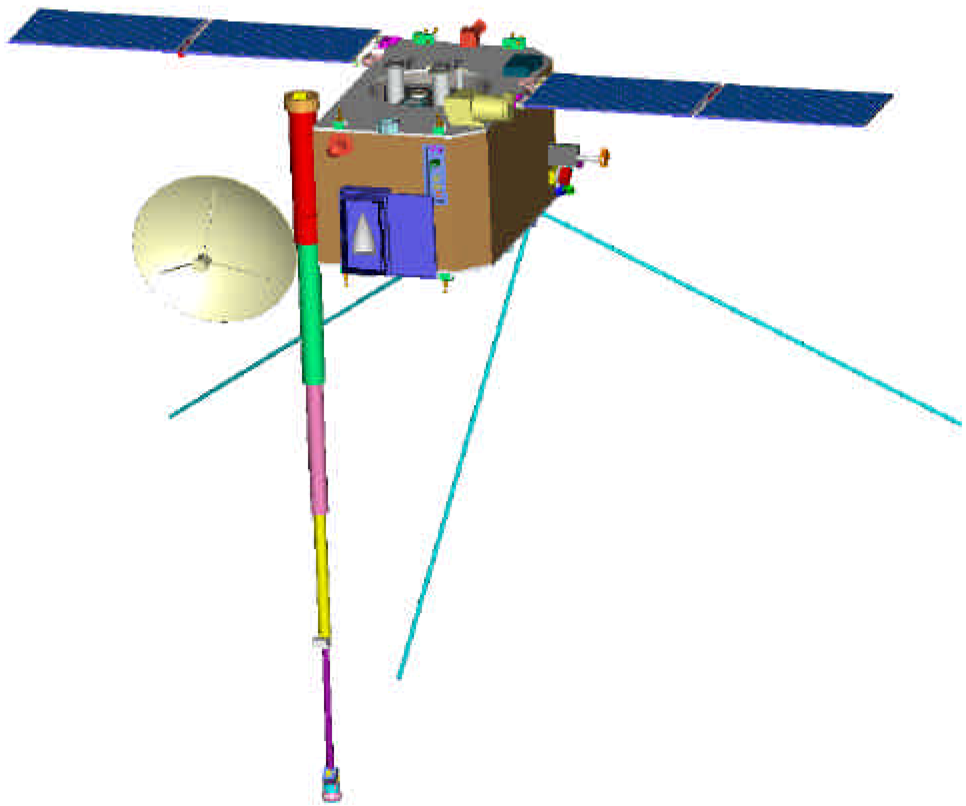
# IMPACT Protoflight Boom Test Results Meeting



# Agenda

| | |
|---|---|
| **9:00 – 9:30** | **Vibration Testing** |
| **9:30 – 10:00** | **Post Vibration Deployment** |
| **10:00 – 10:30** | **Instrument Shock Level and "Pogo Shock" Test** |
| **10:30 – 11:00** | **Thermal Vacuum Test** |
| **11:00 – 11:30** | **Force Margin test** |
| **11:30** | **Lunch, take the afternoon off** |

## Vibration Testing

- **Force limited Vibration Testing**
  - **Location: Performed at Wyle Labs, El Segundo**
  - **Dates: July 21 – 23, 2003**
  - **In Attendance: Paul Turin, Dave Pankow, and Jeremy McCauley**

- **All vibration runs were completed. X, Z, and Y-axis.**
  - **Pre Sine Strength 0.1g Sine Signature**
  - **Sine Strength Test**
  - **Post Sine Strength 0.1g Sine Signature**
  - **-18dB Random with out and then with force limiting**
  - **0dB Random with force limiting**
  - **Post Random 0.1g Sine Signature**

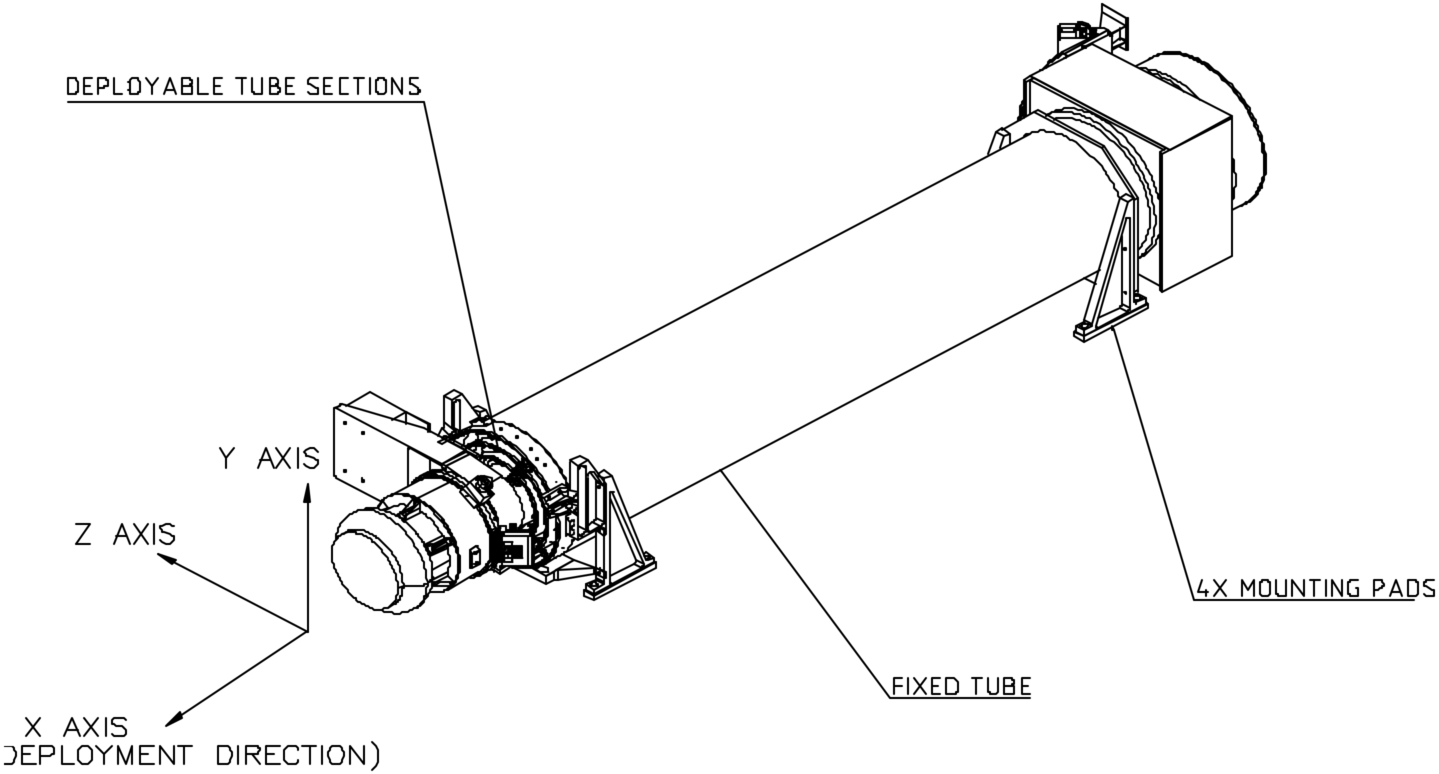
# Vibration Testing

- **No degradation to the boom mechanically, structurally, or functionally.**
  - **Mag Mount slippage in Y-axis sine strength test did not significantly reduce preload or produce loss of function. Slippage was limited as evidenced by post random sine sweep.**
  - **Loose set screw found in Bobbin Housing was from a part only used in stowing. Screw will be staked down for flight.**
  - **Boom deployed fully post-vibration on July 31, 2003. Inspection showed no mechanical or structural degradation to the tubes and assemblies.**
  - **Levels at the STE-U instrument were unacceptably high (18.8grms) due to inadequate stiffness in isolating legs. These have been redesigned.**

- **No further vibration testing is required.**
  - **STE-U vibration levels will be determined by vibration of the instruments on the flight booms after the instrument mounting feet are redesigned.**

## Vibration Testing

- **X-, Z-, and Y-axis Definition**



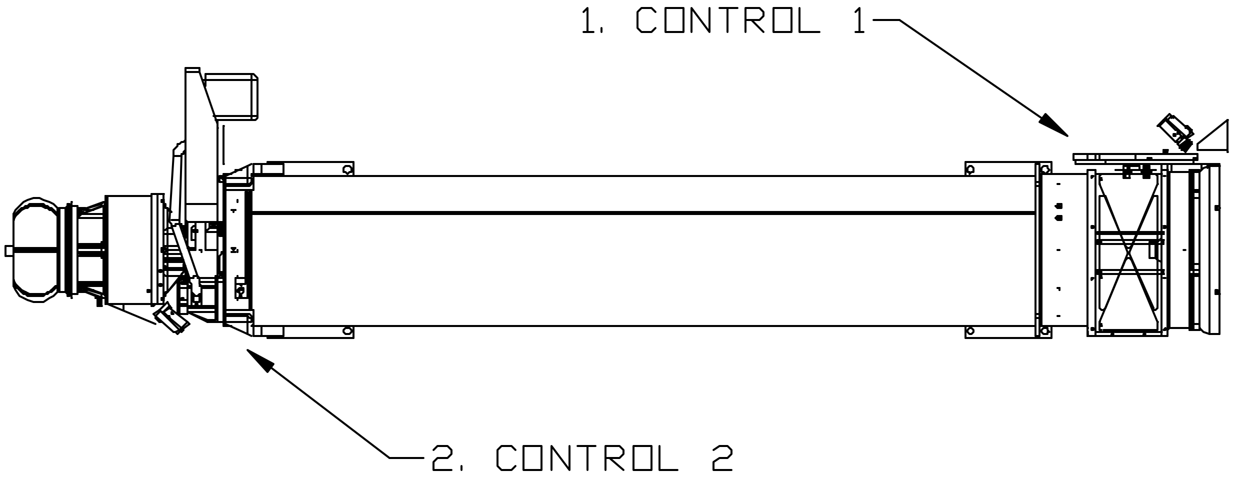
## Vibration Testing

- **Fundamental Frequencies**
  - **The first three fundamental frequencies of the modeled Boom were 60.2, 81.8 and 83.4 Hz.**
  - **Though these are lower than what was found, the estimates were predicted to be low as they lack the restraining action of the lock pin springs.**

| Excitation Axis | Frequency (Hz) |
|---|---|
| X | 114 |
| Y | 92 |
| Z | 75 |

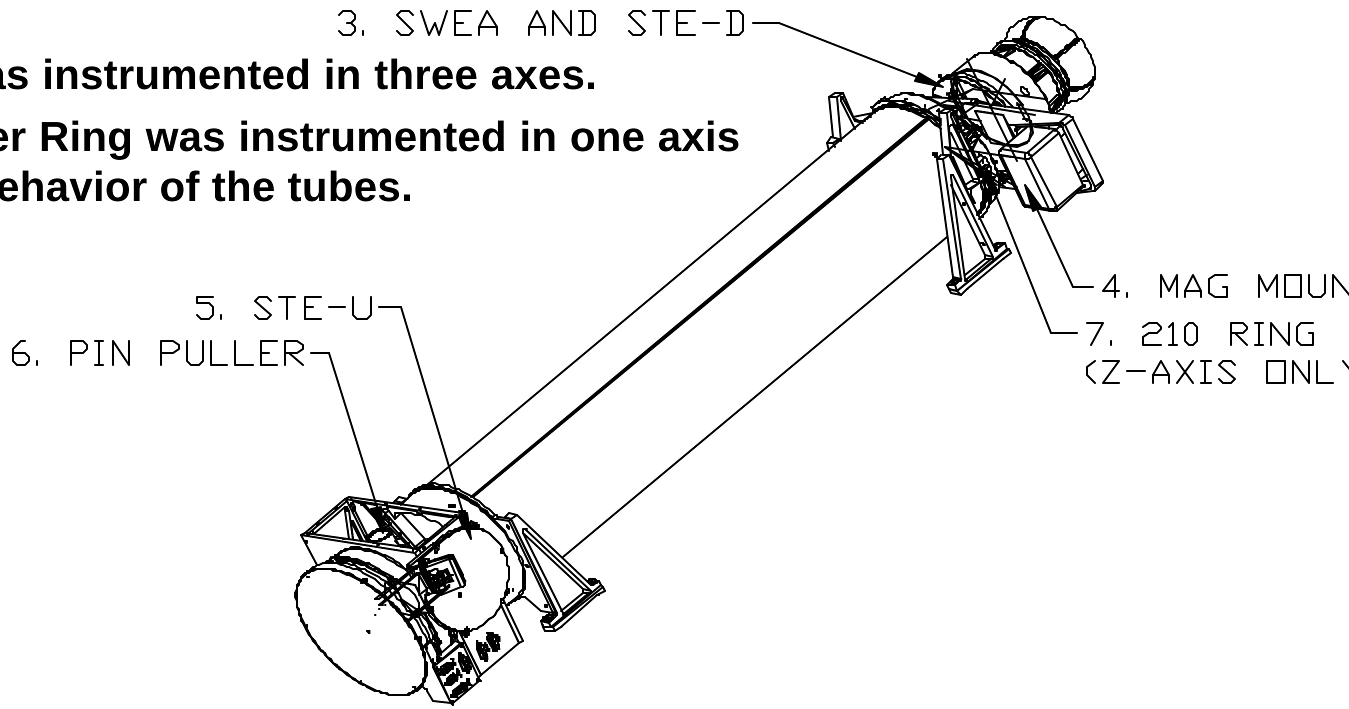
# Vibration Testing

- **Control Accelerometer Placement**
  - **Control accelerometers were placed on the baseplate adjacent to the mounting feet at opposing corners of the Boom.**



# Vibration Testing

- **Accelerometer Placement**
  - **The Boom was instrumented to show the levels of excitation at each of the locations an instrument was attached. Envelopes were later derived from this information.**
  - **The Pinpuller was instrumented in three axes.**
  - **The 210mm Outer Ring was instrumented in one axis to observe the behavior of the tubes.**



# STEREO IMPACT

## Vibration Testing

**Z AXIS .1G**

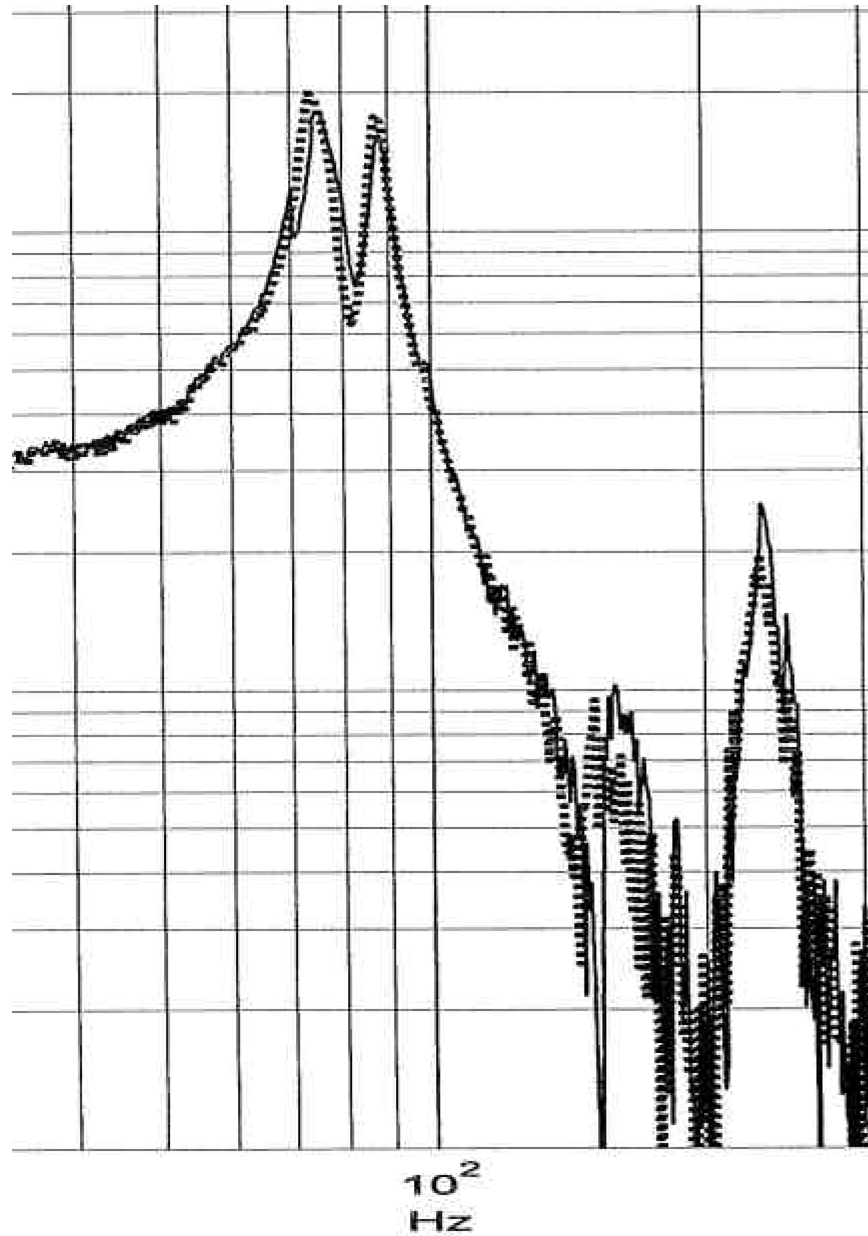
**PRE AND POST**

**SINE OVERLAY**

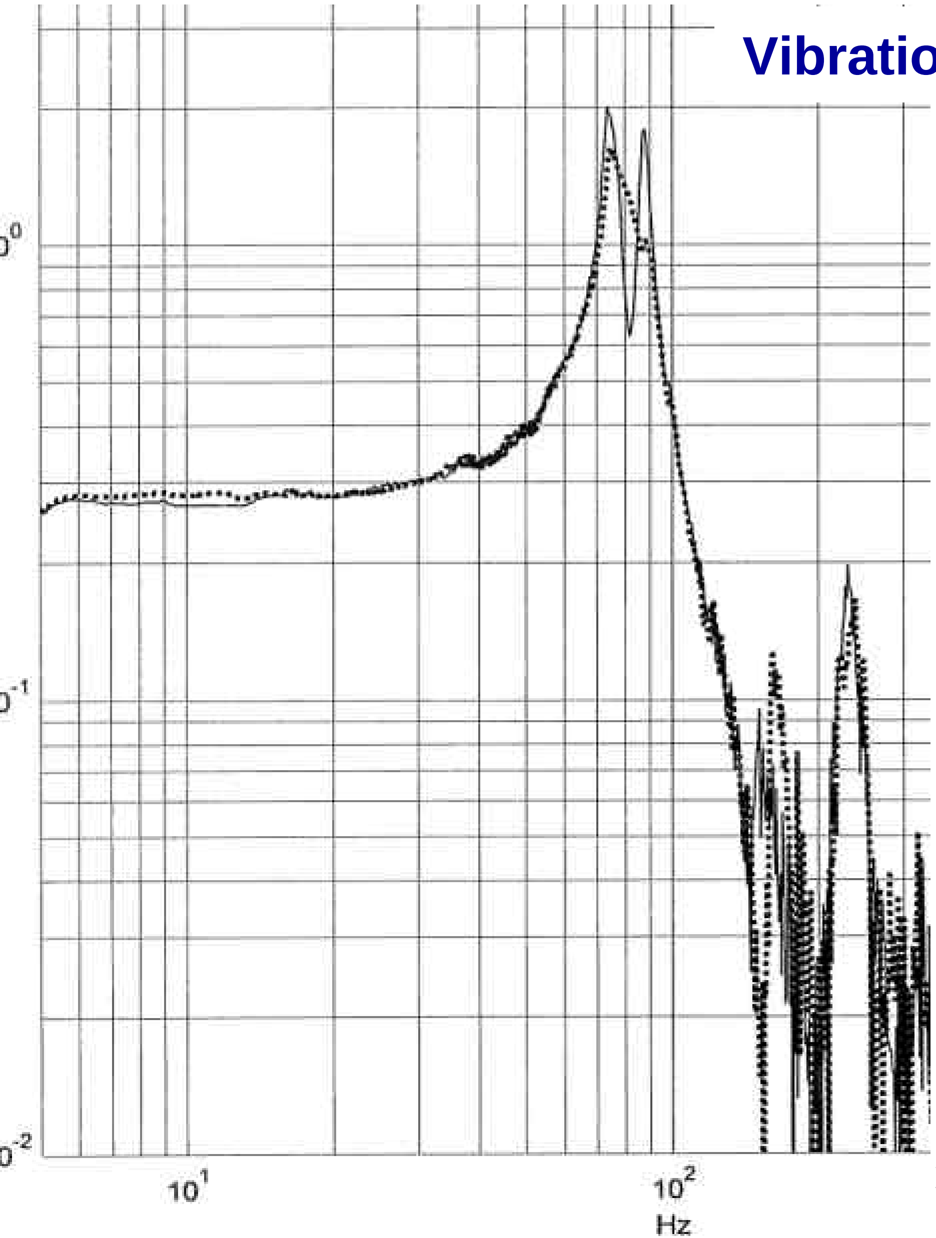
**SUM LOAD CELL**

**NOTE: Apparent shift in frequency of peaks.**

- **The combs which locate the Magnetometer Mount and tubes appear to have slipped in their positions.**
- **The combs will be pinned in place on future Booms.**



# STEREO IMPACT




## Vibration Testing

**Z AXIS .1G**

**POST SINE AND**

**POST RANDOM**

**OVERLAY**

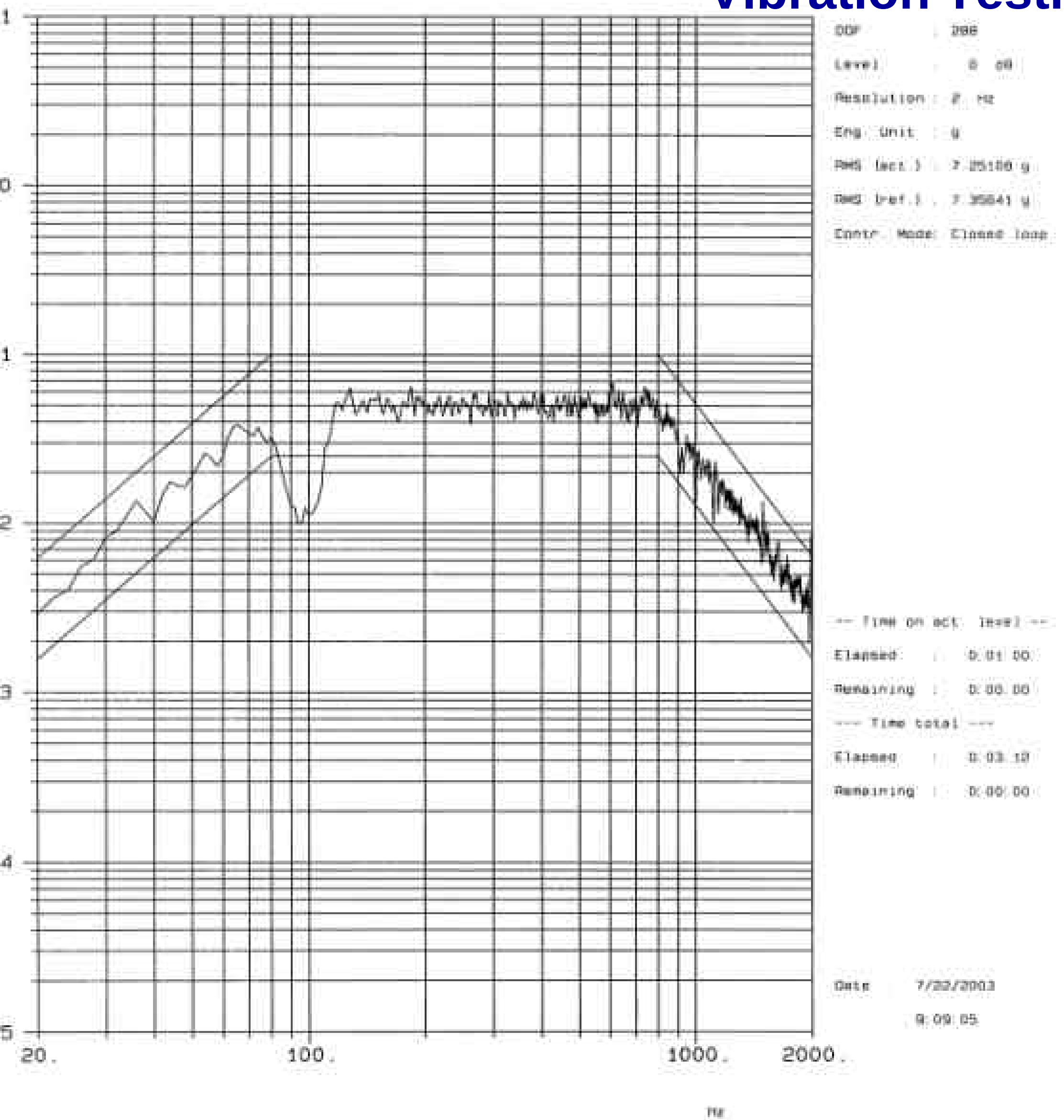
**SUM LOAD CELL**

**NOTE: Frequencies are consistent though some amplitudes change.**

- **Further slippage was limited by the end of travel of the screws within their holes.**
- **Lack of continued frequency shift indicates the parts settled against a physical stop point.**

# STEREO IMPACT

## Vibration Testing



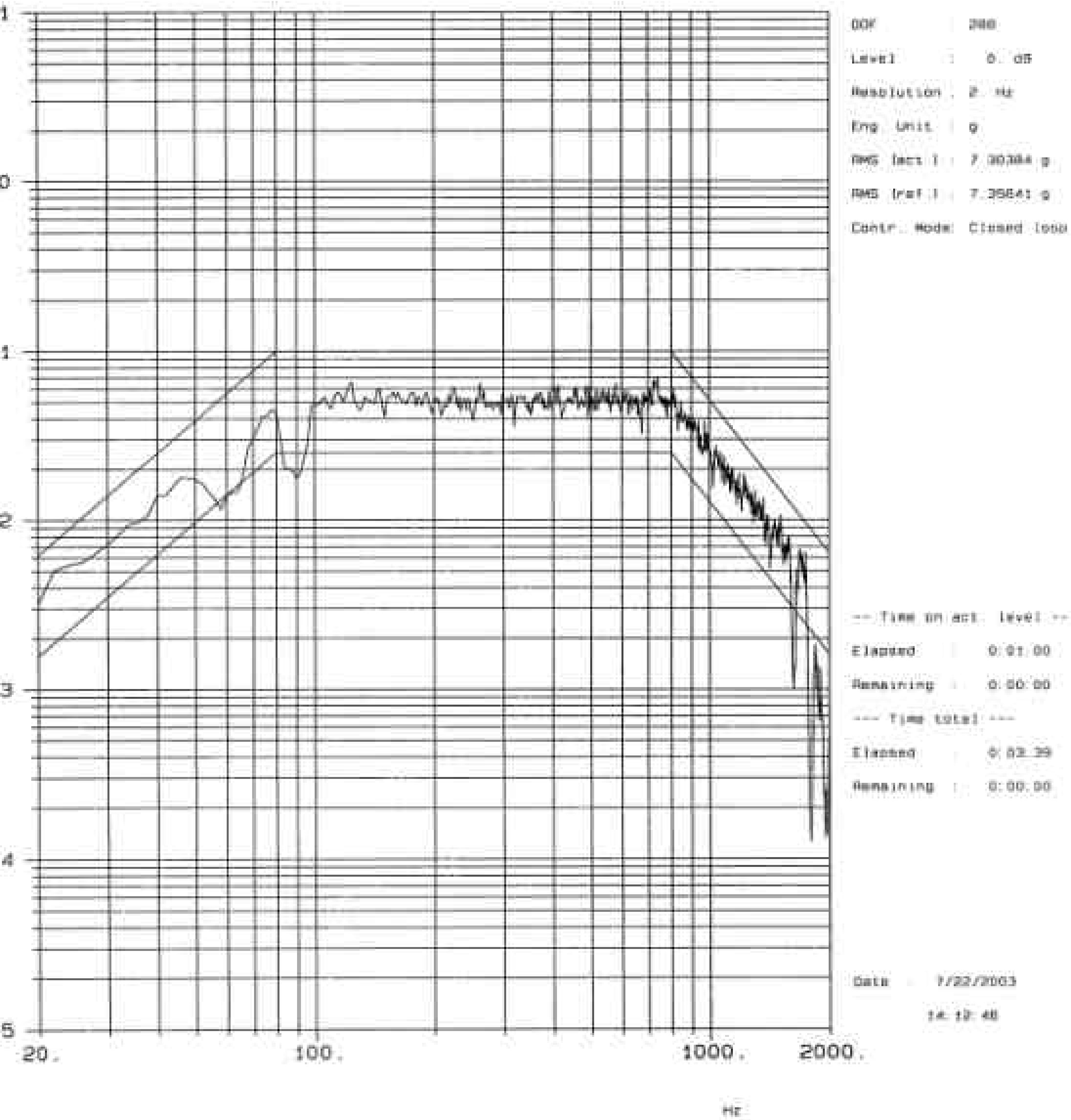

**X AXIS 0dB RANDOM #2**

**AVG. OF C1&C2**

**FORCE LIMITED INPUT**


Turin/Ullrich/McCauley

## Vibration Testing

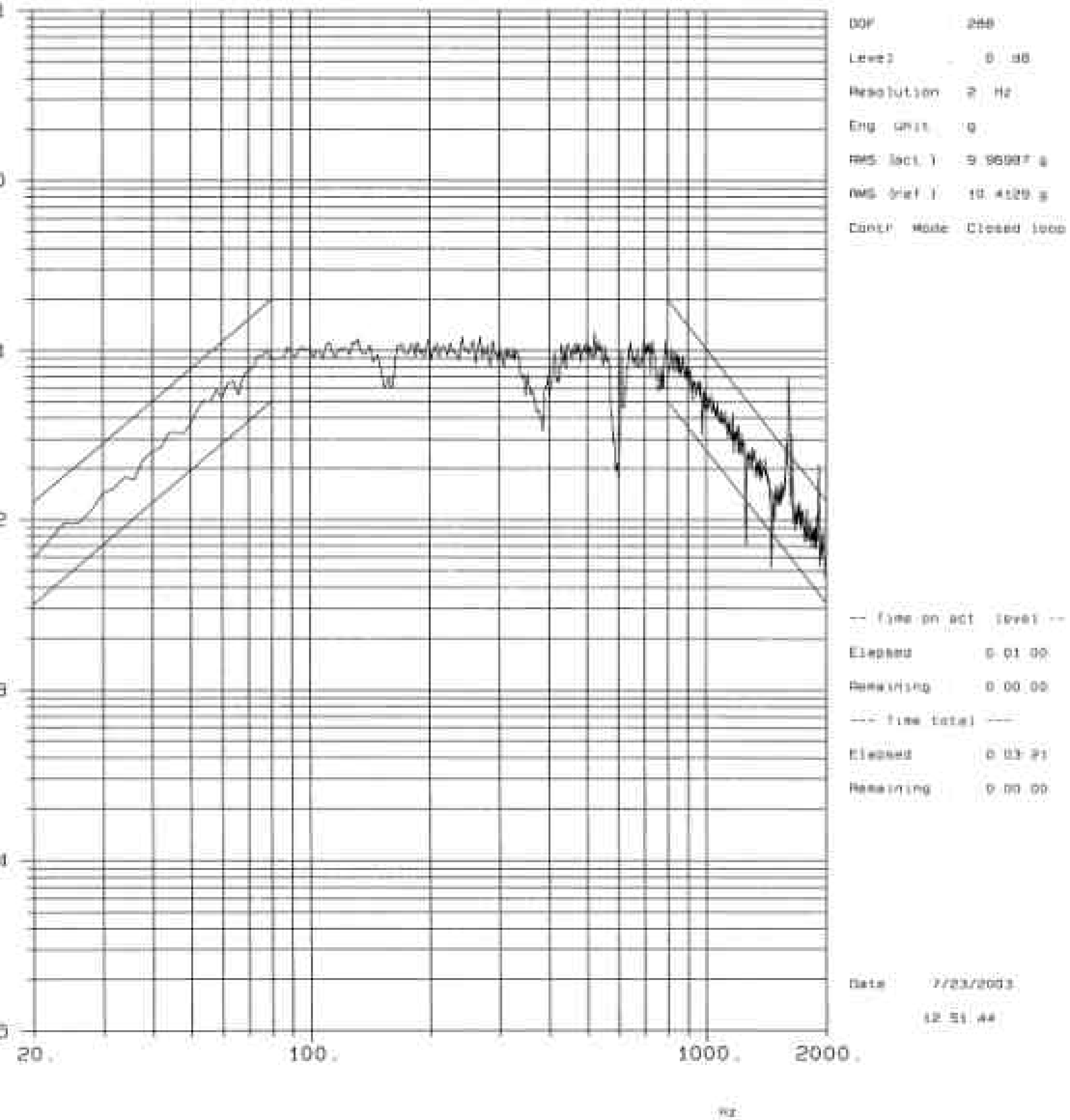



**Z AXIS 0dB RANDOM**

**AVG. OF C1&C2**

**FORCE LIMITED INPUT**

## Vibration Testing



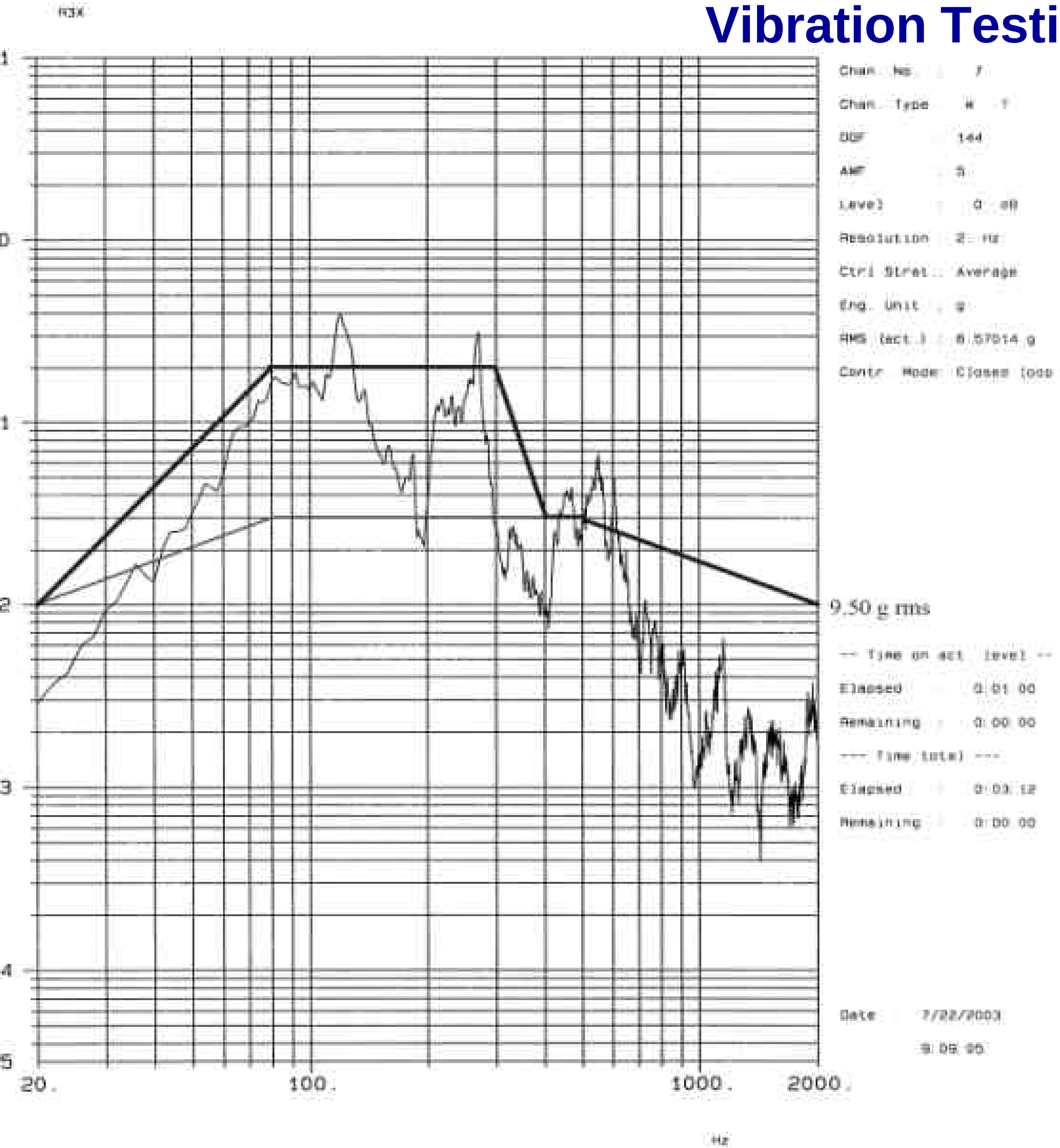

**Y AXIS 0dB RANDOM**

**AVG. OF C1&C2**

**FORCE LIMITED INPUT**

# *STEREO IMPACT*

## Vibration Testing




**X AXIS 0dB RANDOM**

**R3X**

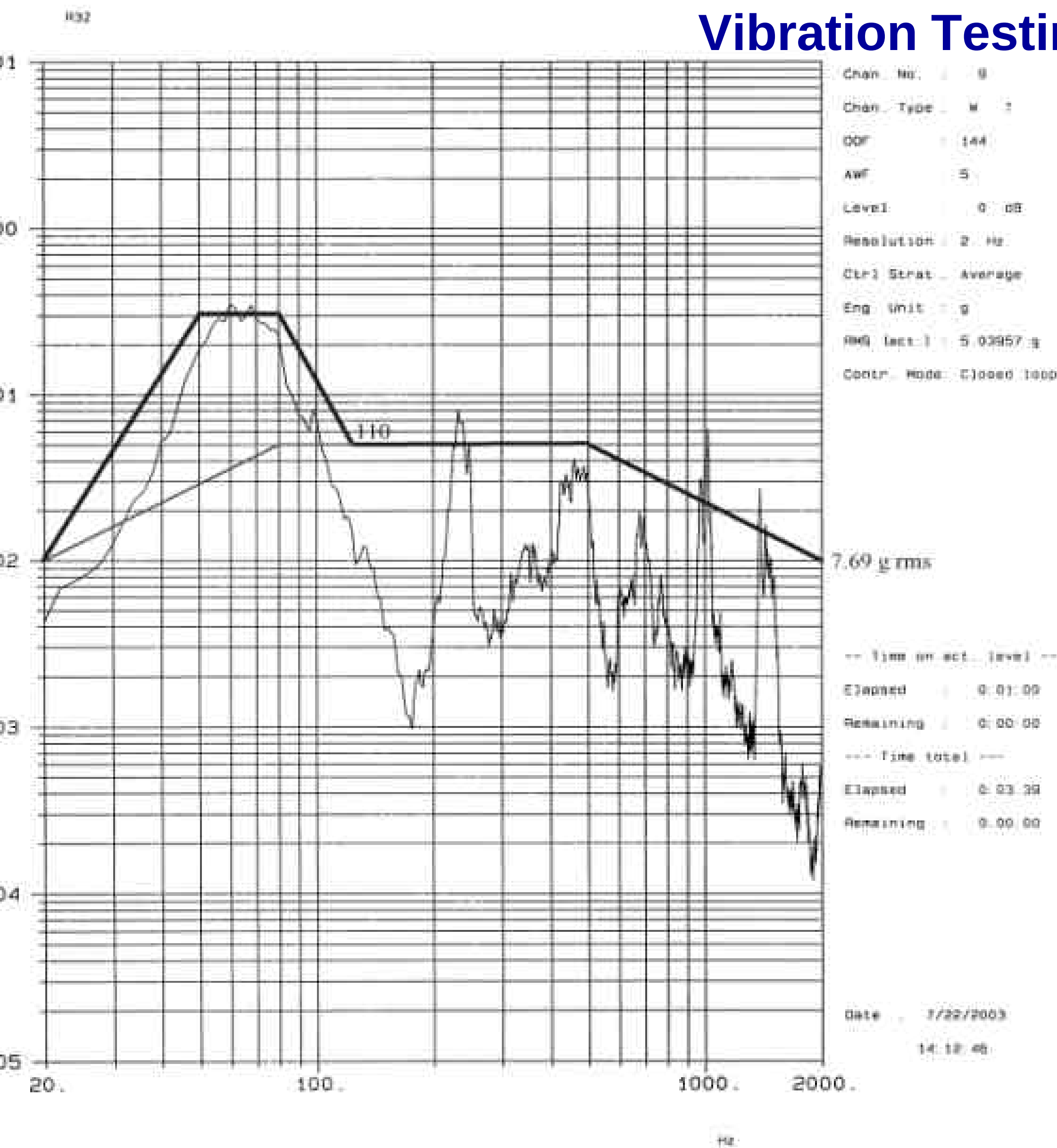
**SWEA and STE-D X-axis and Envelope for instrument vibration**

**Envelope: 9.50 g rms**

- **Created from The FEMCI Book - Creating a Random Vibration Component Test Specification**

Turin/Ullrich/McCauley

## Vibration Testing




**Z AXIS 0dB RANDOM**

**R3Z**

**SWEA and STE-D Z-axis and Envelope for instrument vibration**

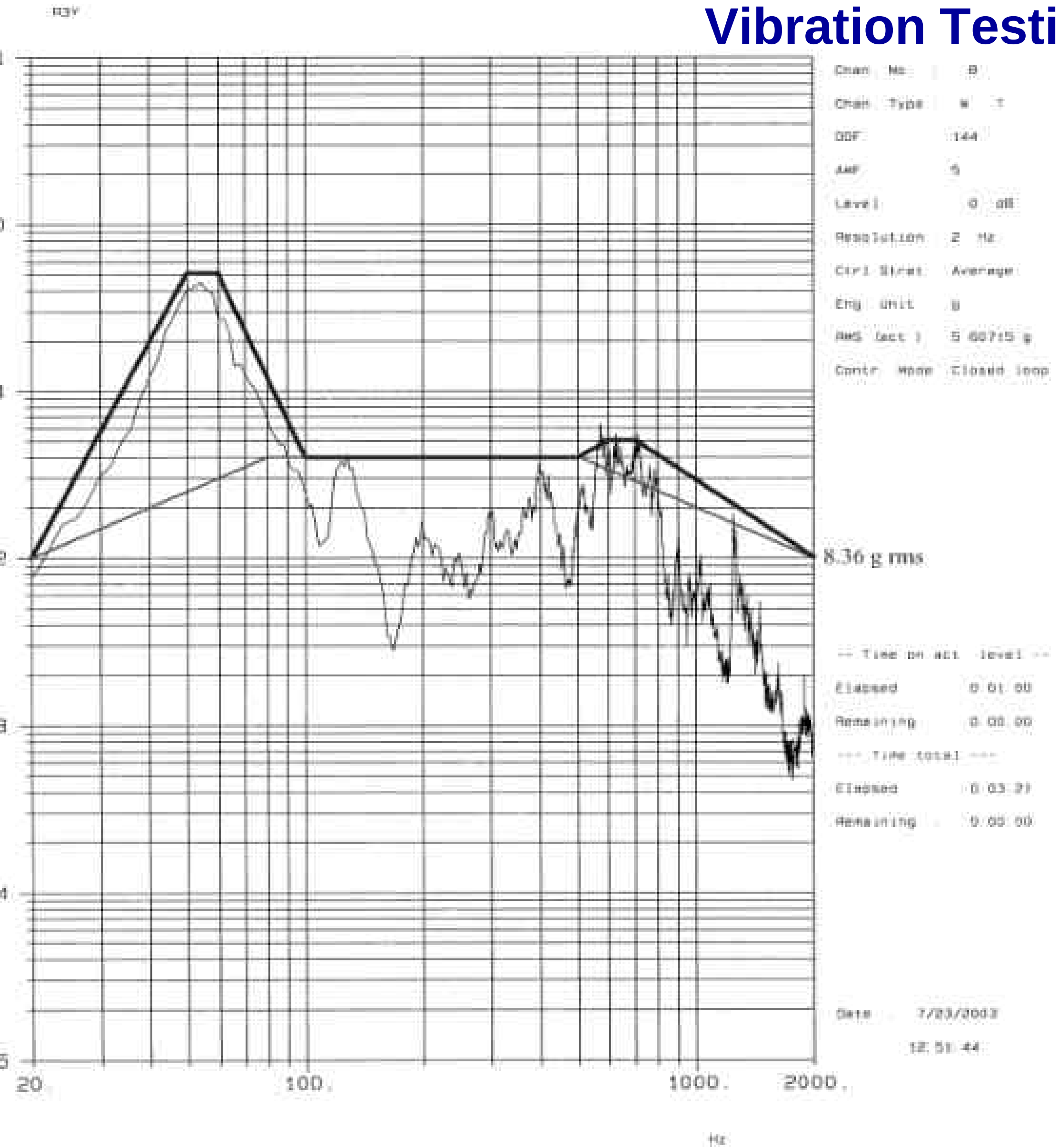
**Envelope: 7.69 g rms**

- **Created from The FEMCI Book - Creating a Random Vibration Component Test Specification**

# STEREO IMPACT



## Vibration Testing




**Y AXIS 0dB RANDOM**

**R3Y**

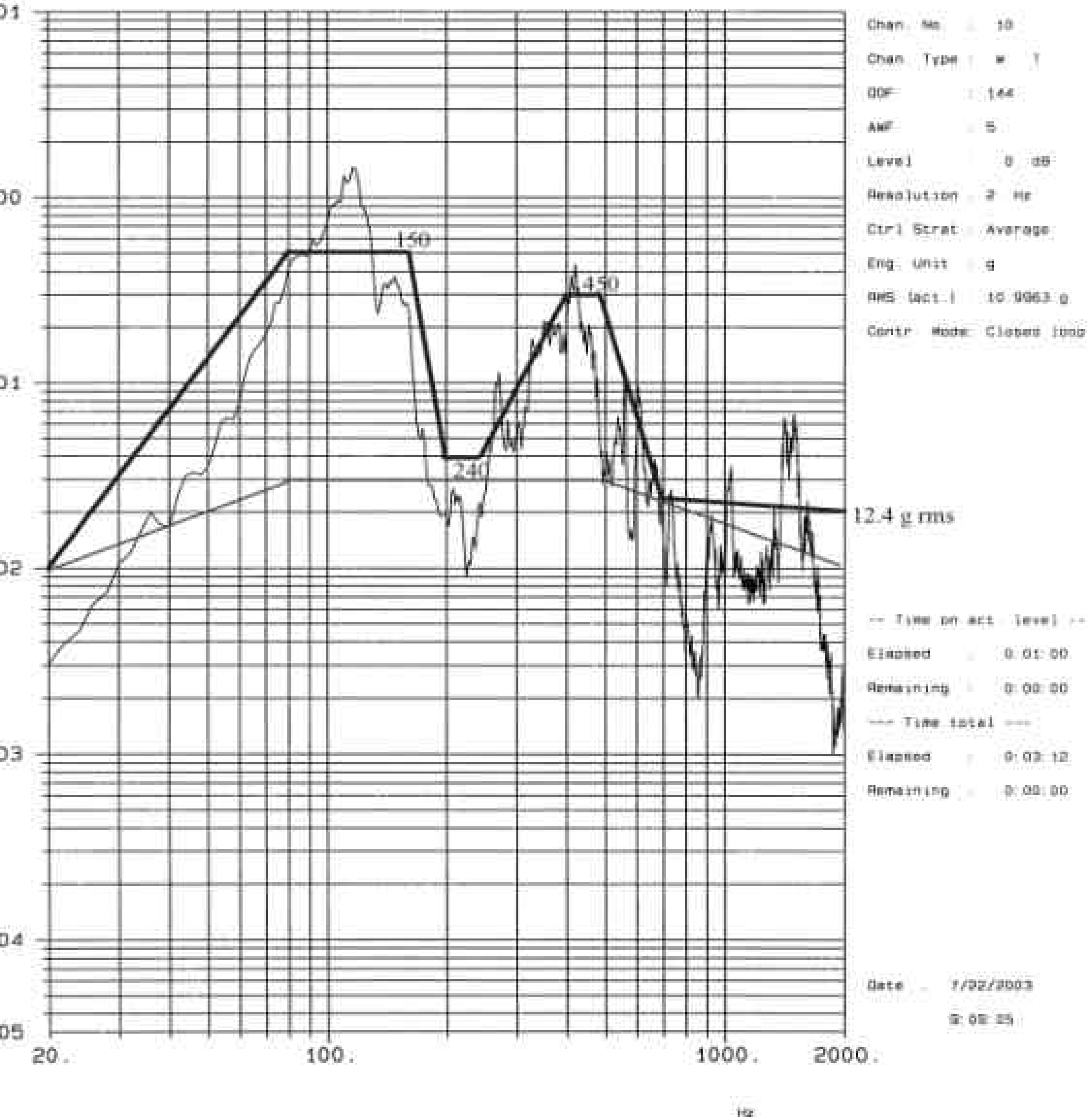
**SWEA and STE-D Y-axis and Envelope for instrument vibration**

**Envelope: 8.36 g rms**

- **Created from The FEMCI Book - Creating a Random Vibration Component Test Specification**

Turin/Ullrich/McCauley

## Vibration Testing




**X AXIS 0dB RANDOM**

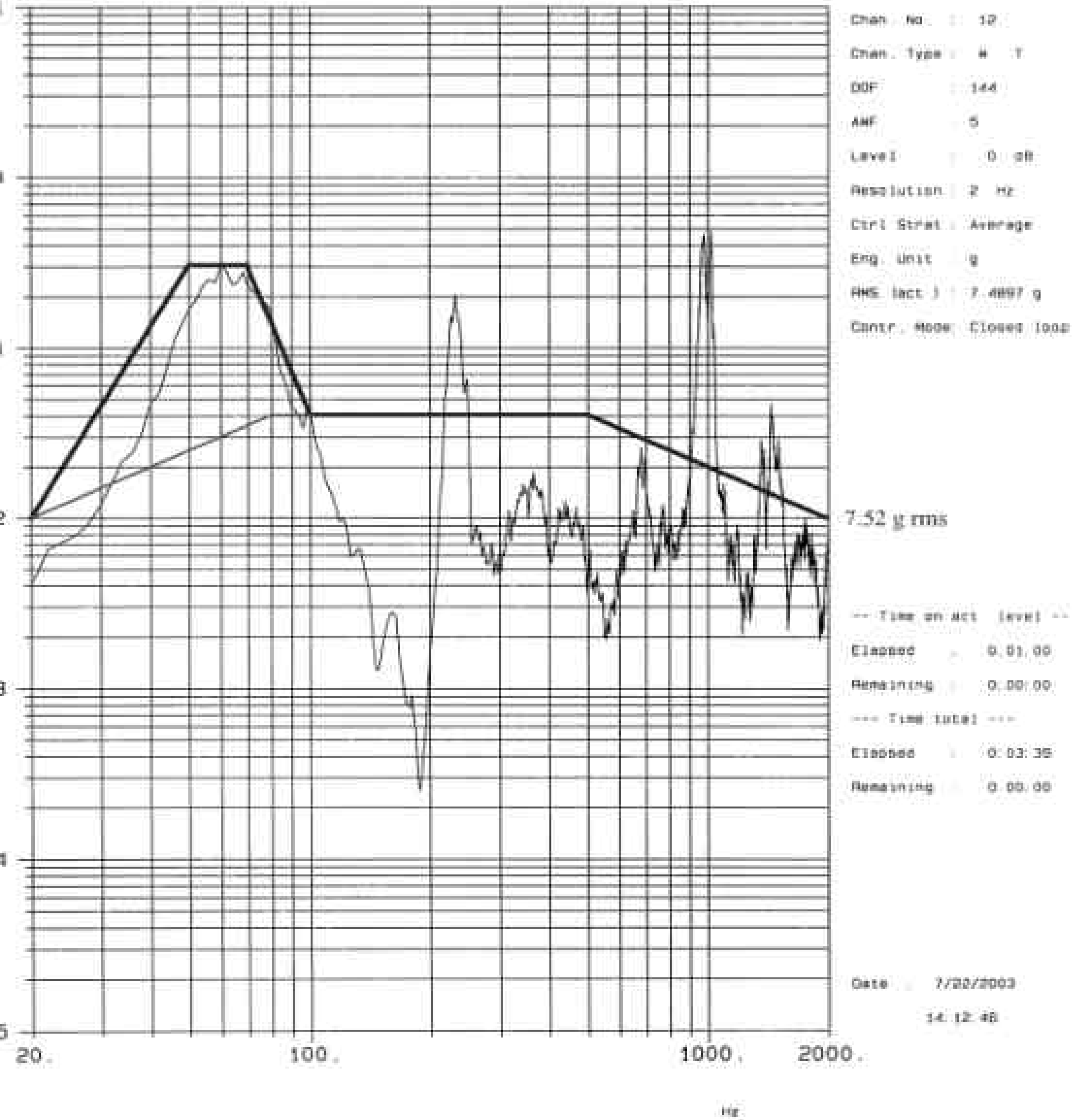
**R4X**

**Magnetometer X-axis and Envelope for instrument vibration**

**Envelope: 12.4 g rms**

- **Created from The FEMCI Book - Creating a Random Vibration Component Test Specification**

# Vibration Testing




**Z AXIS 0dB RANDOM**

**R4Z**

**Magnetometer Z-axis and**

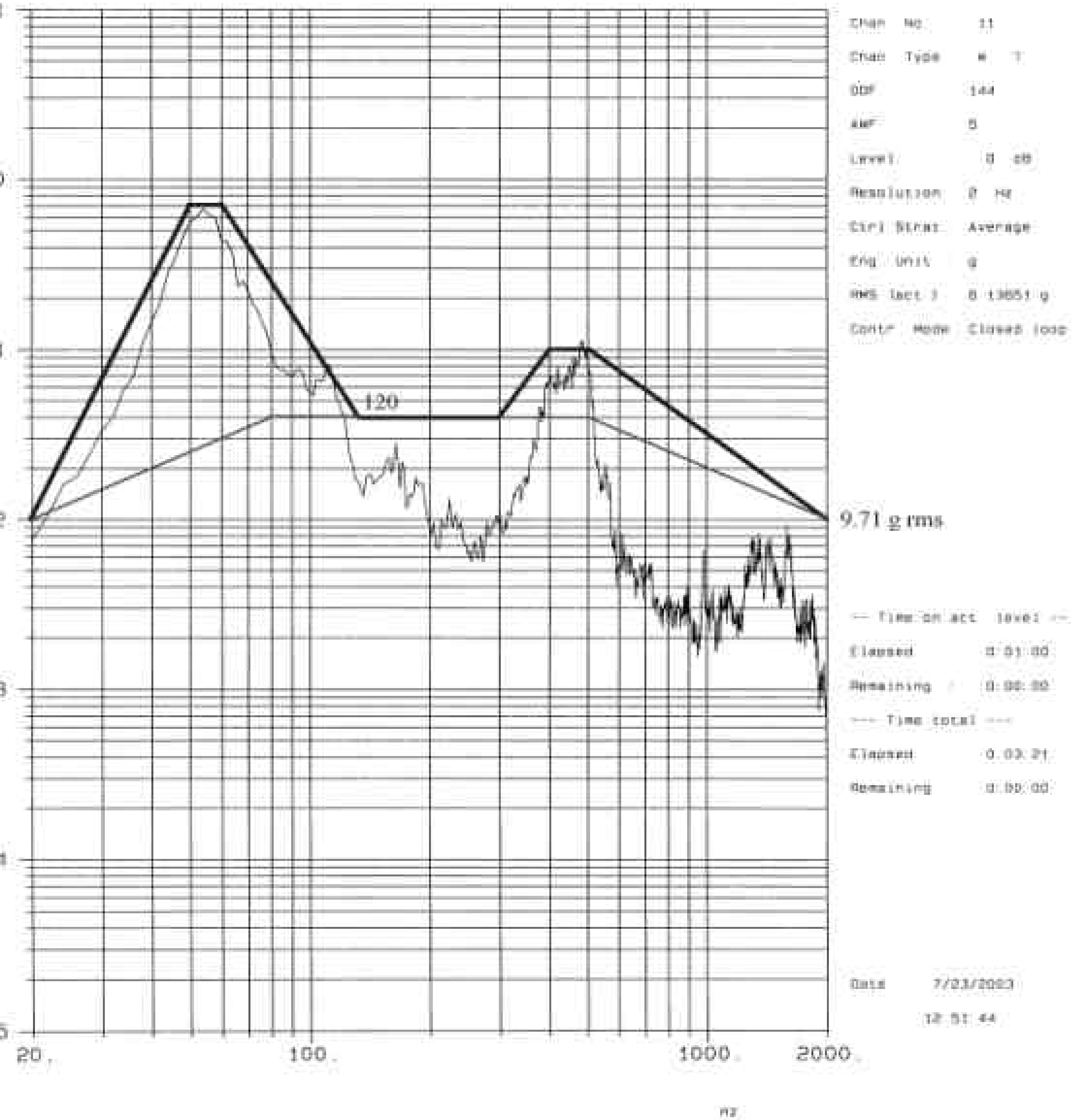
**Envelope for instrument vibration**

**Envelope: 7.52 g rms**

- **Created from The FEMCI Book - Creating a Random Vibration Component Test Specification**

# STEREO IMPACT

## Vibration Testing




**Y AXIS 0dB RANDOM**

**R4Y**

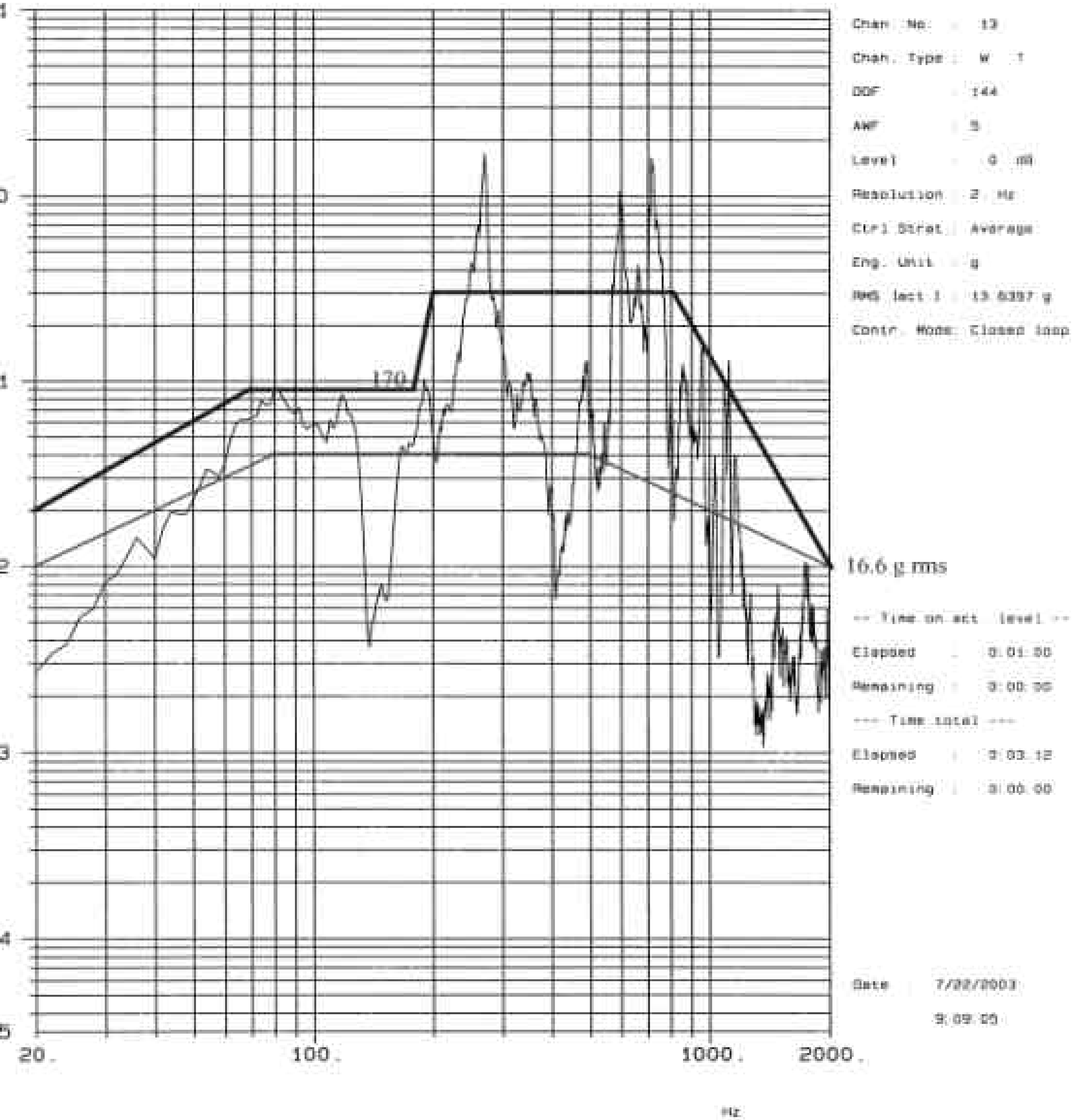
**Magnetometer Y-axis and**

**Envelope for instrument vibration**

**Envelope: 9.71 g rms**

- **Created from The FEMCI Book - Creating a Random Vibration Component Test Specification**

## Vibration Testing




**X AXIS 0dB RANDOM**

**R5X**

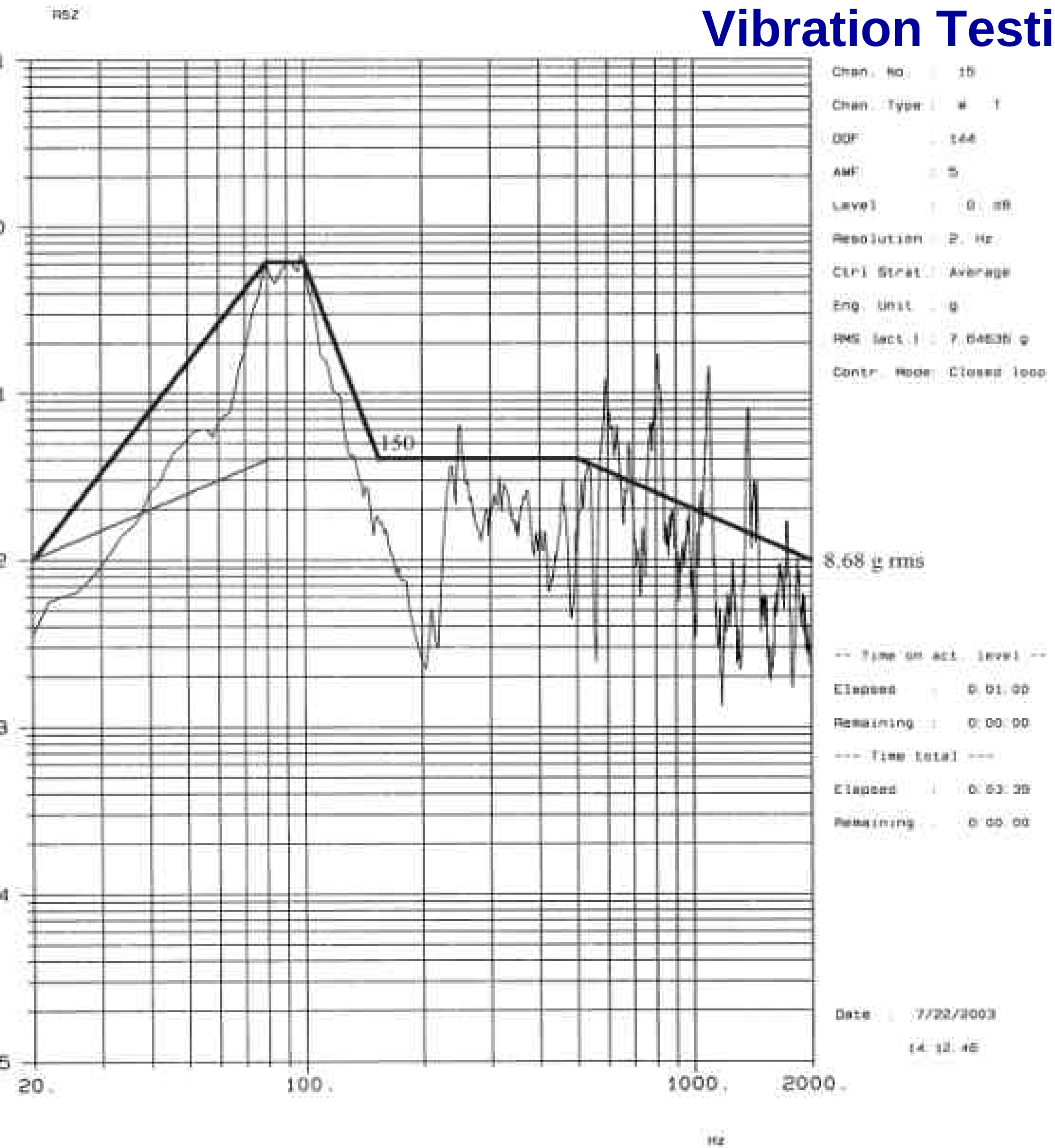
**STE-U X-axis and**

**Envelope for instrument vibration**

**Envelope: 16.6 g rms**

- **Created from The FEMCI Book – Creating a Random Vibration Component Test Specification**
- **This value is unreasonably high and will be lowered by redesigning the mounting feet for the STE-U. Change is possible due to new thermal constraints.**
- **STE-U instruments will be tested on flight Booms.**

## Vibration Testing




**Z AXIS 0dB RANDOM**

**R5Z**

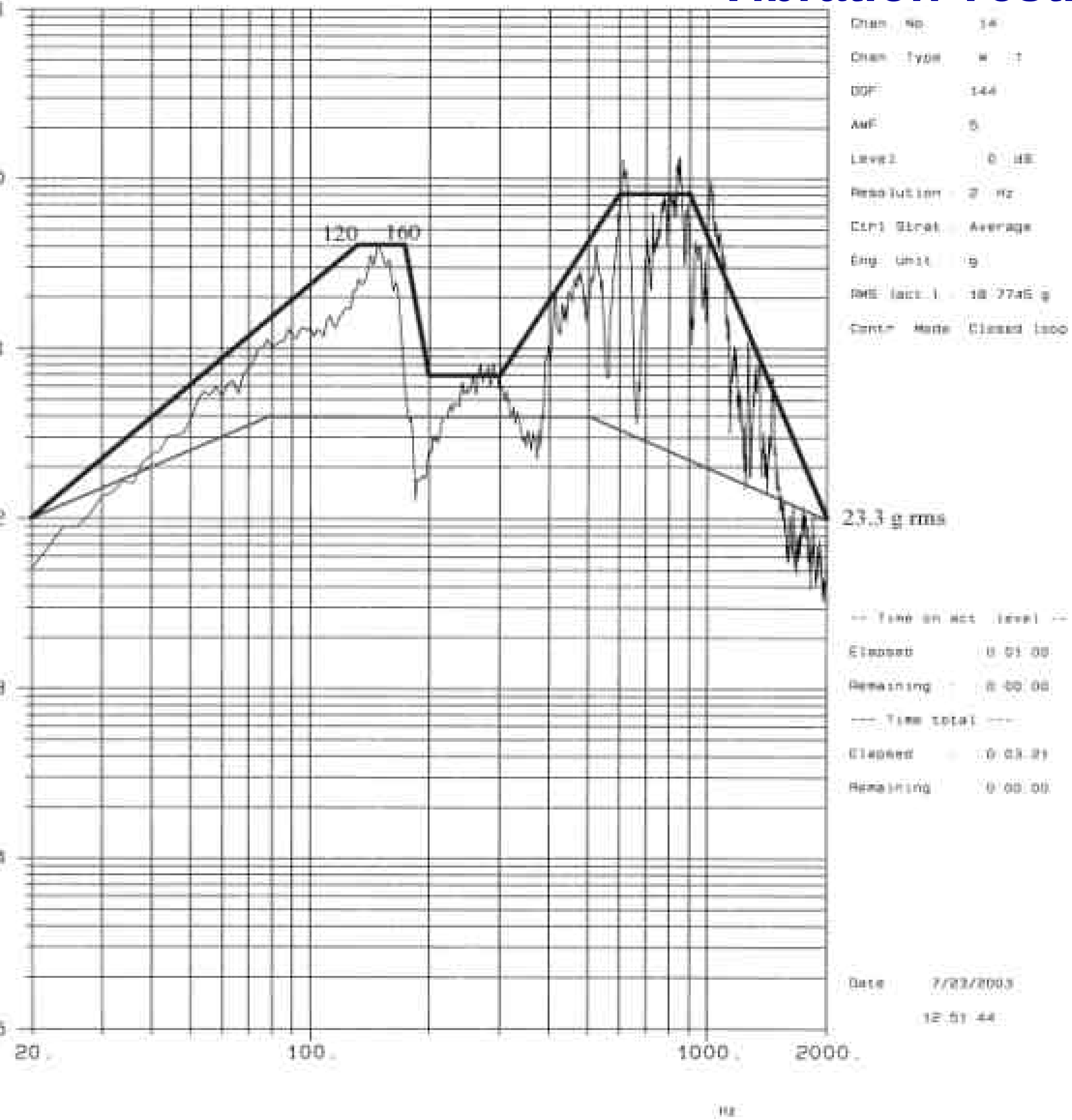
**STE-U Z-axis and**

**Envelope for instrument vibration**

**Envelope: 8.68 g rms**

- **Created from The FEMCI Book - Creating a Random Vibration Component Test Specification**

## Vibration Testing




**Y AXIS 0dB RANDOM**

**R5Y**

**STE-U Y-axis and**

**Envelope for instrument vibration**

**Envelope: 23.3 g rms**

- **Created from The FEMCI Book – Creating a Random Vibration Component Test Specification**
- **This value is unreasonably high and will be lowered by redesigning the mounting feet for the STE-U. Chang is possible due to new thermal constraints.**
- **STE-U instruments will be tested or flight Booms.**

## Post-Vibe Deployment

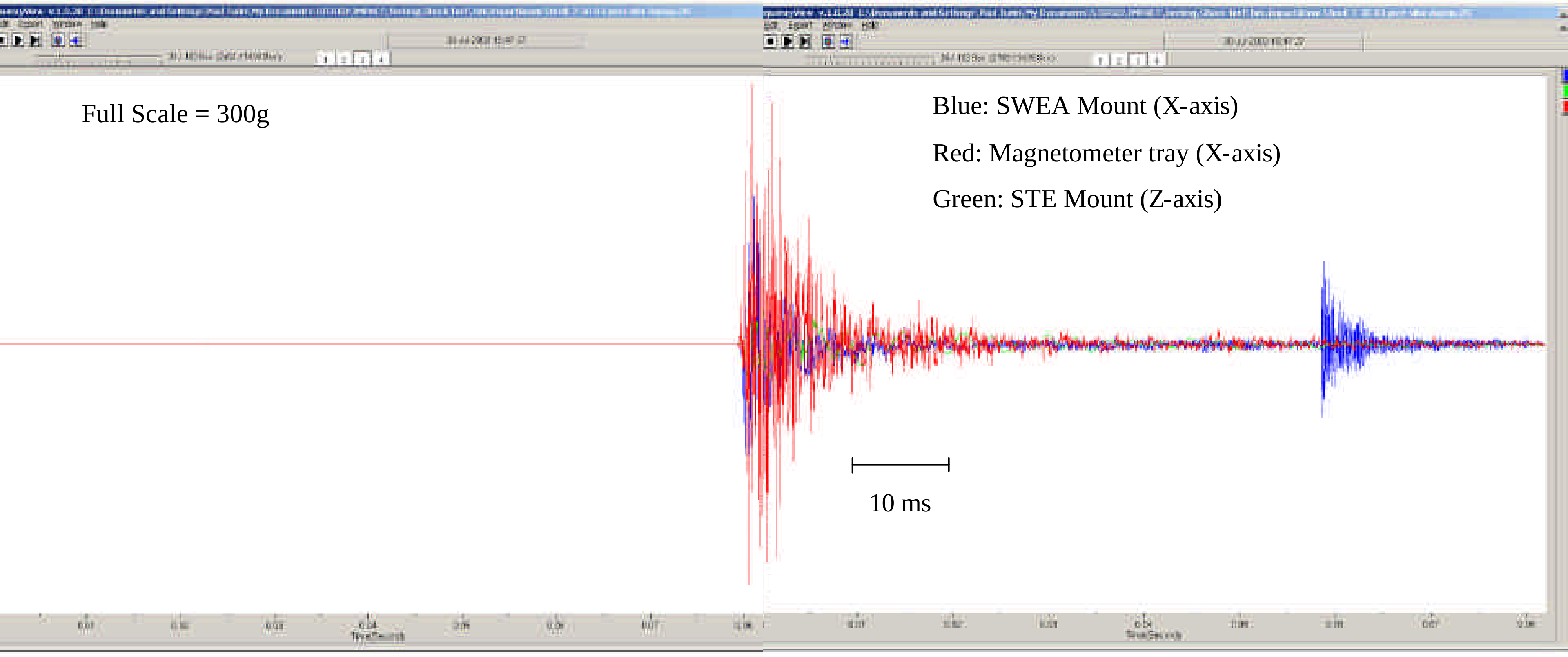
- **Due to a Mag tray shift detected during vibration, we decided to add a deployment between vibration and TV to verify movement did not cause any damage.**
- **Boom was deployed in TV chamber offload gantry, also instrumented for instrument shock and "pogo" shock test at same time.**
- **Boom deployed nominally, no evidence that mag tray shift caused problems.**
- **Boom was restowed for TV.**
- **It was determined that although the slippage between the Mag tray and combs reduced the preload somewhat, it was still adequate to prevent the SWEA from lifting off during vibe.**
- **The mag tray combs will be pinned on the flight units to prevent a reoccurrence of the slippage.**

## Instrument Shock Level and "Pogo Shock" Test

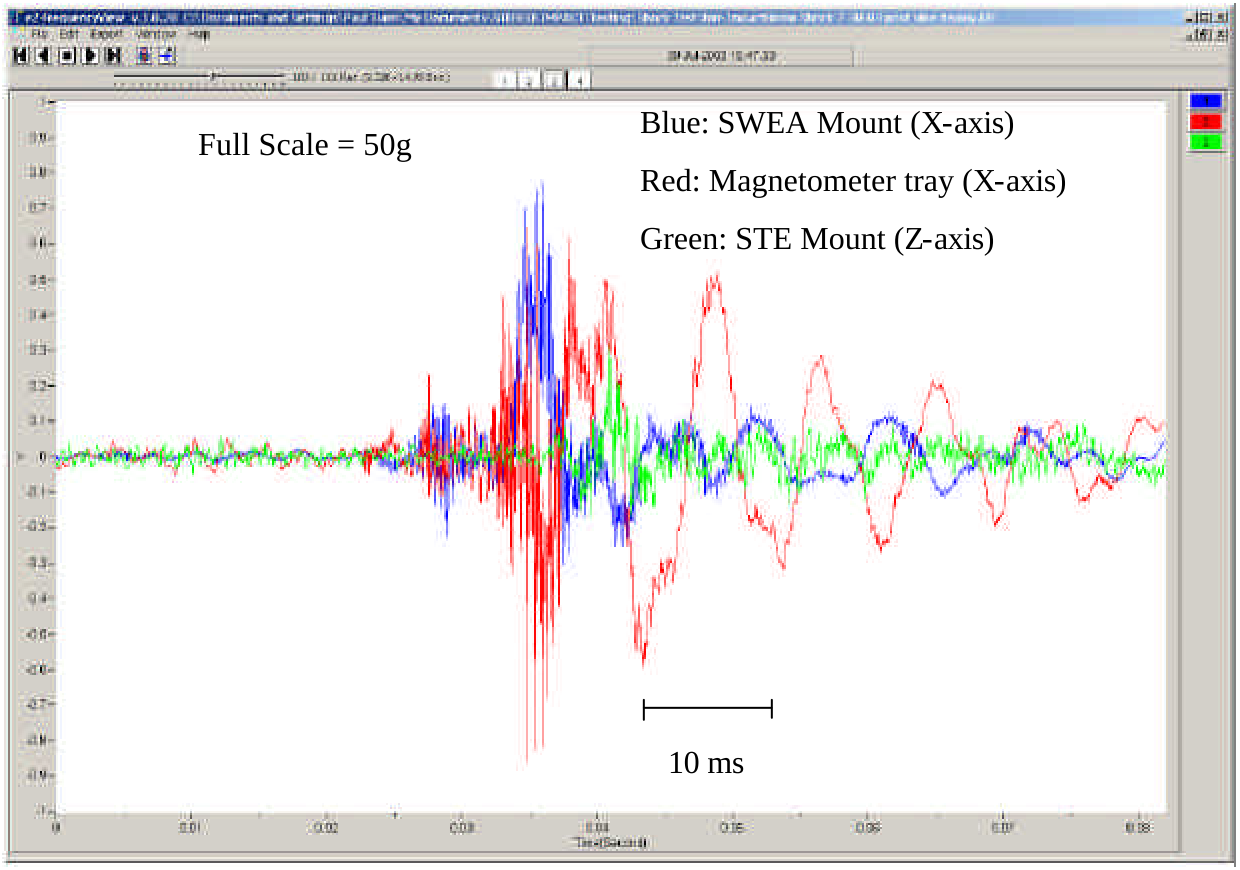
- **Given the possibility of damage to the instruments during boom handling and stowing, we do not want to deploy the flight booms with instruments on for more than the single deployment necessary to satisfy the "end-to-end" deployment requirement.**
- **We measured the shock at the instrument interfaces to determine if a shock test needs to be added to the instrument vibe test spec to simulate deployment.**
- **This test also gives us a measure of the end-of-travel lock-up " pogo shock" (more of a low freq sine load than a traditional shock), which is mainly of concern for the SWEA and Mag instruments.**
- **The largest shock occurred at the pinpuller firing and was on the order of 290g's, but of very short duration and so of little concern.**
- **The "pogo shock" reached ~25g at ~140Hz at both the SWEA and Mag mounts. The Mag saw the highest low-freq. shock at the latch up of the 90mm tube of ~50g at~100Hz. We should consider adding these to the instrument qualification tests.**

# *STEREO IMPACT*

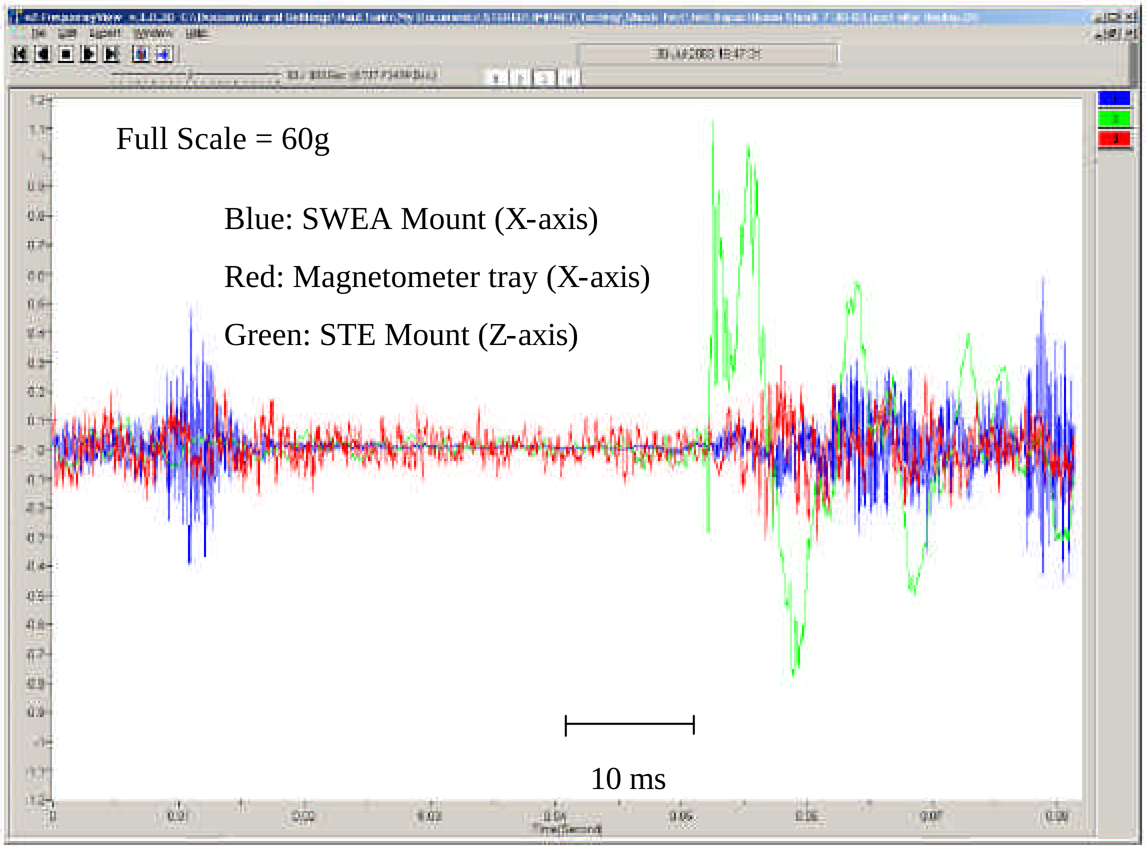
**The largest shock occurred at the pinpuller firing was on the order of 290g's, but of very high frequency and so of little concern. The low freq. components appear to be more on the order of 30g's, but further analysis would be required to verify this.**



**The "pogo shock" at the end of travel was about 25g's on both the SWEA and Mag mounts.**



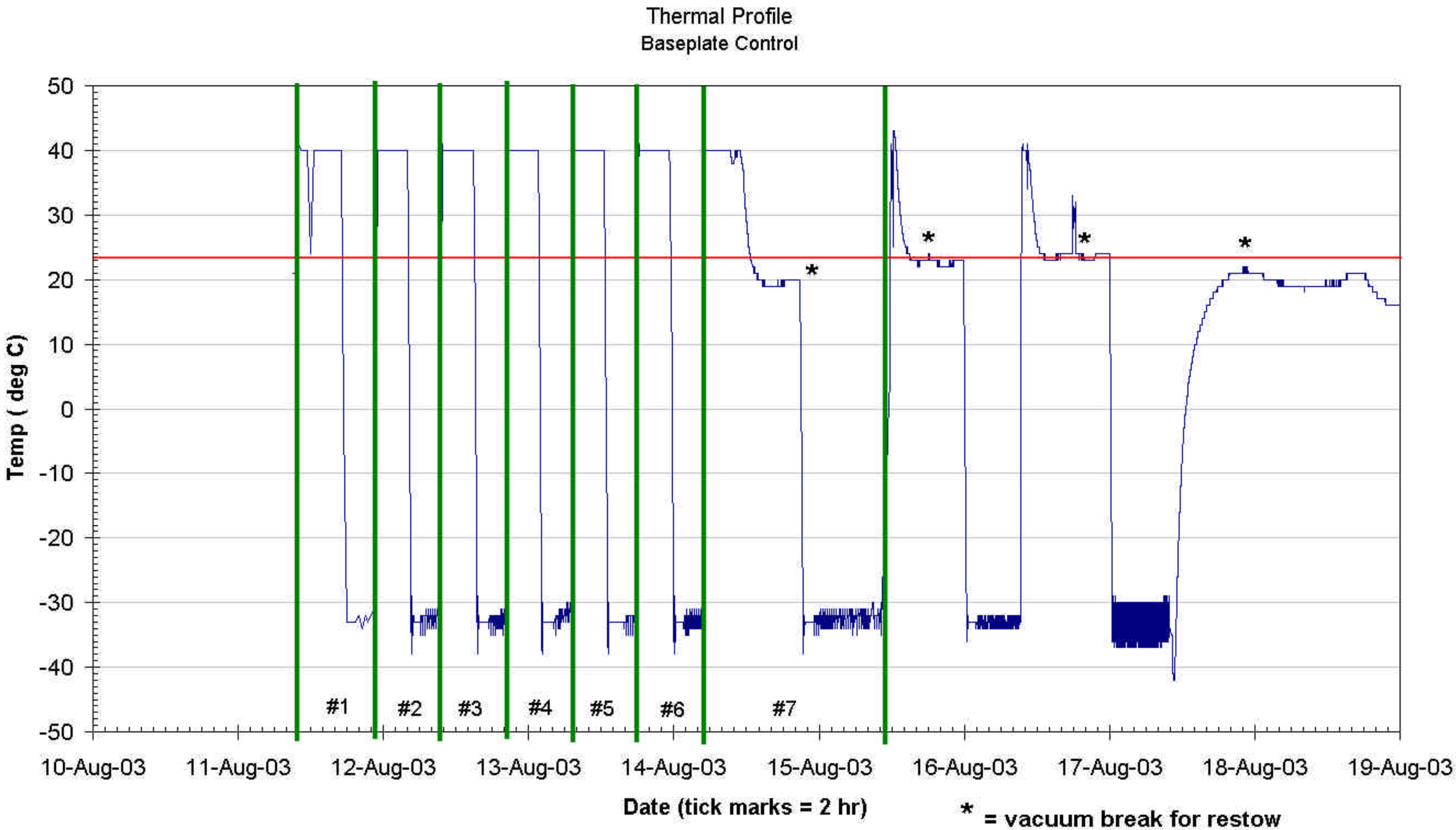
**The Highest low freq. Shock on the Mag occurred when the 90mm tube latched with a magnitude of ~50g's.**



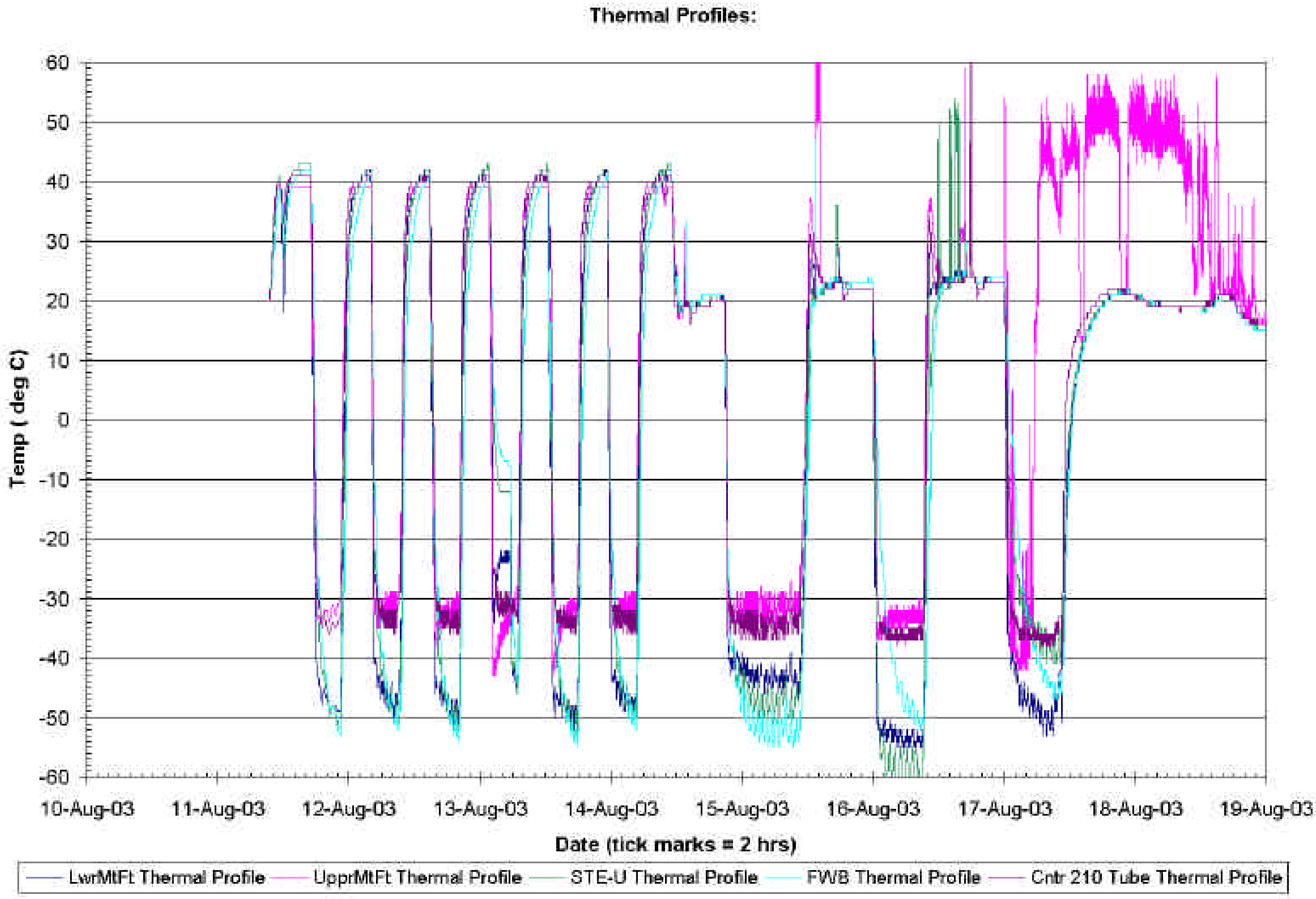
# Thermal Vacuum Test

- **Thermal Vacuum testing of the Impact Proto-flight Boom was begun on 11 August 2003 with Proto-flight unit installed in chamber, armed for hot deployment.**
- **The Baseplate Thermocouple was used as the main control for the temperature of the testing. The upper and lower shrouds were set to track the baseplate.**
- **12 additional TCs were positioned at various locations on the Instrument and their outputs recorded.**
- **Chamber pressure ranged from 2.5 X $10^{-5}$ (hot cycles) to 6.8 X $10^{-6}$ Torr (cold) during the cycling.**
- **6 cycles from ambient at start (~22 $^{0}$C) to hot (40 $^{0}$C) , to cold (-33 $^{0}$C) and back to ambient, were performed without interruption of the system.**
- **The 7$^{th}$ cycle was split into 2 parts: a hot soak, followed by a deployment using the SMAR primary circuit.**

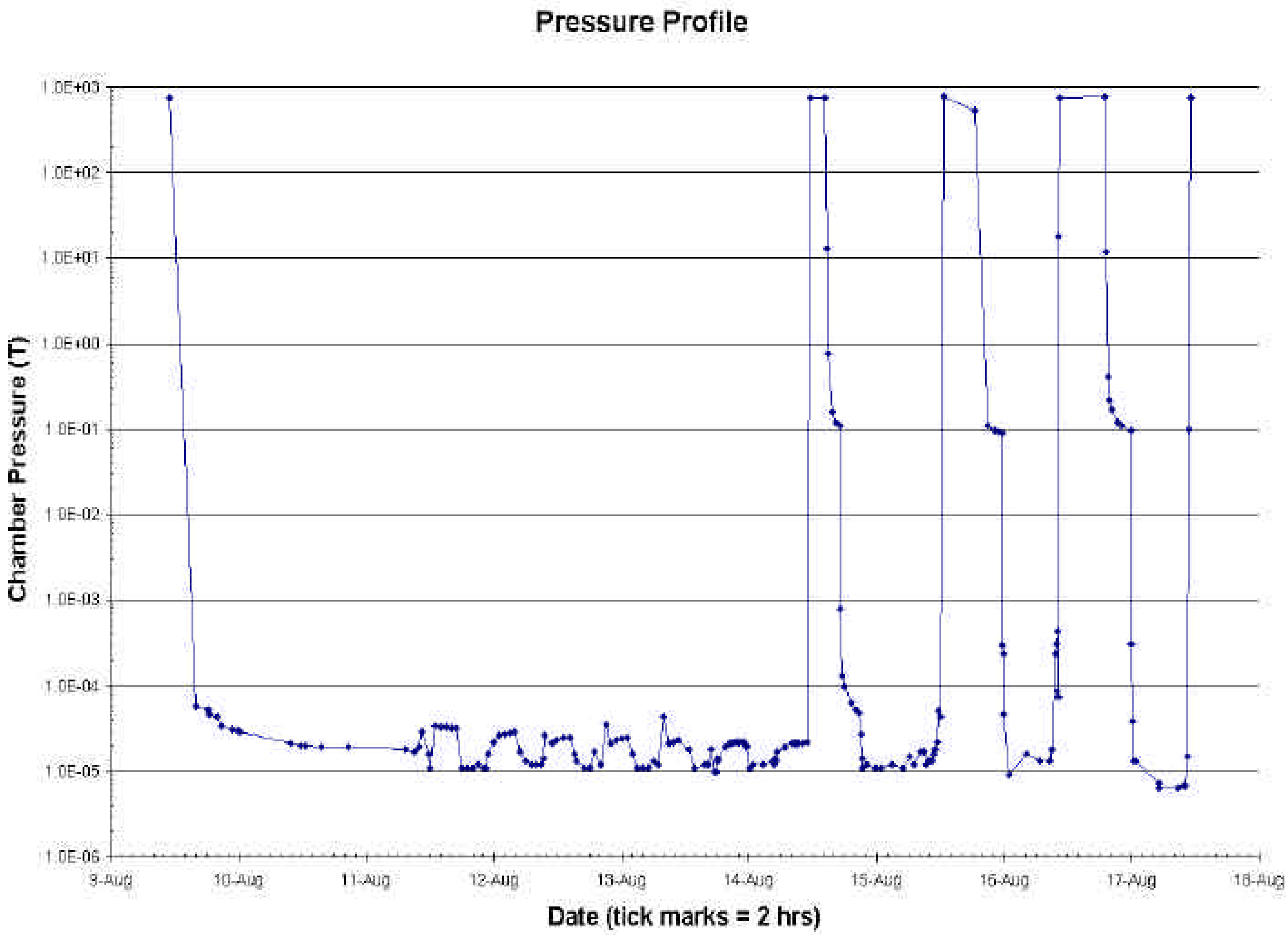
# Thermal Vacuum Test



# Thermal Vacuum Test



# Thermal Vacuum Test



## Thermal Vacuum Test

- **The hot deployment was successful, performed at 11:00 on 14 August. The chamber was then vented, and the Impact Proto-flight Boom was restowed, and replaced in the chamber.**

## Thermal Vacuum Test

- **The unit was pumped down to vacuum, then given a cold soak. The cold deployment was then scheduled for 10:00 on 15 August, using the SMAR secondary circuit.**
- **The cold deployment did not function. The Thermal Vacuum test was halted, and the chamber vented and opened for investigation of the anomaly.**
- **There were no obvious signs of difficulties with the unit on the test stand, the tubes would not deploy, so the unit was 'safed' by installing the safety pin, and removed from the chamber.**

# Thermal Vacuum Test

- **After removal, the tubes were free, and were able to be moved manually.**
- **The unit was then investigated by subsystem to attempt to identify the problem.**
  - **The flyweight brake (f.w.b.), initially suspected, was operational, and appeared to be assembled correctly.**
    - **It was removed from the assembly, disassembled and inspected for incorrect operation. No new problems noted.**
    - **There was sufficient slack on the lanyard to allow the spool lock to release and the lanyard to pay out. (This was verified prior to removal from test stand, and again after).**
    - **The lanyard and harness were not wrapped around any object, thereby preventing deployment.**
  - **The bobbin was removed and appeared nominal. Harness was unaffected.**
  - **SMAR pinpuller appeared to have functioned correctly.**
  - **The SMAR was reset, and a 'first motion' test was performed successfully. The 50mm tube pushed out normally, lanyard was free to pay out. The deployment was halted by manual restraint of the tubes while the boom was reset.**
  - **No 'smoking gun' was found. Theories were offered regarding the f.w.b. hanging up, twisted harness and other lower probability scenarios.**

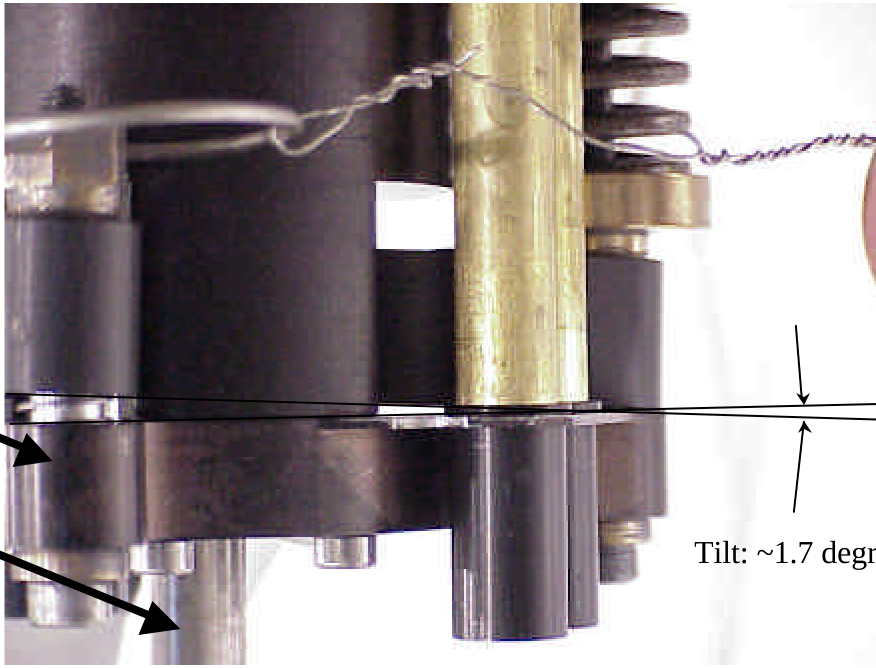
# Thermal Vacuum Test

- The proto-boom was reinstalled on the test stand, carefully inspected for proper assembly and installation.
- The chamber was closed, pumped down, and the cold portion of the test repeated. The cold deployment was then scheduled, using the SMAR secondary circuit.
- The 2$^{nd}$ cold deployment did not function. The Thermal Vacuum test was halted, and the chamber vented and opened for investigation of the anomaly.
- There were no obvious impairment of the unit on the test stand, the tubes would not deploy (or move), so the unit was removed from the test stand. The boom was not ‘safed’ this time with the safety pin.
- The unit was then investigated by subsystem removal, to attempt to identify the problem.
  - The flyweight brake (f.w.b.) was operational, and appeared to be assembled correctly.
  - The bobbin was nominal. Harness was unaffected.
  - SMAR pinpuller appeared to have functioned correctly.
  - The source of the anomalous behavior was then able to be seen: The tail of the tip piece was trapped in the SMAR ‘floating’ mount.

# Thermal Vacuum Test

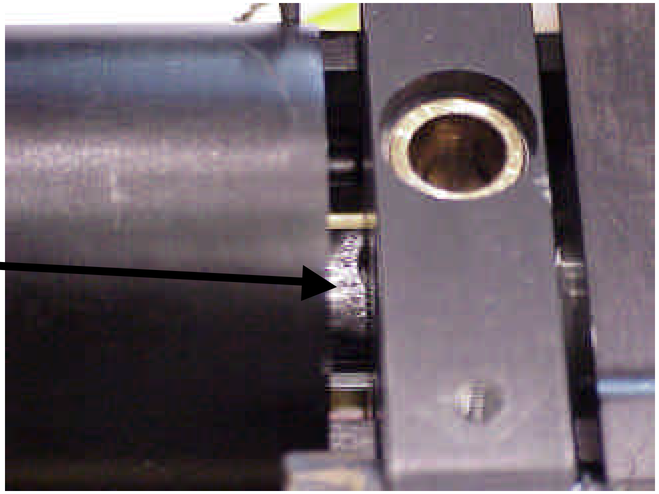
- **The mount is used to preload the tubes for resisting launch loads. There are 2 fixed pivots, and a coil spring used to apply the load to the tip piece tail. The release of the SMAR pinpuller allowed the coil spring to unload faster than the tip piece could clear the floating mount. This induced a tilt to the mount.**

  **Due to the tight tolerance required, there was insufficient room for the tip piece to withdraw from the mount, and thus became locked into the SMAR mount.**



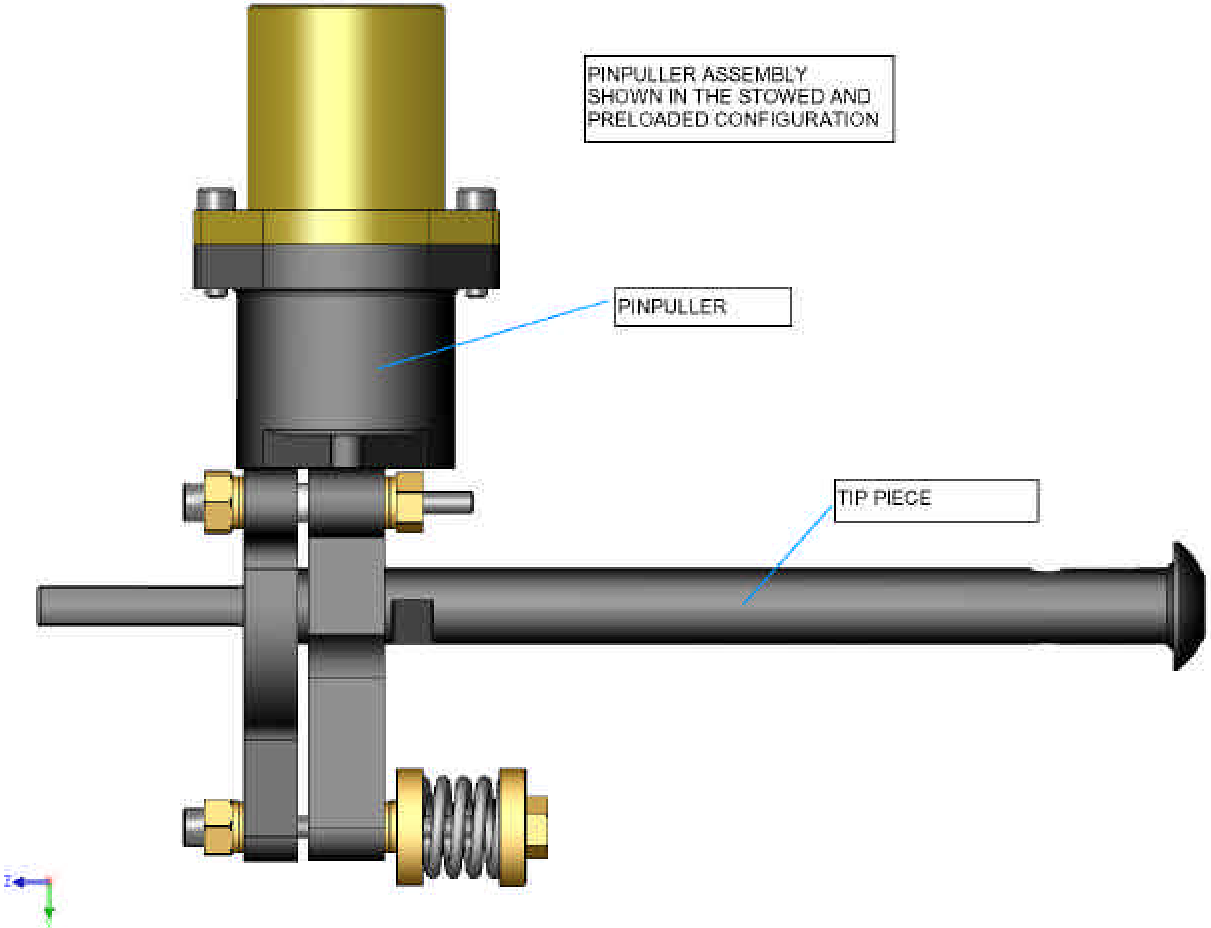
# Thermal Vacuum Test

- **This was not seen during the previous anomaly as the latching had been released when the safety pin was installed**
- **Close inspection revealed galling of the Ti tip piece, as wear had accumulated from deploying. The mount functioned as a sliding clamp, with 2 edges grabbing the tip piece. The second picture shows the wear on the mount from hanging up the tip.**



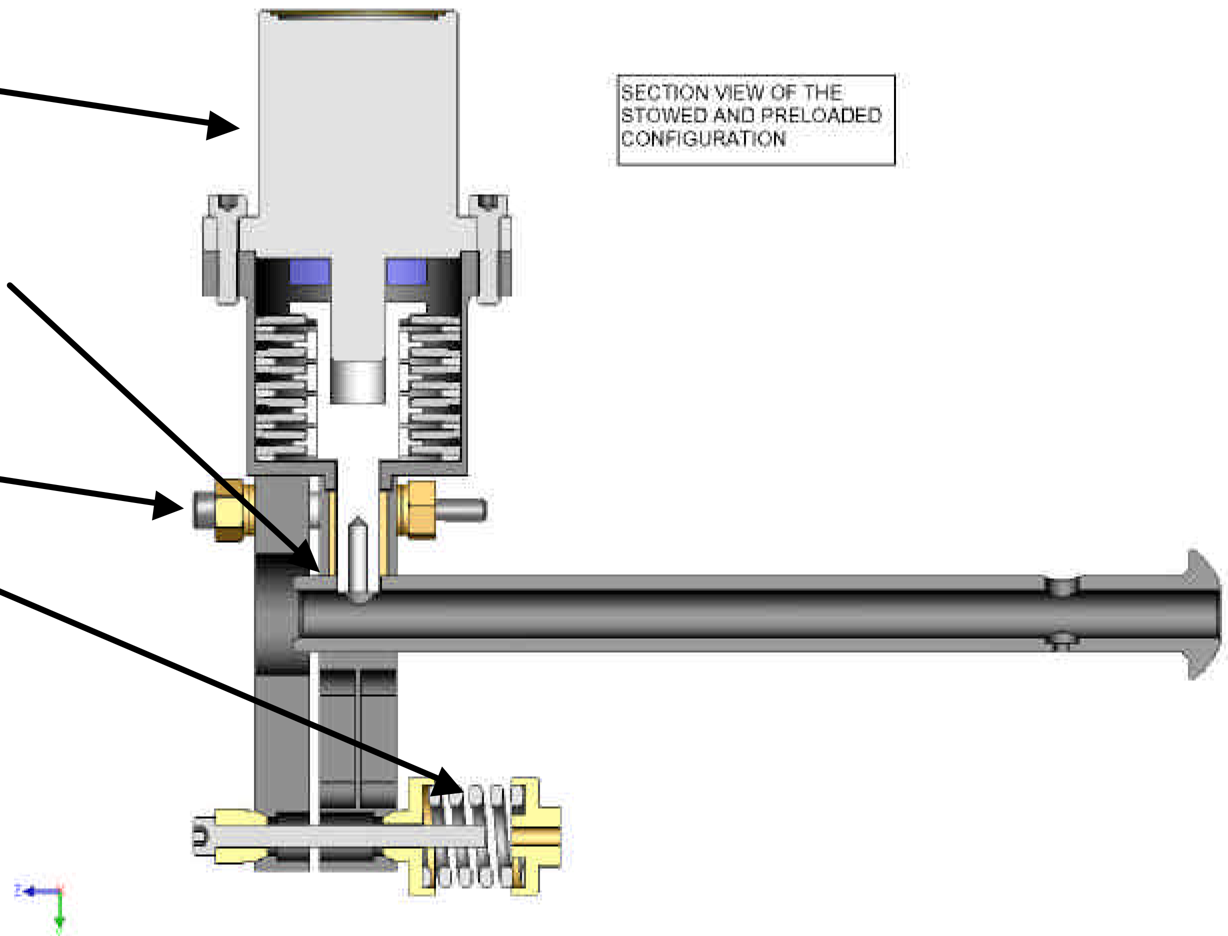
# Thermal Vacuum Test

- The solid model was re-examined for verification of the anomalous condition
- This first drawing shows the affected parts, in their stowed, nominal condition



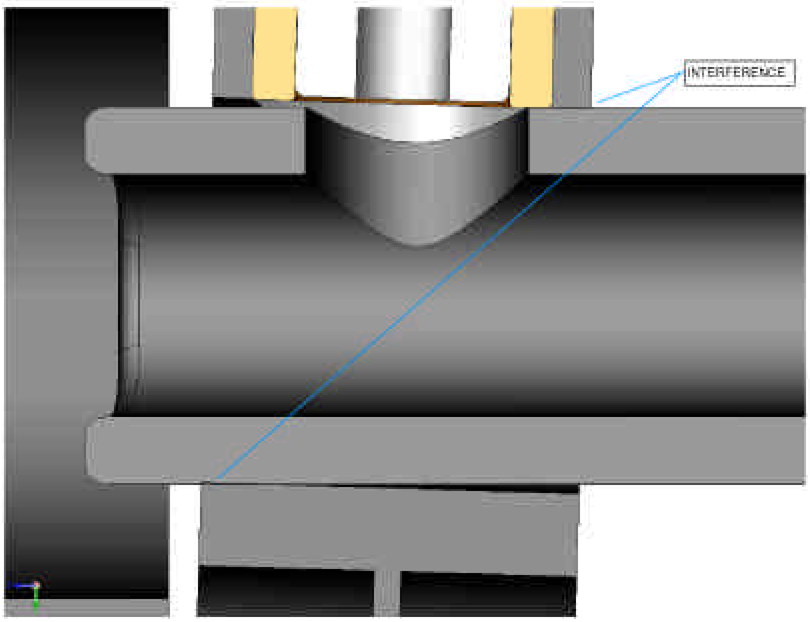
# Thermal Vacuum Test

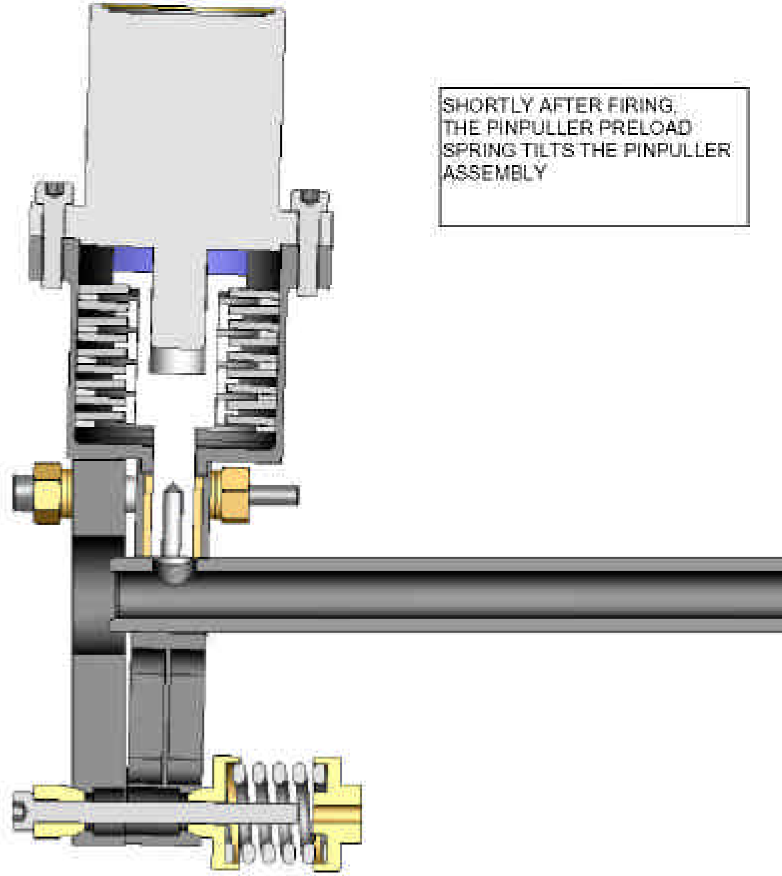
- Same drawing, section view
- SMAR pinpuller
- Note the close fit of the tip piece to the floating mount, where the SMAR pinpuller is inserted into the tip piece.
- Solid pivots
- Coil preload spring



# Thermal Vacuum Test

- This drawing is the section view, post SMAR firing
- Coil preload spring has pushed the mount against the housing sooner than the tip piece can clear the through hole.
- The tip piece binds in the mount (detail)

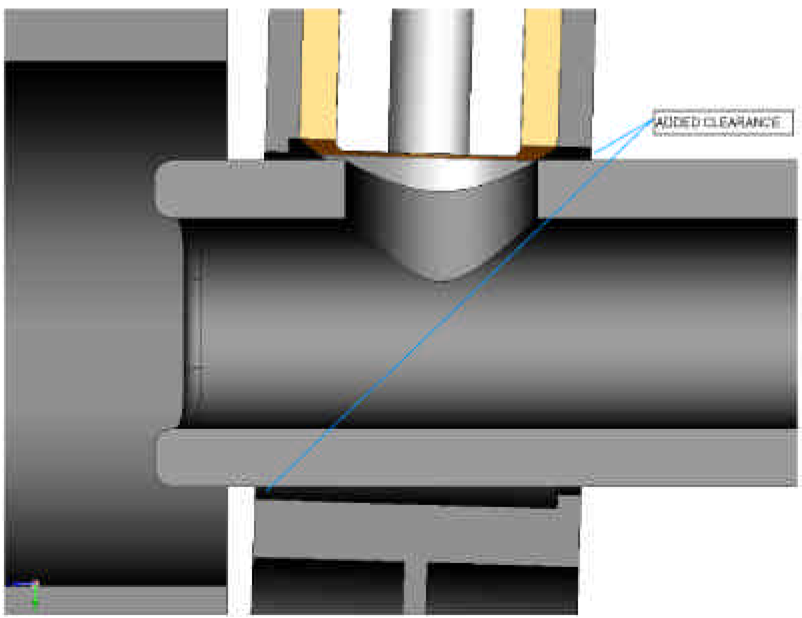


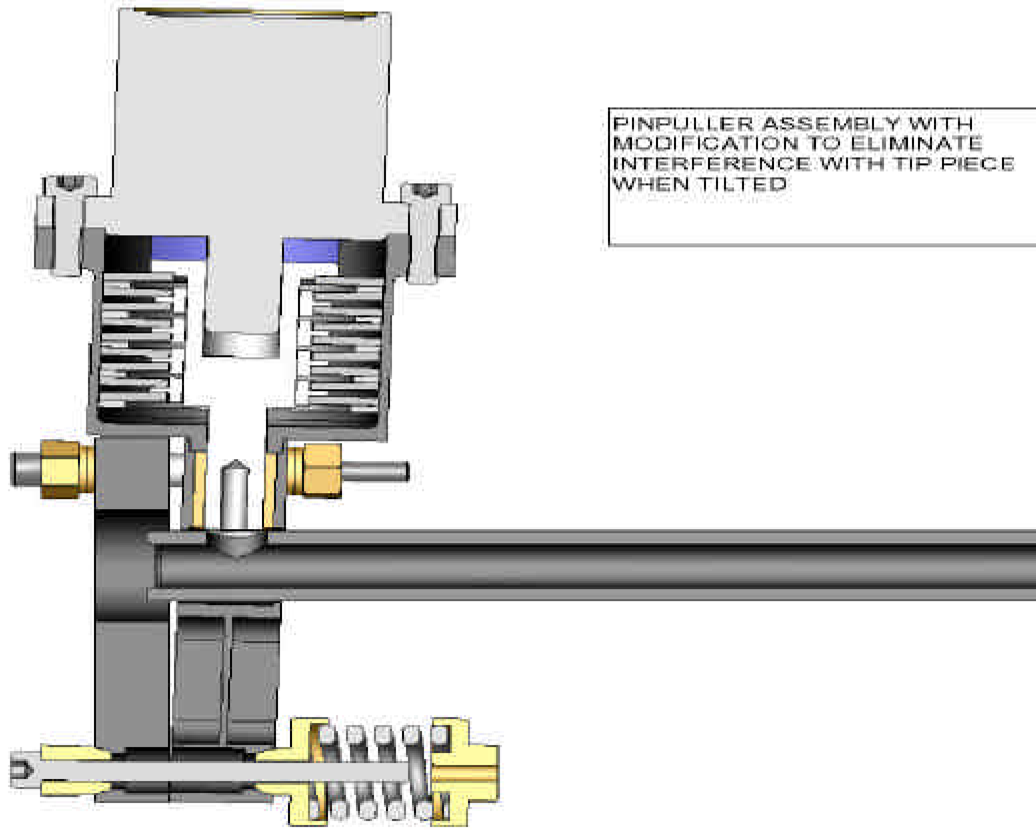



# STEREO IMPACT

## Thermal Vacuum Test

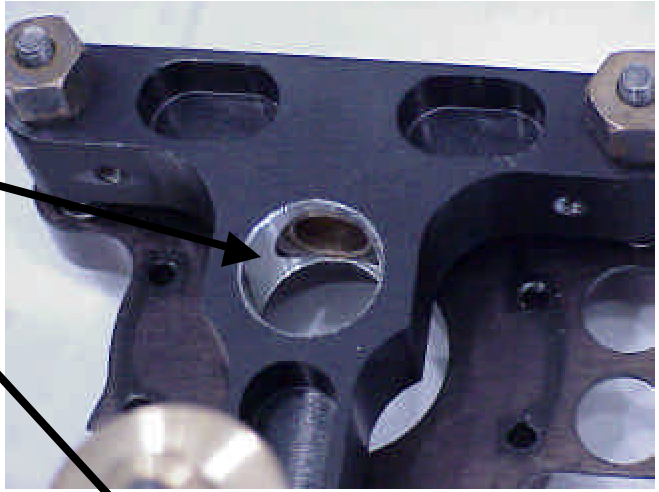
- This drawing is the section view, post SMAR firing
- The hole has been relieved by milling an offset into both sides of the mount, while leaving a lip to guide the tip while the pinpuller is installed and preloaded.
- The tip piece no longer binds in the mount (detail)

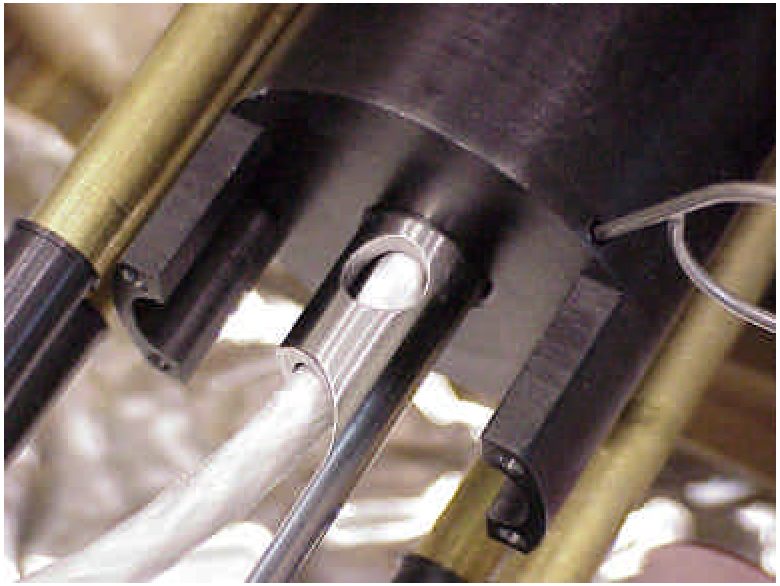


# Thermal Vacuum Test

- **Reworking the part, the through hole in the floating mount was relieved to allow free travel of the tip piece, while maintaining the needed tolerances.**
- **The galling was removed from the tip piece tail.**





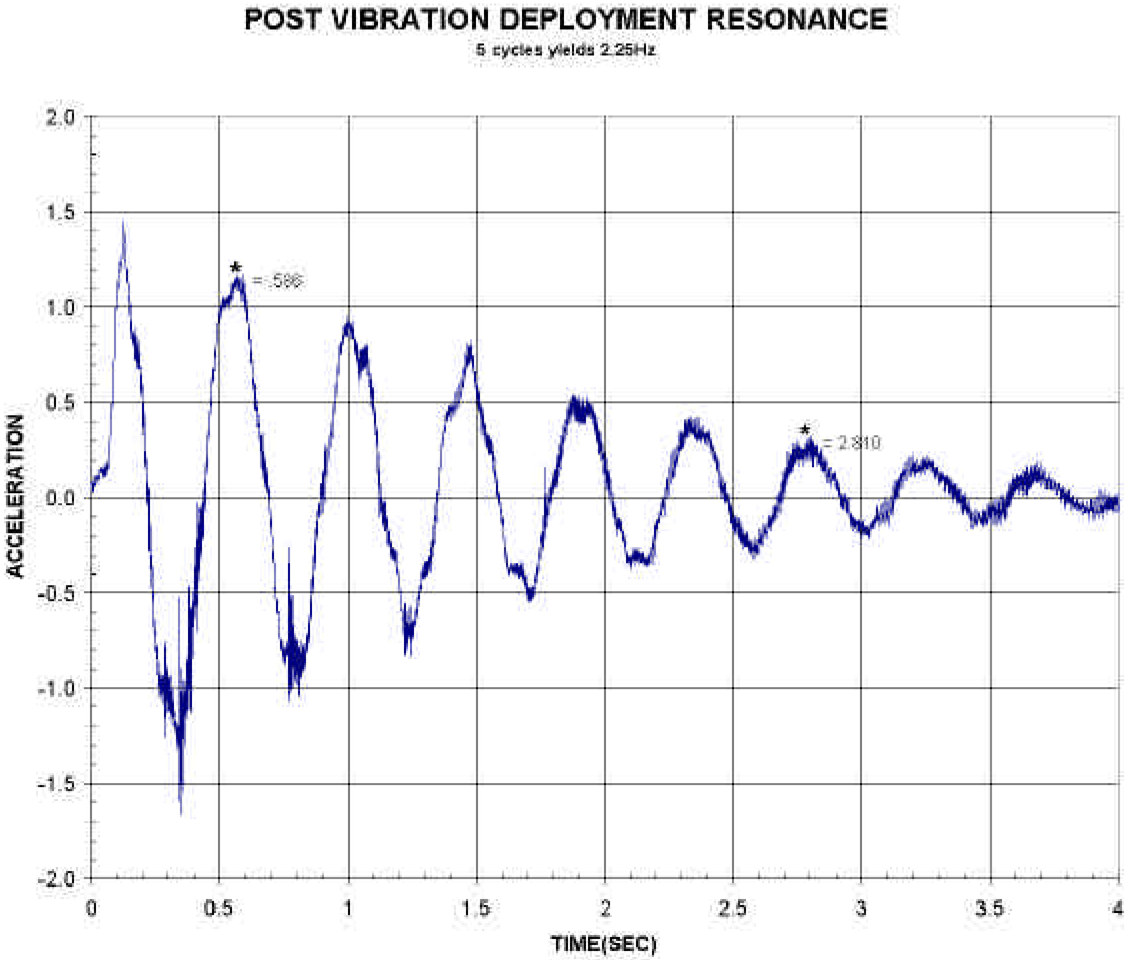
# Thermal Vacuum Test

- **Additional Data taken for the Boom:**
  - **Resonance data for post hot and cold deployments.**
  - **SMAR pinpuller current profile (cold case)**
  - **TQCM data**
- **Resonance (raw) Data**
  - **is in queue for analysis**
  - **See next sheets**

# Thermal Vacuum Test

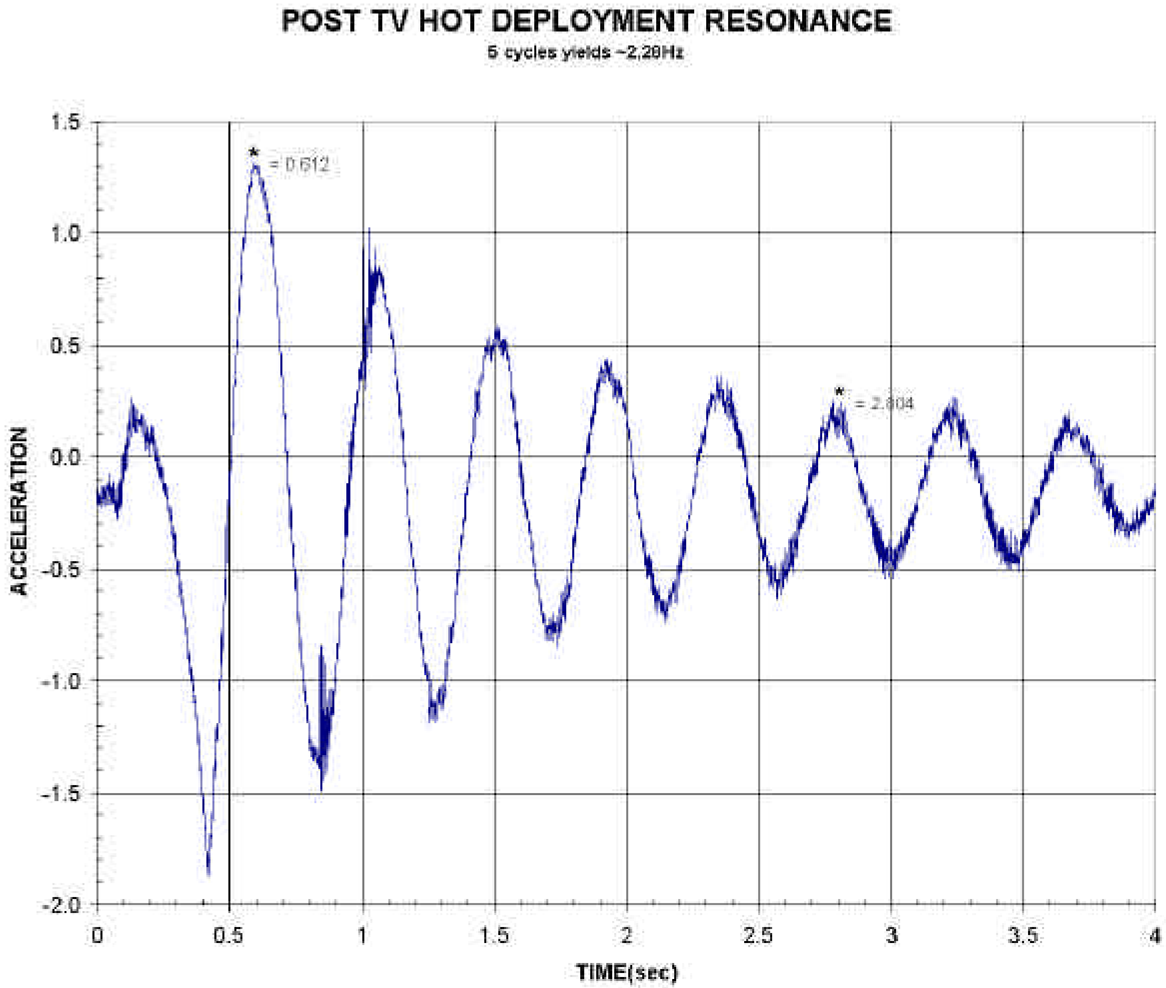
Resonance measured using Endevco 61-A500 Isotron Accel through Model 133 signal conditioner into DAQView.

Averaging 5 cycles gives 2.25Hz
All mass dummies included.



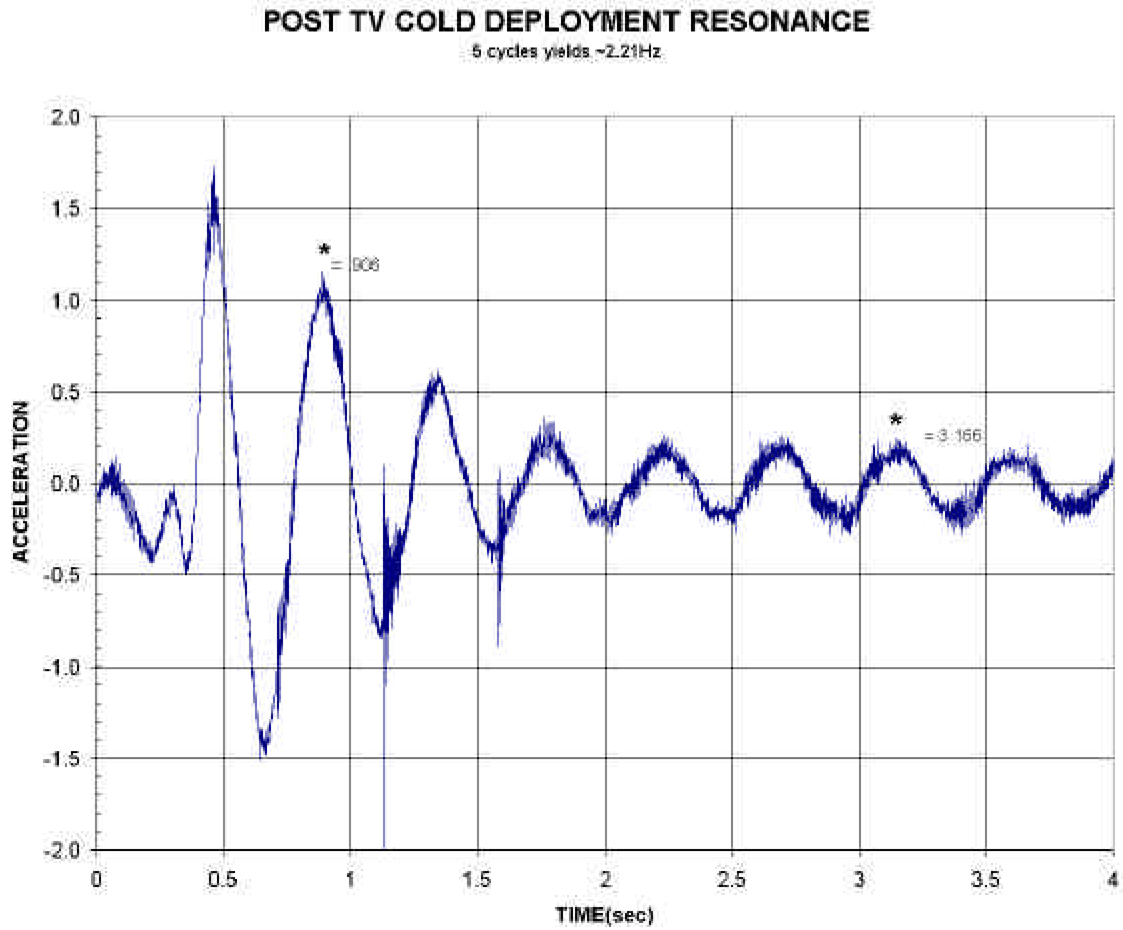
# Thermal Vacuum Test

Averaging 5 cycles gives 2.28Hz
All mass dummies included.



# Thermal Vacuum Test

Averaging 5 cycles gives 2.21Hz
All mass dummies included.



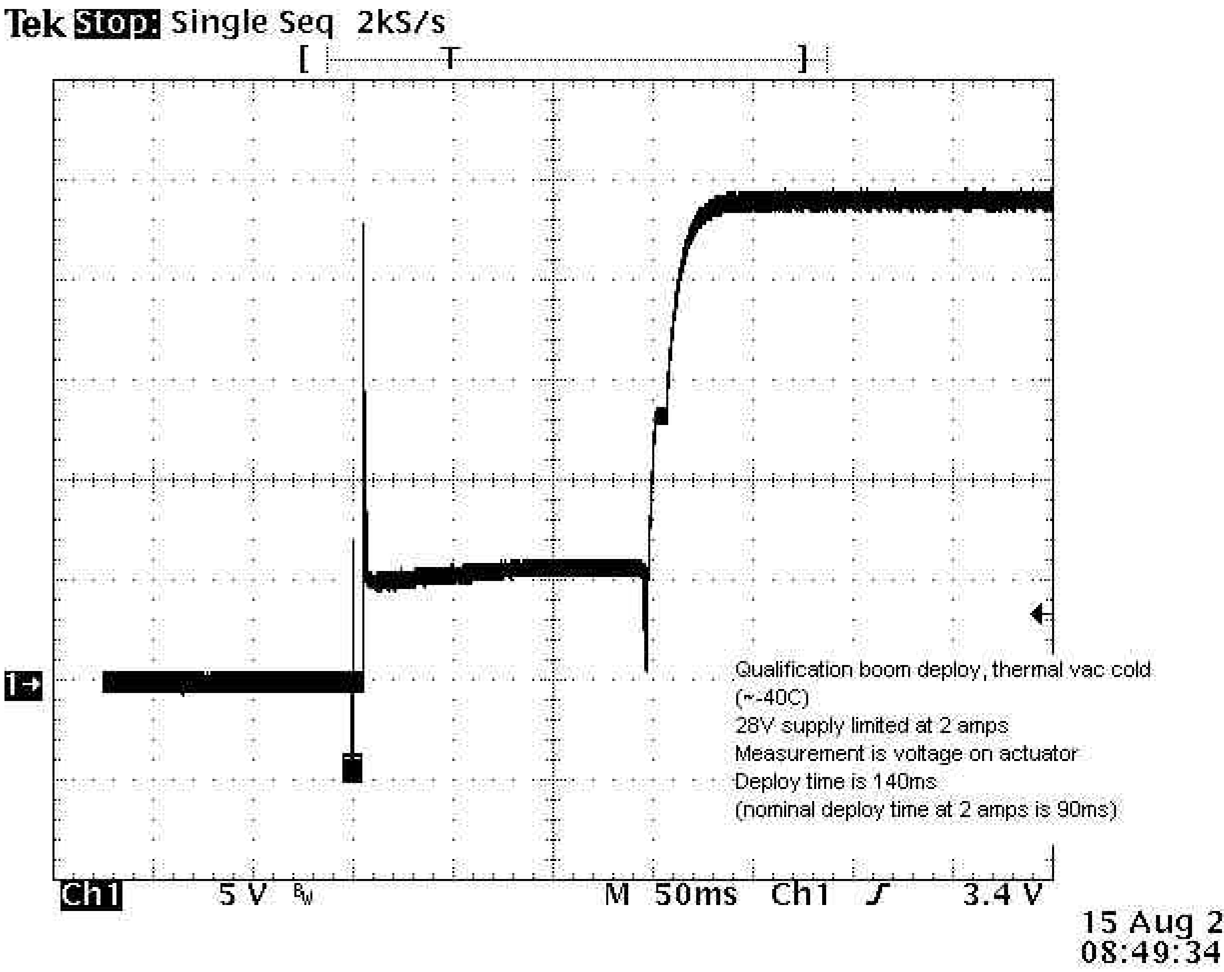
# STEREO IMPACT

## Thermal Vacuum Test

SMAR Pinpuller Release Data

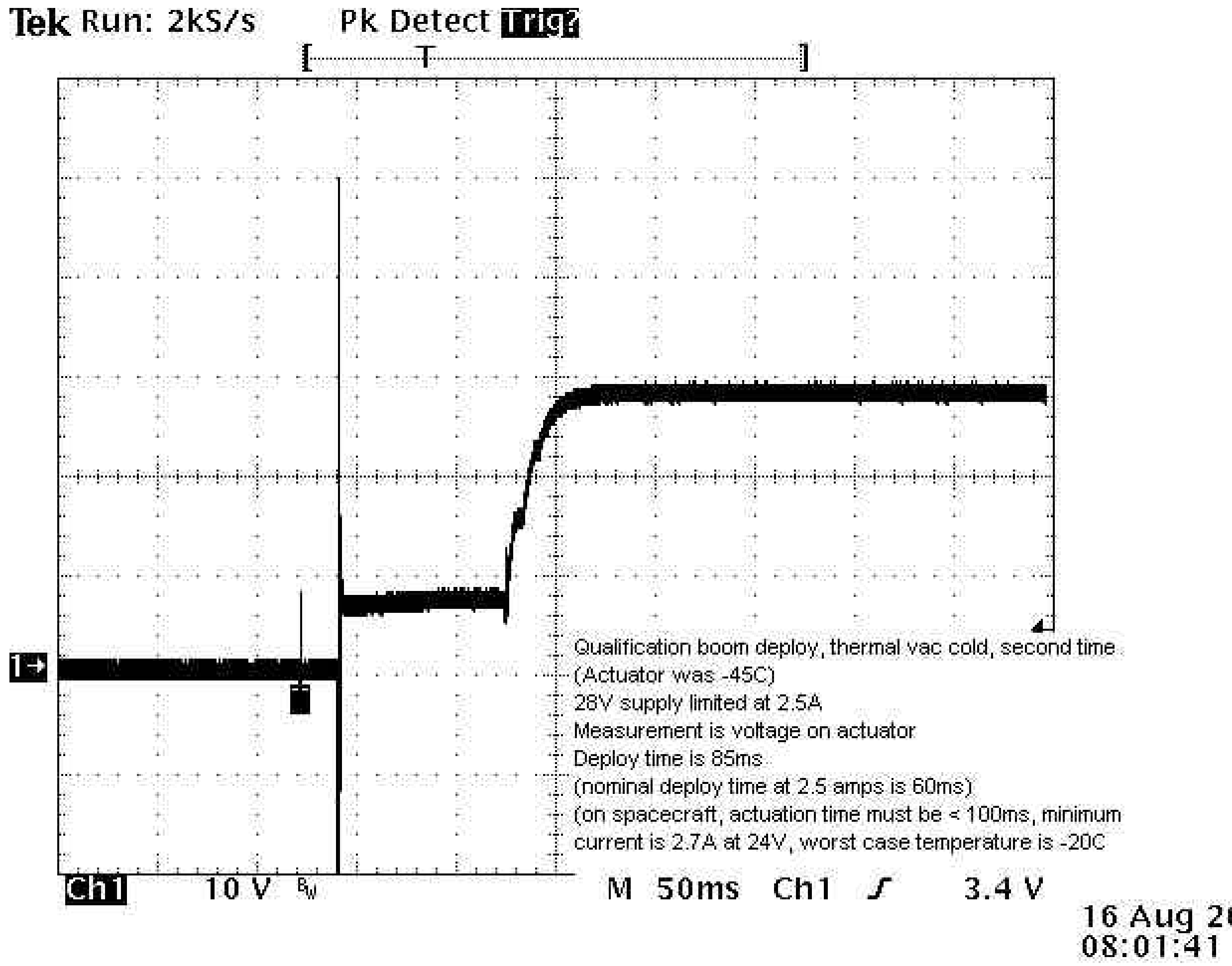
O'scope data taken from first cold deploy SMAR pinpuller release.

- 28 VDC supply
- 2.0A maximum current
- -40 $^{0}$C
- Full preload
- Deployment time: 140ms



# Thermal Vacuum Test

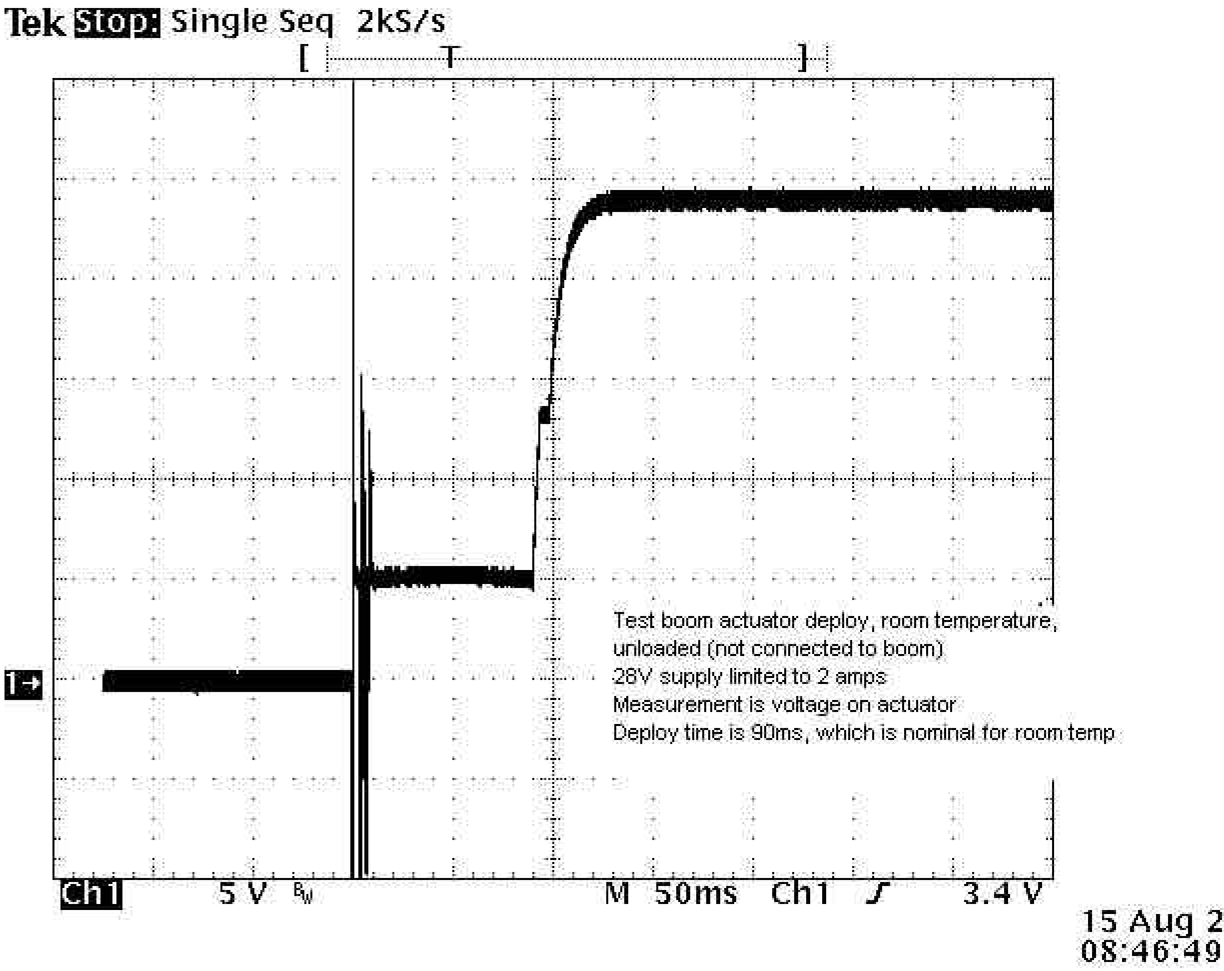
O'scope data taken from second cold deploy SMAR pinpuller release
- 28 VDC supply
- 2.5A maximum current
- -45 $^{0}$C
- Full preload
- Deployment time: 85ms



# Thermal Vacuum Test

O'scope data taken from ambient SMAR pinpuller release
- 28 VDC supply
- 2.0A maximum current
- 23 $^0$C
- Unloaded condition
- Deployment time: 90ms

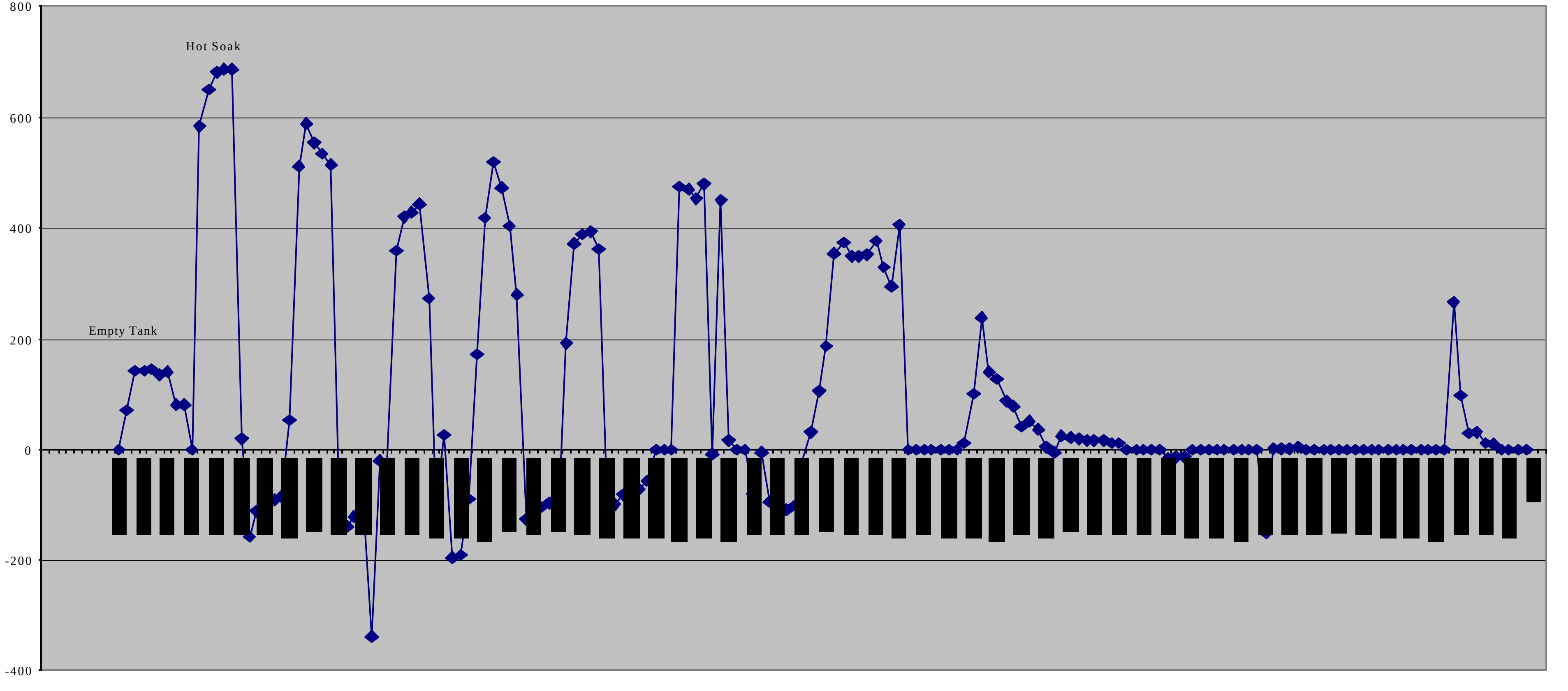
On orbit:
- Required actuation time <100ms
- Expected actuation temp: 0 $^0$C
- Max current: 2.5A
- 28 V



# Thermal Vacuum Test

TQCM data from Thermal Vacuum testing of the Impact proto-flight Boom

- When chamber set cold, TQCM temp exceeded chamber temp., thus the chamber served as a ‘getter’ for the TQCM.
- Hot values continued to drop as chamber was baked out. Final hot value at end of hot cycle # 7 is ~250 Hz/hr



## Thermal Vacuum Wrap-Up

- **New chamber worked very well.**
  - **Controls were functional**
  - **GSE off load fixtures etc. worked correctly**
  - **It wasn't the test equipment this time.**
- **Improvements for Flight Acceptance Testing**
  - **Tighten up the control 'deadband' to give the required 3 degree control band (currently +/- 3 degrees)**
  - **Pot and mechanically fasten all TCs.**
  - **Some convenience upgrades for those long nights: i.e. LN2 manifold**
  - **Auto-recording of chamber pressure.**
  - **Label the buttons.**
- **Boom**
  - **Found a problem, more attributable to wear than temperature, although cold had minor effect. Solved.**
  - **Overall performance has proved suitability for space environments.**

# Force Margin test

- Due to the difficulty of attempting to measure the boom force margin directly, we separately measured the Stacer push force and the boom drag force.
- We deployed the Stacer in a test track and measured the force it generated when stopped every meter through its stroke. This resulted in a force that linearly ramped from 12lbs at the beginning of stroke to 7lbs at the end of stroke.
- We then installed the boom without the Stacer in the deployment gantry with the offload weights, and added 3 lbs to the 50mm counterbalance weight in an attempt to deploy the boom with 1/3 the minimum available Stacer push force (Min margin ratio of 3: 12/3=4>3 at start, 7/3=2.3=(3-0.7 where 0.7=deployed cable weight)).
- The boom deployed fully and without any slowdowns or other indications that this force was marginal.
- In static boom pullout tests, the drag force was separately measured to be about 2 lbs.
- The force latch was deleted as a result of having adequate margin, in the interest of simplicity.

# Conclusion

- **All qualification tests have been successfully completed.**
- **The boom meets the force margin requirements.**
- **The boom has been deployed over 20 times with no part failures and without excessive wear.**

- **Action items**
  - **Add pins to Mag tray to prevent slippage.**
  - **Incorporate changes to Pinpuller mount for flight units.**
  - **Complete Thermal Balance Test.**
  - **Forward vibration and self-shock test results to instrument teams.**