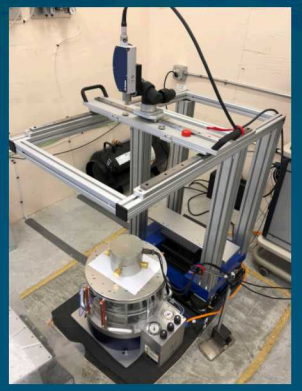
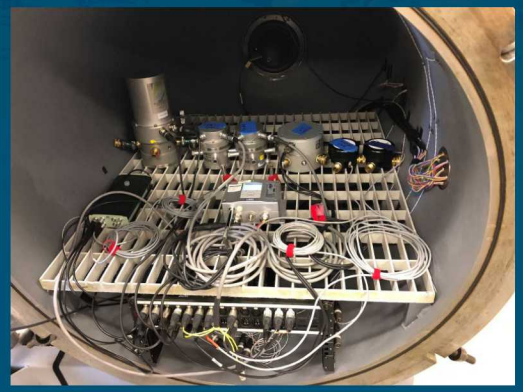
SAND2019-13488PE

Environmental Calibration of Infrasound Sensors in a Long-Term Field Study





PRESENTED BY

B. John Merchant, Randy K. Rembold

This work was supported by the Nuclear Arms Control Technology (NACT) Program at Defense Threat Reduction Agency (DTRA)

Outline

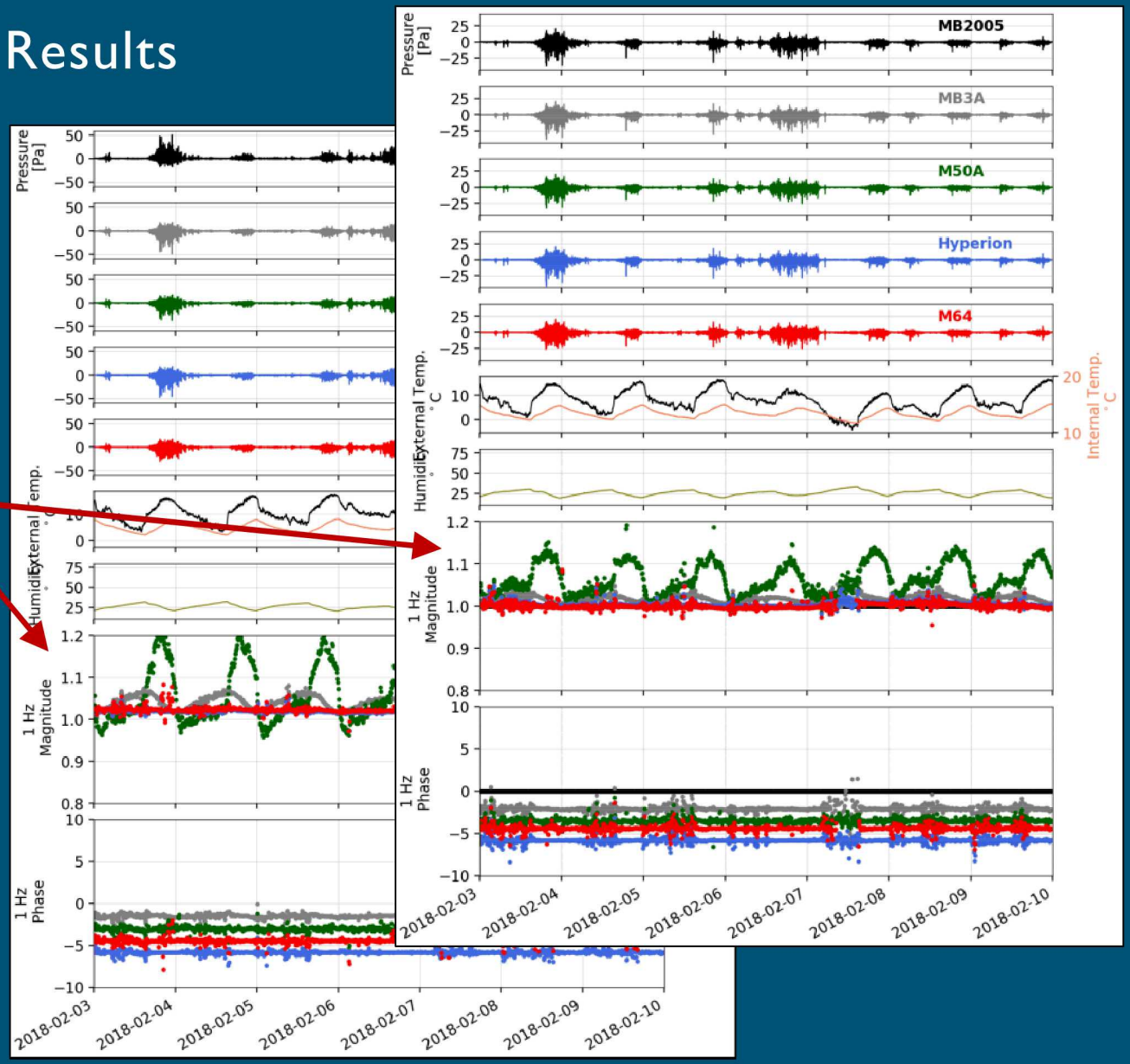
- Objective:
  - Determine the effect of static temperature and pressure on the response of the infrasound sensors in a Long-Term Field Study and support sensor Type Approval.
- Change in Static Pressure Testbed & Testing Protocol
- Change in Static Pressure Amplitude & Phase Response Results
- Change in Static Temperature Testbed & Testing Protocol
- Change in Static Temperature Amplitude & Phase Response Results
- Application to Type Approval

Highlight Issue from Prior Field Results

- Earlier presentation (Fee, ITW 2018) showed sensors having relative diurnal changes in sensitivity:

  Correlated with temperature and pressure.

- Desire for this work was to verify sensor performance in laboratory environment under controlled conditions.



Fee, ITW 2018

Changes in Field Study

Chaparral 50A removed from the field study.

Earlier presentations (Fee, 2018) showed issues with the MB3a sensors in the long-term field study, which will be referred to at "MB3a – SNL".

In mid-2019, CEA loaned SNL two MB3a sensors, referred to as "MB3a – CEA", to evaluate.

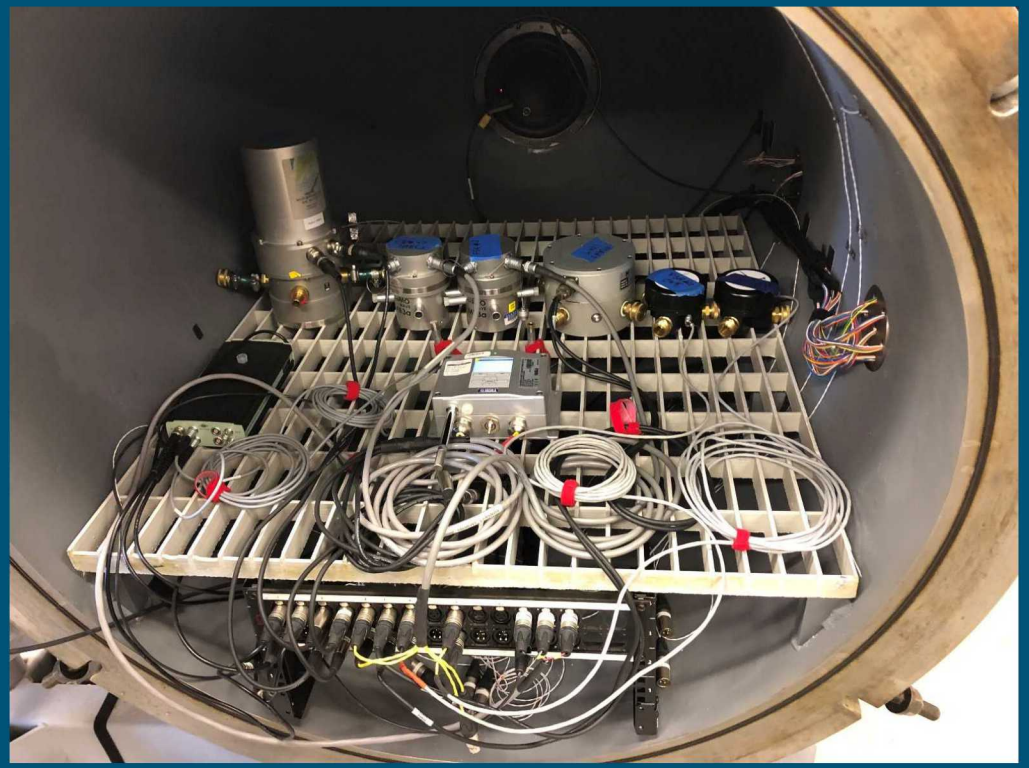
These MB3a – CEA sensors were added to the long-term field study and all 4 MB3a sensors were evaluated for their performance under static temperature and pressure changes.

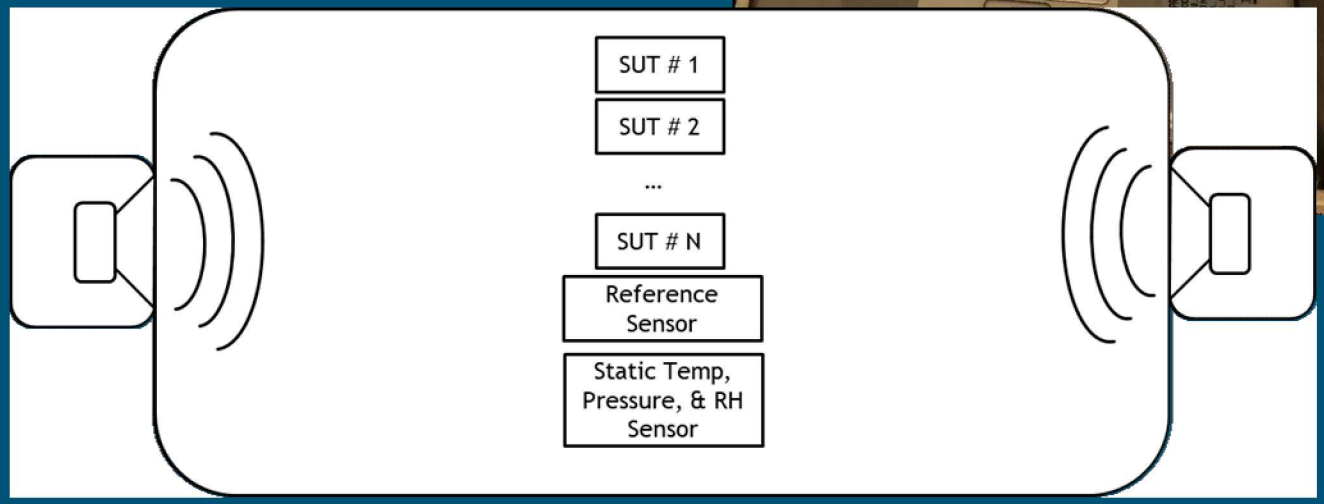
The MB3a – SNL sensors were found to have some anomalous behavior:

- Suggests that the sensors are not performing properly.
- Those results will not be presented, as we believe they do not represent MB3a sensors
- SNL is arranging to send the MB3a – SNL sensors to CEA for diagnosis.

Static Pressure Testbed

- Infrasound Chamber supports pressurization and evacuation
- Better than 0.5 hPa resolution in controlling static pressure
- Temperature, Pressure, Humidity recorded continuously
- B&K 4193 Microphone used as the reference to measure sensitivity.
  The B&K microphone sensitivity was corrected for static pressure



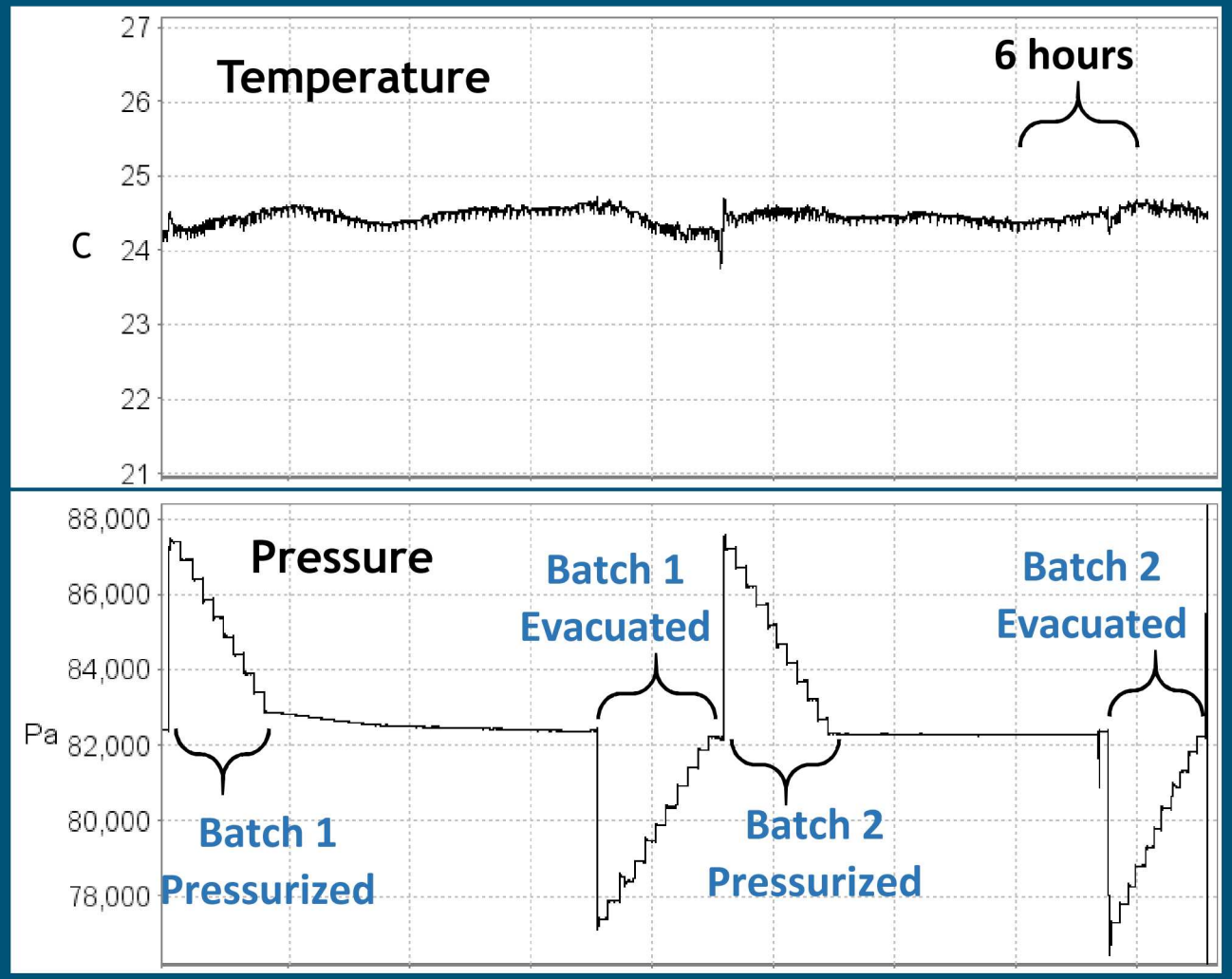


Static Pressure Test Protocol

- Sensors were divided into two batches, consistent with their deployment in field conditions.
- Performed calibrations using discrete tones over 0.1 to 10 Hz at each static pressure level.

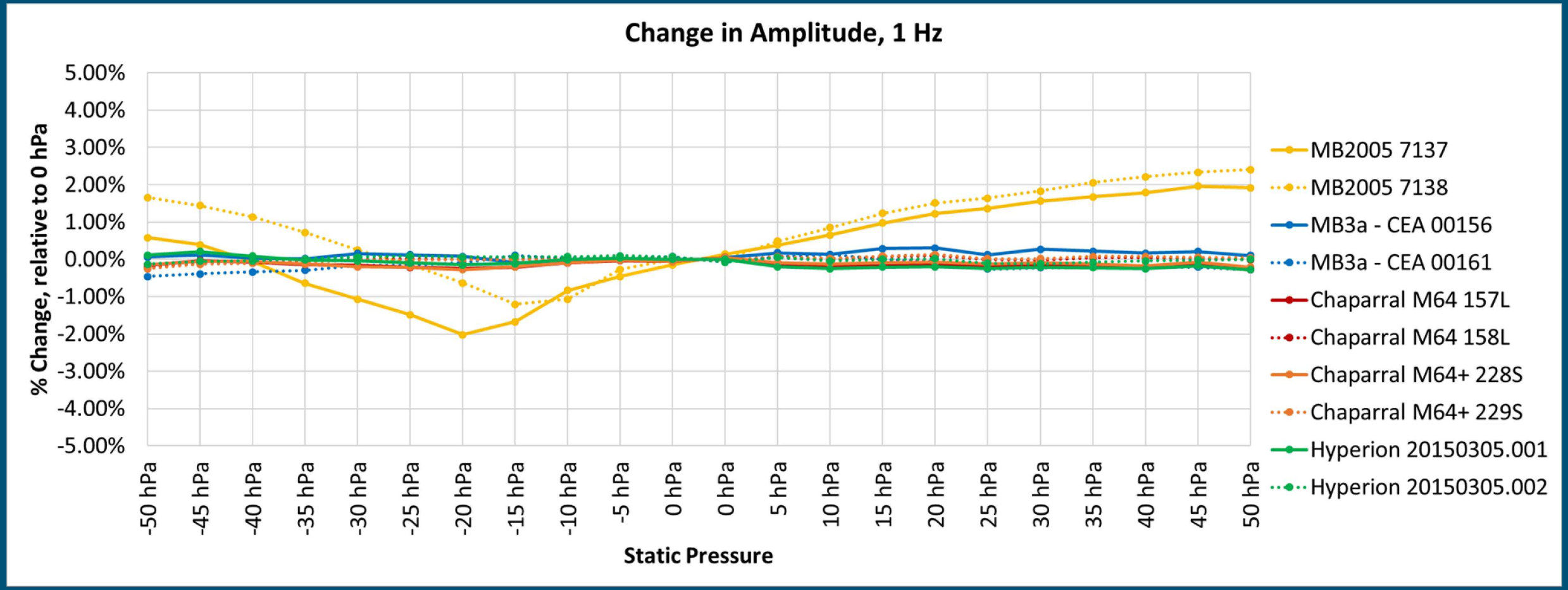
Batch 1	MB2005 # 7137 MB3a - SNL # 10 / 0715 MB3a - CEA # 00156 Hyperion # 20150305.001 Chaparral M64 # 157L Chaparral M64+ # 228S
Batch 2	MB2005 # 7138 MB3a - SNL # 20 / 0715 MB3a - CEA # 00161 Hyperion # 20150305.002 Chaparral M64 # 158L Chaparral M64+ # 229S

- Temperature was 24.5 C, +/- 0.25 C
- For each batch of sensors (12 hours):
  - Calibration at each step, resting for 5 minutes.
  - Pressurize to +50 hPa
  - Decrease pressure in 5 hPa steps back to ambient
  - Evacuate to -50 hPa
  - Increase pressure in 5 hPa steps back to ambient



Static Pressure Results - Amplitude

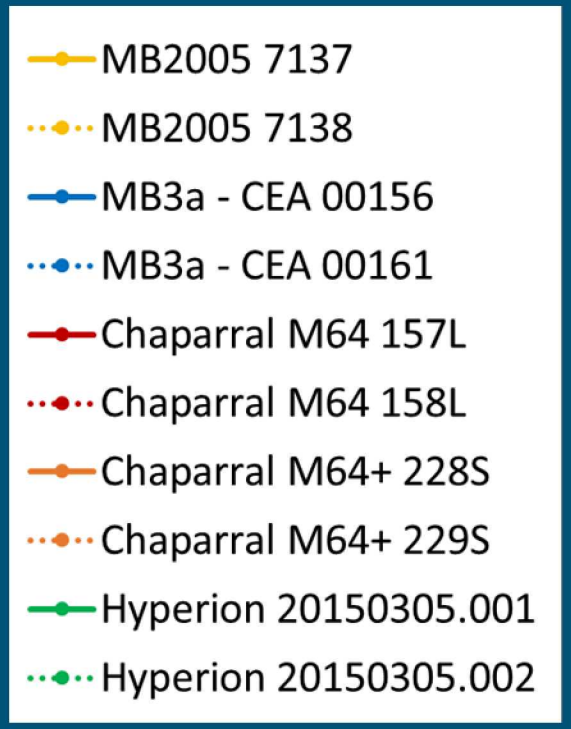
- MB2005 has a discernable transition at about -20 hPa from ambient, with clear trend from -2% to +2%, consistent with results reported by CEA.
- The remaining sensors range from +/- 0.5% over +/- 50 hPa with no obvious trend

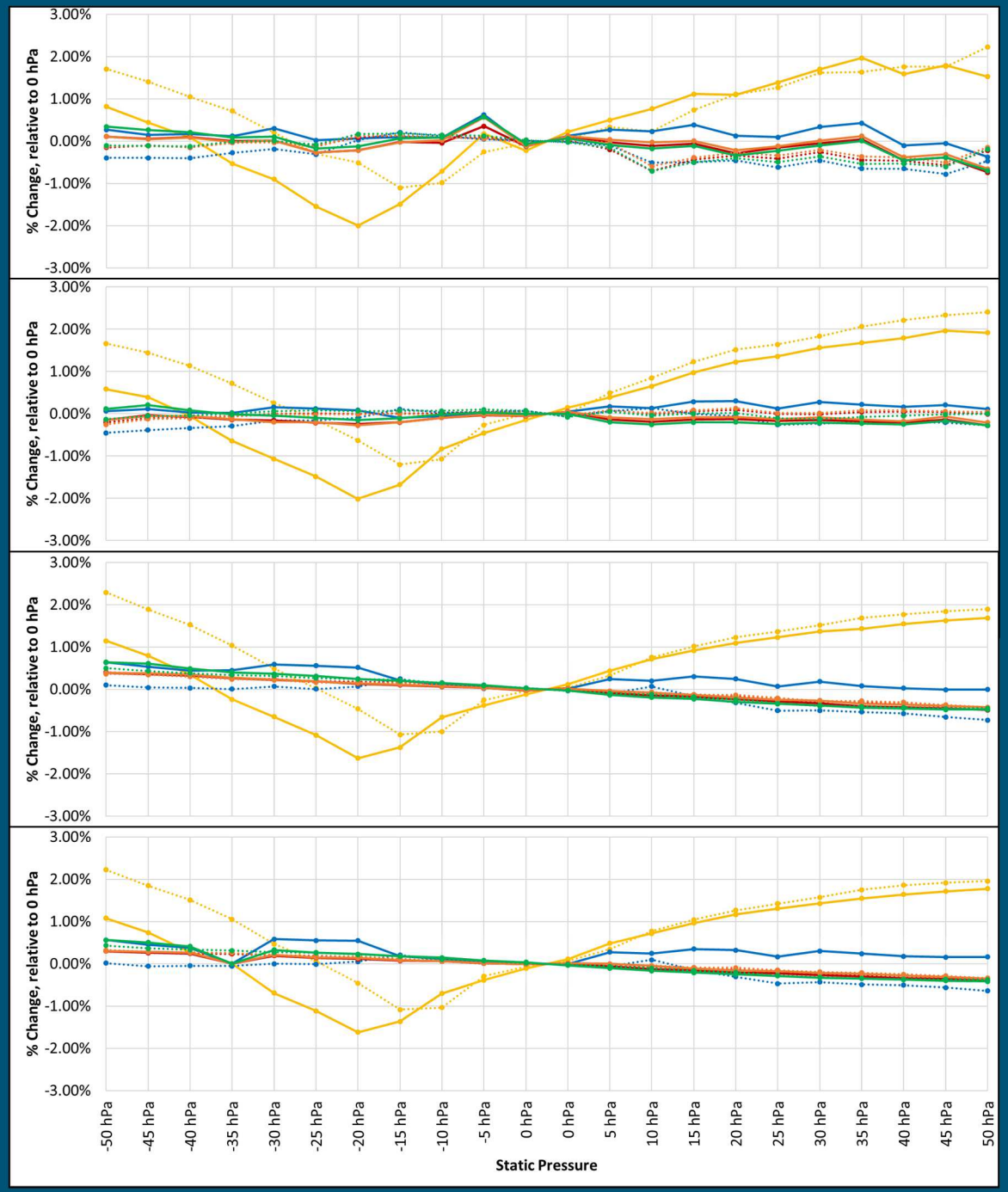


Static Pressure Results - Amplitude

The results are consistent across the passband.

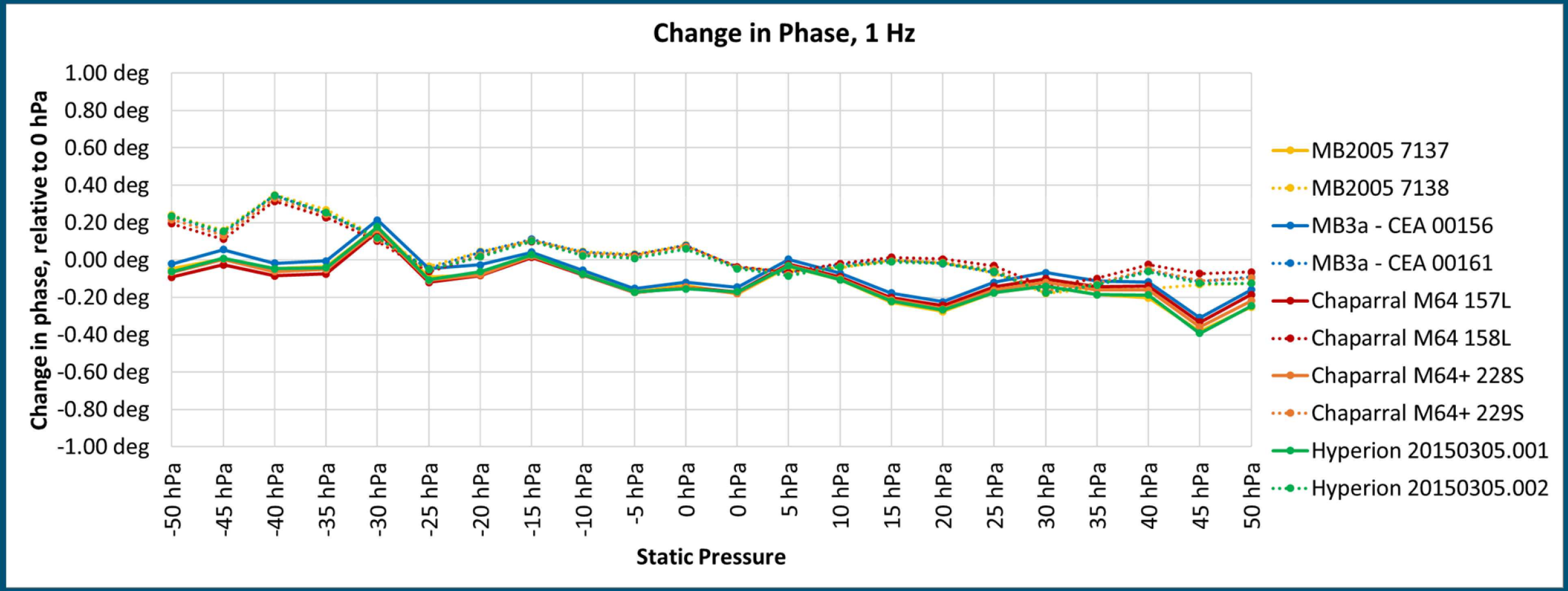
Note that the increased variability at frequencies below 1 Hz is due to the degraded SNR as the reference microphone passband rolls off.





Static Pressure Results - Phase

- All of the sensors demonstrated a change in phase at 1 Hz of less than +/- 0.4 degrees.
- Variability is consistent to the batch of testing, indicating that it is likely a contribution of the reference microphone.



Static Pressure Results - Phase

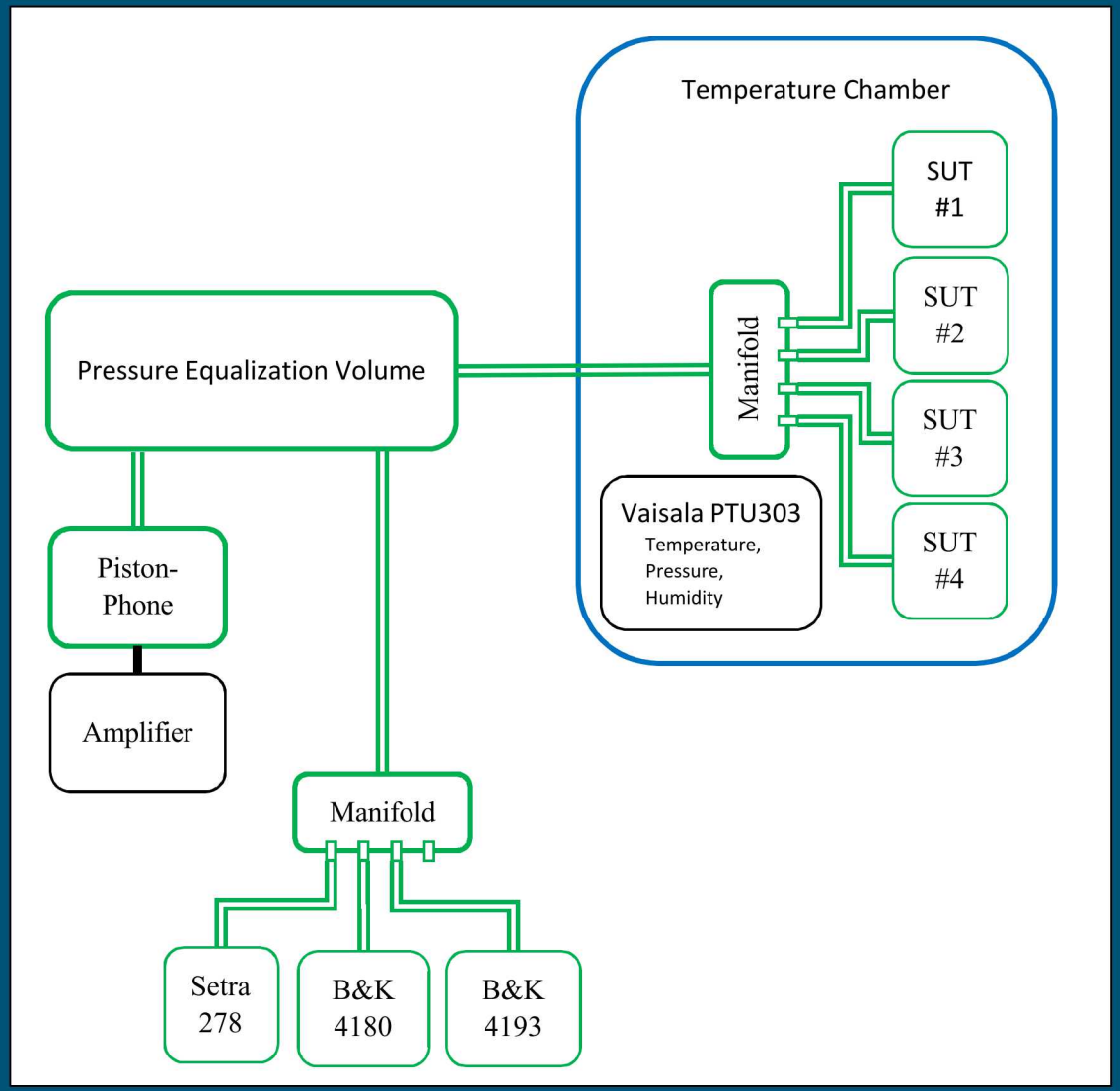
The results are consistent across the passband, with no discernable trend in phase related to static pressure.

Note that the increased variability at frequencies below 1 Hz is due to the degraded SNR as the reference microphone passband rolls off.

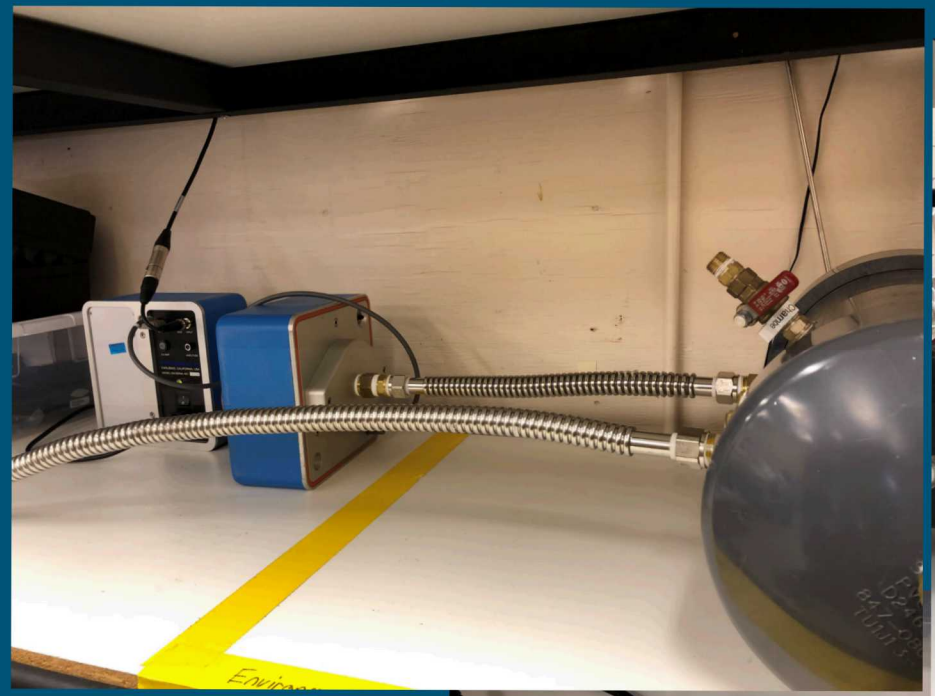
- MB2005 7137
- MB2005 7138
- MB3a - CEA 00156
- MB3a - CEA 00161
- Chaparral M64 157L
- Chaparral M64 158L
- Chaparral M64+ 228S
- Chaparral M64+ 229S
- Hyperion 20150305.001
- Hyperion 20150305.002

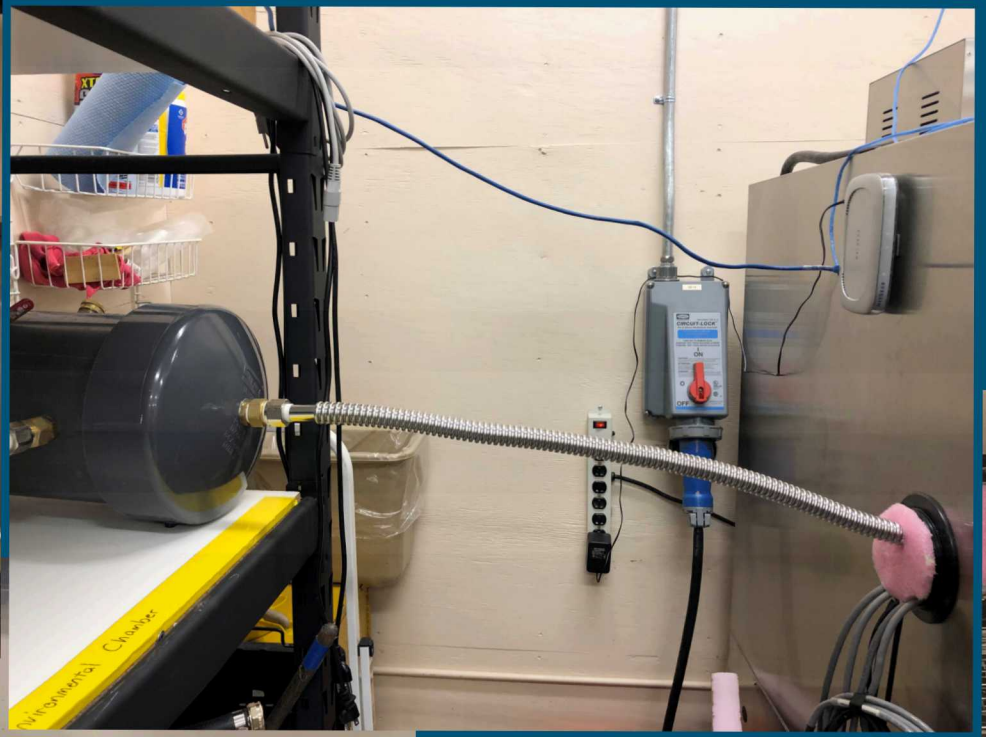
Static Temperature Testbed

- Used Thermal Chamber to test over -20 C to 50 C range
- Ambient pressure varies over test duration.
- B&K 4193 microphone used as the reference.
  - Reference microphone is outside temperature chamber, room temperature maintained at 23 C, +/- 0.5 C
  - Reference microphone sensitivity was not corrected for any change in barometric pressure during the test.
- Evaluated sensor response using discrete tones: 0.1 to 10 Hz



Static Temperature Testbed, continued



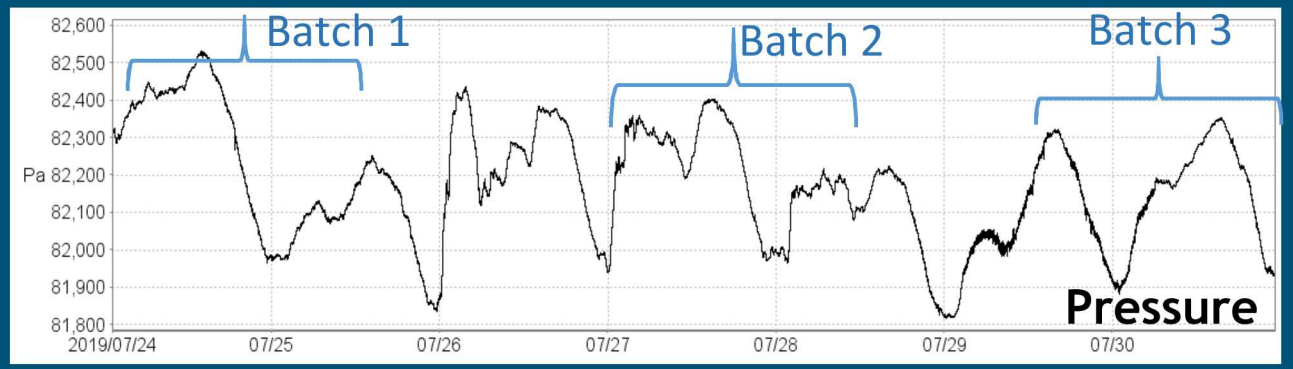


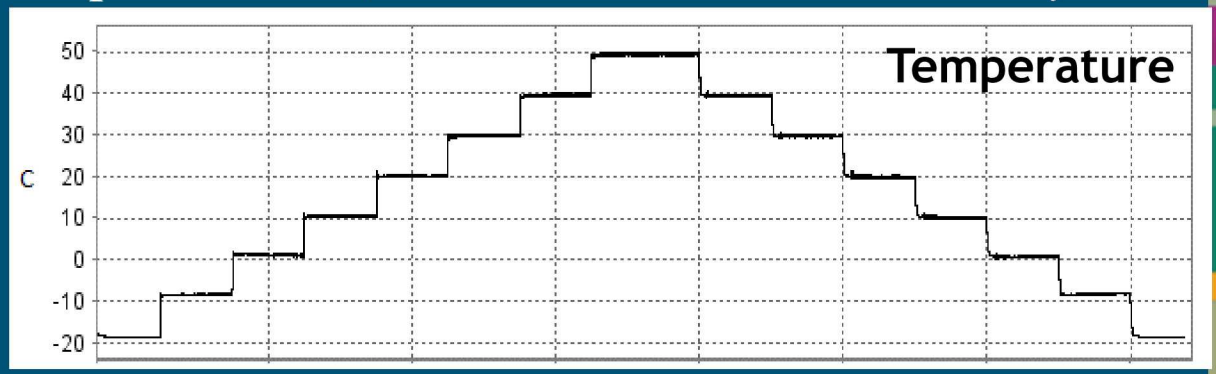
Static Temperature Test Protocol

- Sensors were divided into three batches
  - Limited by the size of the temperature chamber
  - Grouped sensors by model
- For each batch of sensors (36 hours):
  - Calibrated at each temperature step, after stabilizing for 1.5 hrs
  - Start at -20 C
  - Increase temperature in 10 C steps to 50 C
  - Decrease temperature in 10 C steps to -20 C
  - Air temperature rise time: 10 C change in 30 seconds

Batch 1	MB3a 00156 MB3a 00161 MB3a 10 / 0715 MB3a 20 / 0715
Batch 2	Chap64 157L Chap64+ 228S Chap64 158L Chap64+ 229S
Batch 3	MB2005 7137 MB2005 7138 Hyperion 20150305.001 Hyperion 20150305.002

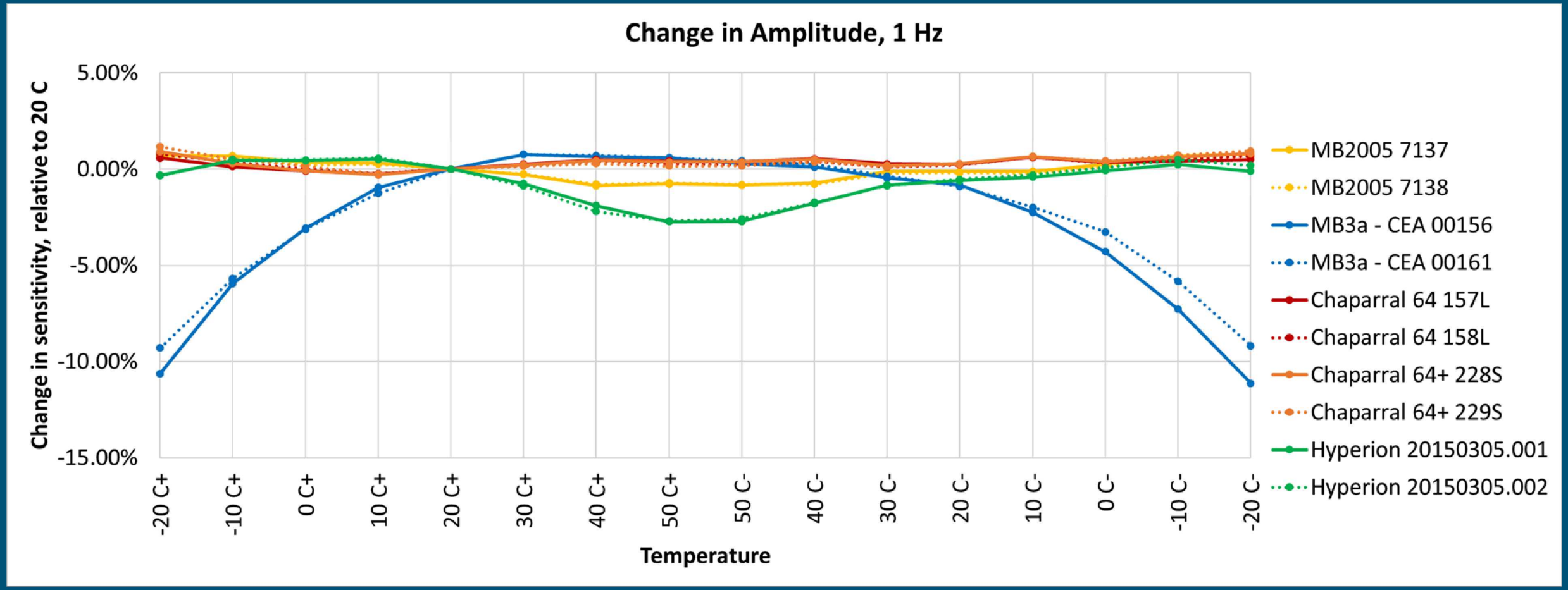
- Ambient pressure, measured within the manifold, was 822 hPa, +/- 4 hPa
  Reference microphone sensitivity not corrected for static pressure: +/- 0.05 % of added uncertainty





Static Temperature Results - Amplitude

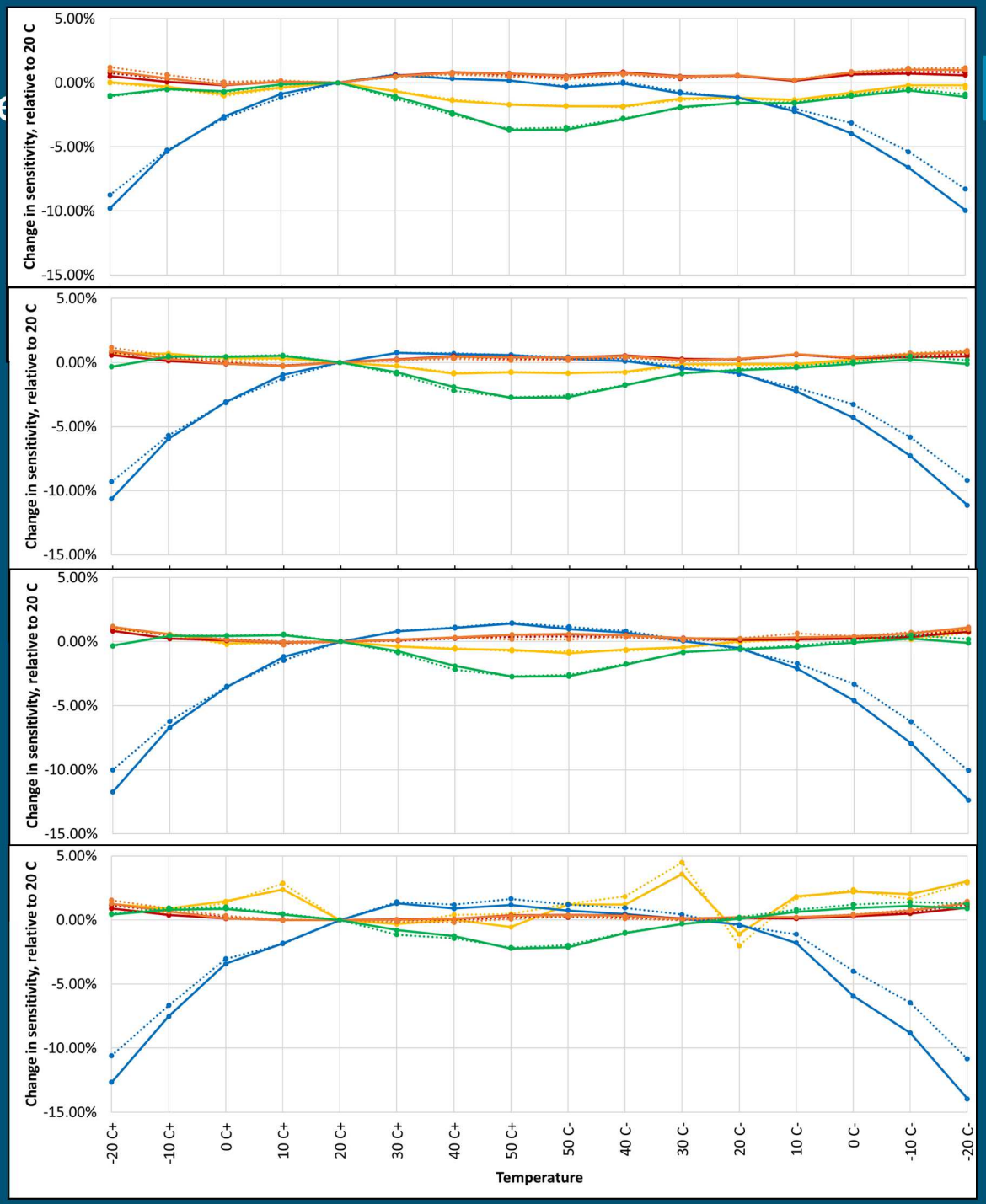
- MB3a's have a decrease in sensitivity at colder temperatures, consistent with results reported by CEA.
- The Hyperion's have a decrease in sensitivity at temperatures above 30 C.
- The remaining MB2005 and Chaparral sensors have minimal change in sensitivity versus temperature.



Static Temperature Results - Amplitude

The results are consistent across the passband.

Note that the increased variability at frequencies above 4 Hz is due to the presence of ambient noise in the environment.



MB2005 7137
MB2005 7138
MB3a - CEA 00156
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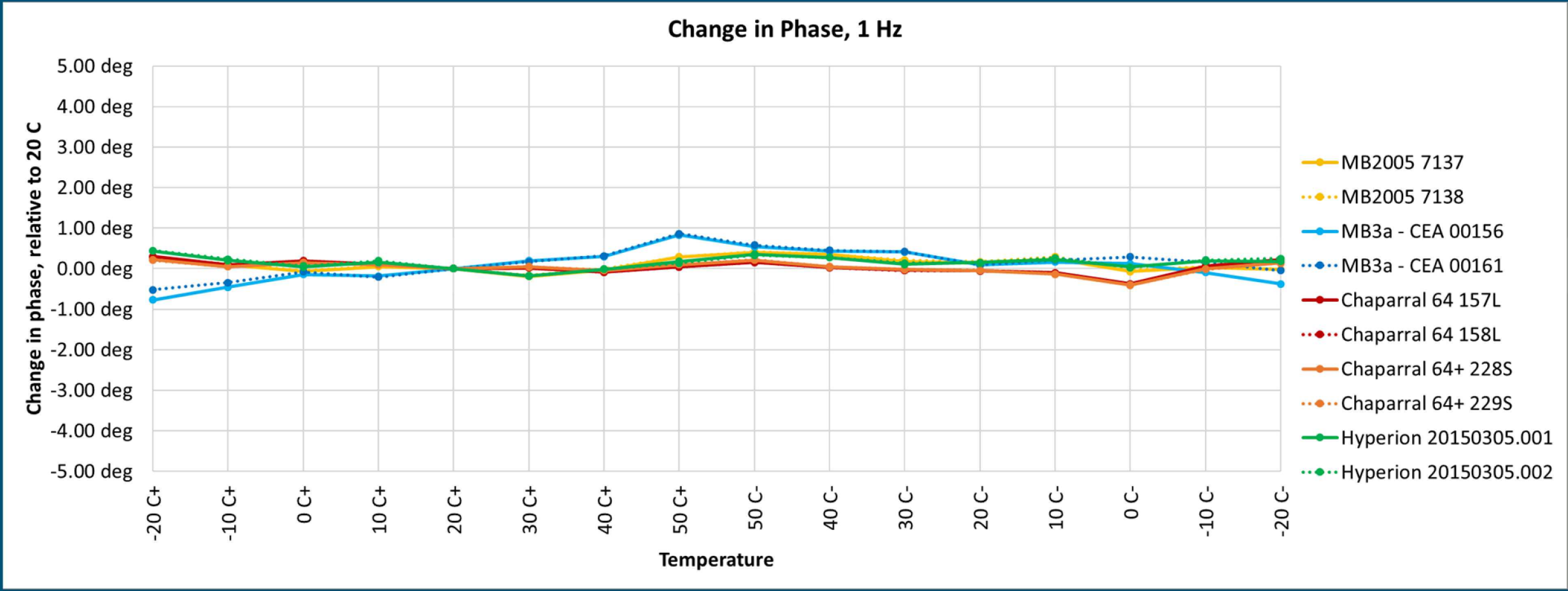
Chaparral M64 157L
Chaparral M64 158L
Chaparral M64+ 228S
Chaparral M64+ 229S
Hyperion 20150305.001
Hyperion 20150305.002

Static Temperature Results - Phase

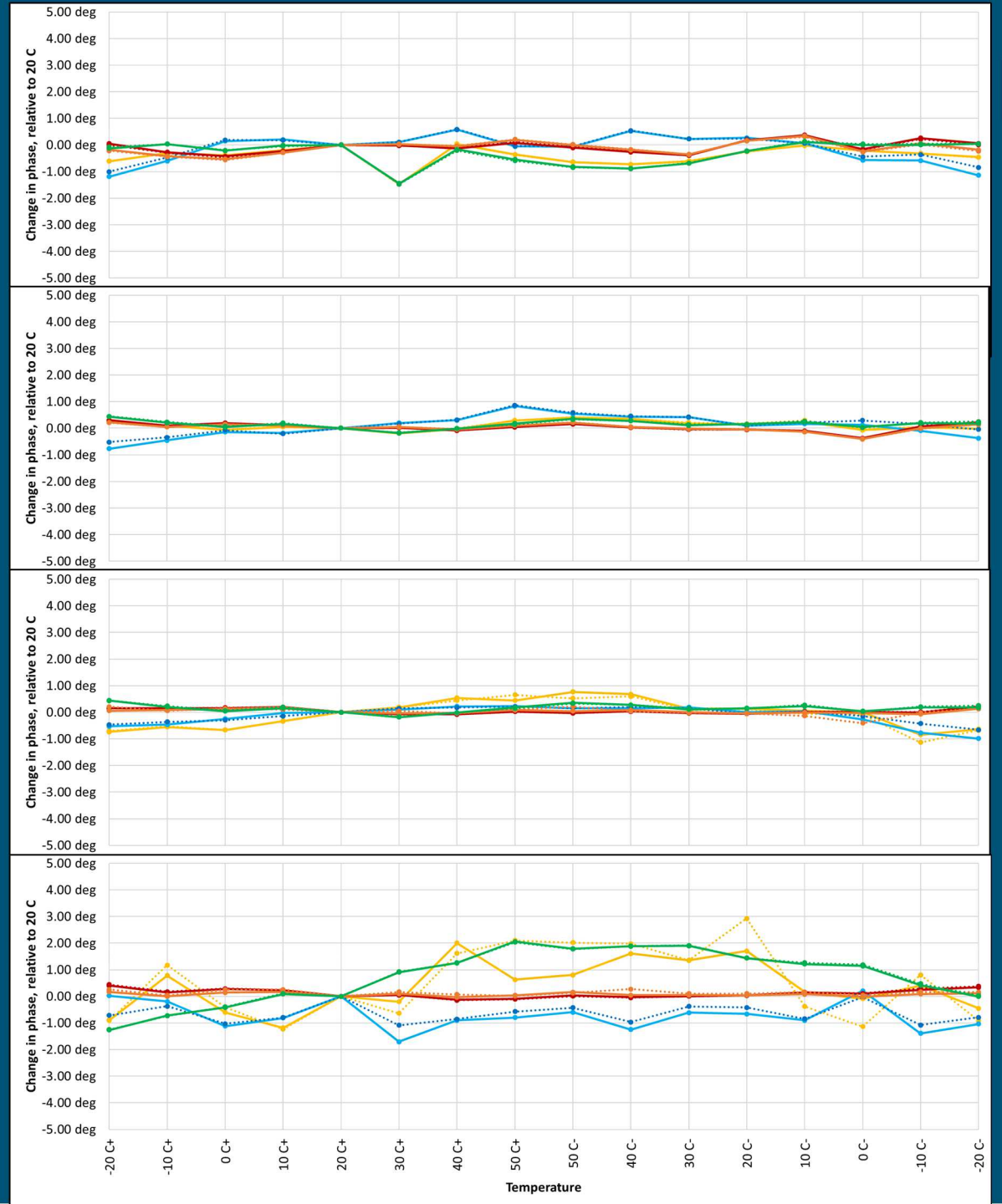
- All of the sensors demonstrated a change in phase at 1 Hz of less than +/- 1 degree.
- Variability is consistent to the batch of testing, indicating that it is likely a contribution of the reference microphone.



Static Temperature Results - Phase

The results are consistent across the passband, with the sensors having small changes in phase.

Note that the increased variability above 4 Hz due to the presence of ambient noise in the environment.



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Chaparral M64 157L
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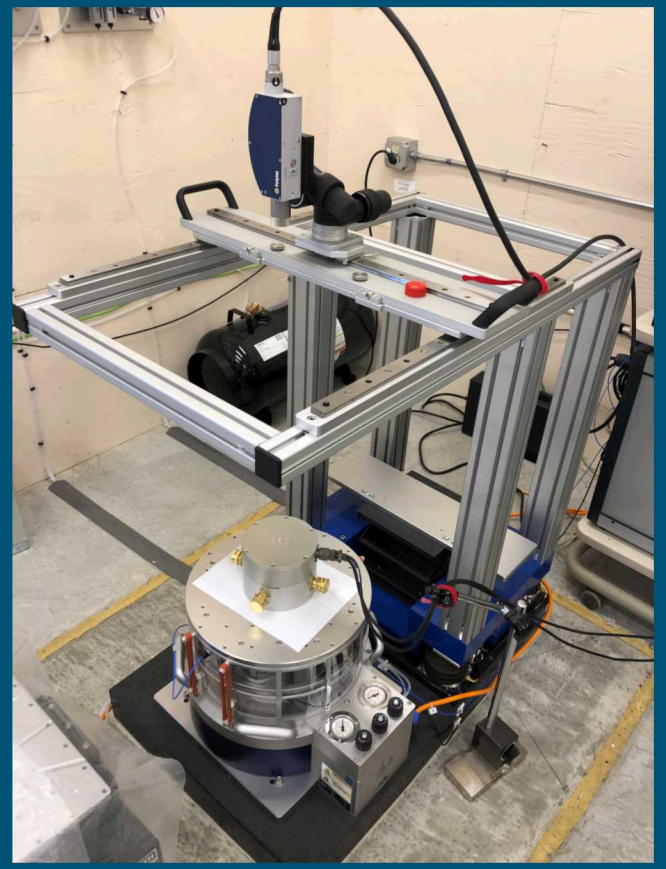
Hyperion 20150305.001
Hyperion 20150305.002

Application to Type Approval

SNL performed Type Approval testing on two models of Hyperion Sensor in August, 2019:

- Hyperion 5313A – identical to 5113A in field study, with lower power consumption
- Hyperion 5119A – mid-level power consumption and automatic solenoid vent for easier deployment

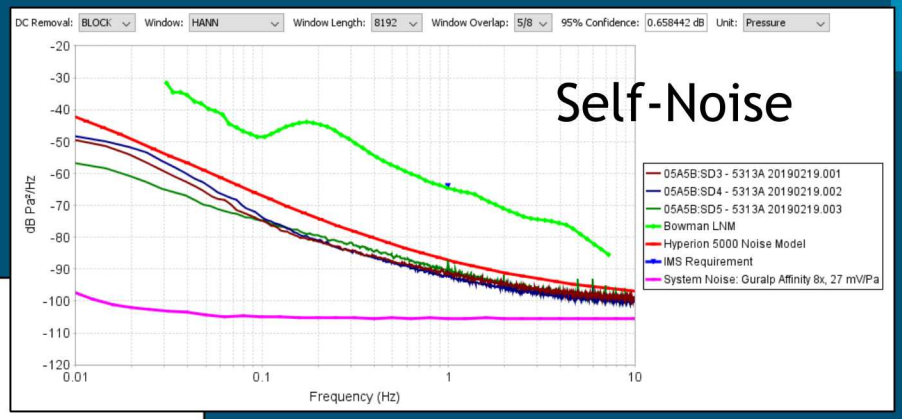
Static Temperature and Pressure tests were performed on these sensors:
Results were consistent with the Long-Term Field Study.

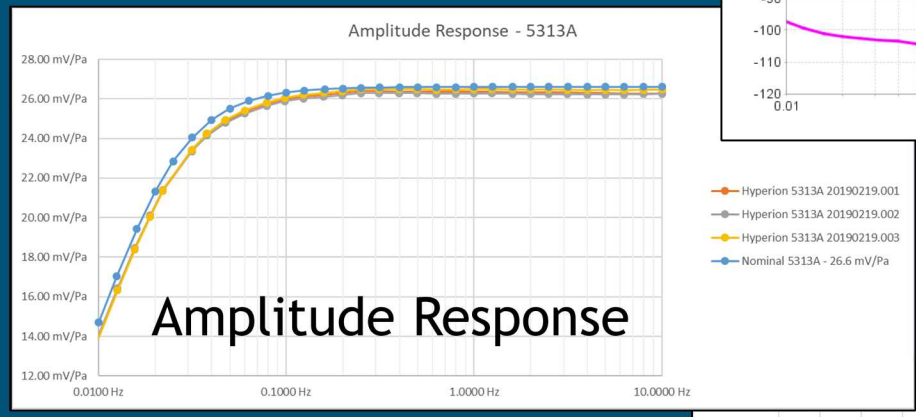


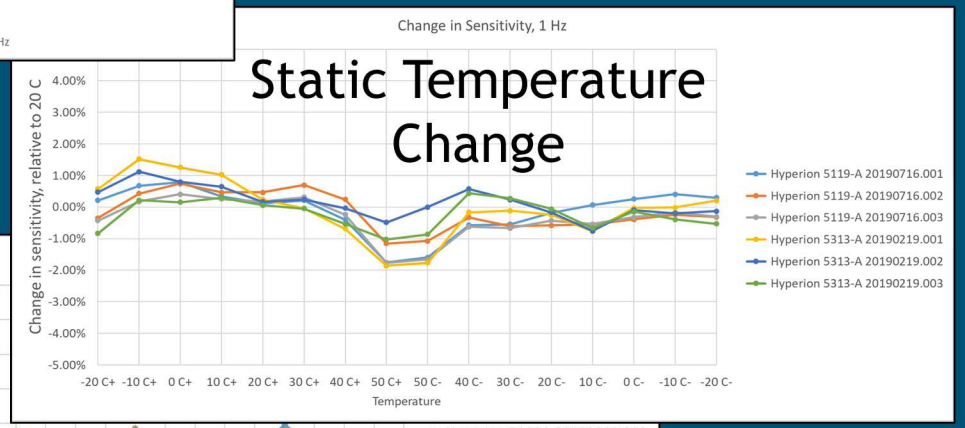
Hyperion Type Approval

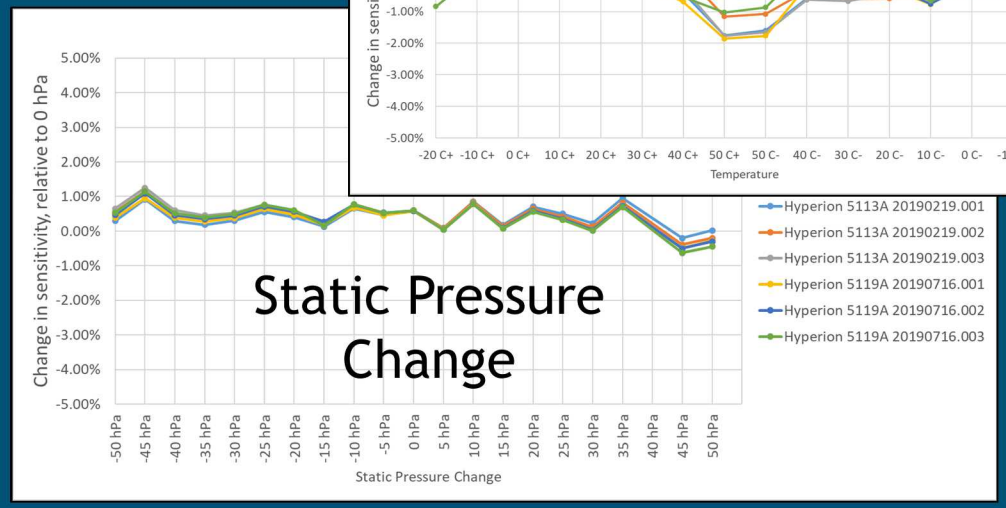
Testing performed using laboratory capabilities:

- Power Consumption
- Sensitivity
- Linearity to Amplitude
- Full Scale
- Self-Noise
- Dynamic Range
- Frequency Response
- Static Temperature Sensitivity
- Static Pressure Sensitivity
- Sensitivity to Vertical Acceleration









Conclusions

- Improved laboratory capabilities are enhancing our understanding of infrasound sensors in ways that we were never able to do before.
- Laboratory calibrations are better able to represent performance seen in the field.
- Sensors were demonstrated to have small changes in amplitude relative to static temperature and pressure.
- There were no significant changes in phase observed, which is important for array processing.

Future Work

- SNL is arranging to return the MB3a sensors that are not functioning properly to CEA for diagnosis.
- SNL and CEA are collaborating on a future field-study comparing infrasound sensor performance
  - Improved environmental diagnostics (i.e. temperature sensors inside sensor cavities)
  - Direct comparison of results at independent testing laboratories.