Modeling Of Active Seismic Isolation Platforms For Performance Evaluation

Nairwita Mazumder for Seismic Group

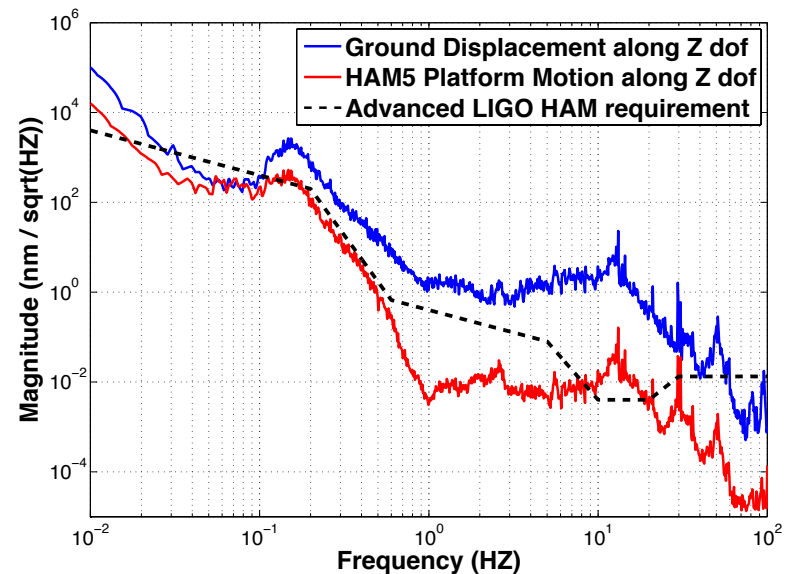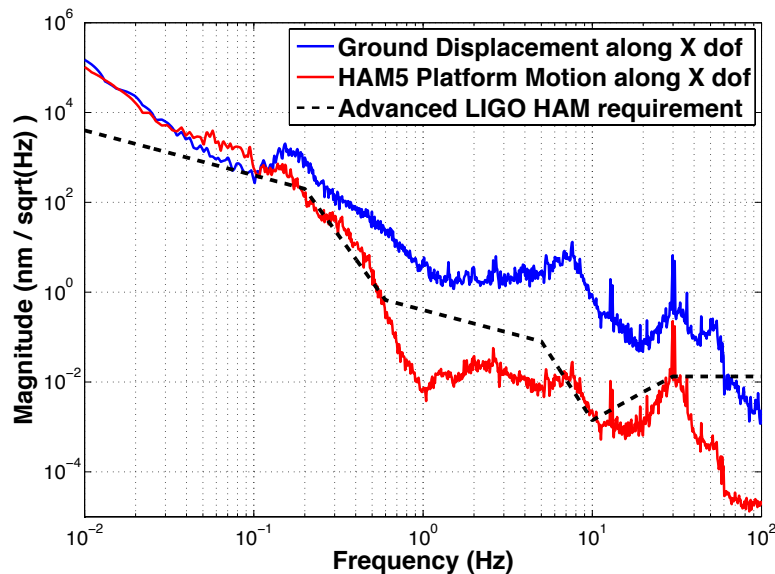LVC, March 2016

DCC- LIGO-G1600544-v2

Outline

- Motivation
- Brief overview of the system
- Sensor Noise Sources
- HAM-ISI control loop
- Loop Performance
- Current Status and Future work
- Conclusion

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Motivation

- Better understanding of the loop design
  - ➢ noise contribution from different paths
  - ➢ targeted improvements of loop components

- Evaluate the performance of seismic Isolation platforms
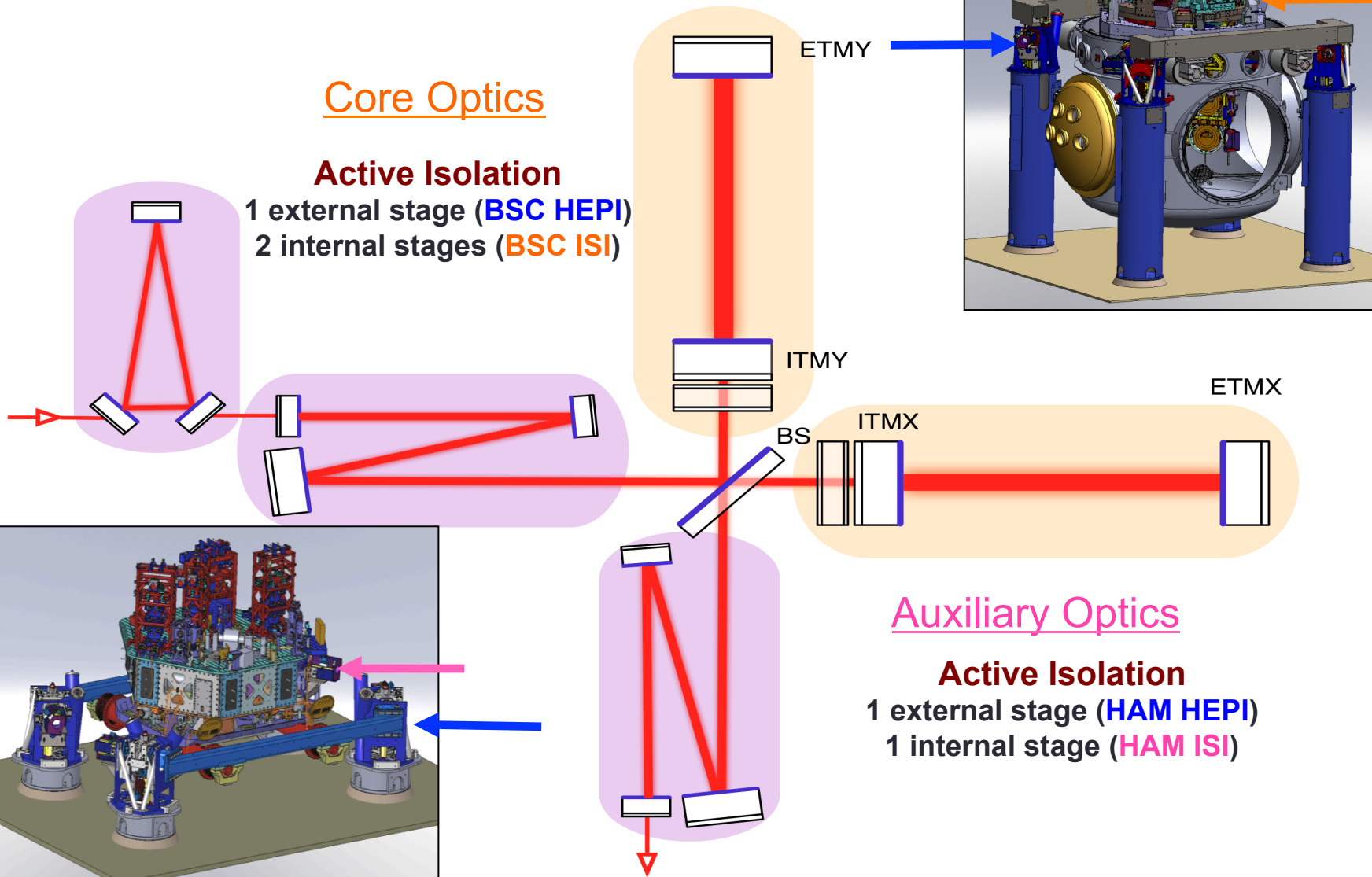 - ➢ provide initial test bed for future enhancements

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aLIGO Active Seismic Isolation

Core Optics

Active Isolation
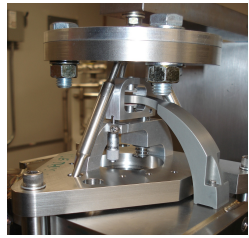1 external stage (**BSC HEPI**)
2 internal stages (**BSC ISI**)

ETMY

ITMY

BS

ITMX

ETMX

Auxiliary Optics

Active Isolation
1 external stage (**HAM HEPI**)
1 internal stage (**HAM ISI**)

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Sensor Noise Sources

IPS
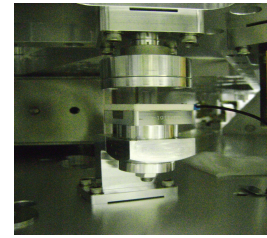Kaman's Inductive Position Sensors
Used On: HEPIs
f ≤ 0.5 Hz

DC

CPS
MicroSense's Capacitive Displacement Sensors
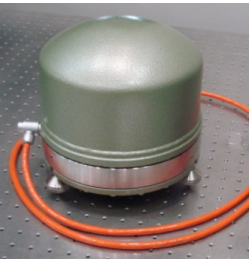Used On: HAM-ISIs & BSC-ISIs
f ≤ 0.5 Hz Control

10   mHz

STS2
Strekheisen's STS-2
Used On: HEPIs
0.01 ≤ f ≤ 1Hz

T240
Nanometric's Trillium 240
Used On: BSC-ISIs
0.01 ≤ f ≤ 1Hz

1   Hz

GS13
GeoTech's GS-13
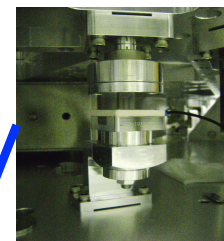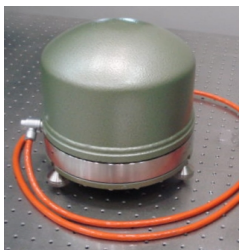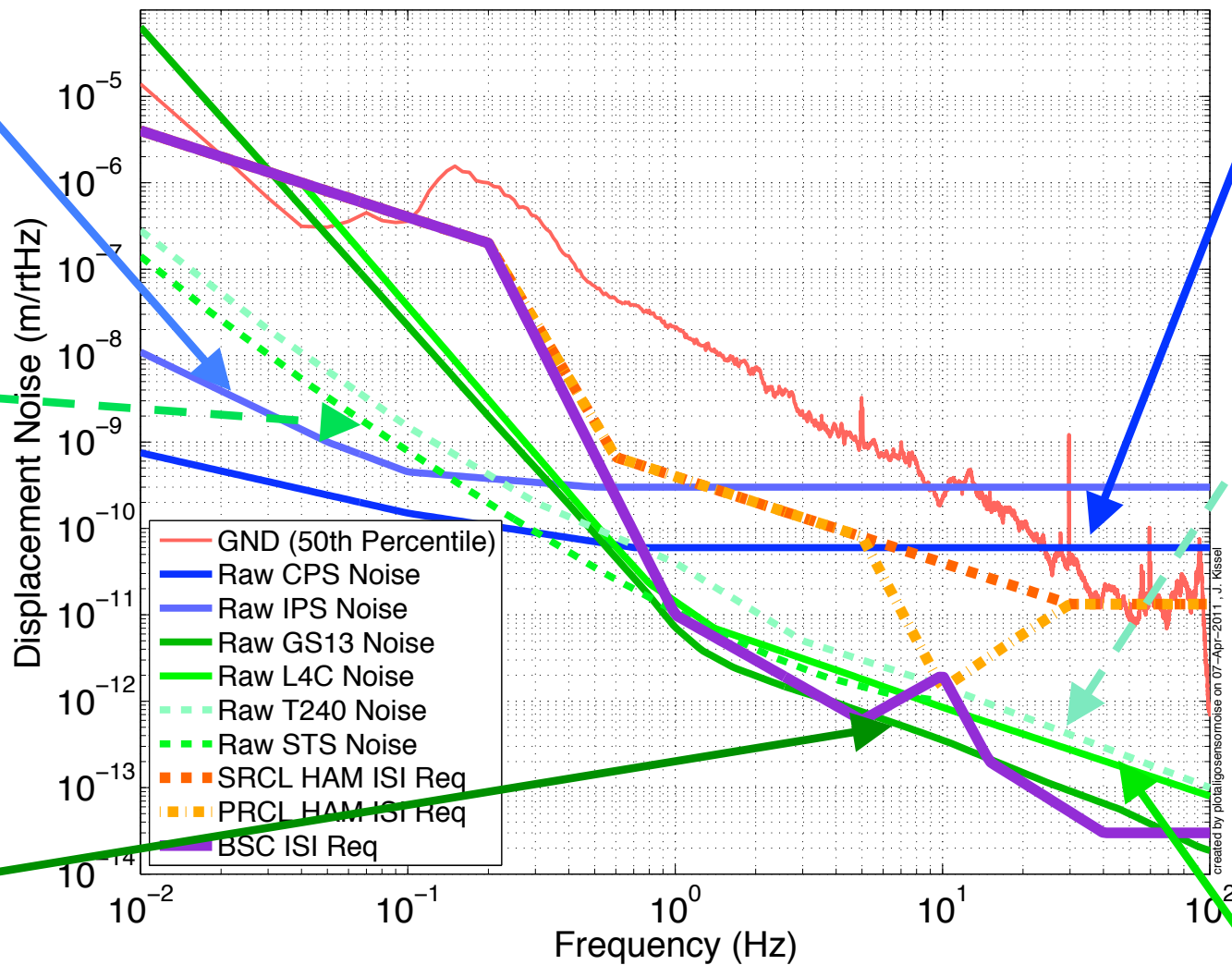Used On: HAM-ISIs and BSC-ISIs
f: ≥ 0.5 Hz

L4C
Sercel's L4-C
Used On: All Systems
f≥ 0.5 Hz

800 Hz

Sensor Noise Sources

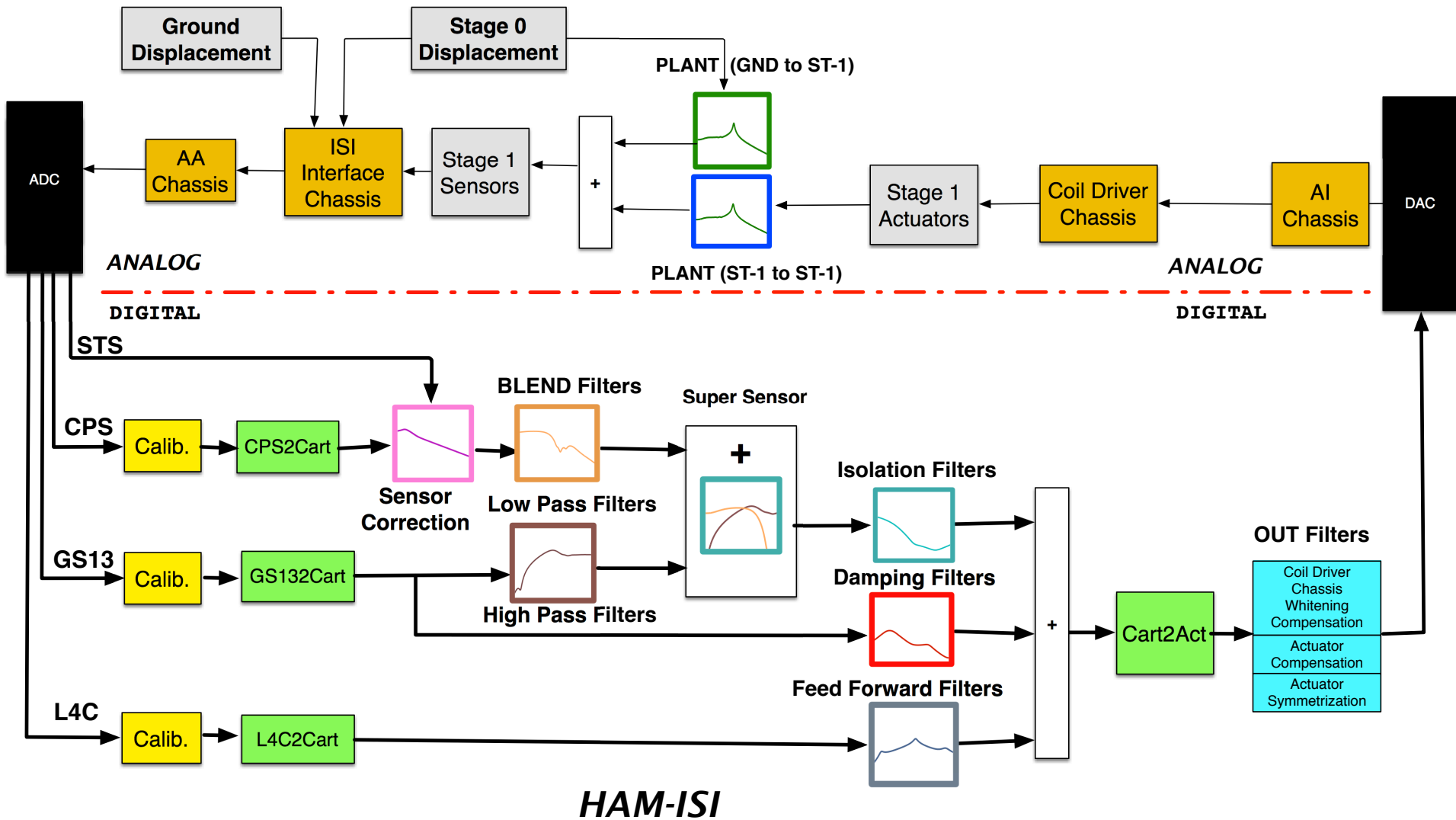How different noise sources dominate over different frequency ranges?

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HAM Control diagram

Noise flow through the control loop in HAM-ISI

- Input ST-0 displacement to Platform motion:

- Ground STS motion to Platform motion:

- Residual ST0 motion to Platform motion:
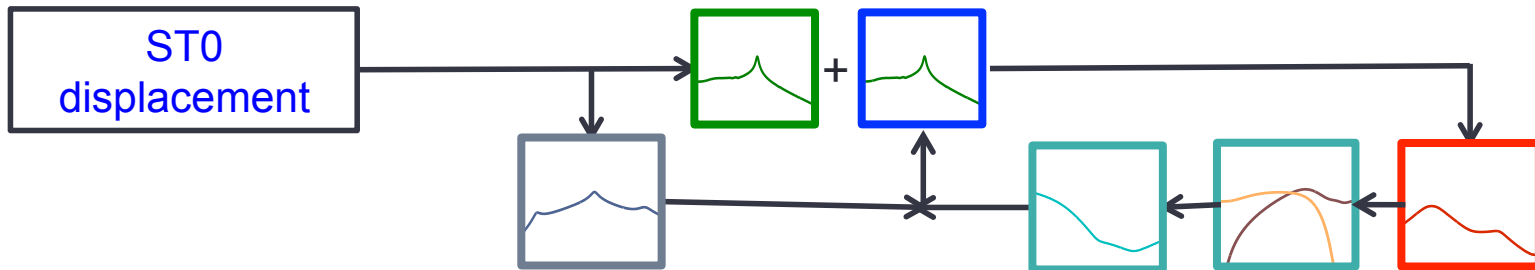

- Sensor Noises to Platform
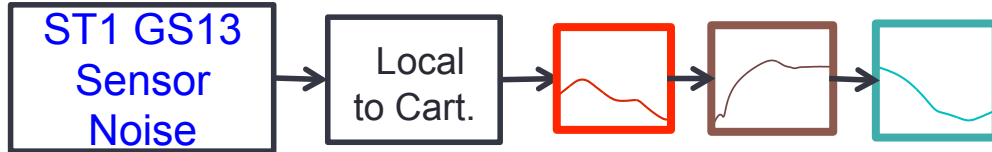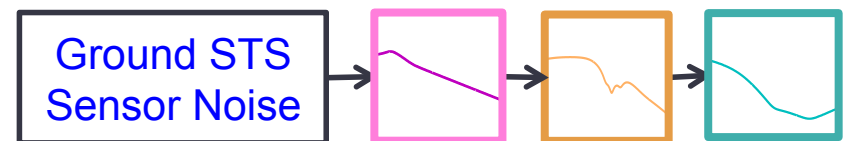
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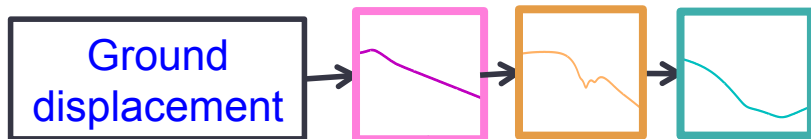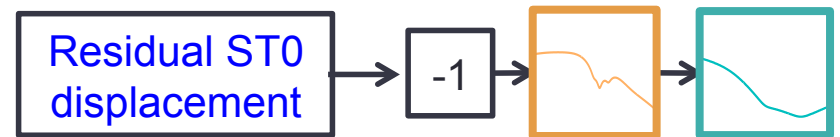- Current Status and Future work
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Damped Model
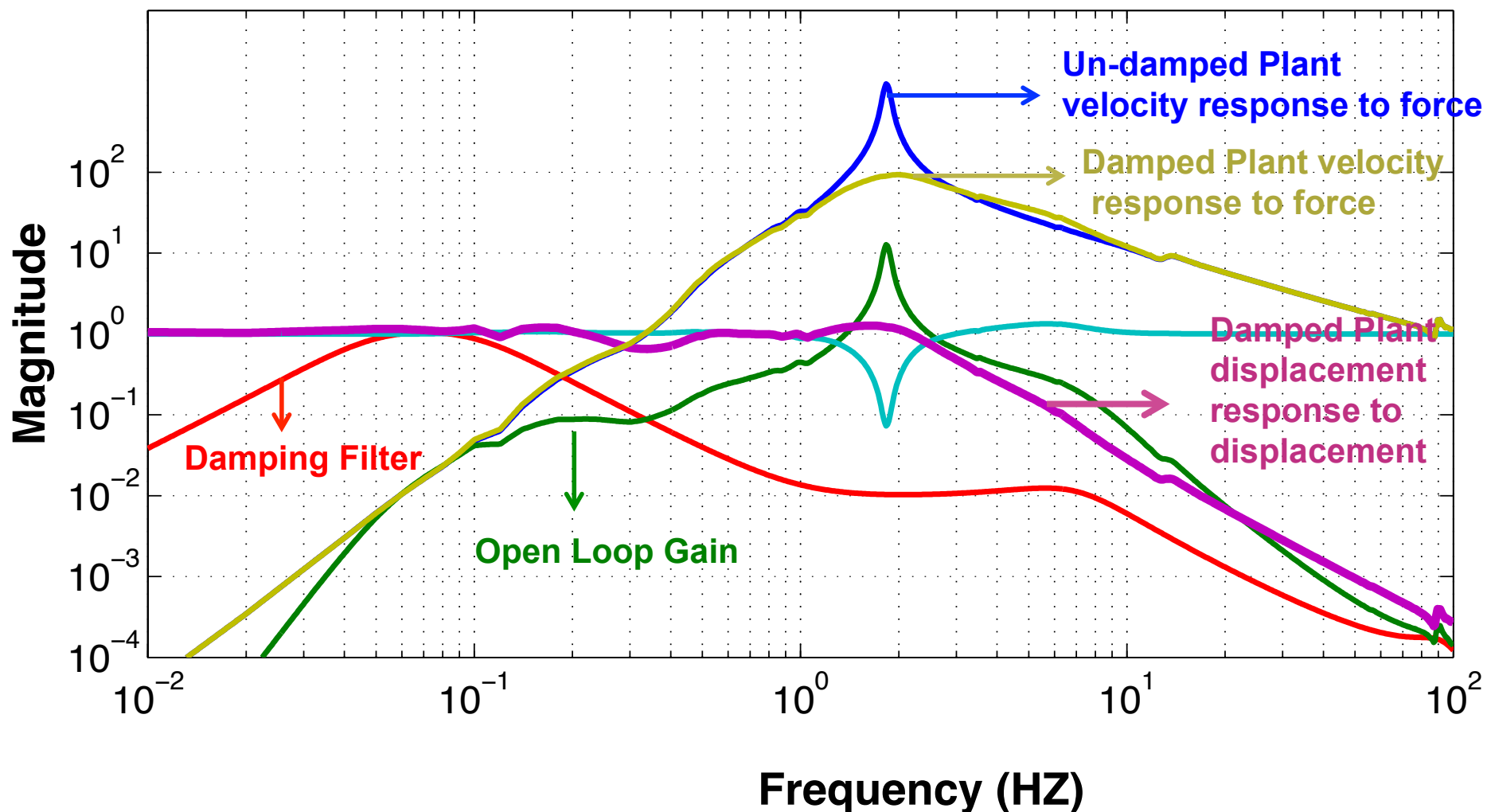
Isolated model (Loop Gain)

Closed Loop TF: Isolated Model (without sensor correction)

ST0 –> ST1 TF through Feedback path

Linear Sum

ST0 –> ST1 TF through plant

ST0 –> ST1 TF through Feed-forward path

Magnitude

Frequency (Hz)

Closed Loop TF: Isolated Model (without sensor correction)

Successive Loop Closure
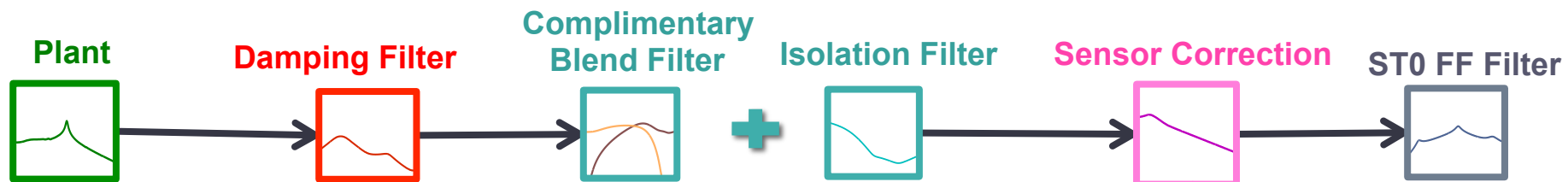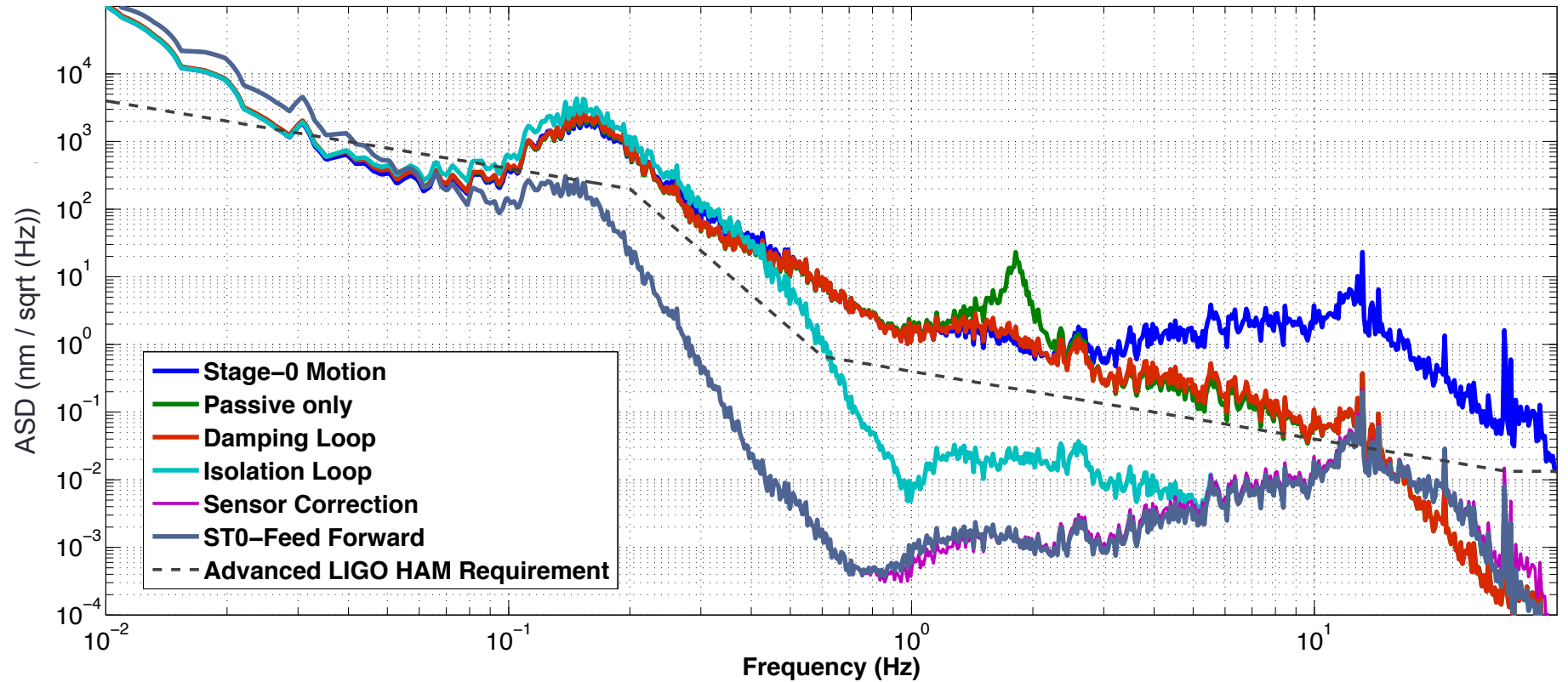
Sensor Noise Limitation

Noise Budget Plot

Noise Budget for HAM5   Z DOF

Legend:
- Ground motion
- Measured platform motion
- From L4CZ
- From GS13Z
- From CPSZ
- Motion From STSZ
- ST0 and Ground motion via sensor correction
- Total sensor noise limitation
- Total platform motion predicted by model
- Advanced LIGO HAM Requirement

Y-axis: ASD (nm / sqrt (Hz))
X-axis: Frequency (Hz)

Noise Budget Plot

Noise Budget for HAM5 Z DOF

Legend:
- **Ground motion** (blue)
- **Measured platform motion** (green)
- **From L4CZ** (purple)
- **From GS13Z** (dark blue)
- **From CPSZ** (violet)
- **Motion From STSZ** (cyan)
- **ST0 and Ground motion via sensor correction** (red)
- **Total sensor noise limitation** (yellow)
- **Total platform motion predicted by model** (green dashed)
- **Advanced LIGO HAM Requirement** (black dashed)

Axes: ASD (nm / sqrt (Hz)) vs Frequency (Hz)

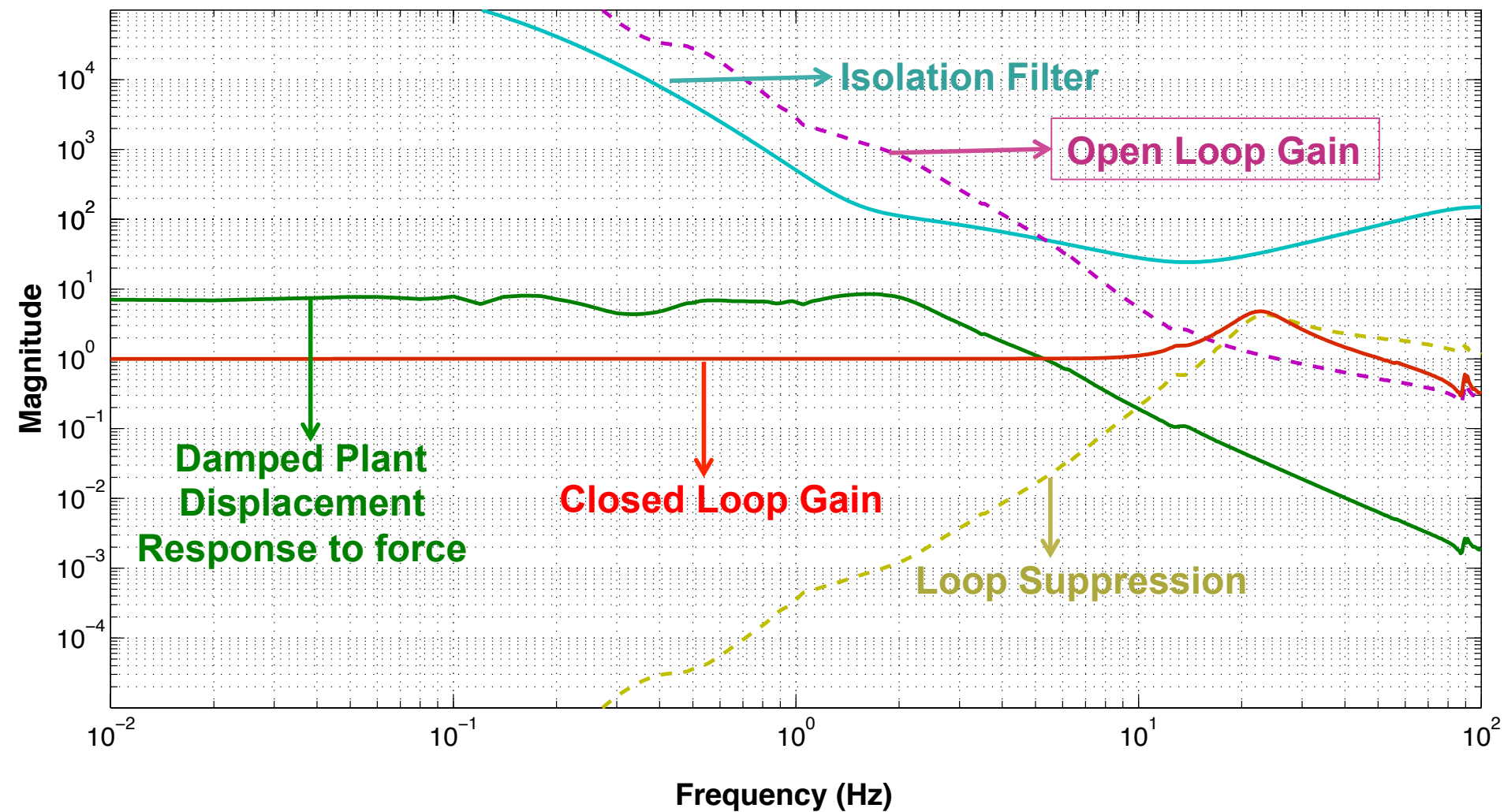# Outline

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- Brief overview of the system

- Sensor Noise Sources

- HAM-ISI control loop

- Loop Performance
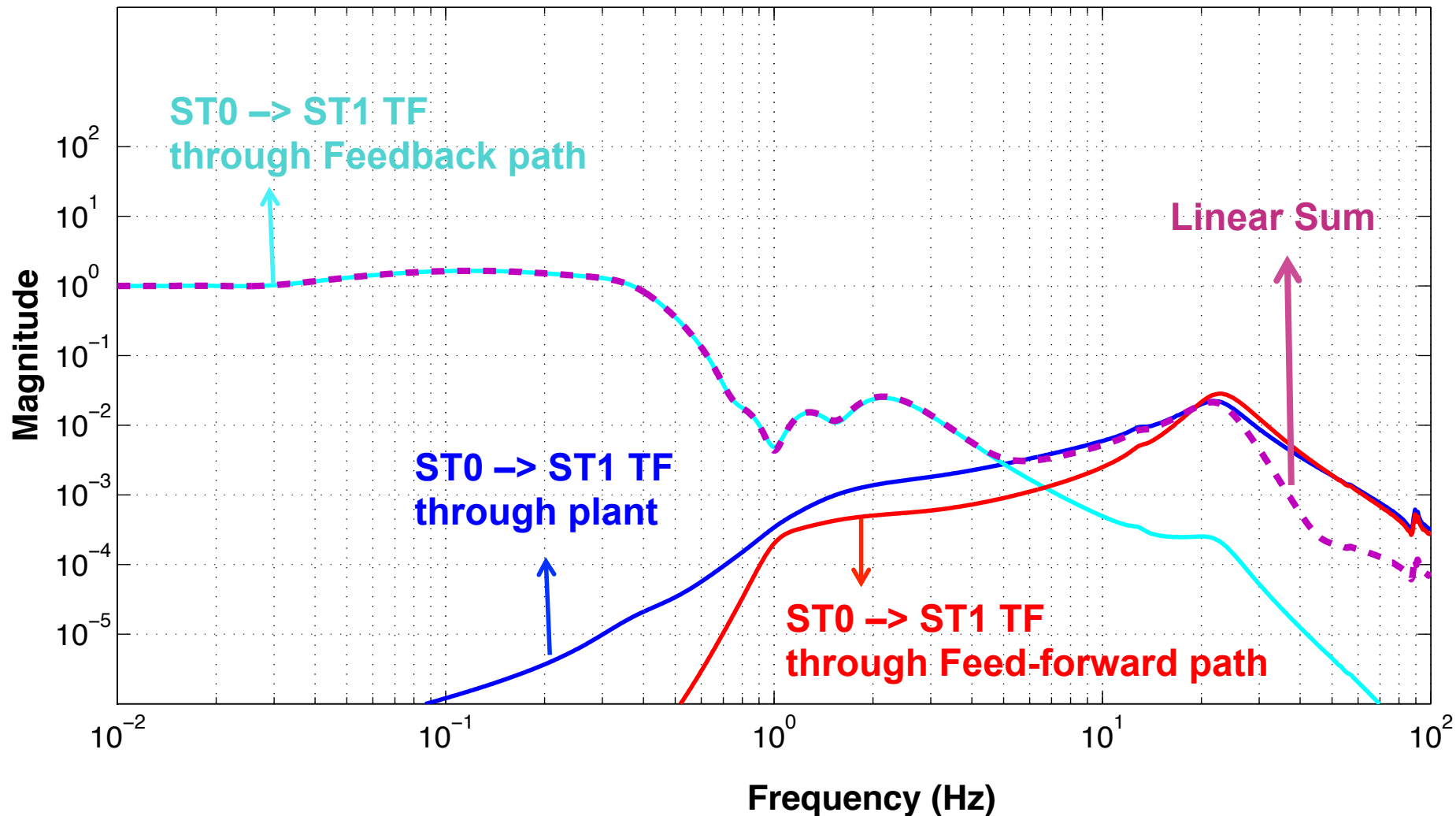
- **Current Status and Future work**

- Conclusion

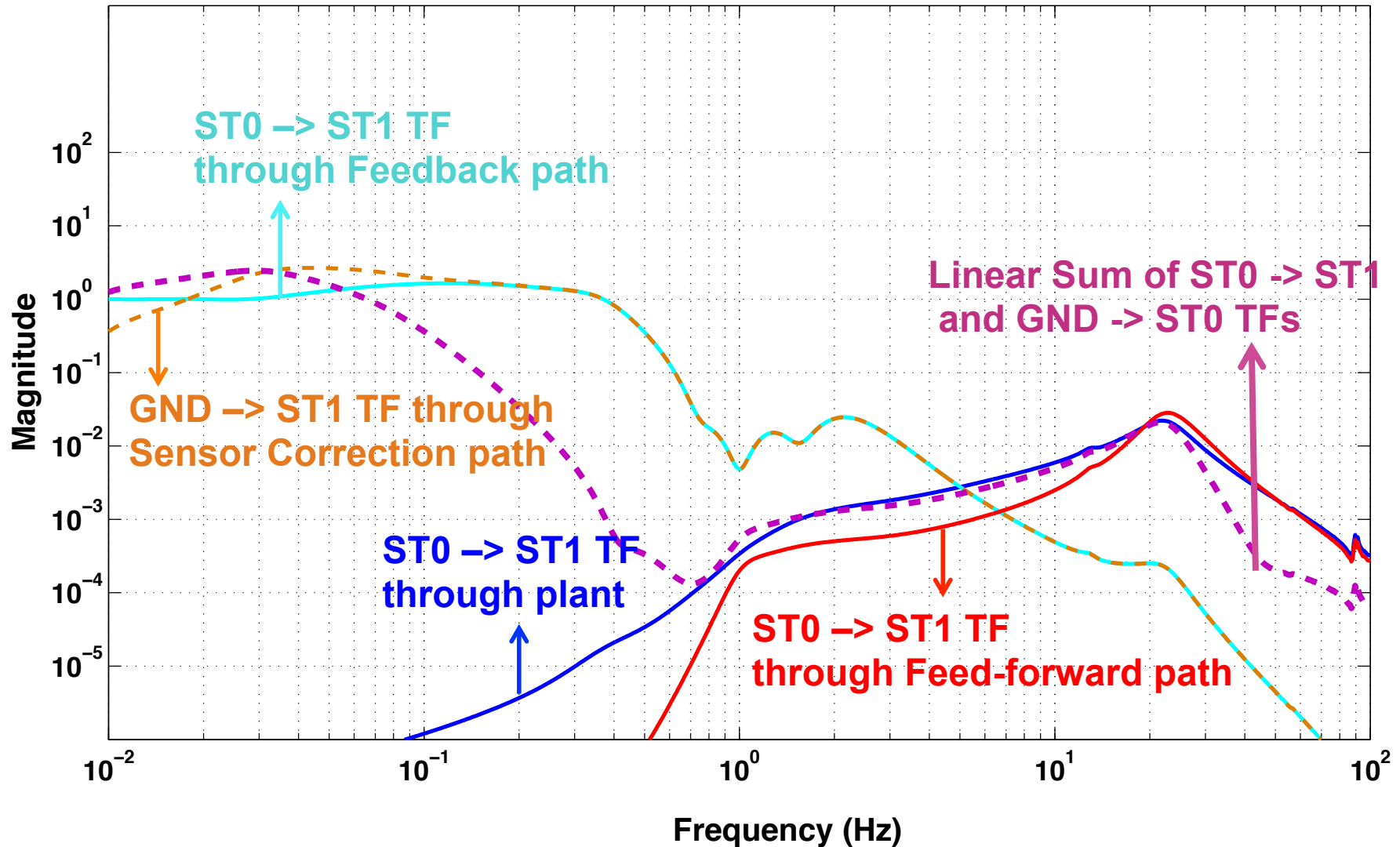# Current Status and Future work

- HAM-ISI model has been developed .

- Different control loop paths and noise propagation through the loops are thoroughly studied .

- Analyzing the individual control design paths for the BSC-ISI chambers more exhaustively.

- Working on a generalized version of the Model which can be used for all the seismic chambers at both the IFOs.

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- **Conclusion**

Conclusion
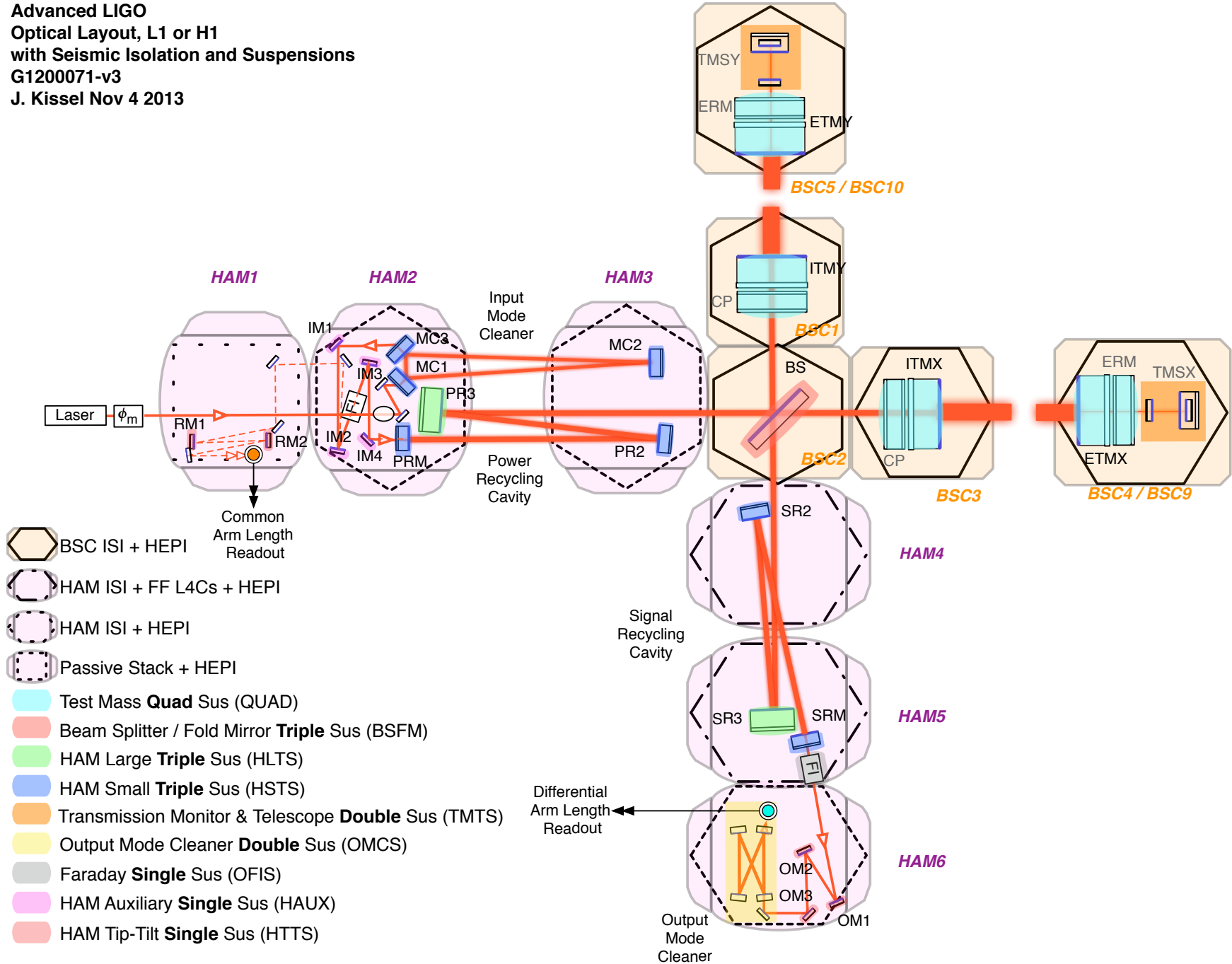
- Developed control loop model Seismic Isolation platforms to:
  - ➢ Analyze
  - ➢ Understand
  - ➢ Predict

- Demonstrated HAM-ISI Z dof model as an example
  - ➢ Other dofs for HAM-ISI chambers have been similarly studied
  - ➢ BSC-ISI models need further study

- Useful as an initial test bed for future upgrades
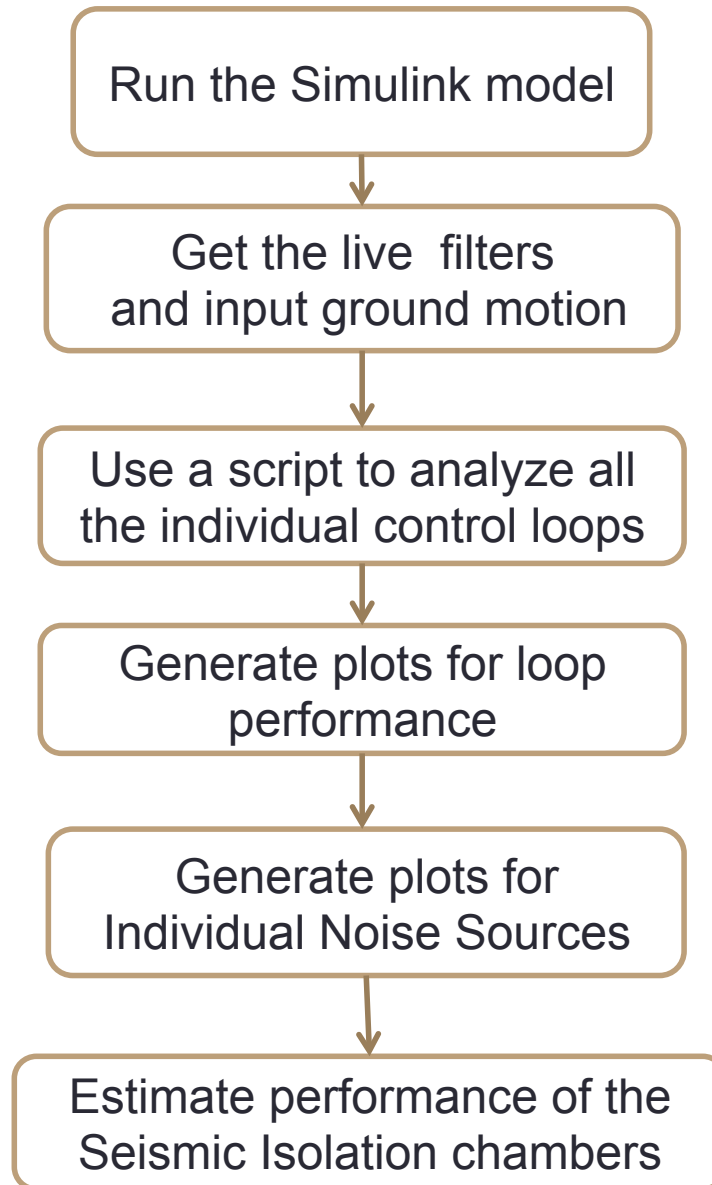 - ➢ Model can be useful for other groups too
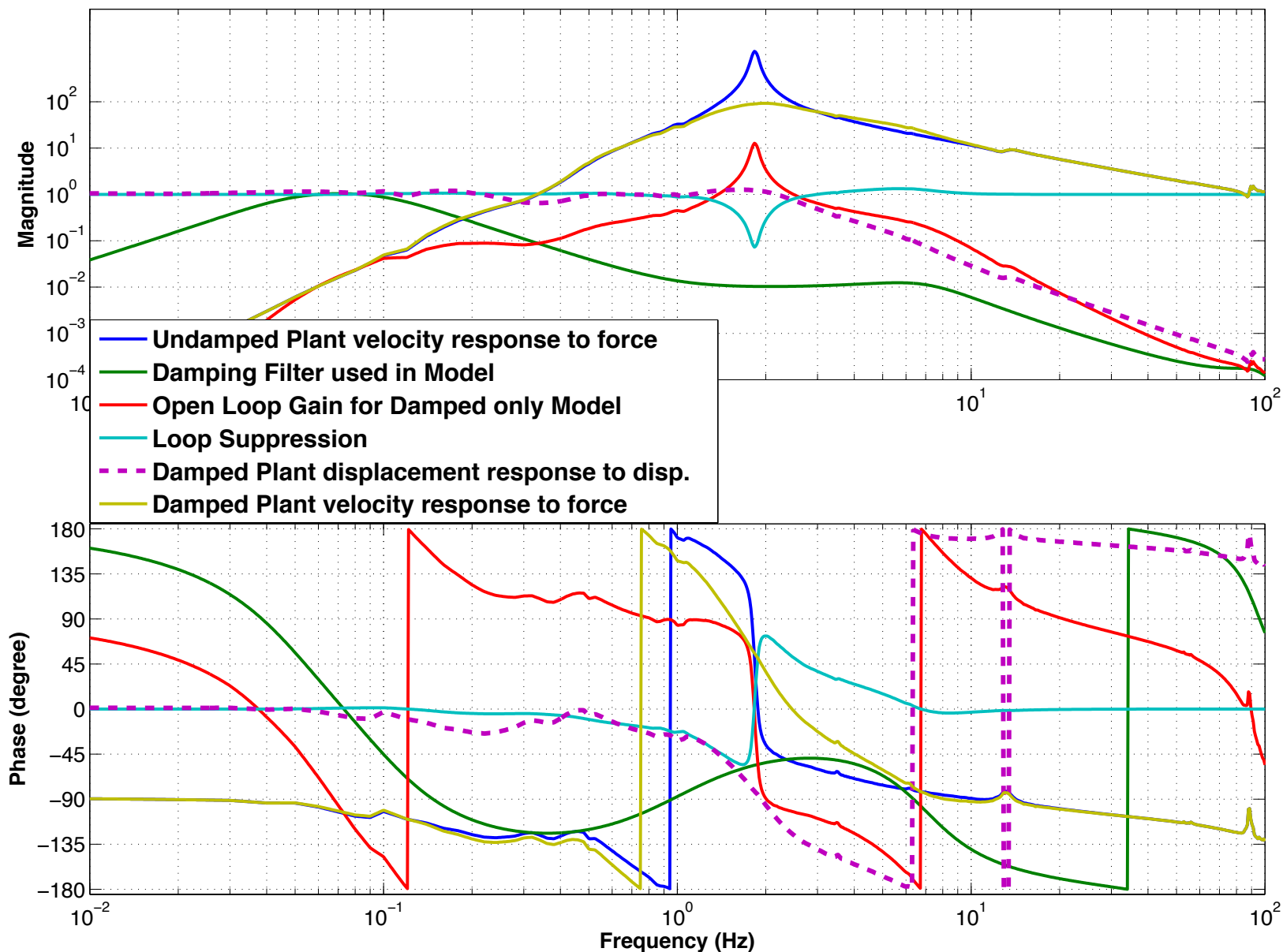
Thank you!!

Extra Slide

Advanced LIGO
Optical Layout, L1 or H1
with Seismic Isolation and Suspensions
G1200071-v3
J. Kissel Nov 4 2013

Legend:

- BSC ISI + HEPI
- HAM ISI + FF L4Cs + HEPI
- HAM ISI + HEPI
- Passive Stack + HEPI
- Test Mass **Quad** Sus (QUAD)
- Beam Splitter / Fold Mirror **Triple** Sus (BSFM)
- HAM Large **Triple** Sus (HLTS)
- HAM Small **Triple** Sus (HSTS)
- Transmission Monitor & Telescope **Double** Sus (TMTS)
- Output Mode Cleaner **Double** Sus (OMCS)
- Faraday **Single** Sus (OFIS)
- HAM Auxiliary **Single** Sus (HAUX)
- HAM Tip-Tilt **Single** Sus (HTTS)

How does the Model work?

Run the Simulink model

↓

Get the live filters
and input ground motion

↓

Use a script to analyze all
the individual control loops

↓

Generate plots for loop
performance

↓

Generate plots for
Individual Noise Sources

↓

Estimate performance of the
Seismic Isolation chambers

Closed Loop Response: Damped Model

Legend:
- **Undamped Plant velocity response to force**
- **Damping Filter used in Model**
- **Open Loop Gain for Damped only Model**
- **Loop Suppression**
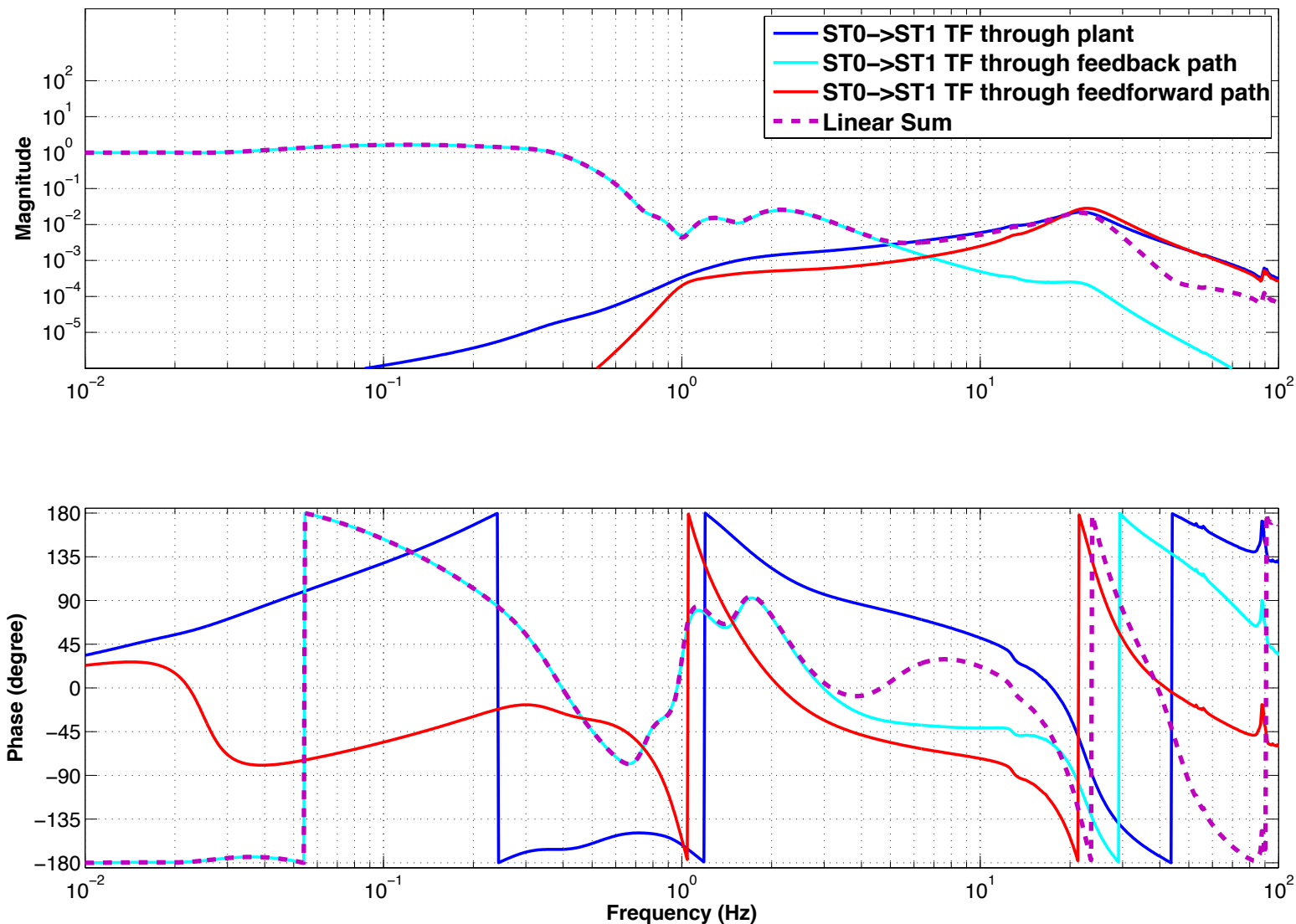- **Damped Plant displacement response to disp.**
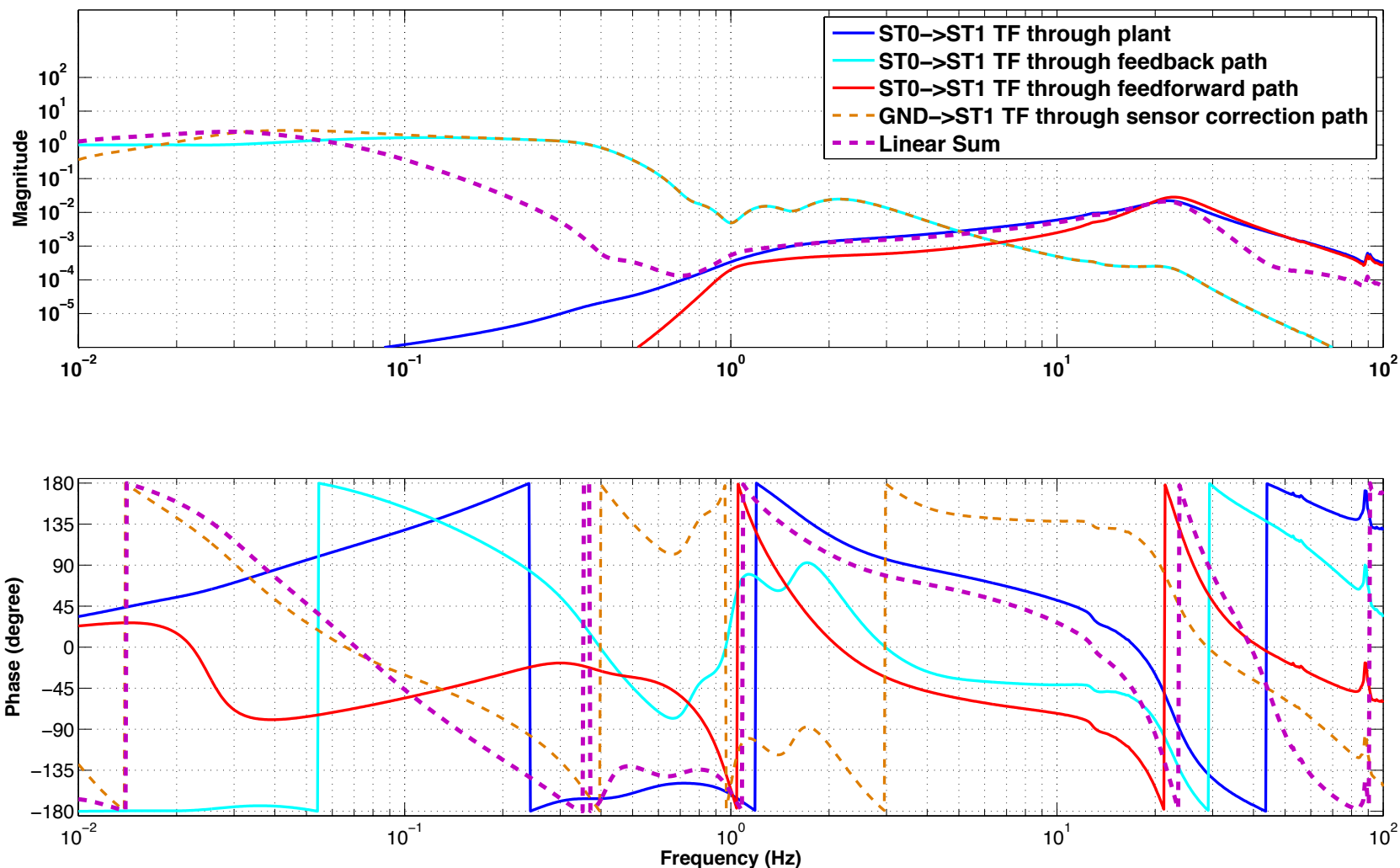- **Damped Plant velocity response to force**
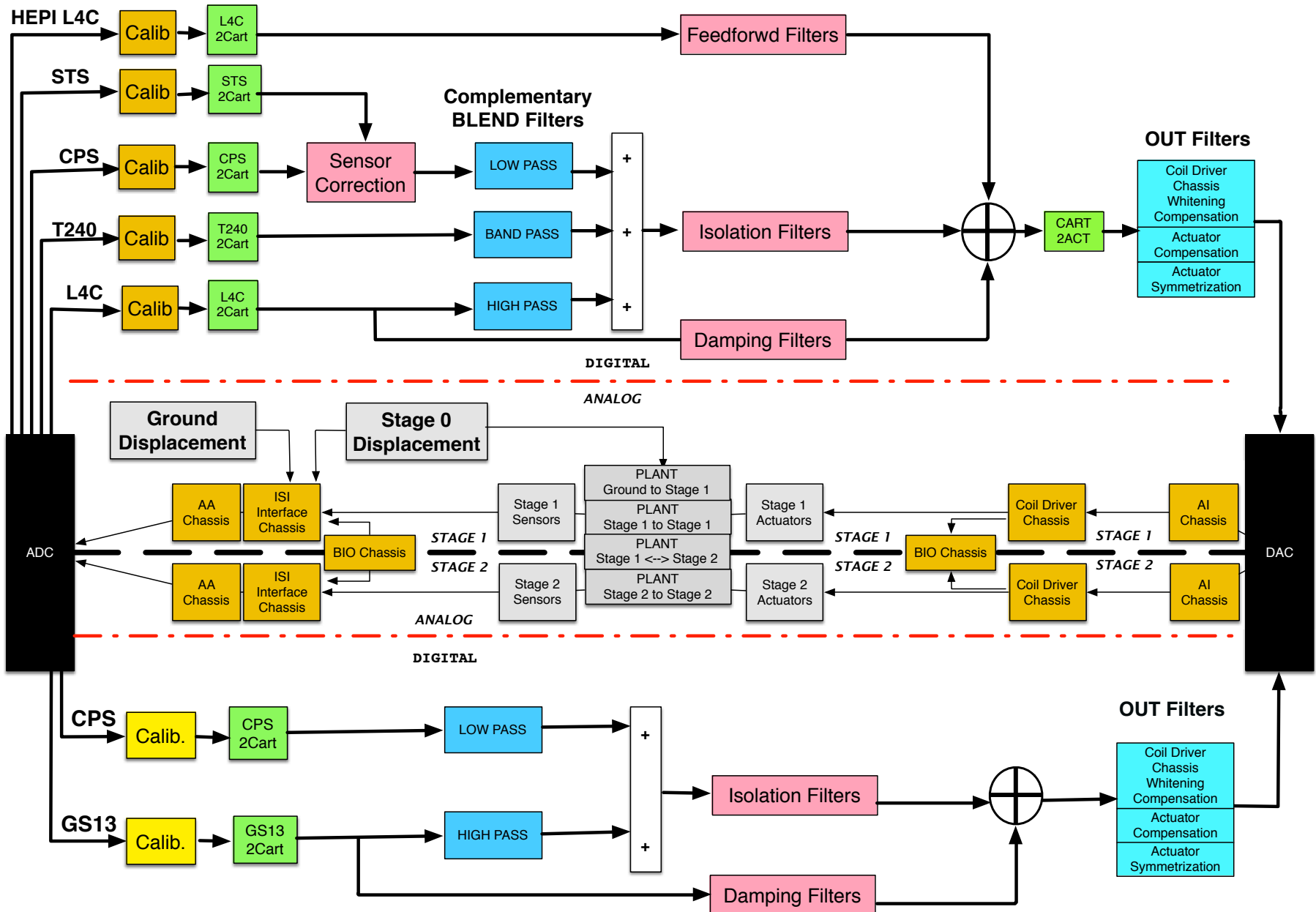
Isolated model (Loop Gain)
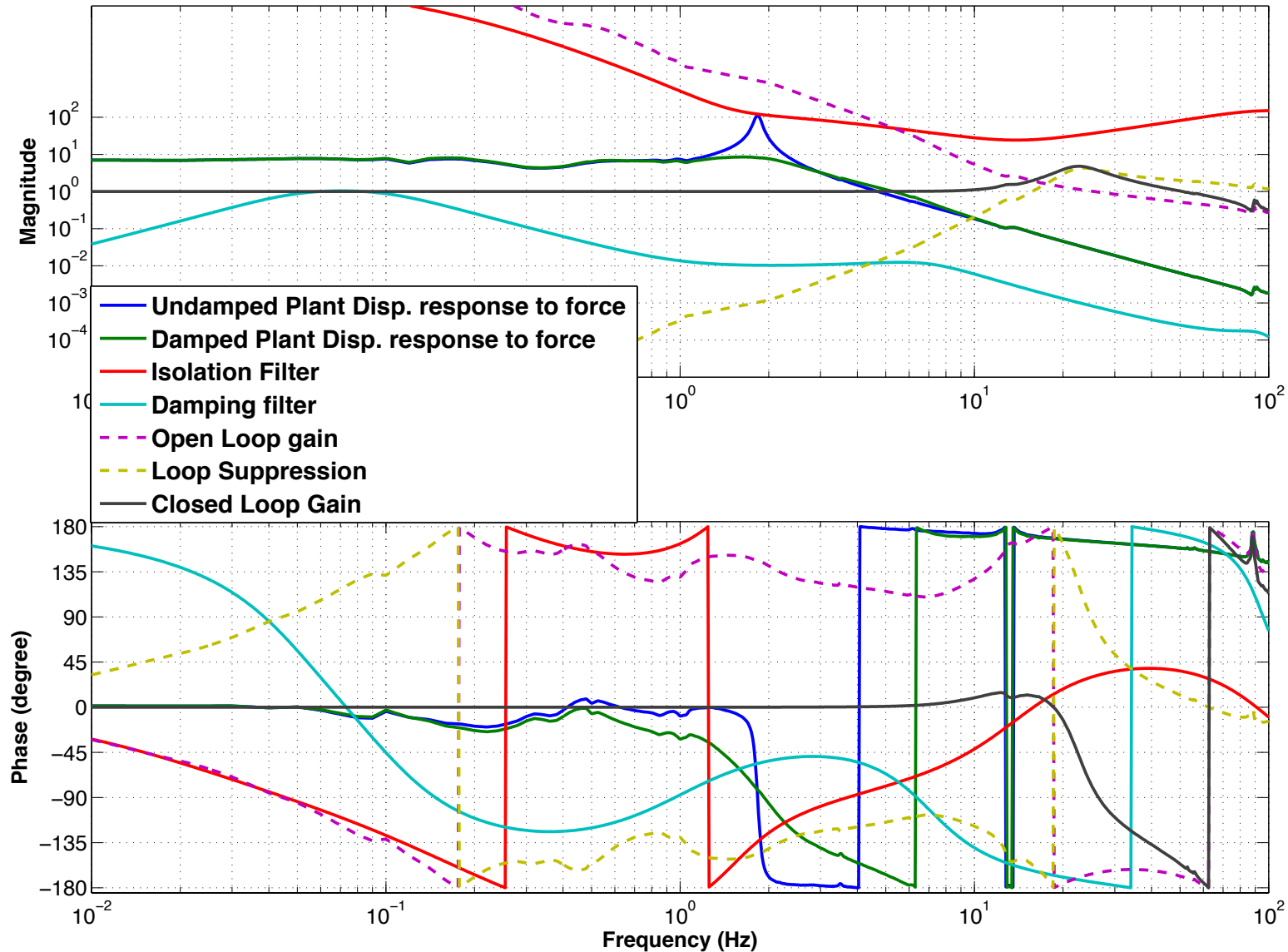
Closed Loop Response: Isolated Model (without sensor correction)

Closed Loop Response: Isolated Model (with sensor correction)

BSC-ISI Control Diagram

BSC ITMY Z ST1

NB Plot of ITMY–ST1 T240 Z IN1at 1112945792
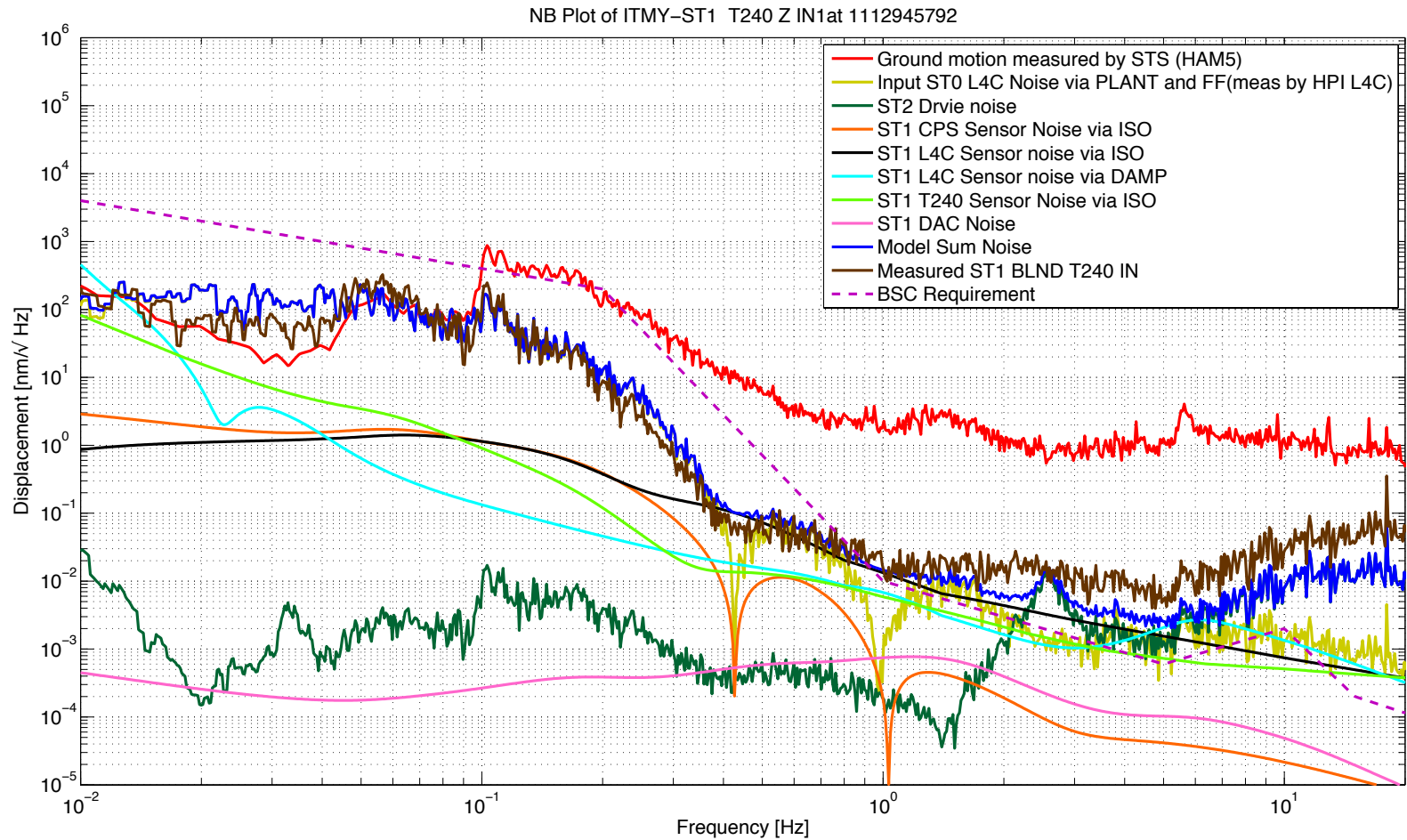
BSC ITMY Z ST2

ITMY –ST2 GS13 Z IN1 for GPS 1125042762