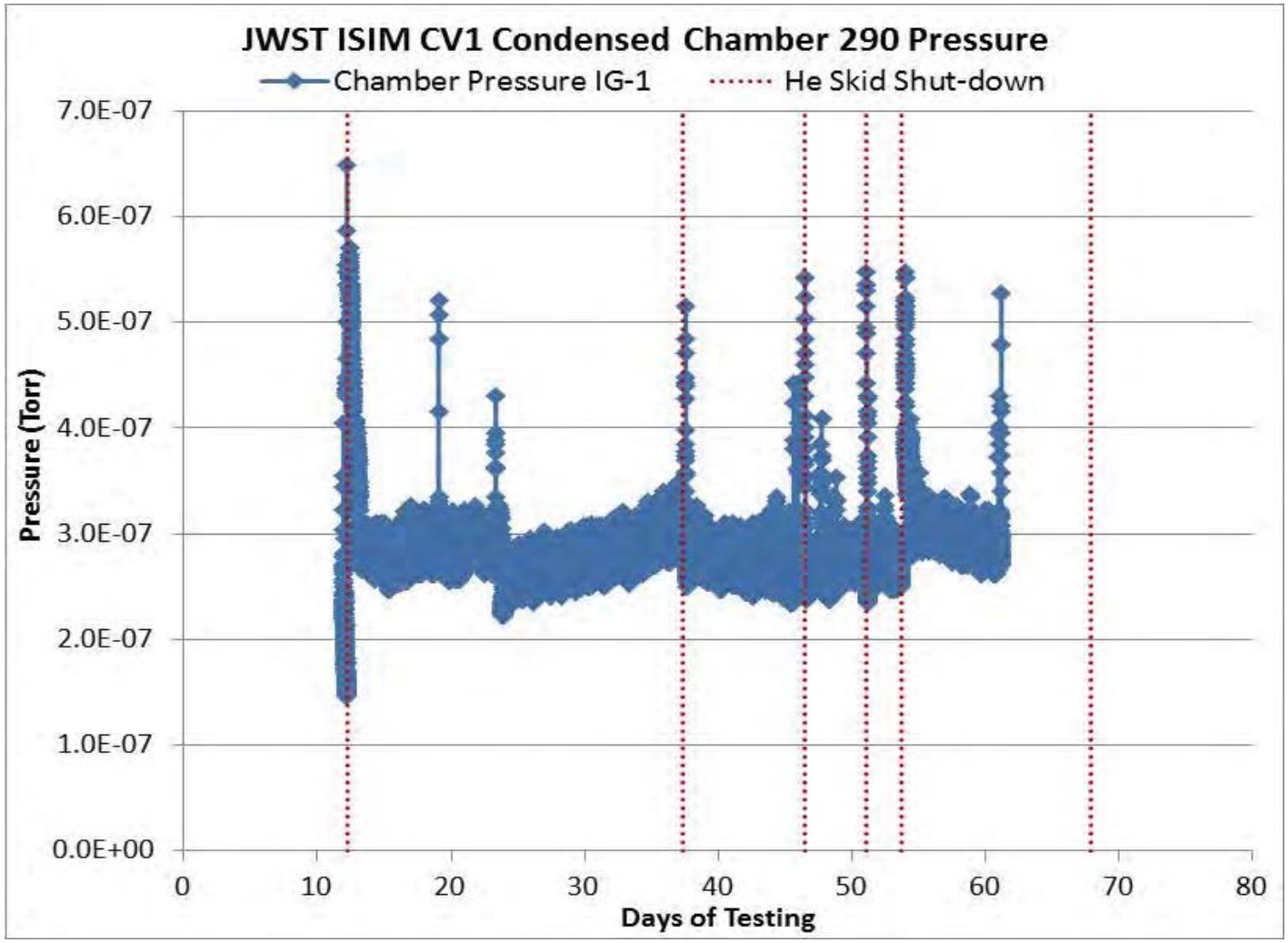
Chamber Vacuum Performance

Chamber pressure from pump-down to back-fill



Chamber Vacuum Performance

With cool-down, warm-up, & He skid shut-down pressure spikes omitted, normally 3 x 10^{-7} Torr



Improvements for CV2 & CV3

- Helium skid reliability needed to be improved in order to reduce risk to flight hardware and to schedule
- Detection of helium leaks needed to be more stringent in order to verify MIRI head loads

Helium Skid Reliability: Summary of Helium Skid Shutdowns

Total of six (6) helium skid shutdowns:

- Cause #1: low turbine bearing gas temperature alarm
- Cause #2: compressor oil level/temp alarm

#	Date	Cause	Action (back online)	Pressure Spike	Duration*	He Temp (Temp rise)	Duration**
1	09/10/13	#1	Re-start skid (<1 hr)	4.1 x 10^{-6} Torr	4.0 hrs	52K (+16K)	11.2 hrs
2	10/05/13	#1	Re-start skid (<1 hr)	2.8 x 10^{-4} Torr	5.3 hrs	42K (+15K)	8.5 hrs
3	10/15/13	#2	Re-start skid (<0.5 hr)	1.1 x 10^{-4} Torr	1.1 hrs	33K (+9K)	14.0 hrs
4	10/19/13	#2	5-sec interlock to delay shutdown command	9.3 x 10^{-5} Torr	1.1 hrs	32K (+8K)	6.5 hrs
5	10/22/13	#2	Override compressor load/unload status	9.2 x 10^{-5} Torr	6.1 hrs	37K (+13K)	N/A
6	11/05/13	#2	Re-start skid (~1 hr)	6.8 x 10^{-6} Torr	2.1 hrs	N/A (warm-up)	N/A (warm-up)

*Duration for pressure to return to 5 x 10^{-7} Torr

**Duration for helium shroud average temperature to return to temp before shut-down

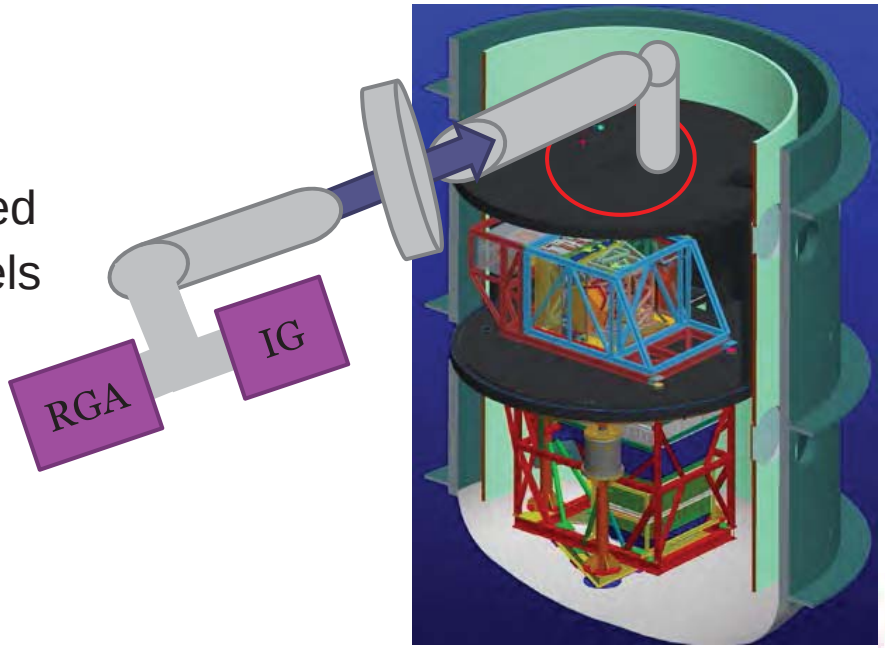
Replace Dunham Busch Compressor
6 to 10 week delivery
Successfully installed & checked out May 2014

Old

New

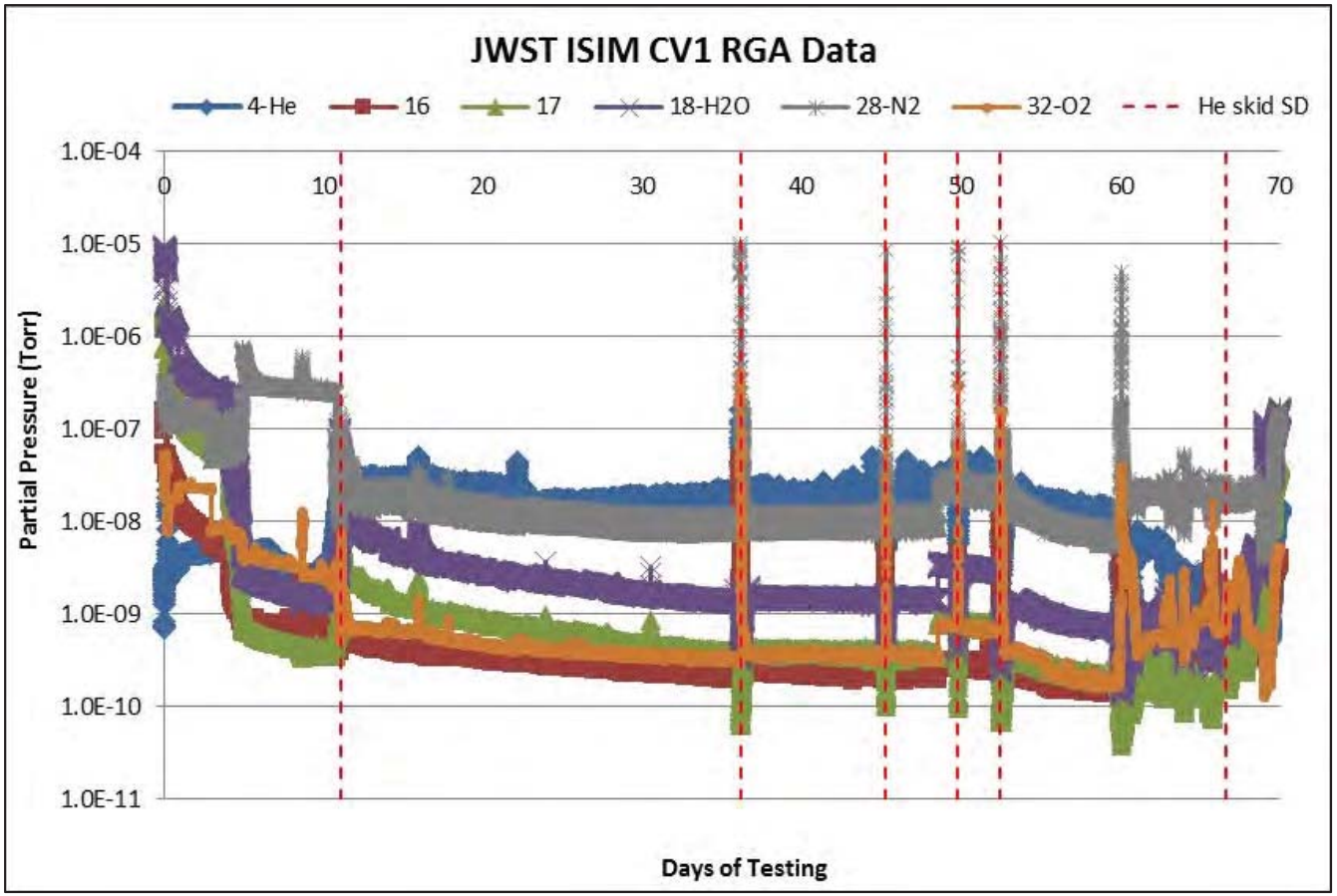
Helium Leak Detection Improvement

- MIRI requirement: 6.2 K (-266.8°C) at the instrument
  - 2-stage cooler system
  - Accurate heat map required during environmental testing
- Issues encountered during CV1
  - Measured heat loads to cooler from MIRI higher than expected
  - Presumed cause is higher levels of helium in chamber
- Actions
  - Add RGA in STMS volume a
  - Implement more stringent leak checking requirements

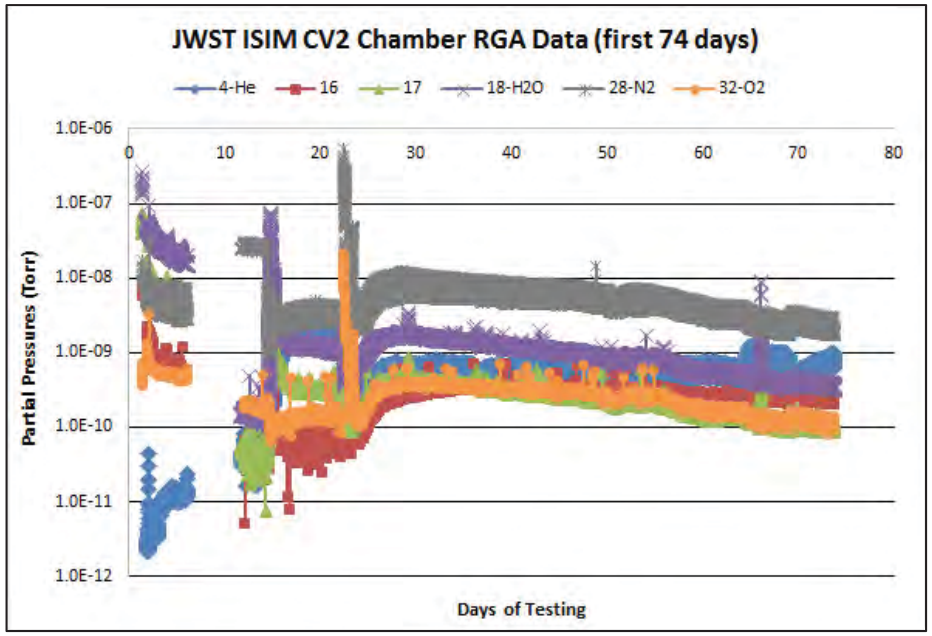


JWST ISIM CV1 RGA Data

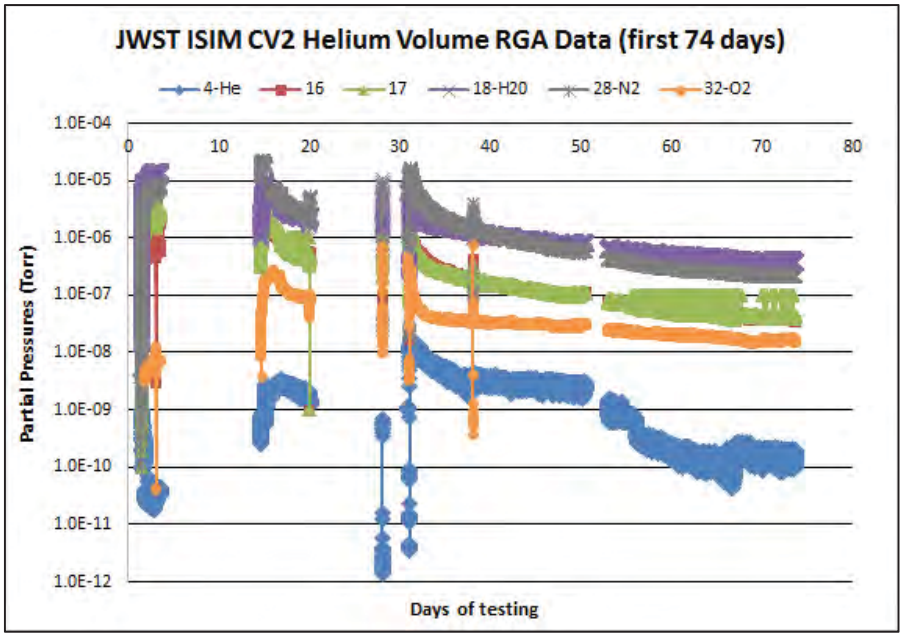
The chamber RGA detected helium levels of 5.0 x 10^{-7} Torr



JWST ISIM CV2 RGA Data Preview



Helium levels consistently detectable to levels of 1.0 x 10^{-9} Torr (as opposed to 5.0 x 10^{-7} in CV1)

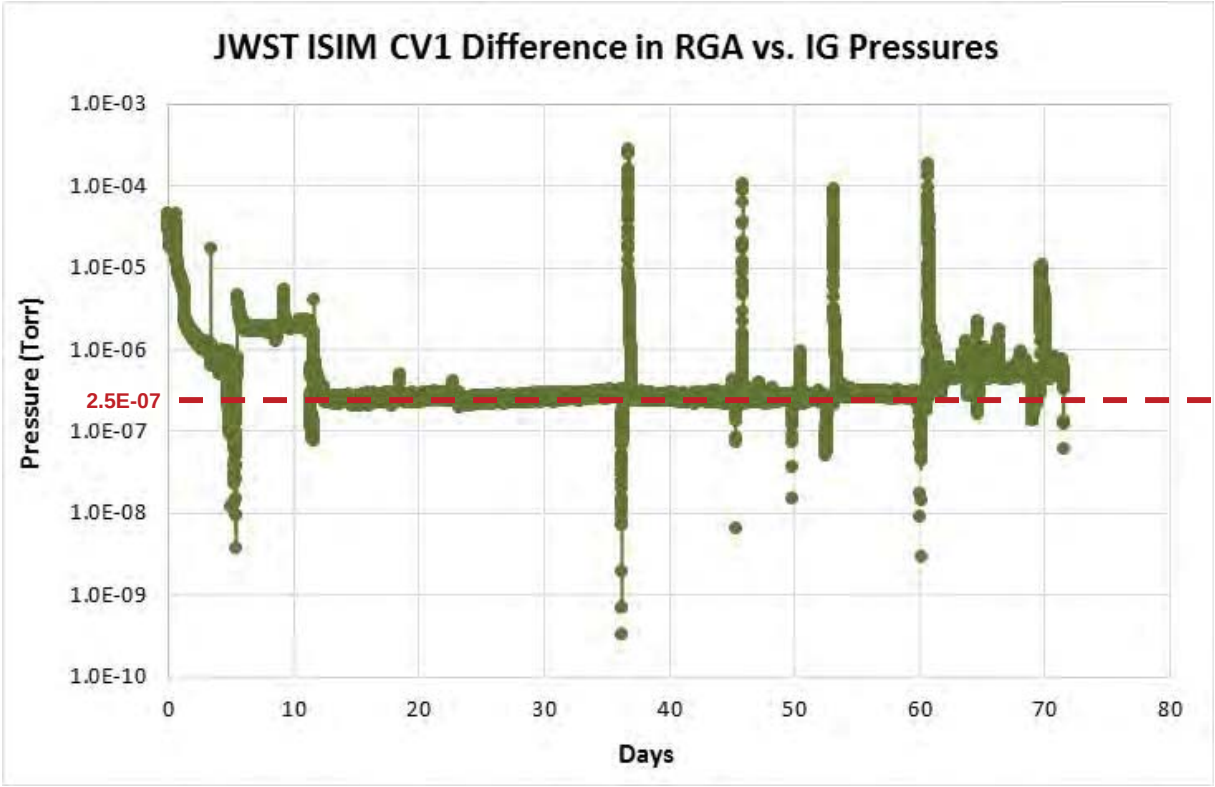


Helium levels in ISIM volume slightly higher than in the N_2 chamber volume: consistently <1.0 x 10^{-8} Torr

The MIRI predicted thermal loads matched the measured within the prediction and measurement uncertainties

JWST ISIM RGA Data Reliability

- The need for a calibrated RGA is being investigated for CV3 testing as the total RGA pressure does not match the chamber ion gauge pressure readings: chamber RGA was ~2.5 x 10^{-7} Torr higher
- Currently, qualitative statements can only be made using the RGA data



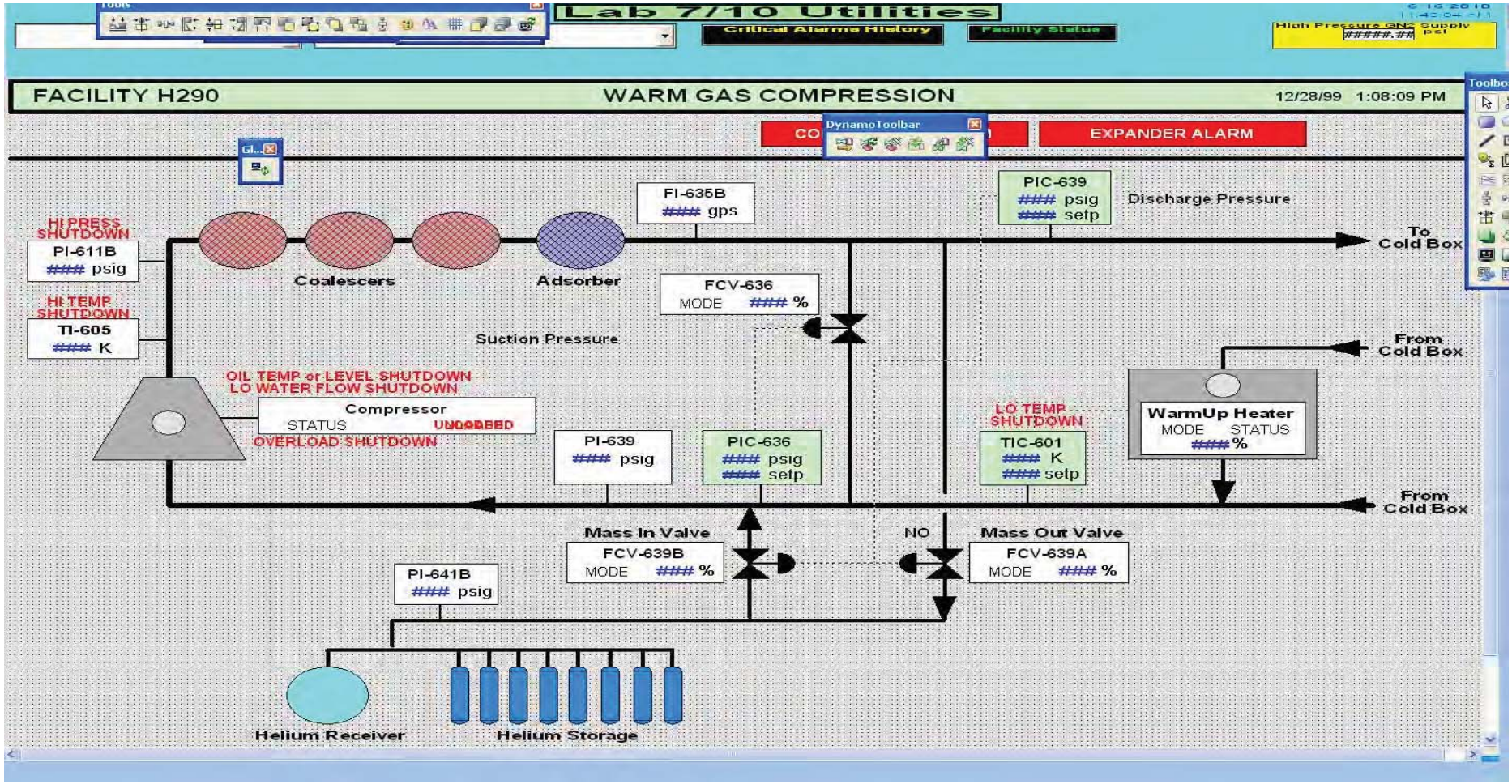
Summary

- Successful CV1 test
  - Dry run of test procedures and processes
  - Achieved thermal requirements
  - Identified facility performance improvements necessary
- Two notable facility improvements
  - New helium skid compressor
  - Additional helium shroud RGA
- Future investigation into improving confidence in RGA readings

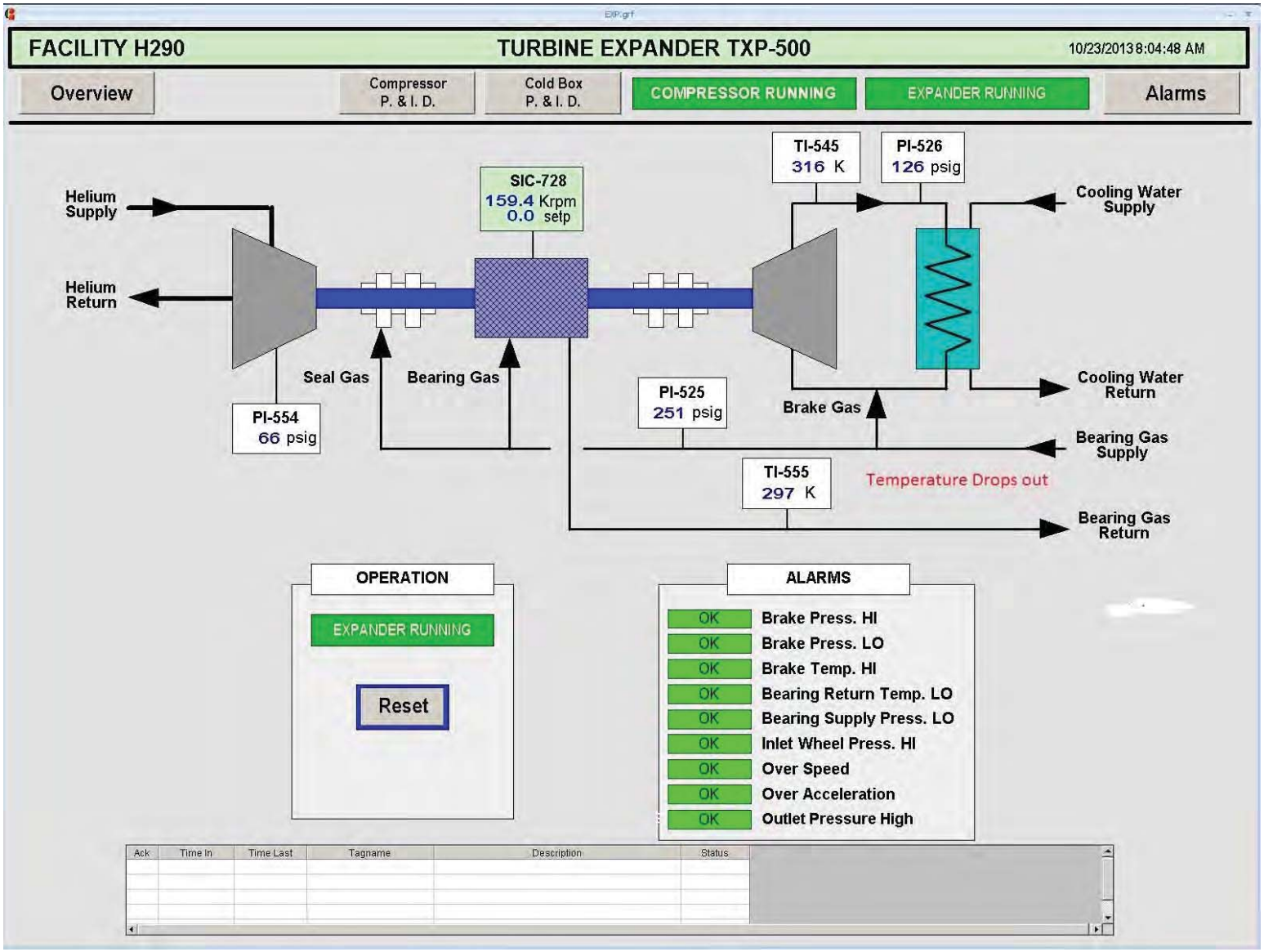
Questions?

Back-Up Slides

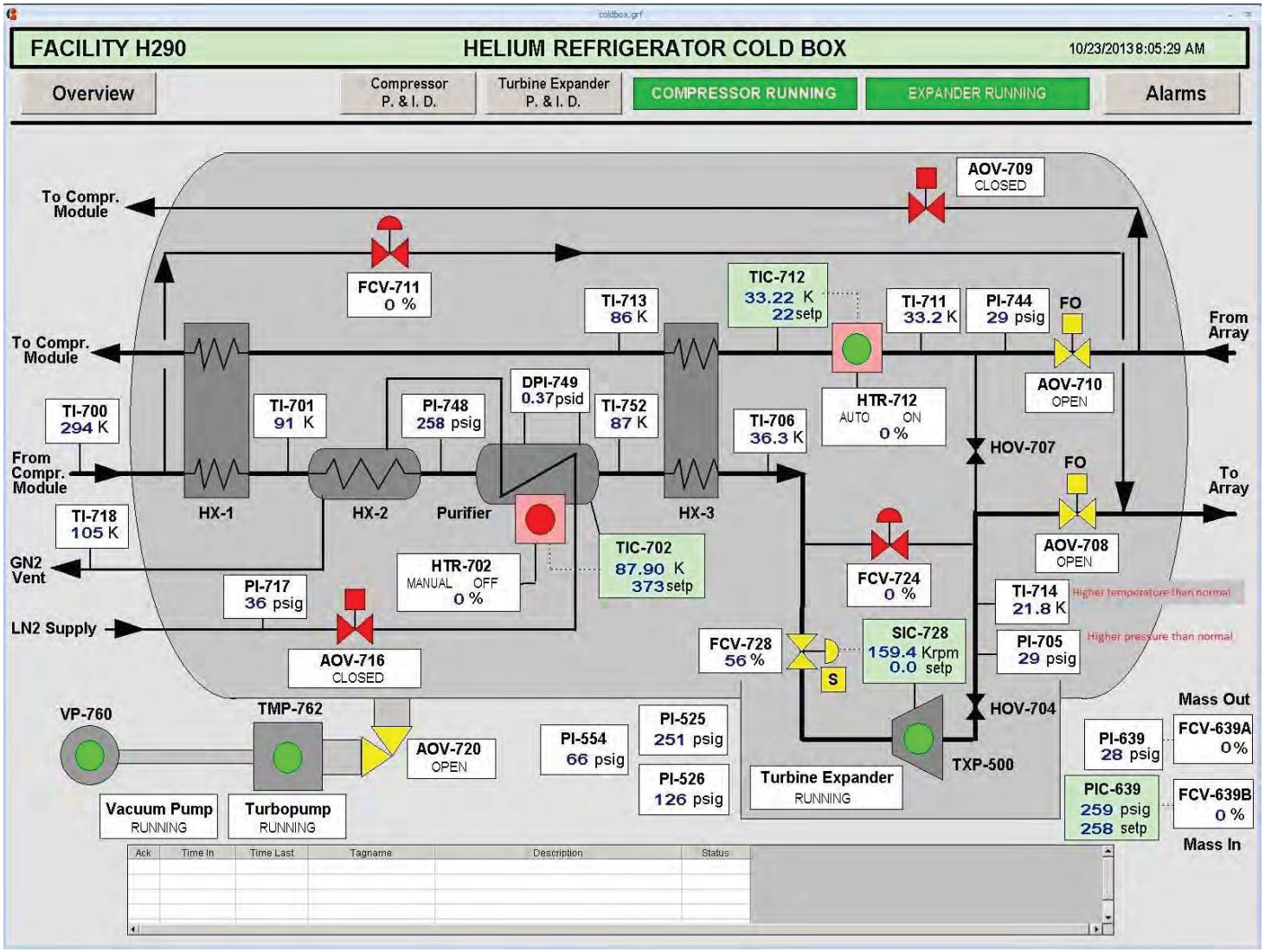
Helium Skid Shutdown Cause #1: Low & high oil temperature interlocks (false readings)



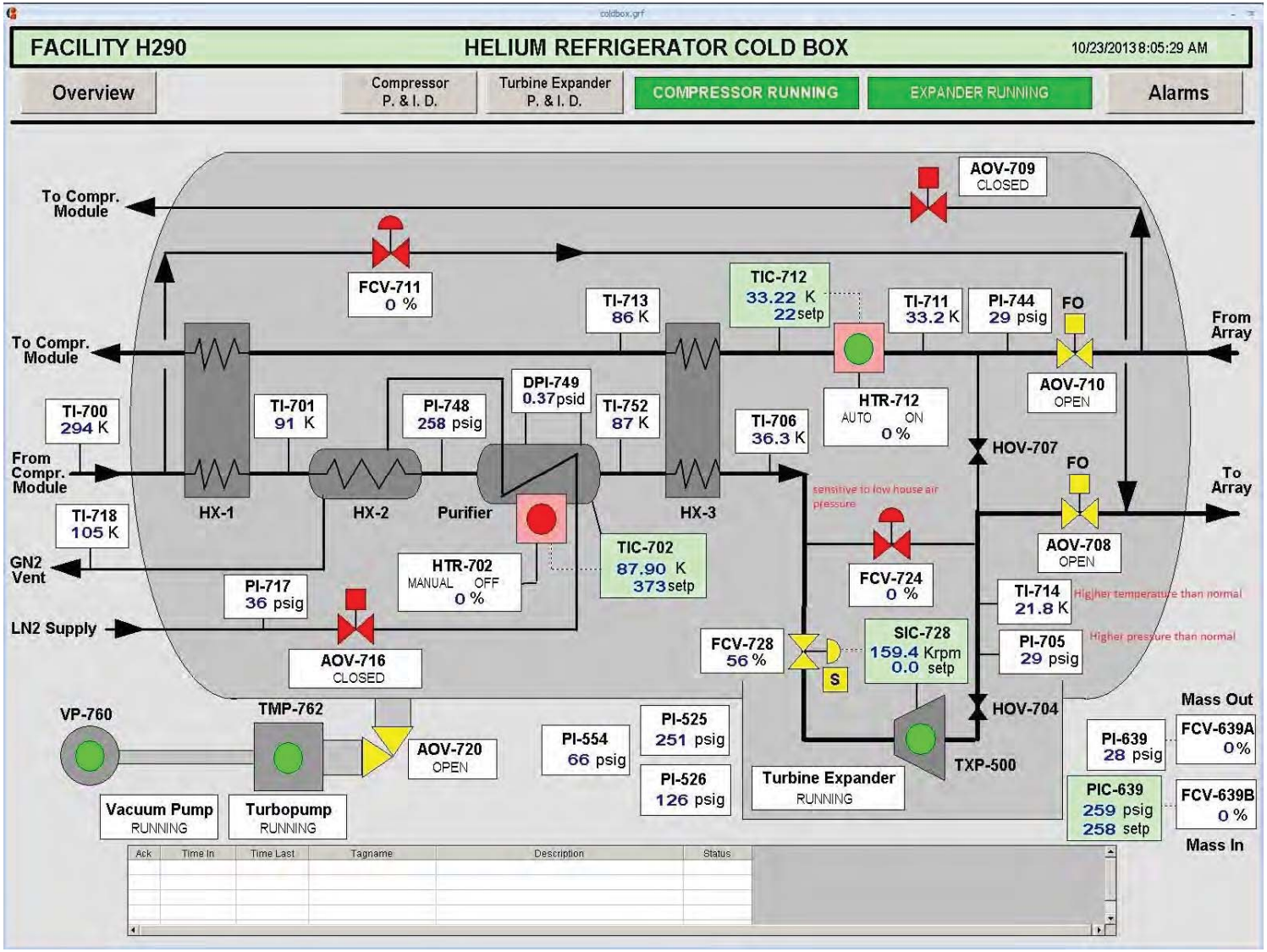
Helium Skid Shutdown Cause #2: Low turbine bearing return temperatures



Helium Skid Issues #3: Unable to achieve 20K on refrigerator due to compressor loading mechanism malfunction



Helium Skid Issues #4: In-house air pressure fluctuations
House air pressure drops cause helium skid to warm up



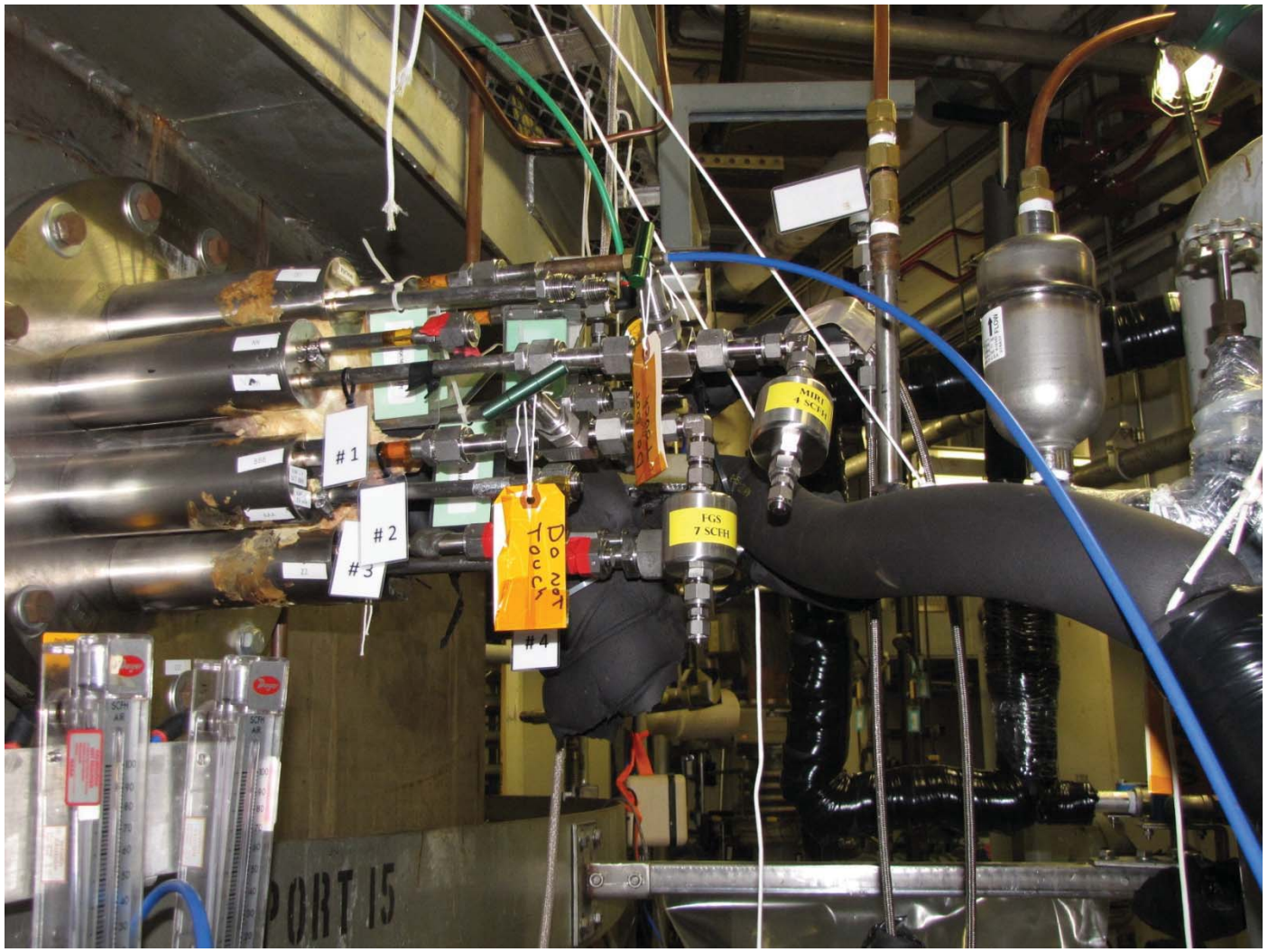
Power Supply Operation

- All heater racks functioned as required for entire test duration
  - 9 heater racks
  - 14 LS-336s
- Only issue: heater circuit 8-2
  - Control sensors failed
  - Placed in local mode during the test
  - Resolution: Fix broken wire

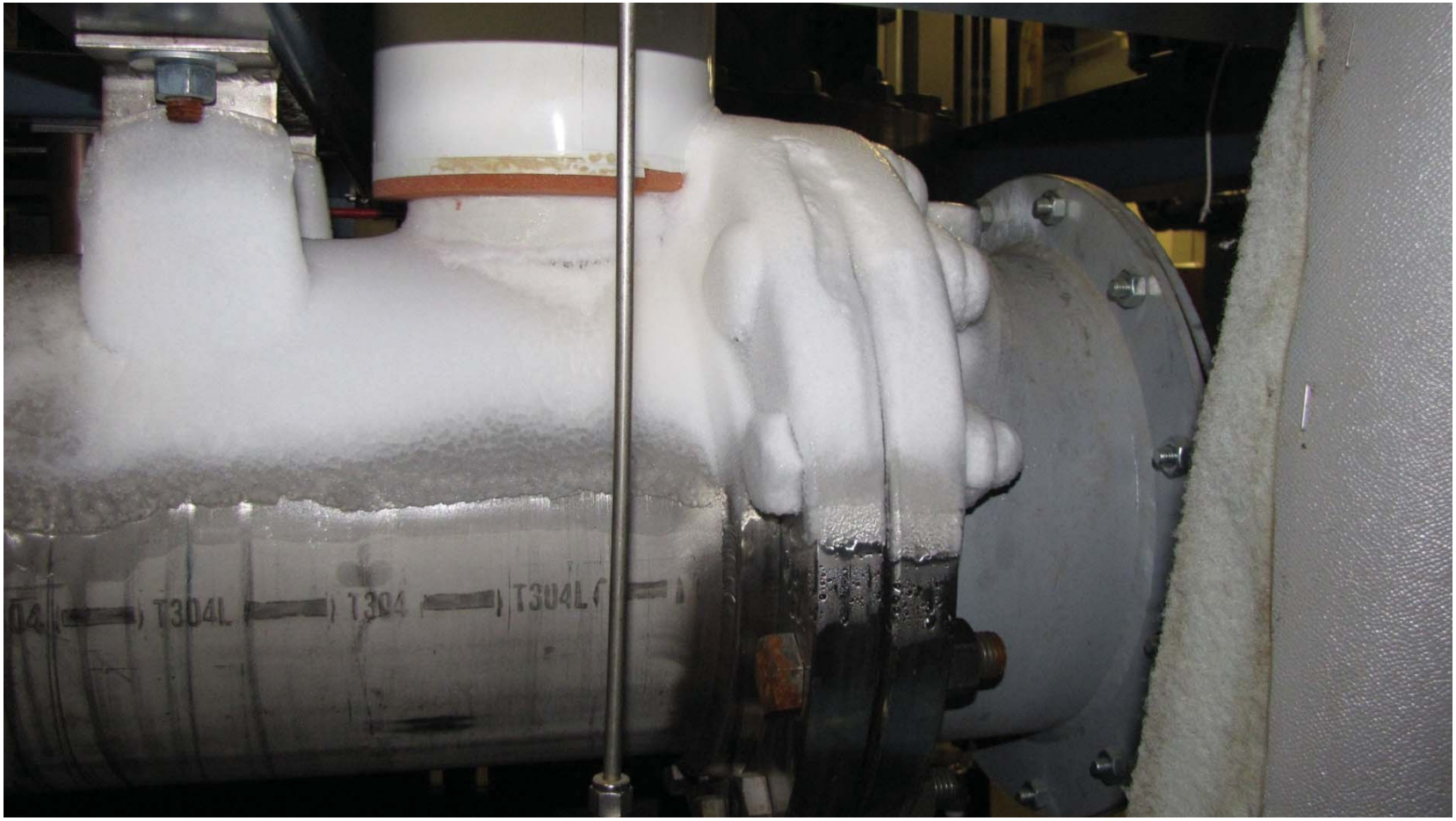
Power outages: Generators & UPS

- # of power outages: 1
- Operated seamlessly. B10 generator & Helium skid UPS
- Short commercial power outage experienced on 09/21/2013 (approx. 21:43).
  - Several heater racks needed to be manually reset, but no significant impacts to test hardware.
  - He skid operation not impacted.
  - After coming back online, CQCM heaters came on full power and CQCMs achieved >350K.

MIRI Air Leak



Helium Skid Issues #5: LN_2 purifier needed to be cleaned
Warm up heater begins to leak when cold
Causes differential pressure to increase



Updated Predict

Steady State Predict Versus Measured

Thermal Load	Thermal Model Predict *	ISIM CV2 Measured (7/15/14 12:00PM UTC)	ISIM CV2 Measured (7/21/14 8:46AM UTC)	ISIM CV2 Measured (7/28/14 1:02PM UTC)	ISIM CV2 Measured (7/29/14 5:30PM UTC) **
MIRI Thermal Shield	9.5 mW ± 2 mW	8.1 mW ± 7.5 mW	7.2 mW ± 7.5 mW	6.14 mW ± 7.5 mW	5.26 mW ± 7.5 mW
MIRI OM	17.6 mW ± 6 mW	25.9 mW ± 2.8 mW	30.6 mW ± 2.8 mW	23.12 mW ± 2.8 mW	19.27 mW ± 2.8 mW
Boundary Conditions	**Assumed Thermal Model (7/15/14 at 12:00PMUTC)**	**ISIM CV2 Measured**	**ISIM CV2 Measured**	**ISIM CV2 Measured**	**ISIM CV2 Measured**
ISIM Conductive Temp at HSA feet (ISIM HKT-14)	35.91 K	35.91 K			34.74 K
ISIM Conductive Temp at MIRI feet (ISIM HKT-35/36/37)	32.79 K	32.79 K			
ISIM Radiative Temp (STMS T^4 * Area Weighted Avg)	Used actual measured STMS panel temps and includes other actual instrument temperatures	34.65 K			
MIRI Shield Temp (Avg of Rails)	29.53 K	29.53 K			30.5 K
MIRI OM Temp	6.31 K	6.31 K		6.2 K	6.27 K
MIRI Detectors	OFF	OFF	ON	OFF	OFF
MIRI CQCM	OFF	ON	ON	ON	OFF

Delta between 7/15 & 7/21 = 4.7 mW accounting for detector dissipation

Delta between 7/28 & 7/29 = 3.85 mW accounting for MIRI CQCM dissipation

* See presentation note field for details on changes in predicted loads.

** At equilibrium on MIRI OM load however this is not the officially declared steady state data point.