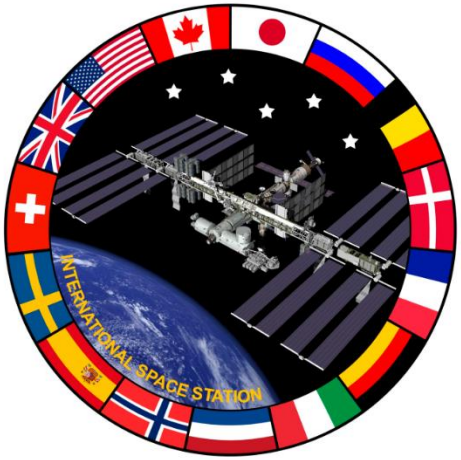

Natural and induced environment around the International Space Station (ISS) as observed during on-orbit operations of the Robotic External Leak Locator (RELL)

August 20, 2018

Katie L. Fox[a], Alexandra M. Deal[a], Alvin Y. Huang[a], Michael J. Heiser[a], William A. Hartman[a], Ronald R. Mikatarian[a], Matthew J. Davis[a]

Adam Naids[b], Timothy A. Bond[b], Brien Johnson[b]

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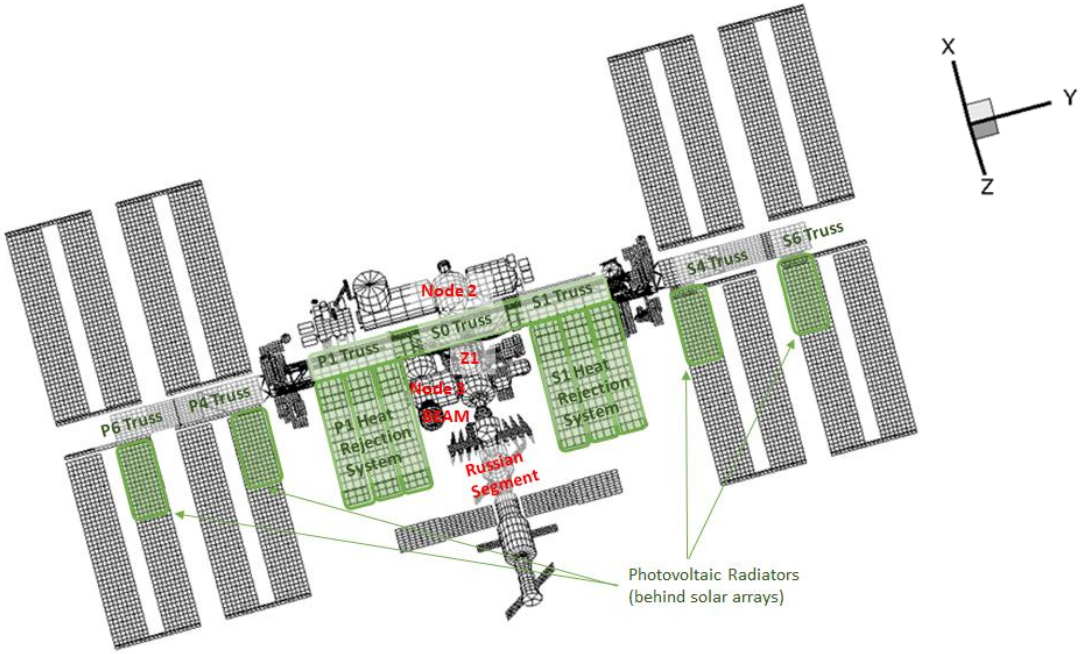
[c]Conceptual Analytics, NASA Goddard Space Flight Center

Background

- *The United States External Active Thermal Control System (EATCS) on the International Space Station (ISS) uses liquid ammonia in closed loops to collect, transport, and reject heat.*
- *Detection and location of small ammonia leaks (estimated to be < 50 lbm per day) from the EATCS was identified as a risk by the ISS program and the Robotic External Leak Locator (RELL) was commissioned to demonstrate the capability to locate these small leaks.*



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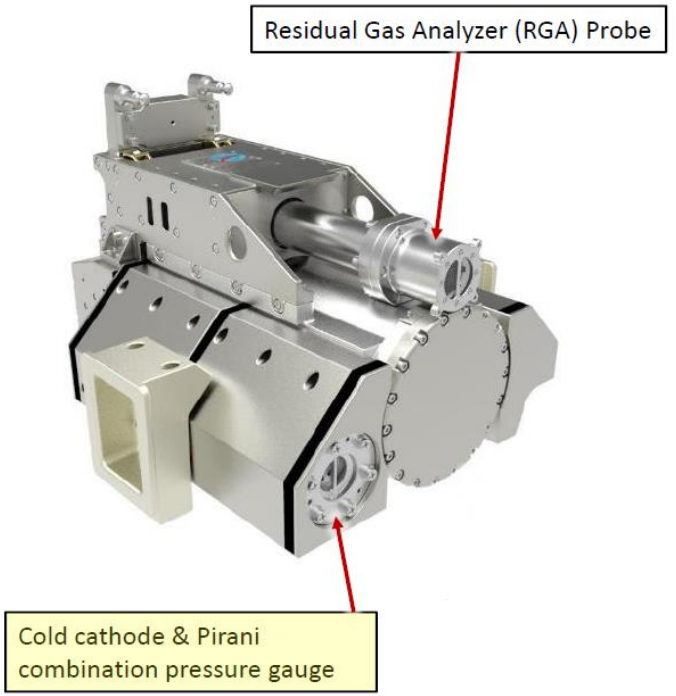
Robotic External Leak Locator

- *Collaboration between NASA's Goddard Space Flight Center and Johnson Space Center*
- *Maneuvered with Space Station Remote Manipulator System (SSRMS) and Special Purpose Dexterous Manipulator (SPDM) robotic arms*
- *PKR 251 Ion Gauge: Combination total pressure gauge*
  - *Pirani gauge*
    - *Pressure is determined from heat dissipation rate of a hot filament due to gas collisions with the filament.*
  - *Cold cathode system*
    - *Utilizes orthogonal electric and magnetic fields to trap electrons.*
    - *Allows for a current measurement which is proportional to the gas density.*
  - ***Measurement range is 3.75×10-9 to 750 Torr.***
  - ***Response times range from ~10 ms for pressures above 7.50× 10-7 Torr to ~1 s for pressures at the low end of the range.***



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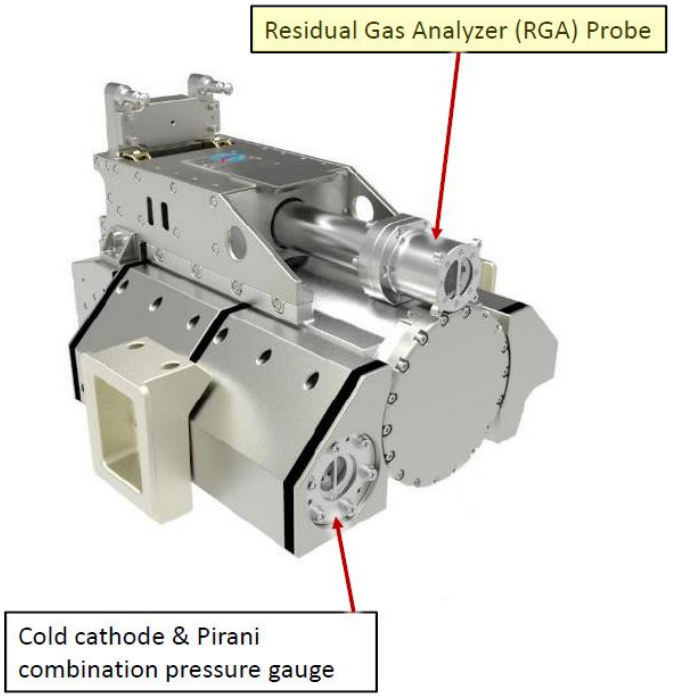
Robotic External Leak Locator

- *Residual Gas Analyzer – 100*
  - *Quadrupole gas analyzer that measures for a mass range from 1 to 100 ion mass-to-charge ratios*
  - *Heated filament bombards incoming gas with electrons creating positive ions.*
  - *The ions are directed toward the quadrupole filter where they are separated by their mass-to-charge ratio.*
  - *A Faraday Cup detector measures current directly and for increased sensitivity, an electron multiplier measures the electron current proportional to ion current.*
  - *The measurement range is 10^{-13} to 10^{-4} Torr.*
  - *Scan times can vary from several seconds to a minute based on the parameters (e.g., mass range).*



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ISS Environmental Control and Life Support Systems (ECLSS) Vents

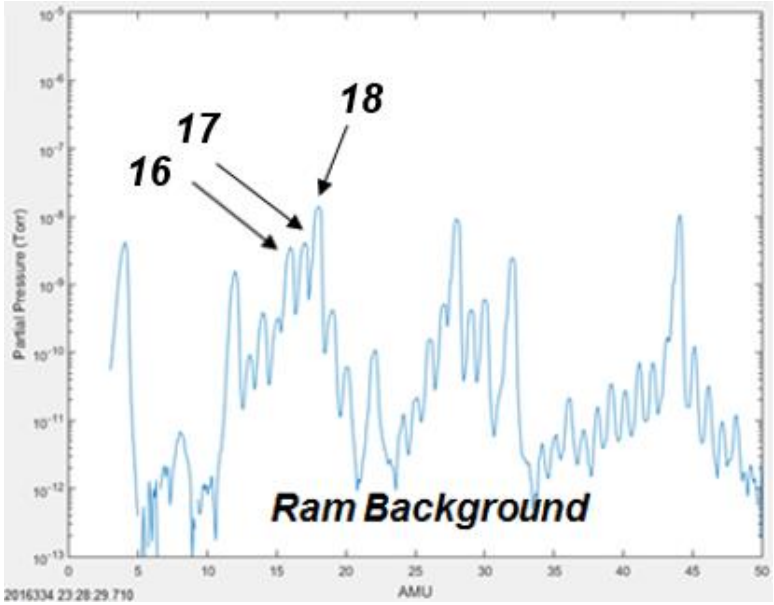
- *Life support systems are located on both the U.S. Operating Segment (USOS) and Russian segment.*
- *There are two main ECLSS operating on the USOS: 1) in Node 3, and 2) in U.S. Laboratory.*
  - *Typically operates on a 144 minute cycle.*
  - *Node 3 Regenerative ECLSS*
    - *Carbon Dioxide Removal Assembly (CDRA) vents CO_2 overboard. There is telemetry data on the opening time of the vent valve.*
    - *Oxygen Generation Assembly (OGA) produces oxygen and hydrogen from the electrolysis of water.*
    - *Sabatier Assembly on occasion converted CO_2 from CDRA and H_2 from the OGA to CH_4 and H_2O.*
      - *When the Sabatier was operational, the system vented CO_2 and CH_4 from the CO_2 vent line and H_2 from the H_2 vent line.*
      - *Sabatier assembly was removed in late 2017.*
    - *Water Recovery System*

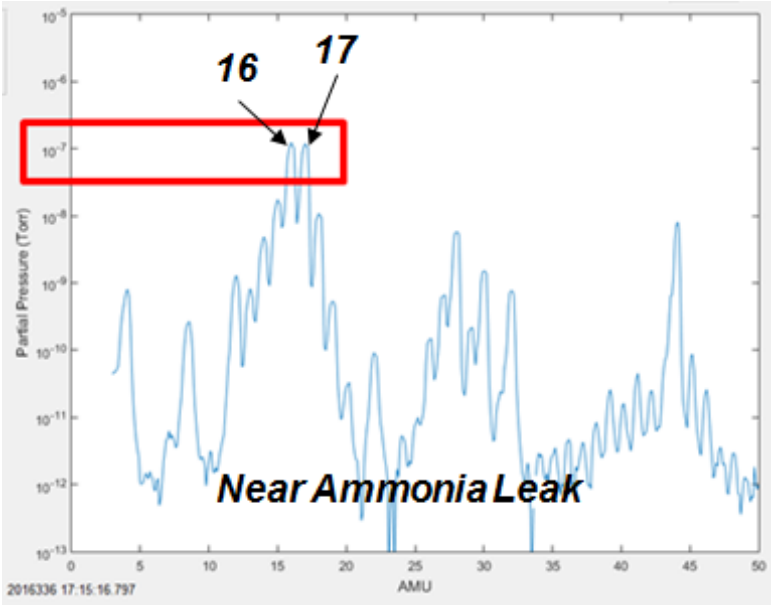
ISS Environmental Control and Life Support Systems (ECLSS) Vents, Cont.

- *USOS ECLSS, cont.*
  - *U.S. Laboratory does not have a Sabatier assembly.*
- *On the Russian segment, there are two continuous vents, Vozdukh and Elektron, both located on the Service Module. Similar gas byproducts are generated except for water which is recovered in the USOS.*
  - *Currently operating on a 20 minute cycle.*

RELL Measurement of Water and Ammonia

- Use ion mass ratios of 16 to 17, in additional to total pressure, to distinguish between water and ammonia
  - Water: 0.04
  - Ammonia: 0.80





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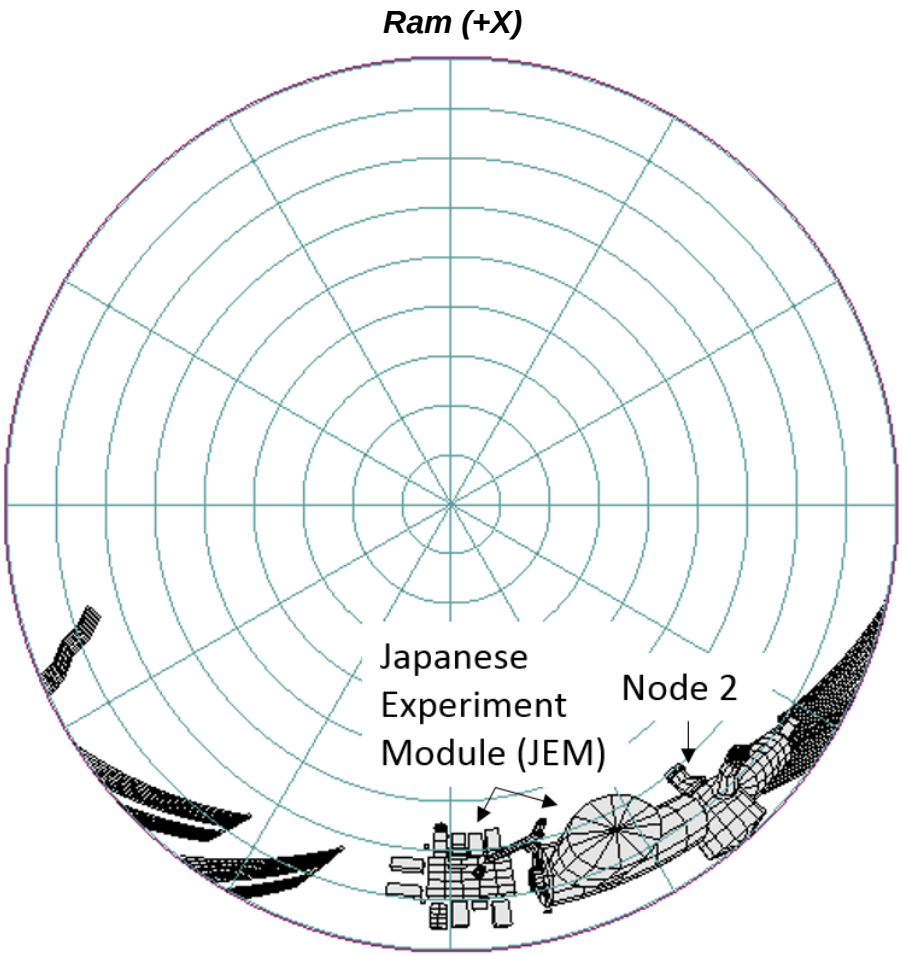
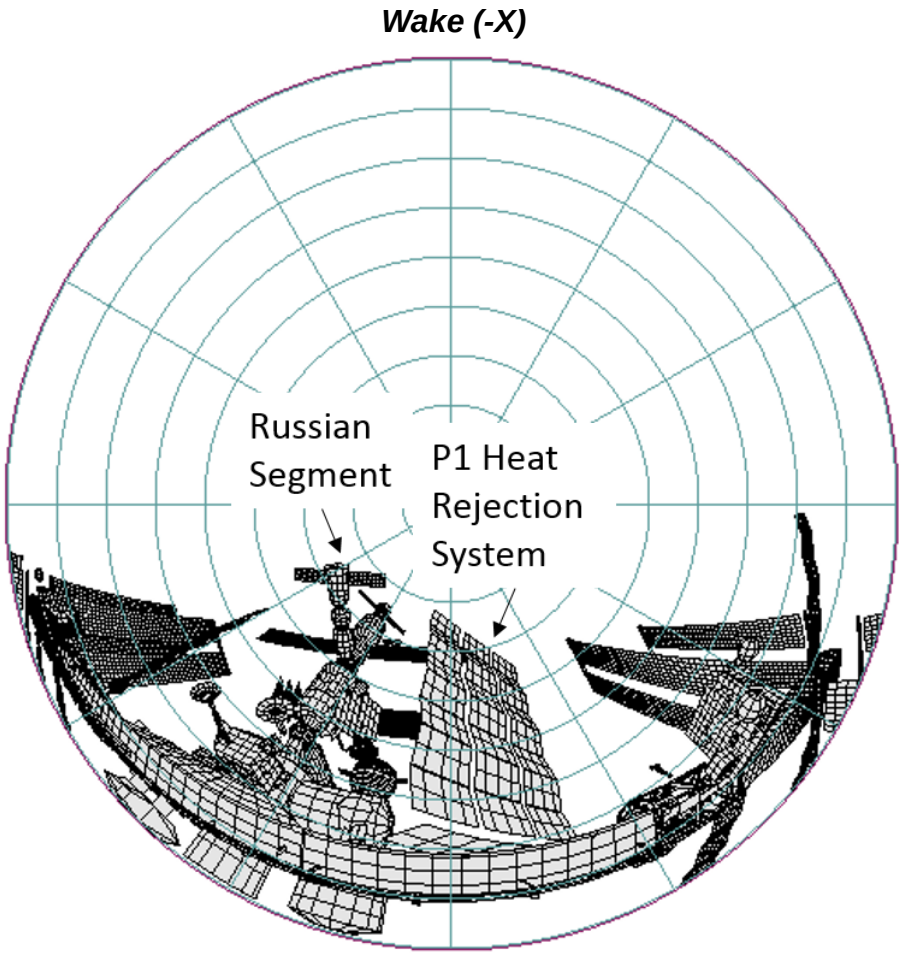
RELL Background Environment Scans

- *Three scanning activities performed during RELL on-orbit demonstration and validation in November – December 2016.*
- *Background Scanning A*
  - *Ram (+X) direction, as far from ISS structure as possible*
  - *Wake (-X) direction, as far from ISS structure as possible*
- *Background Scanning B*
  - *P1 Truss face scanning*
- *Background Scanning C*
  - *Port-side EATCS radiator*

Background Scanning A





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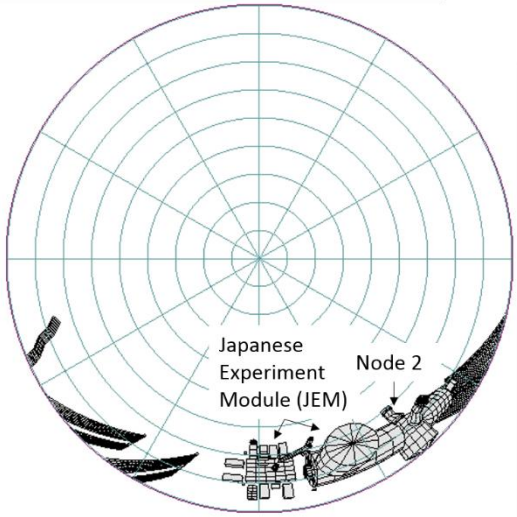
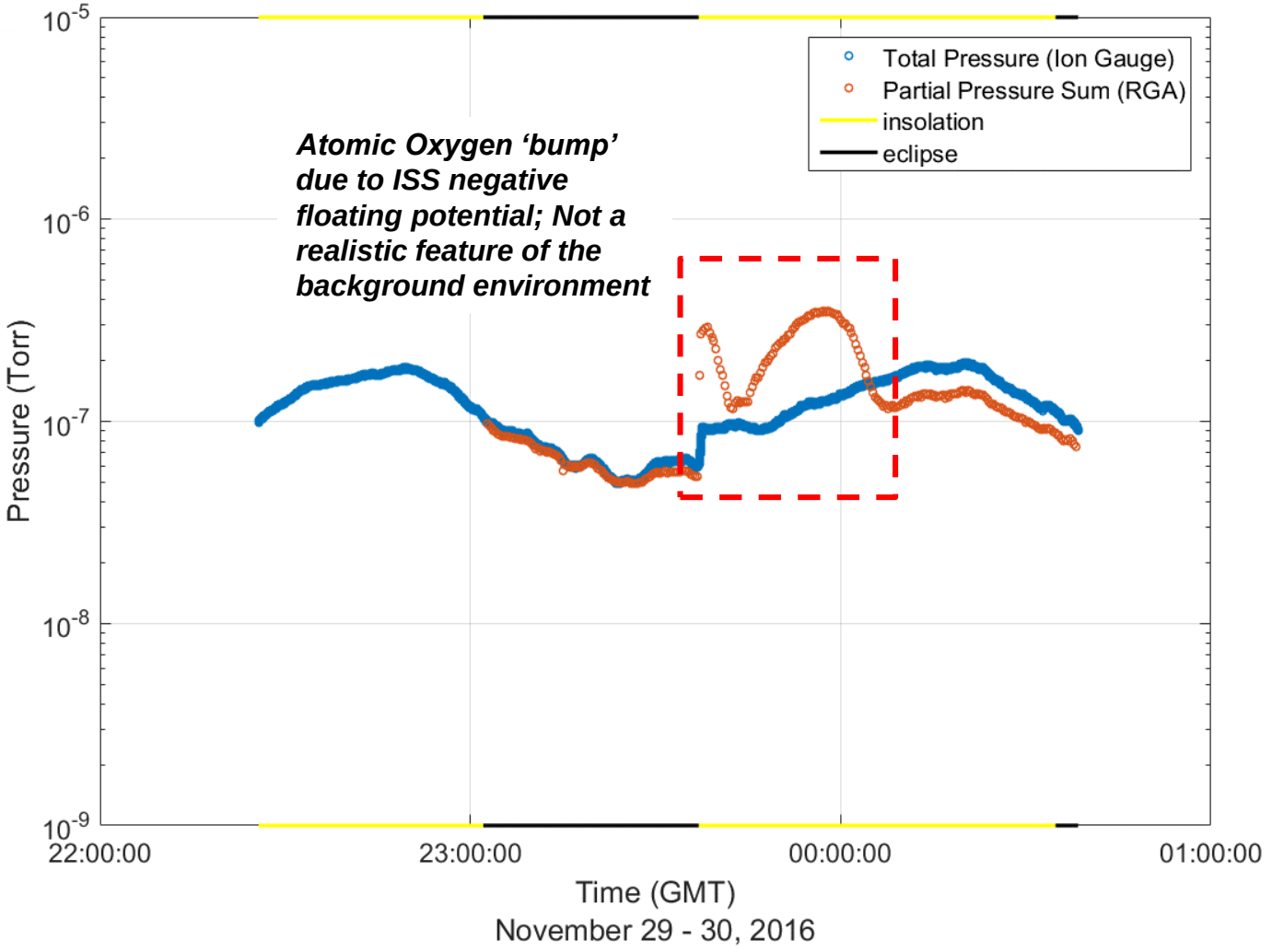
Background Scanning A: Ram (+X)



- ***Sum of RELL RGA partial pressures includes AMU 3 to 50***



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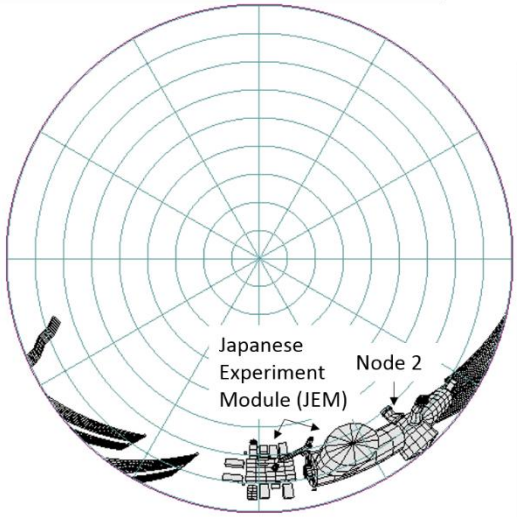
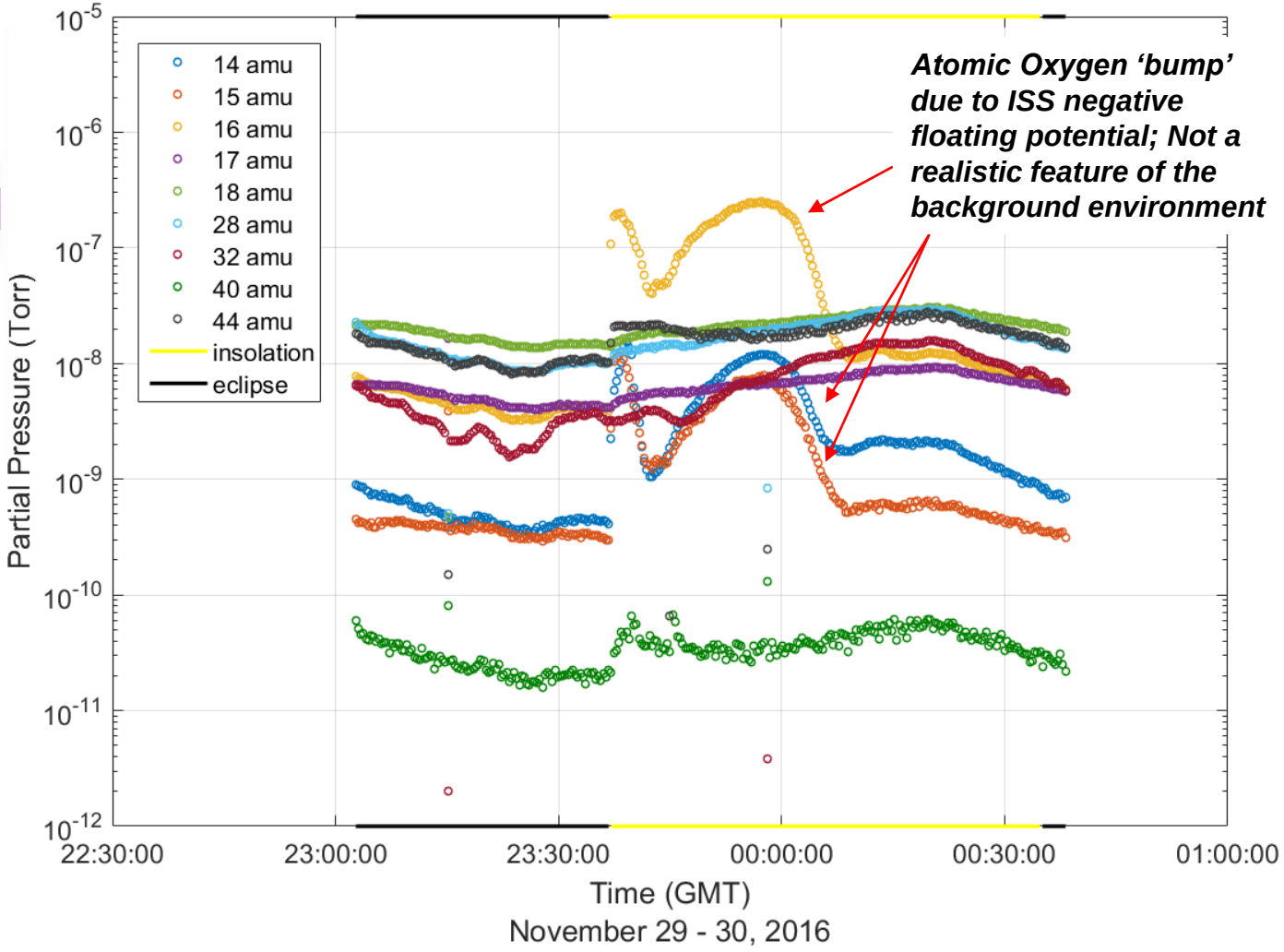
Background Scanning A: Ram (+X)





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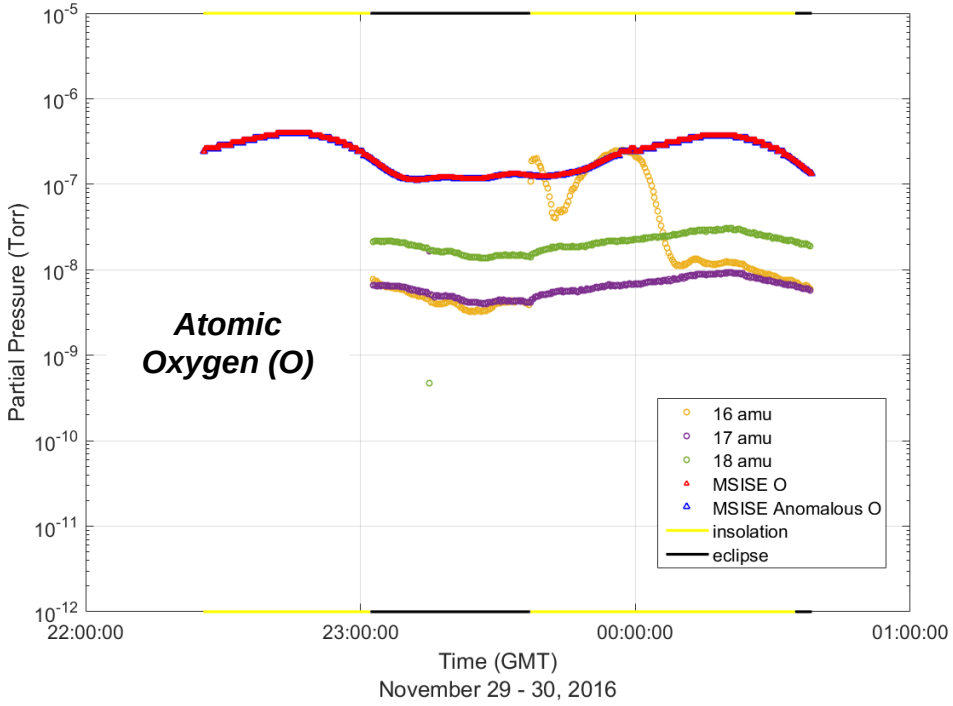
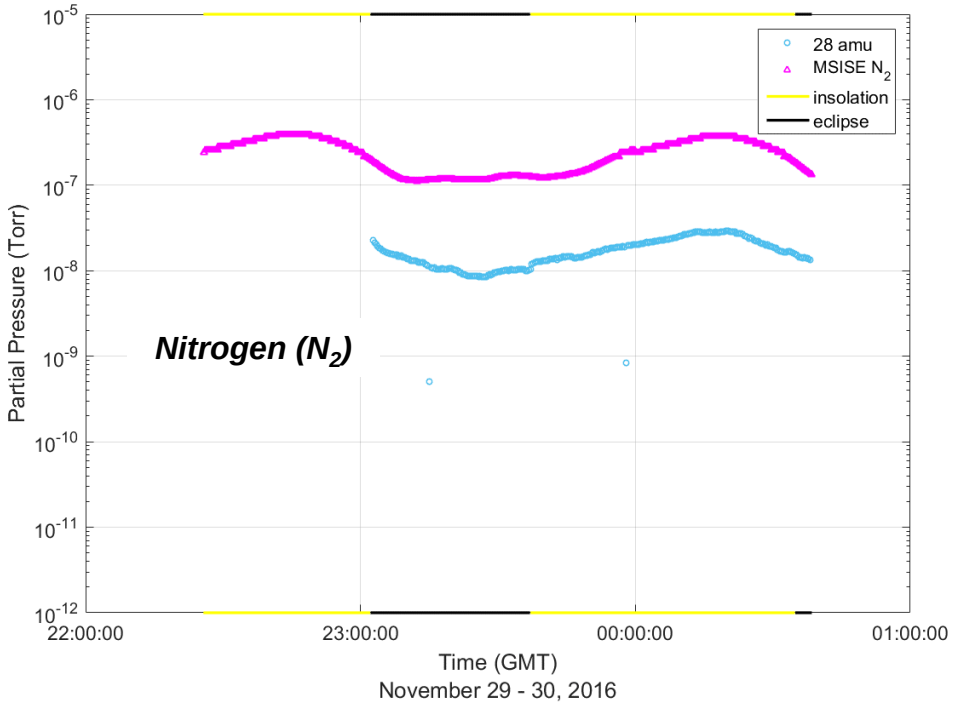
Publically available – NASA EDAA NF1676 TN58665

Background Scanning A: Ram (+X)



- **Compare to MISSE-00 data**
  - **Includes dynamic pressure with V_{ISS} = 7600 m/s**



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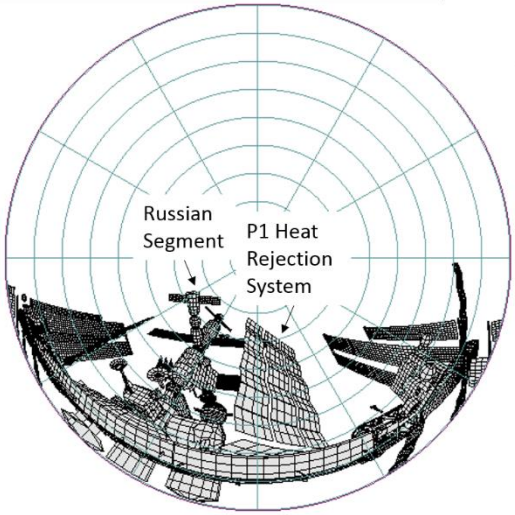
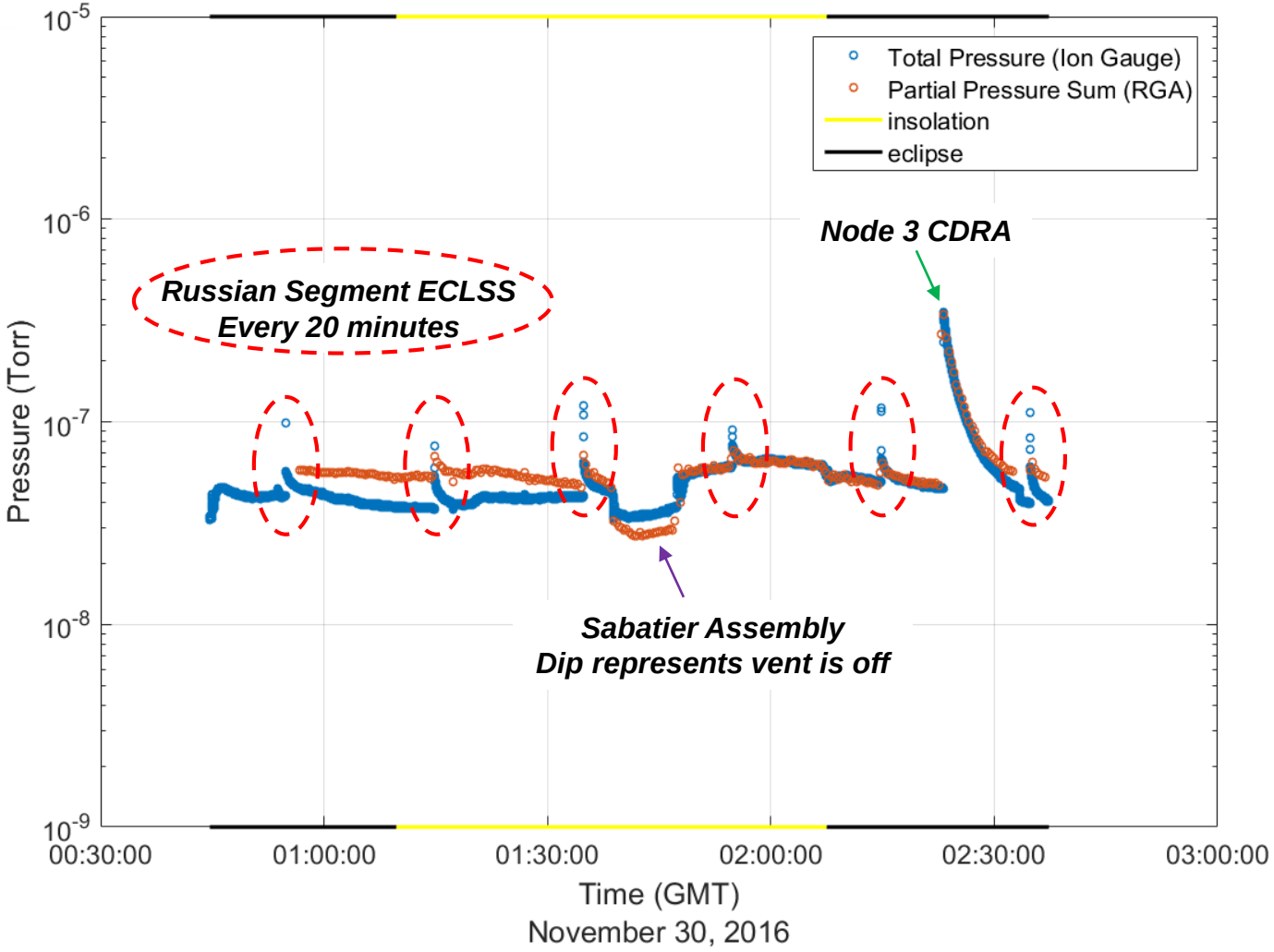
Background Scanning A: Wake (-X)





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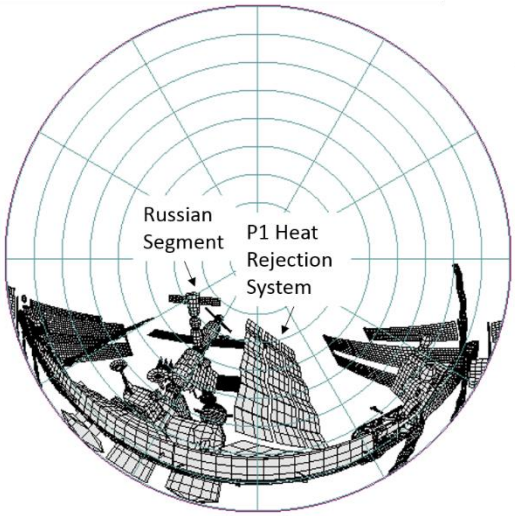
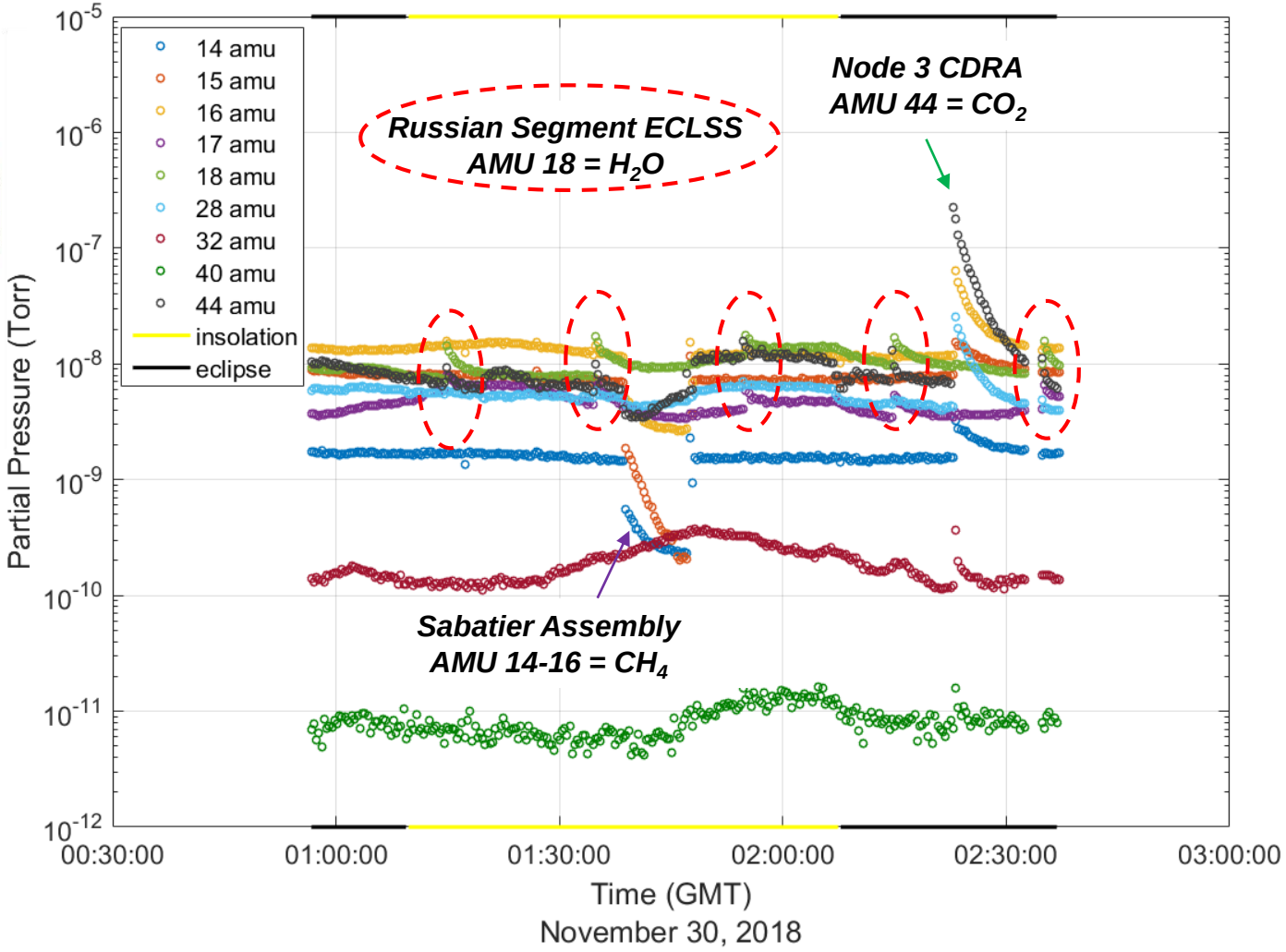
Background Scanning A: Wake (-X)





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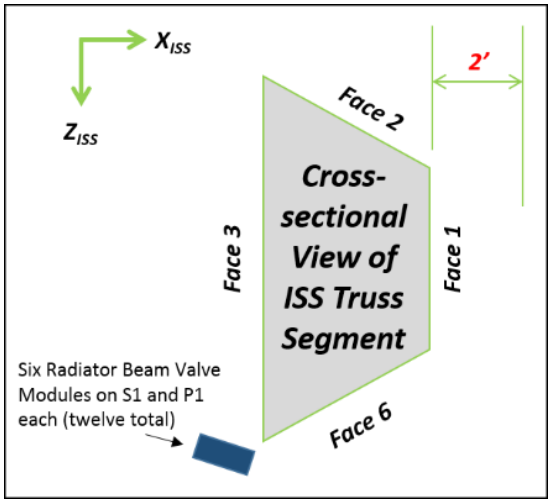
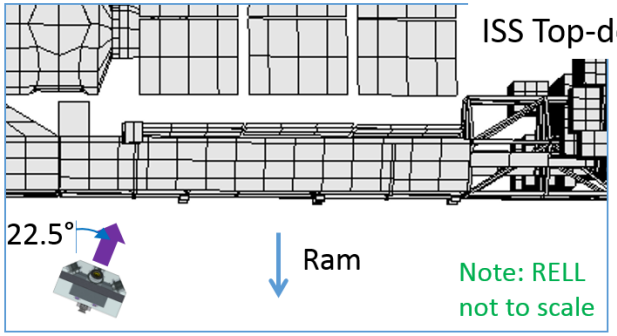
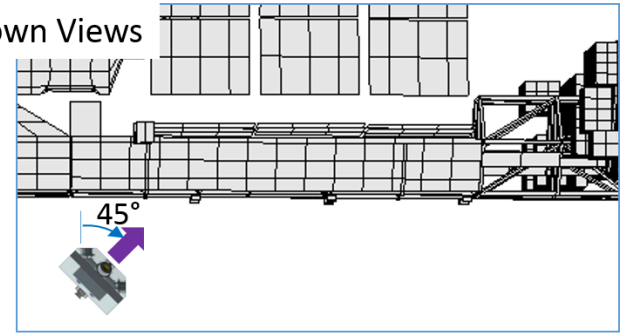
Background Scanning B

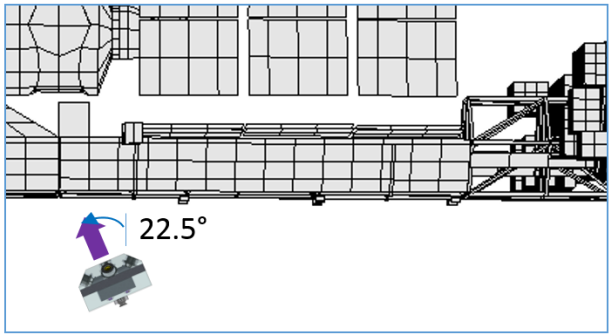




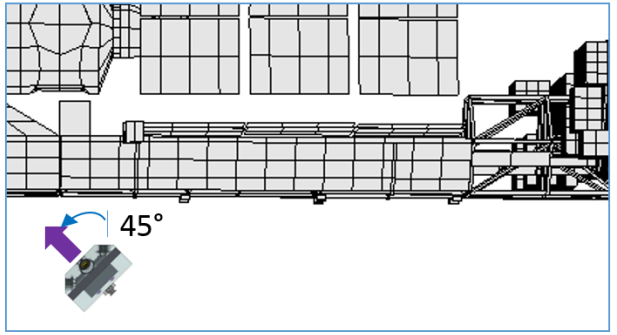
Measurement 2: Rotate the RELL 22.5° in the port/outboard direction (-Y) maintaining 2 feet clearance from Face 1



Measurement 3: Rotate the RELL another 22.5° in the port/outboard direction (-Y) maintaining 2 feet clearance from Face 1



Measurement 4: Rotate the RELL 22.5° in the starboard/inboard direction (+Y) maintaining 2 feet clearance from Face 1



Measurement 5: Rotate RELL another 22.5° in the starboard/inboard direction (+Y) maintaining 2 feet clearance from Face 1

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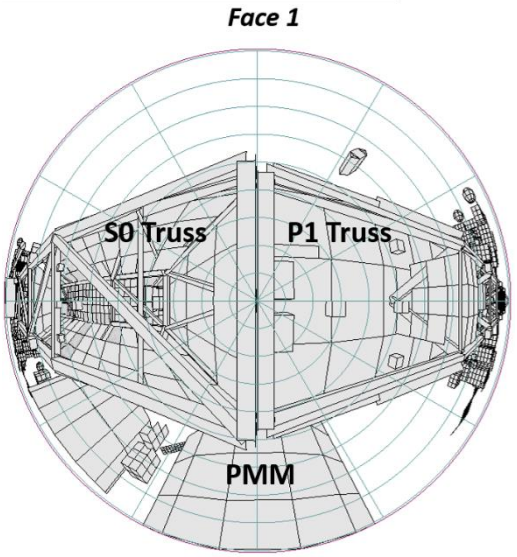
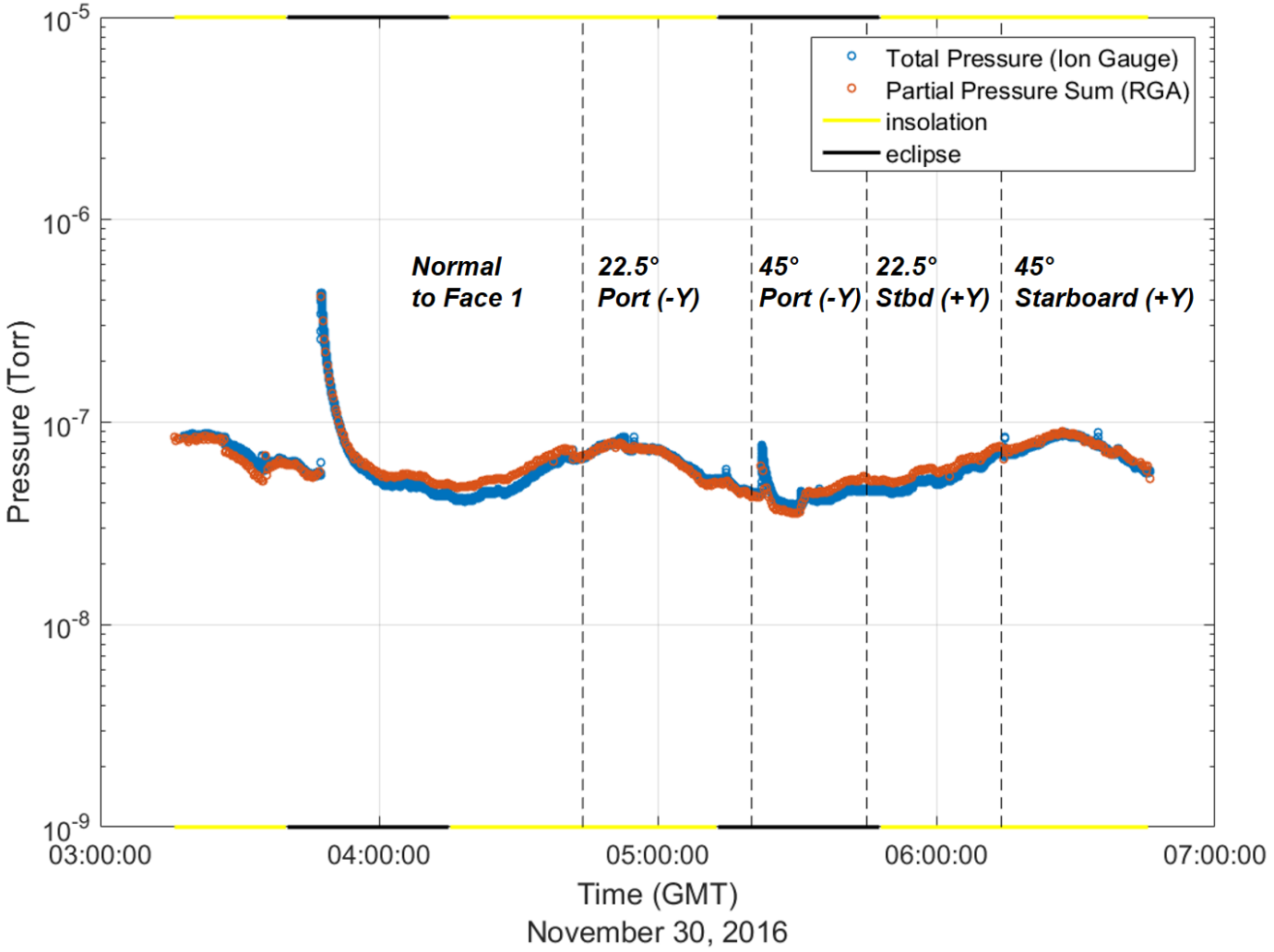
Background Scanning B: P1 Truss Face 1



- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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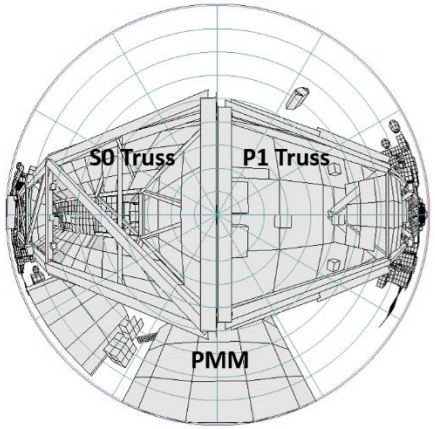
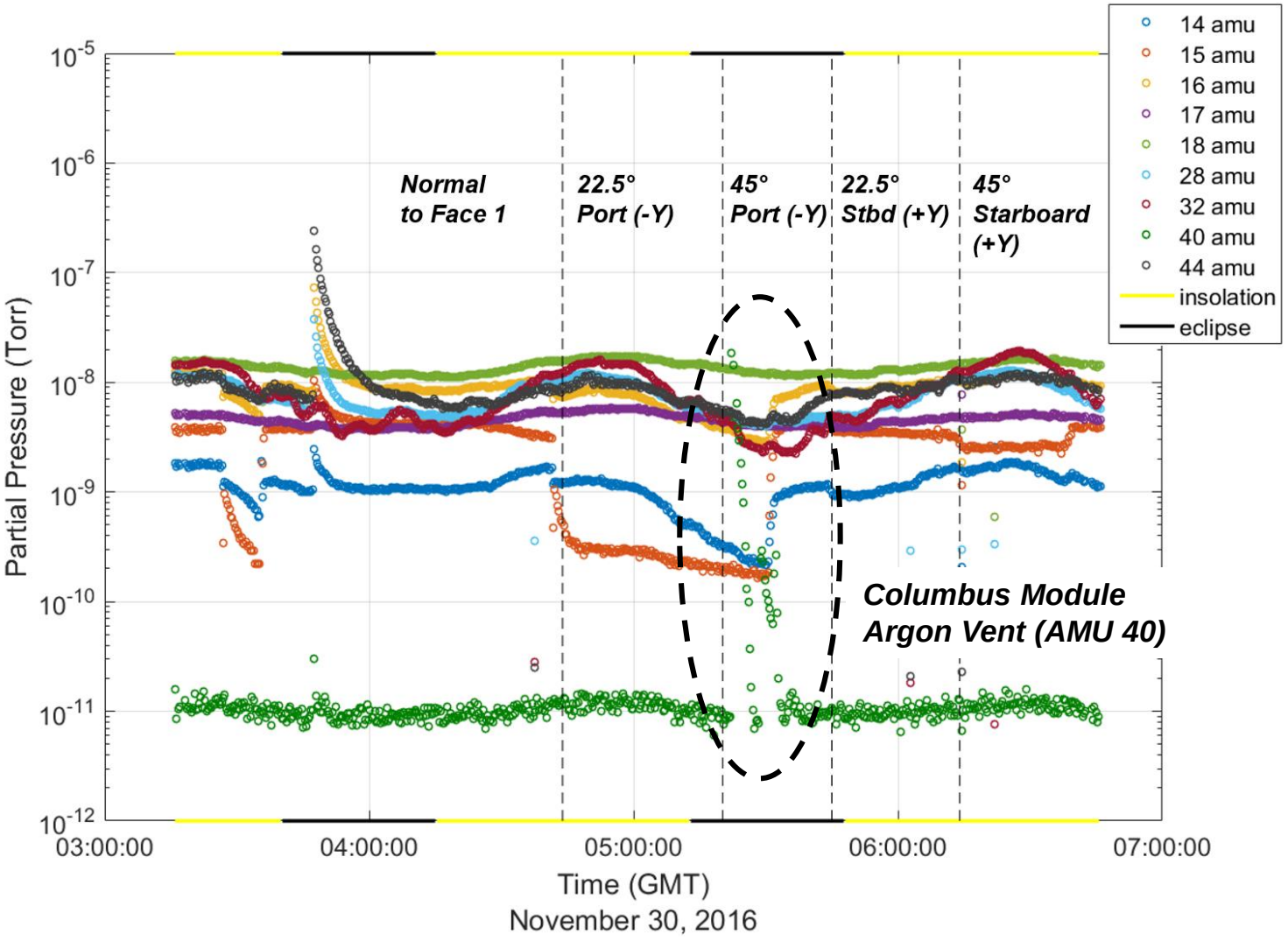
Background Scanning B: P1 Truss Face 1



- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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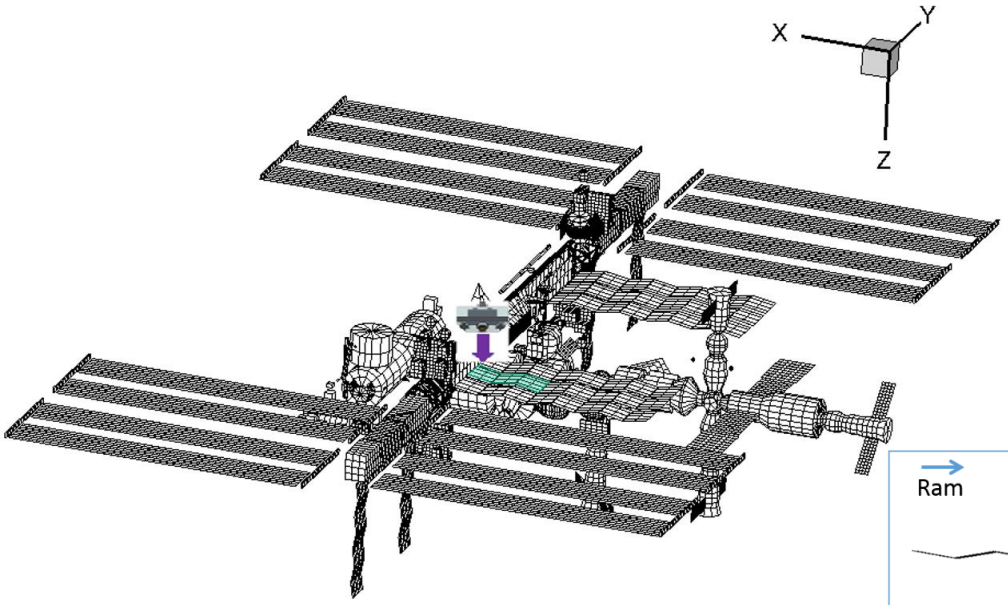
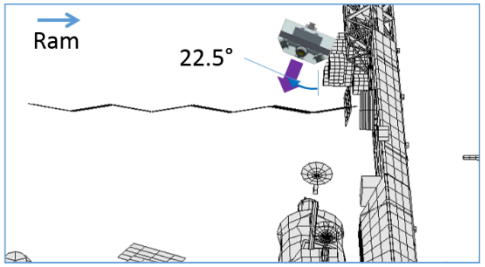
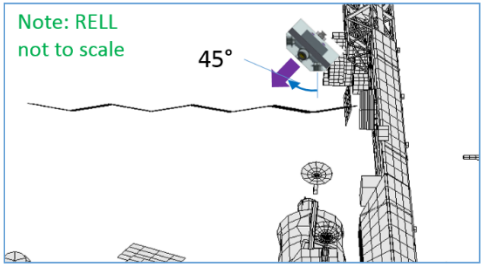
Background Scanning C

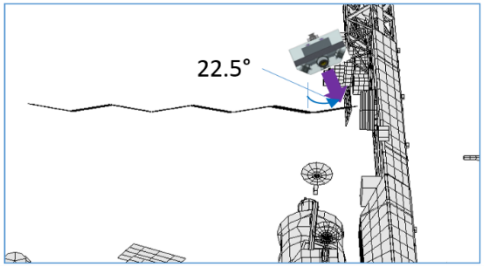




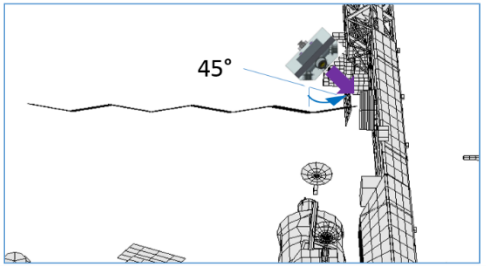
Measurement 2: Rotate the RELL 22.5° along the length of the radiator towards ISS wake direction (-X) maintaining 2 ft clearance



Measurement 3: Rotate the RELL another 22.5° along the length of the radiator towards ISS wake direction (-X) maintaining 2 ft clearance



Measurement 4: Rotate the RELL 22.5° along the length of the radiator towards ISS ram direction (+X) maintaining 2 ft clearance



Measurement 5: Rotate the RELL another 22.5° along the length of the radiator towards ISS ram direction (+X) maintaining 2 ft clearance

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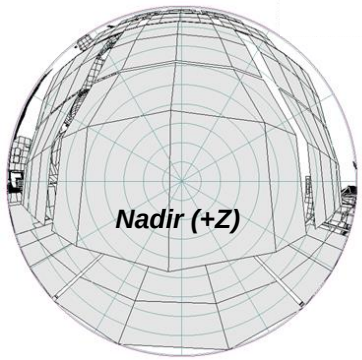
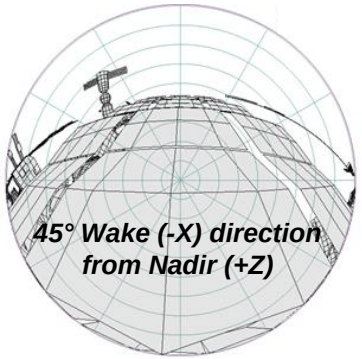
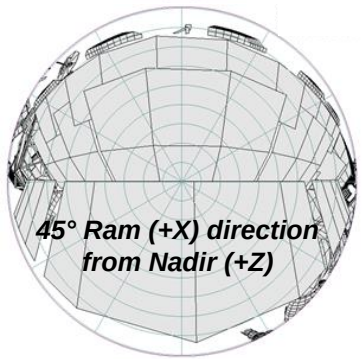
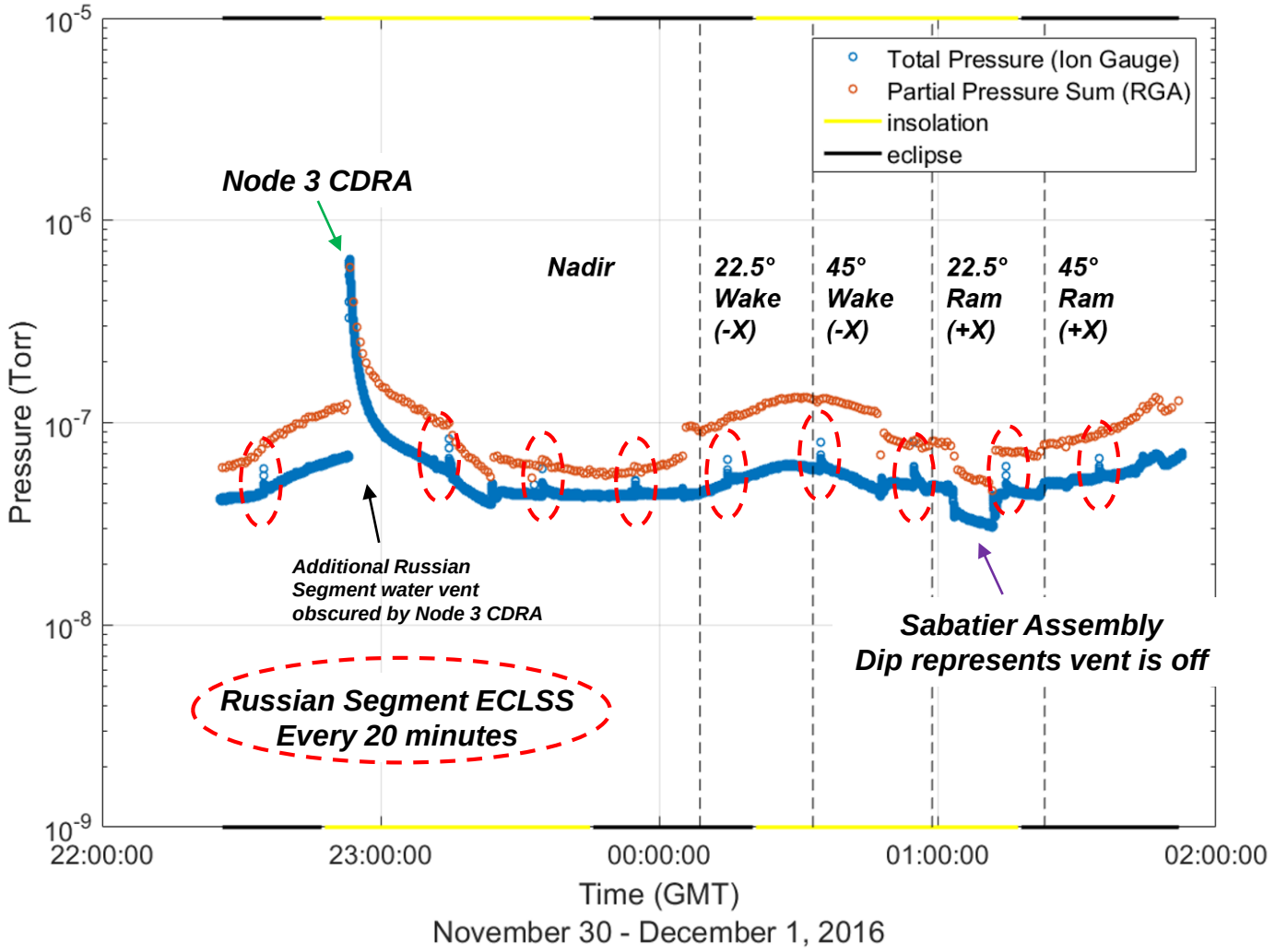
Background Scanning C: Port-Side EATCS Radiator, 0” from Base









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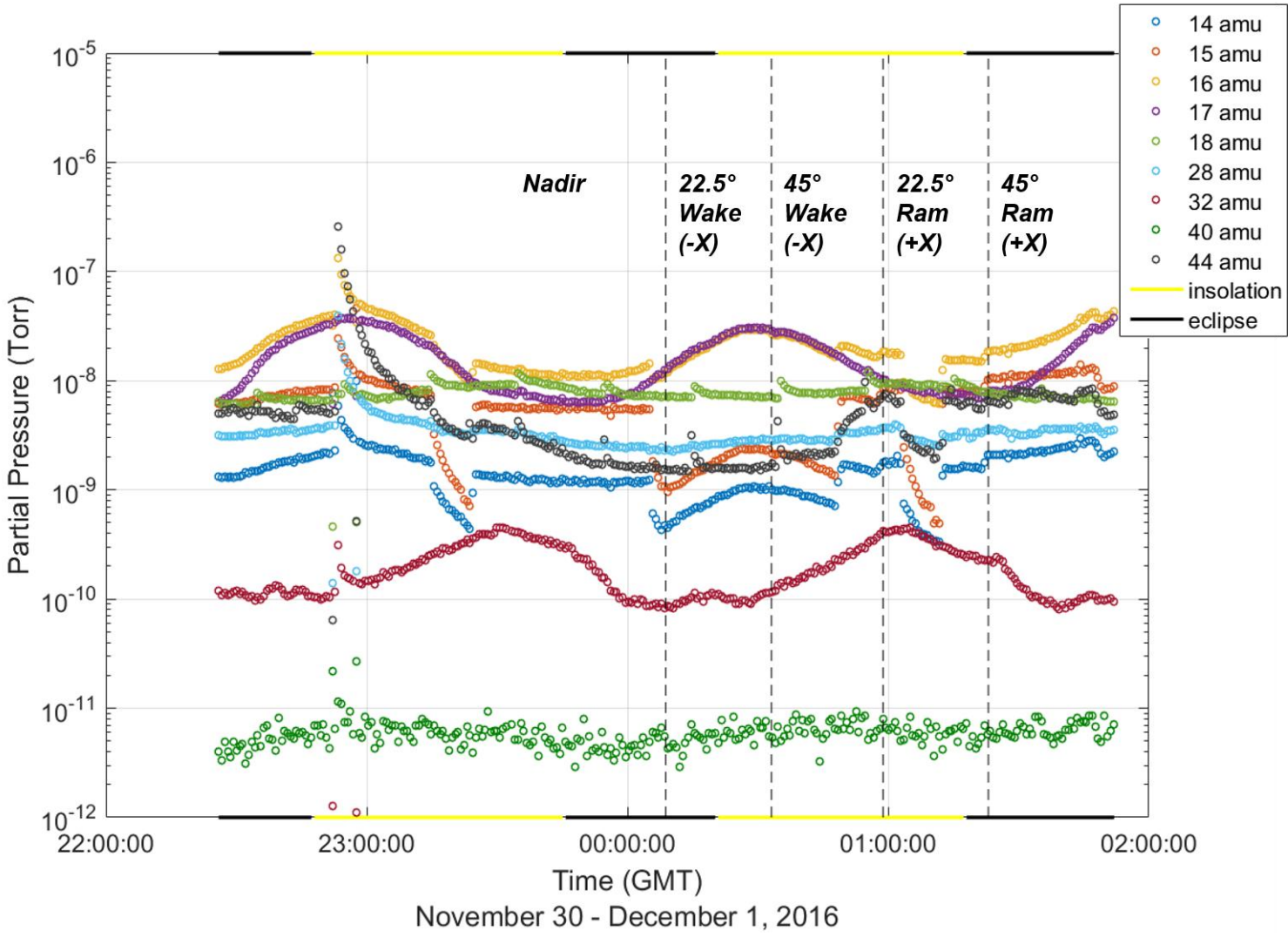
Background Scanning C: Port-Side EATCS Radiator, 0” from Base

- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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Conclusions

- *A thorough understanding of the sensitivity of RELL in the natural and induced environment around ISS supported the success of RELL in detecting and locating ammonia leaks during the on-orbit demonstration.*
- *Negative ISS floating potential impacted several mass-to-charge ratios, including 16 or atomic oxygen, when RELL was pointed in the ram (+X) direction.*
- *RELL detected several U.S. and Russian segment ECLSS vents, including the Node 3 CDRA vent, Sabatier Assembly, and Russian segment water venting even when not sensors not pointed in the direction of the vent.*
  - *Communicate with hardware owners prior to RELL operations.*
- *Ammonia was detected in the environment around the port-side EATCS radiator panels and RBVMs. Likely due to ammonia leak in one of the RBVMs, rather than a consistent presence of ammonia in the induced environment.*

Acknowledgements

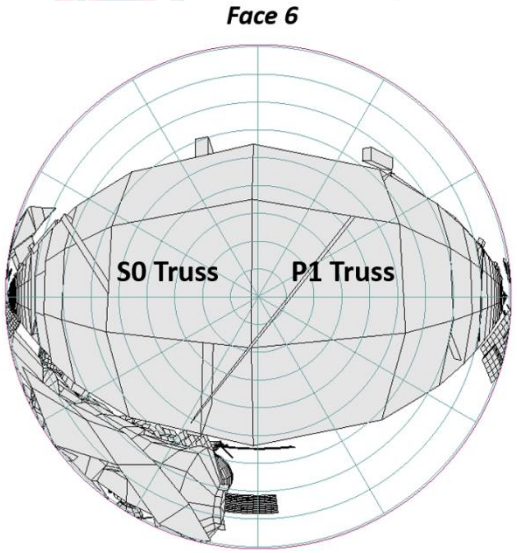
- *Contributions during the design and verification stages of the Robotic External Leak Locator:*
  - *Jesse A. Buffington*
  - *David Autrey*
  - *Carlos E. Soares*
  - *Matthew J. Roode*
  - *Steven B. Morris*
  - *Michael S. Woronowicz*
- *Stanford Research Systems for their support during on-orbit operations in November – December 2016 and February 2017:*
  - *Matt Kowit*
  - *Dave Doheny*

- ***Contact Information***
  - ***Katie Fox, katie.l.fox@boeing.com***

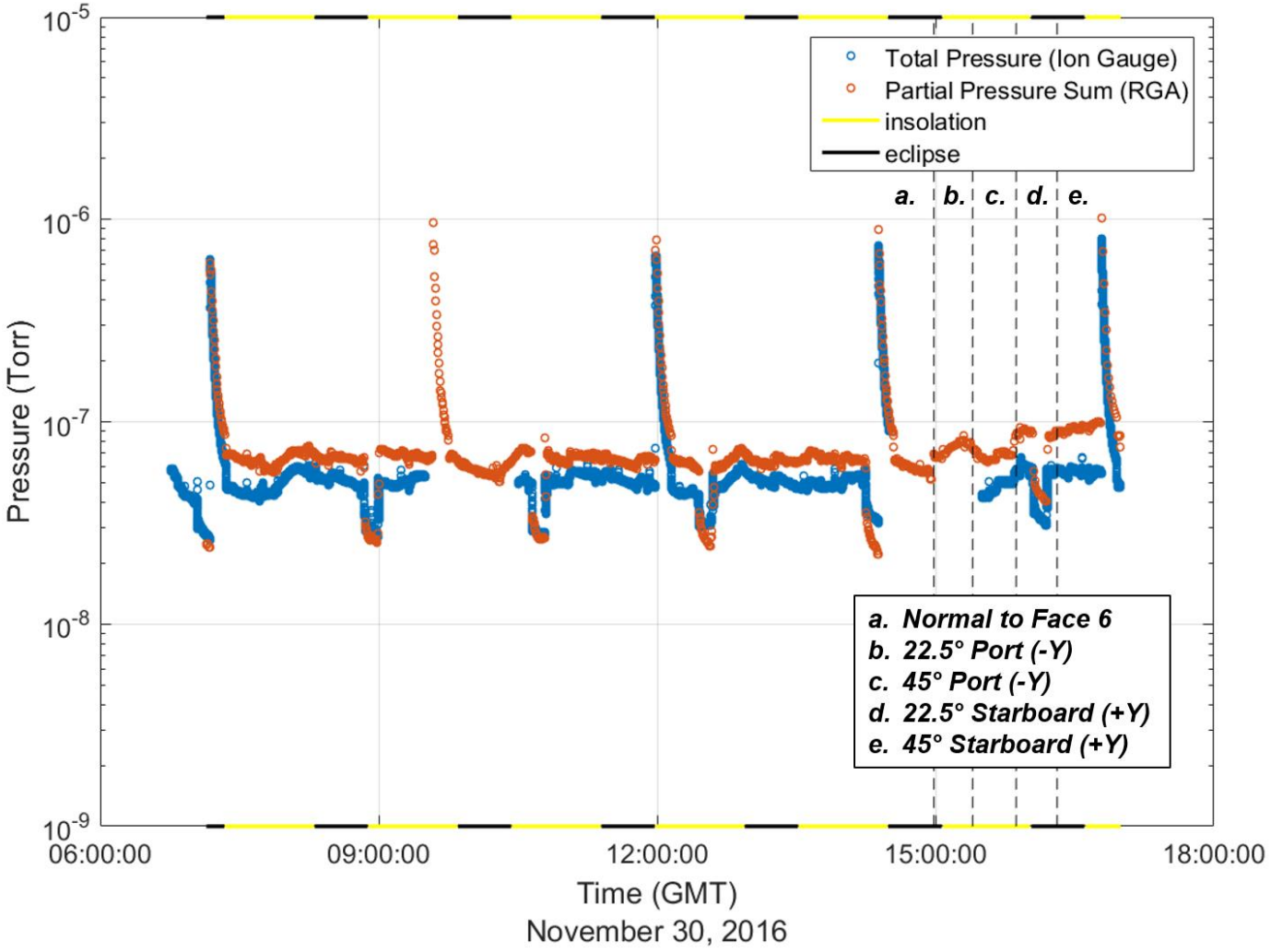
- ***Questions?***

Back Up

Background Scanning B: P1 Truss Face 6



- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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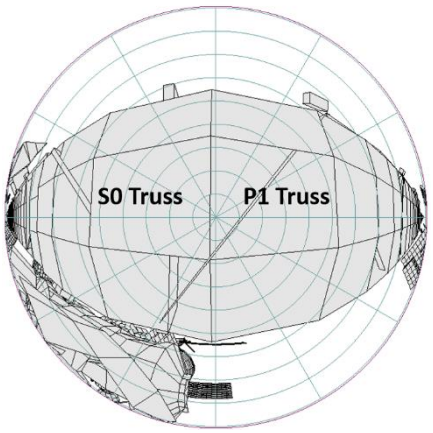
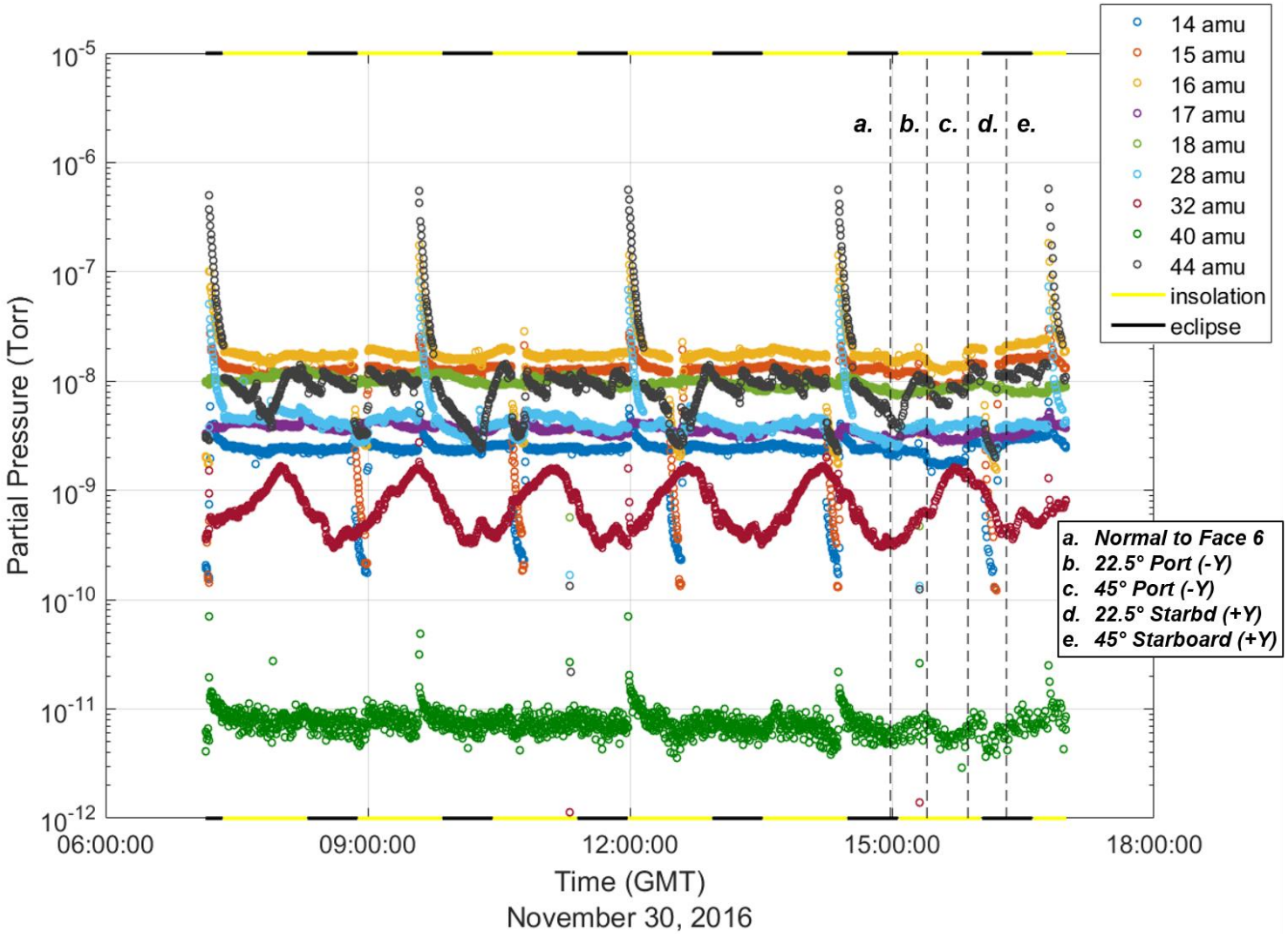
Background Scanning B: P1 Truss Face 6



Face 6

- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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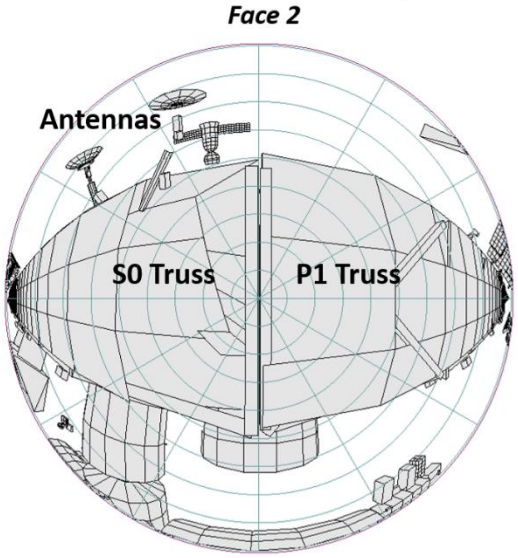
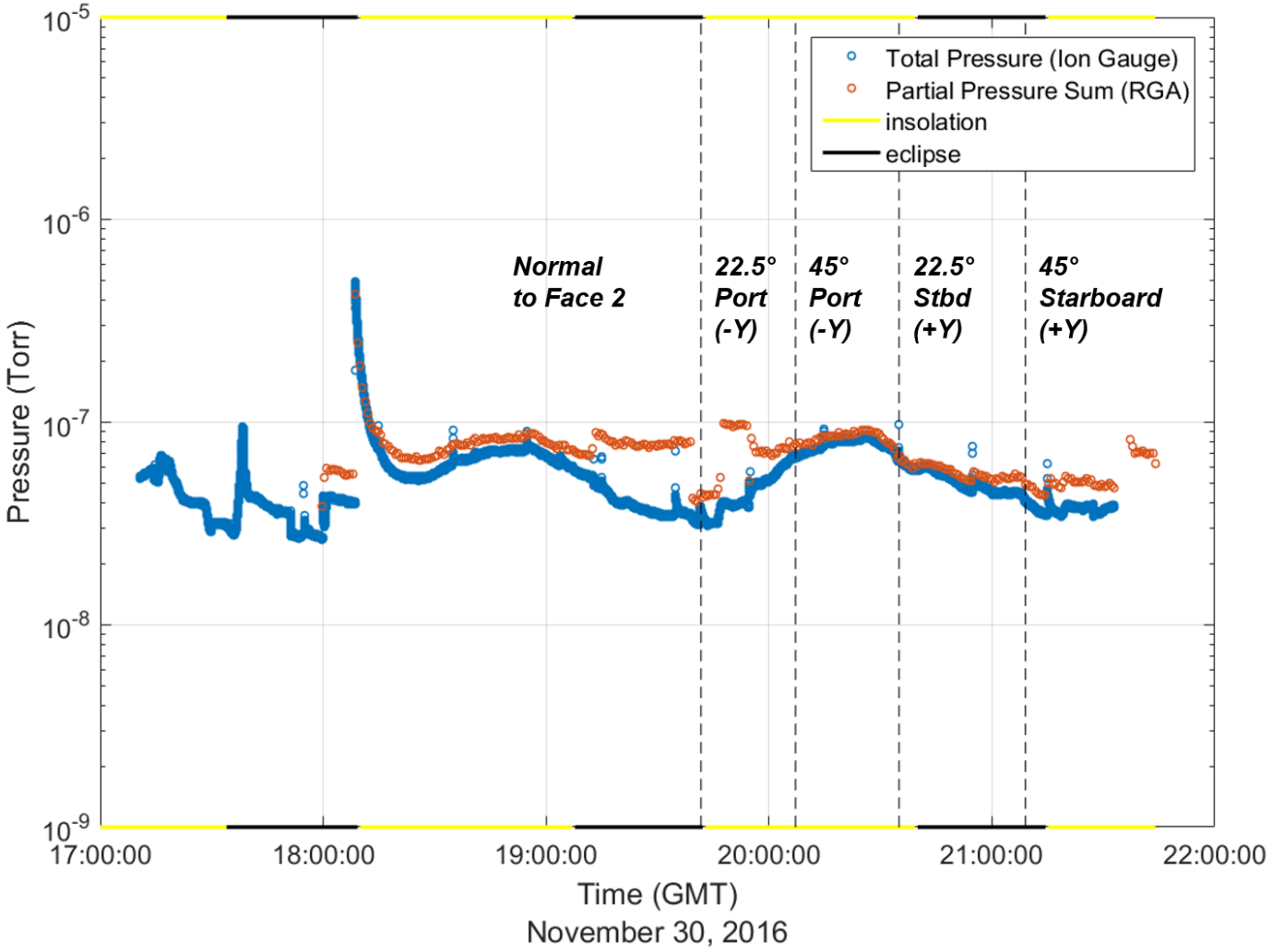
Background Scanning B: P1 Truss Face 2



- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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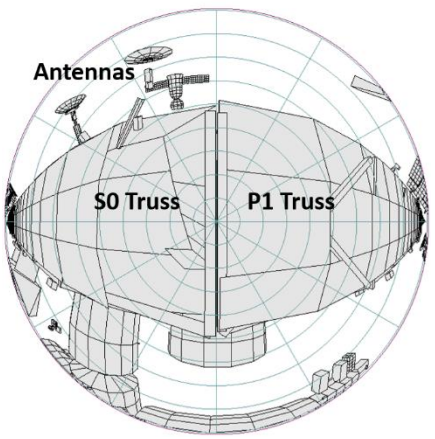
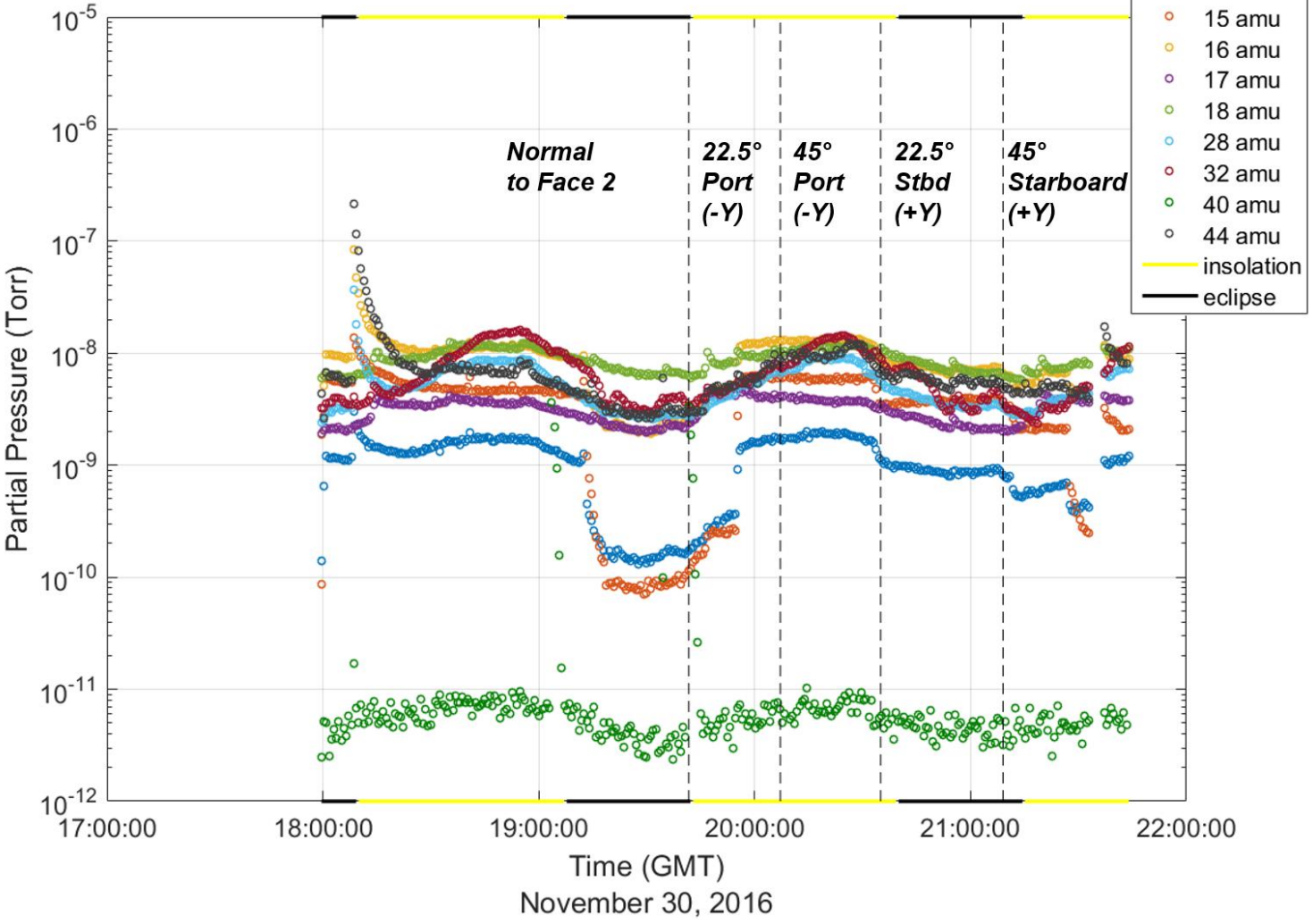
Background Scanning B: P1 Truss Face 2



- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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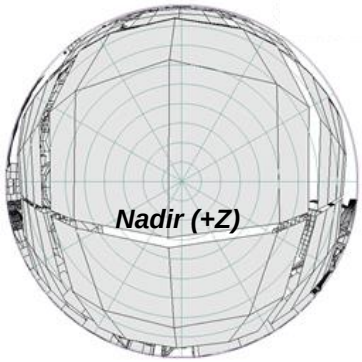
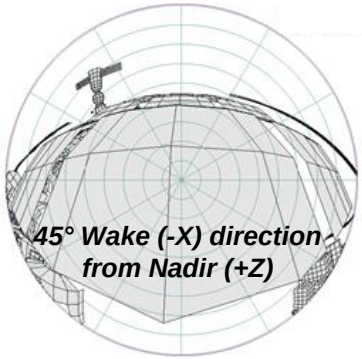
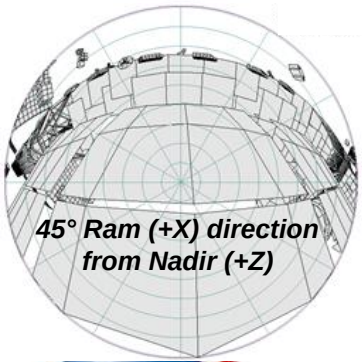
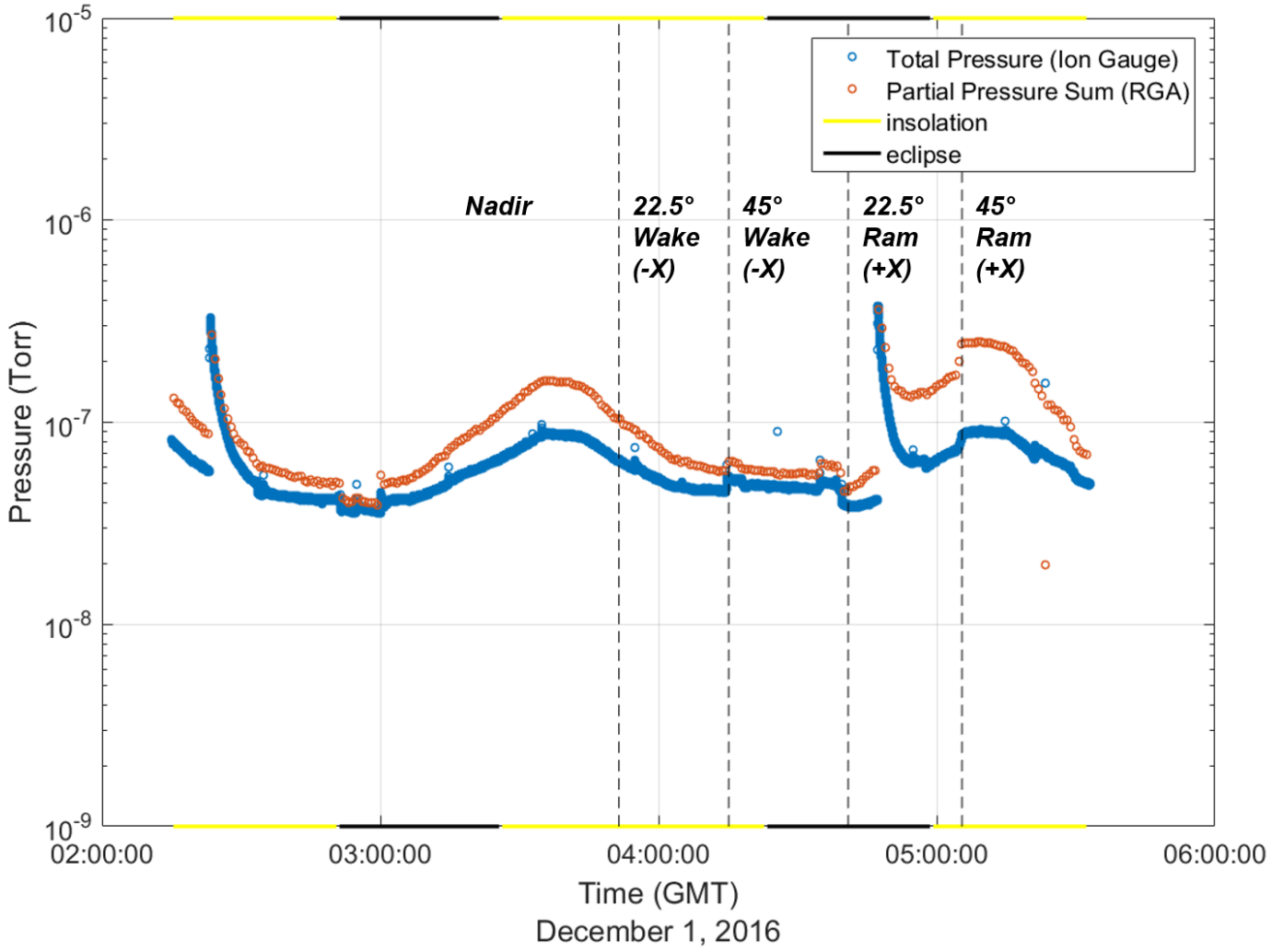
Background Scanning C: Port-Side EATCS Radiator, 8” from Base









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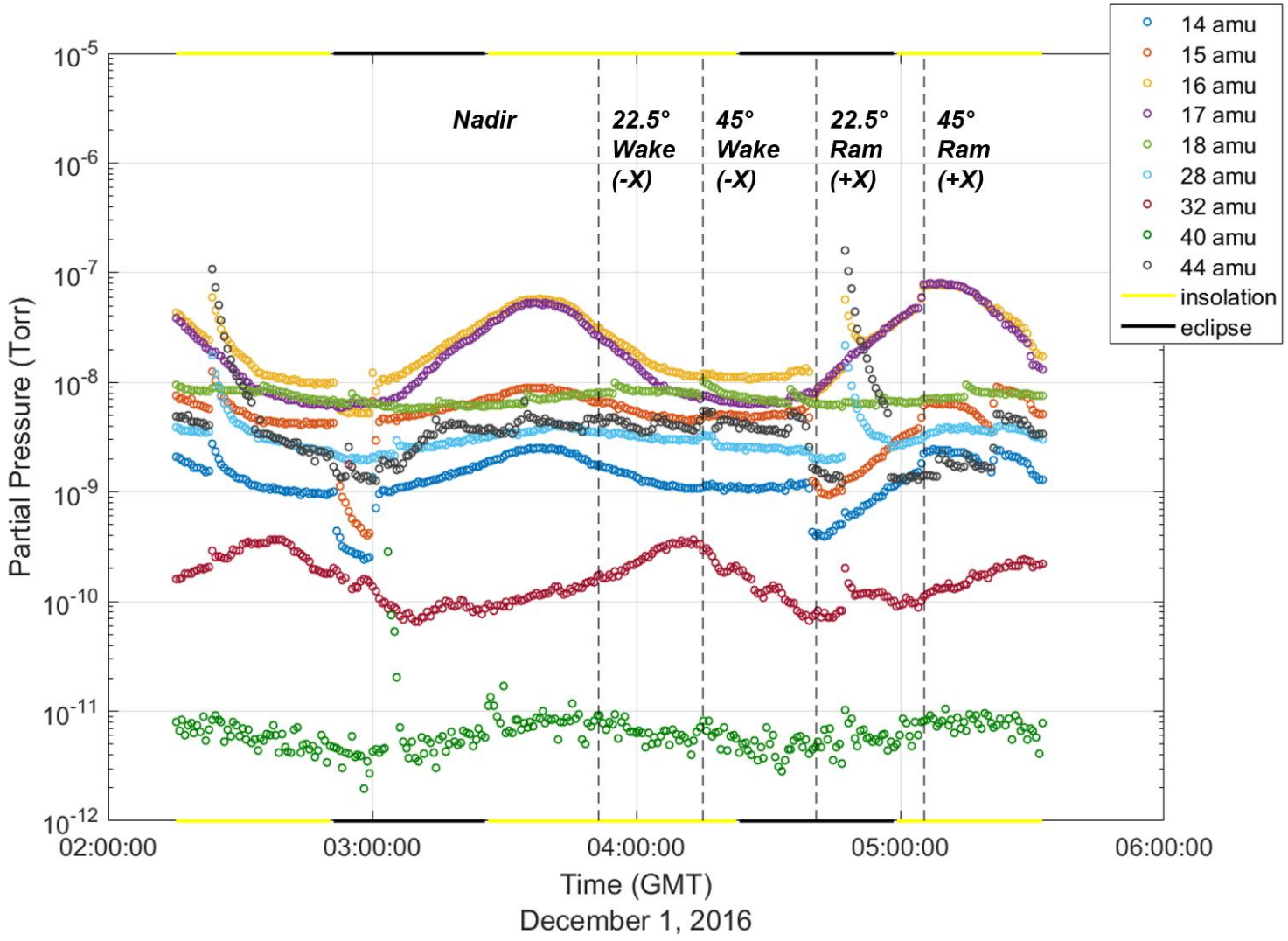
Background Scanning C: Port-Side EATCS Radiator, 8” from Base

- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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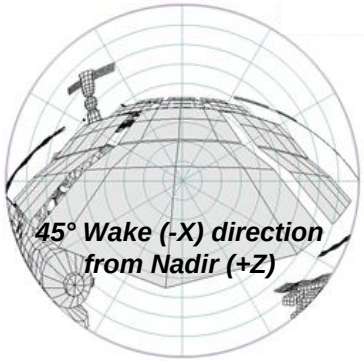
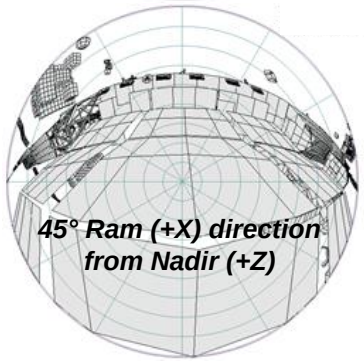
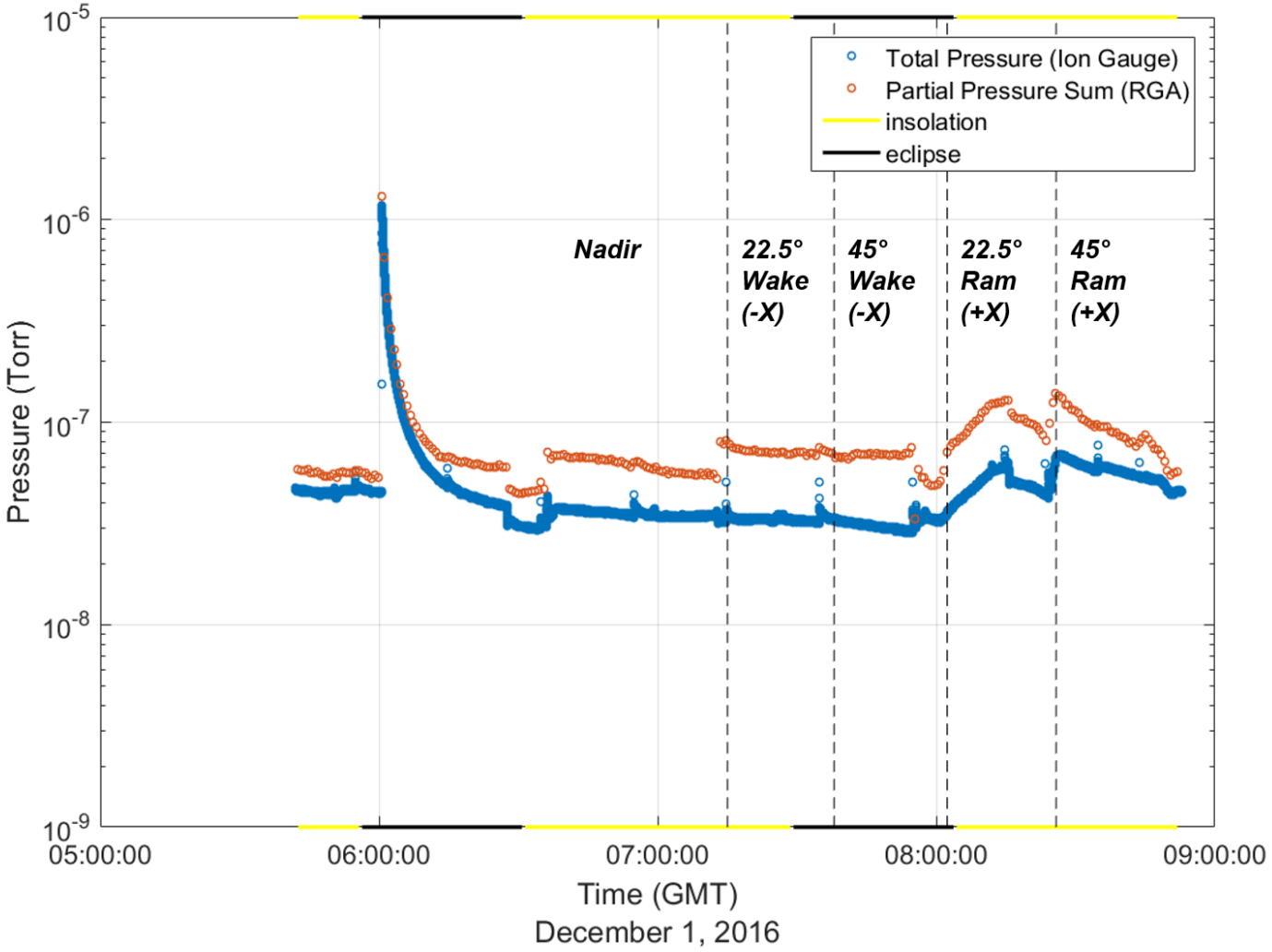
Background Scanning C: Port-Side EATCS Radiator, 16” from Base







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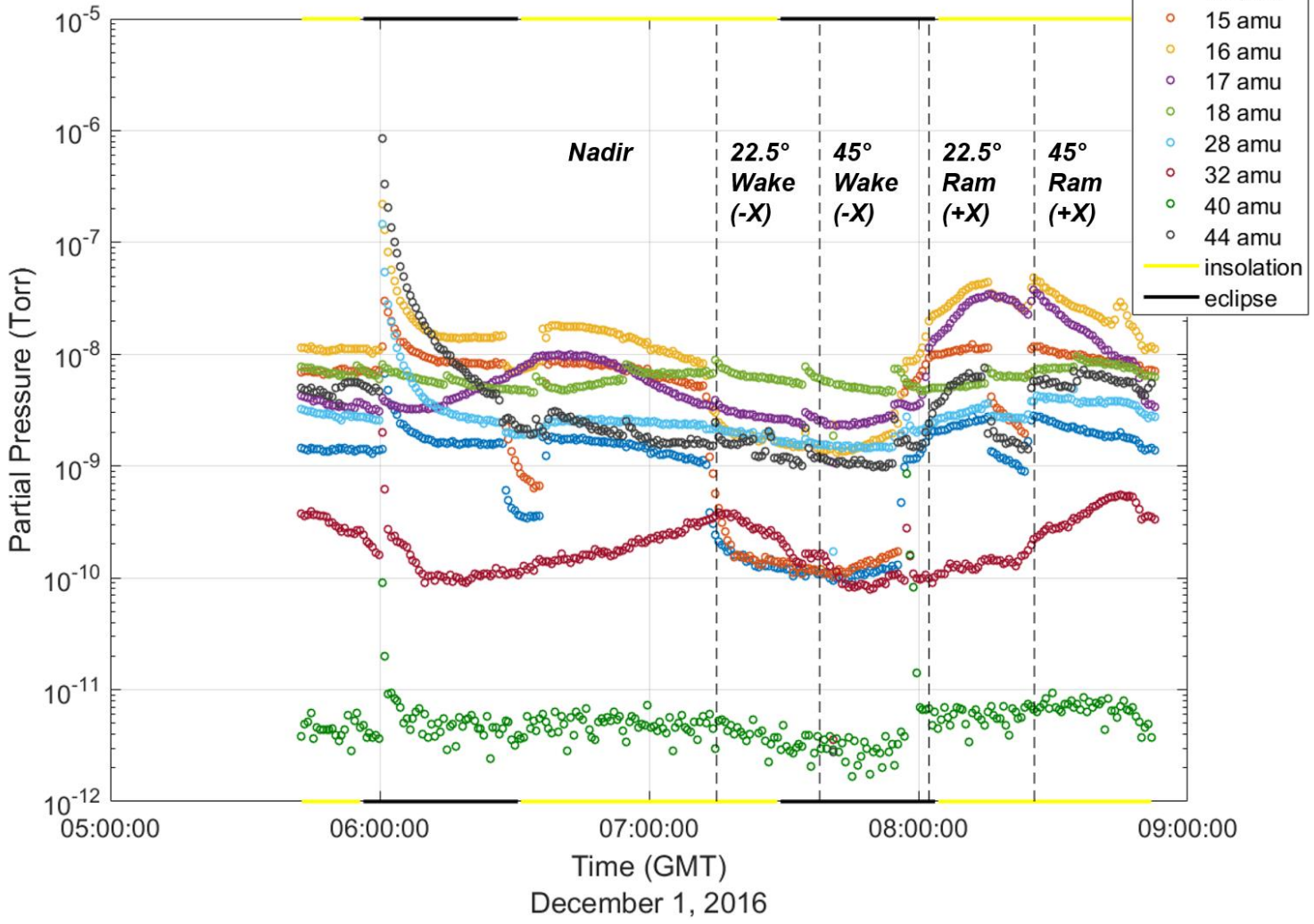
Background Scanning C: Port-Side EATCS Radiator, 16” from Base

- Node 3 CDRA
- Sabatier Assembly
- Russian Segment ECLSS



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