A Review of Pump Package Assembly Anomalies and Demonstration to Gain Motor Controller Replacement Capability

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Purpose/Agenda

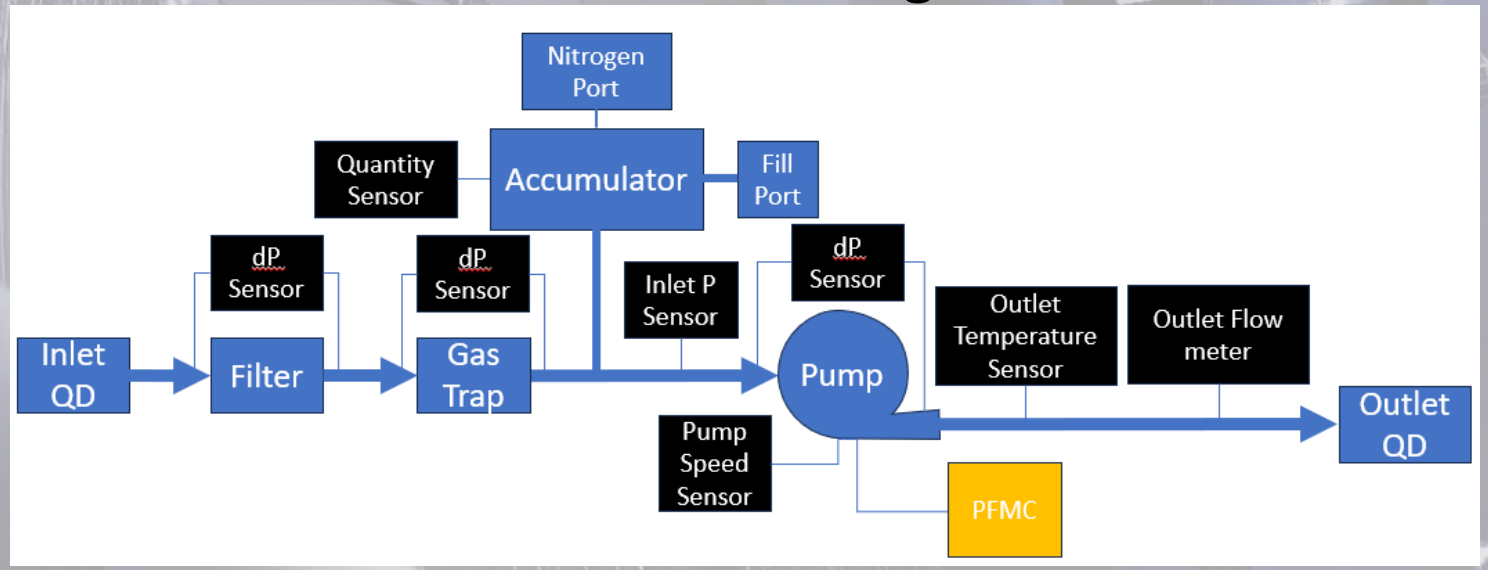
- **PURPOSE:** Discuss ISS PPA anomalies and repair demonstration
- **AGENDA:**
  - **Overview of ISS IATCS**
  - **History of PPA Anomalies and Failures**
    - **On-Orbit PFMC Removal**
    - **PFMC TT&E**
  - **Ground PFMC R&R Demonstration**
  - **Implication for Future Space Missions**
  - **Conclusion**

PPA (Pump Package Assembly)

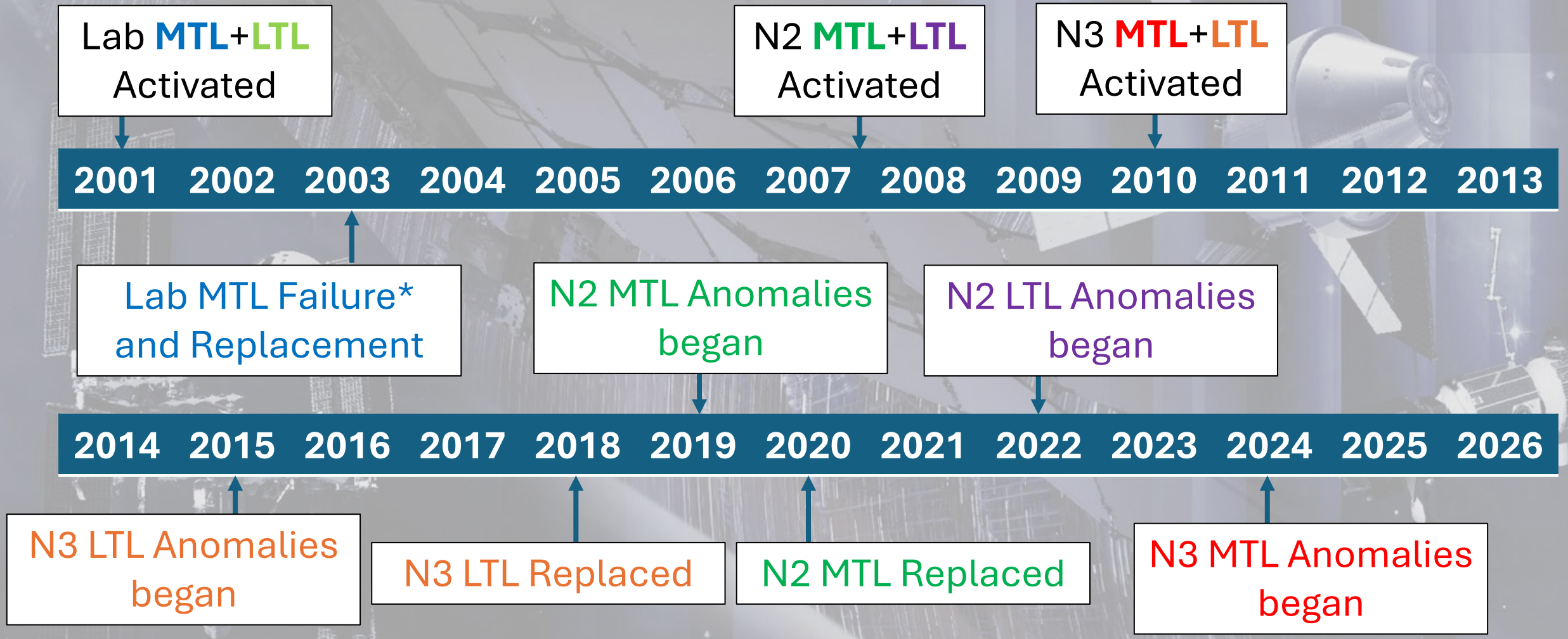
Overview of ISS IATCS and PPA

- IATCS collects heat from the ISS modules and rejects it to the ammonia-filled EATCS loops for rejection to space.
- The PPA provides the motive force for the IATCS water loops
- There are 2 PPAs in Lab, Node 2 and Node 3
  - One PPA for the MTL and LTL in each of the modules
  - 6 Total

PPA Functional Diagram



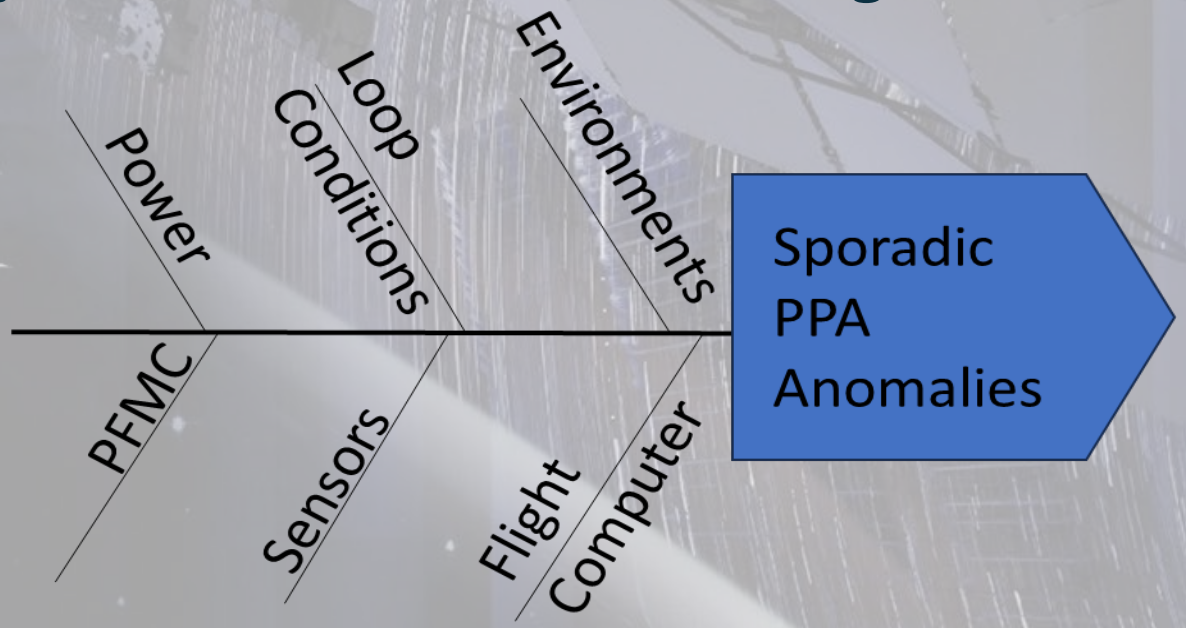
History of PPA Failures and Anomalies



*Due to Coolant Chemistry, not covered in paper

Root Cause Determination Challenges

- PFMC has a Built-In Test (BIT) but doesn't always trigger
- 1Hz telemetry is insufficient for capturing highly dynamic events
- Limited troubleshooting techniques
- Limited ability to return hardware to the ground for TT&E

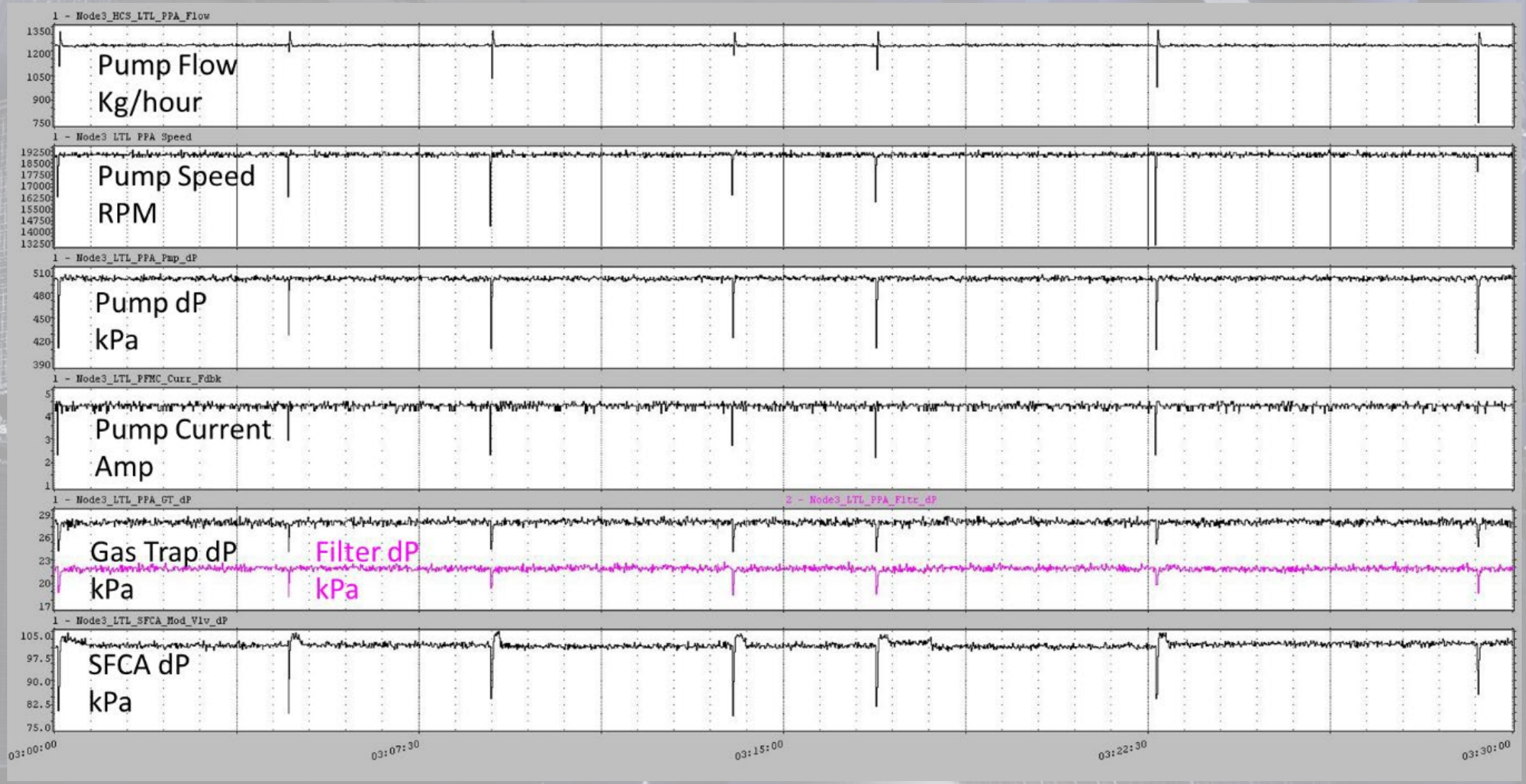


Node 3 LTL PPA Anomaly

Installed: 2010
Start of Anomalies: 2014
Replacement: 2018

- Rapid (<1 second) speed drops – 19K to 12K RPM
- Otherwise, nominal performance
- Anomaly was captured in pressure and flowrate telemetry it was a true hydraulic event
- Only seen at elevated pump speed which are used when MTL and LTL are combined
- Frequency of anomalies increased from 2015 to 2018 (up to multiple times per hour)
- PPA was replaced due to its criticality to EVA operations
- PPA was not returned to ground

30 minutes of N3 LTL PPA data



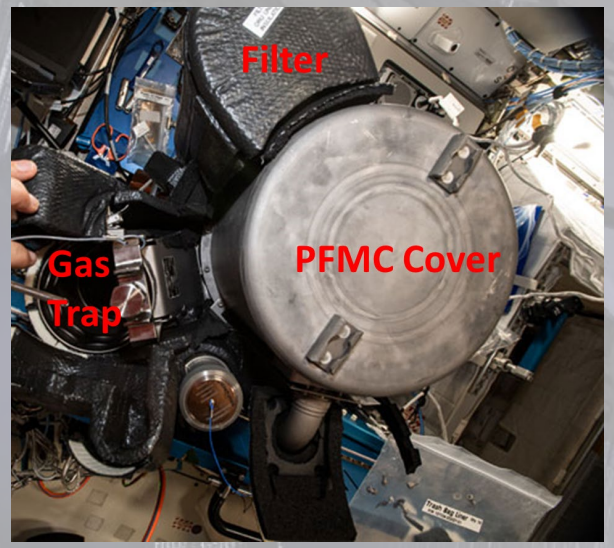
Node 2 MTL PPA Anomaly

Installed: 2007
Start of Anomalies: 2019
Replacement: 2020

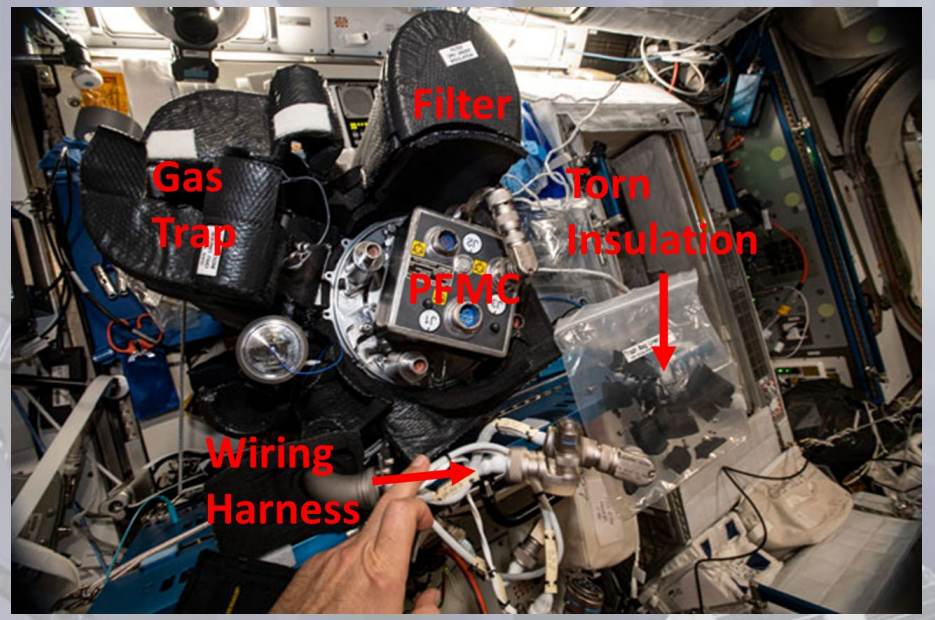
- Rapid (<1 second) speed spike with some going off-scale high – >17M RPM, with a corresponding hydraulic response
- Occasionally triggered overspeed fault which caused an automatic restart - returned pump to nominal operation
- Frequency of anomalies increased rapidly until 2020 when operation became too cumbersome for flight controller and PPA was replaced
- To aid in investigation, PFMC was removed on-orbit and returned for TT&E

N2 MTL PFMC Removal

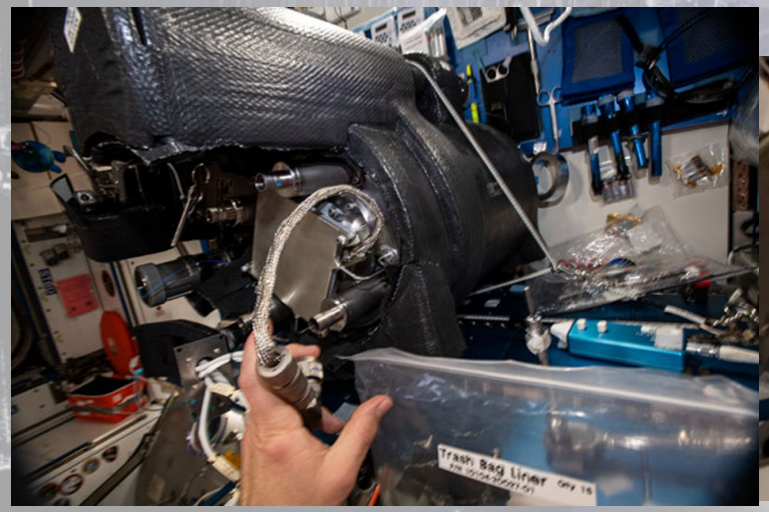
1) Remove insulation around PFMC Cover



2) Remove PFMC Cover and disconnect wire harness



3) Remove PFMC



Node 2 MTL PFMC TT&E

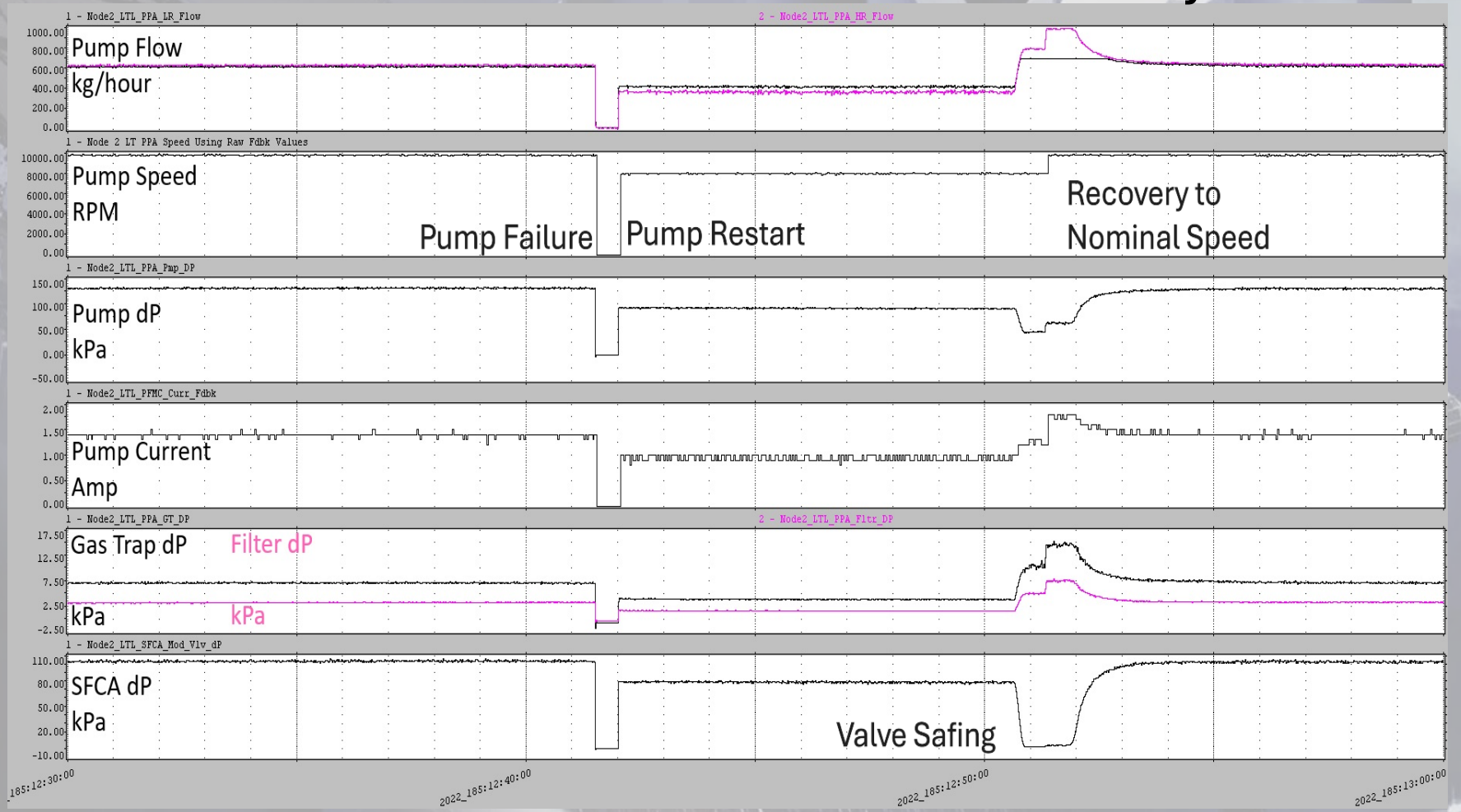
- Some difficulty recreating the exact signature on the ground and transients were very intermittent
- Use of an oscilloscope was required due to the extremely fast current spiked (0.03-0.04s)
- Root Cause: Isolated to the Microprocessor CCA and a Schmitt trigger which was corrupting the hall-effect speed signals
- PFMC was deemed repairable but shelved due to cost and the current available spares in the program

Node 2 LTL PPA Anomaly

Installed: 2007
Start of Anomalies: 2022
Replacement: Still Operational

- PPA would intermittently restart itself
- No flag or other indication of issue would be present
- Plan is to operate until it becomes too burdensome for Flight Controllers

Initial occurrence of Anomaly

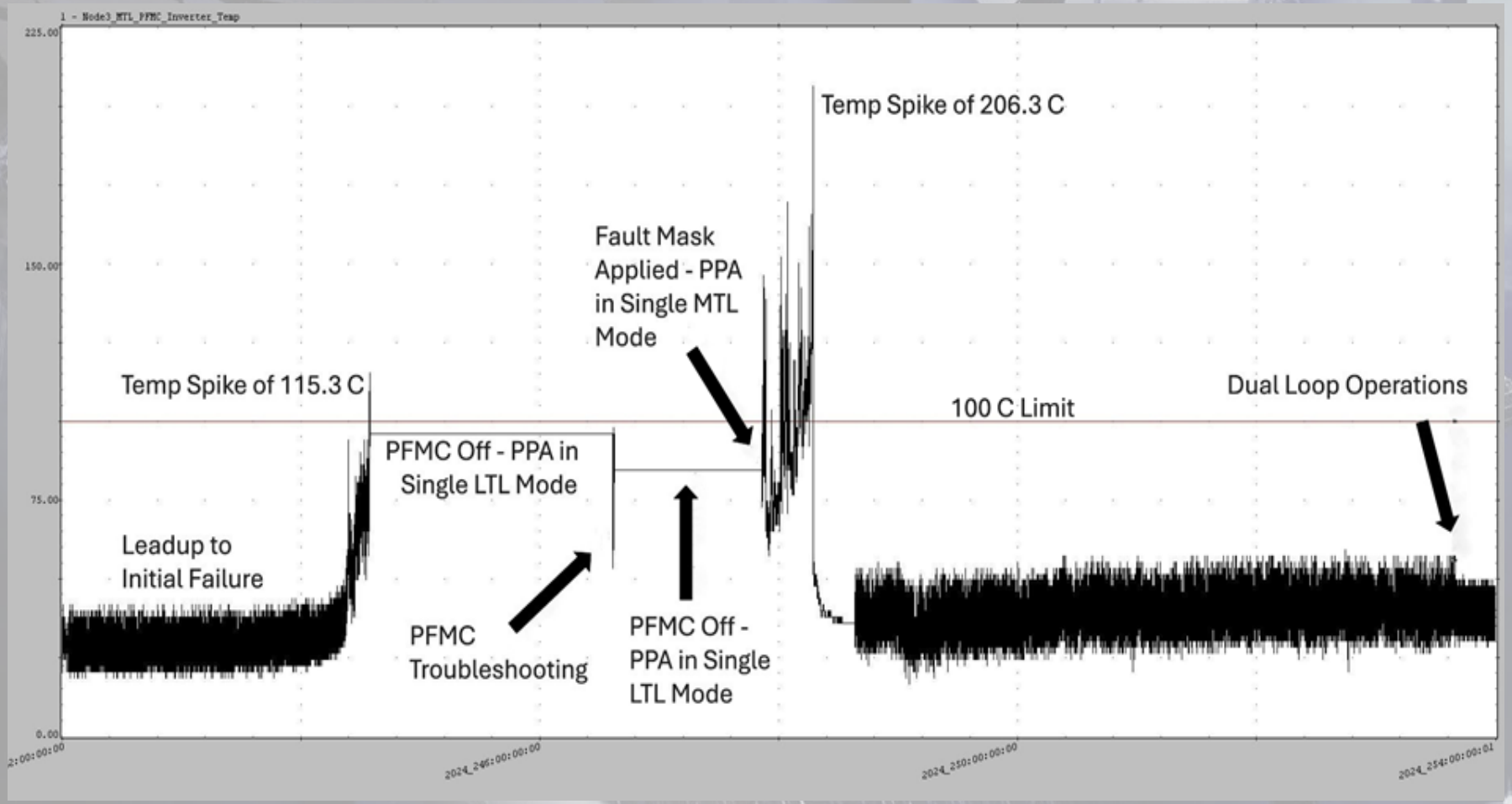


Node 3 MTL PPA Anomaly

Installed: 2010
Start of Anomalies: 2024
Replacement: Still Operational

- Inverter Temperature exceeded limit
- No other indication of fault, also seen in CDRA
- Masked the fault and continue to monitor for hard-failure

PFMC Inverter Temperature – 12 days of data



PFMC R&R Demonstration

- Conducted a ground demonstration to show PFMC could be R&Rd using crew tools.
- Performed tests to show PFMC was not damaged and that insulation could be re-installed

Implications for ISS and Future Missions

- The PFMC has proven to be the life limiting factor on the PPA but we have shown it is possible to perform an on-orbit R&R to extend the life of the pump.
- Added benefit of reducing launch mass and stowage
- Recommendations:
  - Design pumps for future space missions with the ability to easily replace the motor controller
  - Use higher rate data to gain better insight into hardware health
  - Add the ability to update the motor controller firmware on-orbit

Discussions/Conclusions

- All PPAs have exceeded their design life
- Lab PPAs have operated for over 20 years and have shown no degradation
  - PPAs operate near their design point in Lab
  - Node 2 and Node 3 are much smaller loops
- On-orbit PFMC R&R is feasible but crew time intensive so designing the motor controller with replaceability in mind would be beneficial

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