External Pre-Isolation Progress on the Seismic Retrofit

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Outline

Description of the problem and Overview of program

Geometry of a solution

Installation of candidate solutions at LASTI

(Preliminary) Performance Electromagnetic Actuators

(Preliminary) Performance of Hydraulic Actuators

Program Overview

- Ground motion issues:
  - @ LLO
    - Steady-state ambient noise is higher due to anthropogenic sources; Transients, particularly from logging.
    - Impossible to hold the interferometers locked reliably during the day.
  - @ LHO
    - Wind induced seismic noise at LHO exceeds locking threshold at ~25 mph, or 10% of the time
    - Expect that up-conversion is a problem at significantly lower wind speeds & a large fraction of the time
- External Pre-Isolation (EPI) Upgrade is required to allow both reliable locking and to allow better noise performance while locked
  - Prototype testing at LASTI facility has demonstrated 10x reduction in 0.5 to ~2.5 Hz band (compared to 15x reduction requirement in the 1-3 Hz band); testing and optimization continues
  - Design review scheduled for ~4/18
  - Earliest installation start is Oct with completion ~Jan
  - To date have focused on LLO (more acute) problem; Plan to install PEPI systems at LHO for wind noise needs more evaluation.

Histograms of the ground motion

2 years of data compiled by Ed Daw 1-3 Hz BLrms monitor

We appear to need a factor of 10 isolation in the 1-3 Hz band.

Many caveats to this, please see Ed's talk tomorrow at 10 in D.C.

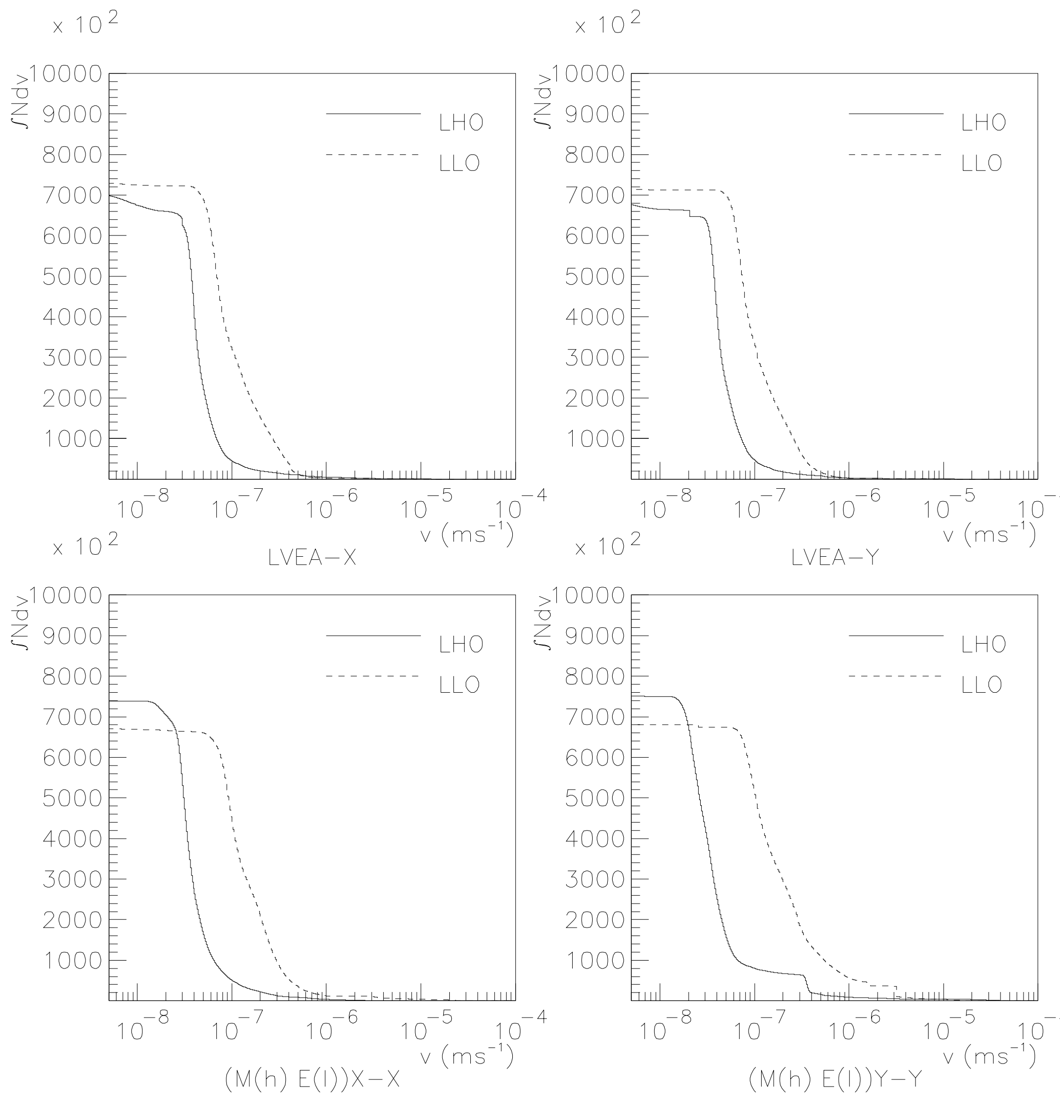
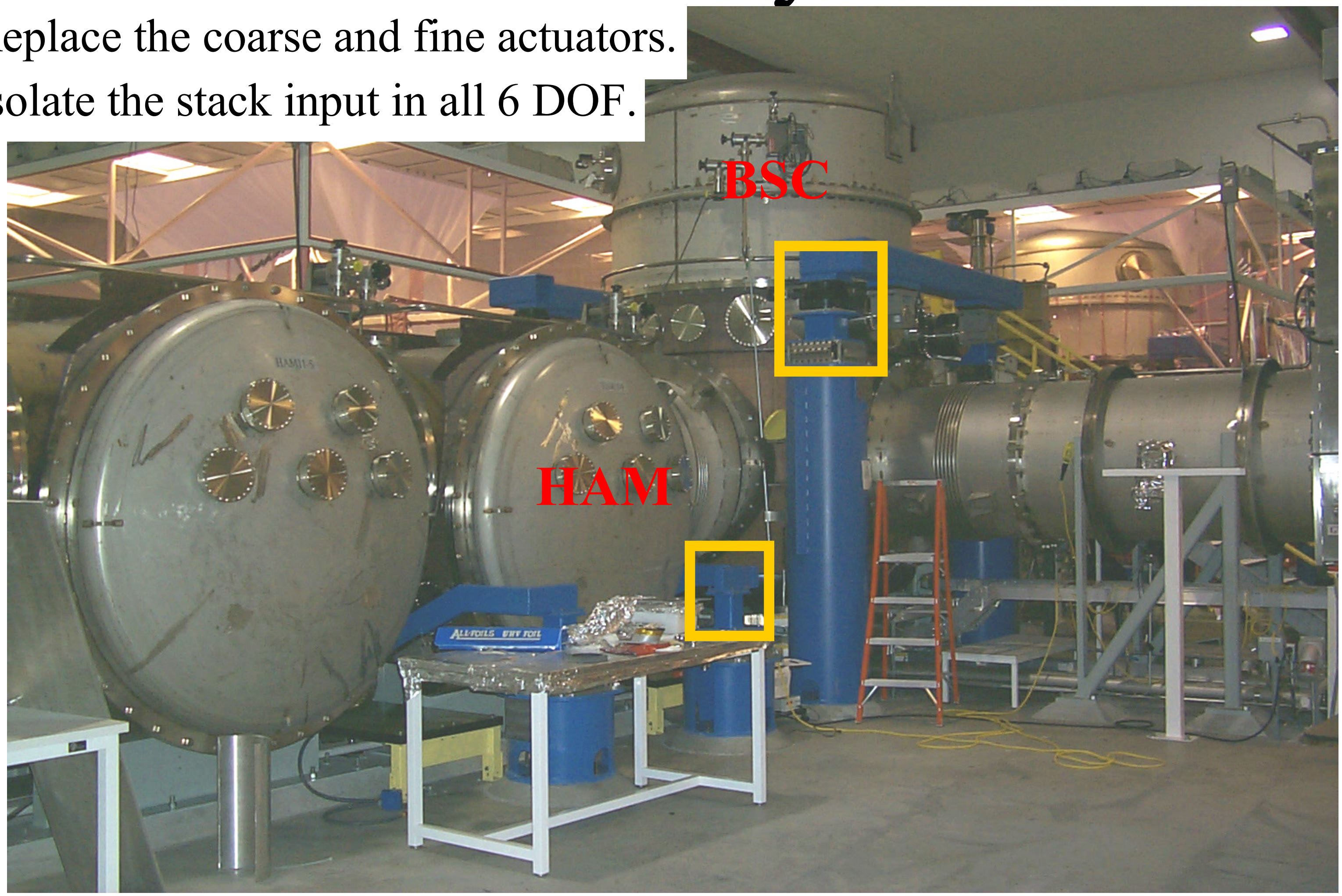


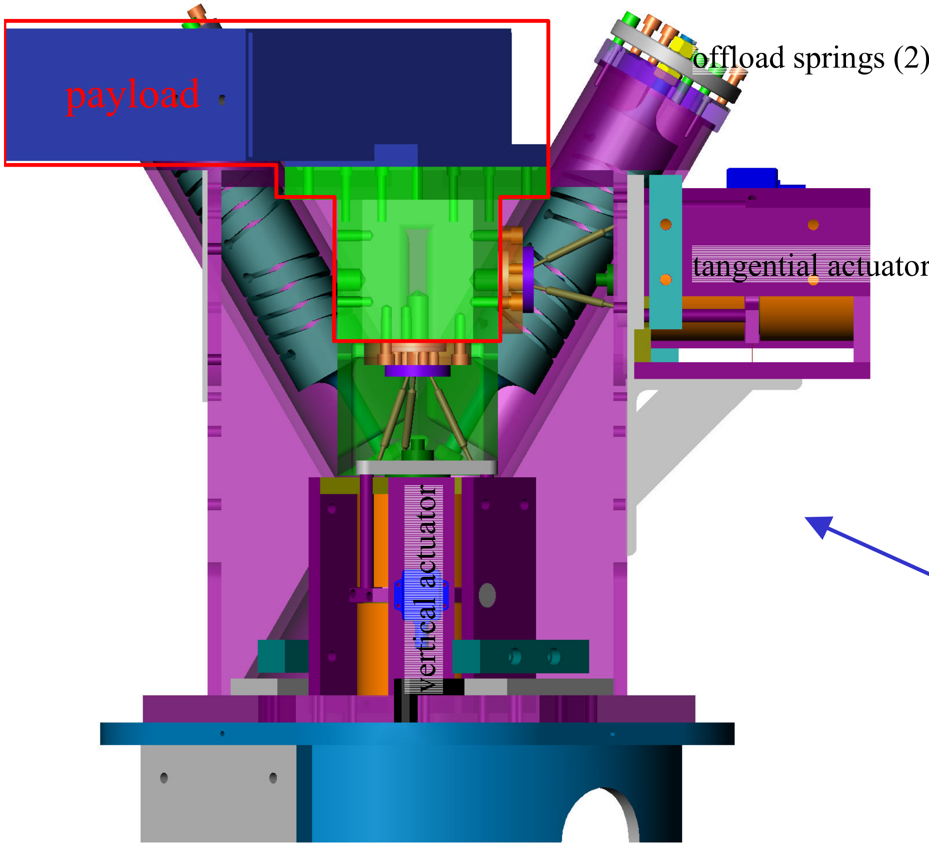
Figure courtesy of Ed Daw

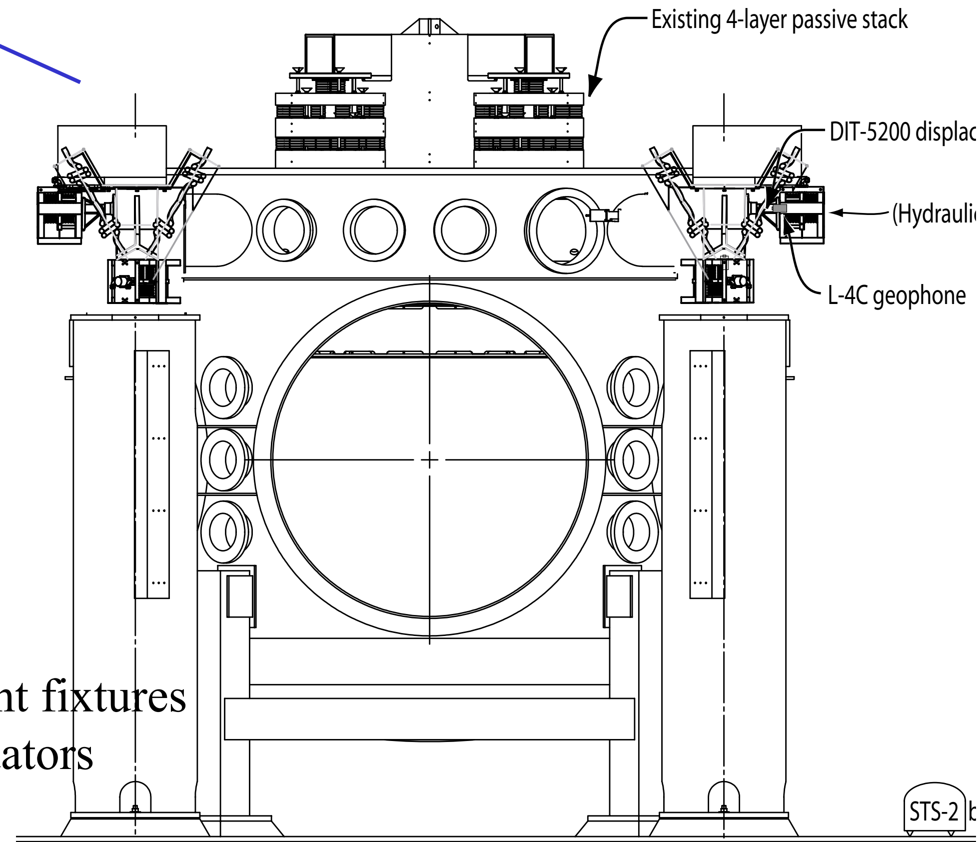
Placement of an External Isolation System

- Replace the coarse and fine actuators.
- Isolate the stack input in all 6 DOF.



Placement of the Actuators and Offload Springs



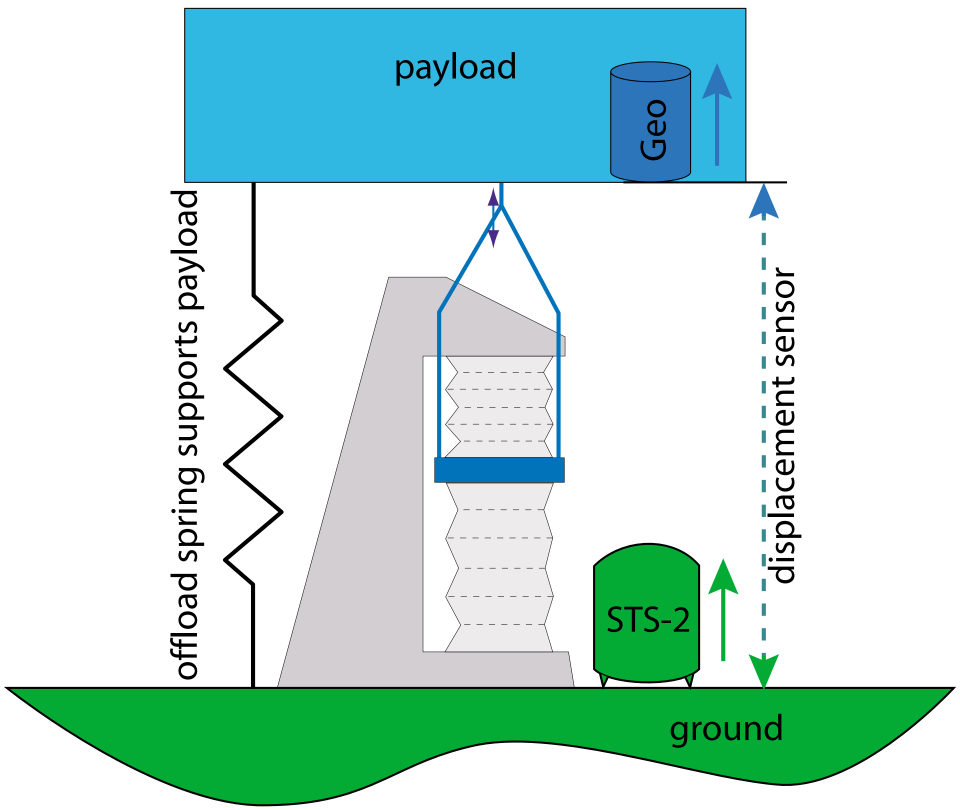


All the pier-top components are mounted into a frame

Frame holds:

- 1 vertical and 1 tangential actuator,
  (isolation and alignment in 6 DOF)
- Pair of offload springs and initial alignment fixtures
- Sensors which are not included in the actuators

How to maintain Alignment, and have Isolation from the Ground



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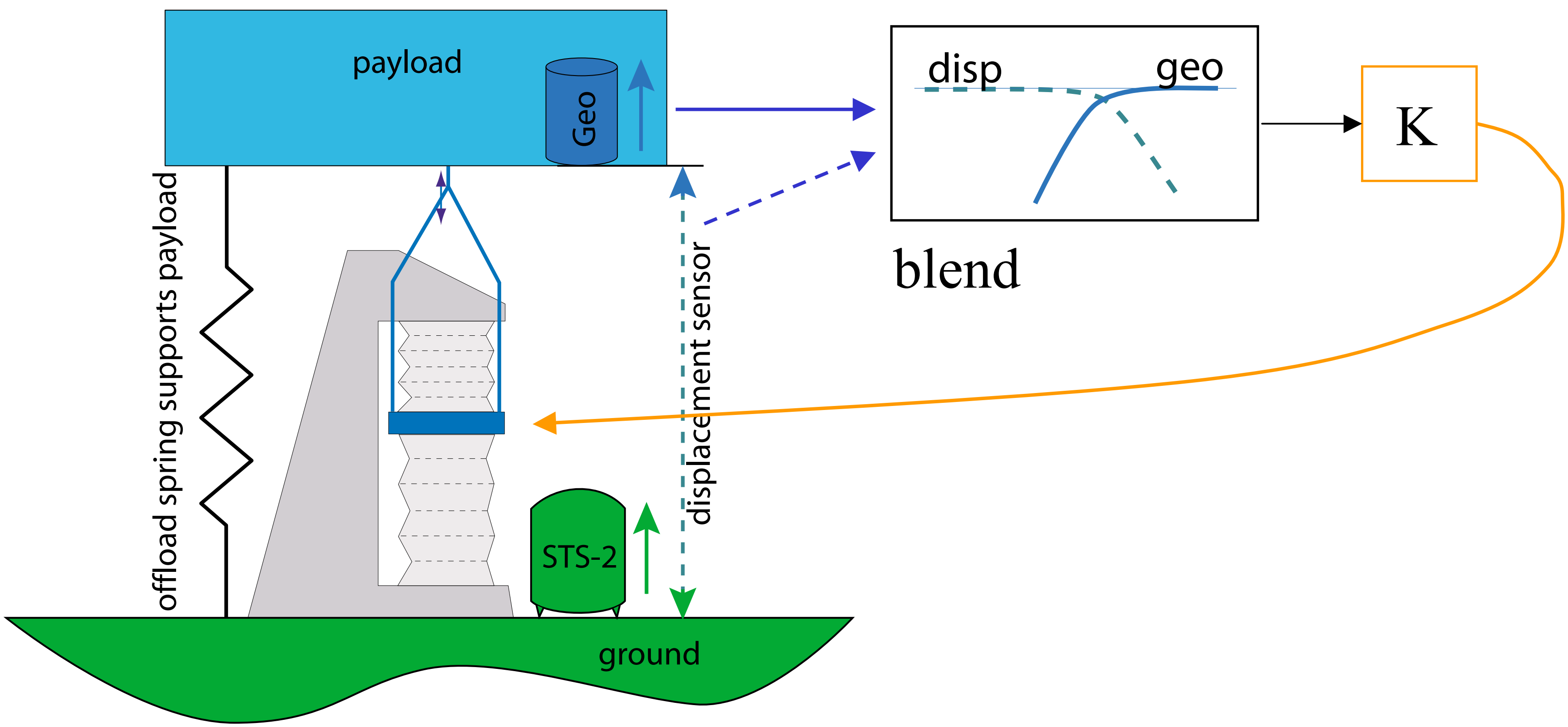

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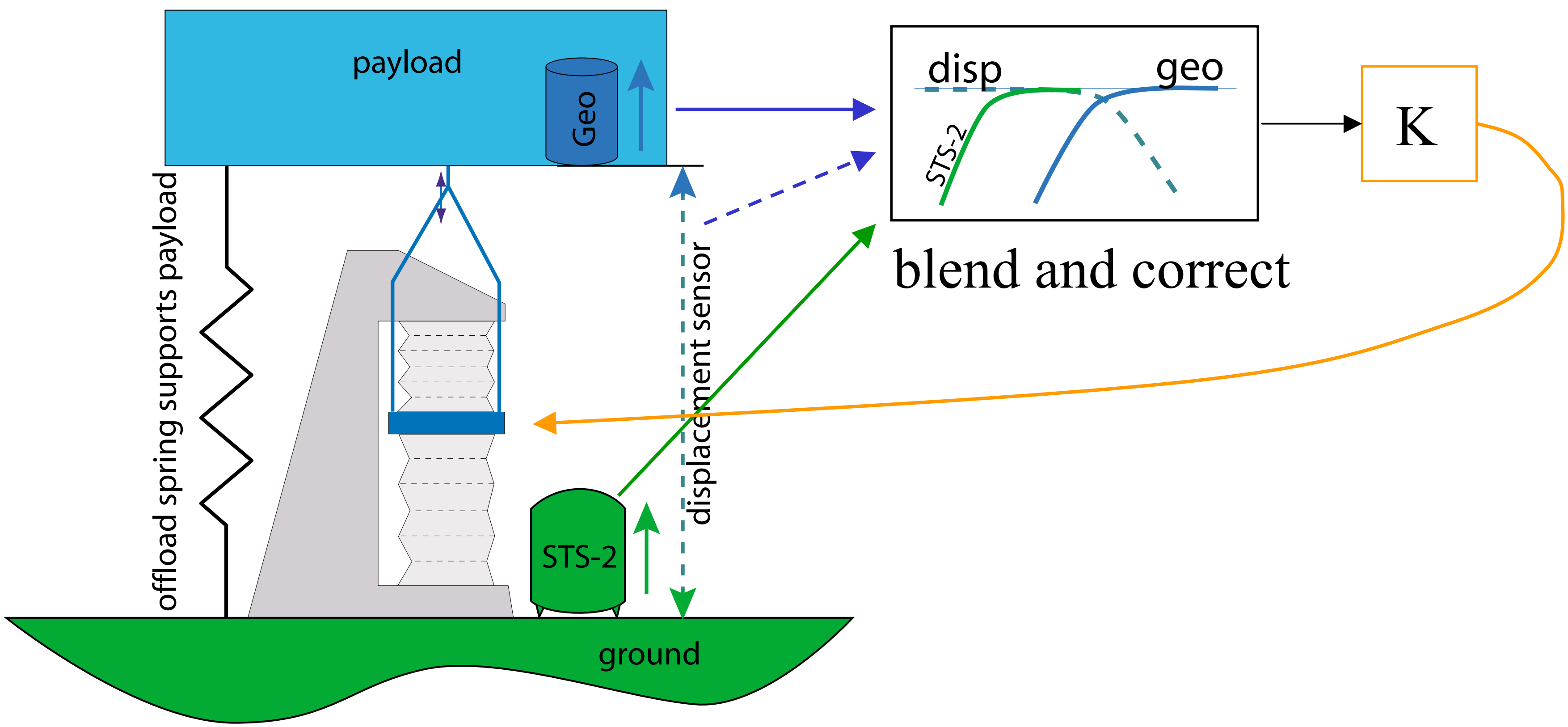


Recently…

There are now 2 full systems installed at LASTI.

Baseline is a system with hydraulic actuators
now installed on the LASTI BSC.

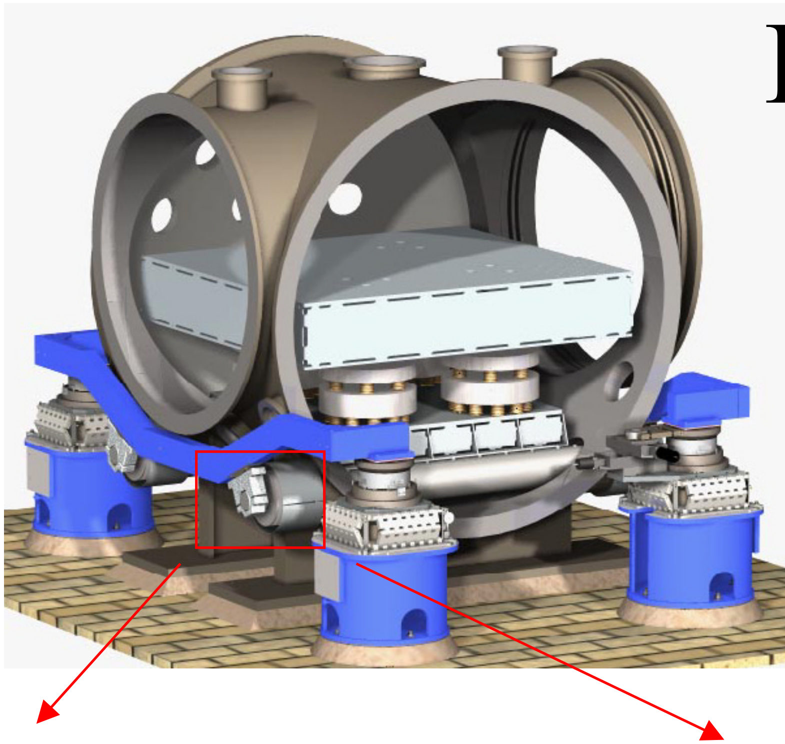
Backup system uses electromagnetic actuators
now installed on a HAM chamber.

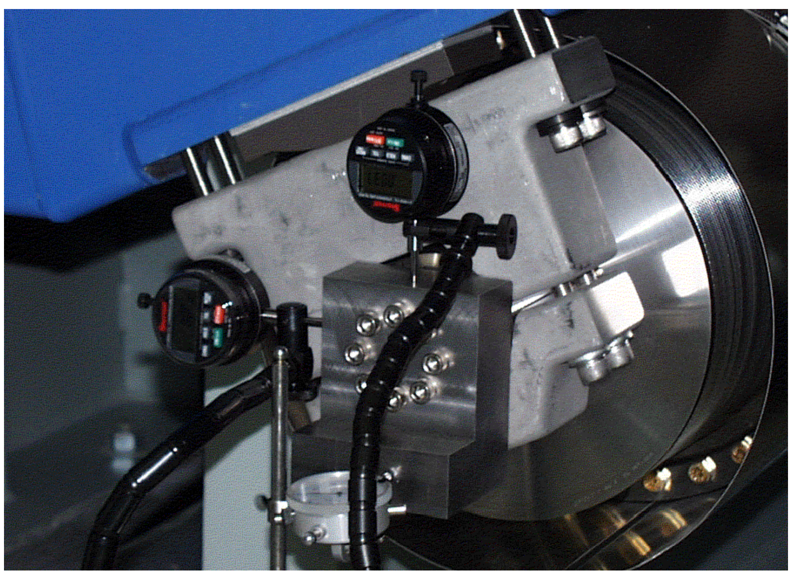
Installation

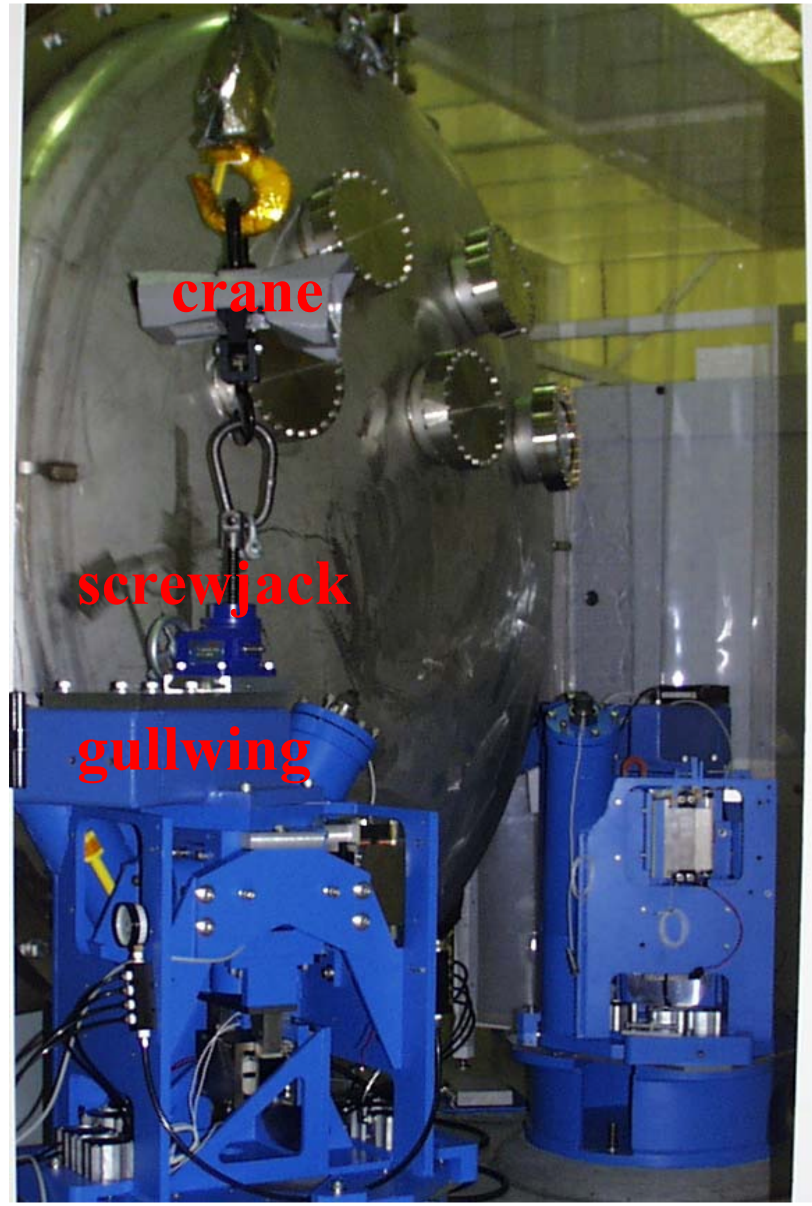
Do not open the vacuum chambers.
Do not disturb the alignment of the installed optics.
Do not drop the baby.

1. Instrument the position of the support table
2. For each corner, lift the crossbeam weldment (.010”) with the crane and manual screwjack
   a) Lower the scissor jack
   b) Remove the old coarse and fine actuators
   c) Install the new frame and actuators
   d) Align the frame, align the payload, align the sensors & actuators
3. With all 4 new corners installed, iterate the alignment with the offload springs and coarse actuation system. (.001”)

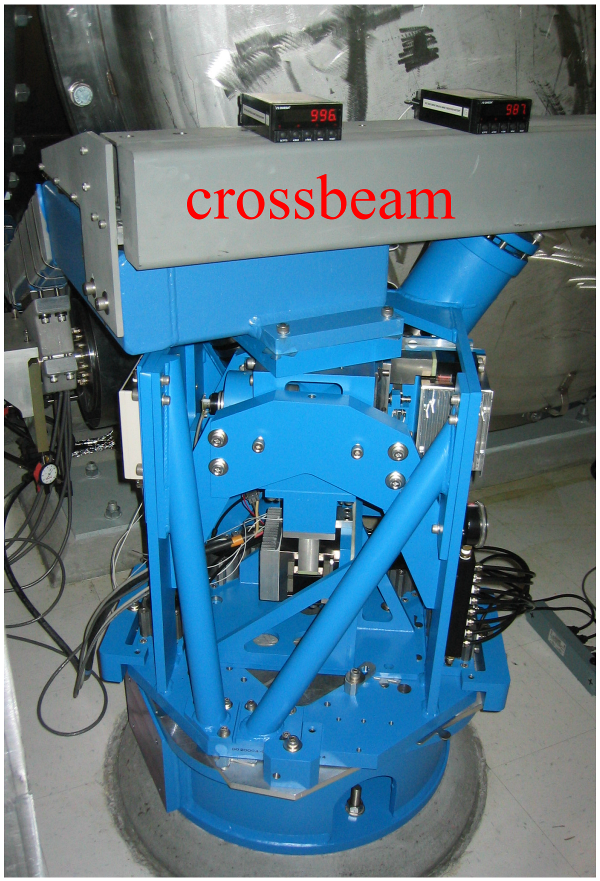
HAM Installation

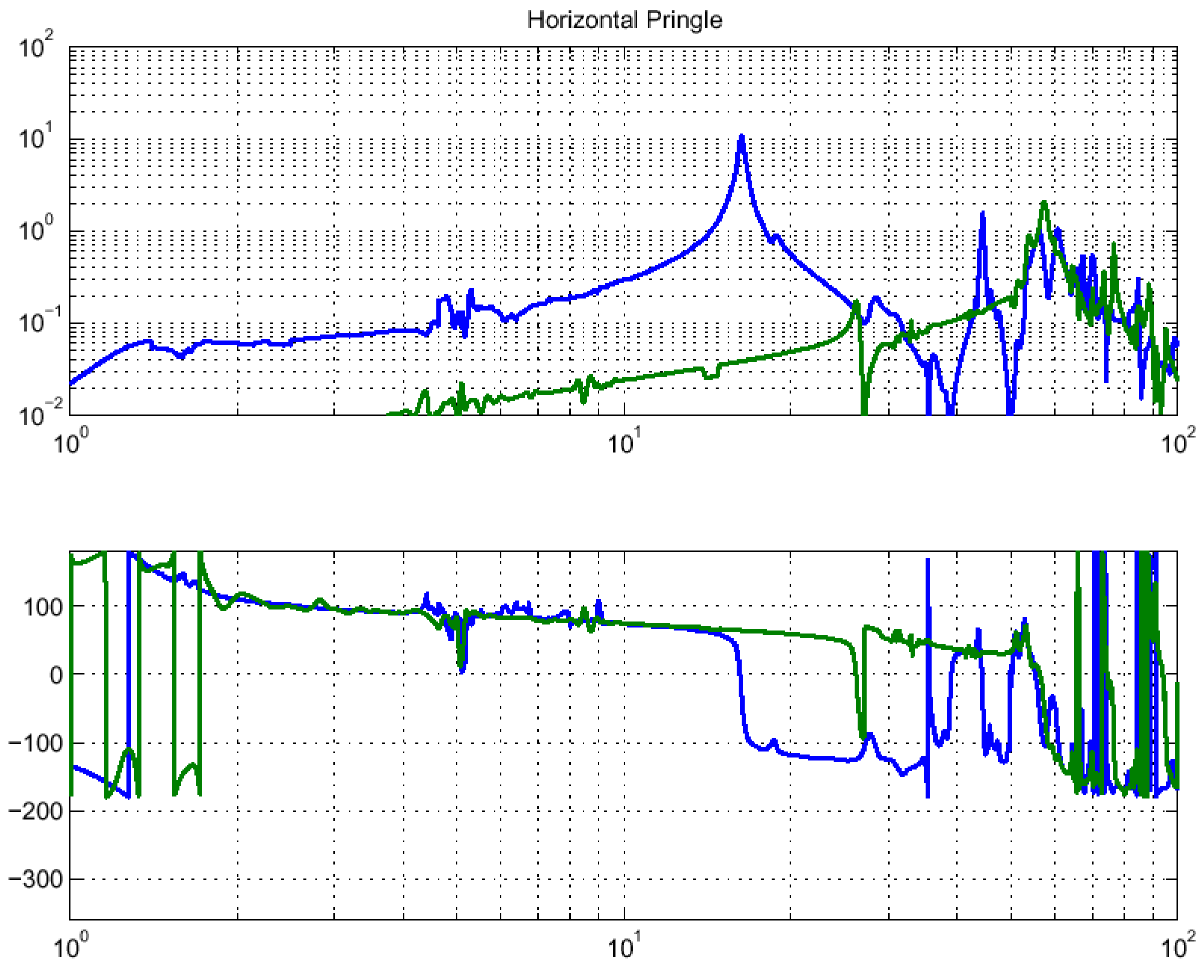






Adding External Crossbeams to Electromagnetic System





Commissioning of the Electromagnetic System

Preliminary results

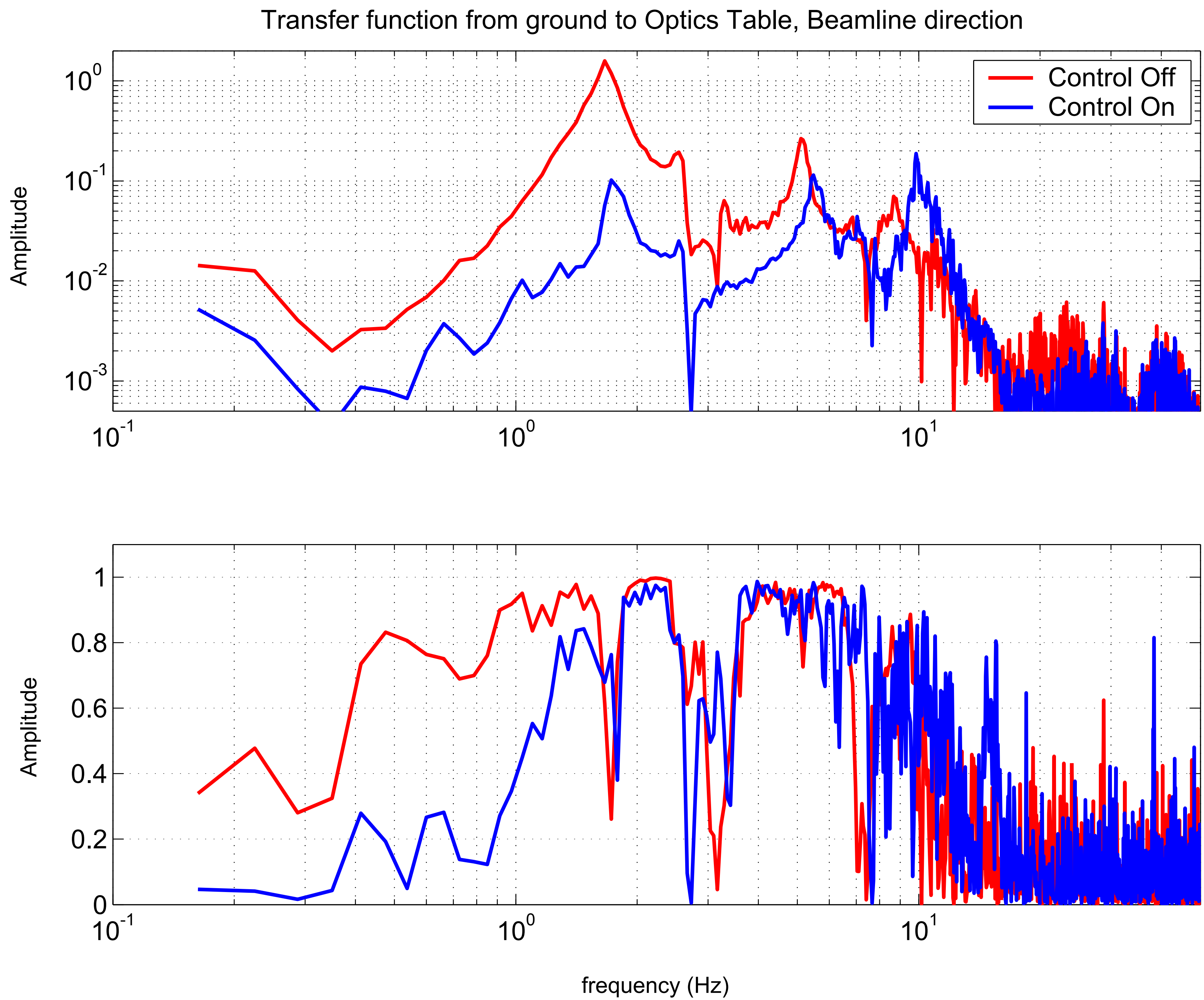
Bandwidth of 10 Hz

Blended sensors, using –
  corrected displacement sensors, and
  inertial feedback geophones,
  blended at 0.5 – 0.7 Hz

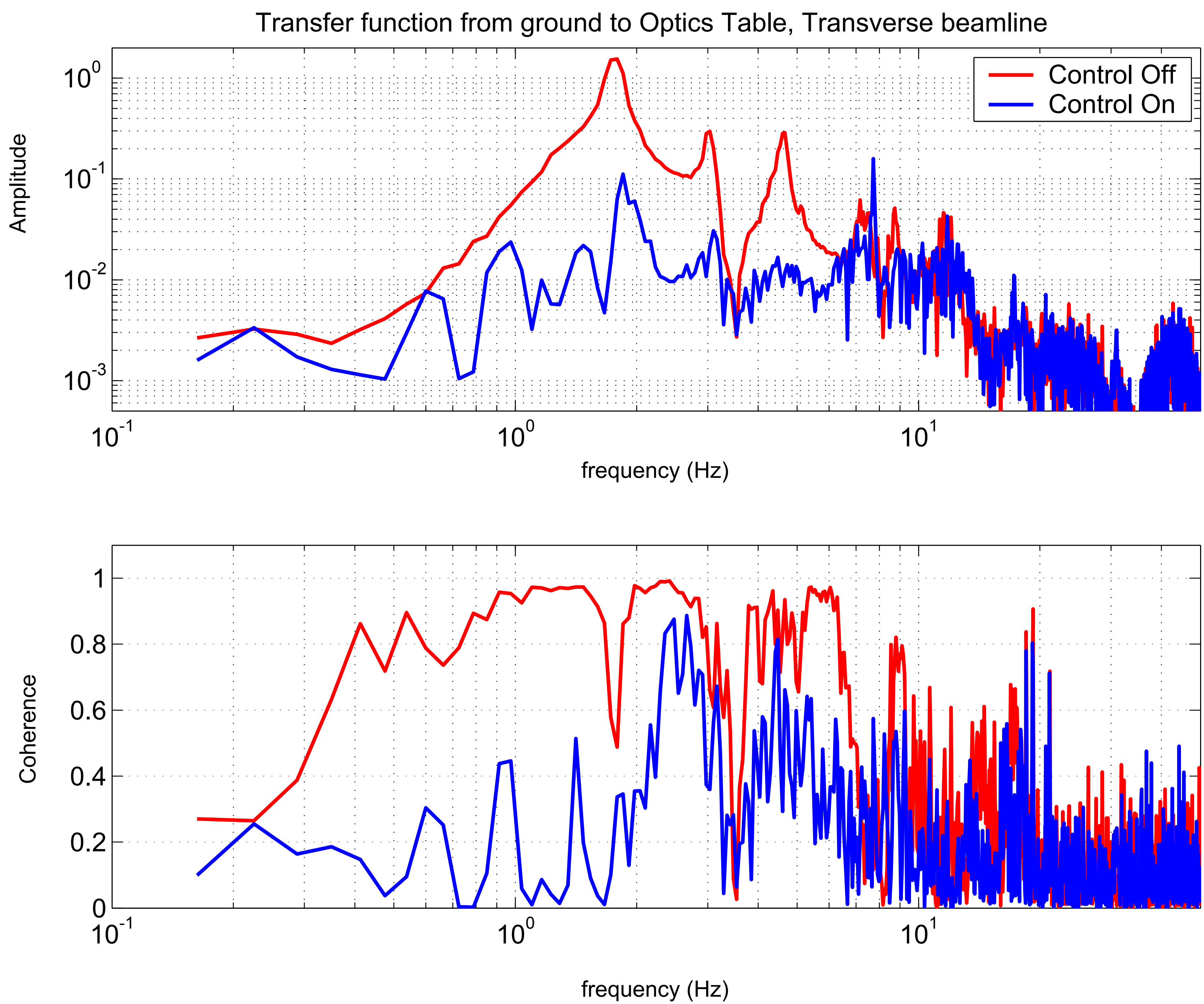
Loops in the coordinate basis (x, y, z, pitch, roll, yaw, O.C.)

Close all 6 DOF

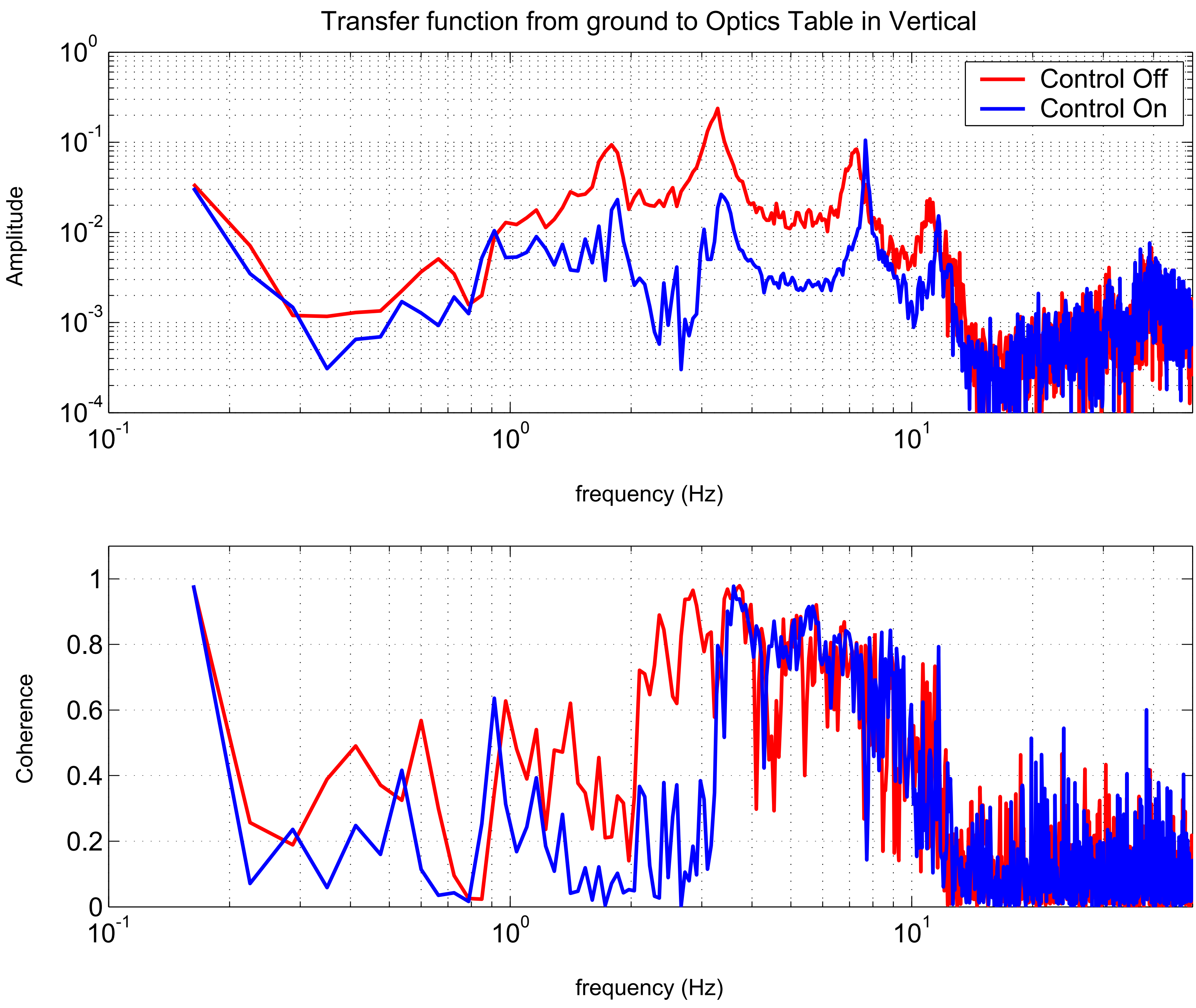
Reasonable isolation at target frequency



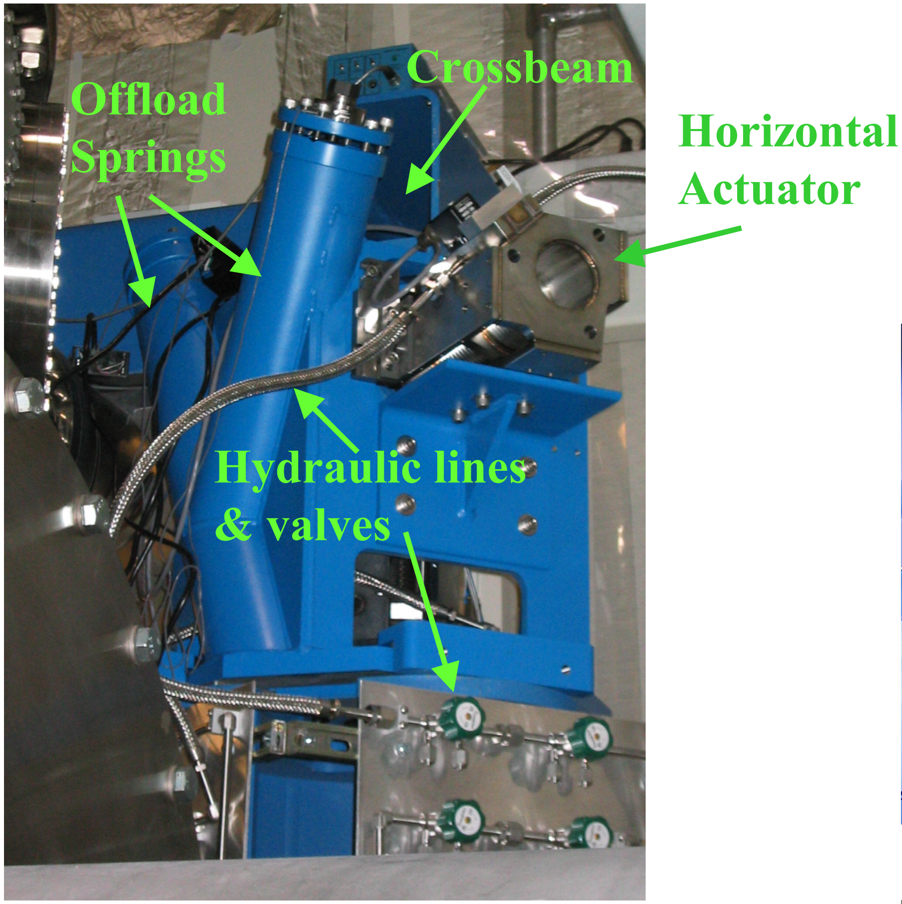
Transfer function from ground to Optics Table, Beamline direction
Control Off
Control On
Amplitude
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-1}
10^{0}
10^{1}
Amplitude
1
0.8
0.6
0.4
0.2
0
10^{-1}
10^{0}
10^{1}
frequency (Hz)

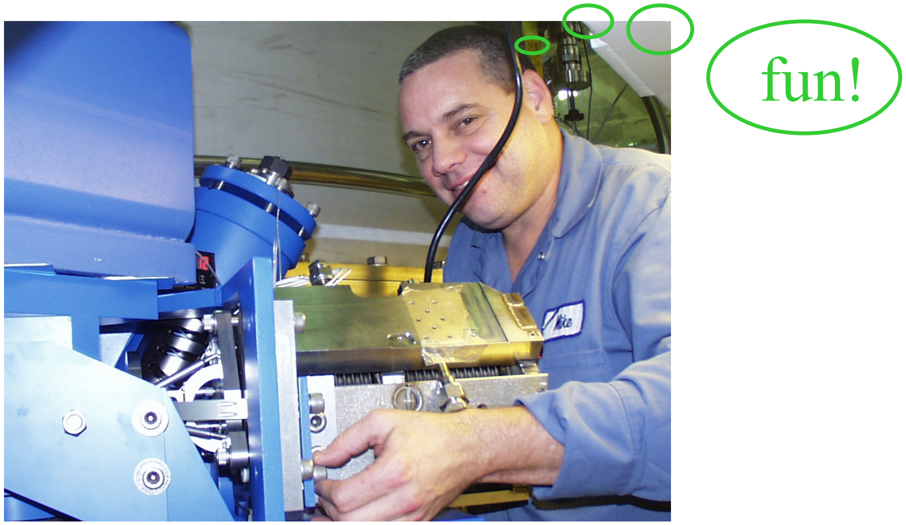


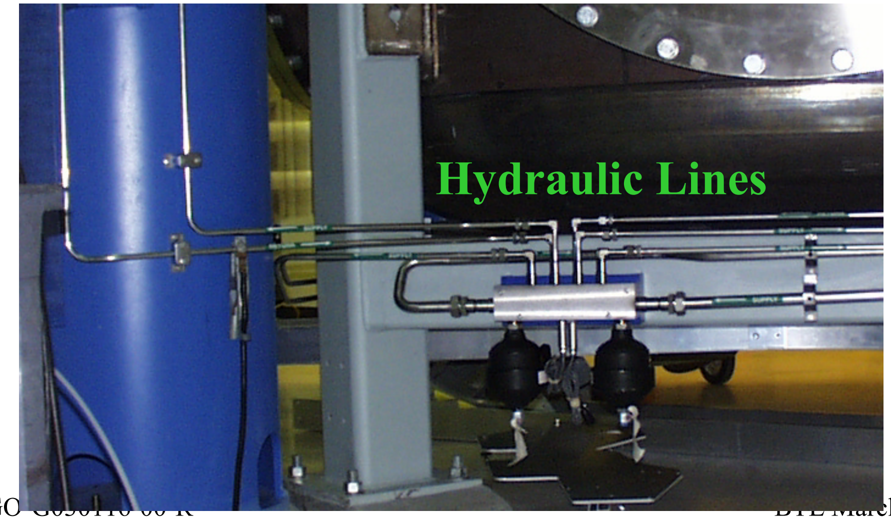
Transfer function from ground to Optics Table, Transverse beamline
Control Off
Control On
Amplitude
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-1}
10^0
10^1
frequency (Hz)
Coherence
1
0.8
0.6
0.4
0.2
0
10^{-1}
10^0
10^1
frequency (Hz)

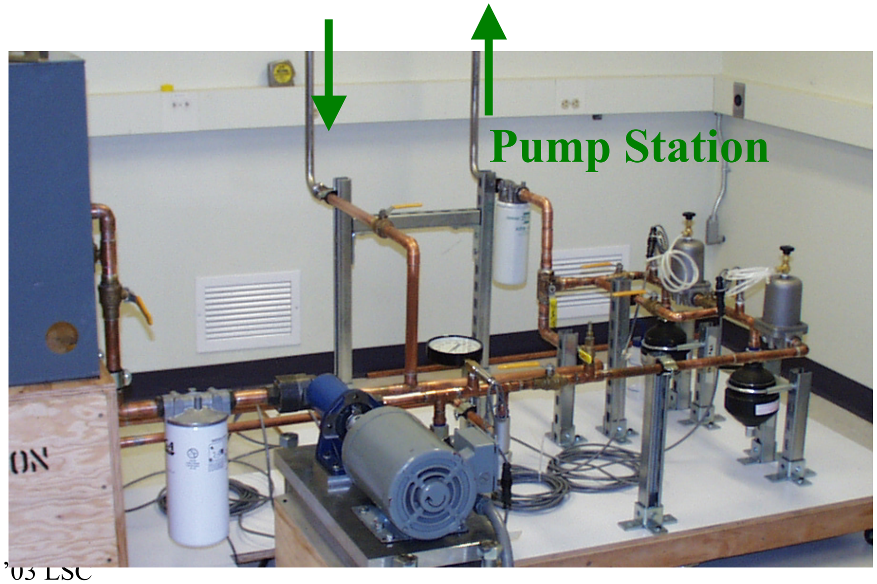

Transfer function from ground to Optics Table in Vertical
Control Off
Control On
Amplitude
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-1}
10^0
10^1
frequency (Hz)
Coherence
1
0.8
0.6
0.4
0.2
0
10^{-1}
10^0
10^1
frequency (Hz)

Hydraulic Installation









Commissioning of the Hydraulic system

Preliminary results

Bandwidth of 10 Hz

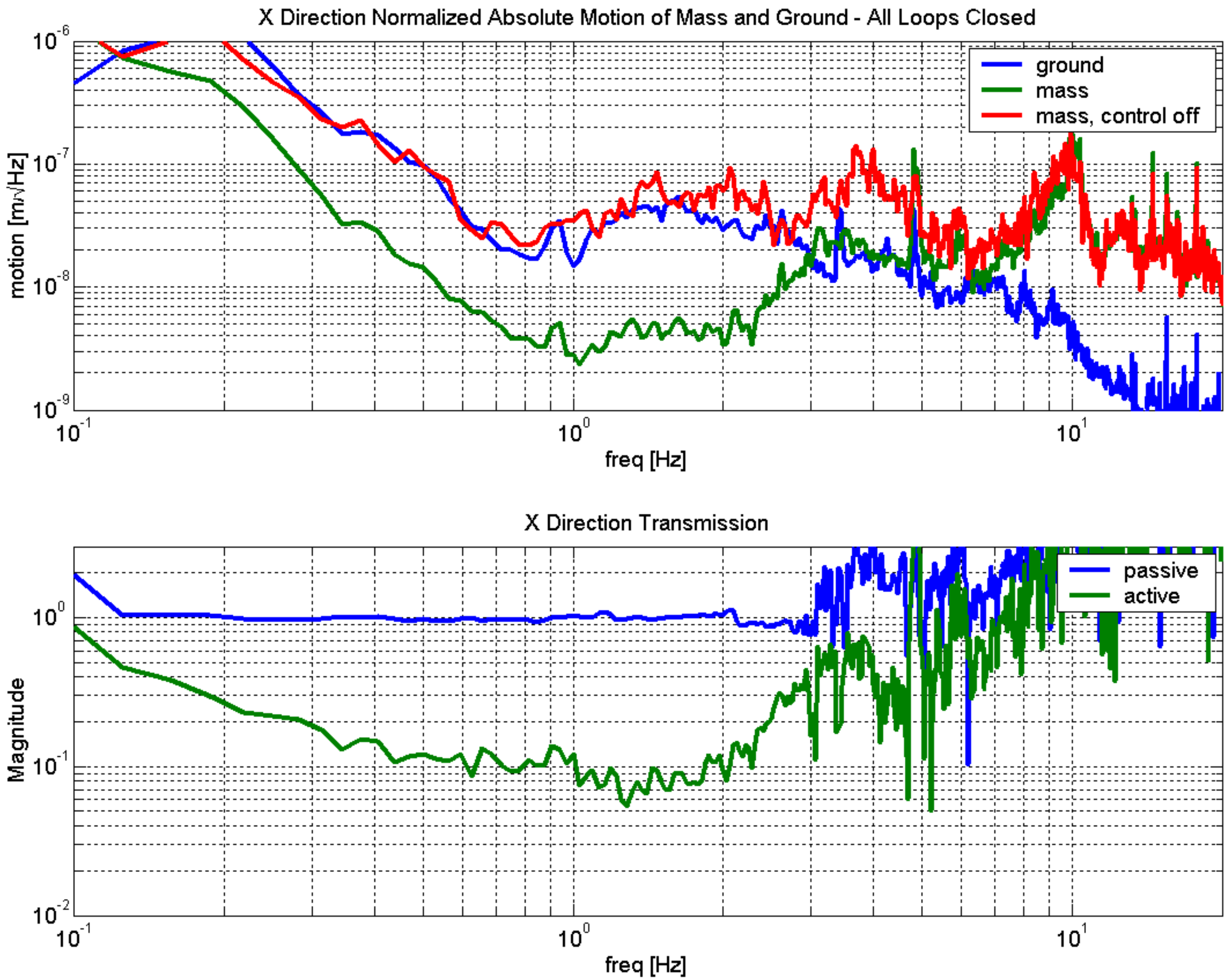
Blended sensors in the vertical direction, using –
corrected displacement sensors, and
inertial feedback geophones,
blended at 0.8 Hz

Loops in the coordinate basis (x, y, z, pitch, roll, yaw, O.C.)

Close all 6 DOF

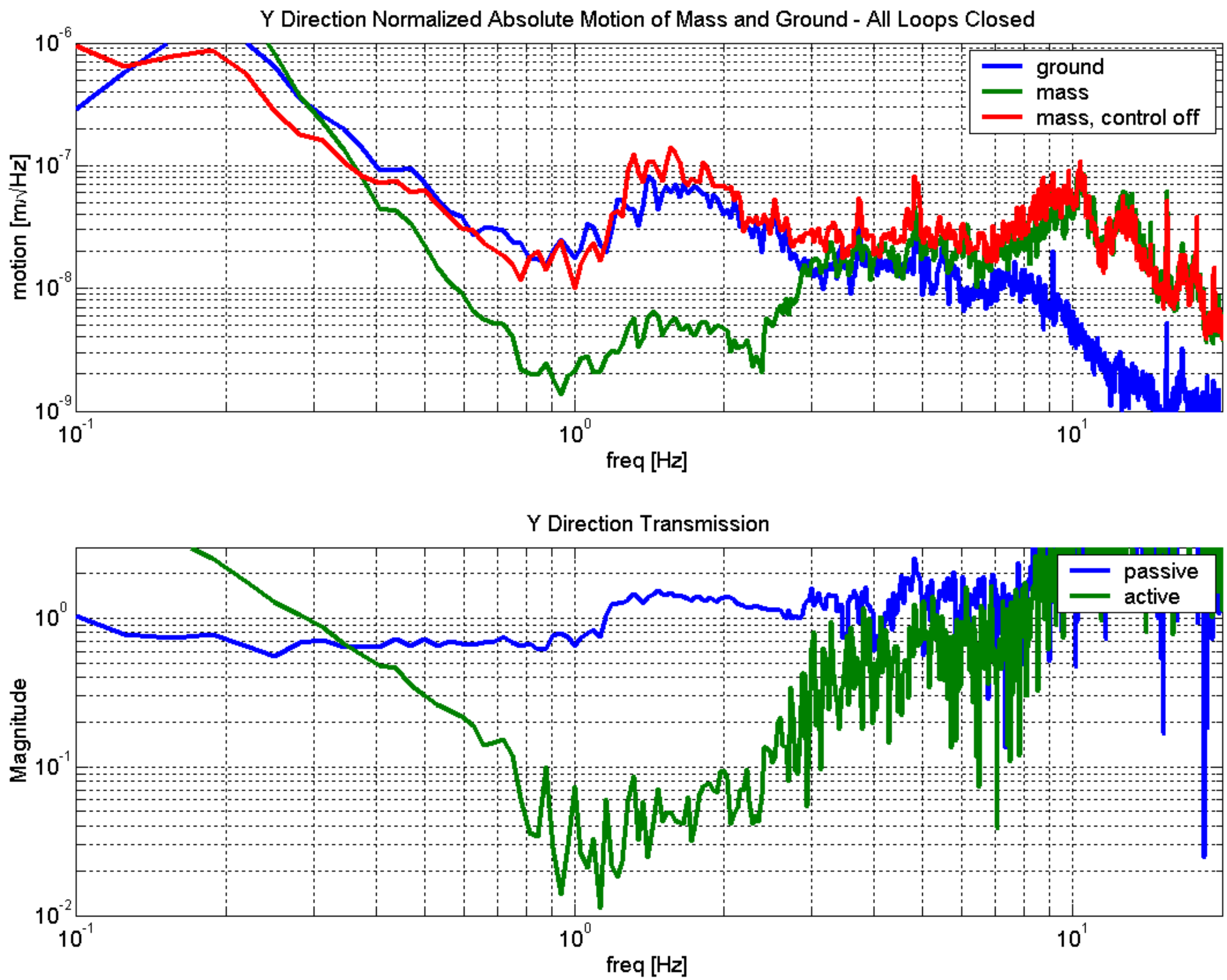
Reasonable isolation at target frequency

Preliminary Performance in X



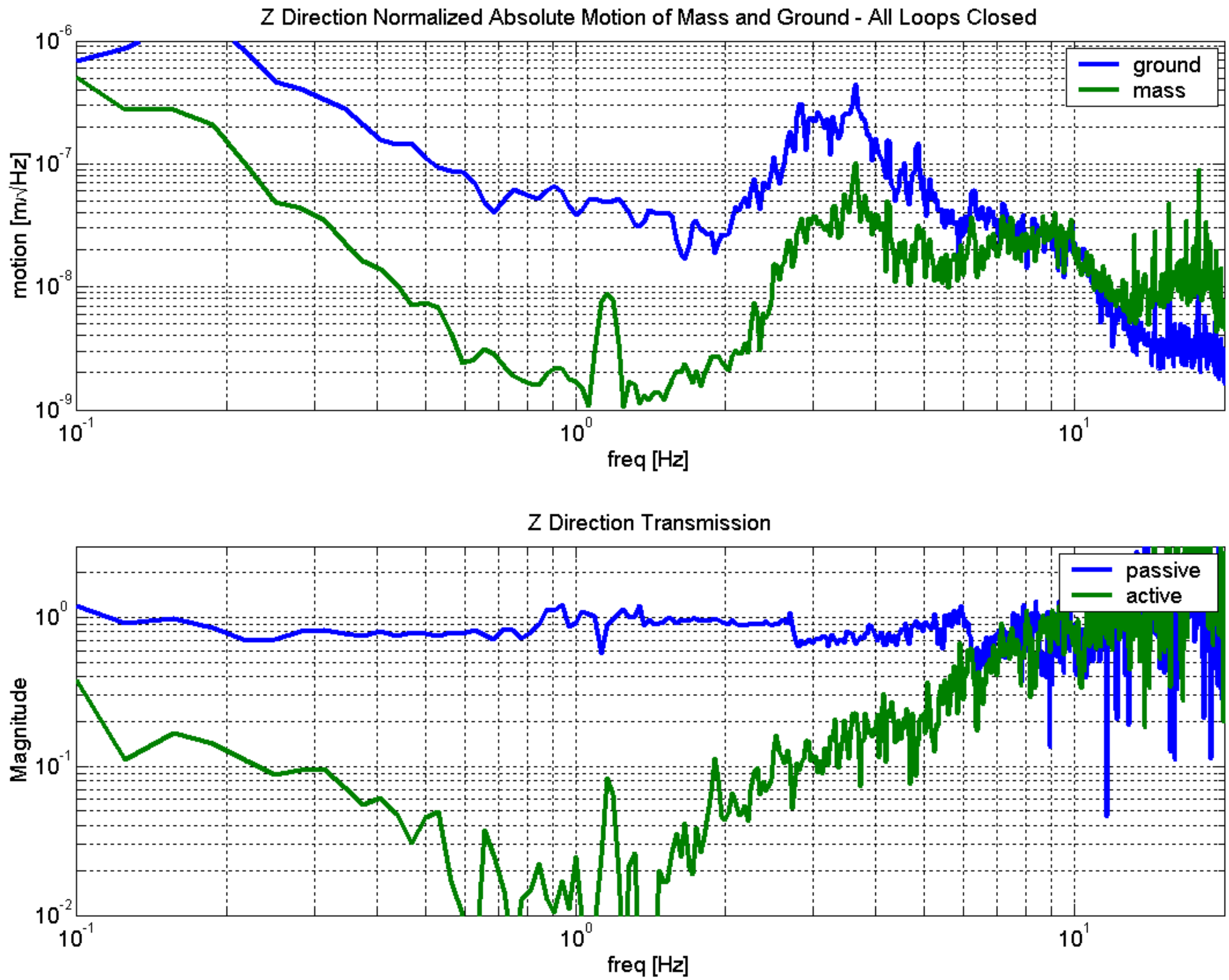
data: Corwin Hardham Jan ’03

Preliminary Performance in Y



data: Corwin Hardham Jan ’03

Preliminary Performance in Z



data: Corwin Hardham Jan ’03

To Conclude

We can install an external isolation system with minimal disruption to the LIGO optics.

We have achieved ~10x isolation performance from the microseism to ~2 Hz, partly covering the problematic frequency band.

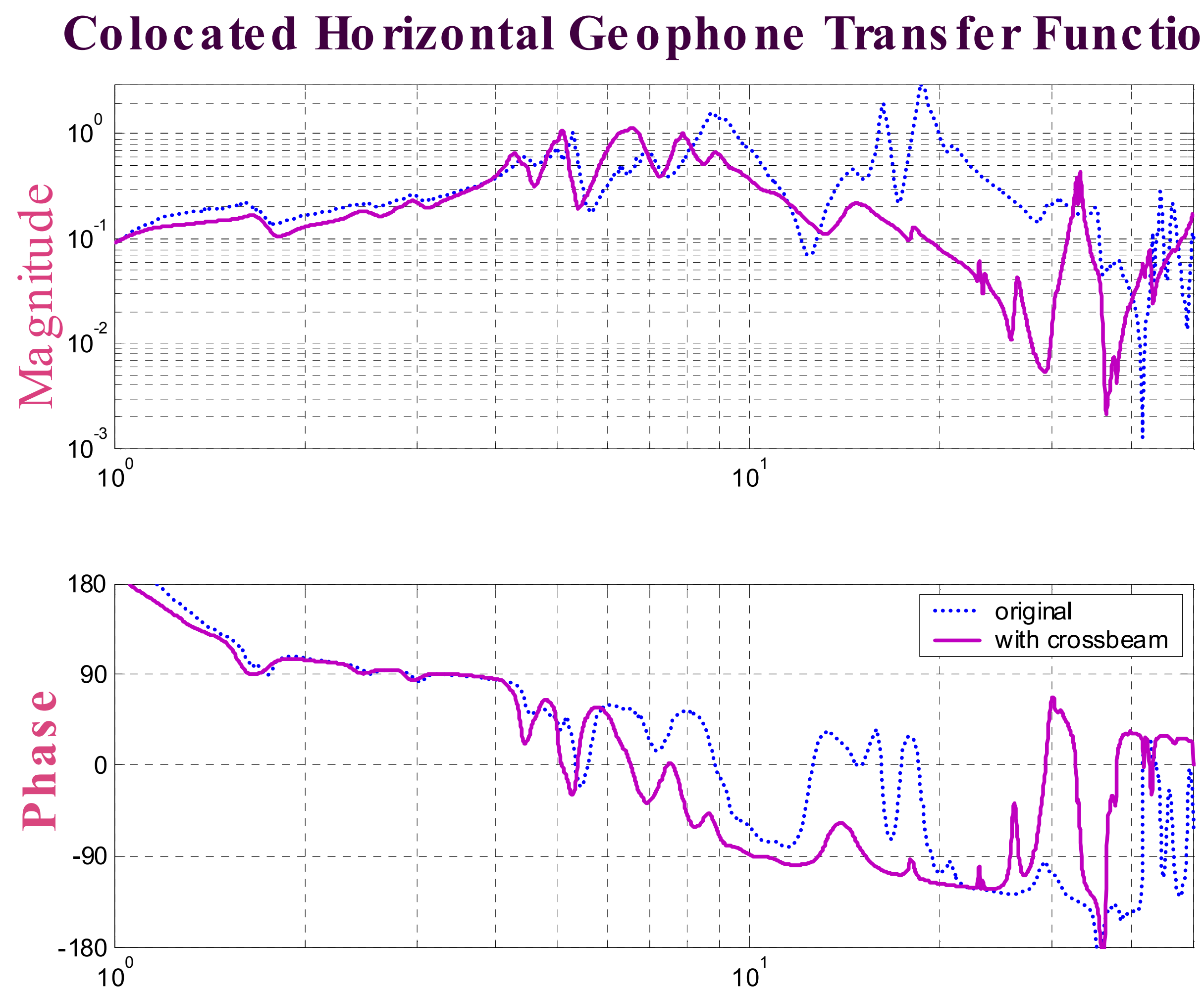
We can easily track the tidal motion with the hydraulic system.

Modifications the HAM simplify the installation and control.

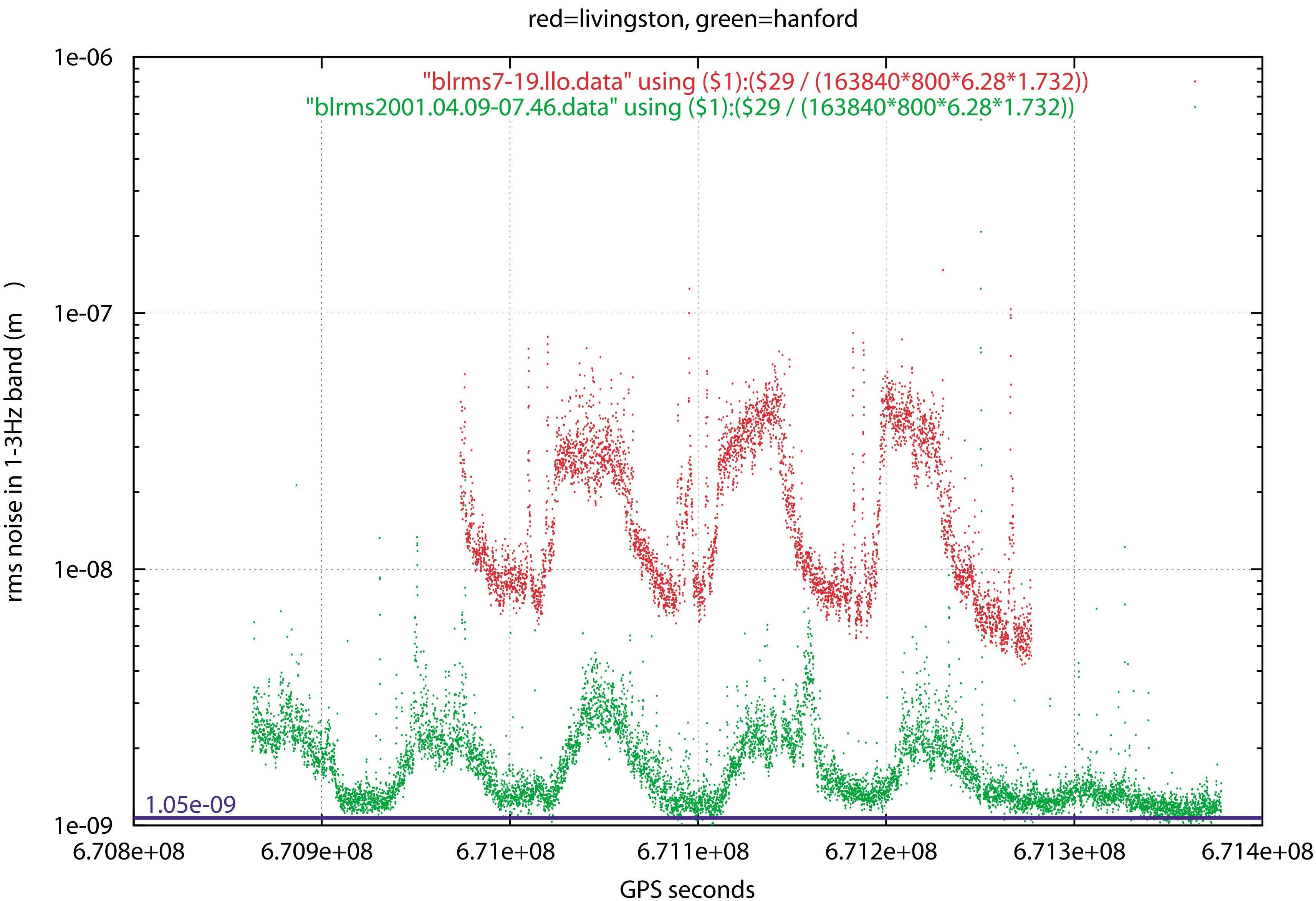
We are actively preparing for a review in mid-April.

We are eager to begin installation next door.

Improvement in the bending mode



Comparison of the sites

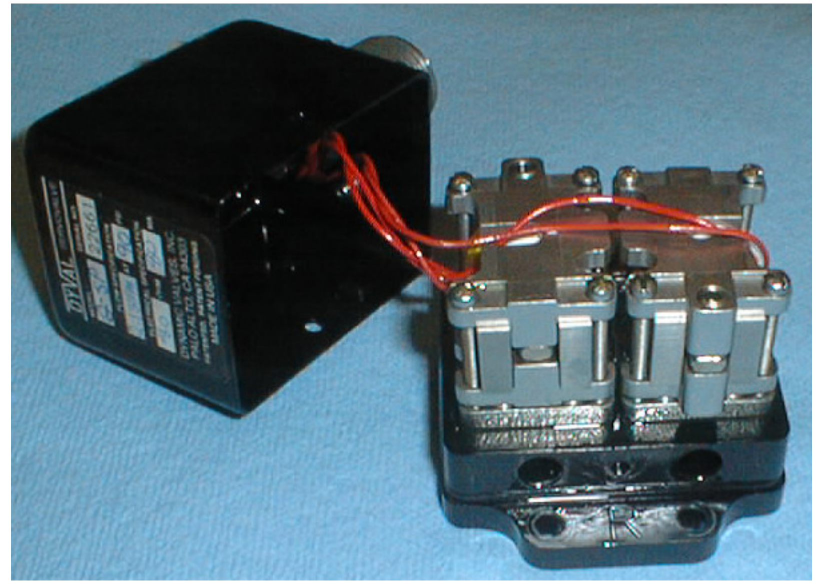


Design Trades

Performance \ Parameter		Specification		Design					Related Parameter	
		δ=1mm	Δt=10 sec	Ps=5 bar	β=2e3 bar	R = 5e10 Pa-sec/m^3	A=.01 m^2	V=3e-4 m^3	m=1e3 kg	k=4e6 N/m
1) Hydraulic Resonance $\omega_n^2 = \frac{2A^2\beta}{mV}$	↑			↑	↑		↑	↓	↓	
2) Damping $\zeta = \frac{1}{RA}\sqrt{\frac{m\beta}{2V}}$	↑			↑	↑	↓	↓	↓	↑	
3) Bridge Power Dissipation $P_b = \frac{P_s^2}{R}$	↓			↓		↑				
4) Acquisition Power $P_{acq} = \frac{k\delta^2}{\Delta t}$	↓	↓	↑							↓
5) Microseism Power $P_\mu = k\delta\delta_s w_s$	↓	↓								↓
6) Microseism vs. Bridge $\frac{P_{acq}}{P_b} = \frac{k\delta\delta_s\omega_s R}{P_s^2}$	↓	↓		↑		↓				↓
7) Microseism vs. Acquisition $\frac{P_\mu}{P_{acq}} = \frac{\delta_s\omega_s\Delta t}{\delta}$	↓	↑	↓							

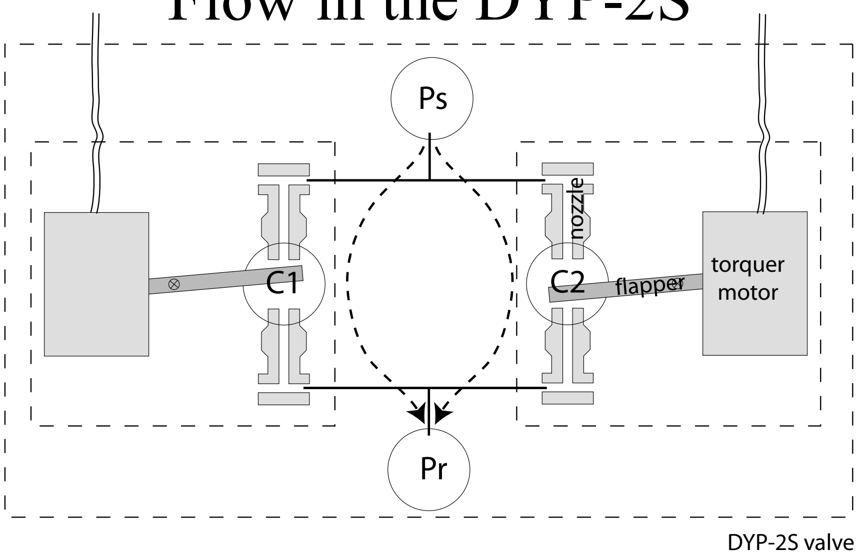
Hydraulic Valve forms the bridge

- Differential bridge in a single valve body
- 4 nozzles – one for each resistor in the bridge
- Original nozzles replaced with custom units shown below right.



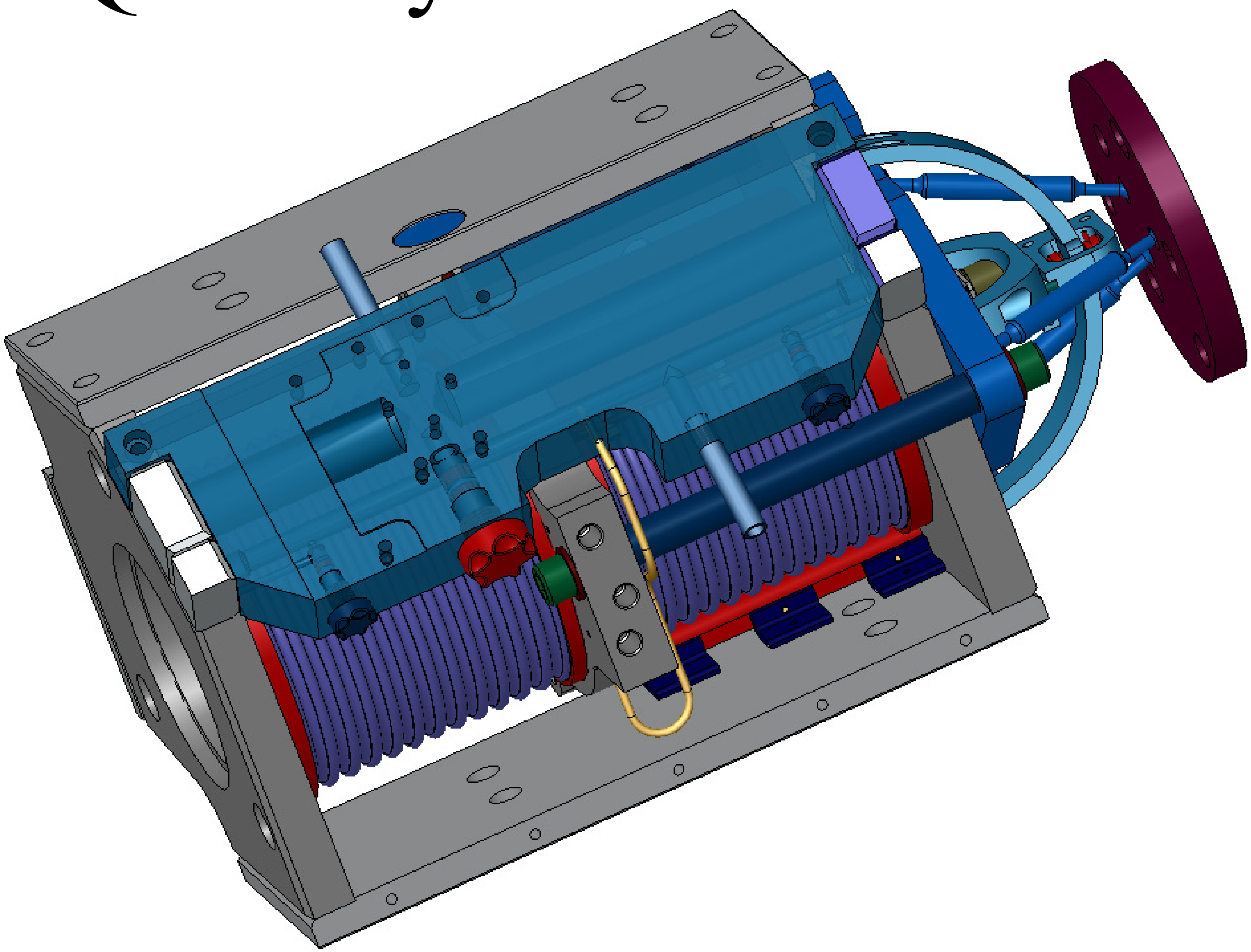
Parker DYP-2S valve

Flow in the DYP-2S



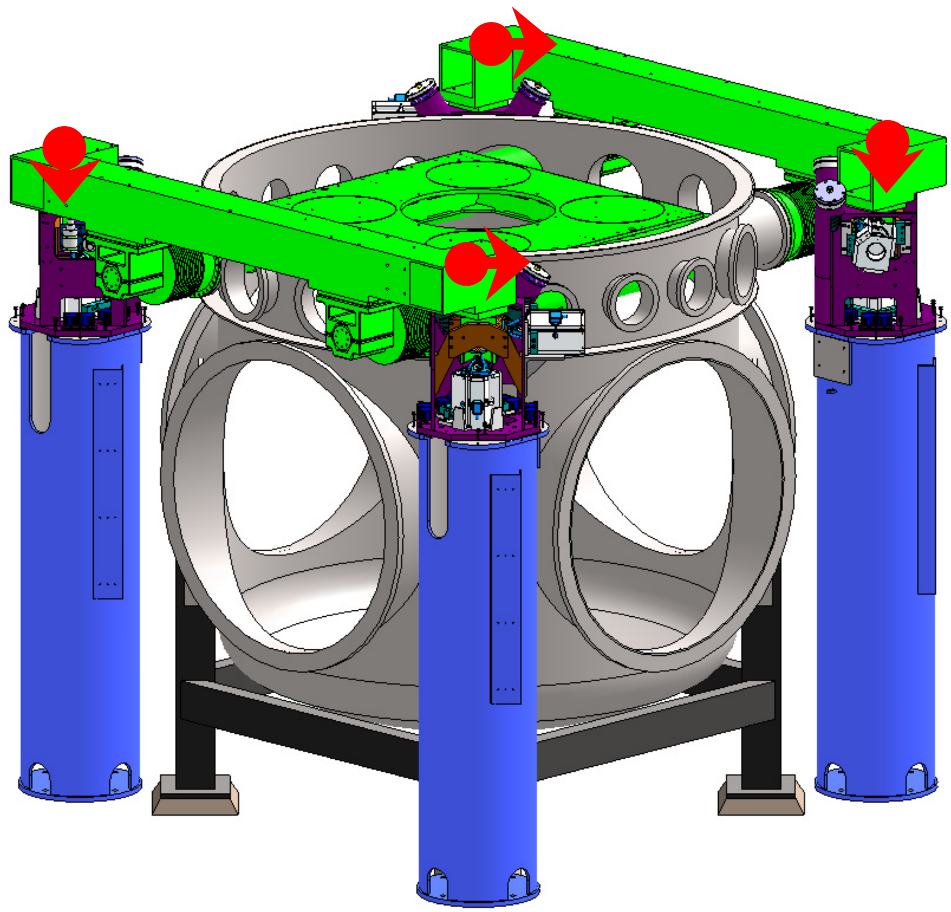
The new nozzle

Quiet Hydraulic Actuator

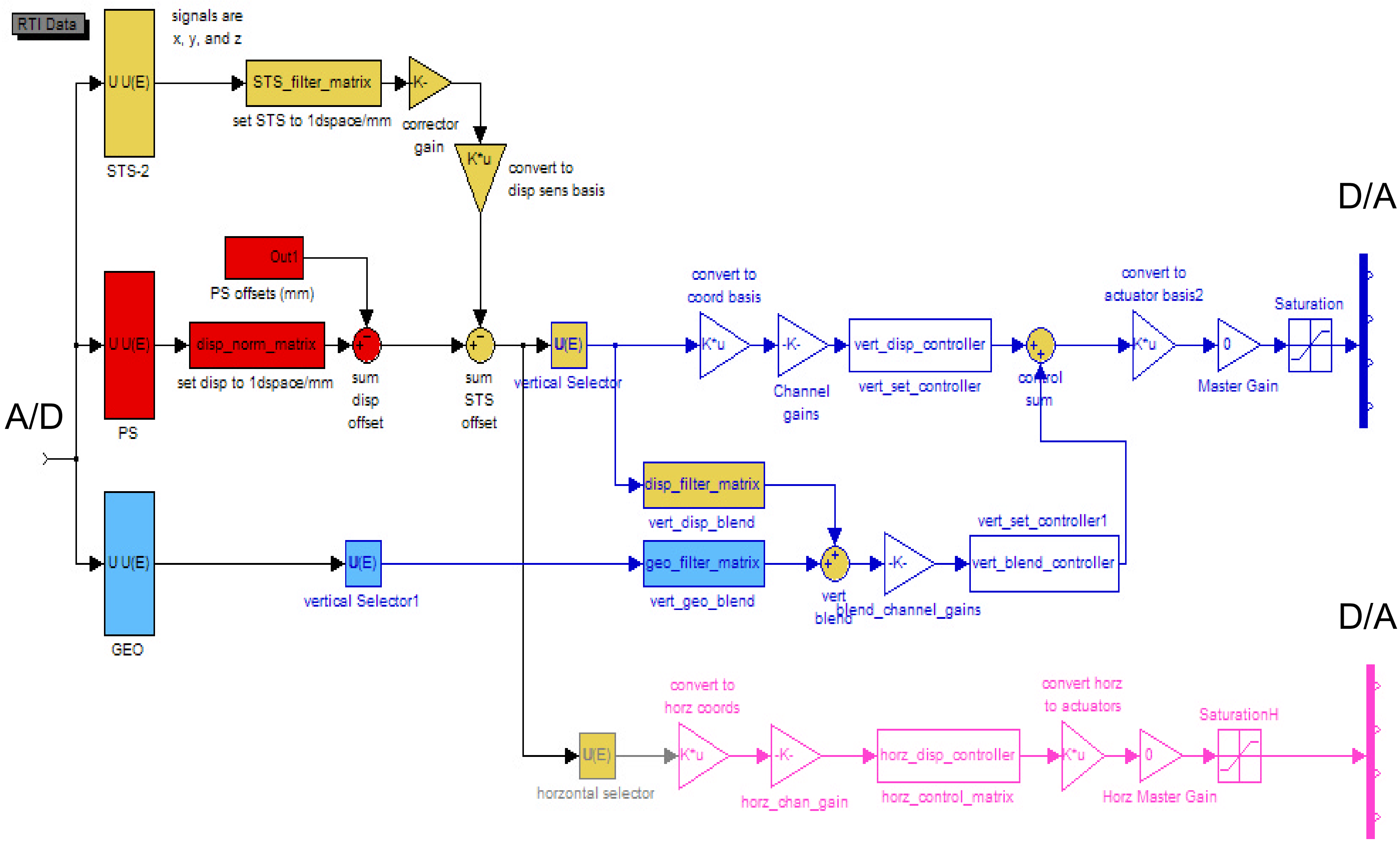


Control Strategy

- Translation X
- Translation Y
- Translation Z
- Pitch
- Roll
- Yaw
- O.C. Vert
- O.C. Horz



Controller


RTI Data
signals are
x, y, and z
U U(E)
STS_filter_matrix
-K-
set STS to 1dspace/mm
corrector
gain
K*u
convert to
disp sens basis
STS-2
D/A
Out1
PS offsets (mm)
disp_norm_matrix
set disp to 1dspace/mm
sum
disp
offset
sum
STS
offset
U(E)
vertical Selector
convert to
coord basis
Channel
gains
vert_disp_controller
vert_set_controller
control
sum
convert to
actuator basis2
Master Gain
Saturation
A/D
PS
disp_filter_matrix
vert_disp_blend
geo_filter_matrix
vert_geo_blend
vertical Selector1
vert
blend
blend_channel_gains
vert_set_controller1
vert_blend_controller
GEO
D/A
horzontal selector
convert to
horz coords
horz_chan_gain
horz_disp_controller
horz_control_matrix
convert horz
to actuators
Horz Master Gain
SaturationH