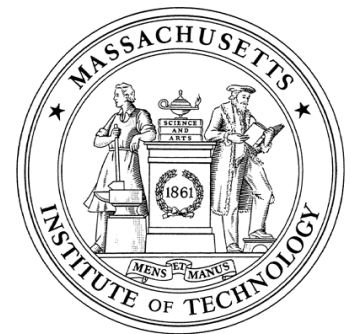


# Current Work on Hydraulics for LIGO 1

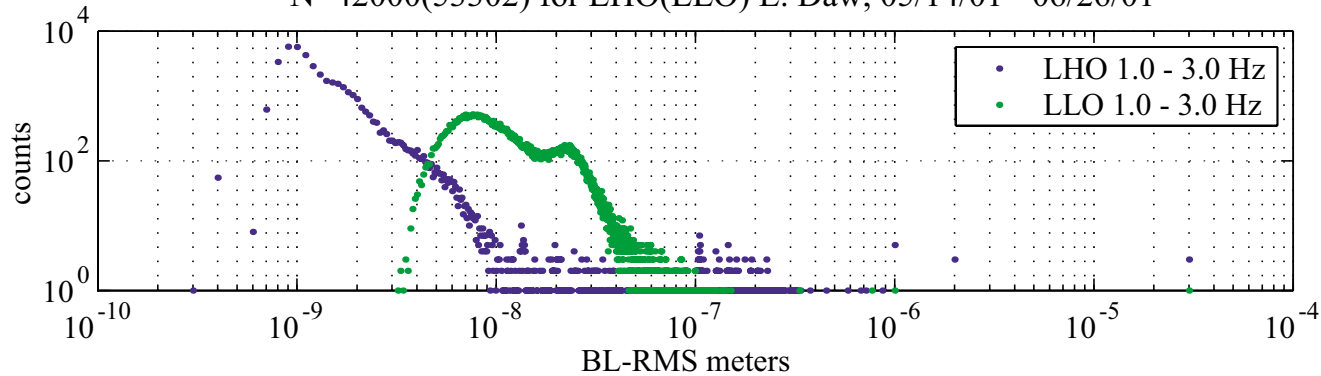
Stanford, Caltech, LSU, MIT, LLO

Rich Abbott, Graham Allen, Daniel DeBra, Dennis Coyne,  
Jeremy Faludi, Amit Ganguli, Joe Giaime, Marcel Hammond,  
Corwin Hardham, Wensheng Hua, **Brian Lantz**, Ken Mailand,  
Ken Mason, Rich Mittleman, Jamie Nichol, Joshua Phinney,  
David Shoemaker, Michael Smith



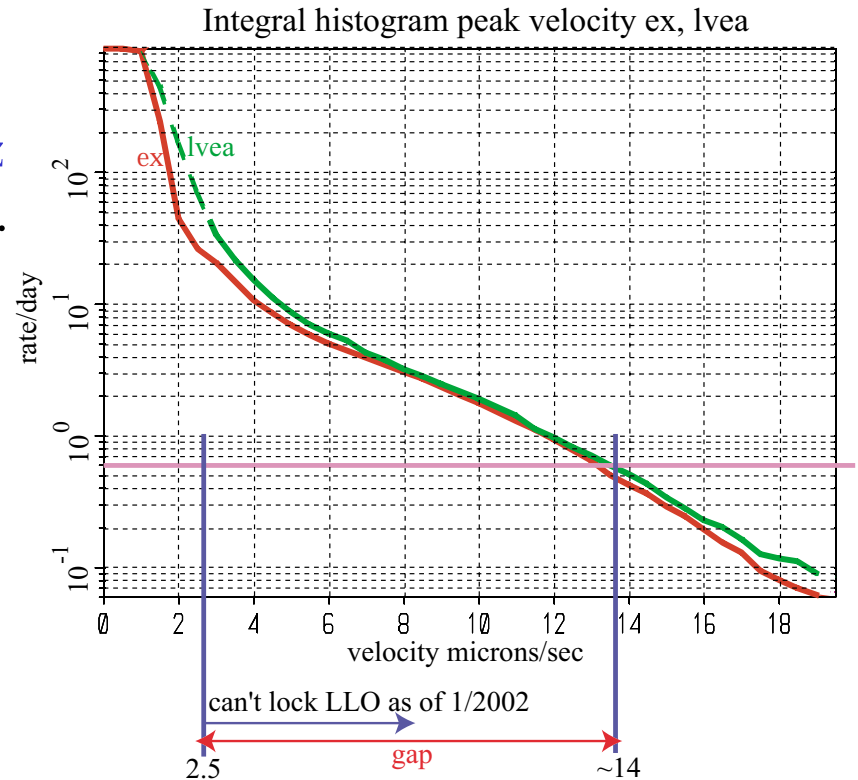
# Additional Isolation for LIGO 1?

Histograms of band limited rms noise in 1 of 5 frequency bands.  
 N=42000(53302) for LHO(LLO) E. Daw, 05/14/01 - 06/26/01



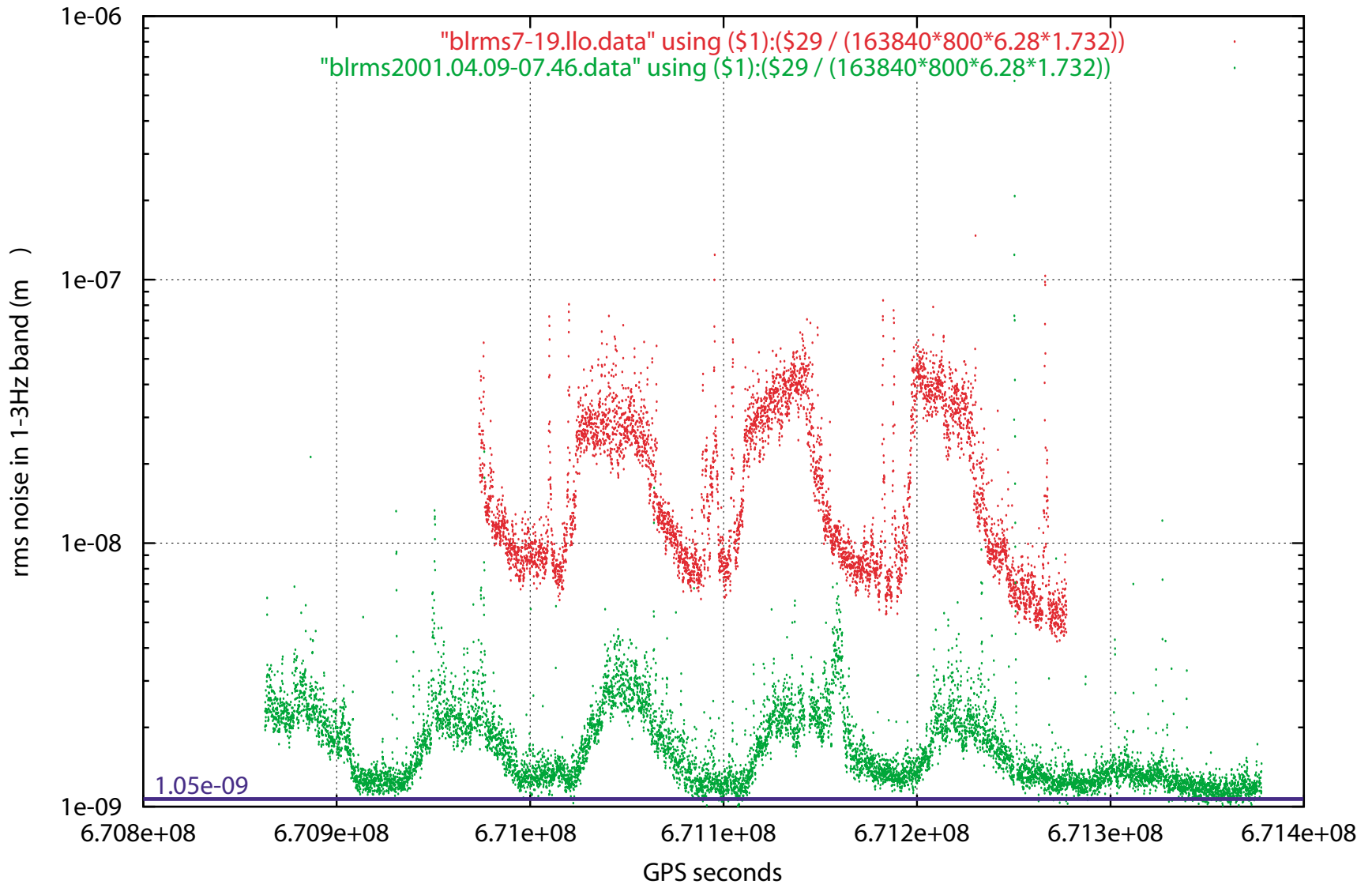
Figures from  
 Ed Daw,  
 Rai Weiss

Excess ground motion at LLO requires  
 reduction in the band limited RMS at 1-3 Hz  
 by  $\sim 15$  to maintain lock for at least 40 hours.



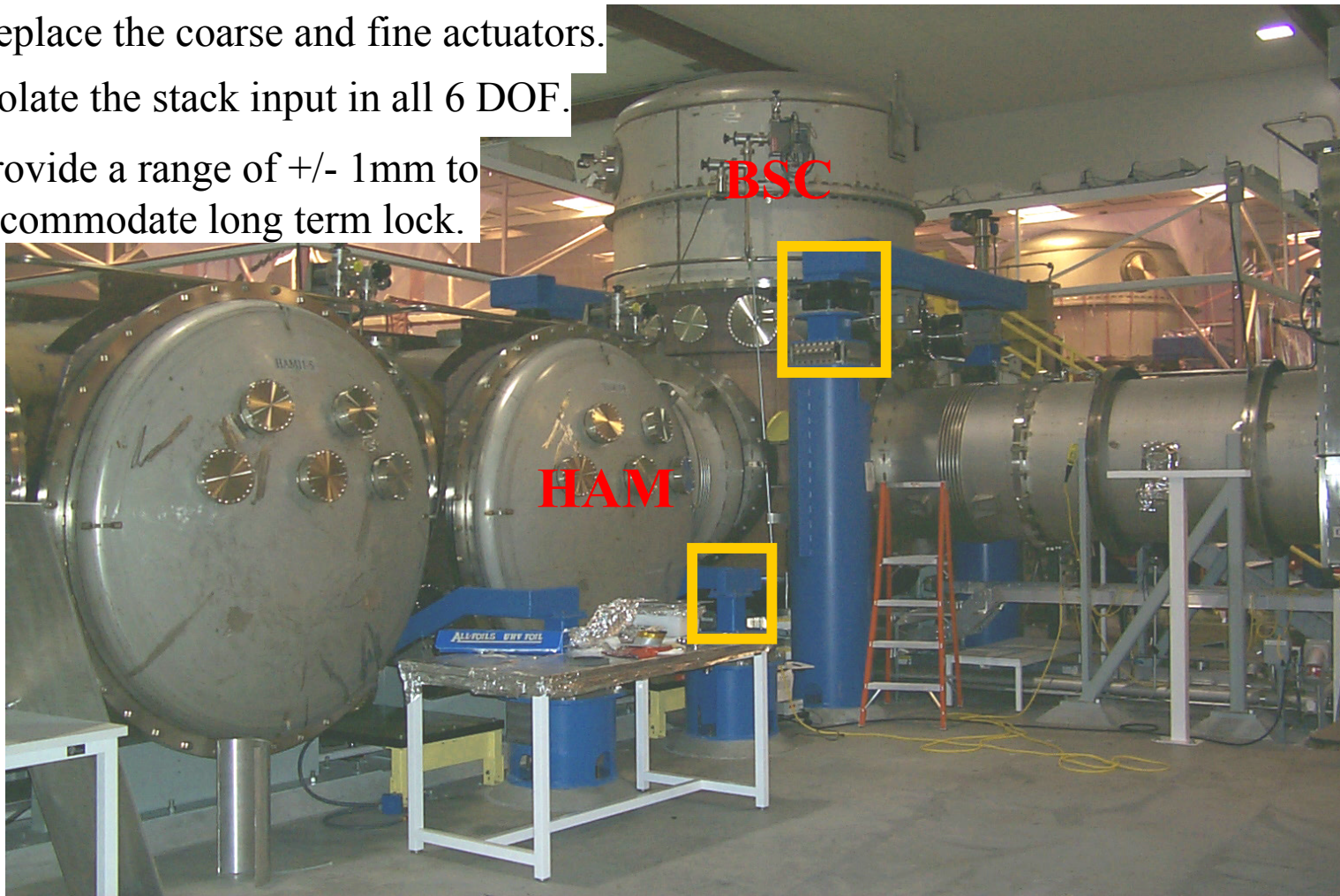
# Time history

red=livingston, green=hanford

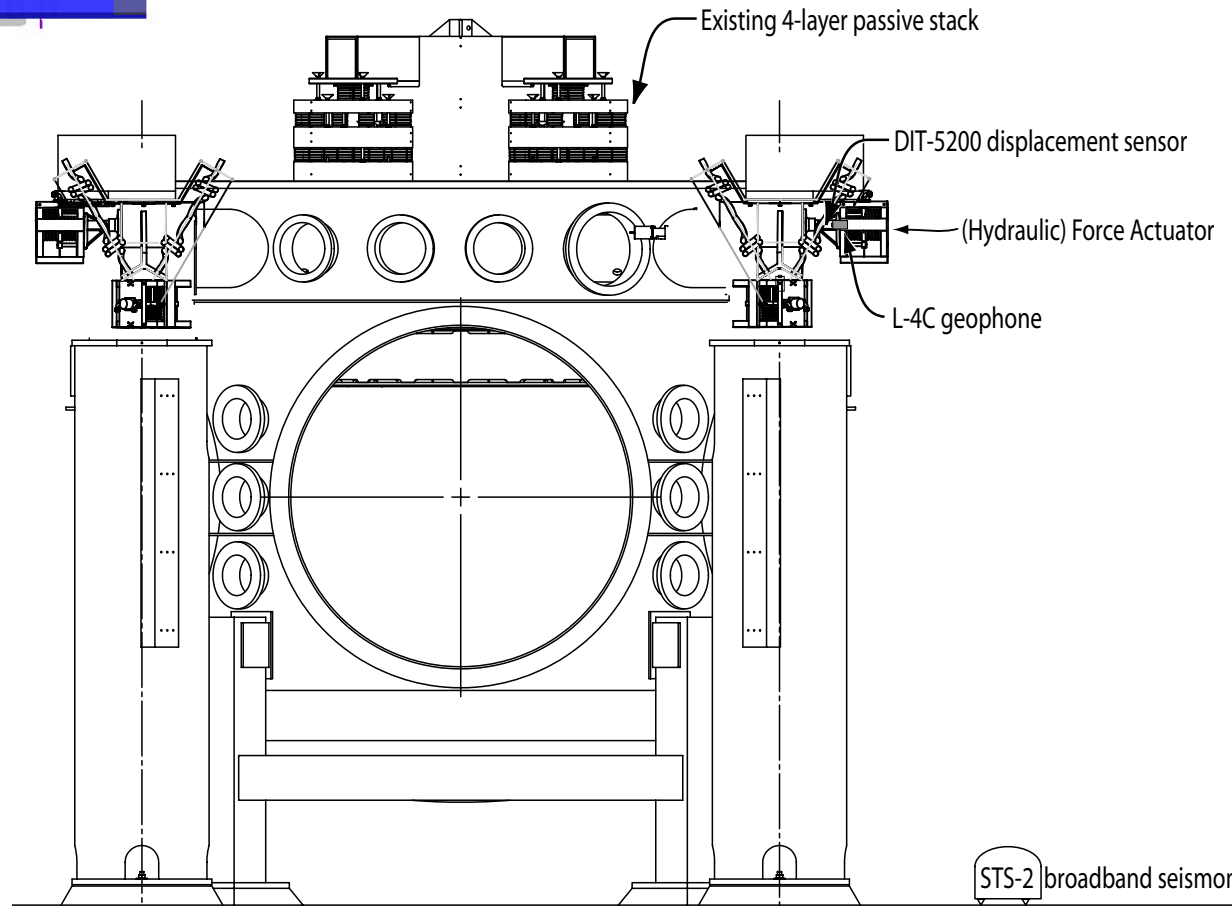
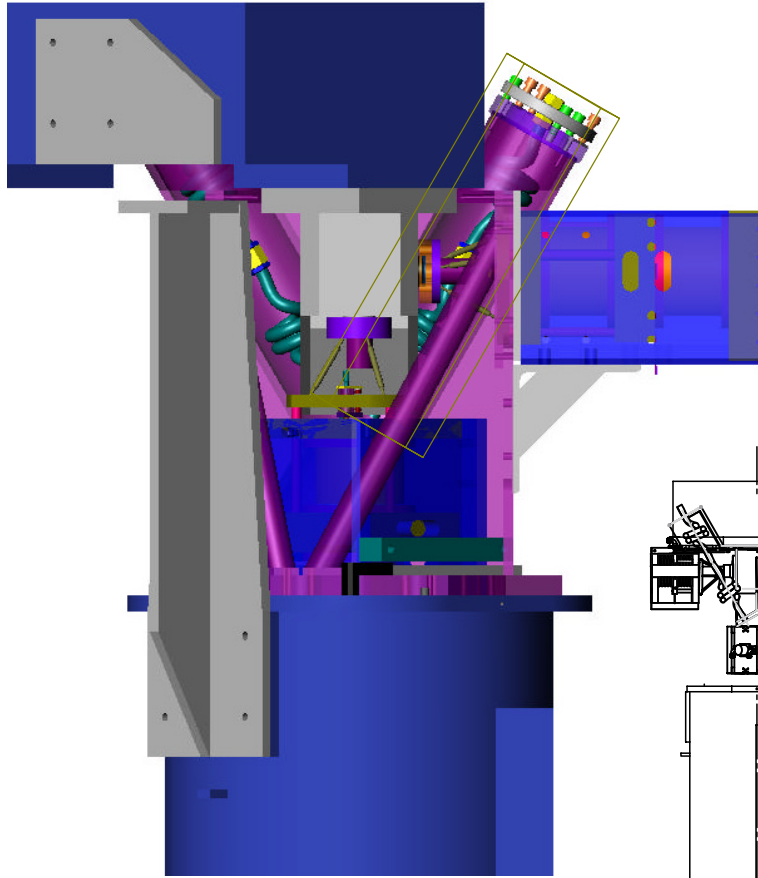


# View of the LIGO vacuum tanks

- Replace the coarse and fine actuators.
- Isolate the stack input in all 6 DOF.
- Provide a range of +/- 1mm to accommodate long term lock.



# Placement of the Actuators and Offload Springs

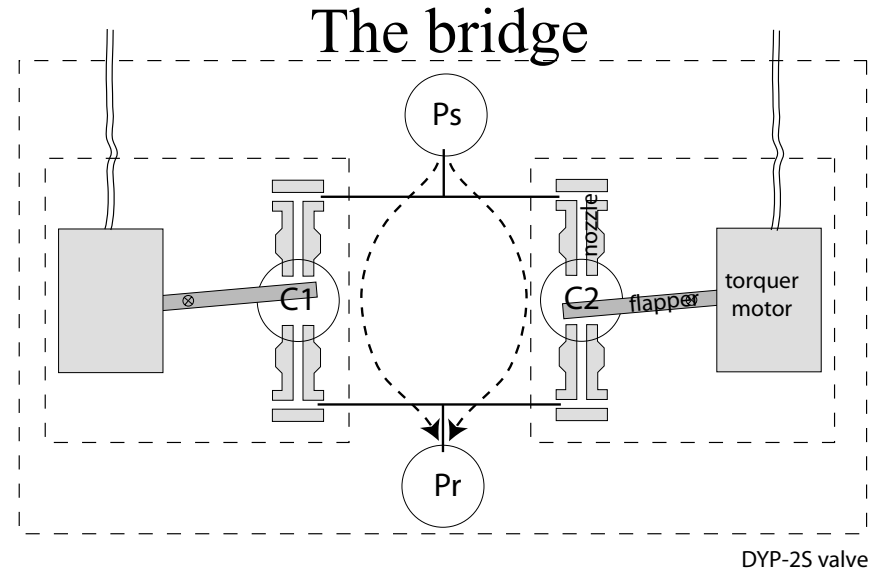
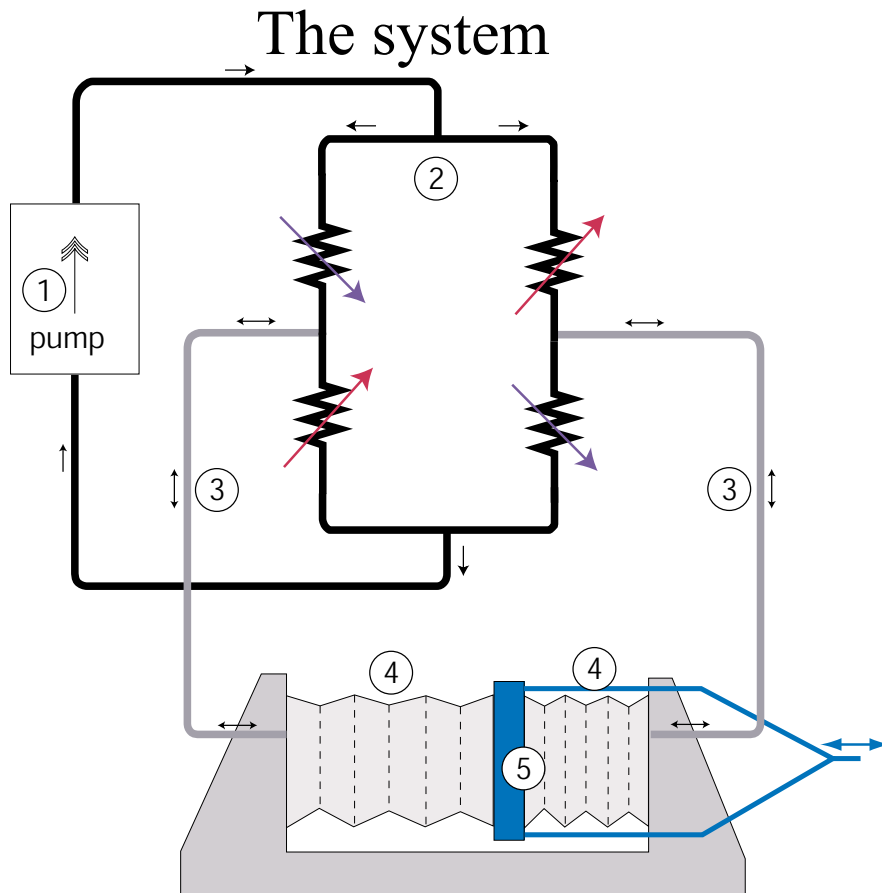


# Candidate Actuators

	Force	Velocity	Stiffness	Displacement	Stiction	Hysteresis	Mechanical Noise
Hydraulic	High	Low	Med	Med	Low	Low	Low
Ball Screw	High	Low	High	High	High	Low	High
Linear Motor	Med	High	Low	High	Low	Low	Low
Piezo or Magnetostriction	High	High	High	Low	Low	High	Low

# Hydraulic Actuator Basics

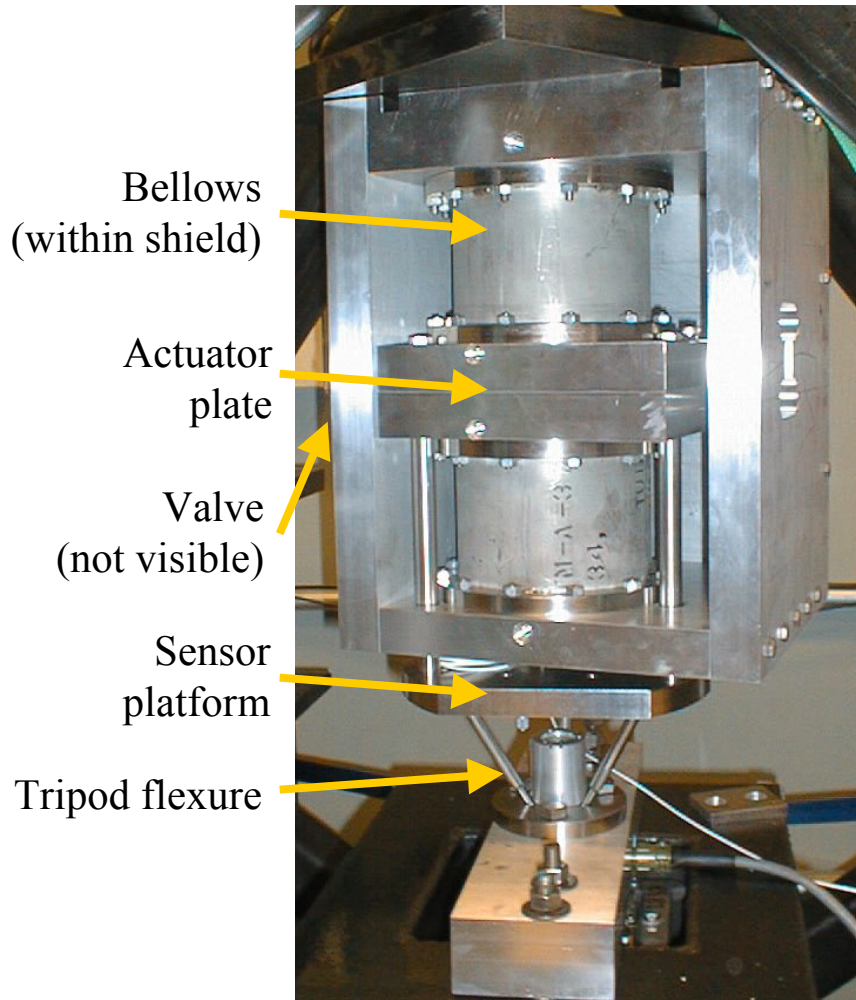
- Laminar flow
- Motion with flexures



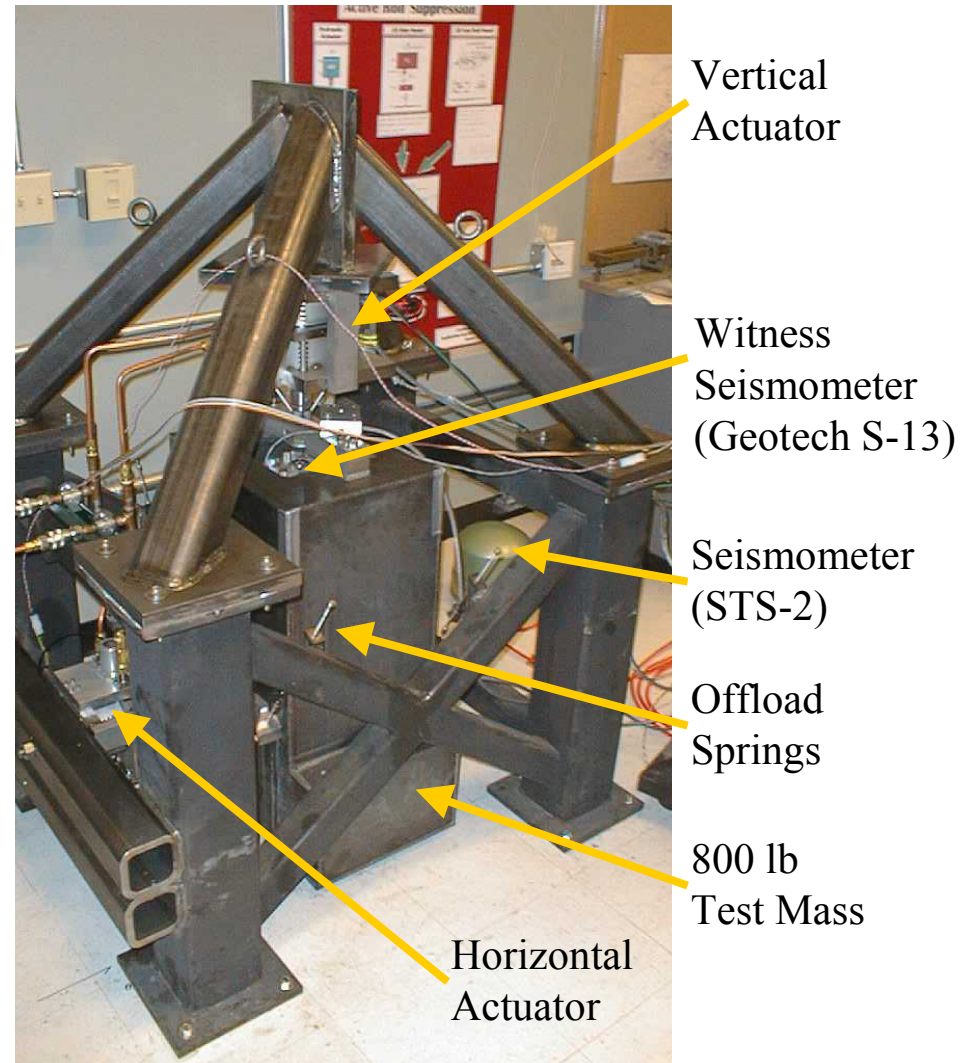
## The nozzle



# The Test Platform at Stanford



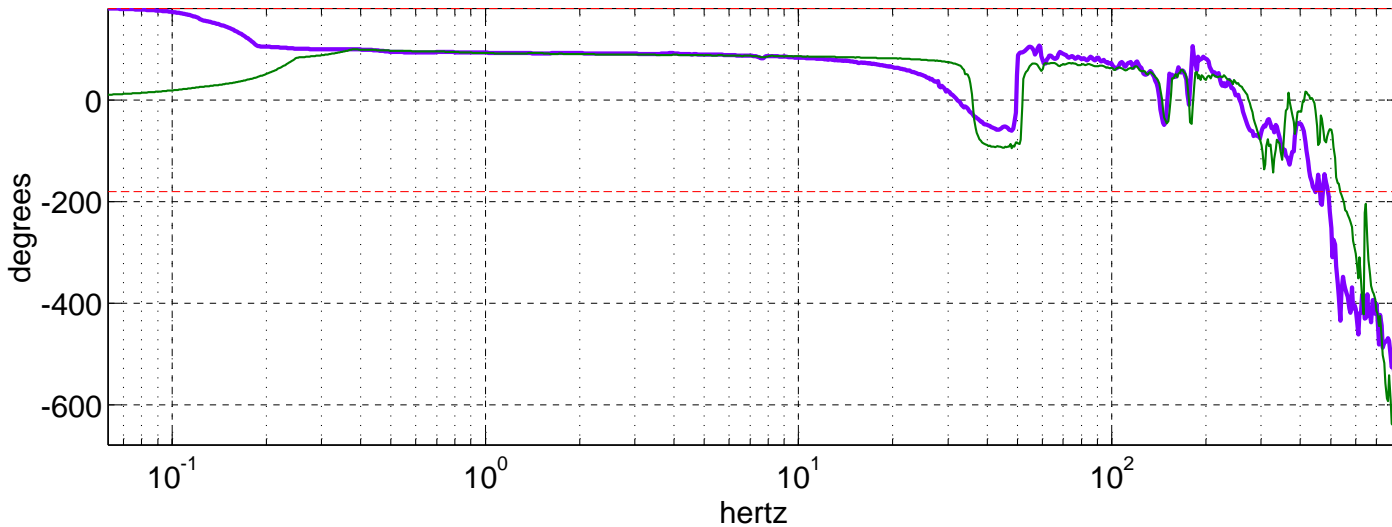
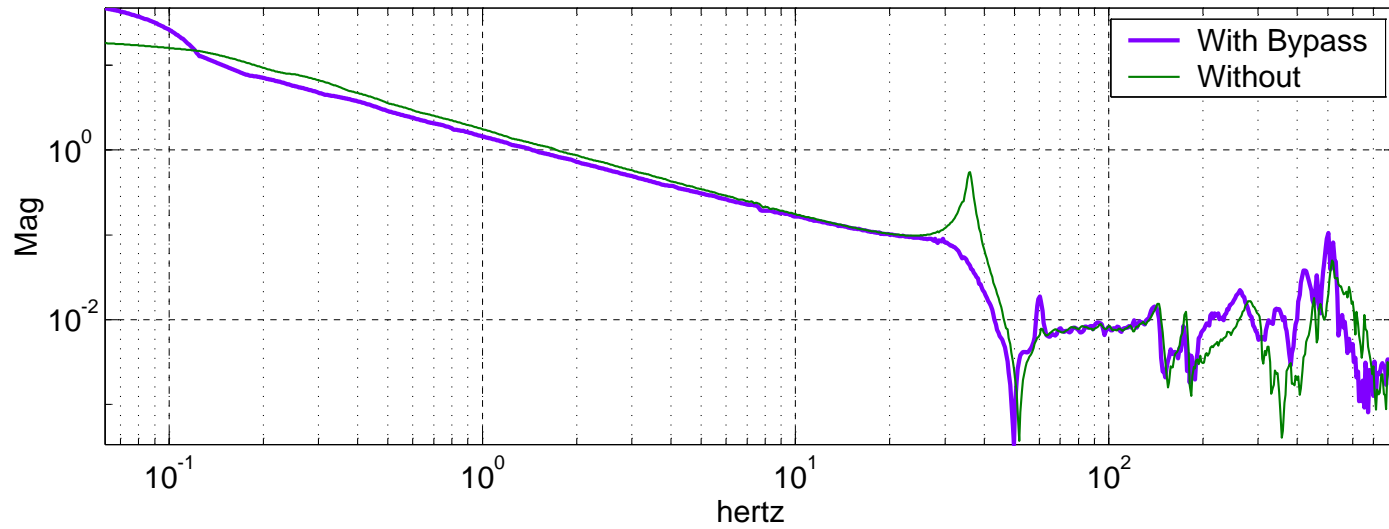
New Vertical Actuator



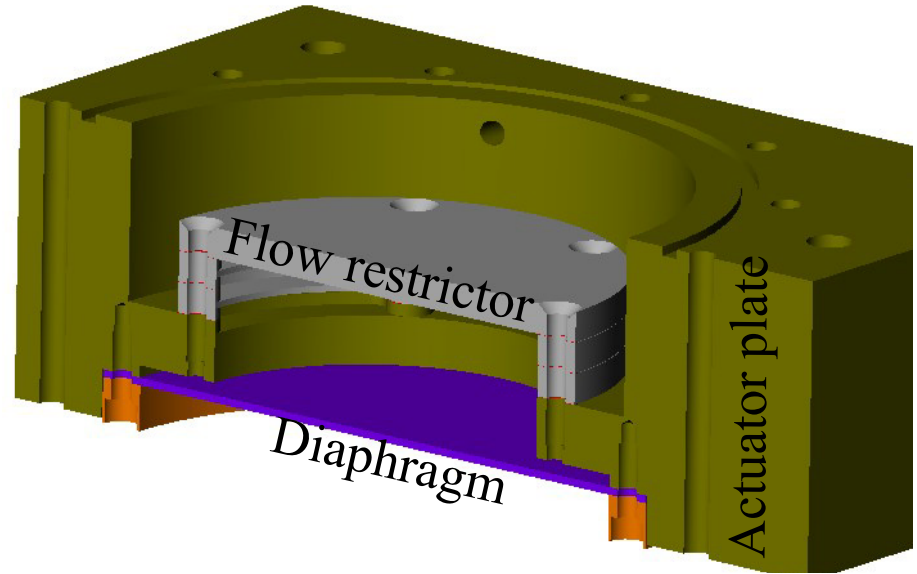
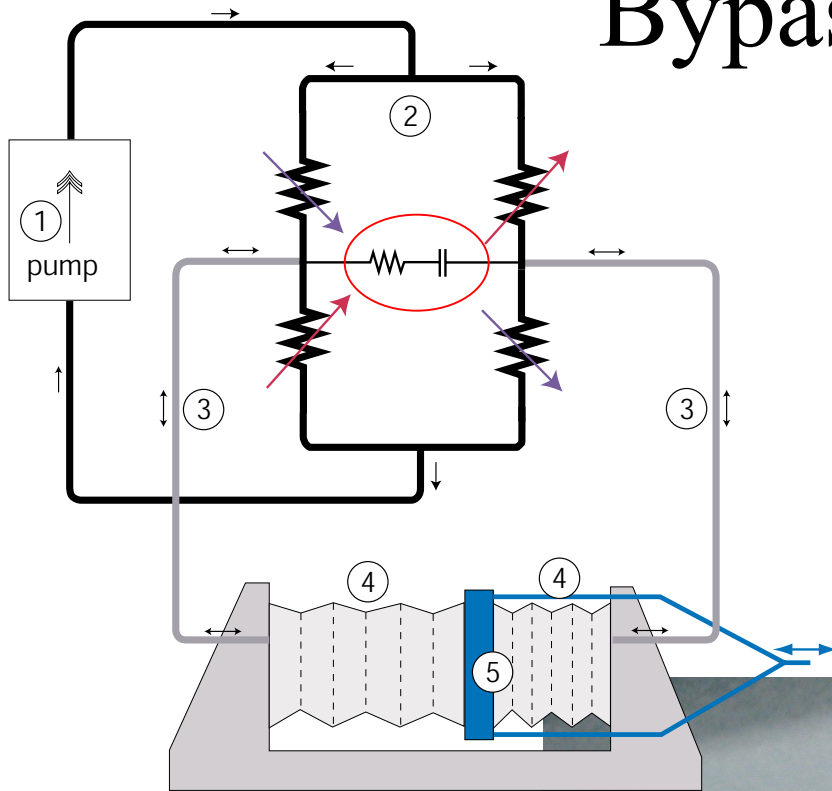


# Test Platform Dynamics

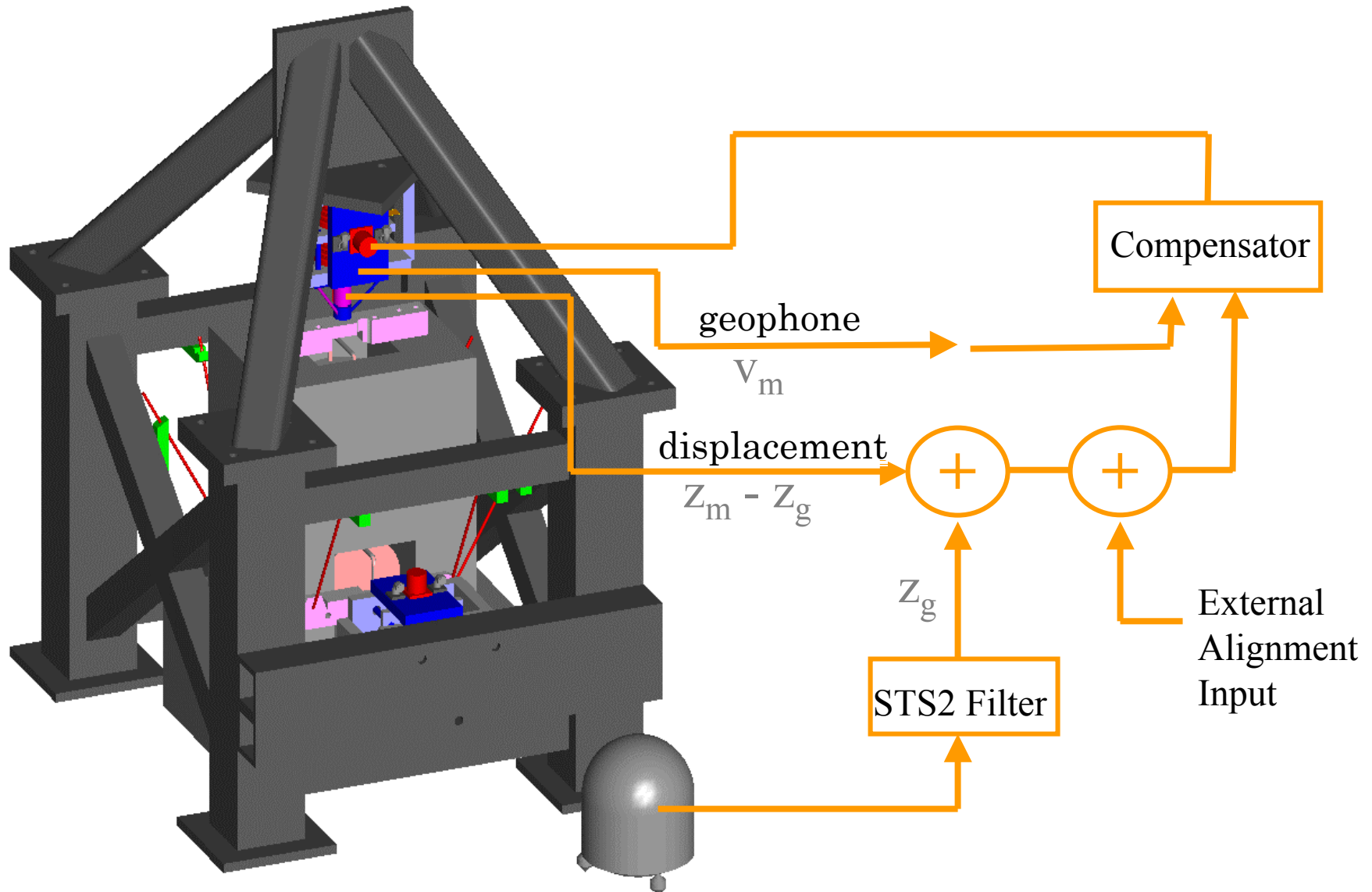
Valve to Displacement Sensor



# Bypass Network

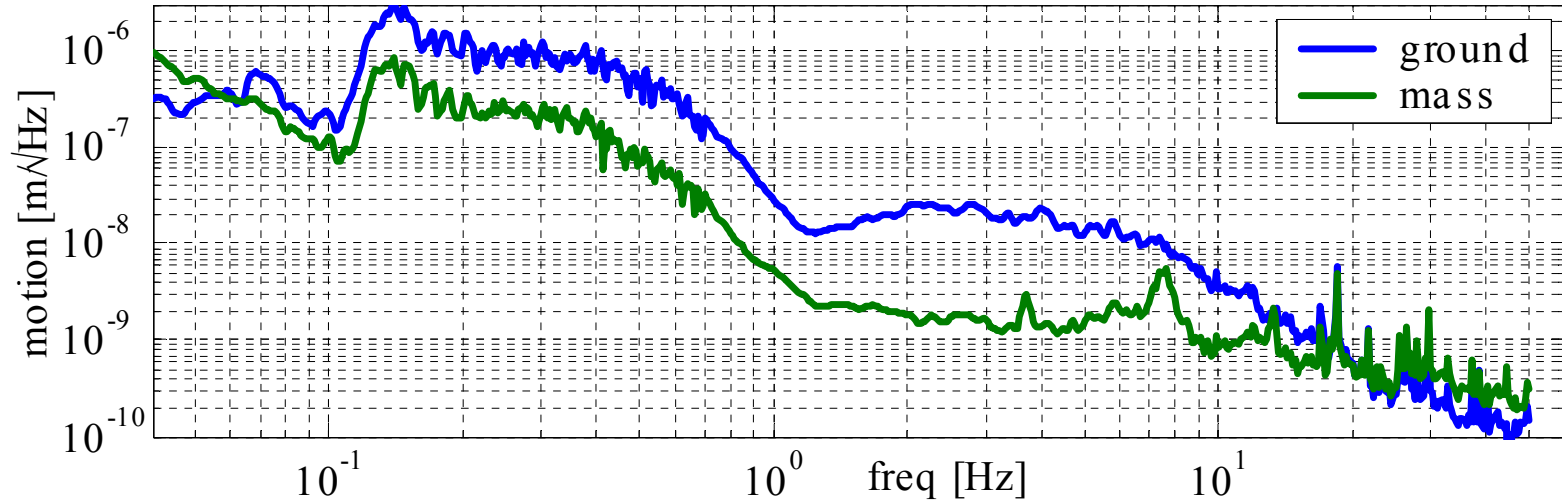


# Sensor Correction

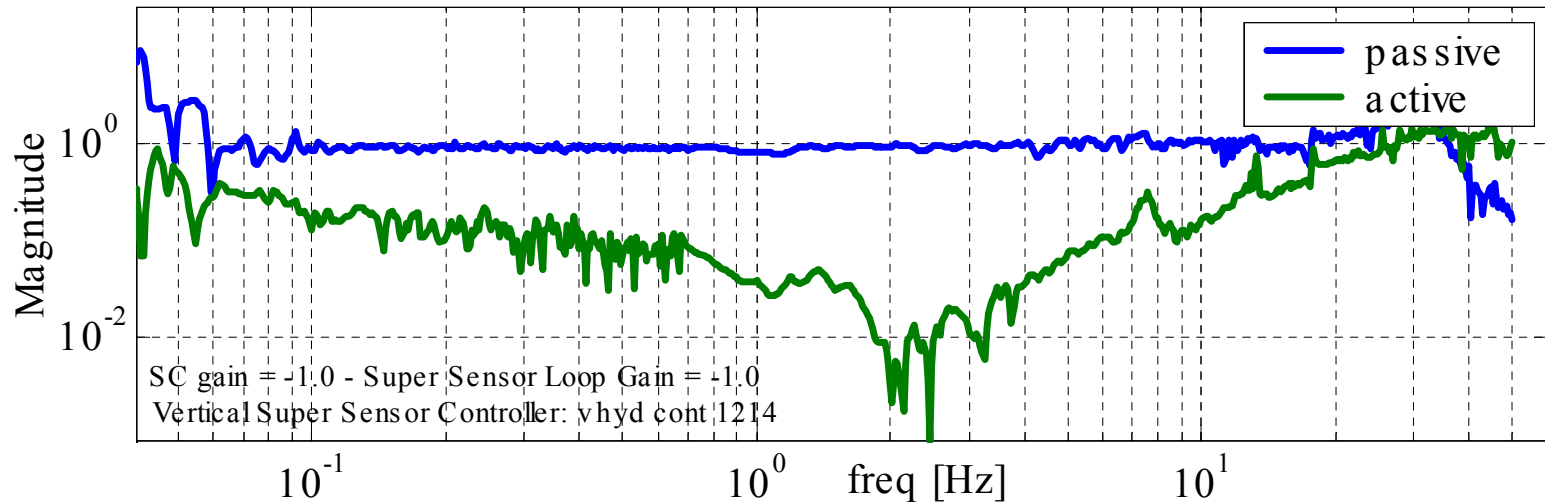


# Vertical Isolation

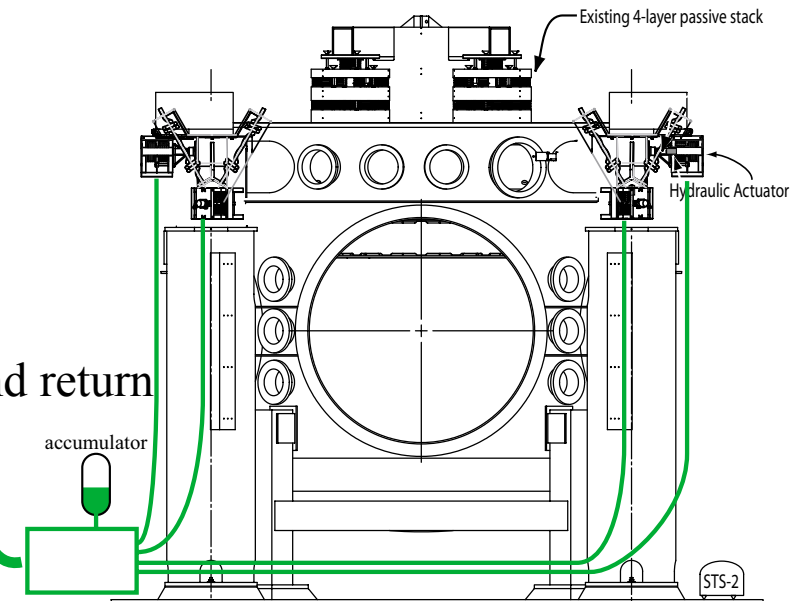
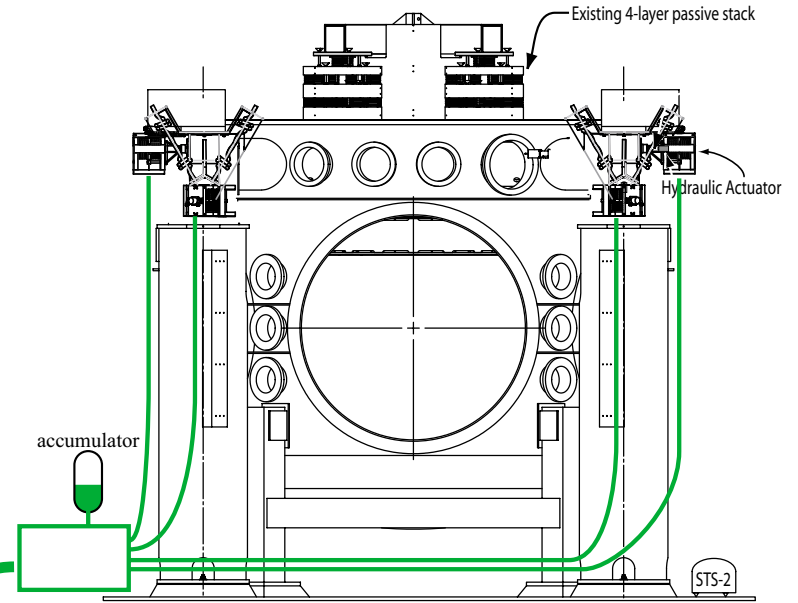
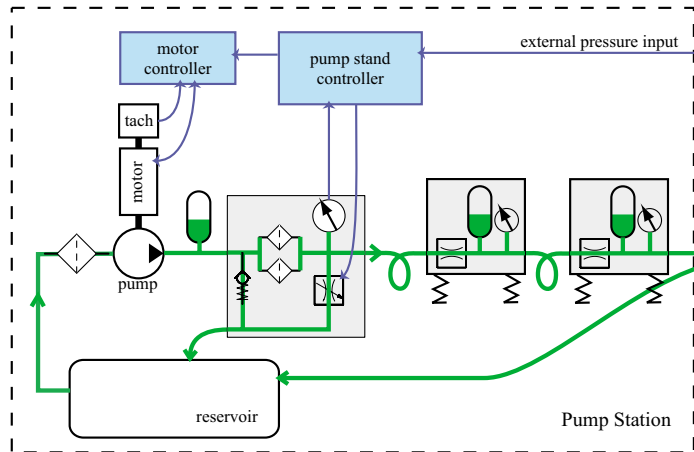
Absolute Motion of Mass and Ground



Vertical Transmission of ground motion with Sensor Correction



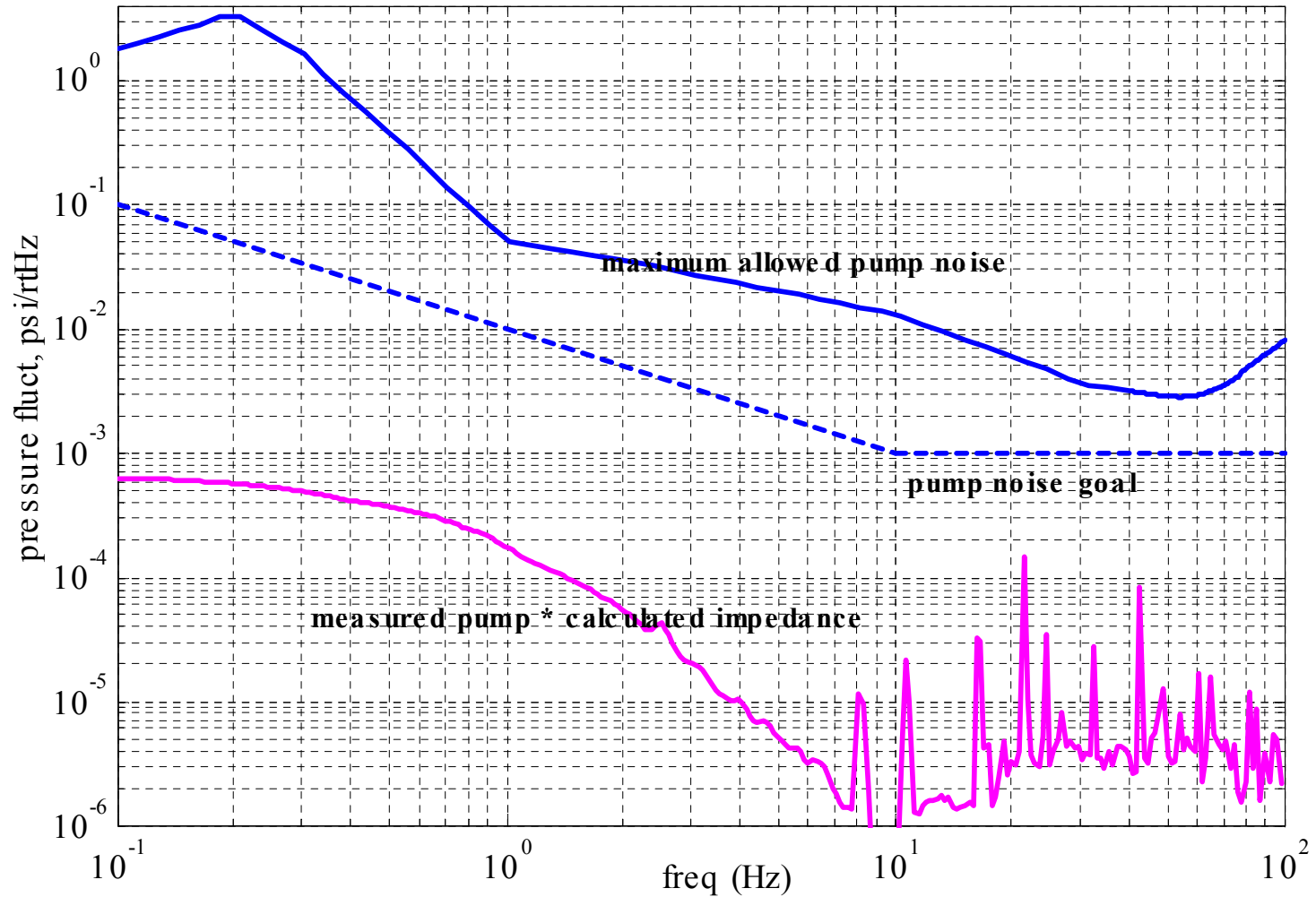
# Distribution Network



60 meter  
supply and return

# Allowed Pump Noise

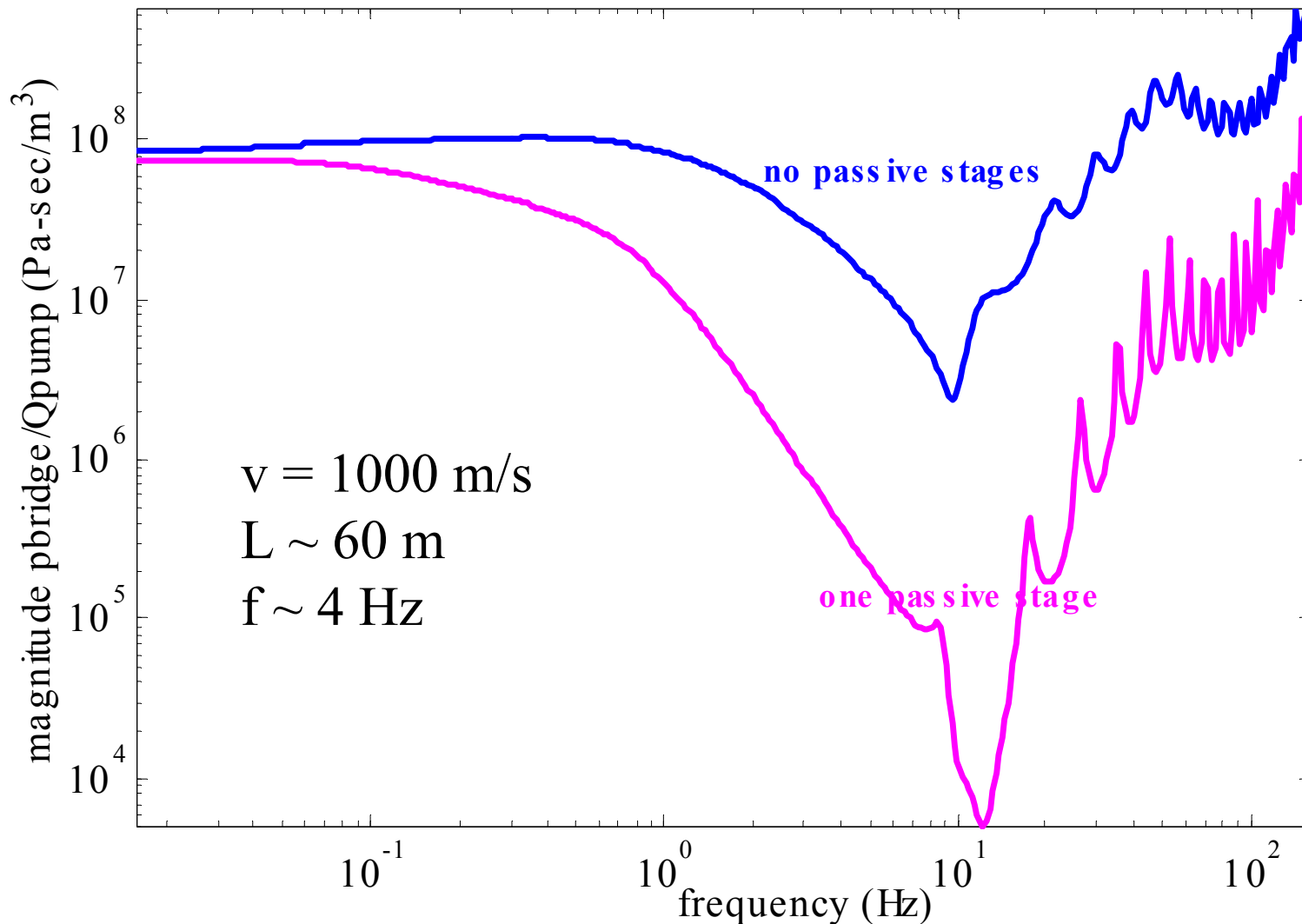
Allowed pressure fluctuations, actuator servos on,  
70 psi nominal, 0.25 pressure recovery



final\_allowed\_noise\_bt14.fig

# Pipeline dynamics impact filtering

LIGO hydraulic-filter transimpedance



# Schedule Highlights

April 12: Preliminary design review

Next stage: Testing in LASTI

2 DOF, simple structure -> 6 DOF, dynamic payload  
(tests continue at Stanford & Caltech)

April: Design of LASTI actuator and frame finalized  
parts start arriving

May: housing arrive

June: Sensors, actuators, fixturing arrive at LASTI

July: Springs arrive

Aug-Sept: Assemble system

Oct: Begin LASTI system tests



# Equations of Motion

## Mass

$$m \cdot \frac{d^2 z}{dt^2} = -(p_2 - p_1) \cdot A - k \cdot (z - z_g) + D$$

## Volumes

$$\frac{d}{dt} p_1 \cdot V = Q_1 - A \cdot \left( \frac{d}{dt} z - \frac{d}{dt} z_g \right)$$

$$\frac{d}{dt} p_2 \cdot V = Q_2 + A \cdot \left( \frac{d}{dt} z - \frac{d}{dt} z_g \right)$$

## Flow

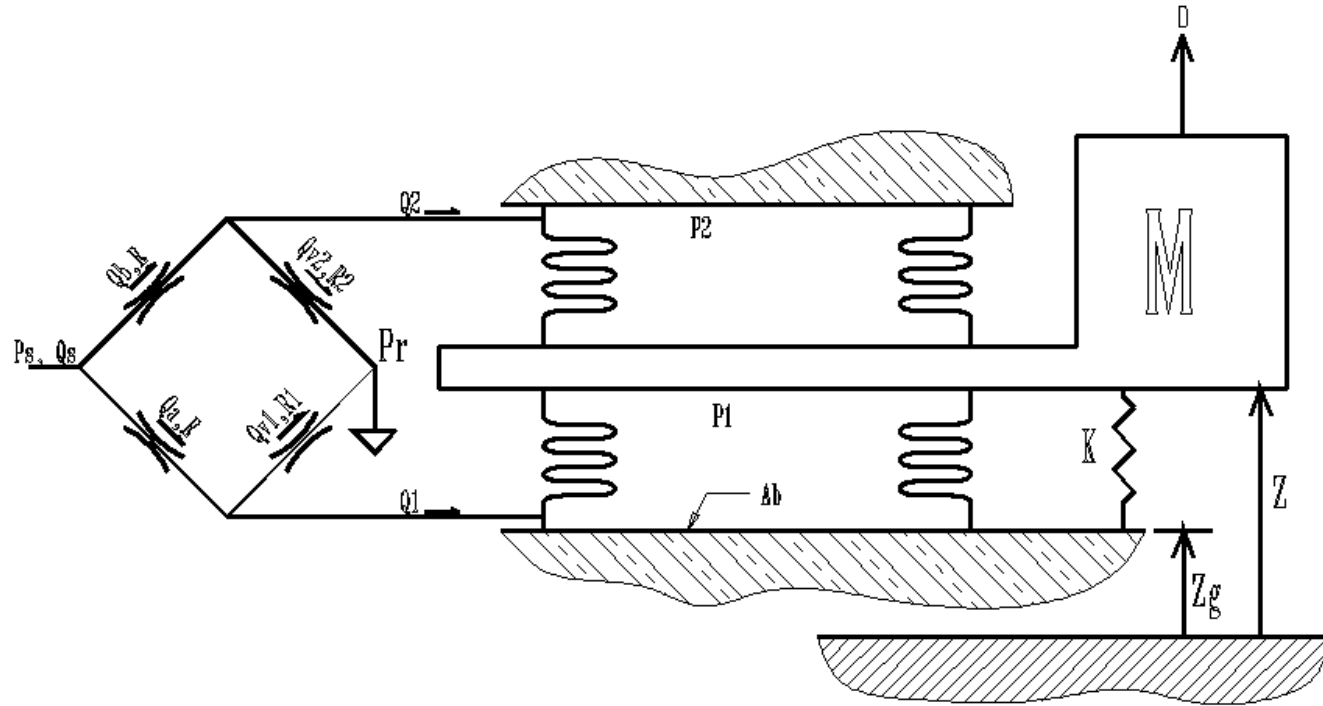
$$\frac{p_s - p_1}{R} - Q_1 - \frac{p_1 - p_R}{R_1} = 0$$

$$\frac{p_s - p_2}{R} - Q_2 - \frac{p_2 - p_R}{R_2} = 0$$

## Valve

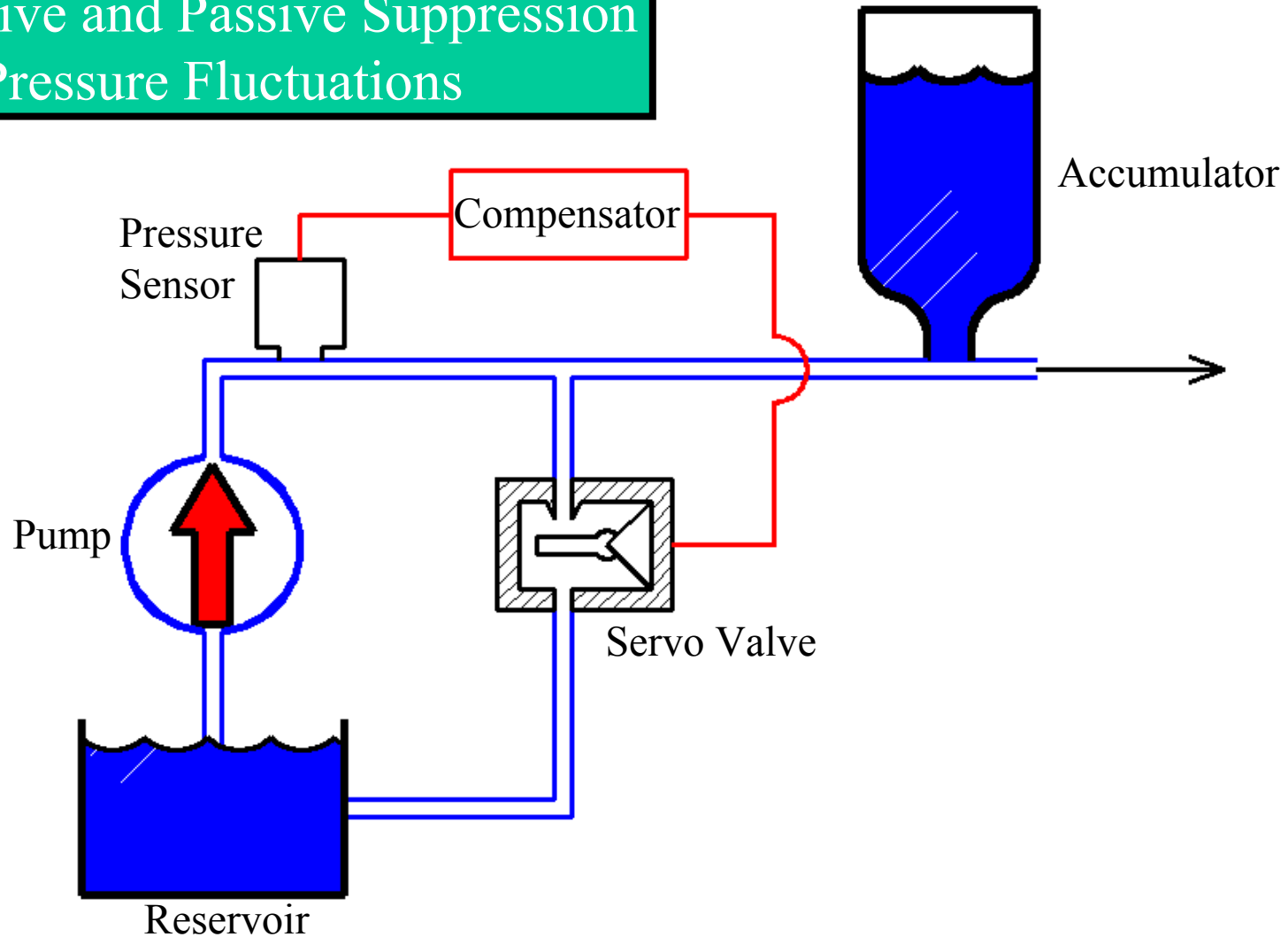
$$R_1 = \frac{R}{1 + C_v \cdot i}$$

$$R_2 = \frac{R}{1 - C_v \cdot i}$$

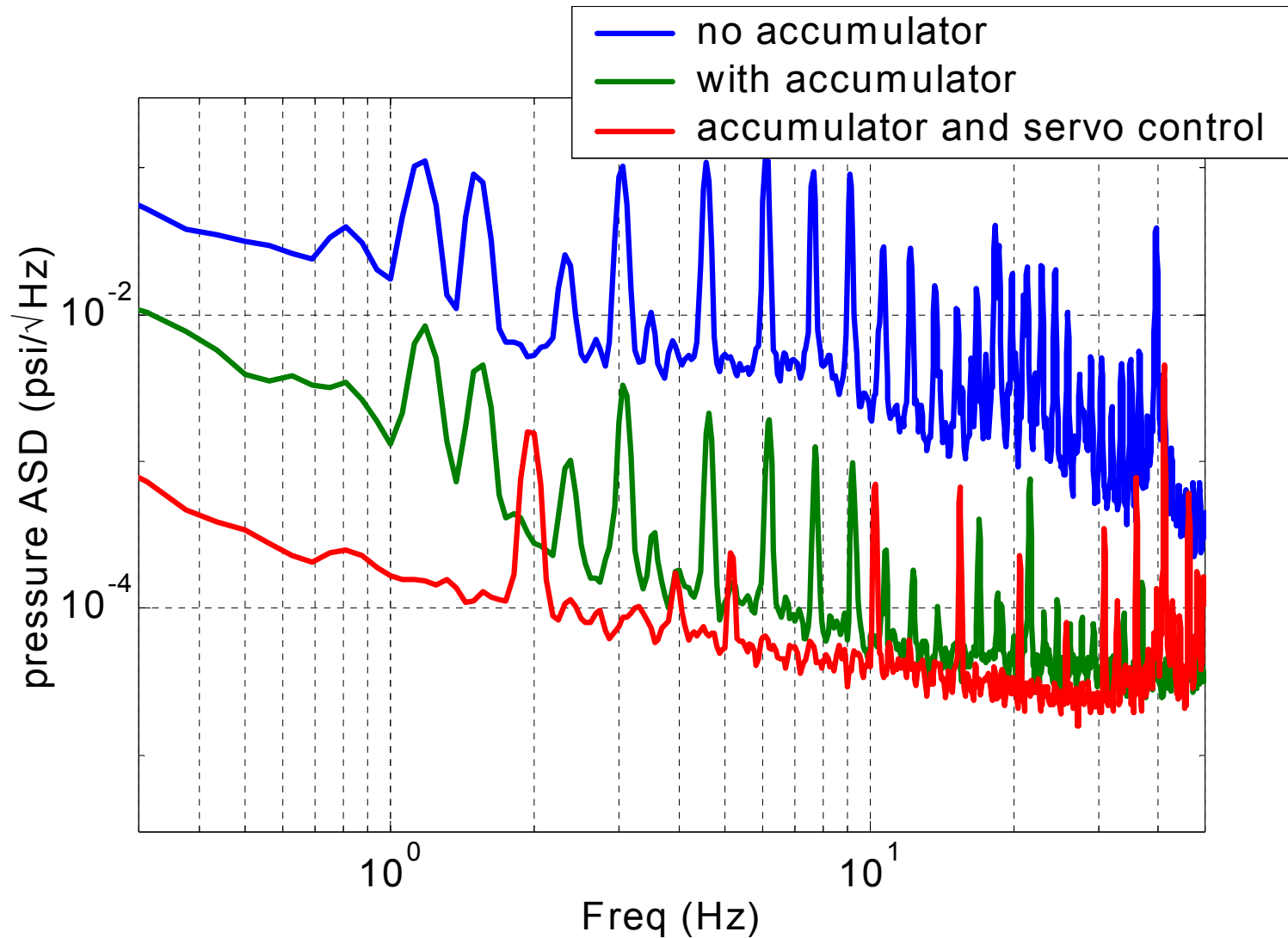


# Conditioning a Pressure Source

Active and Passive Suppression of Pressure Fluctuations

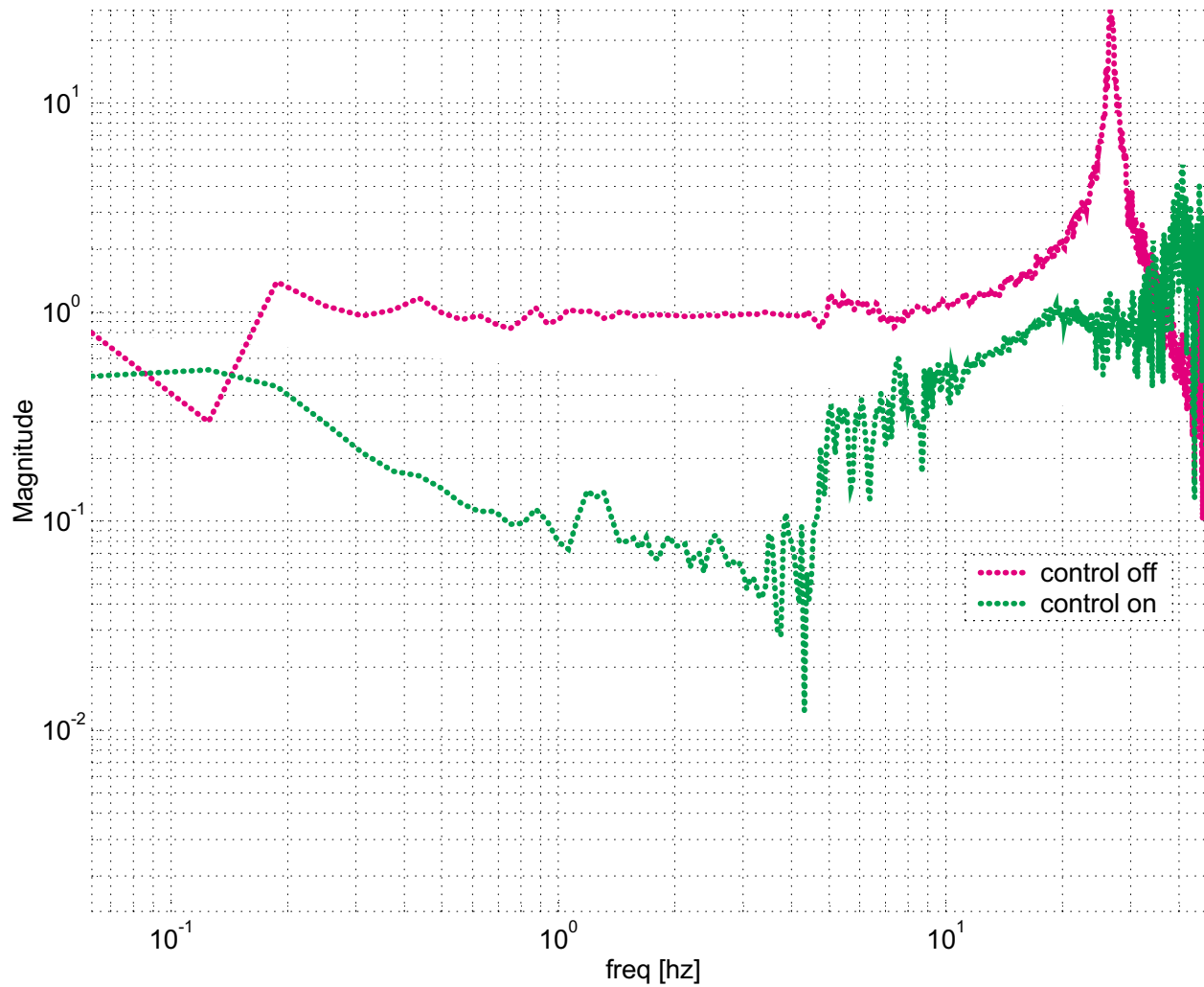


# Pressure Noise at the Actuator



# Horizontal Isolation

Transmission Between S13 horz and sts-2 on 14-May-2001



# More complete servo diagram

