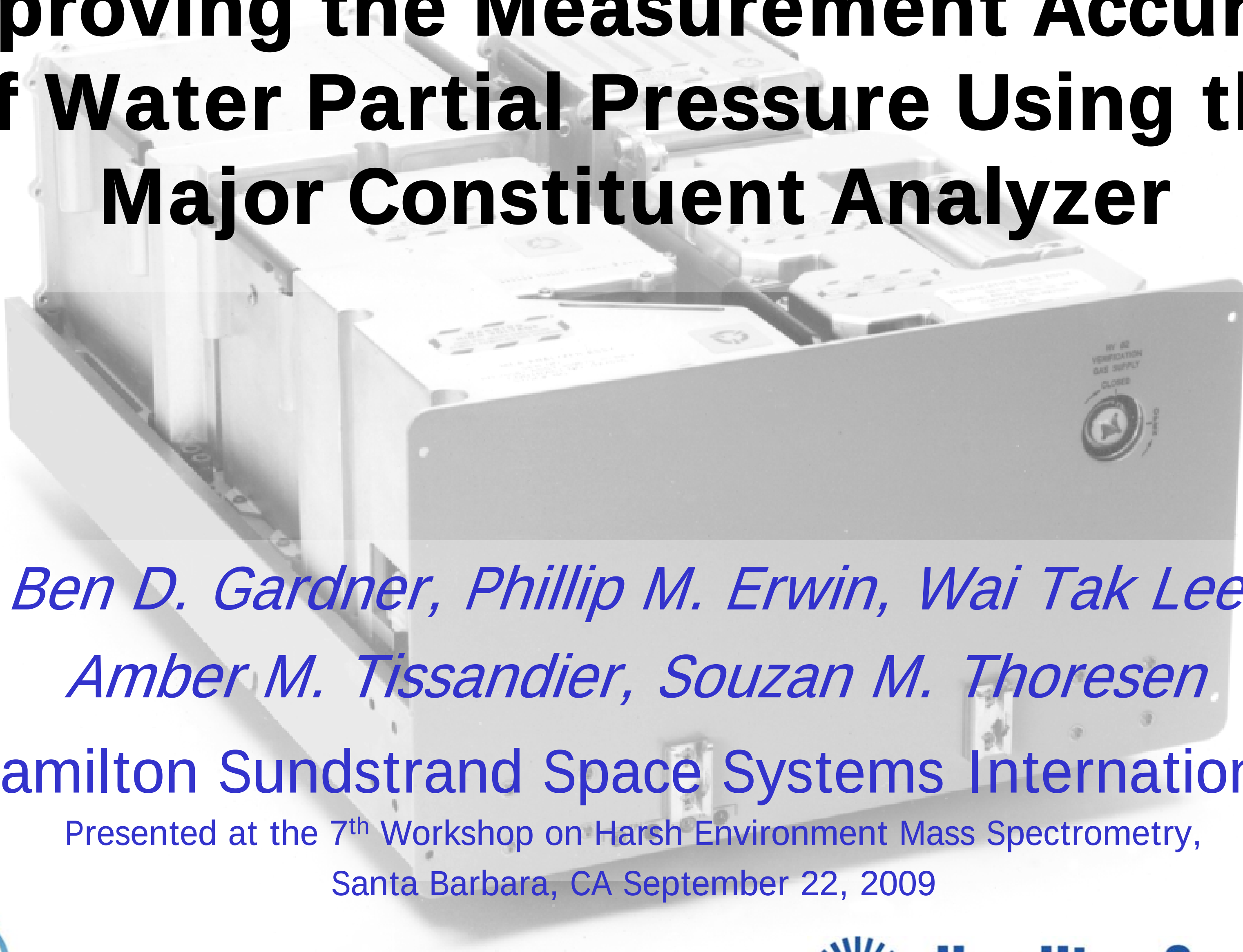

Improving the Measurement Accuracy of Water Partial Pressure Using the Major Constituent Analyzer

Ben D. Gardner, Phillip M. Erwin, Wai Tak Lee,

Amber M. Tissandier, Souzan M. Thoresen

Hamilton Sundstrand Space Systems International

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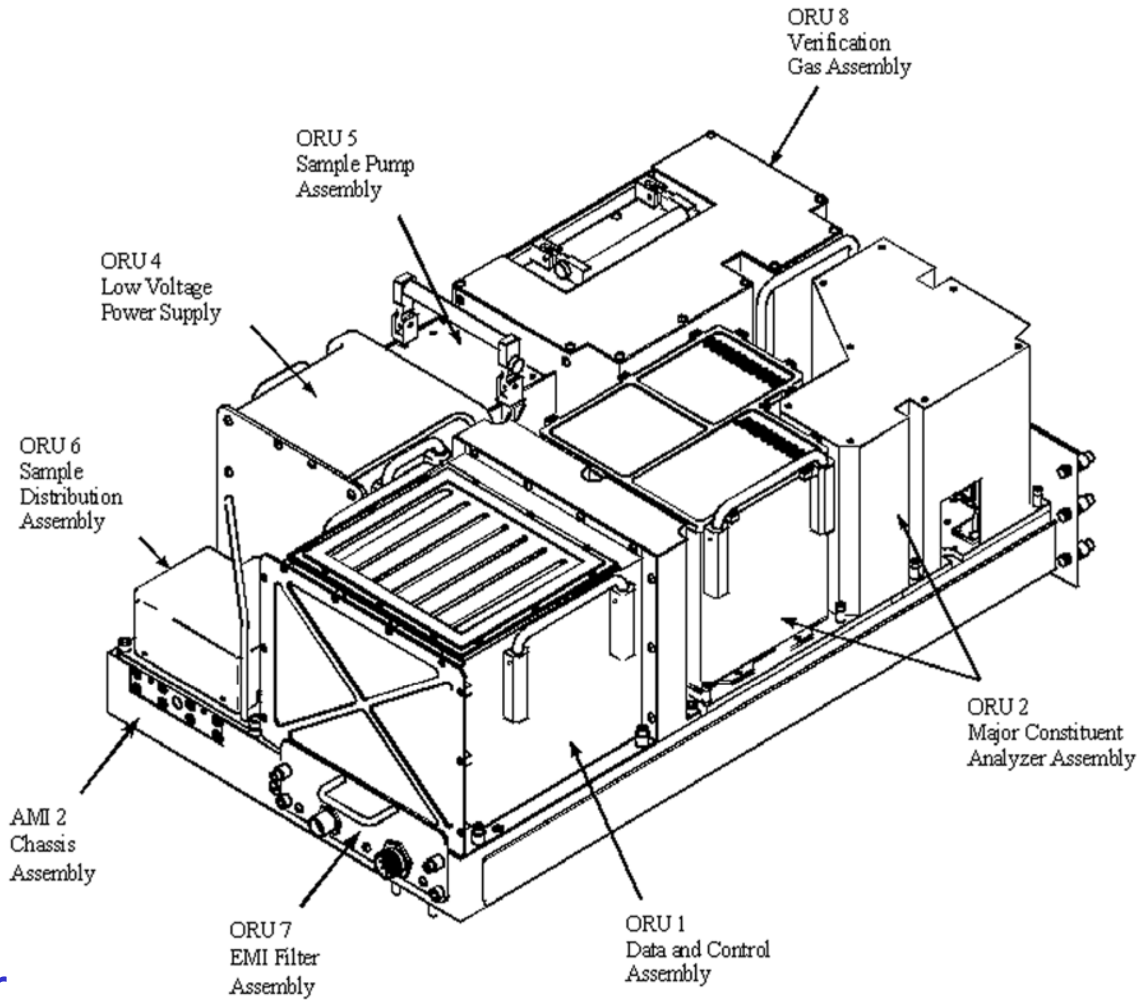
The Major Constituent Analyzer

- Major Constituent Analyzer (MCA) is a magnetic-sector mass spectrometer based system for monitoring ISS air.
- Six simultaneous detection channels; for H_2, CH_4, H_2O, N_2, O_2, and CO_2 which are the major on-board air constituents of ISS.
- Is self-calibrating.
- Includes active built-in-test (BIT) capability.
- Is comprised of seven orbit-replaceable units (ORUs) for easy maintenance.



International Space Station

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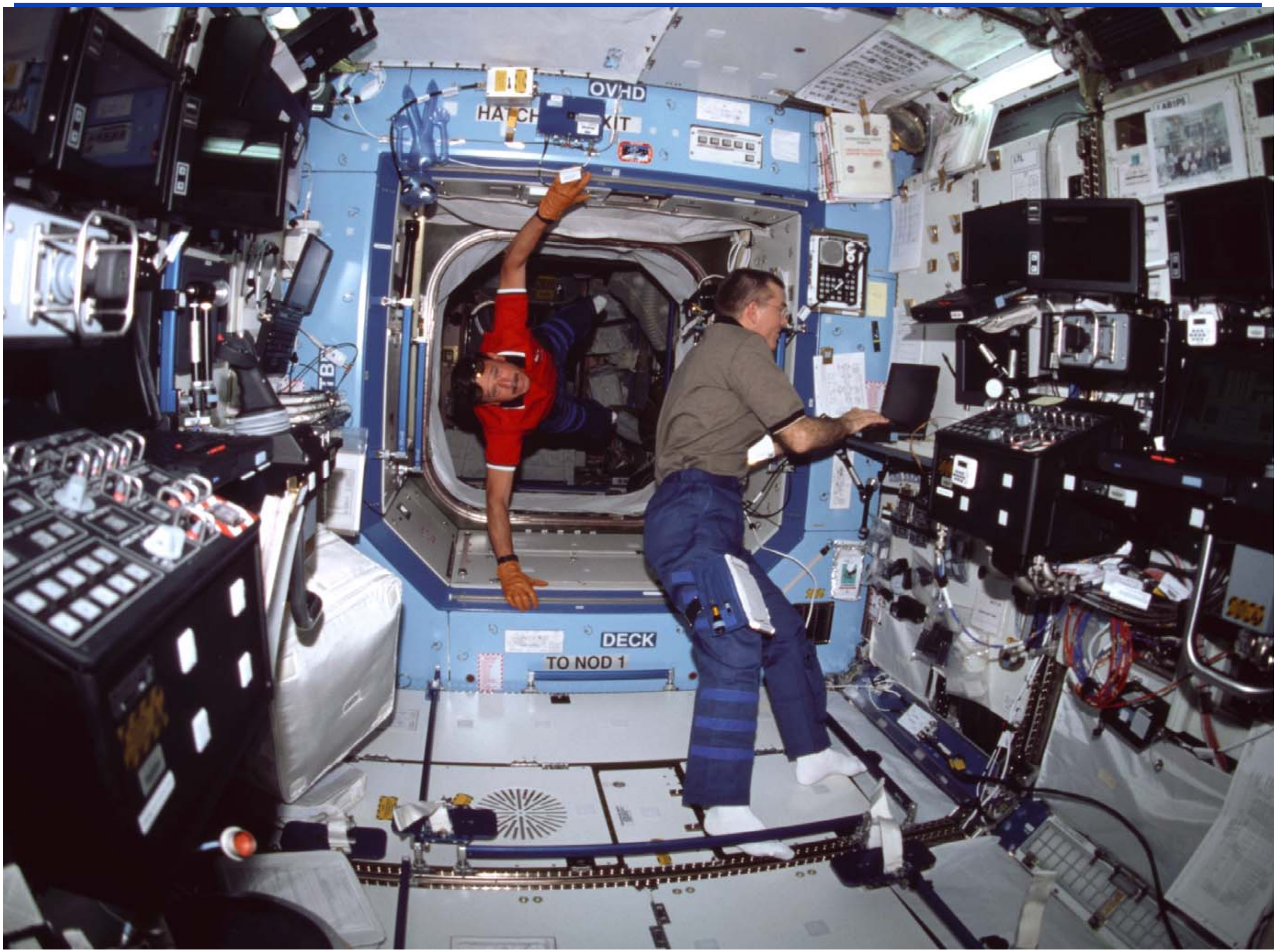

MCA Functionality

- Of the six major constituents that MCA is designed to measure, five (H_2, CH_4, N_2, O_2, and CO_2) are currently being measured as planned.
- Measurement of the sixth constituent, H_2O, was descoped during MCA development. At that time, the issue of transporting humid air through the ISS plumbing was not completely understood and the effect of H_2O surface adsorption on the sampling lines had not been characterized.
- Recently the MCA program has been authorized to revisit the issue through NASA change request CR10773A.

The Calibration Sequence

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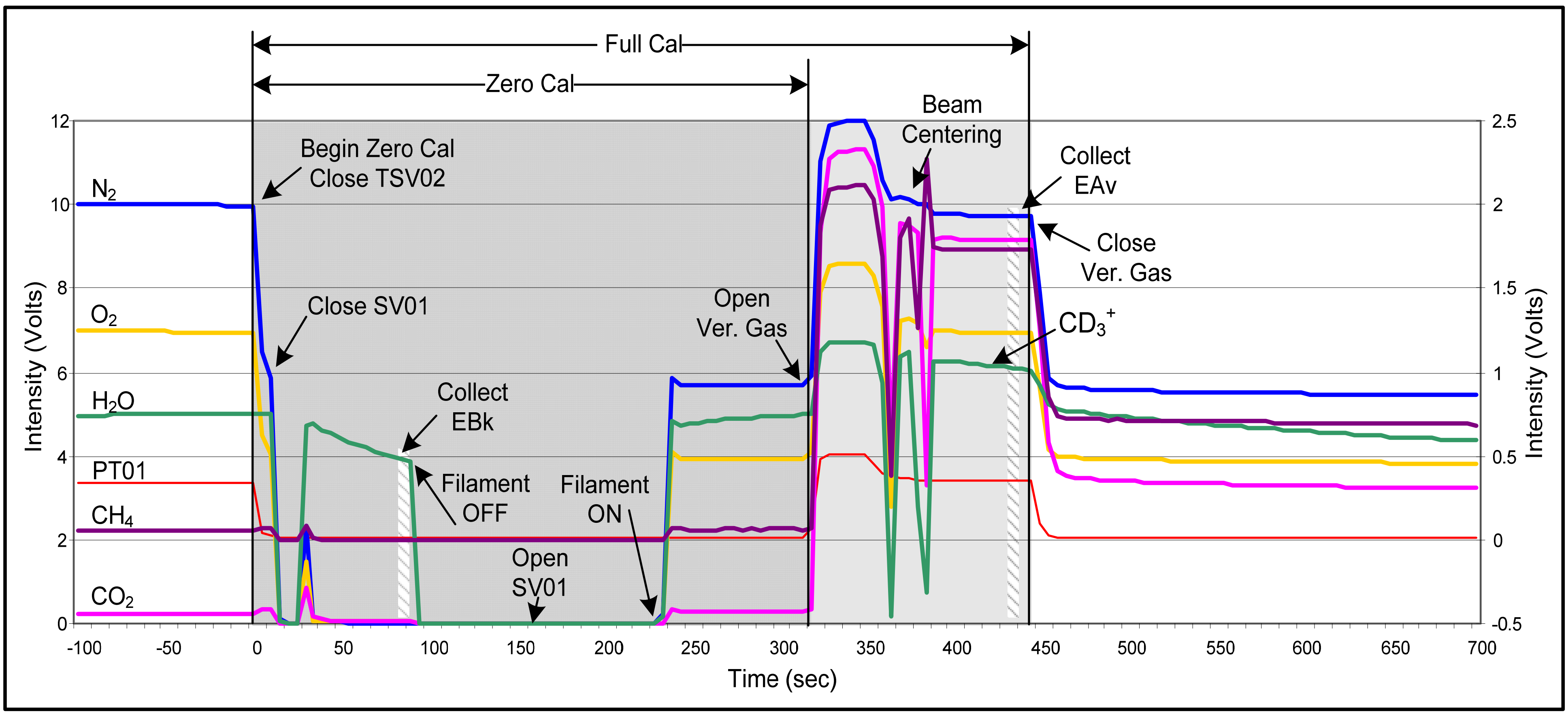
Zero Cal (Offset) → **Beam Centering** → **Full Cal w/ VGA (Gain)**



MCA Normal Operation

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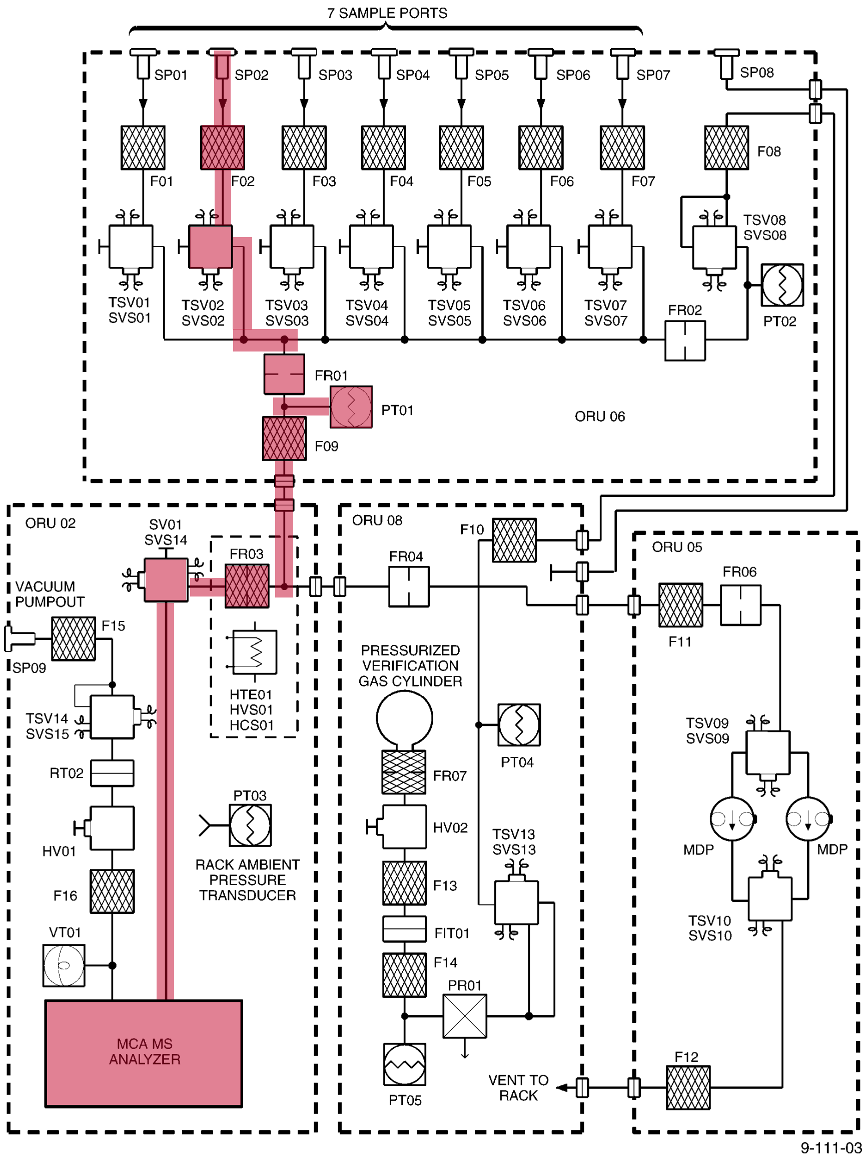
- The plumbing schematic for MCA is shown on the right.
- Under normal operation, the incoming air flows through an inlet valve of the MCA manifold and into the analyzer.



MCA Calibration Start (Zero Cal)

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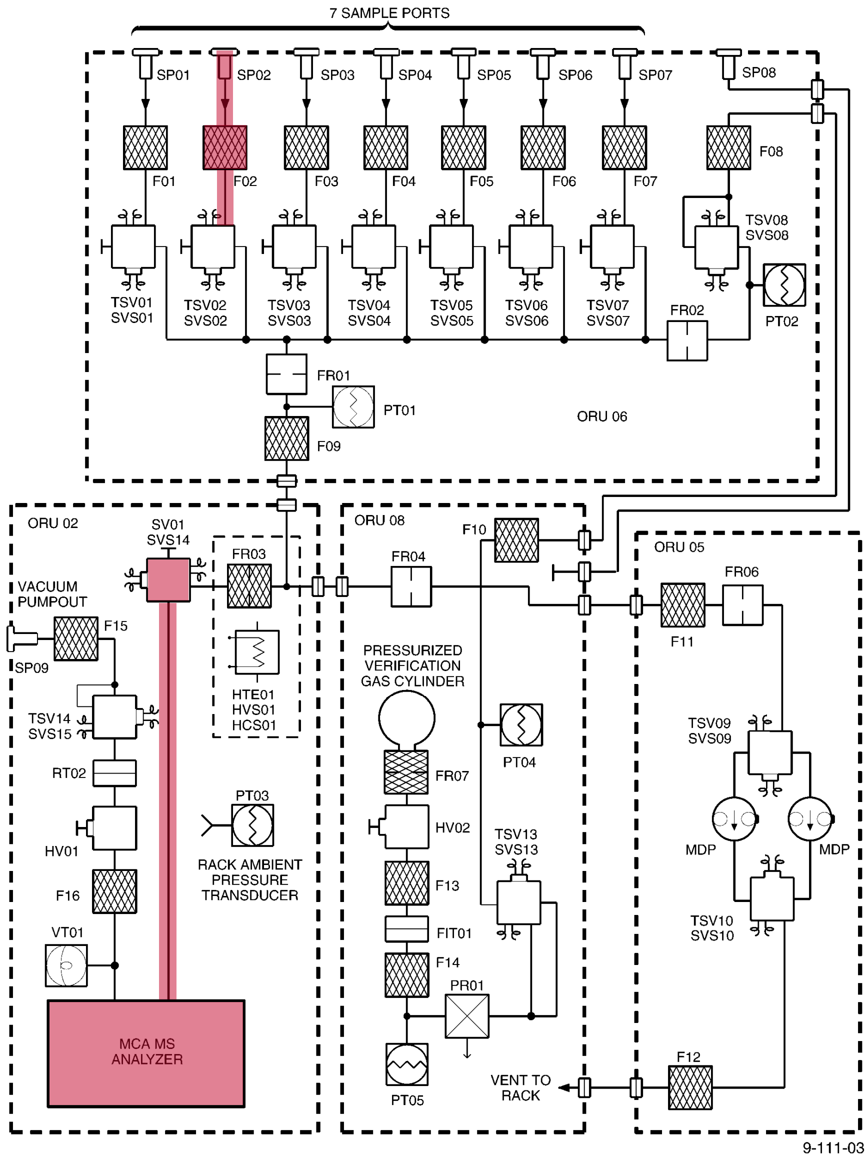
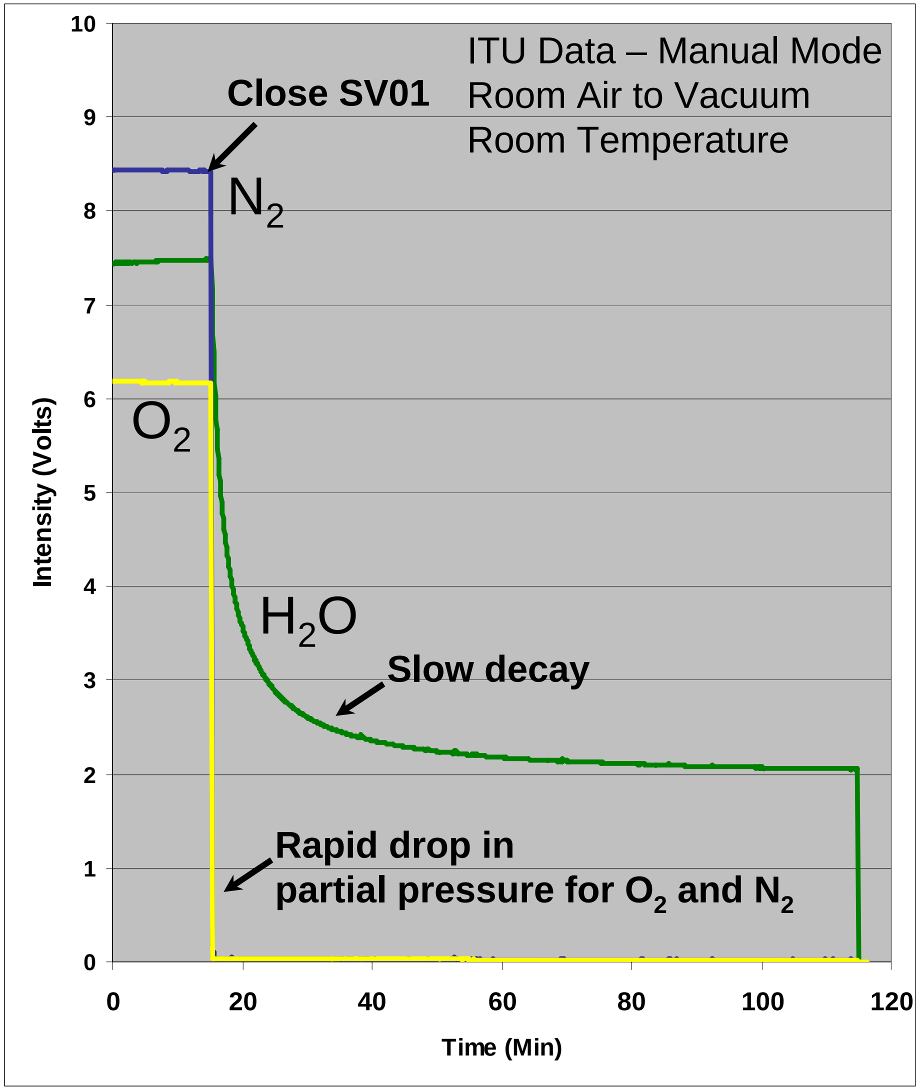
- The plumbing schematic for MCA is shown on the right.
- Under normal operation, the incoming air flows through an inlet valve of the MCA manifold and into the analyzer.
- At the beginning of the zero and full calibration routines, the inlet valve at the analyzer entrance is closed.
- The analyzer then drops to a baseline level to establish background signal amplitudes.



The Problem with Measuring H_2O

- Measuring $p(H_2O)$ has been problematic because, unlike the other constituent gases, H_2O adsorbs onto the interior surfaces of the transport tubing.
- Measured H_2O levels do not reflect the actual gas-phase environment until equilibrium is achieved.
- As shown in the figure, reaching equilibrium can require considerable time (>100 minutes), which in not compatible with MCA operation requirements.
- The decay characteristics are not strictly exponential.
- This phenomenon effects MCA capacity to accurately calibrate the H_2O channel and to predict ISS humidity.



Zero Calibration

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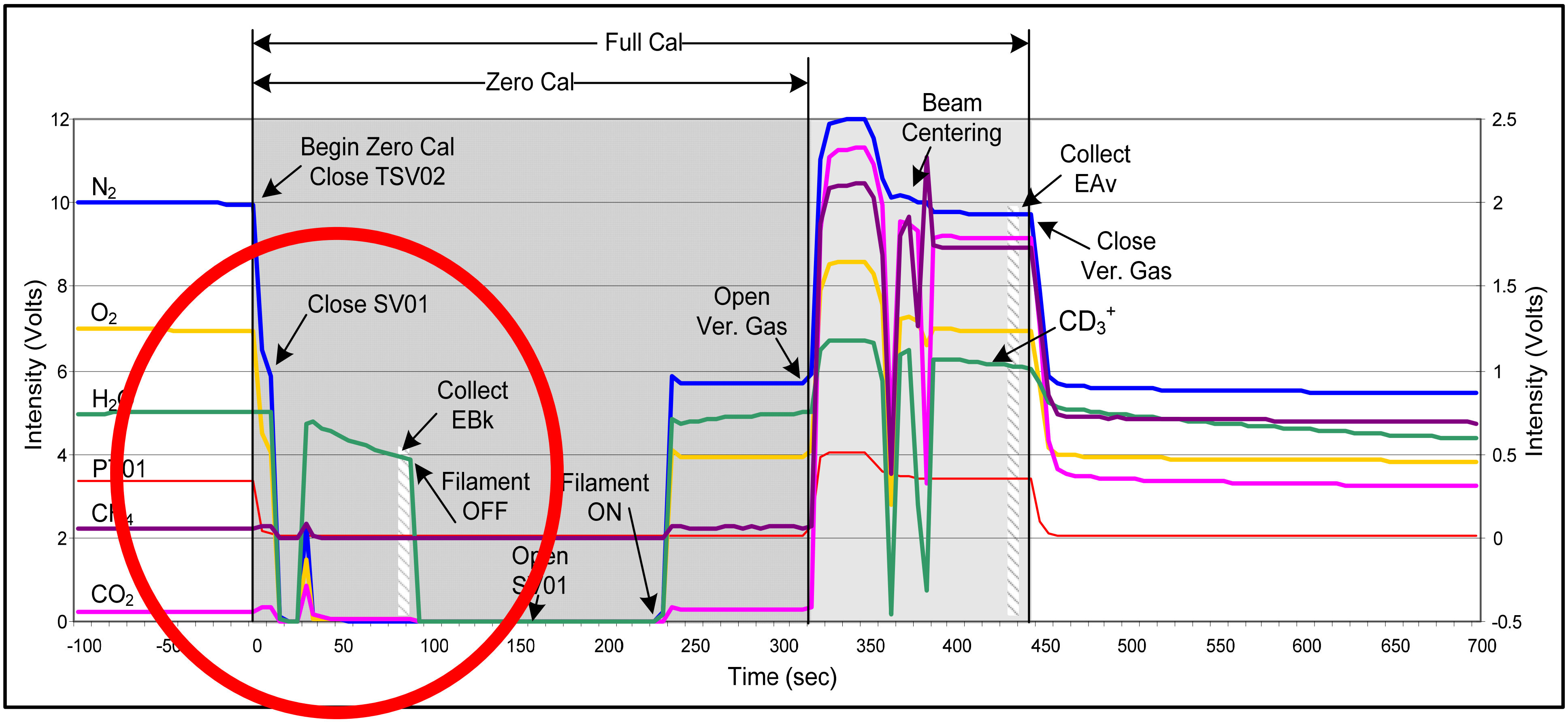
- **Zero Calibration** establishes the electrometer background average (EBk).
- **Full Calibration** then uses EBk to adjust electrometer correction values (ECVs).
- Any error in EBk generates an incorrect calibration.
- As shown in the Figure, EBk is acquired before the H_2O signal is stable.



What is responsible for the slow decay?

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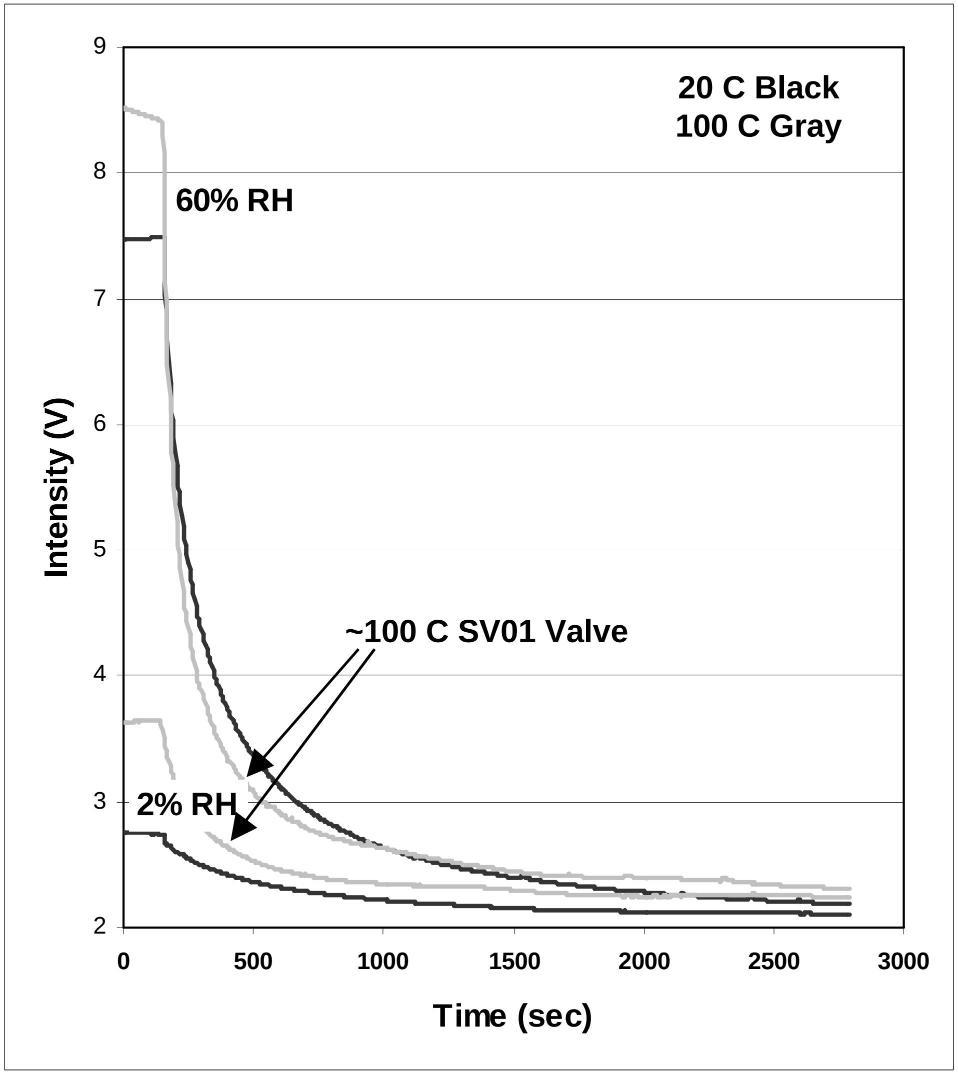
- The primary suspect component responsible for the slow decay rate is the analyzer inlet valve, SV01.
- SV01 has a high internal surface area, low gas conductance, and is unheated.
- Laboratory experiments using the MCA Integration and Test Unit (ITU) revealed that the shape of the decay curve for H_2O can be changed by heating the valve.
- However, the slow decay is not eliminated.
- Furthermore, the baseline levels do not converge even after an extended time period.



Simulink Modeling of the Decay – SV01 Valve

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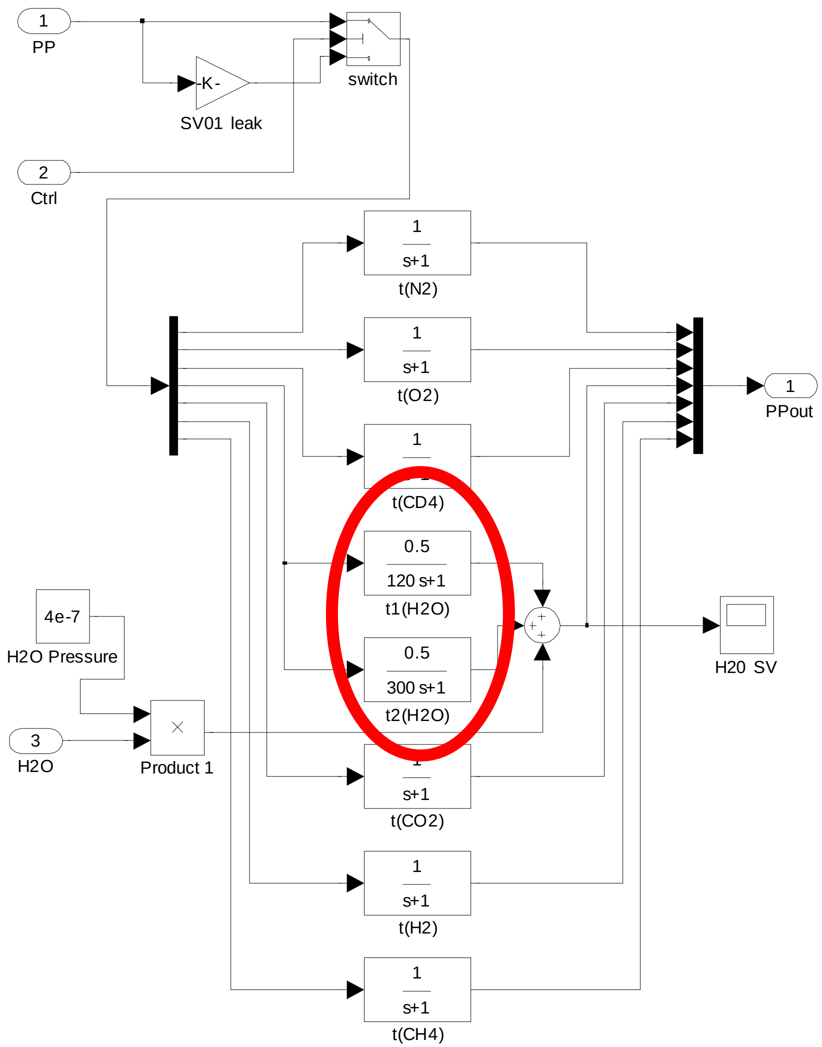

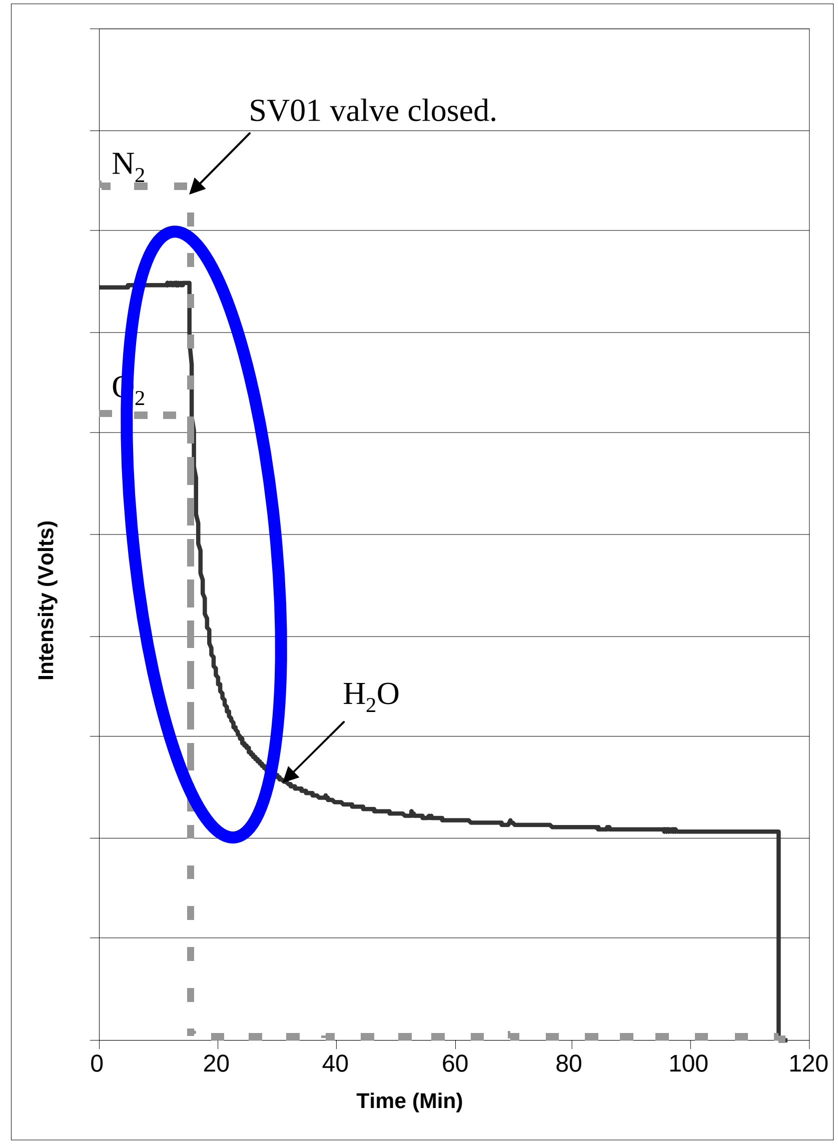

Simulink Modeling of the Decay – Analyzer

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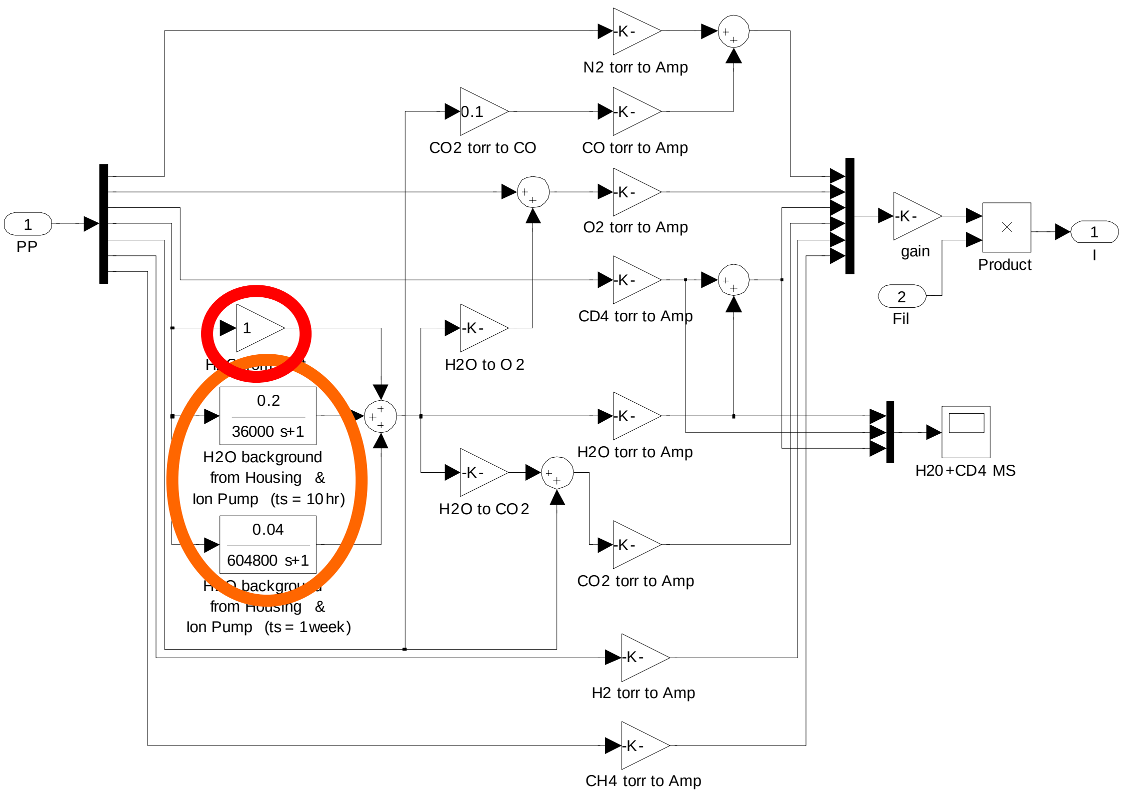

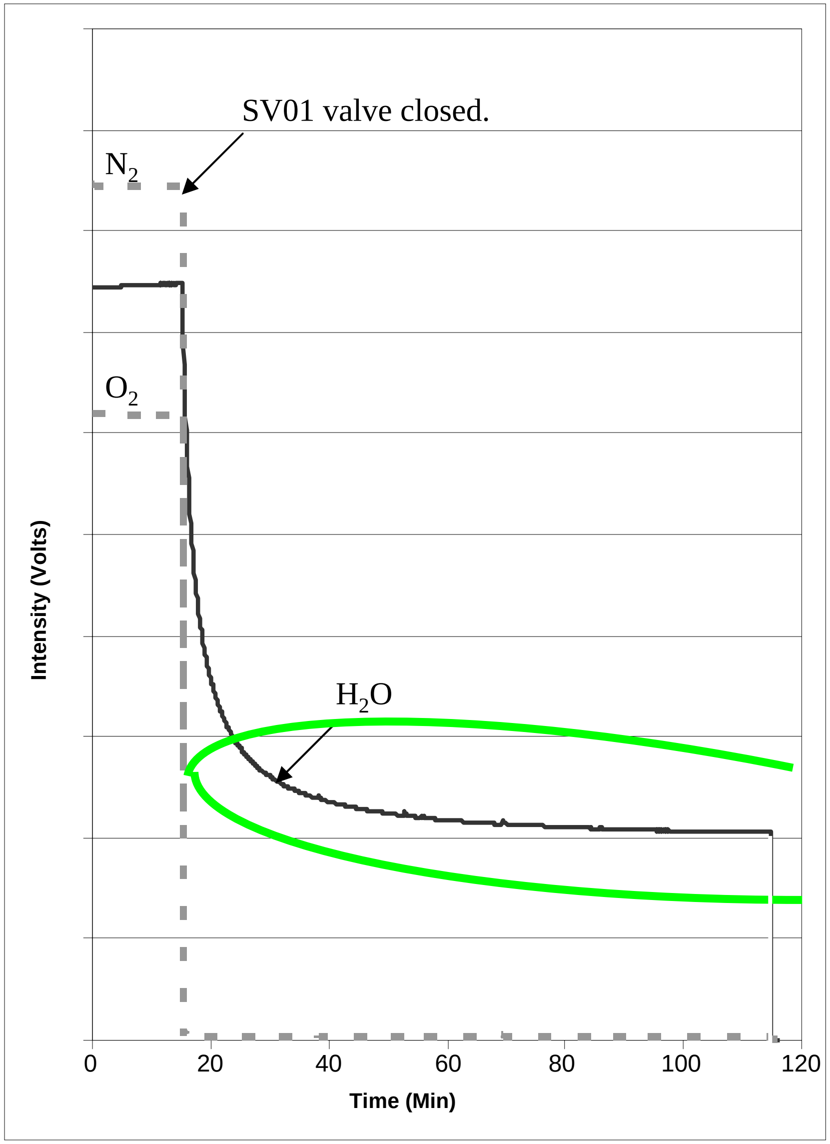

Improving Zero Calibration

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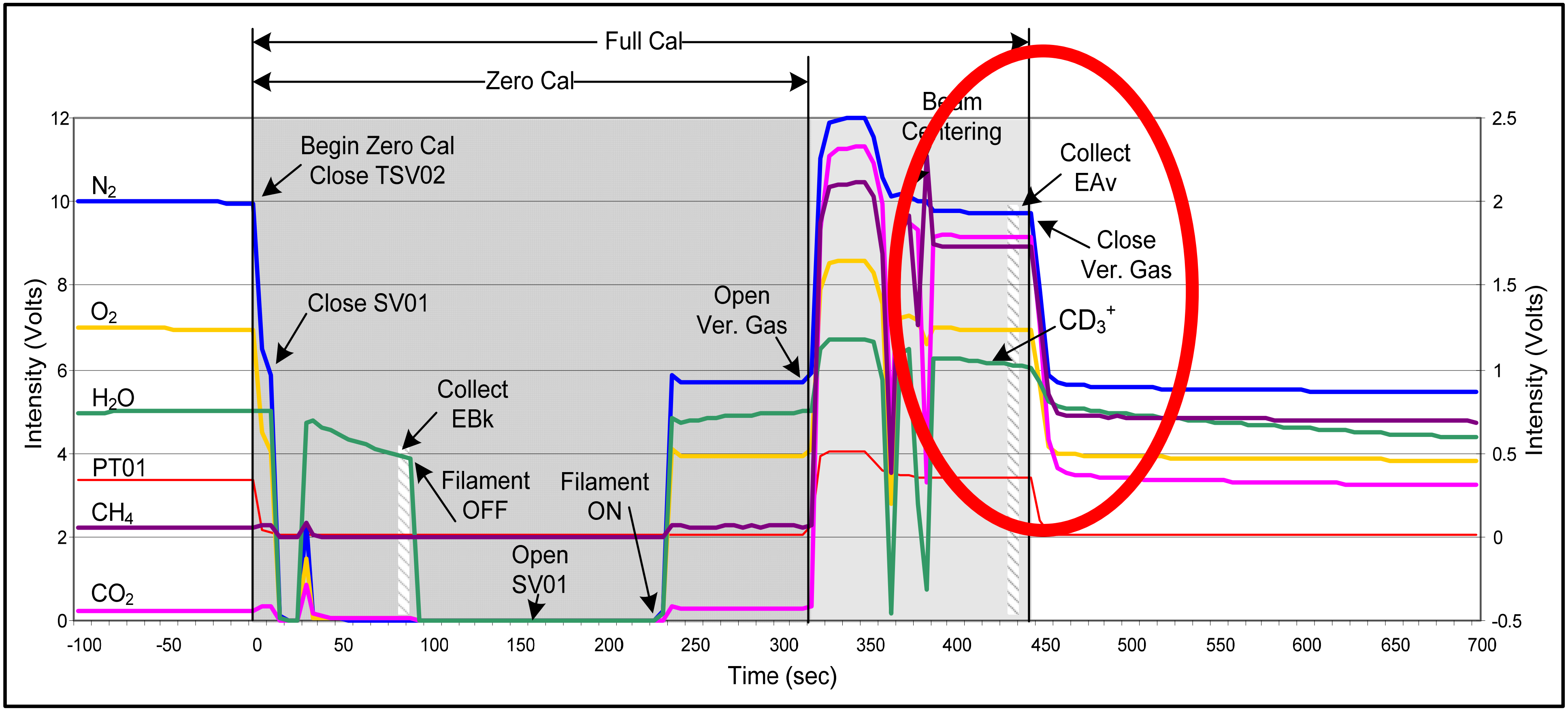
- The experimental thermal and modeling data confirm that the SV01 valve is primarily responsible for the observed decay process.
- With MCA validated and on-orbit, heating the SV01 valve is not an option.
- The modeling suggests that by collecting decay curve data for a short time after one time-constant, the final baseline can be extrapolated.
- This will require a slight increase in the zero calibration time.

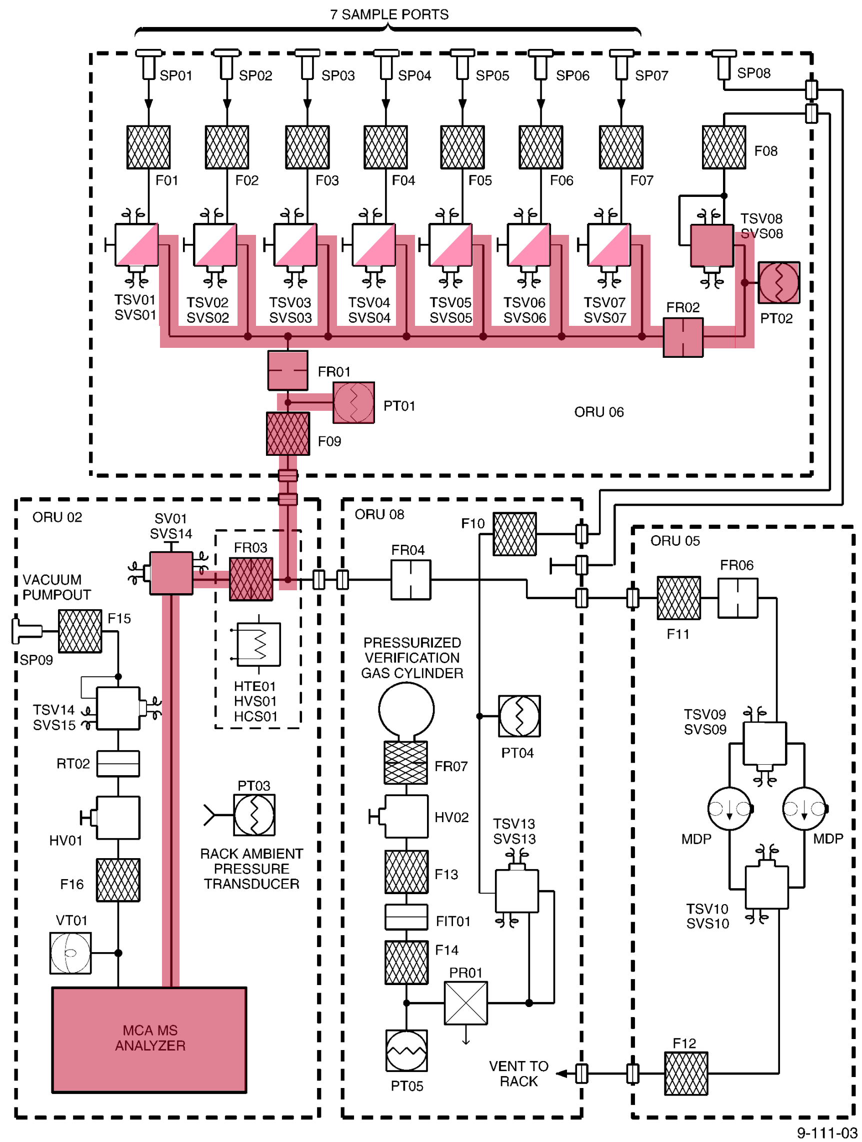
Full Calibration

- **Full Calibration** includes the Zero Calibration, and occurs every 6 weeks on orbit.
- **Full Calibration** uses a verification gas mixture containing CD_4 to determine the EAv.
- The EAv and the EBk are used to determine the electrometer correction values.
- The CD_4 signal rides an unknown amount of H_2O.



Full Calibration

- Sample pathway is closed at 200 torr and uncontrolled when the verification gas inlet is opened, raising the pressure to 400 torr.
- Verification gas is thus forced into the side ports of the manifold, diluting trapped gas-phase H_2O which can diffuse into the verification gas flow path.
- The decay observed is a function of this process as well as desorption processes including those described in the zero calibration.
- This is not a problem for normal MCA operation, where the flow throughput greatly dominates any residual diffusion.



An Alternate Amplitude Method for CD_4

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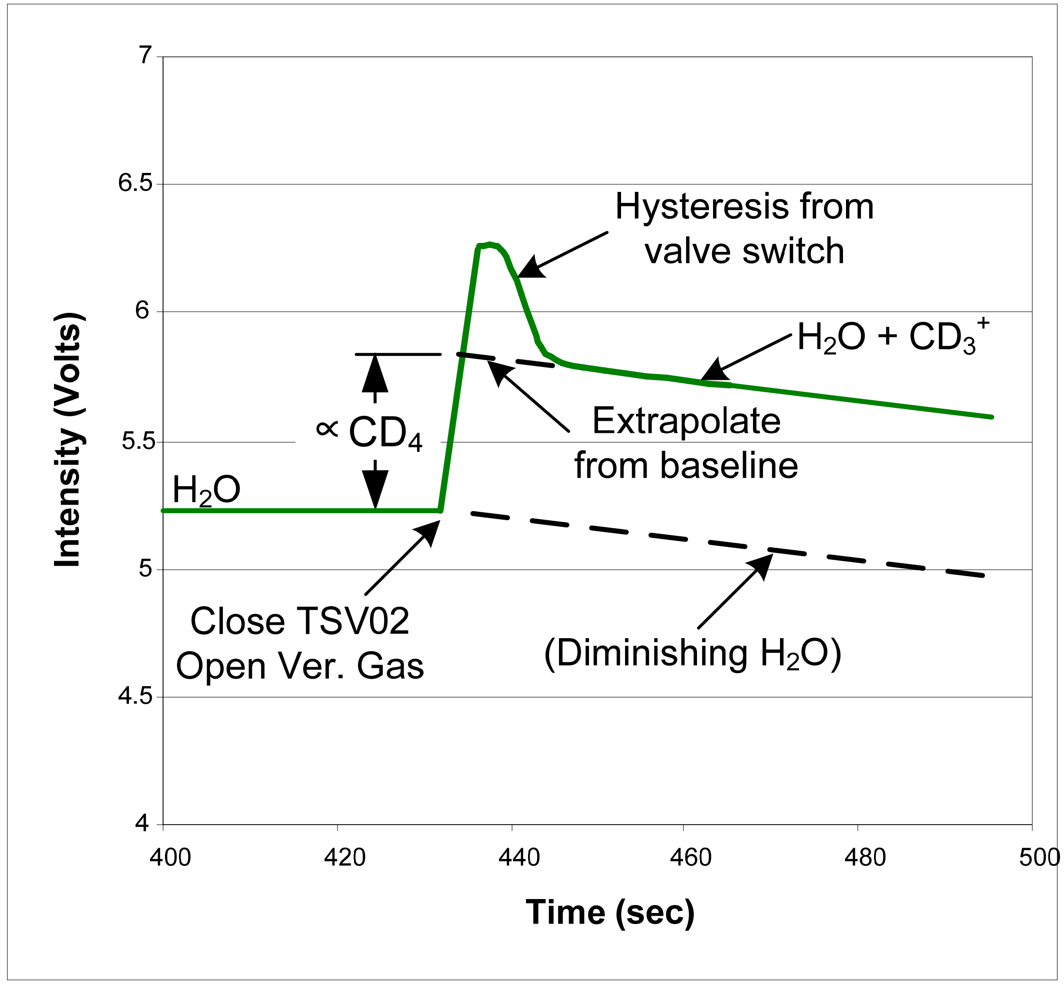
- Switch the manifold valve TSV02 off and the Verification gas valve on simultaneously to preserve controlled flow.
- H_2O level will decay from a known initial level.
- CD_4 amplitude can be extrapolated accurately.



Full Calibration

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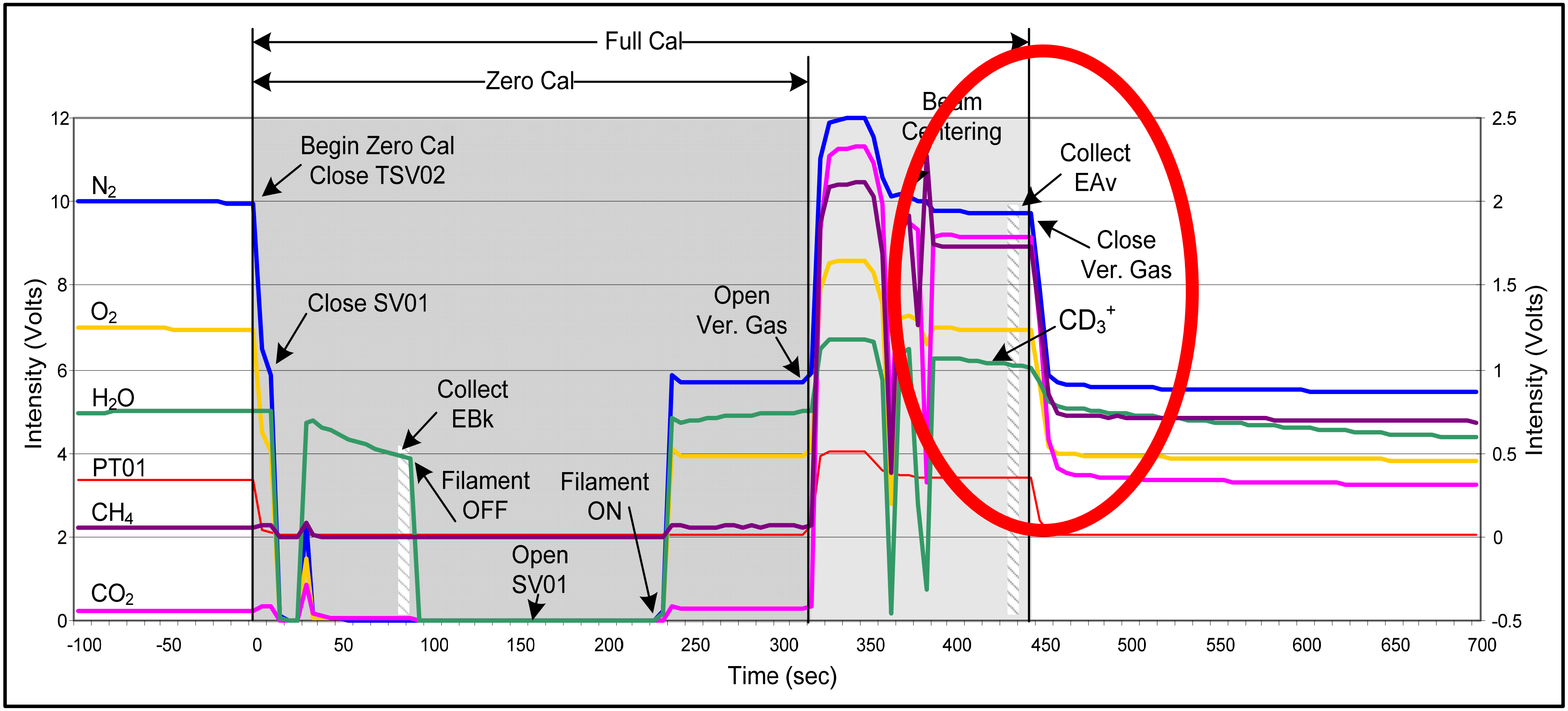

Taking advantage of what we've learned

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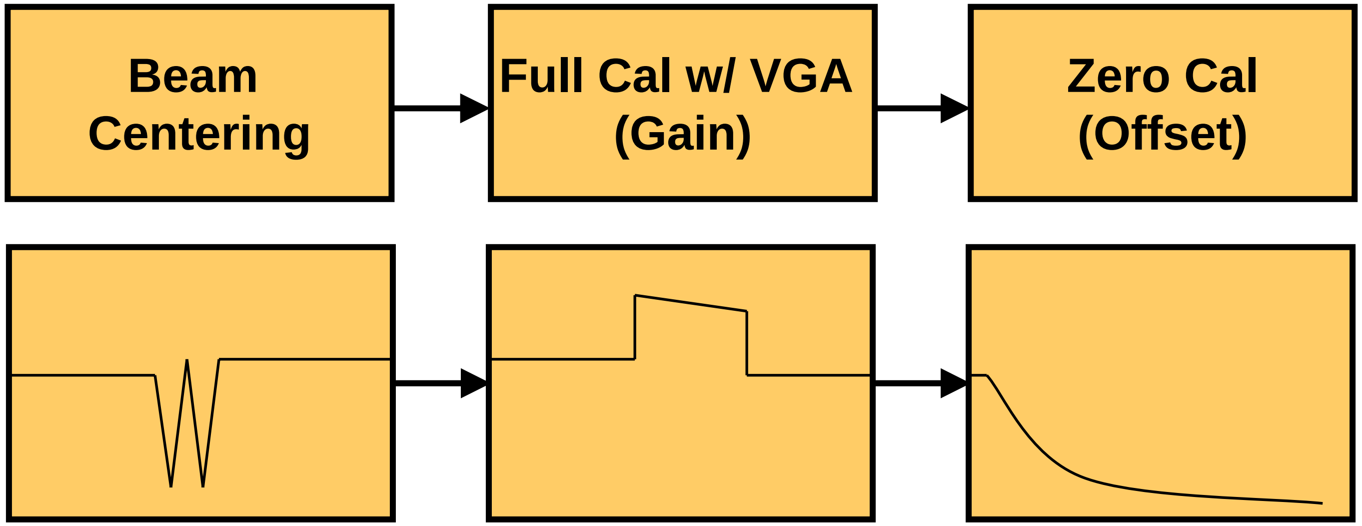

- We are altering the calibration sequence to perform beam centering first using atmospheric gas to reduce consumption of verification gas.
- The "full cal" step will be performed next to take advantage of the logic previously described.
- The "zero cal" will follow, allowing additional time to establish an accurate baseline for H_2O.

Summary

- The improved water accuracy logic is currently being programmed into the MCA firmware as part of NASA CR10773A.
- Testing is nearly complete.
- The firmware upgrade is scheduled for delivery on ULF3 in November, 2009.
- It may be possible to extend the extrapolation logic of the zero calibration to the sampling of humid air from long lengths of sample tubing. This is under review.

Acknowledgements

- MCA Development Team – Hamilton Sundstrand
- John Granahan - Boeing
- John Cover - NASA