Augmenting the Space Environment Complex's Thermal Vacuum Capabilities for Artemis 1 Orion Spacecraft Testing

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Aerospace Testing Seminar

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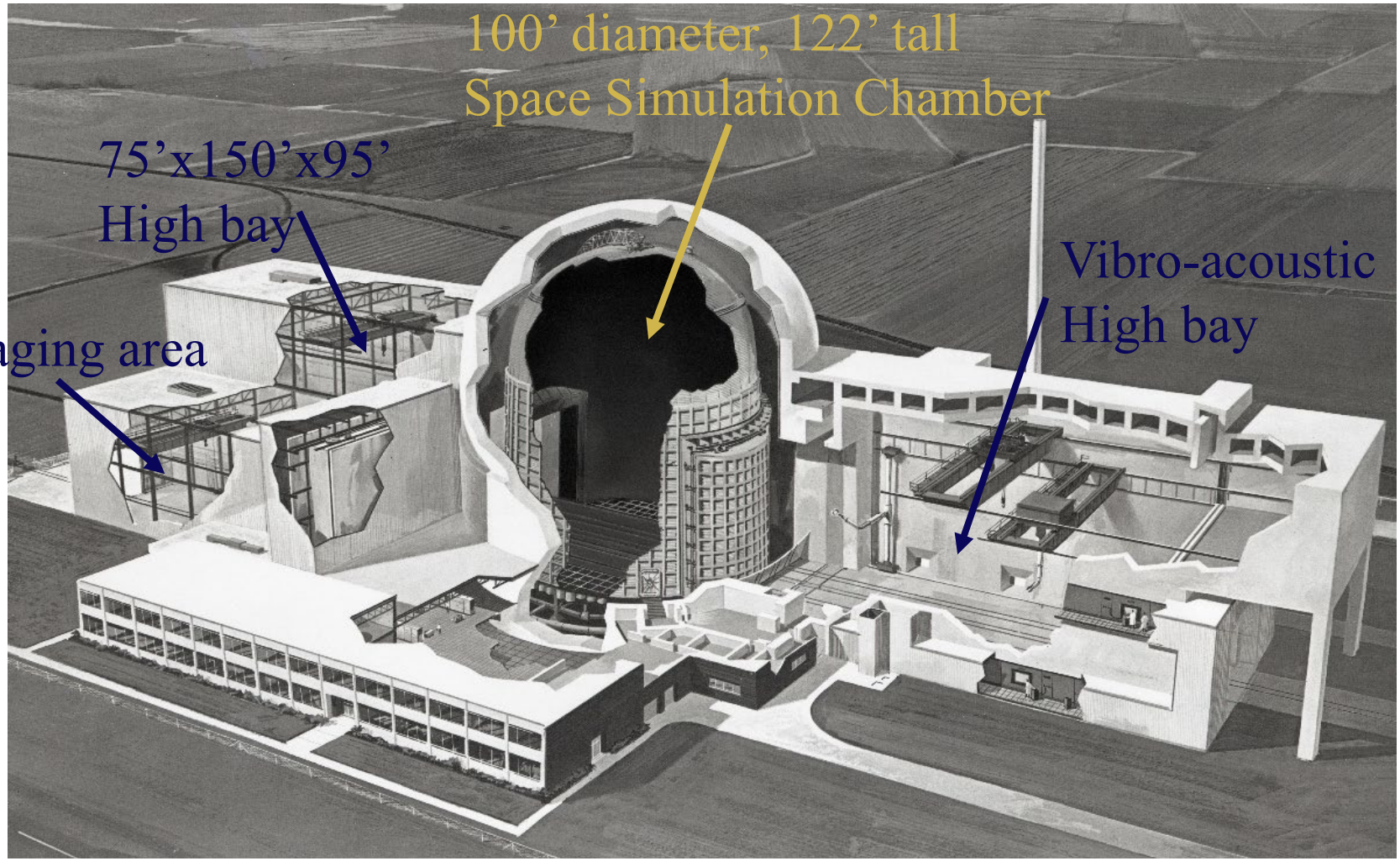
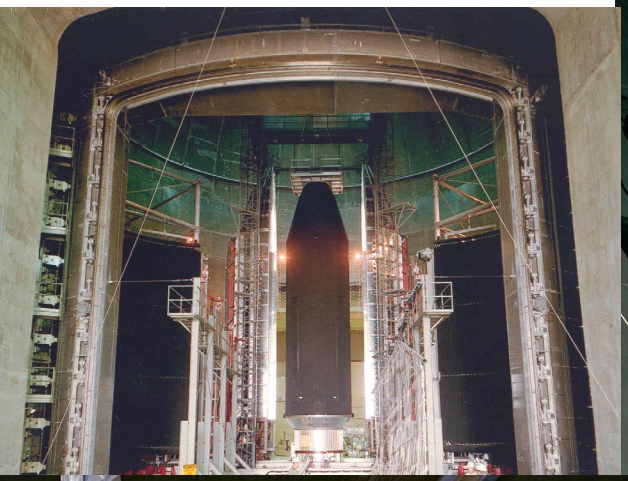
Outline

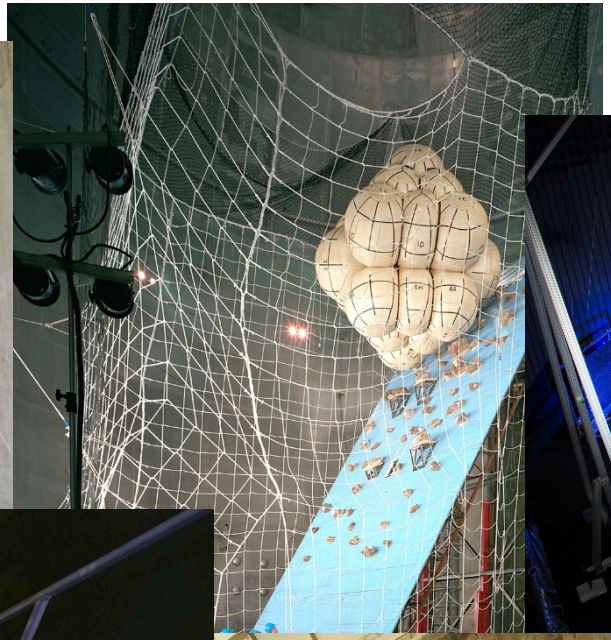
- Brief History of SEC
- Brief Summary of Artemis 1
- Augmented Capabilities
  - Thermal Environment Capabilities
    - Cryoshroud Improvements
    - Heat Flux System
  - Liquid Nitrogen Delivery/Storage Capability
  - Quality Data Capability
  - Contamination Control Capability
  - Test Summary Challenges
  - Lessons Learned
  - Conclusions

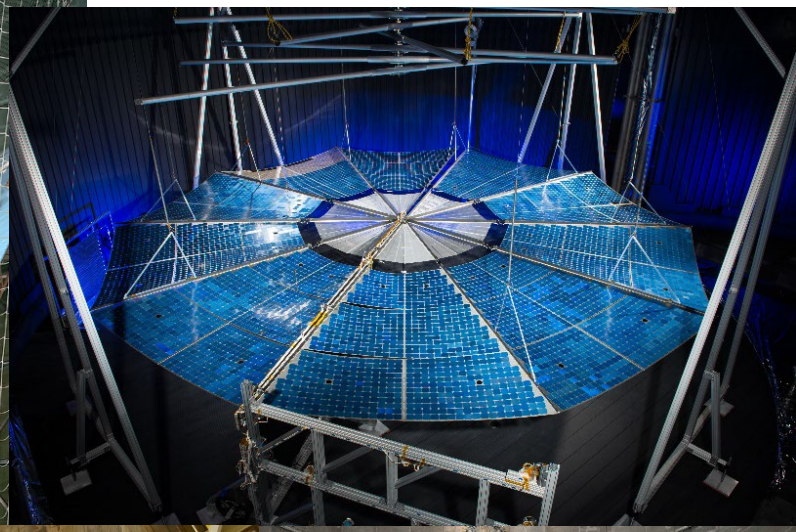
Space Power Facility

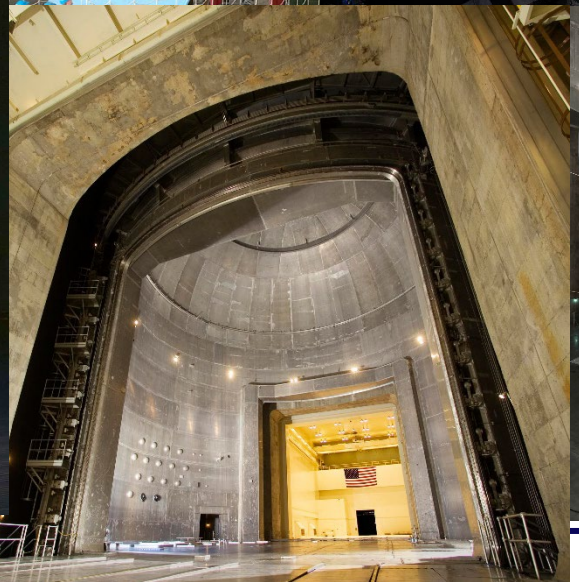


Space Environments Complex

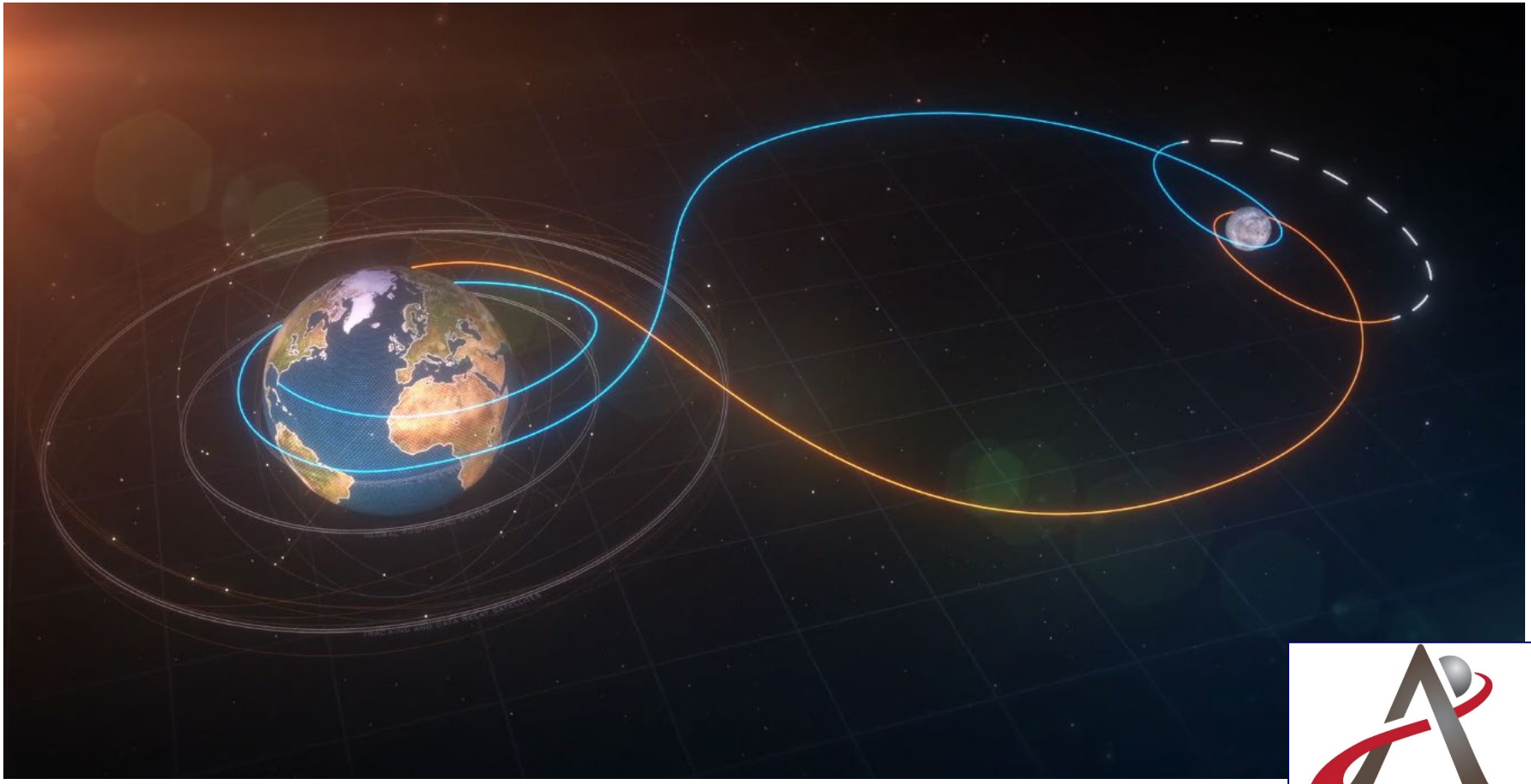




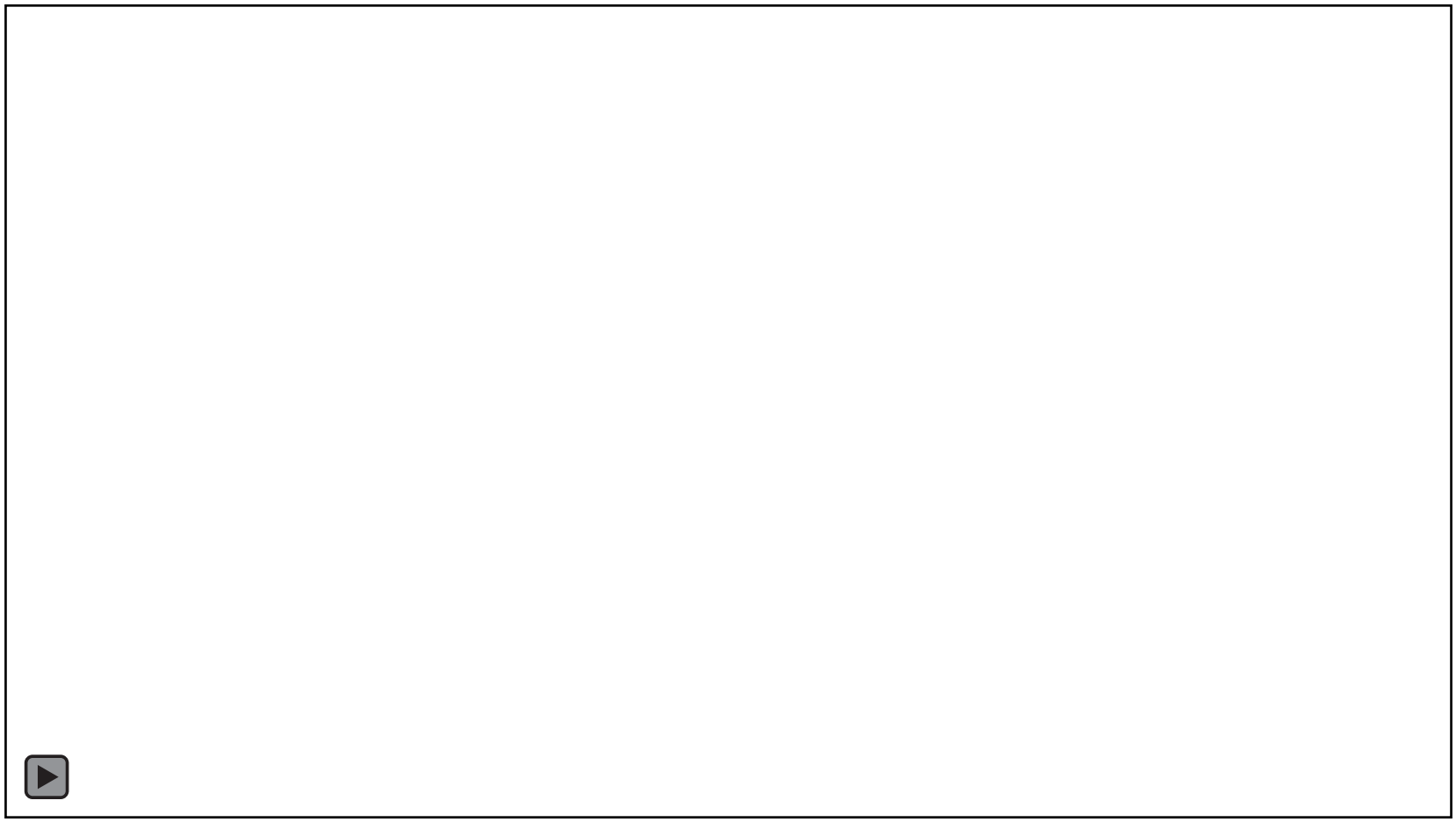




Artemis 1 Orion Program

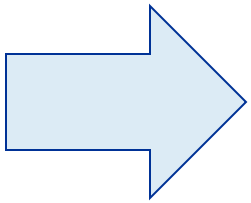


Artemis 1 Orion Thermal Vacuum Testing



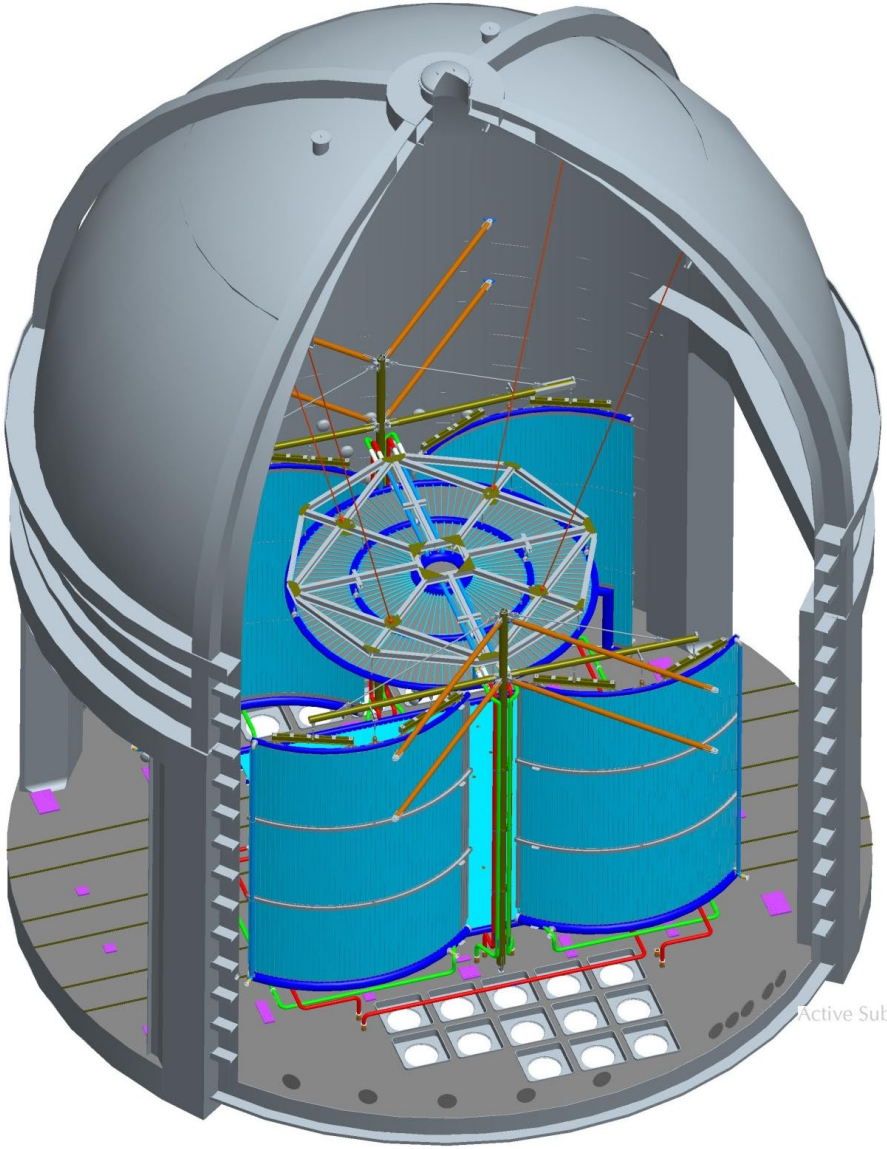
Artemis 1 Test Challenges

- Complex test configuration
- Cold and hot cycles
- Longer duration than previous tests at facility
- Flight vehicle



- Temperature-configurable thermal environment (cryoshroud + heat flux system)
- Increased LN2 storage/usage
- Quality data acquisition
- Contamination control

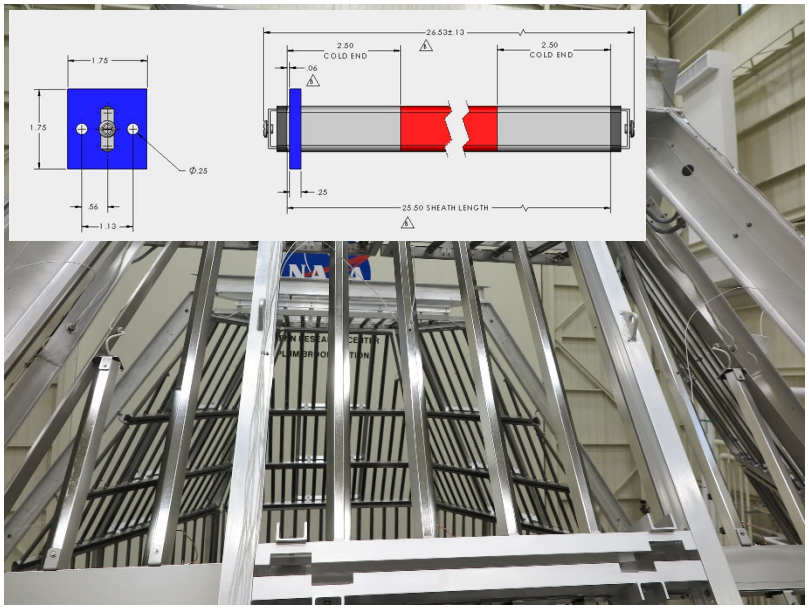
Thermal Environment (Cryoshroud) Capability



- Cryoshroud
  - 40’ diameter shroud walls 40’ high (4 thermal zones)
  - 40’ diameter cryoceiling (4 thermal zones)
  - 40’ x 40’ cryofloor (1 thermal zone)
- Cryoshroud variable temperature range:

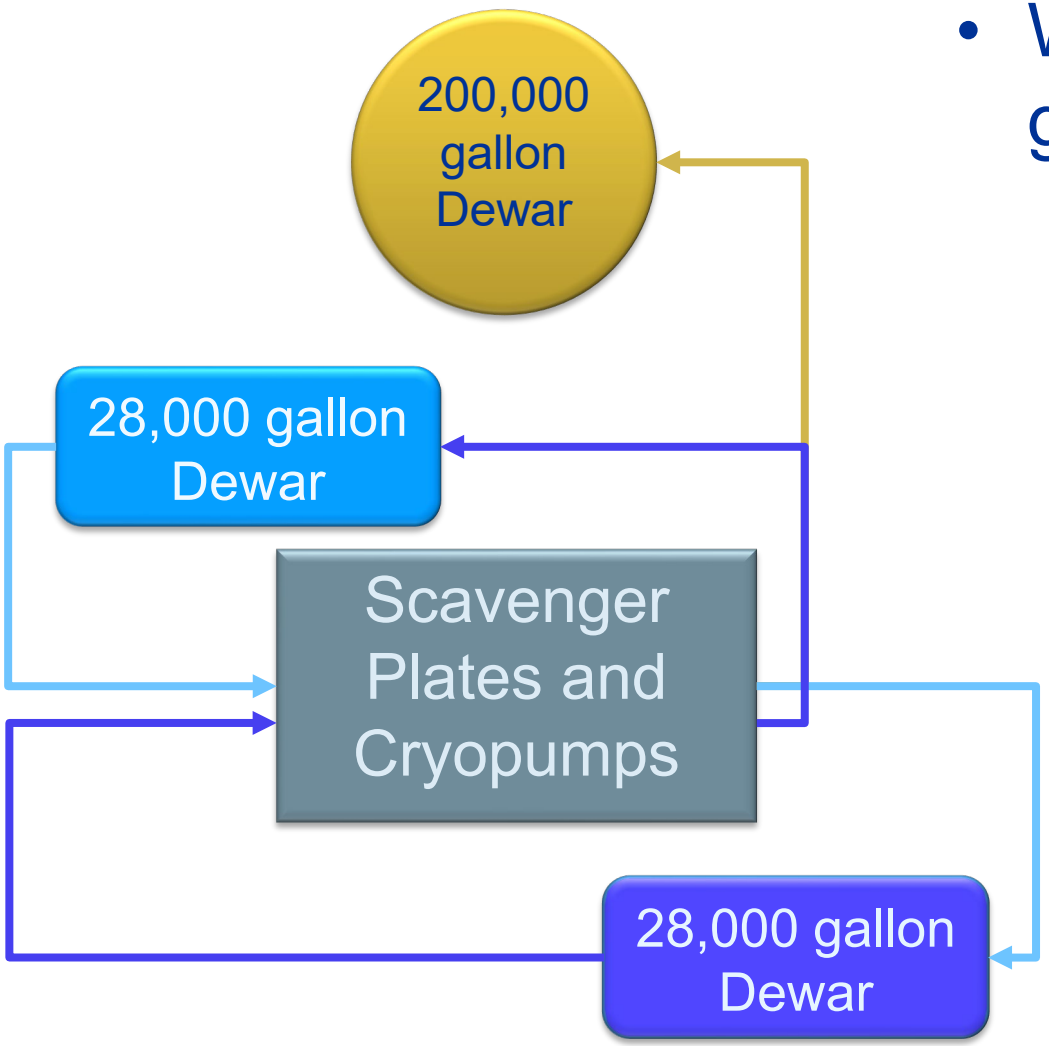
  -255°F to +175°F

Thermal Environment (Heat Flux System) Capability



- About 350 calrod/reflectors
- 32 15-kW, 125VDC zones
- 40 2.5-kW, 100VDC zones
- 36 1.2-kW, 120VAC zones
- 6 200-W, 20VDC zones
- Heating system is highly configurable for test needs

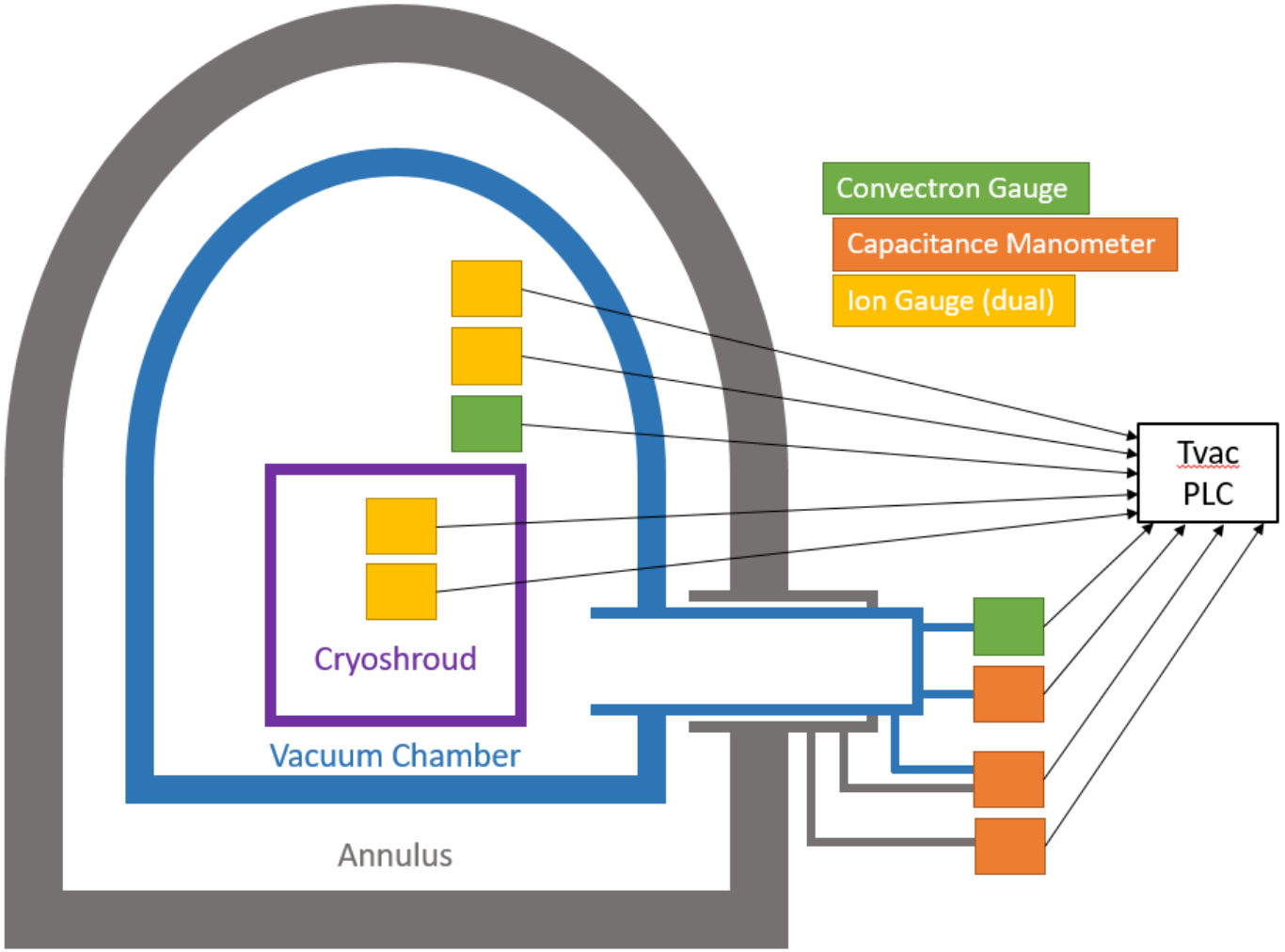
Liquid Nitrogen Capability



- With two 28,000 gallon Dewars:
  - Either Dewar can function as Supply or Receiver Dewar:
  - Doubled liquid nitrogen supply
  - Recovered liquid nitrogen

Vacuum Instrumentation Capability

Empty Chamber Vacuum Capability ~1E-6 Torr



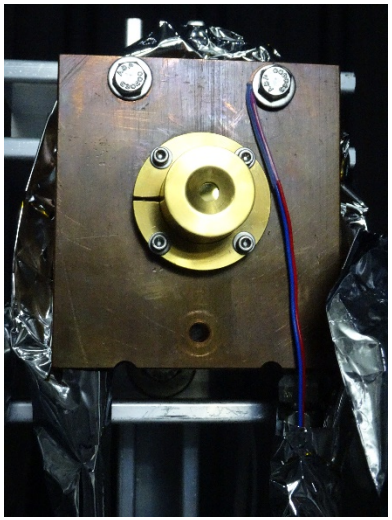
Data Collection Capability

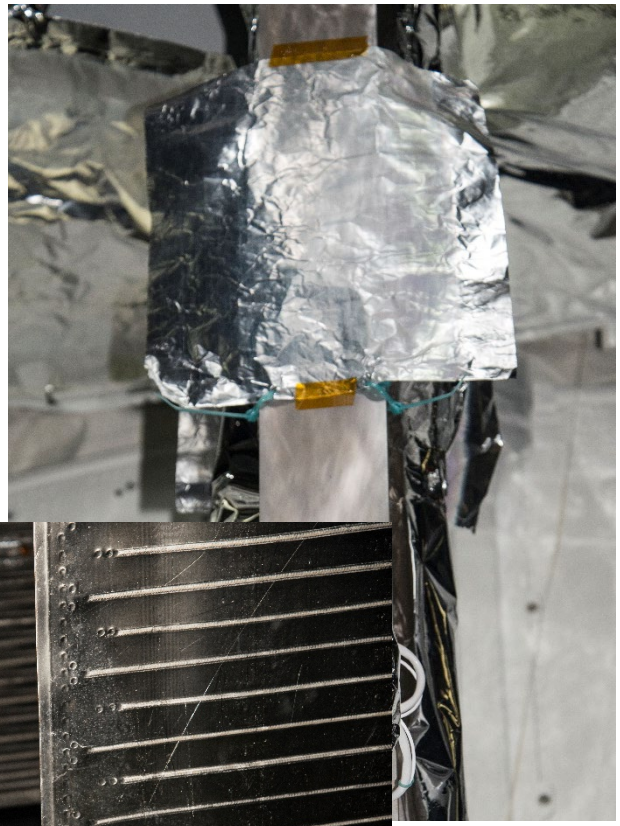
- 22 Scanivalve Digital Temperature Scanner Units
  - 64 Type-T channels per unit
  - 4 TCs per unit connected to 41°F fluid bath
- COBRA data system
- NI/Labview-based data system
- Data Collection tied to IRIG-B clock
- Control and measurement systems are isolated computer systems
  - Data is transferred from system through one “data export computer”

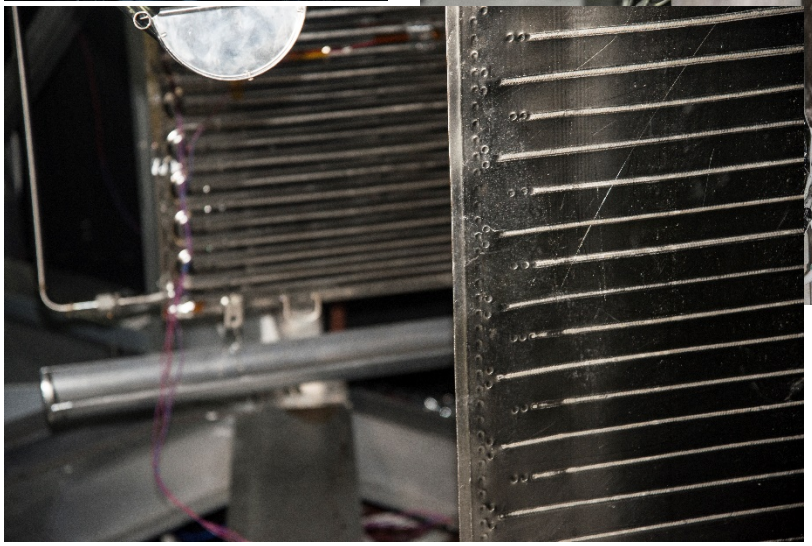
Vehicle Processing Contamination Control Capability

- Maintain highbays and chamber within temperature/humidity requirements
- ISO Class 8.5 (ISO 8.0) Capable
  - Airborne Particle Monitoring (4 units)
  - Housekeeping (Particle and Molecular cleanliness)
  - Gowning
  - Cleanroom operations

Contamination Data Collection/Monitoring Capability







- In-situ contamination monitoring:
  - Quartz Crystal Microbalance (passive and active)
  - Residual Gas Analyzer
- Post-test contamination analysis:
  - Non-volatile residue analysis (and FTIR)
    - Passive witness plates
    - Rinse of scavenger plates and other sensitive surfaces

Test Summary

- Vehicle arrived November 26, 2019
- Pumpdown to Low Vacuum December 22, 2019
- Re-pressurization completed February 10, 2020
- Vehicle left March 22, 2020

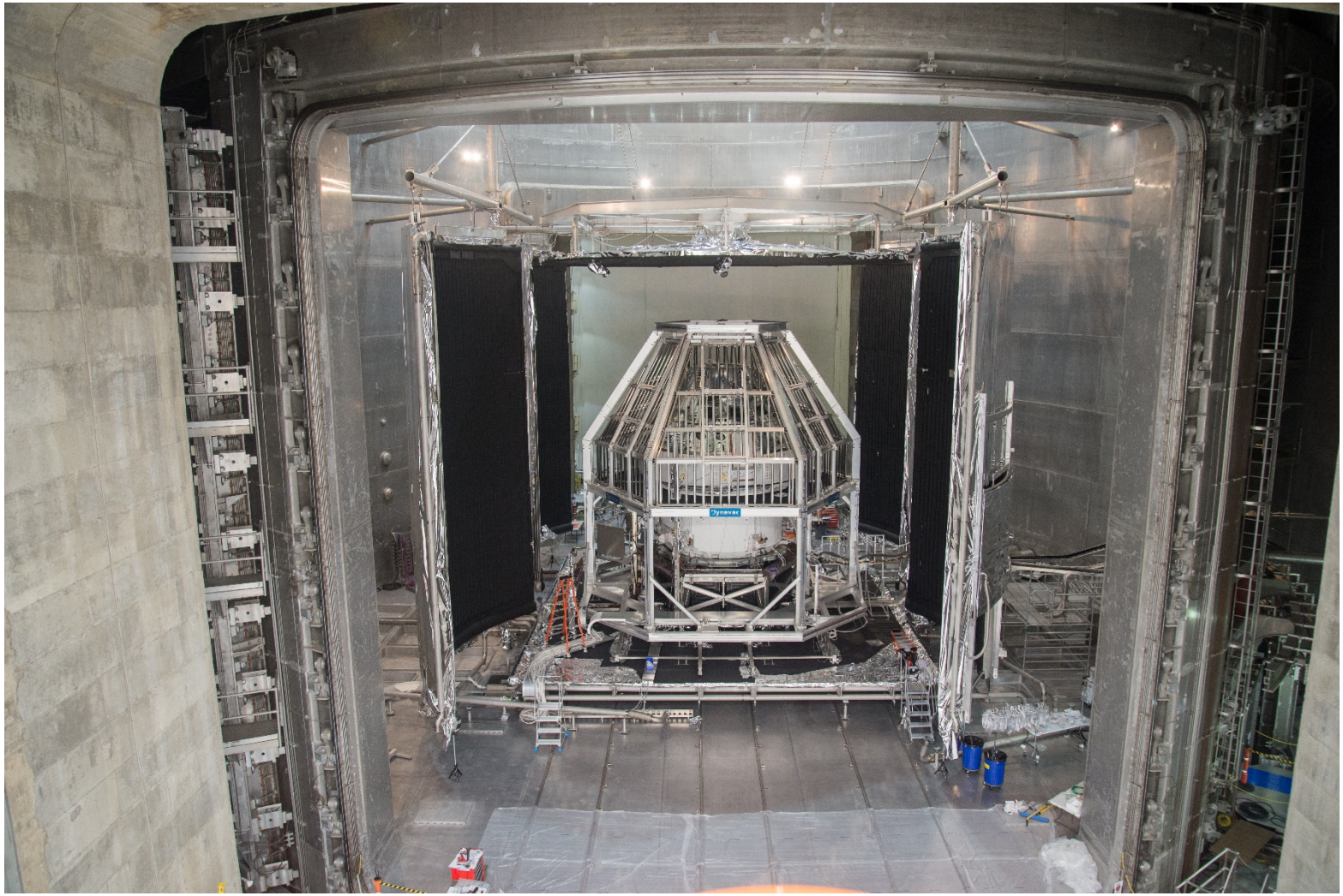
Lessons Learned: the Good

- Facility preparation resulted in no issues that risked test – Longest thermal vacuum test for SEC to date
- Daily coordination with liquid nitrogen supplier prevented significant issues
- Contingency storage (an additional 48k gallons) provided sufficient backup in case of usage issues
- Temperature-variable cryoshroud allowed for flexibility in creating thermal environment, including heating up hardware at the end
- No loss of data – data successfully captured, historized and transferred to customer/stakeholders

Lessons Learned: The Bad

- NI Labview databases overloaded, system response issues
- A lot of different systems were brought together to complete full data acquisition. In retrospect, building a comprehensive data system with all data requirements would have been advantageous
- Significant complexity managing expectations and consensus for contamination control culture and definitions among different organizations

Conclusions



Acknowledgements

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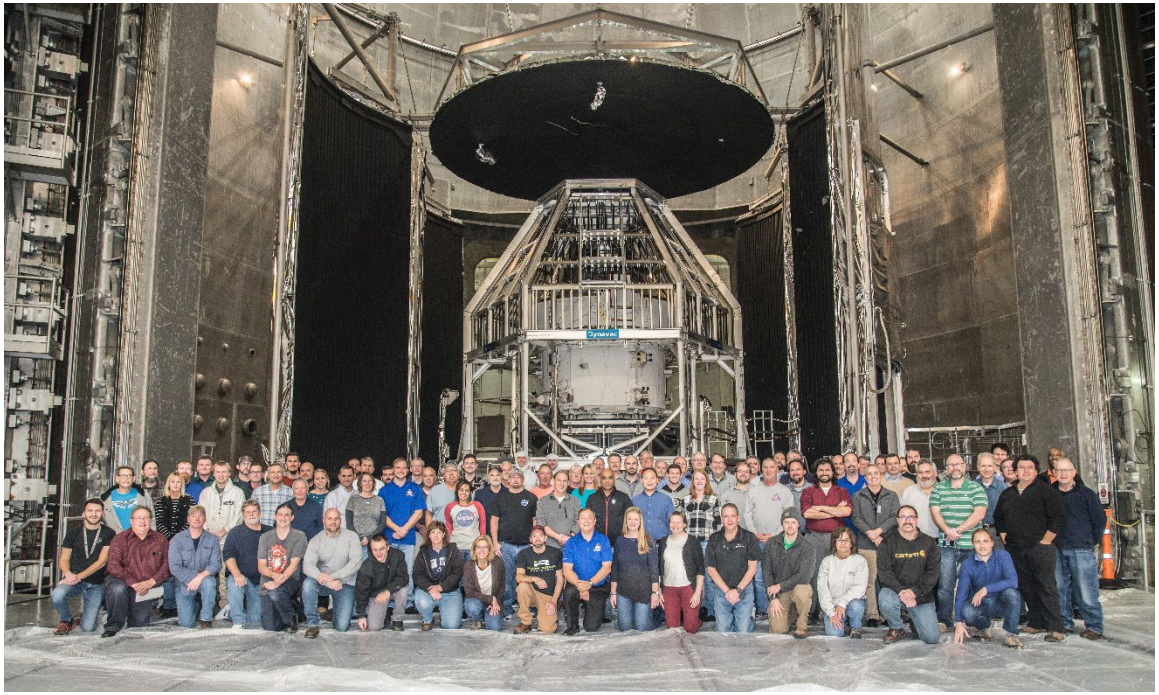

About the Author

- Erin Reed has been a thermal vacuum engineer at the Space Environments Complex at NASA Glenn Research Center's Neil A Armstrong Test Facility (formerly Plum Brook Station) since 2016. For the Artemis 1 Thermal Vacuum testing, she participated as both test conductor and contamination control engineer. She completed a Bachelor's in Mechanical Engineering at Brigham Young University in Provo, Utah and a PhD in Aerospace Engineering at the University of Virginia in Charlottesville, Virginia.