

Advanced LIGO Seismic Isolation

Detector Group Meeting

Céline R, for the SEI team

January 30th, 2014

Overview

- aLIGO Seismic Isolation Systems
- Assembly, Installation & Commissioning Status
 - LIGO Livingston (LLO), LIGO Hanford (LHO), LIGO India (Assembly only)
- Control Schemes
- Control Room Tools

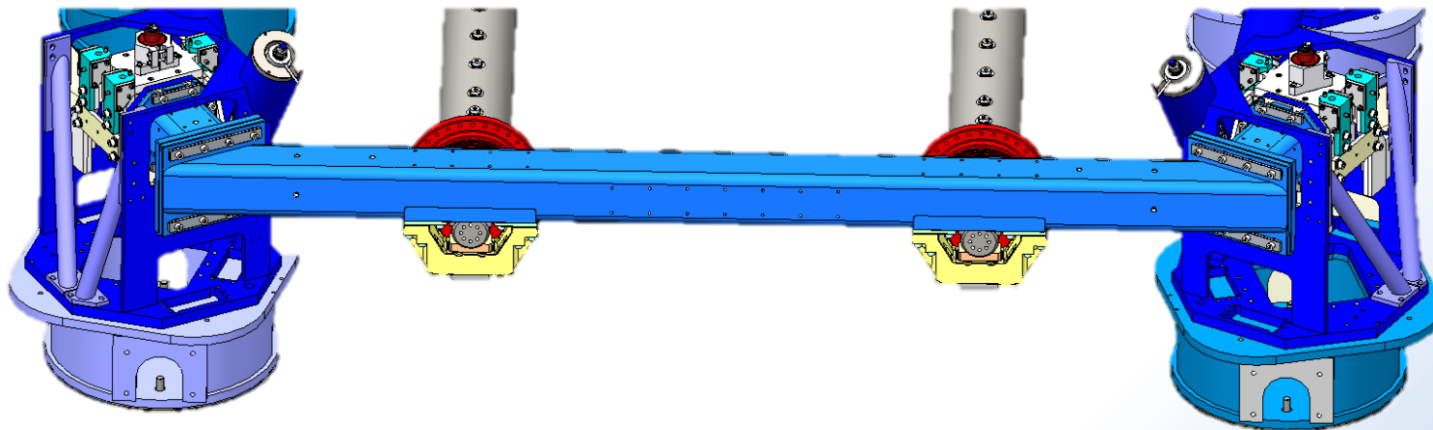


ALIGO SEISMIC ISOLATION SYSTEMS

aLIGO Seismic Isolation Systems

- From the ground to the optical table
- Passive isolation (mass-spring) systems with **active** control (in contrast to iLIGO)
- Sensing loops made of **blended** inertial and capacitive/inductive position sensors (super sensors)
- Goal : Isolating optics + provide positioning & alignment
- 1 Pre-Isolator (present under all chambers)
 - HEPI
- Two in-vacuum Seismic Isolation systems (ISI)
 - HAM-ISI
 - BSC-ISI
- Degrees of freedom = IFO coordinates

- One stage of isolation
- Isolation from 0.1 Hz to ~ 10 Hz
- Out of vacuum
- 16 sensors
- Divided in 4 piers, connected by the support tubes
- Hydraulic actuation



HAM-HEPI

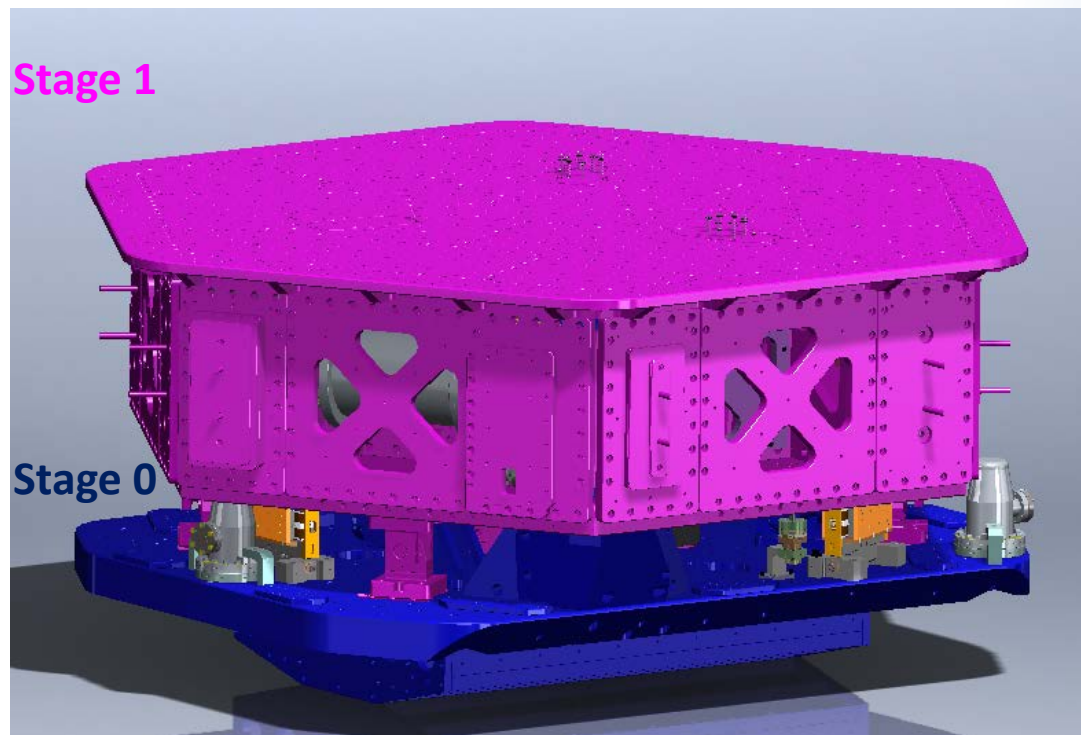


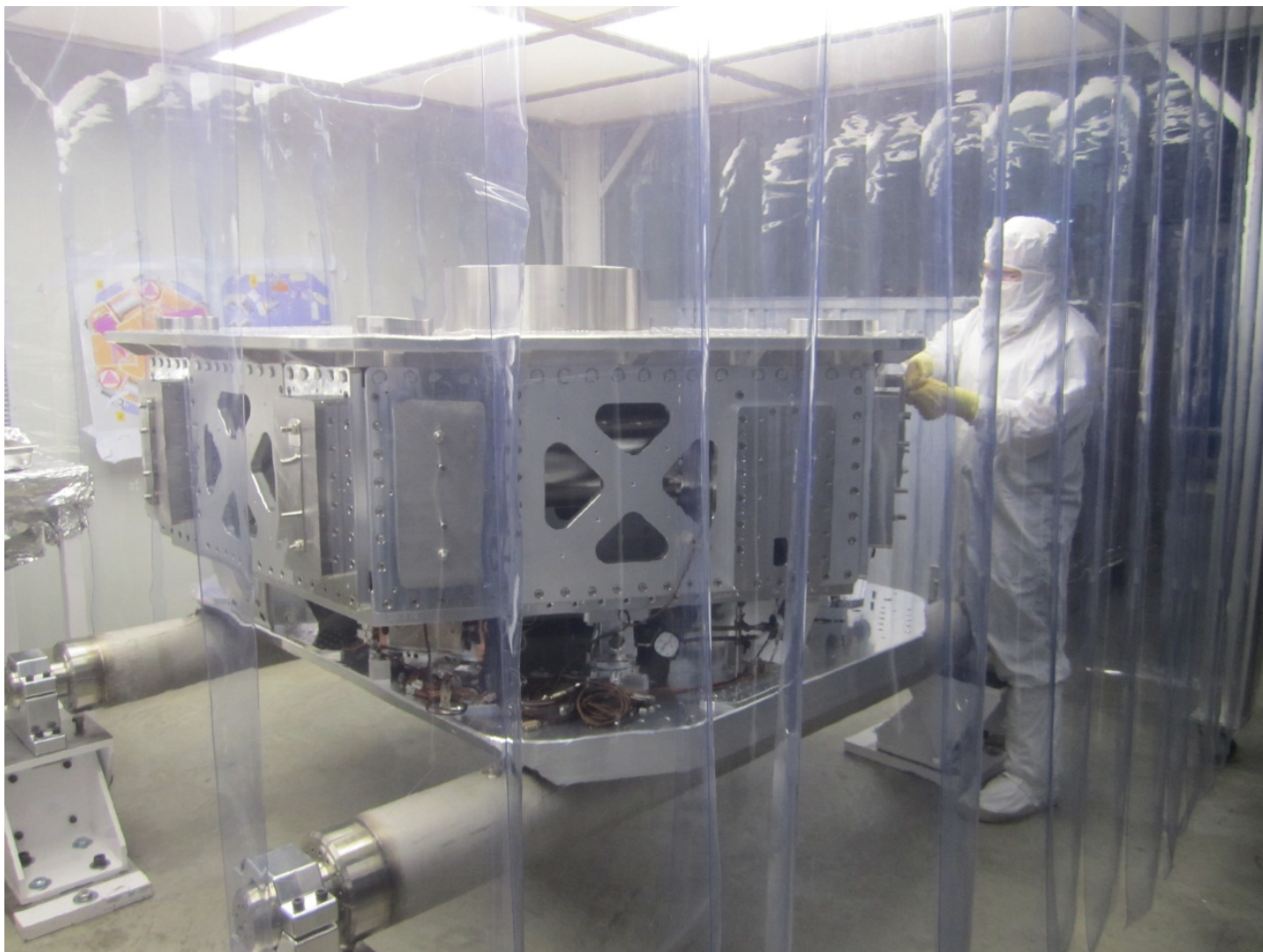
BSC-HEPI

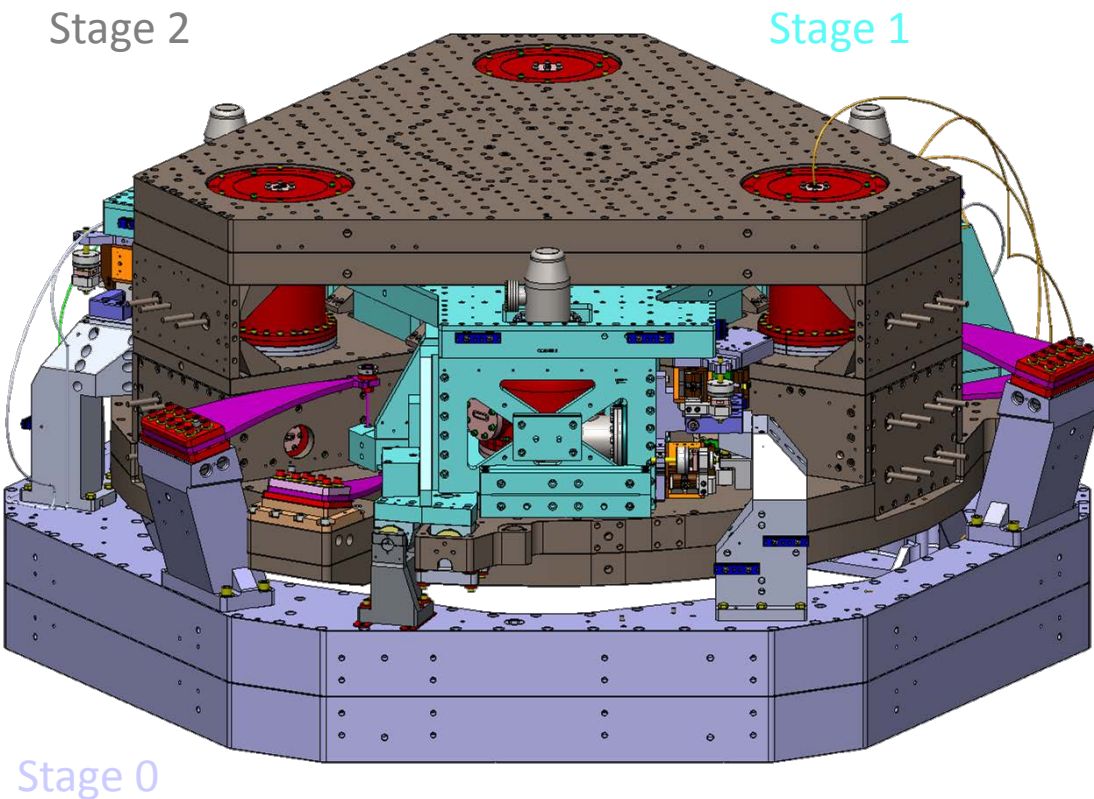


HAM-ISI

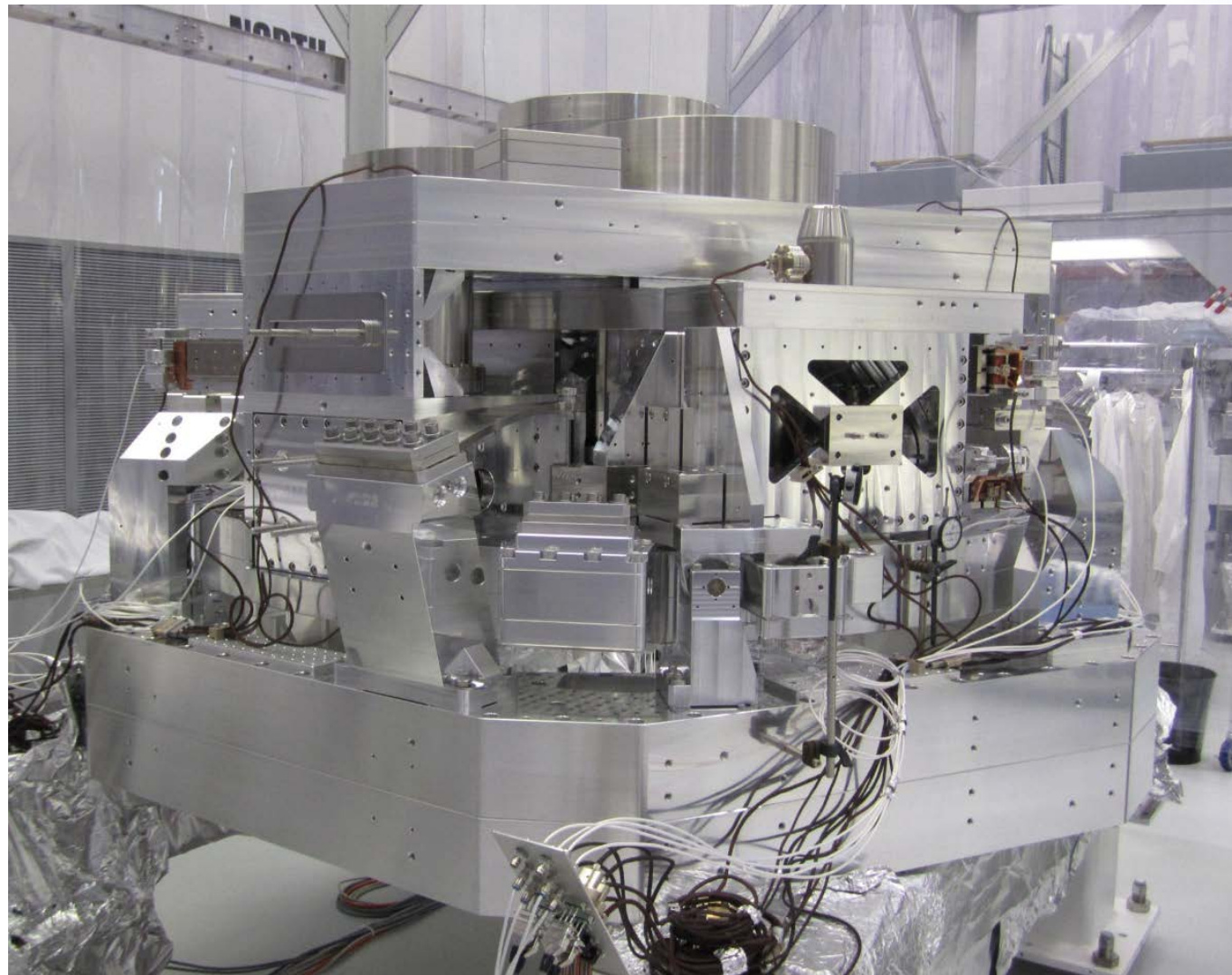
- One stage of isolation
- Effective $> \sim 0.2$ Hz
- In Vacuum
- 12 sensors
- 2 per IFO have additional sensors on Stage 0 for feed-forward
- Optical table facing up
- Carrying Auxiliary Optics







- Two stages of isolation
- Effective > 0.2 Hz
- In vacuum
- 33 sensors
- Optical table facing down
- Carrying Core Optics



LIGO Livingston (Louisiana, USA), LIGO Hanford (Washington St, USA),
LIGO India

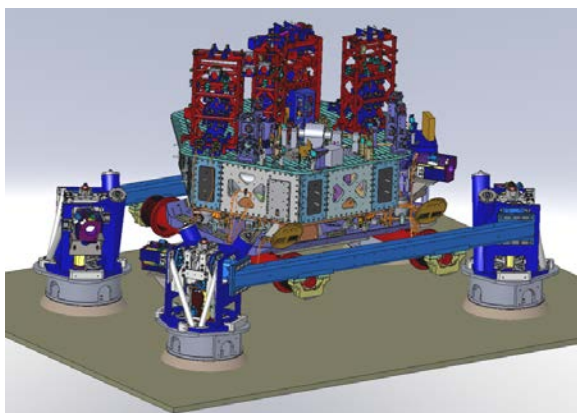
ASSEMBLY, INSTALLATION & COMMISSIONING STATUS

LLO + LHO + India Status

■ HEPI

■ ISI

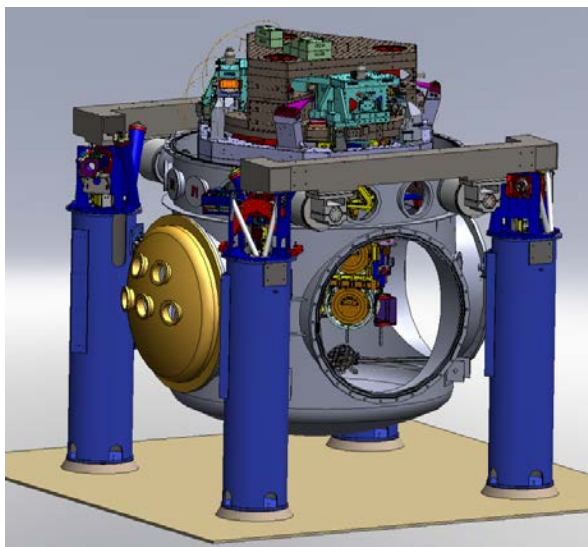
■
H
A
M



- Assembled: 6/6
 - 6/6
 - 6/6
- Installed: 6/6
 - 6/6
- Controlled: 4/6
 - 3/6

- Assembled: 5/5
 - 5/5
 - 4.5/5
- Installed: 5/5
 - 5/5
- Controlled: 5/5
 - 2/5

■
B
S
C



- Assembled: 5/5
 - 5/5
 - 5/5
- Installed: 5/5
 - 5/5
- Controlled: 3/5
 - 4/5

- Assembled: 5/5
 - 5/5
 - 2/5
- Installed: 4/5
 - 4/5
- Controlled: 4/5
 - 4/5

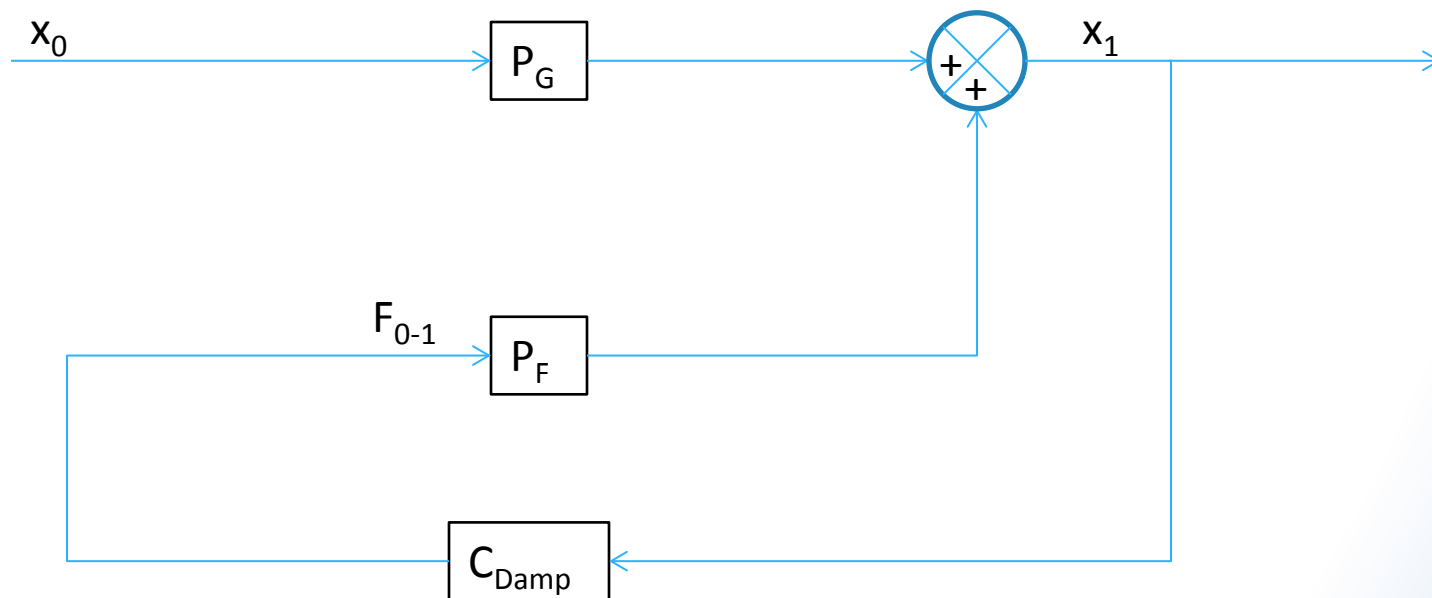


CONTROL SCHEMES

Control Schemes used on all SEI systems

- Feedback
 - Damping loops
 - Isolation Loops
- Feedforward
- Sensor Correction

Feedback - Damping



x_0 : Ground displacement

x_1 : Floating stage displacement

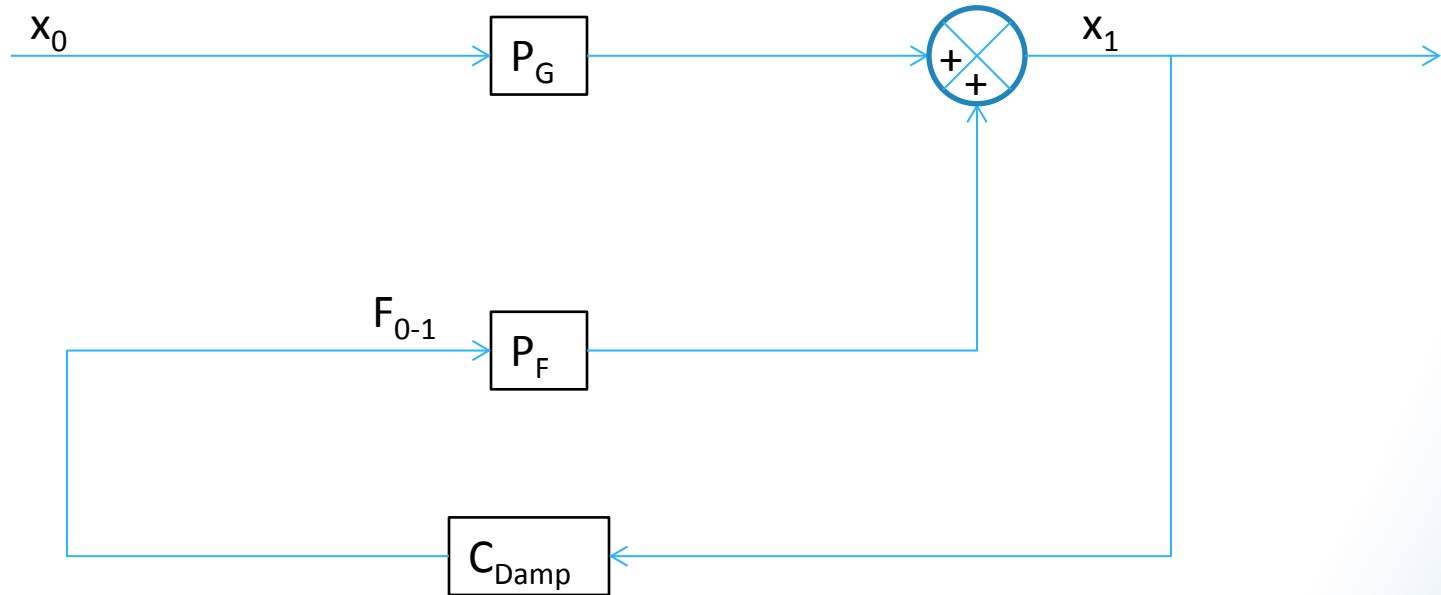
P_G : Seismic plant

P_F : Force plant

F_{0-1} : Actuator force

C_{Damp} : Damping Loop Controller

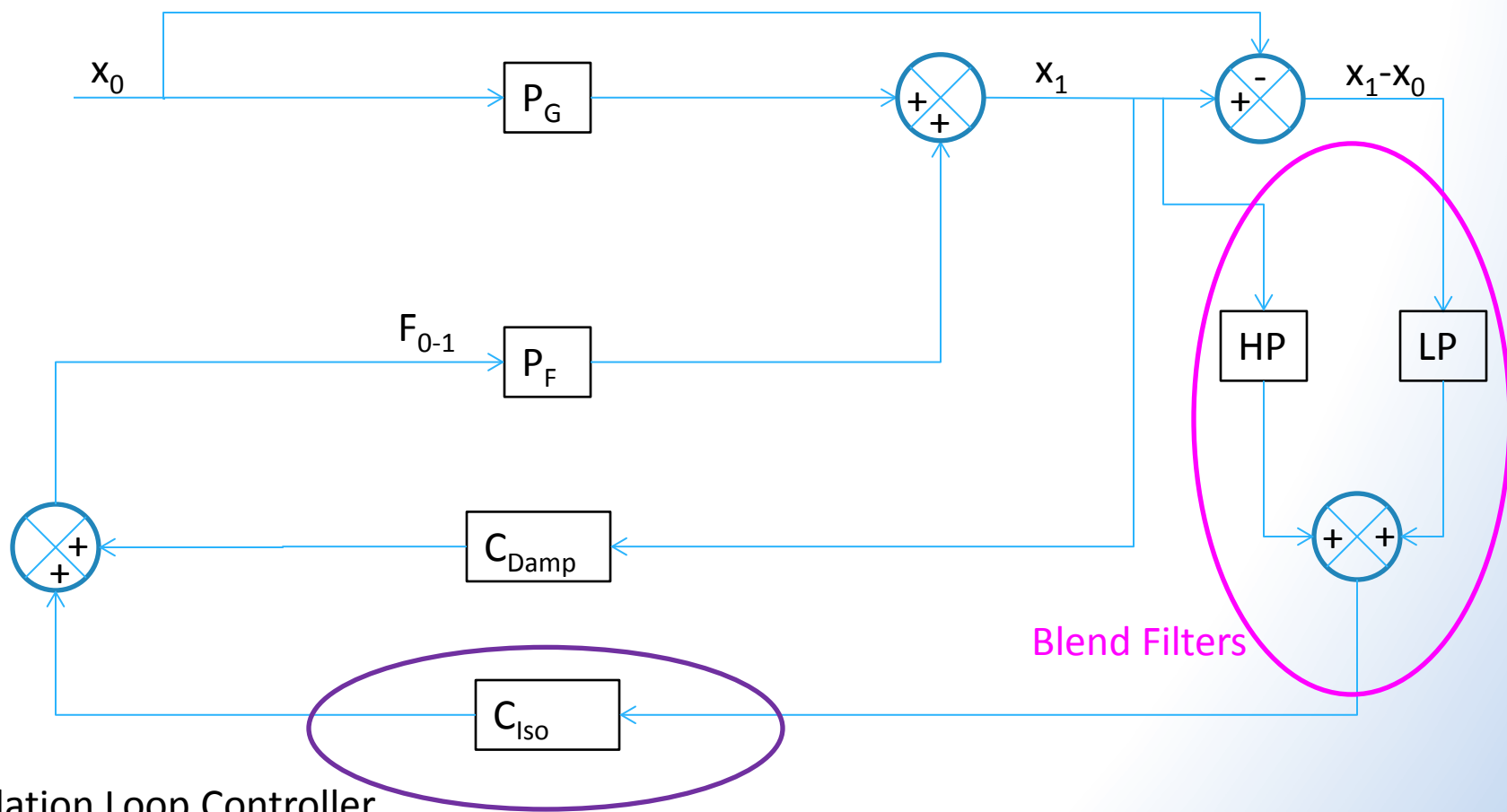
Feedback - Damping



x_0 : Ground displacement
 x_1 : Floating stage displacement
 P_G : Seismic plant
 P_F : Force plant
 F_{0-1} : Actuator force
 C_{Damp} : Damping Loop Controller

- Remove motion amplification at system resonance
- Not used for HEPI

Feedback-Isolation

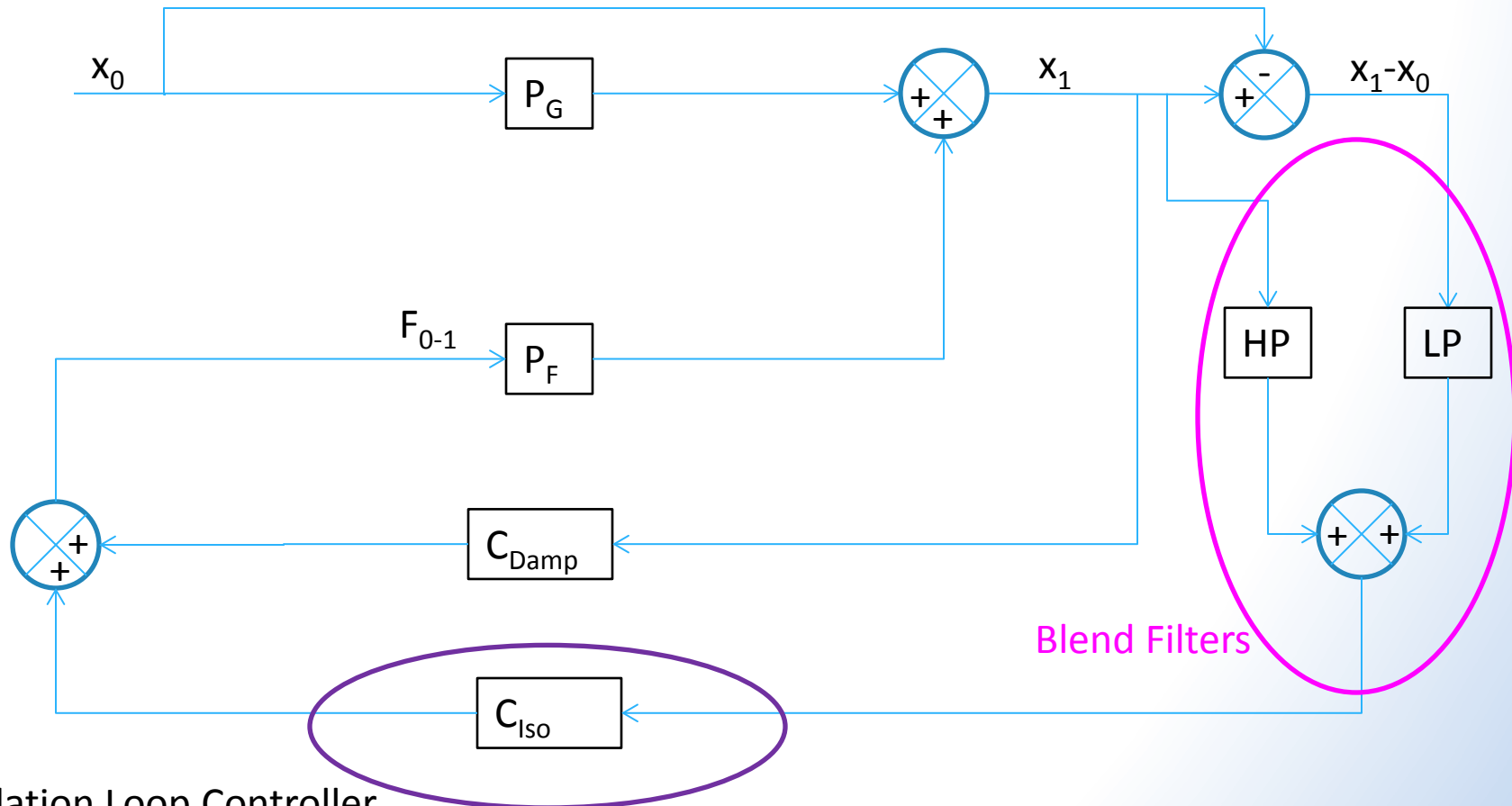


C_{Iso} : Isolation Loop Controller

HP: High Pass

LP: Low Pass

Feedback-Isolation



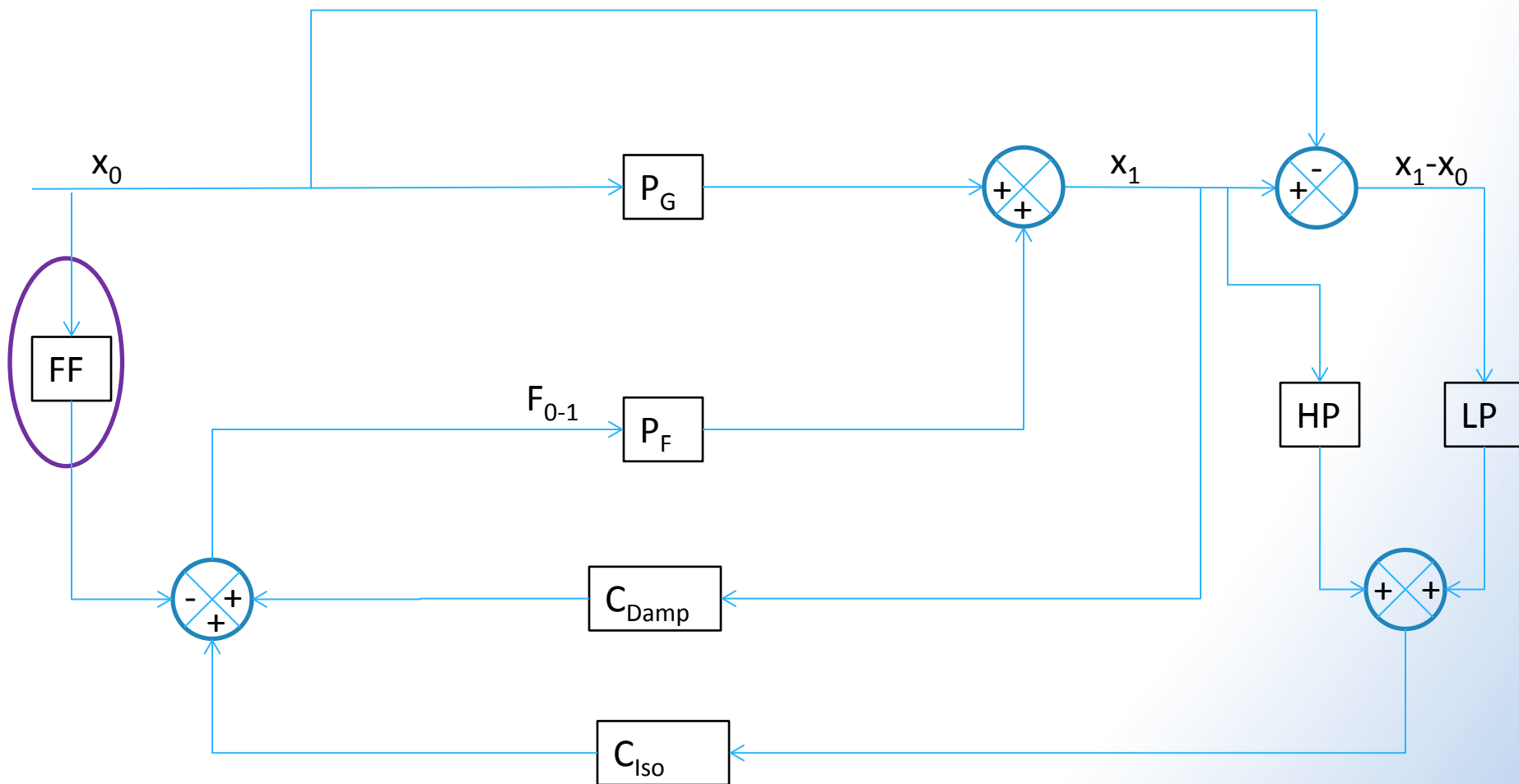
C_{Iso} : Isolation Loop Controller

HP: High Pass

LP: Low Pass

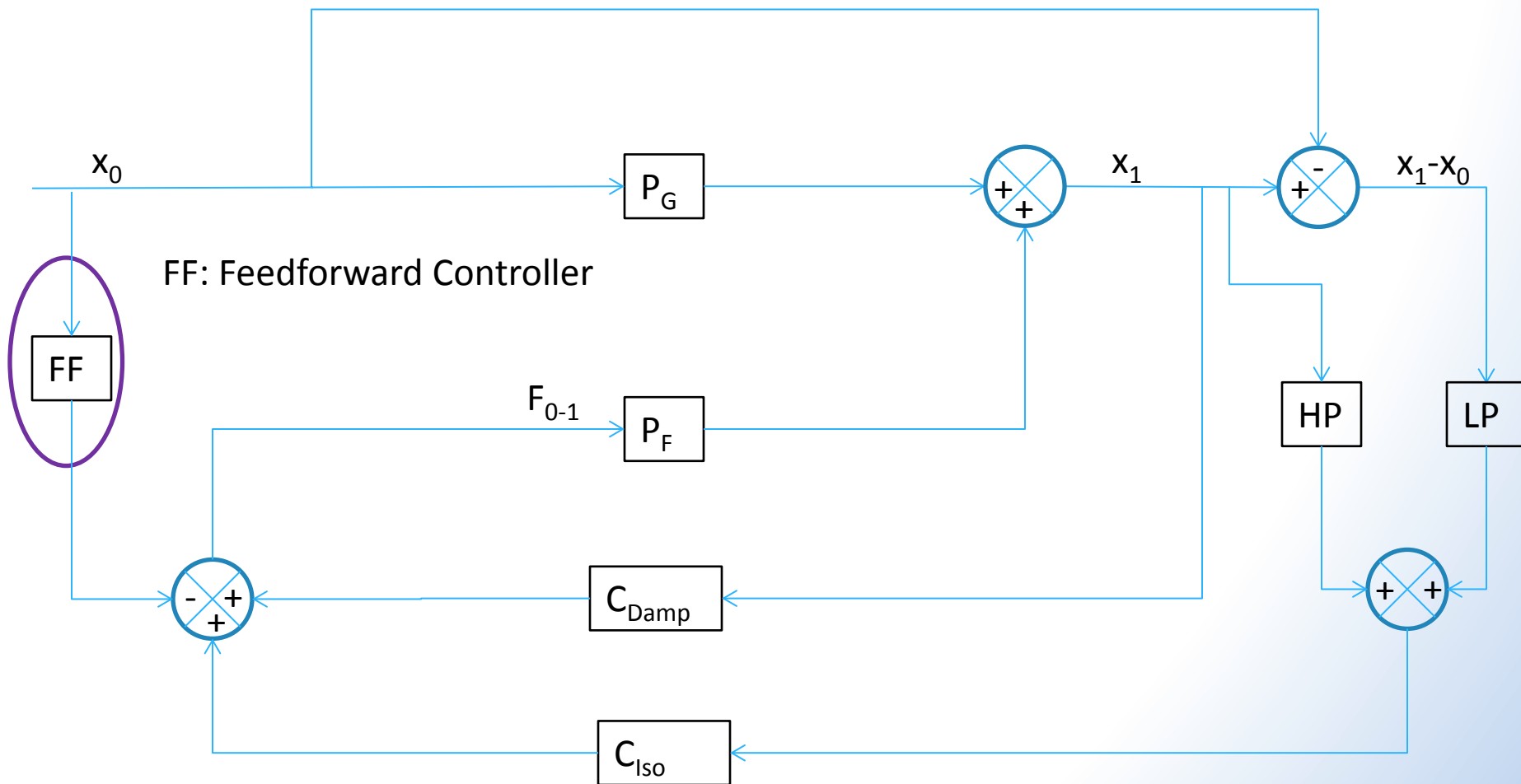
- Provide most of the isolation
- Limited at low frequency by seismometer noise

FF: Feedforward Controller



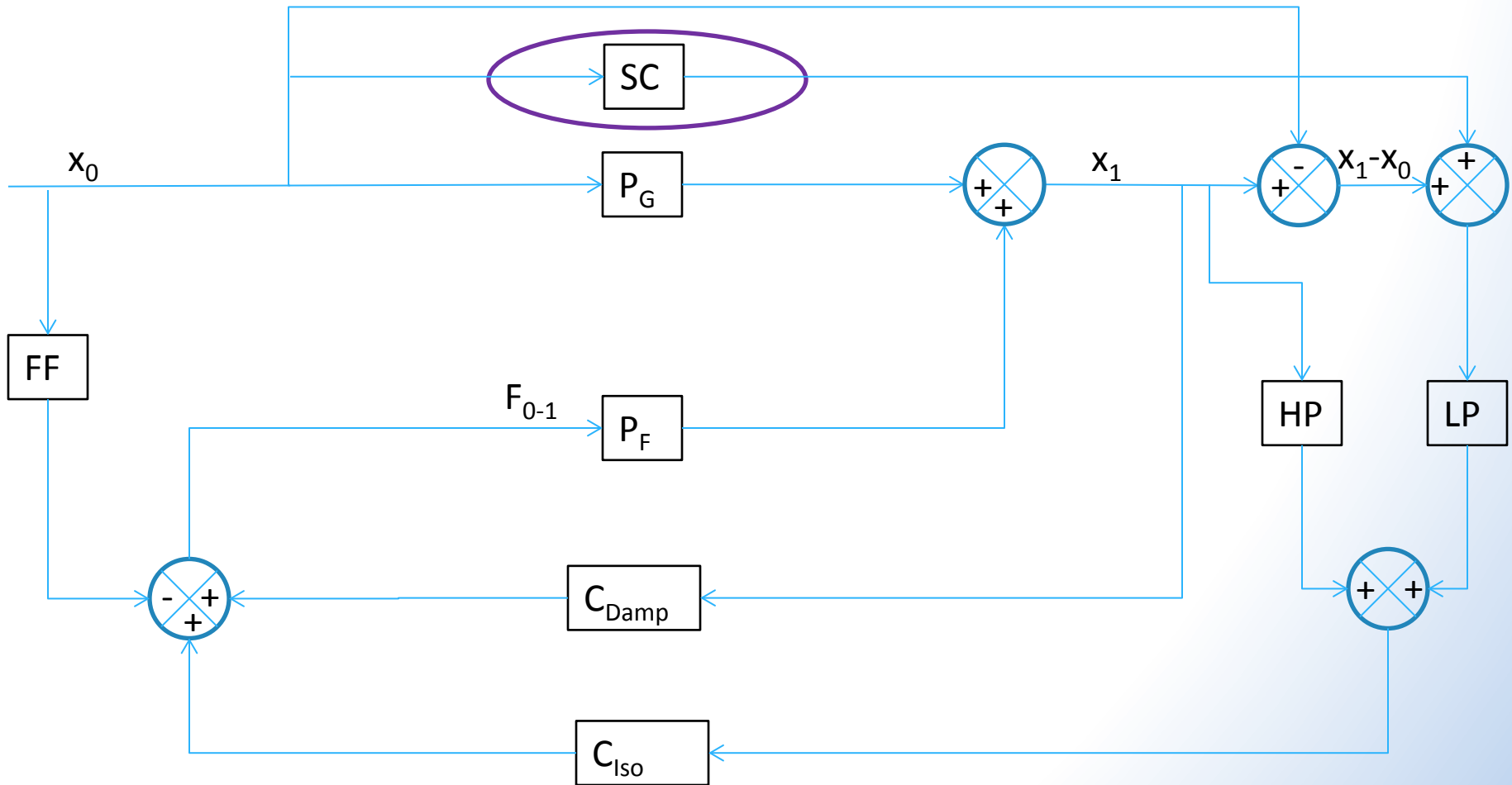
Feedforward

- Provide some additional isolation to feedback when input is large (BSC-HEPI resonance e.g)



Sensor Correction

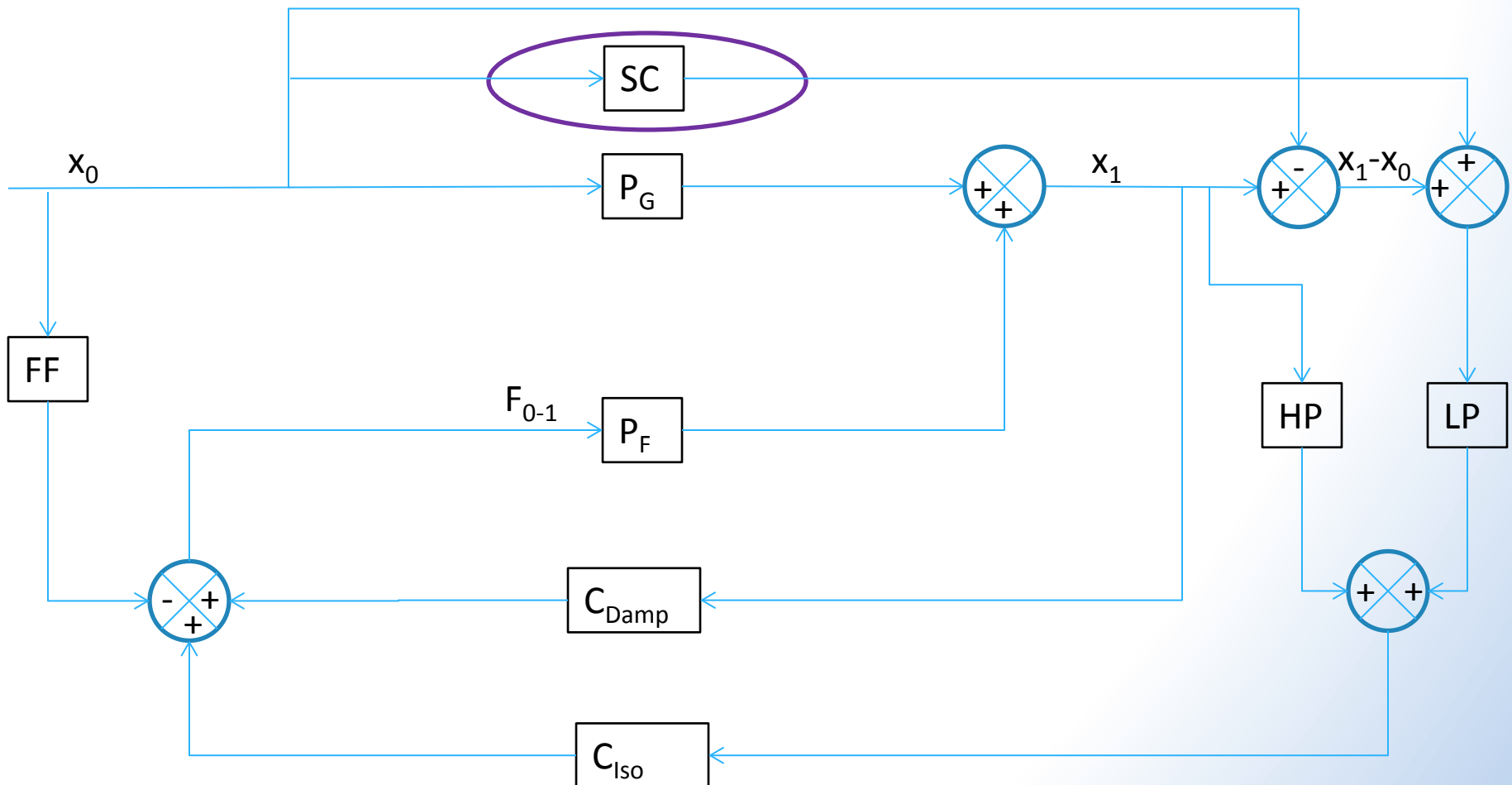
SC: Sensor Correction filter



Sensor Correction

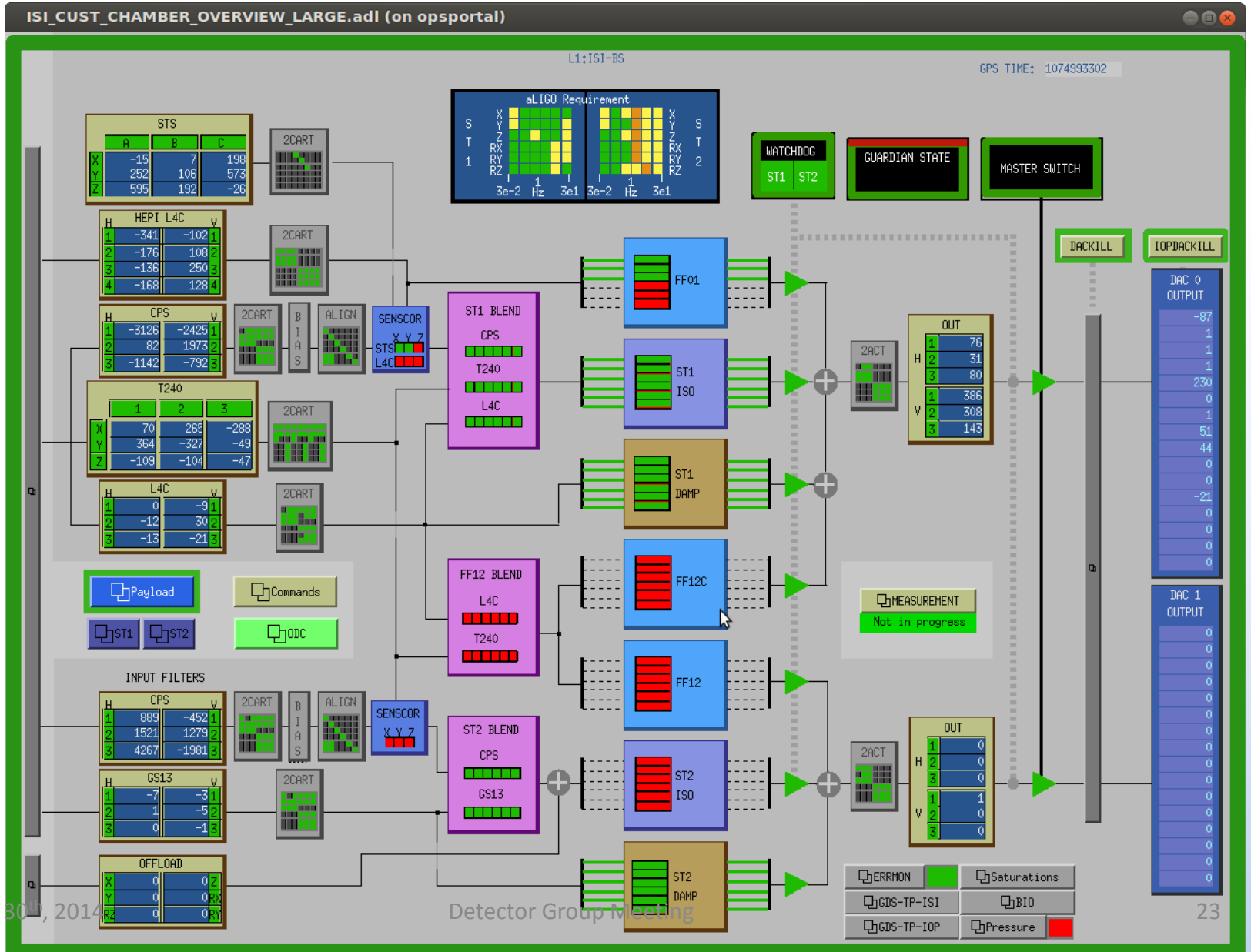
- Prevents from locking floating stage to ground
- Provides isolation starting $\sim 50/100$ mHz

SC: Sensor Correction filter

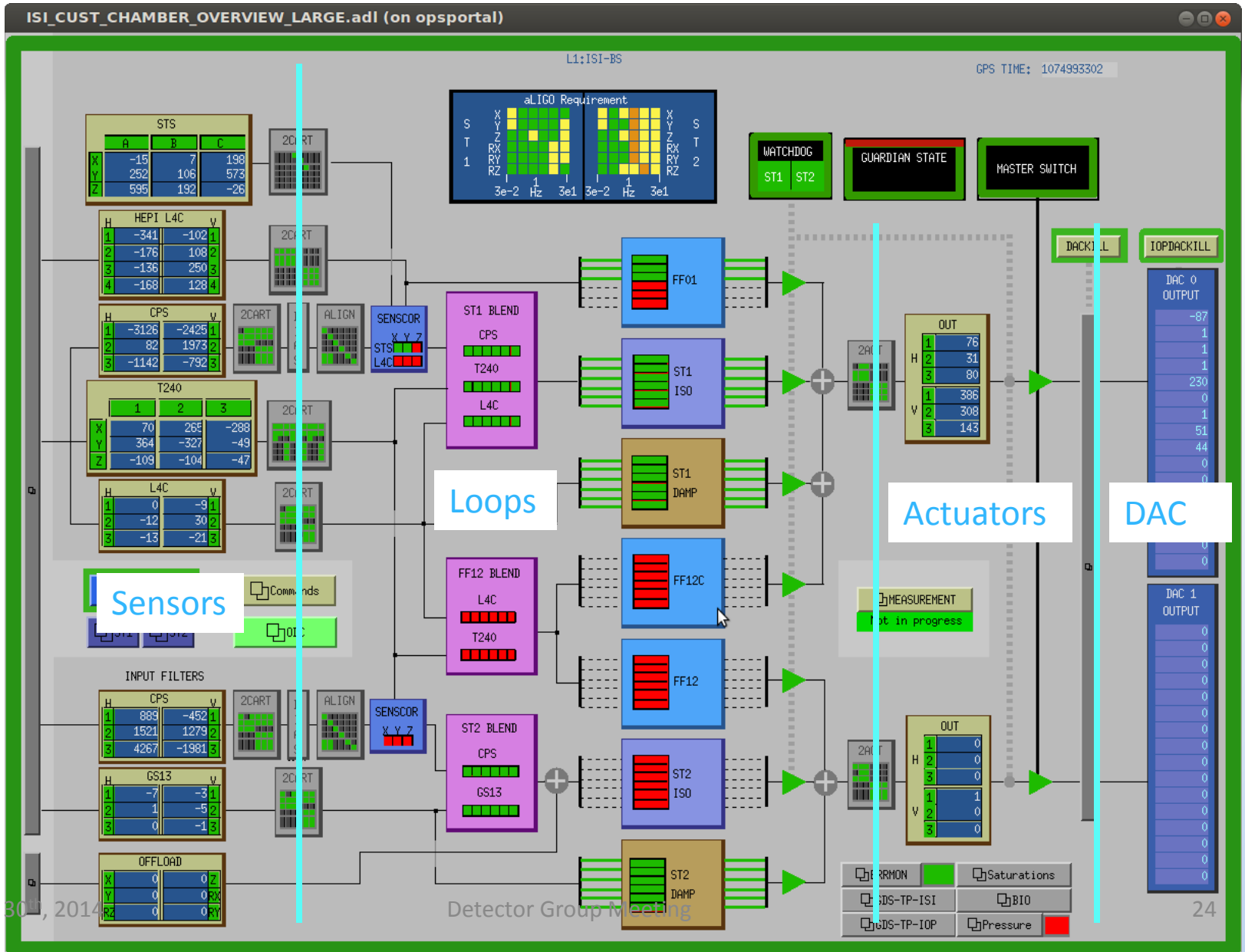




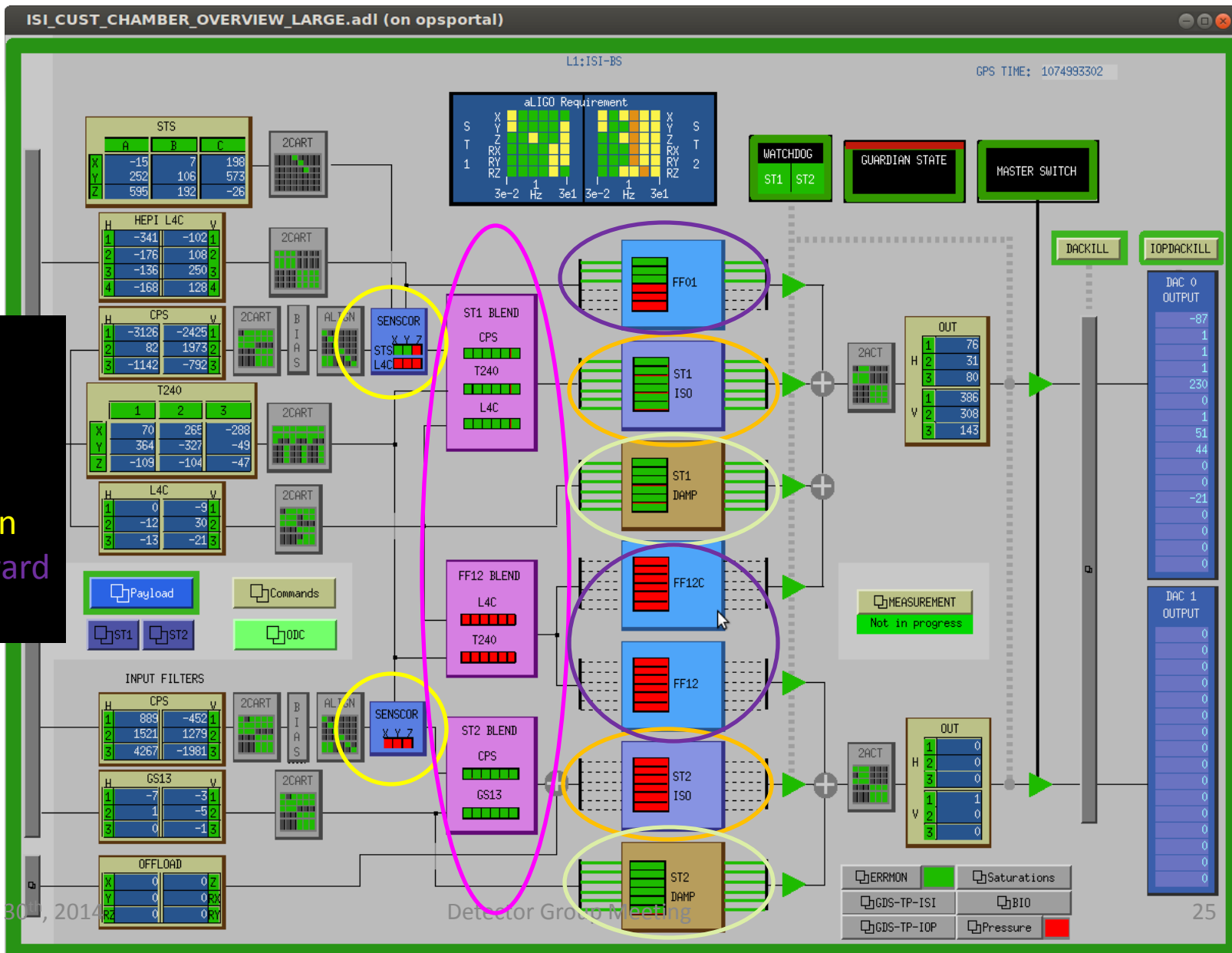
Example of BSC-ISI



Example of BSC-ISI



Example of BSC-ISI



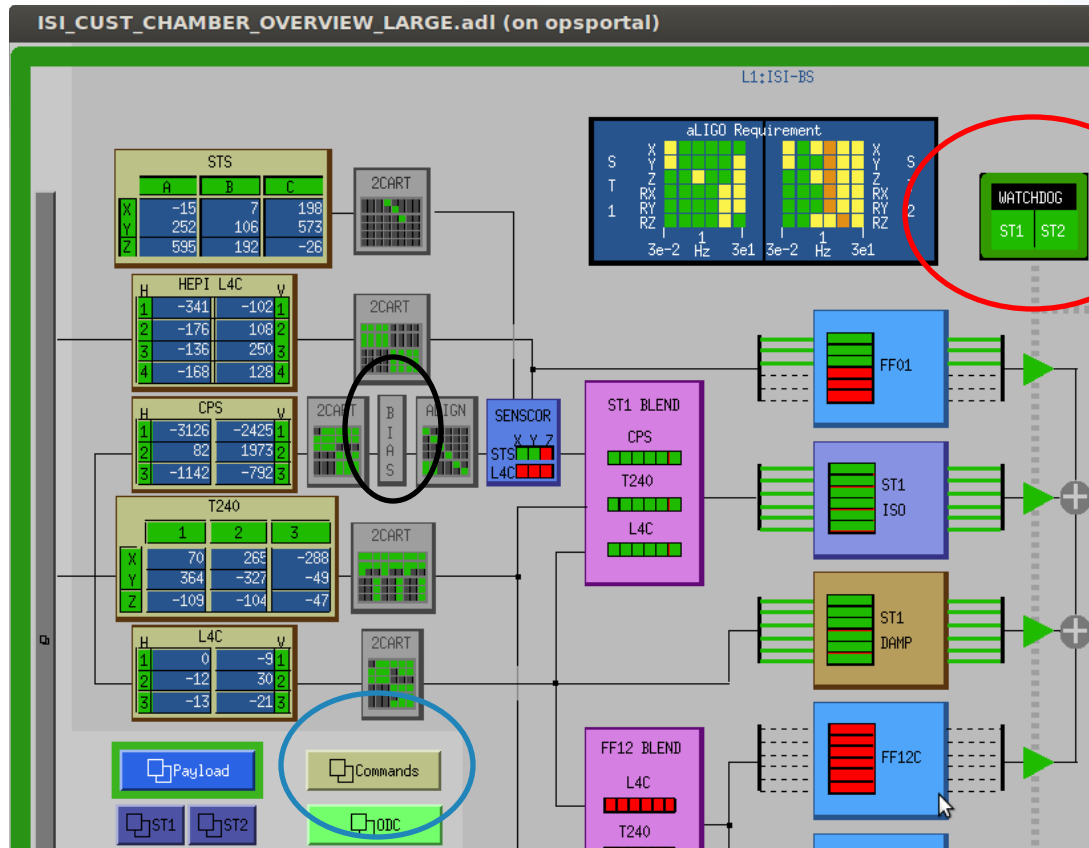
Damping
Isolation
Blend
Sensor
Correction
Feedforward

A few control room tools

- Commands screens-> to turn on feedback
- Watchdog plots
- BIAS screens



Allow to turn on feedback easily & keep positioning alignment

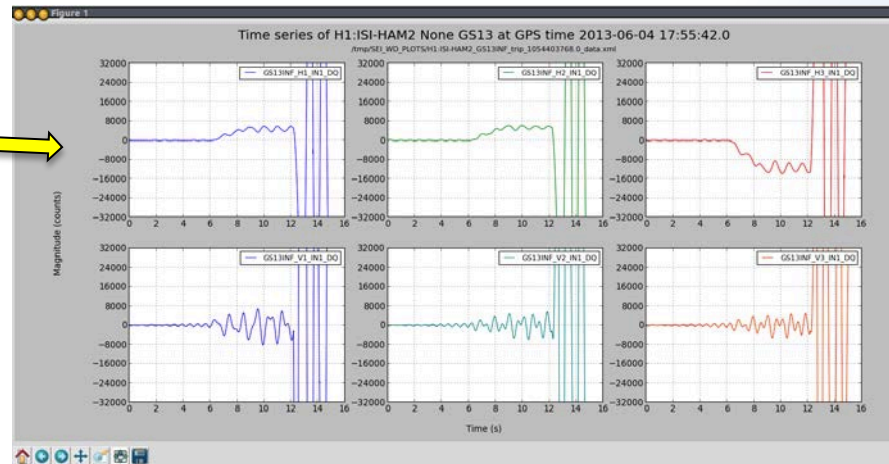
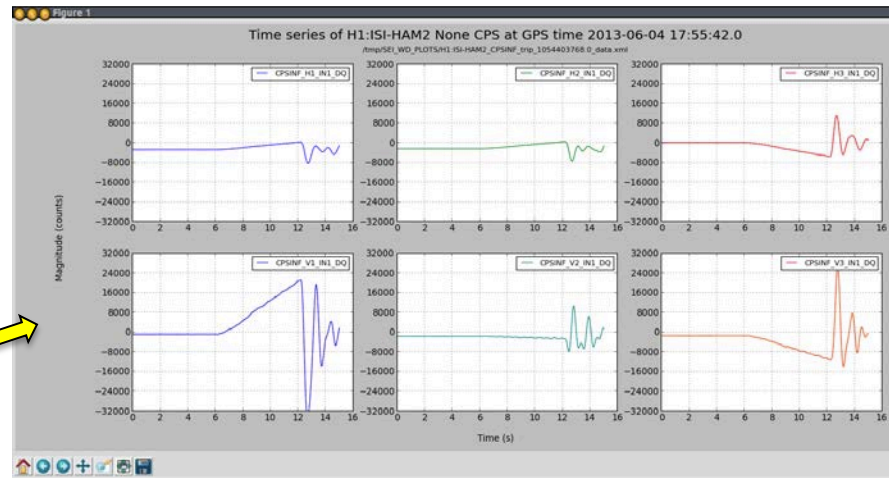


Watchdog plots

Find out which group tripped the ISI

The screenshot shows the 'ISI_CUST_CHAMBER_WATCHDOG.ad' interface. On the left, the system state is 'STATE 1: ARMED'. The main area displays several monitors with their current values and trip status (green for OK, red for tripped). A yellow box highlights the 'CPS limit' monitor, which is currently red. A yellow arrow points from this monitor to the top-right plot. Another yellow arrow points from the 'GS13 limit' monitor to the bottom-right plot. At the bottom left, a legend shows '32: Payload Sat.' highlighted in a red box.

MONITORS	FIRST TRIP	CURRENT TRIP
DISP H1: -2739		
DISP H2: -2328		
DISP H3: 73		
DISP V1: -725		
DISP V2: -1598		
DISP V3: -1364		
GEO H1: 62		
GEO H2: 314		
GEO H3: 238		
GEO V1: -42		
GEO V2: 40		
GEO V3: 265		
L4C H1: 0		
L4C H2: 0		
L4C H3: 0		
L4C V1: 0		
L4C V2: 0		
L4C V3: 0		
ACT H1: 0		
ACT H2: 0		
ACT H3: 0		
ACT V1: 0		
ACT V2: 0		
ACT V3: 0		



From Hugo P. - G1300618

Conclusion

- Currently 95.5% of aLIGO SEI in vacuum components and 100 % of pre-isolators are built
 - 1/3 of all components will not be installed until India is ready.
- Most systems (HAM-ISI, BSC-ISI, HAM-HEPI, BSC-HEPI) are installed and under control at either site.
- Control schemes still evolving but based on principles shown before



Questions ?



EXTRA SLIDES

ISI_CUST_CHAMBER_OVERVIEW_LARGE.adl (on opsportal)

L1:ISI-HAM6

GPS TIME: 1074993248

aLIGO Requirement

H	X					
H	Y					
A	Z					
M	RX					
M	RY					
M	RZ					
		3e-2	1	3e1		

WATCHDOG

GUARDIAN STATE

MASTER SWITCH

DACKILL

IOPDACKILL

INPUT FILTERS

STS

	A	B	C
X	88	-63	-37
Y	-467	-124	51
Z	89	443	572

2CART

ST 0 L4C

	0	0
	0	0
	0	0

2CART

CPS

H		V
1	-1240	8655
2	-3983	-1657
3	1087	-1182

2CART

ALIGN

GS13

H		V
1	1	-15
2	4	67
3	-28	13

2CART

OFFLOAD

X	0	0	Z
Y	0	0	RX
RZ	0	0	RY

2CART

SENSCOR
X Y Z
STS
L4C

ST1 BLEND
CPS
GS13

FF

ST1 ISO

ST1 DAMP

OUT

H		
1	86	
2	708	
3	-311	
V		
1	-79	
2	-669	
3	-1099	

2ACT

DAC 0 OUTPUT

0
0
0
0
0
0
0
0
0
0
0
0
-254
63
-897
543
-1357
-185
0
0

- ERRMON
- Saturations
- GDS-TP-ISI
- BIO
- GDS-TP-IOP
- Pressure

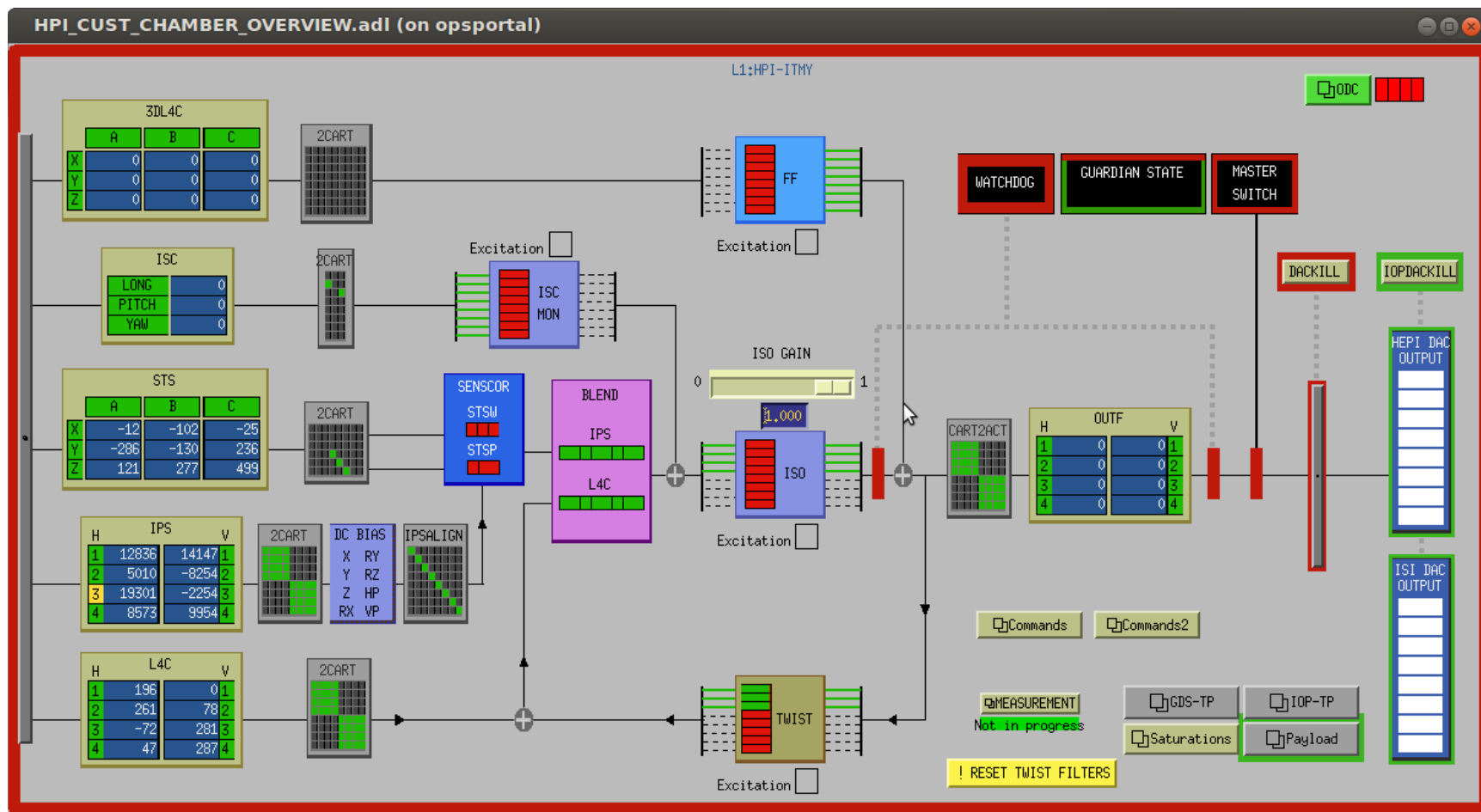
Payload

Commands

ODC

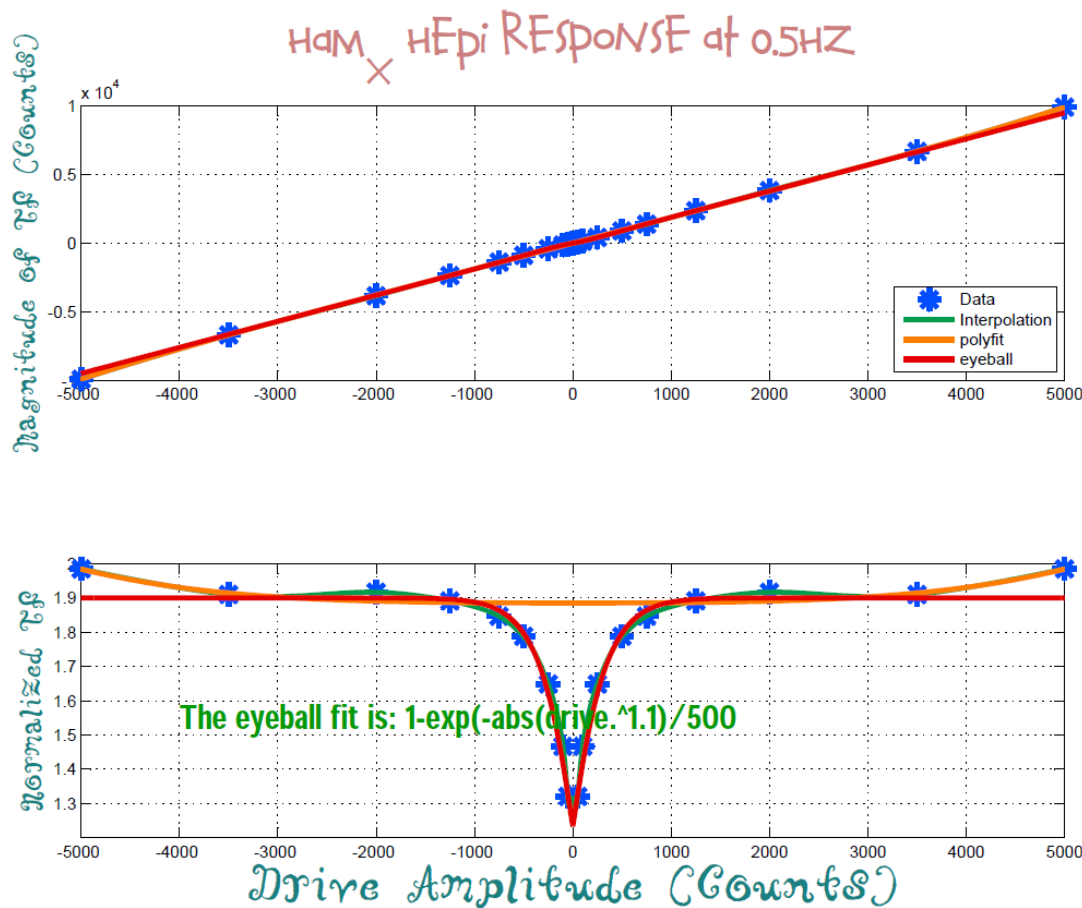
STATE

MEASUREMENT
Not in progress



HAM-HEPI Commissioning (LASTI)

- HEPI limitation?... Non linearity of low amplitude drives



Courtesy: R. Mittleman

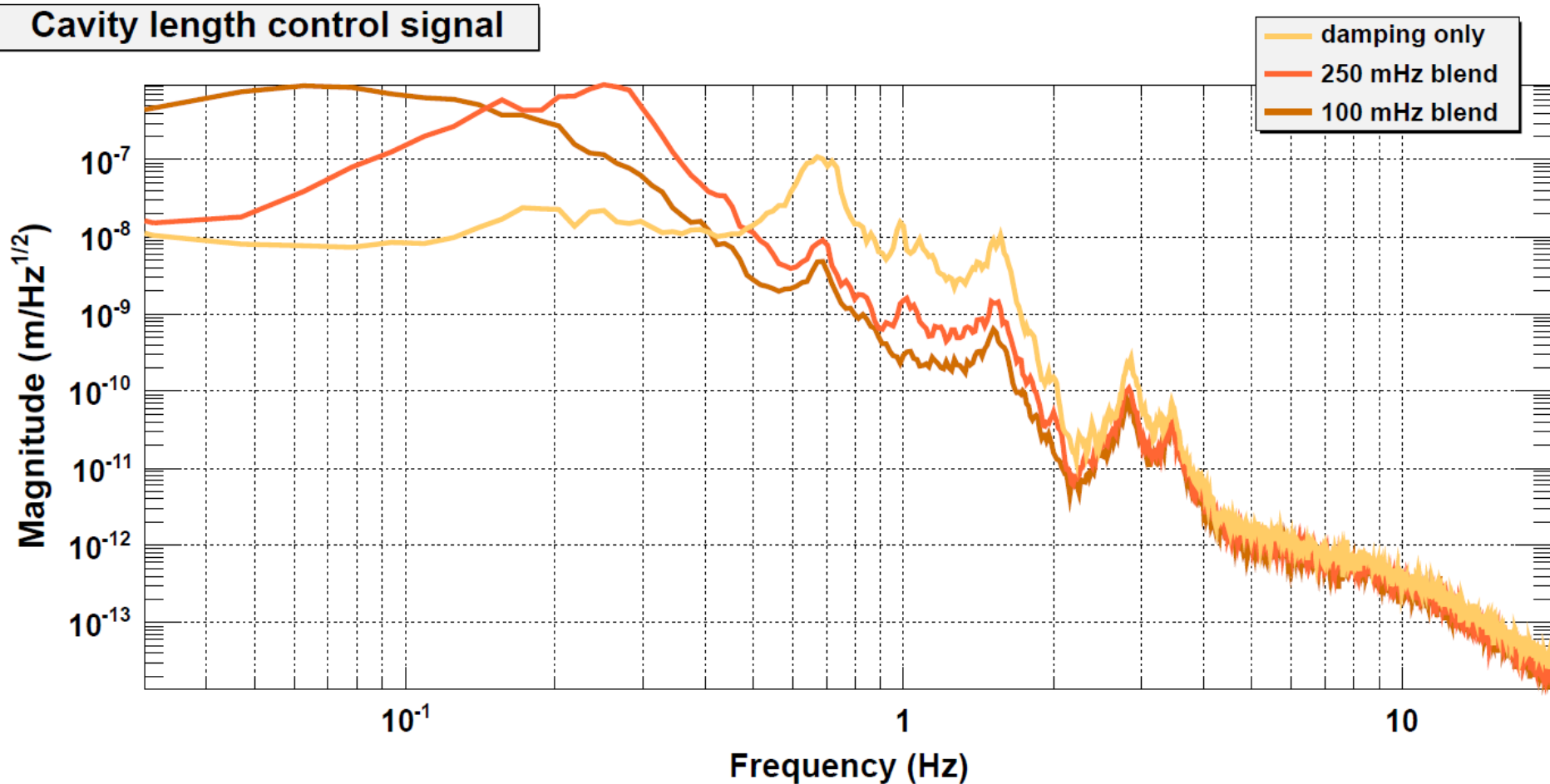
Sept 11th, 2012

IMC Commissioning (LLO)

Courtesy: R. De Rosa

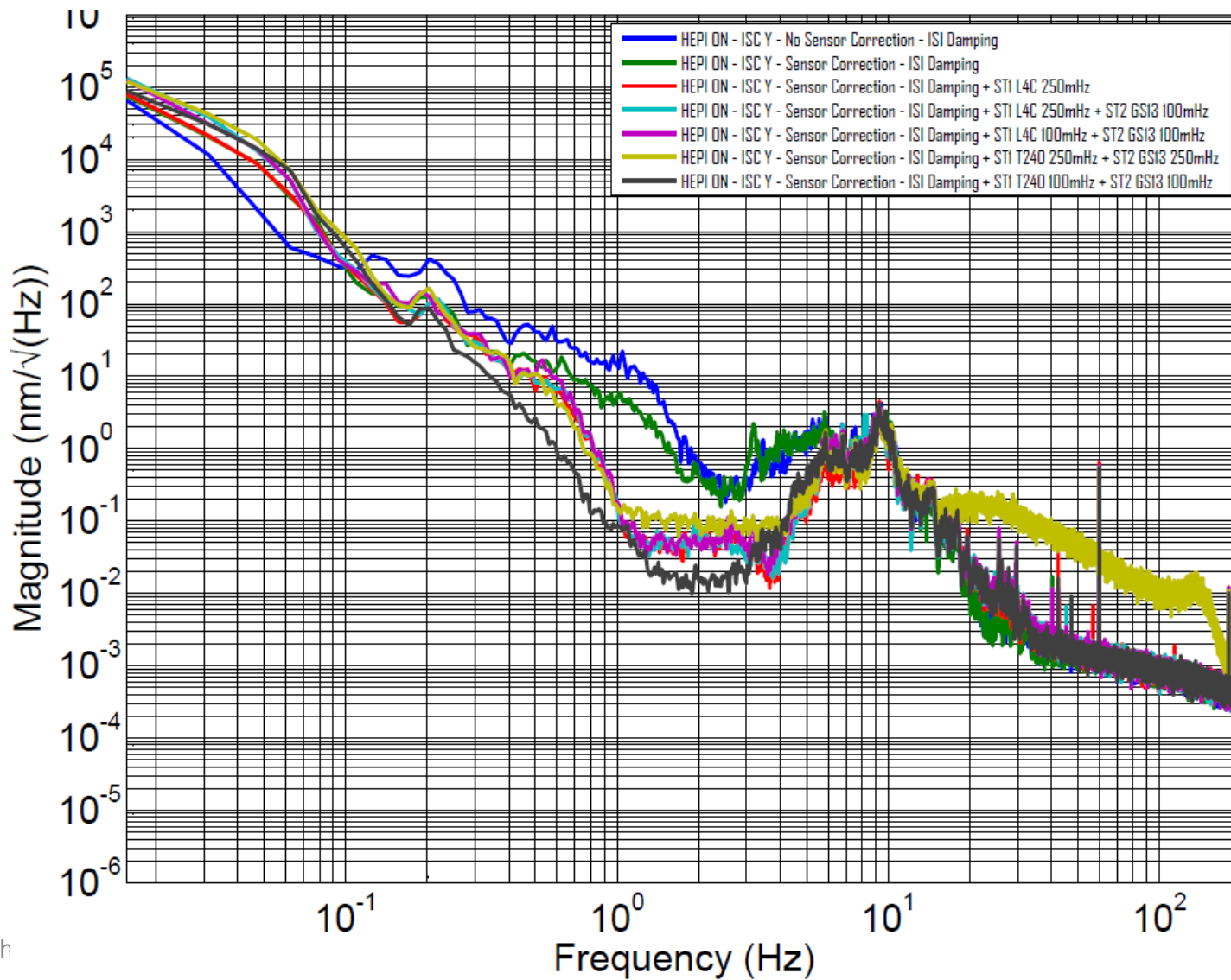
Input Mode Cleaner

Cavity length control signal

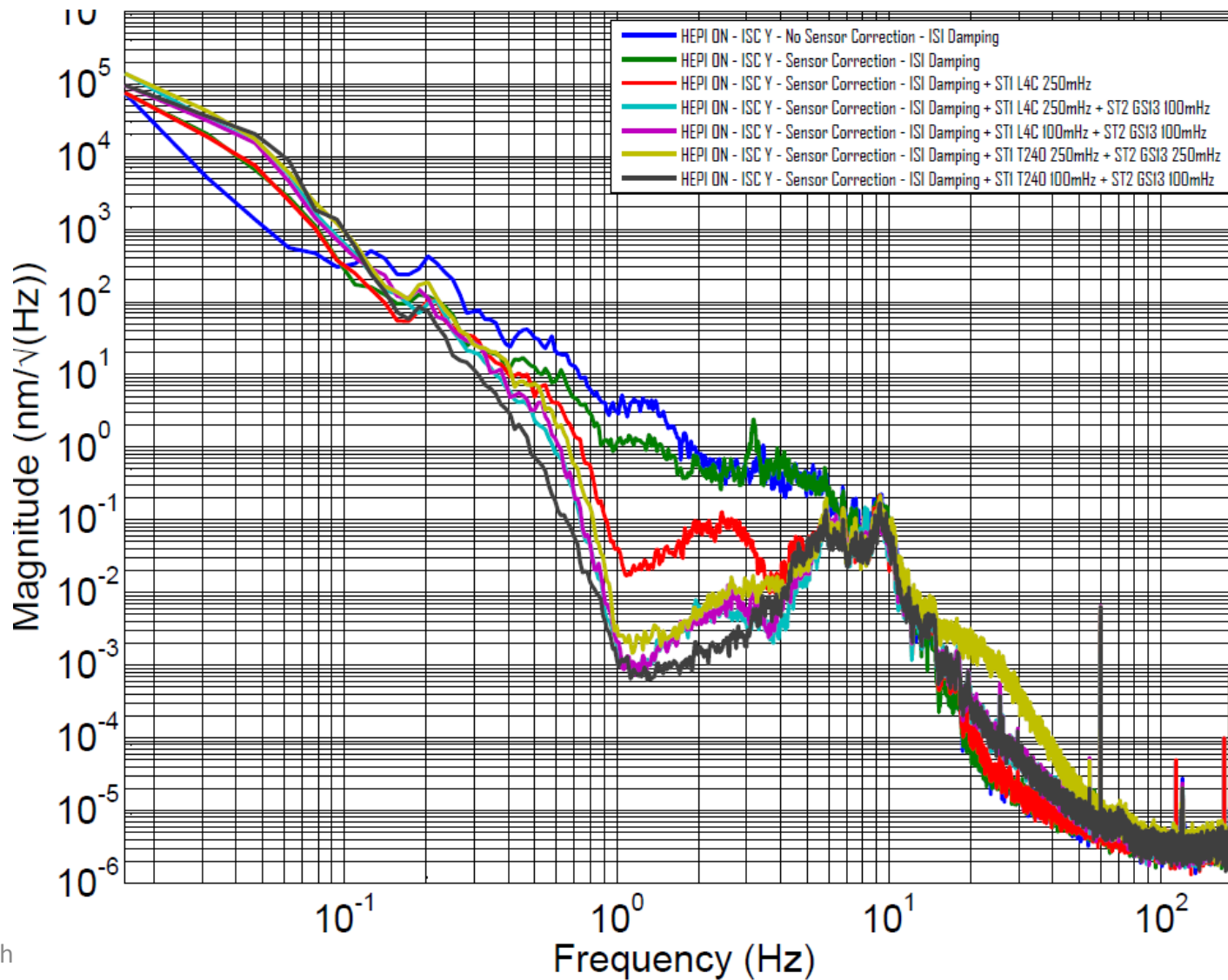


Courtesy: V. Lhuillier

Stage 1



Stage 2



Courtesy: V. Lhuillier

Cavity length control signal

