

International Space Station (ISS) Environmental Control and Life Support System (ECLSS) vent flow reflection and detection by Robotic External Leak Locator (RELL)

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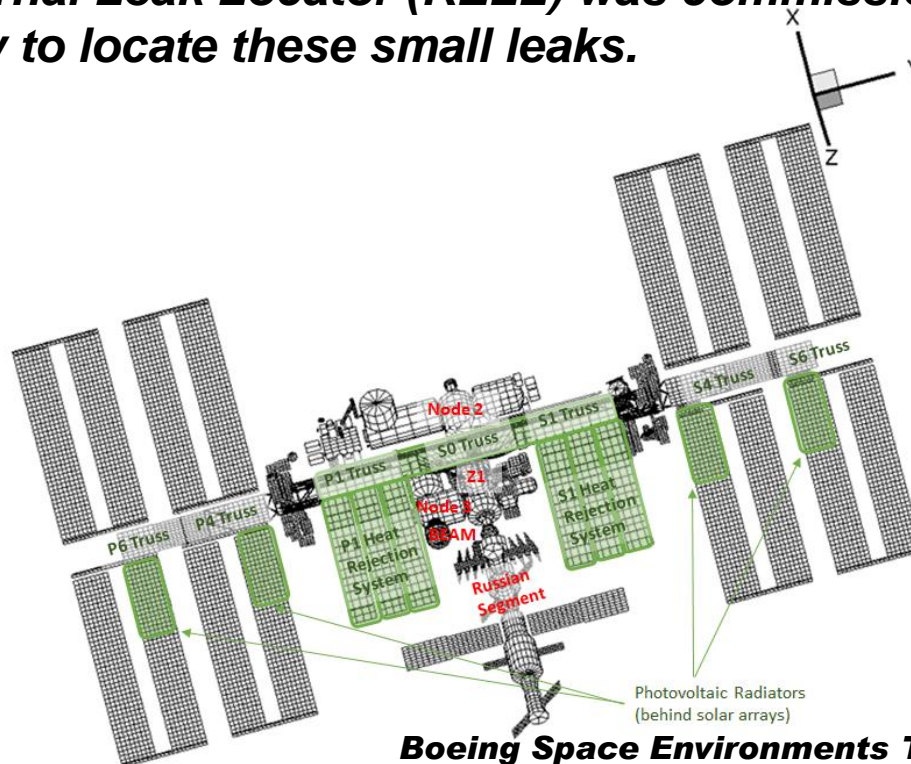




Background



- **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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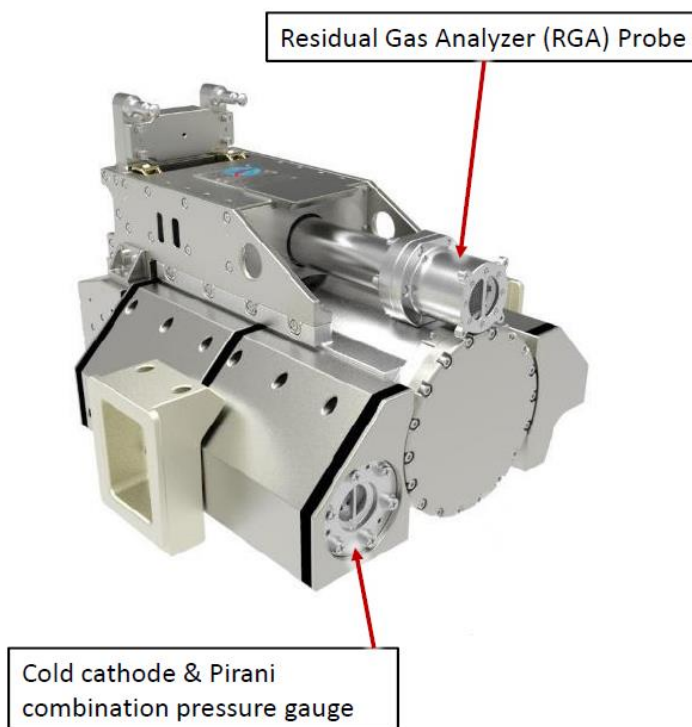
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Purpose



- ***Provide observations on the detection of recurring Environmental Control and Life Support System (ECLSS) vents at multiple ISS locations and RELL pointing directions during RELL operations.***



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Robotic External Leak Locator



➤ **PKR 251 Ion 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 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**



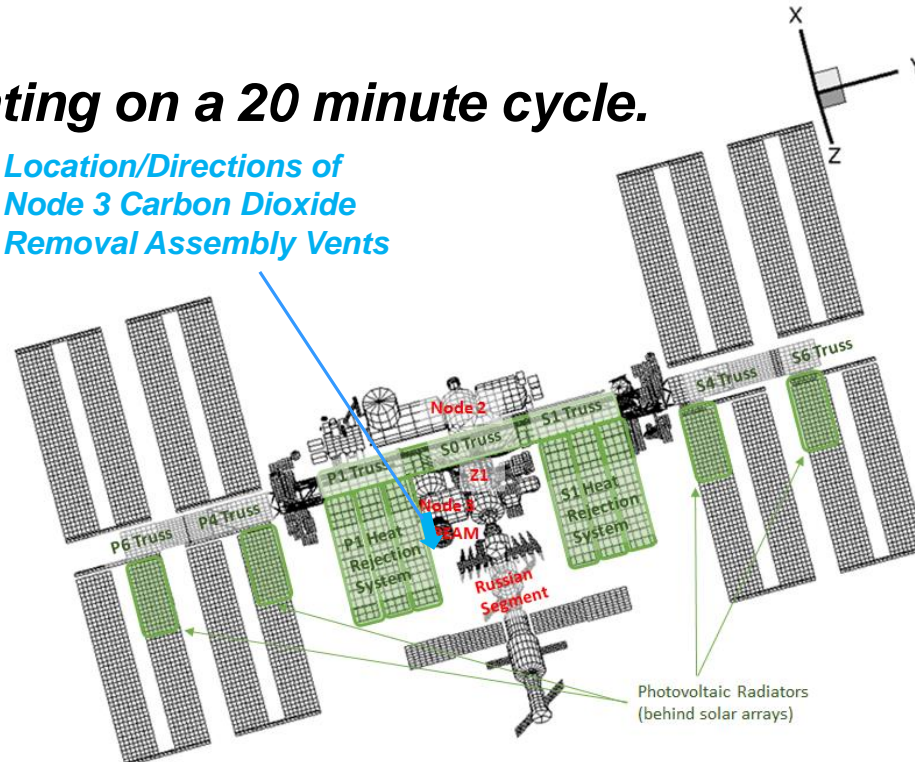


ISS ECLSS Vents



- **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.**

*Location/Directions of
Node 3 Carbon Dioxide
Removal Assembly Vents*



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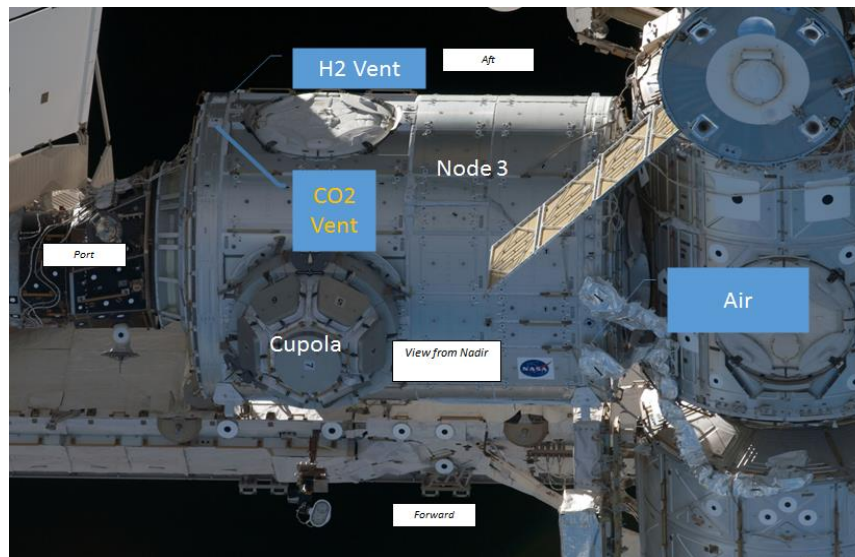




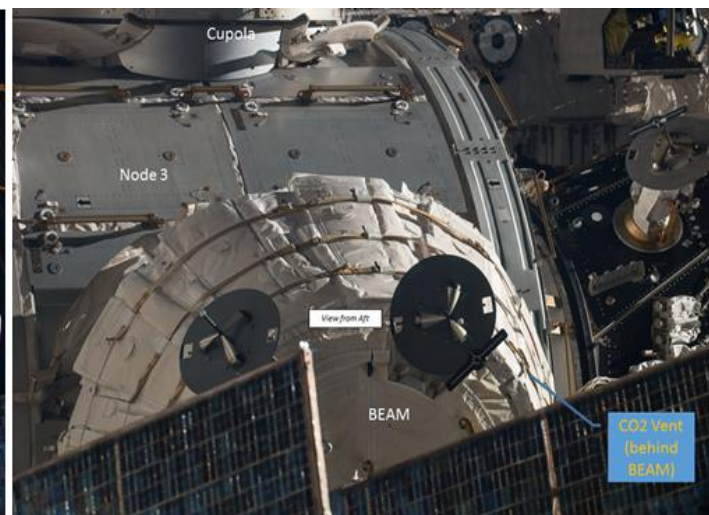
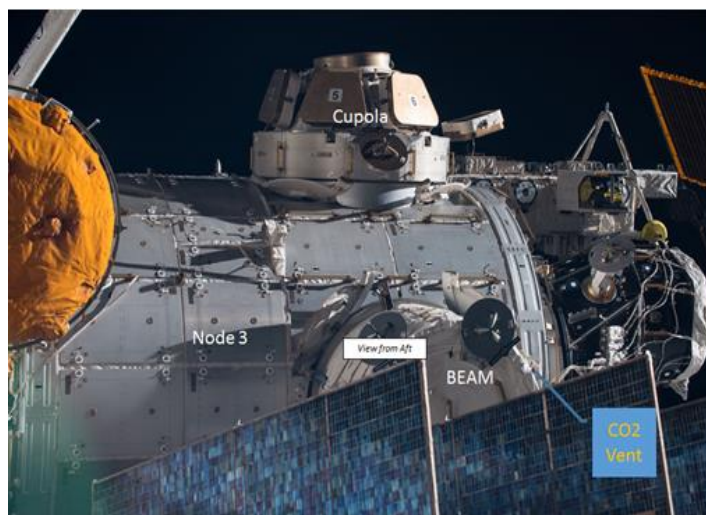
Prior and Post BEAM Installation and Expansion On-Orbit Images



Prior to BEAM Installation



BEAM Installation and Expansion



<https://io.jsc.nasa.gov/app/index.cfm>

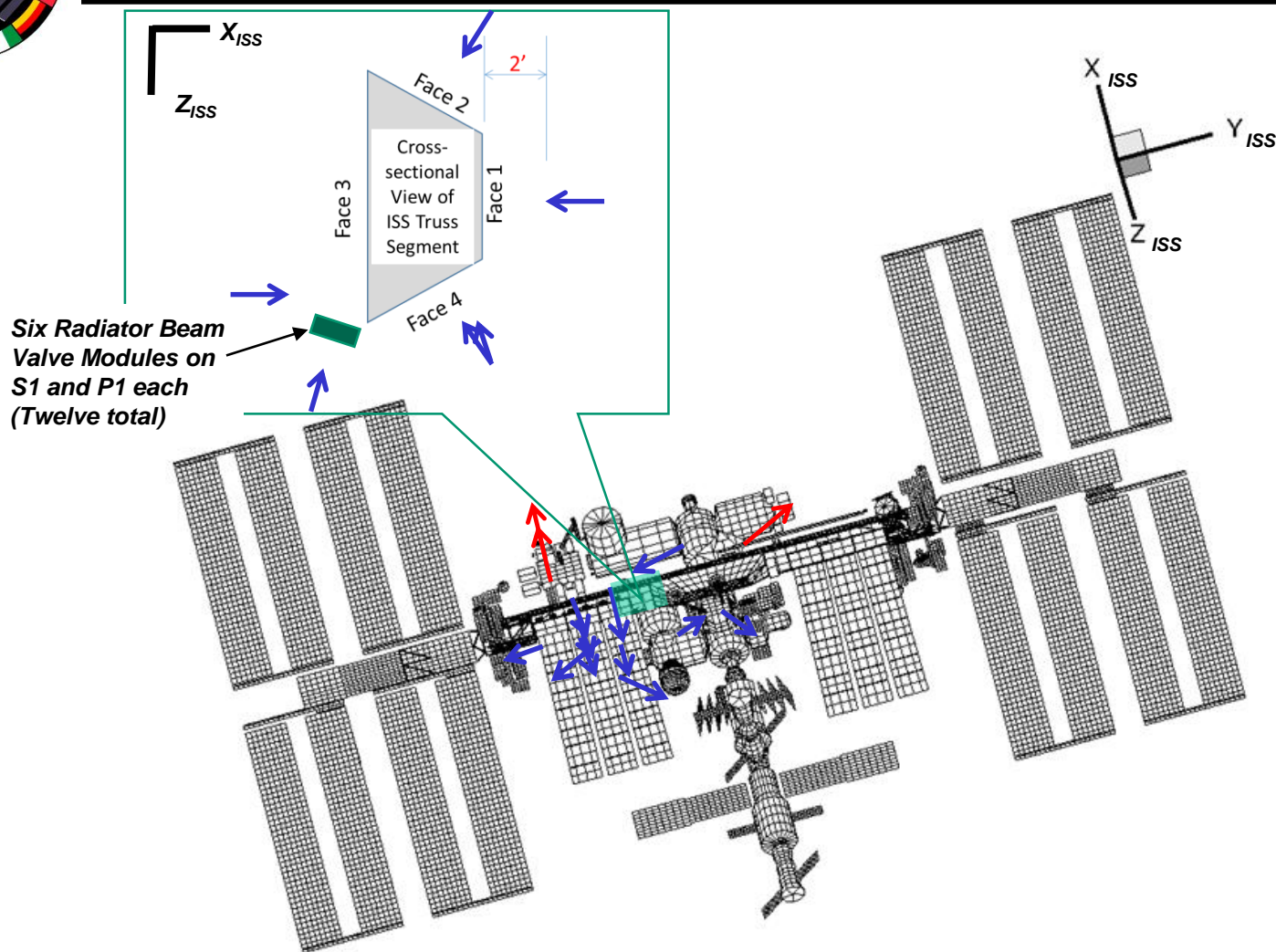
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Detection of Node 3 CDRA Vent at Various RELL Positions and Orientations



Note: Red or blue arrows denote the orientation of RELL during cyclic Node 3 CDRA vents. Blue arrows indicated obvious total pressure increases.



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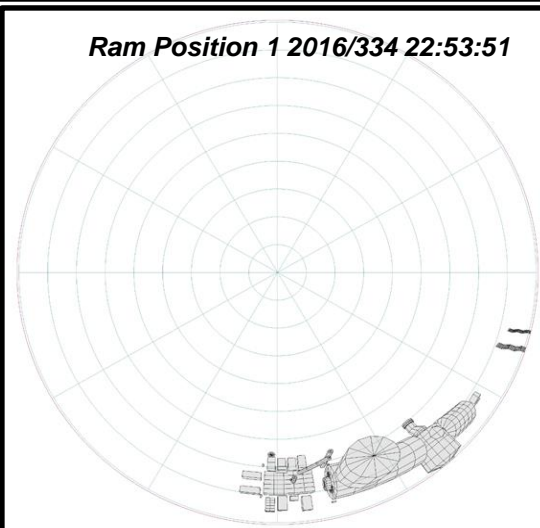




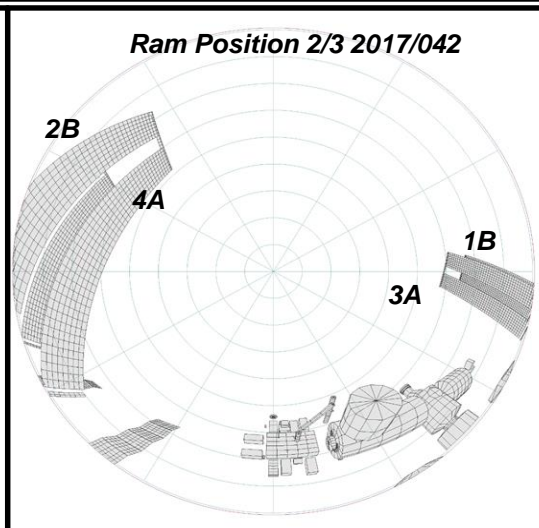
RELL Hemispherical Views



Ram Position 1 2016/334 22:53:51

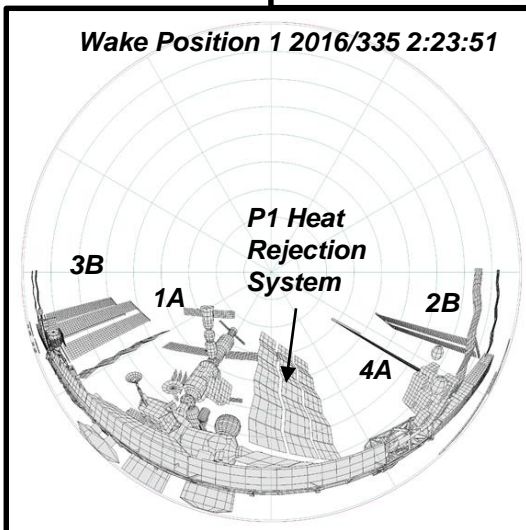


Ram Position 2/3 2017/042

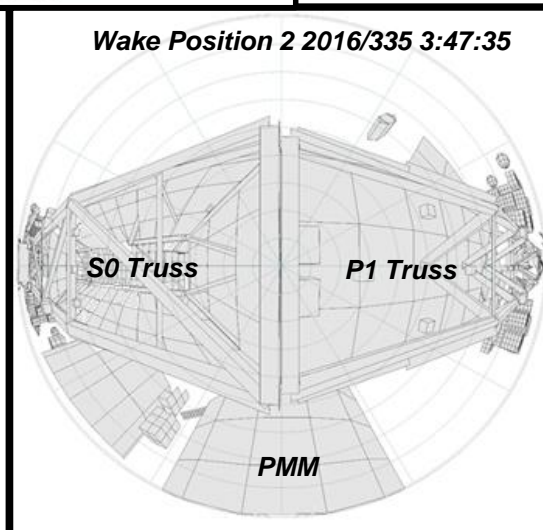


Note: SSRMS is not shown.

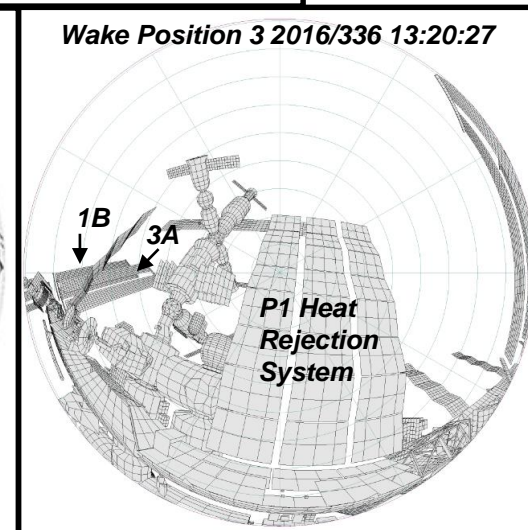
Wake Position 1 2016/335 2:23:51



Wake Position 2 2016/335 3:47:35



Wake Position 3 2016/336 13:20:27



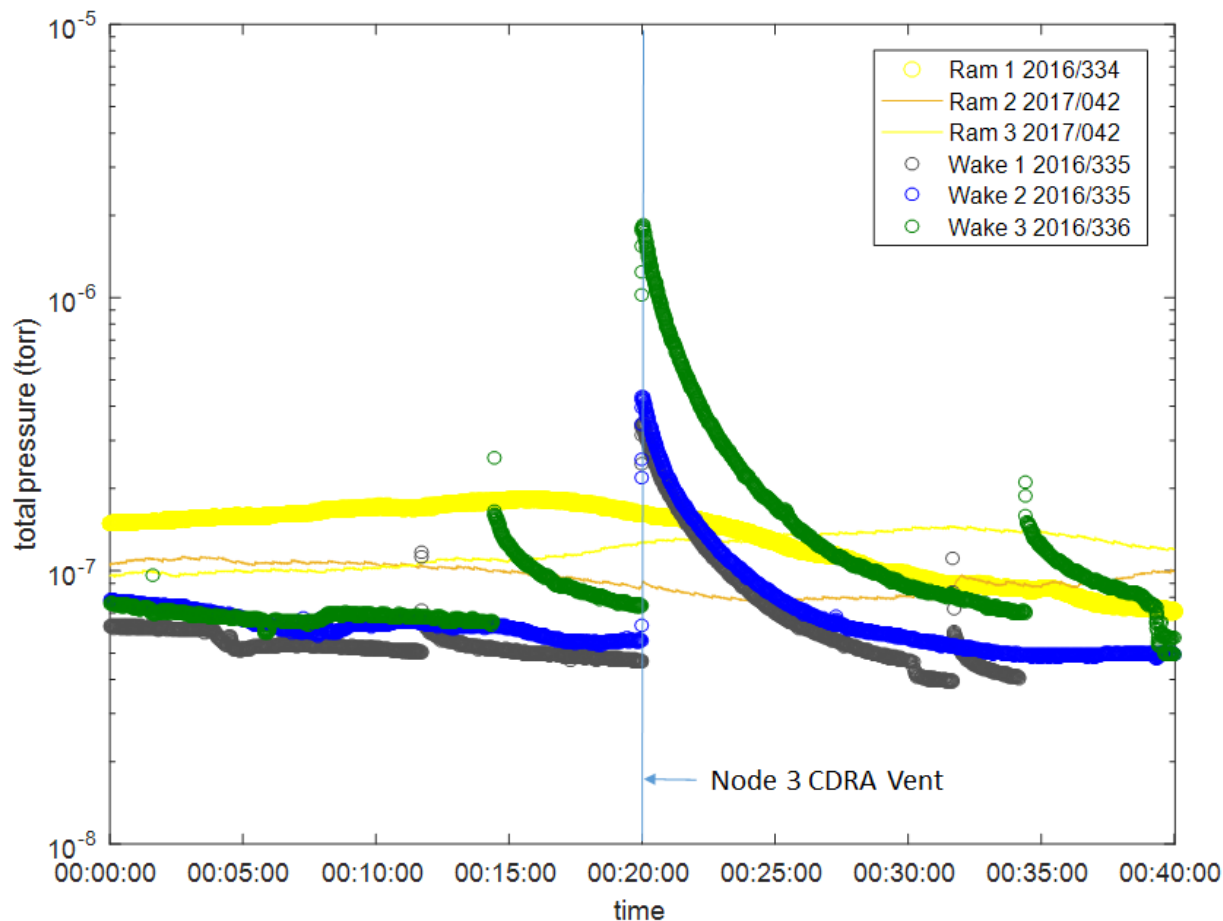
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RELL Detection of ISS Node 3 CDRA Vents – Total Pressure



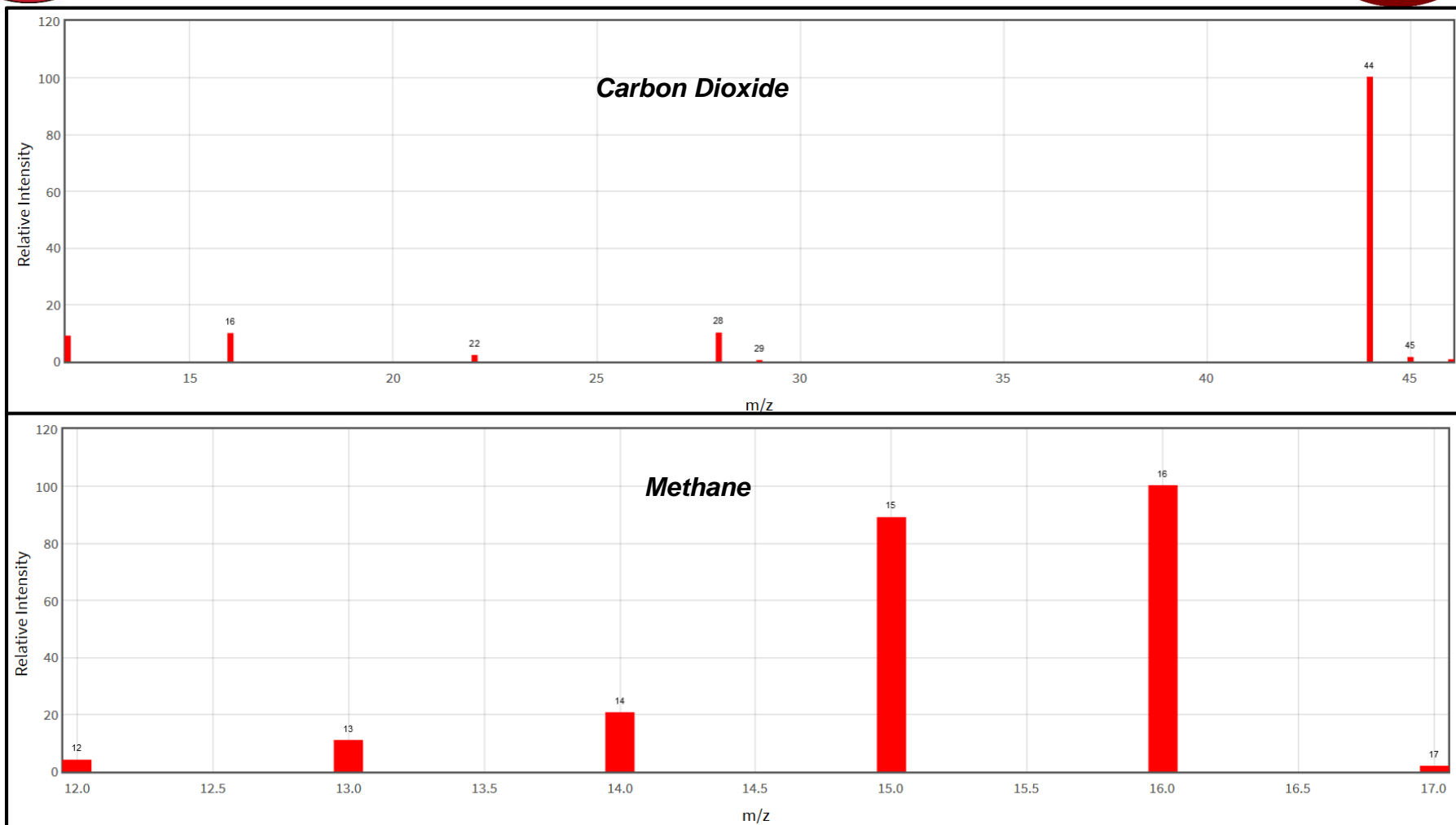
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NIST Mass Spectra of Carbon Dioxide and Methane



<https://webbook.nist.gov/chemistry/form-ser/>



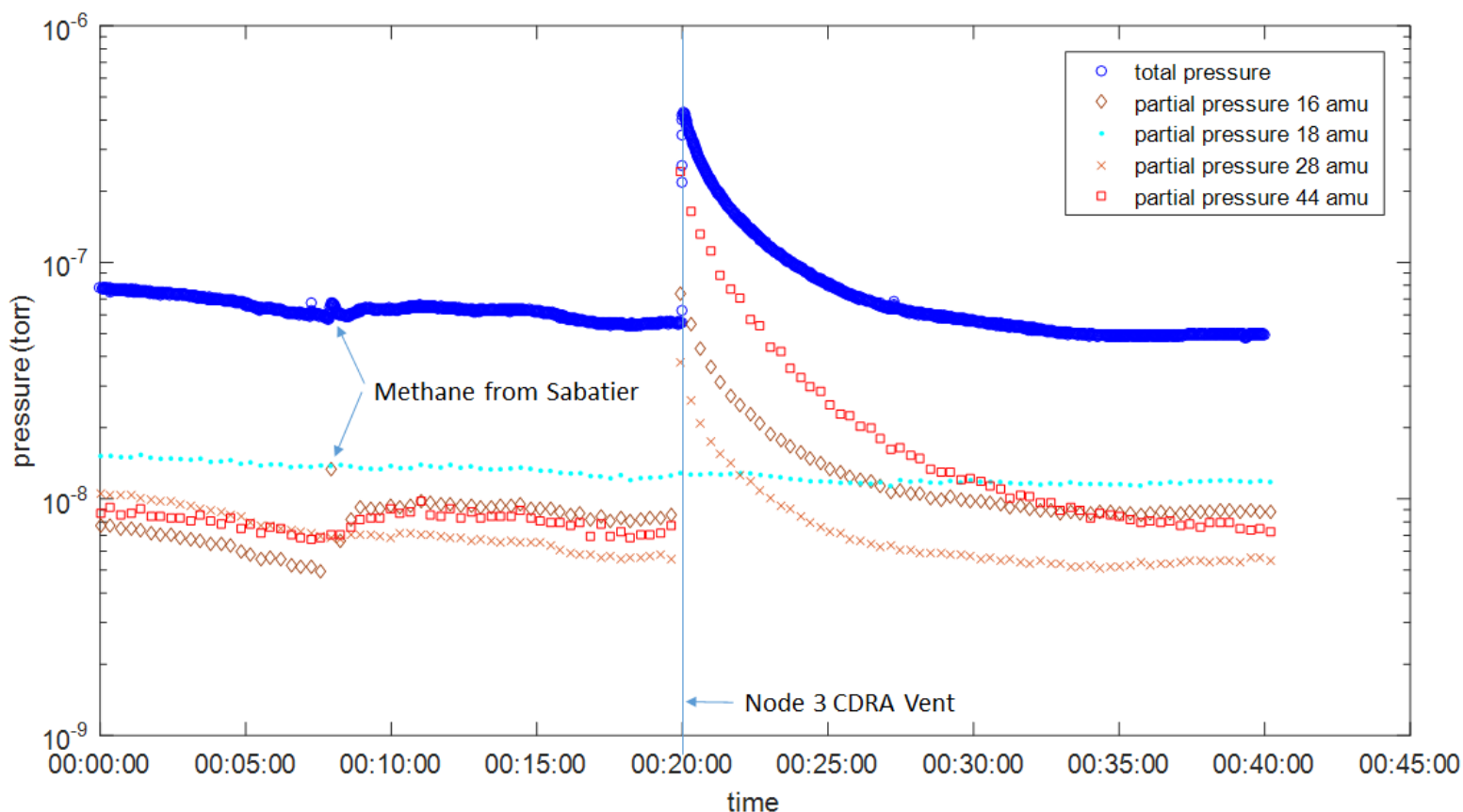
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RELL Detection at Wake 2 position of ISS Node 3 CDRA Vents – Partial Pressure



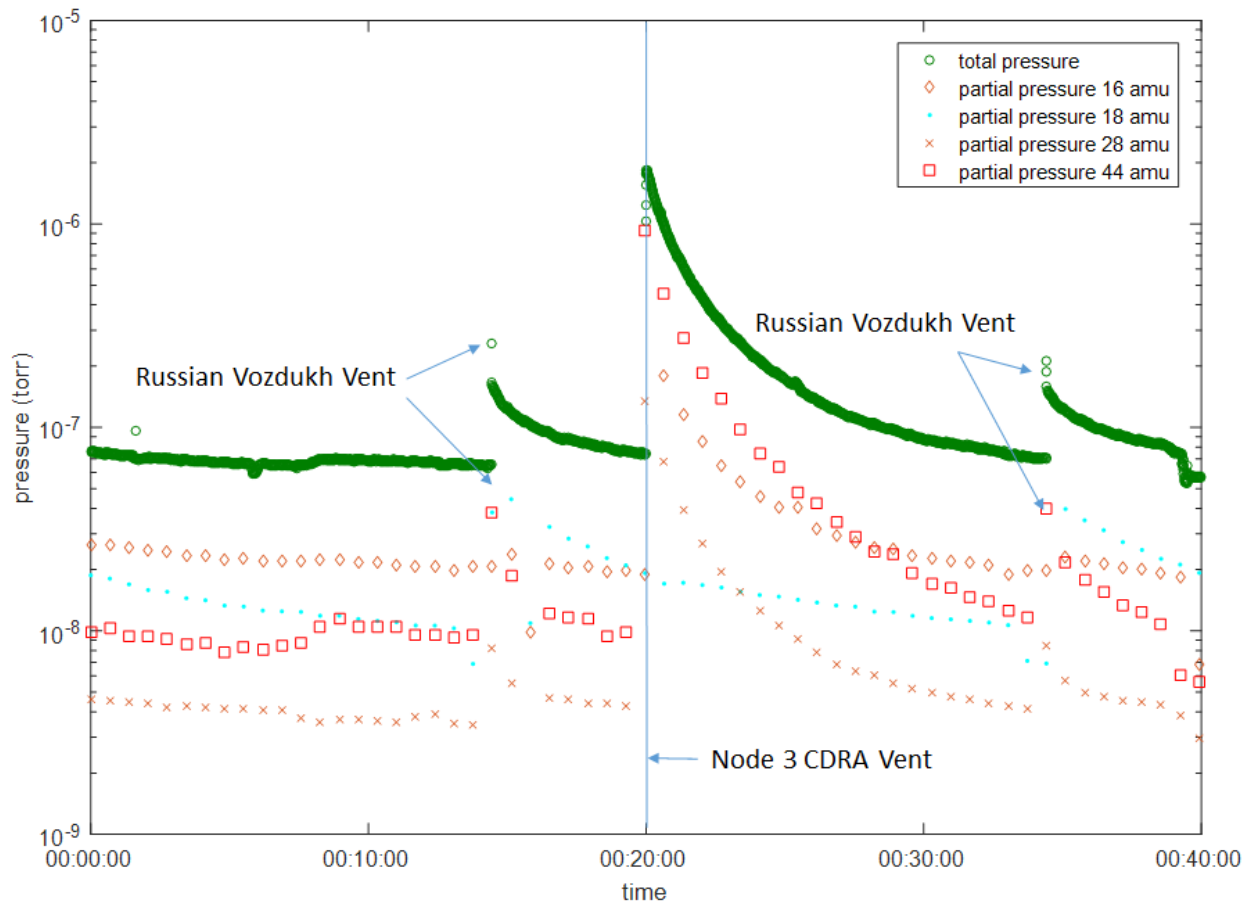
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RELL Detection at Wake 3 position of ISS Node 3 CDRA Vents – Partial Pressure



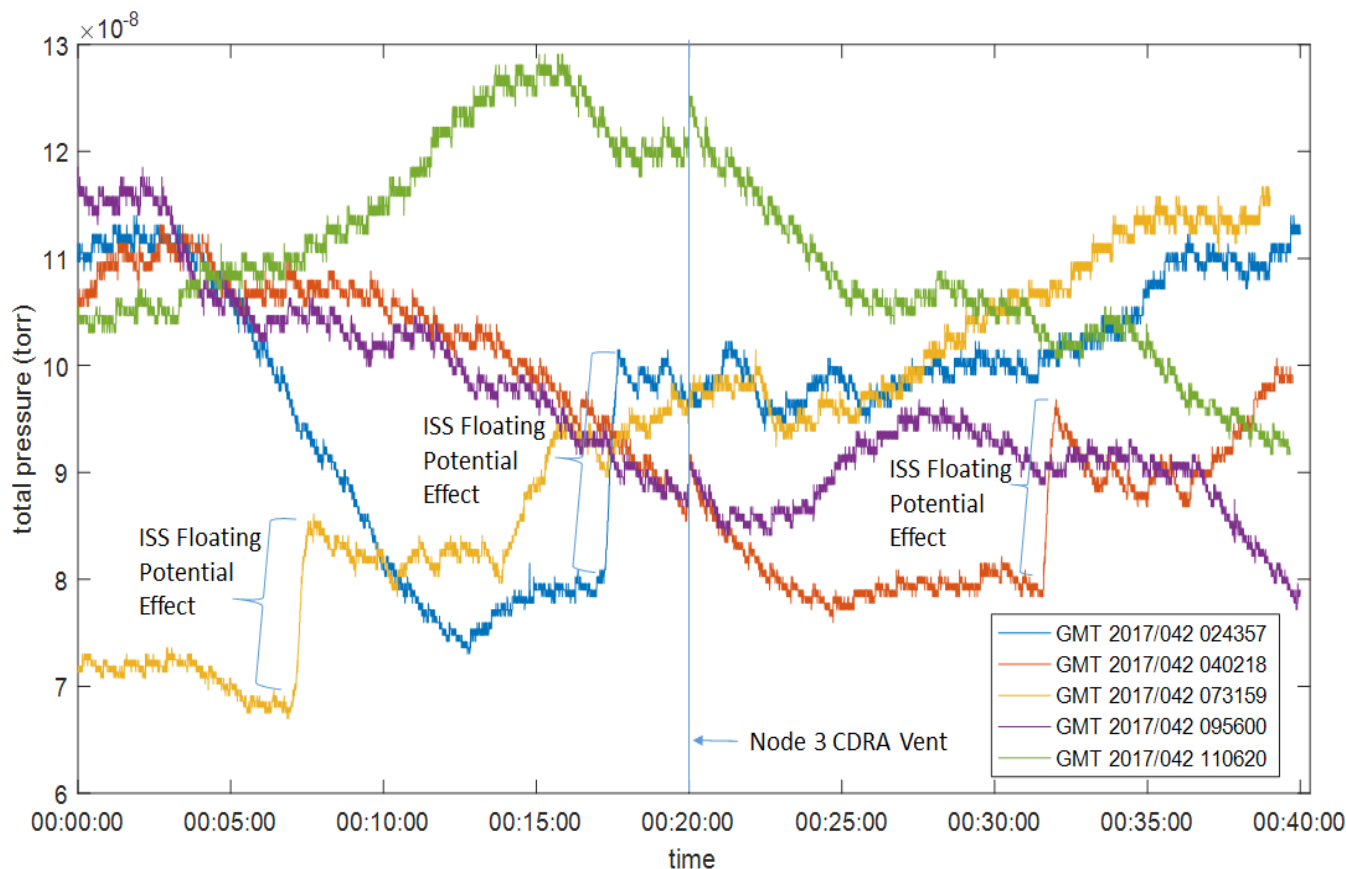
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RELL Detection at Ram 2/3 position of ISS Node 3 CDRA Vents – Total Pressure



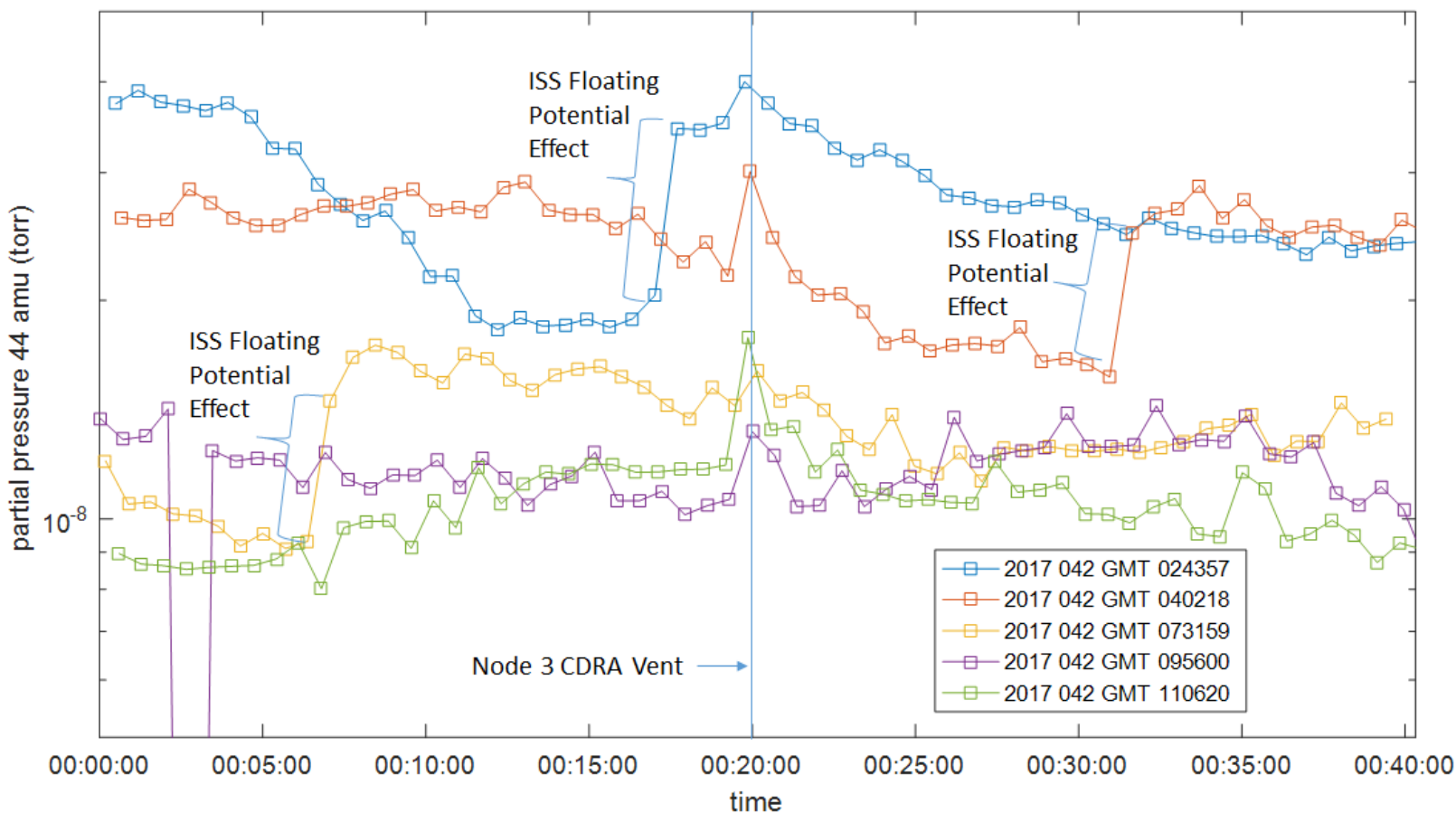
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RELL Detection at Ram 2/3 position of ISS Node 3 CDRA Vents – Partial Pressure



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Conclusions



- ***The detection of multiple recurring ISS ECLSS vents during Robotic External Leak Locator's on-orbit operations to locate an ammonia leak demonstrate that a sensitive mass spectrometer or ion gauge can pick up gas molecules via diffuse reflection or scattering.***
- ***The path to the detector that the gas molecules travel is not always obvious.***
- ***Obvious pressure increases were detected by the total pressure gauge at the start time of the recurring Node 3 Carbon Dioxide Removal Assembly vent in all RELL positions and orientations except for the ram positions and a starboard viewing position at S0 Truss.***
- ***Further examination of the more sensitive RGA at the ram position showed that there were slight increases in the partial pressure measurements for the primary mass-to-charge ratio, 44, of carbon dioxide.***





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