

# Building the aLIGO Noise Budget

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for the aLIGO NoiseBudget team

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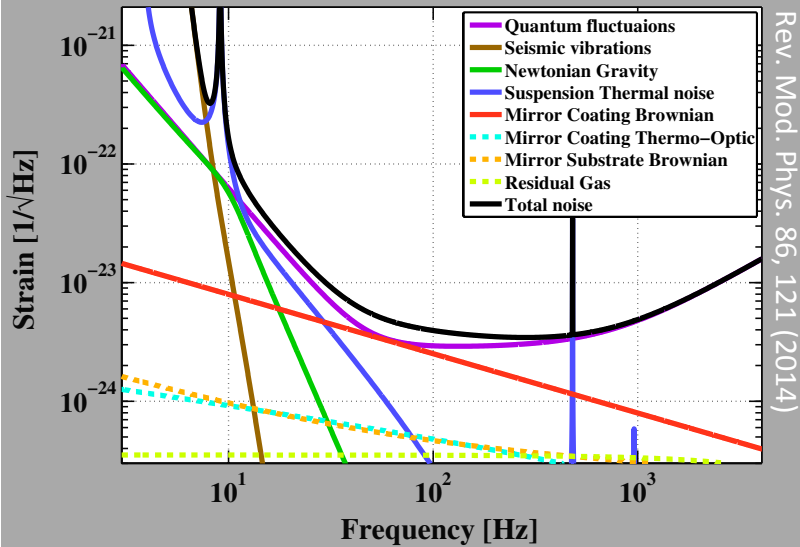
LVC Meeting Stanford, August 2014  
LIGO-G1401000

# Overview

- Goals:  
design-based noise budget  
control model first
- Modeling:  
building up to DRFPMI  
new toolbox for Simulink
- Status update:  
latest plots  
validation
- Summary

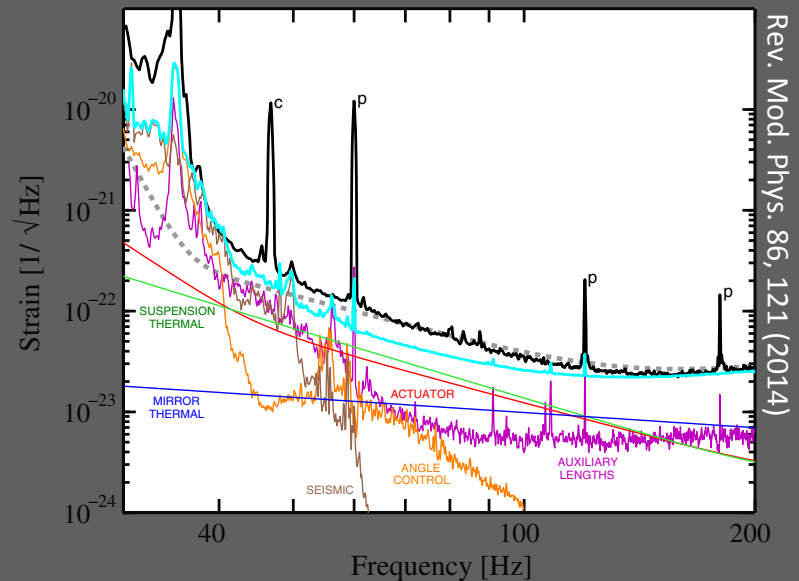
# How We Use Noise Budgets

Theoretical Noise Budget



- Flexible modeling to explore the design parameter space
- Deal with fundamental noise limits only
- Establish sensitivity goals

Realistic Noise Budget



- Mix of measurements and modeling; design is fixed
- Catalog all relevant noise terms in order to explain the observed noise
- Triage mechanism

Conceptual design

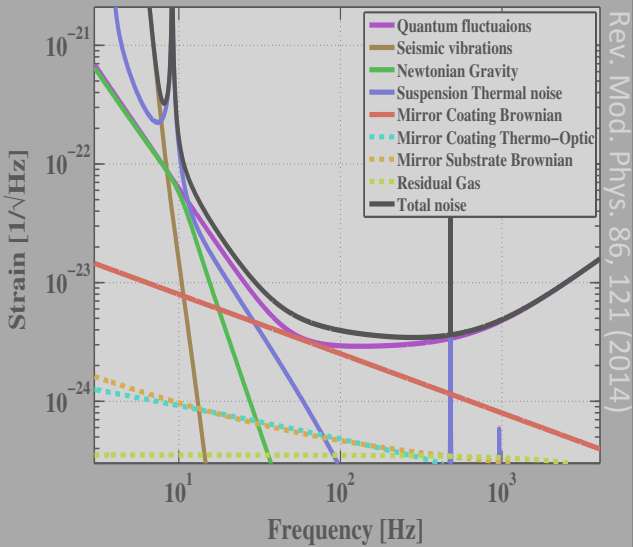
Detailed design

Commission

Operate

# How We Use Noise Budgets

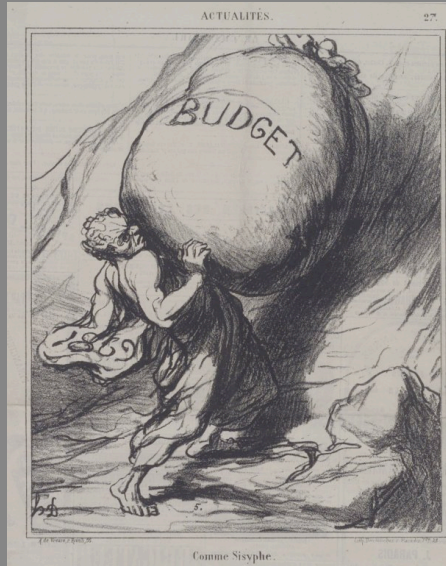
Theoretical Noise Budget



Rev. Mod. Phys. 86, 121 (2014)

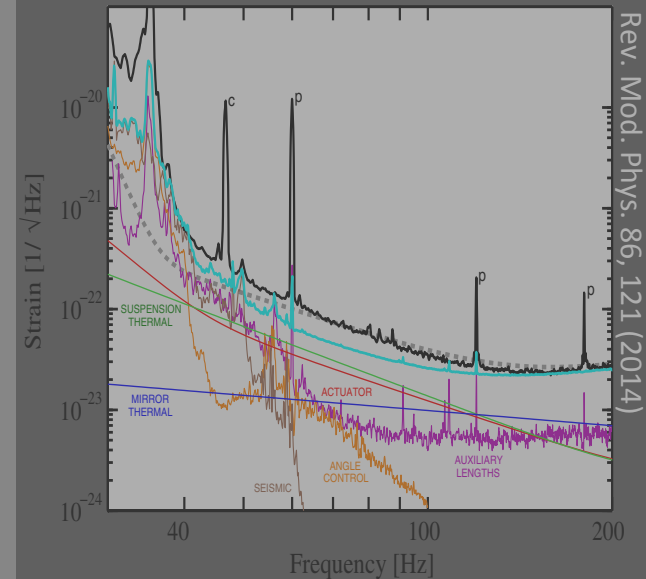
- Flexible modeling to explore the design parameter space
- Deal with fundamental noise limits only
- Establish sensitivity goals

Design-Based Noise Budget



- Flexible modeling; design is still a moving target
- Catalog all relevant noises
- Build and combine NBs for subsystems, intermediate configurations

Realistic Noise Budget



Rev. Mod. Phys. 86, 121 (2014)

- Mix of measurements and modeling; design is fixed
- Catalog all relevant noise terms in order to explain the observed noise
- Triage mechanism

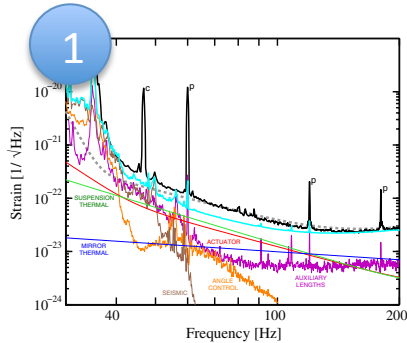
Conceptual design

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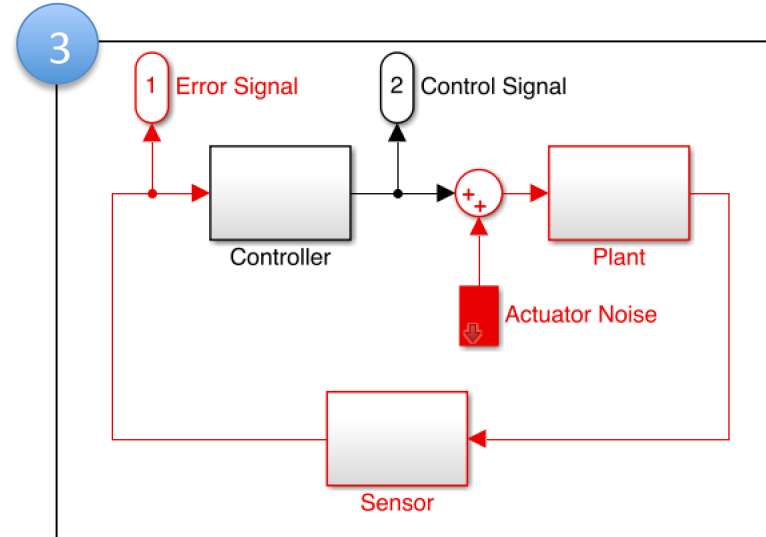
# How We Make Noise Budgets



Identify noise curves needed for the NB plot. For each curve do the following:



Make the noise source's spectrum (model or measure)

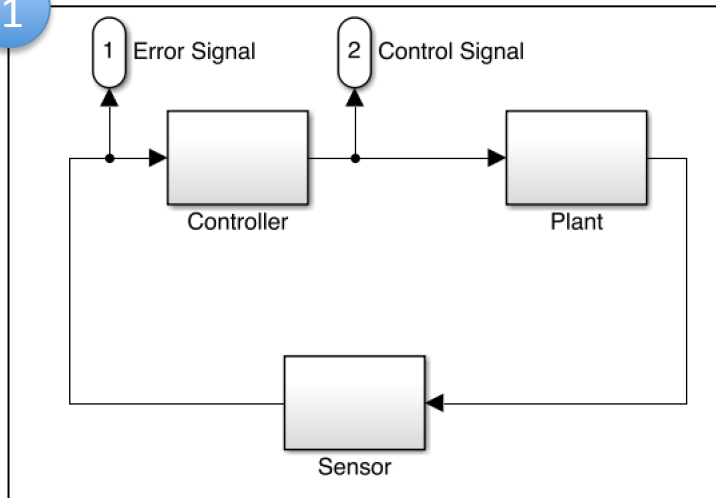


Implement a transfer function to calibrate the noise as a strain (model or measure)

- If you make a simple change to the system, which calibration TFs need to change?
- How do you check consistency vs. a measured open loop gain or other TF?
- How do you reuse all this work for another noise budget or other commissioning task?

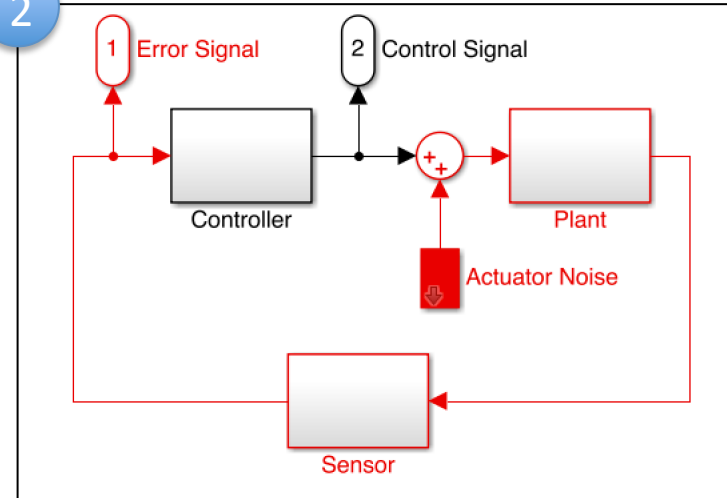
# How We Make Noise Budgets

1



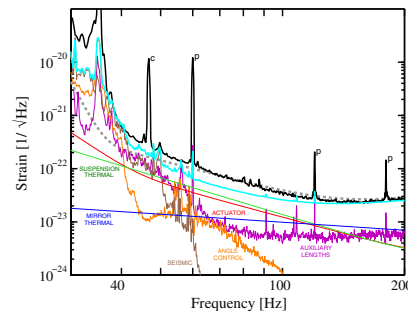
Build a good control model first!

2



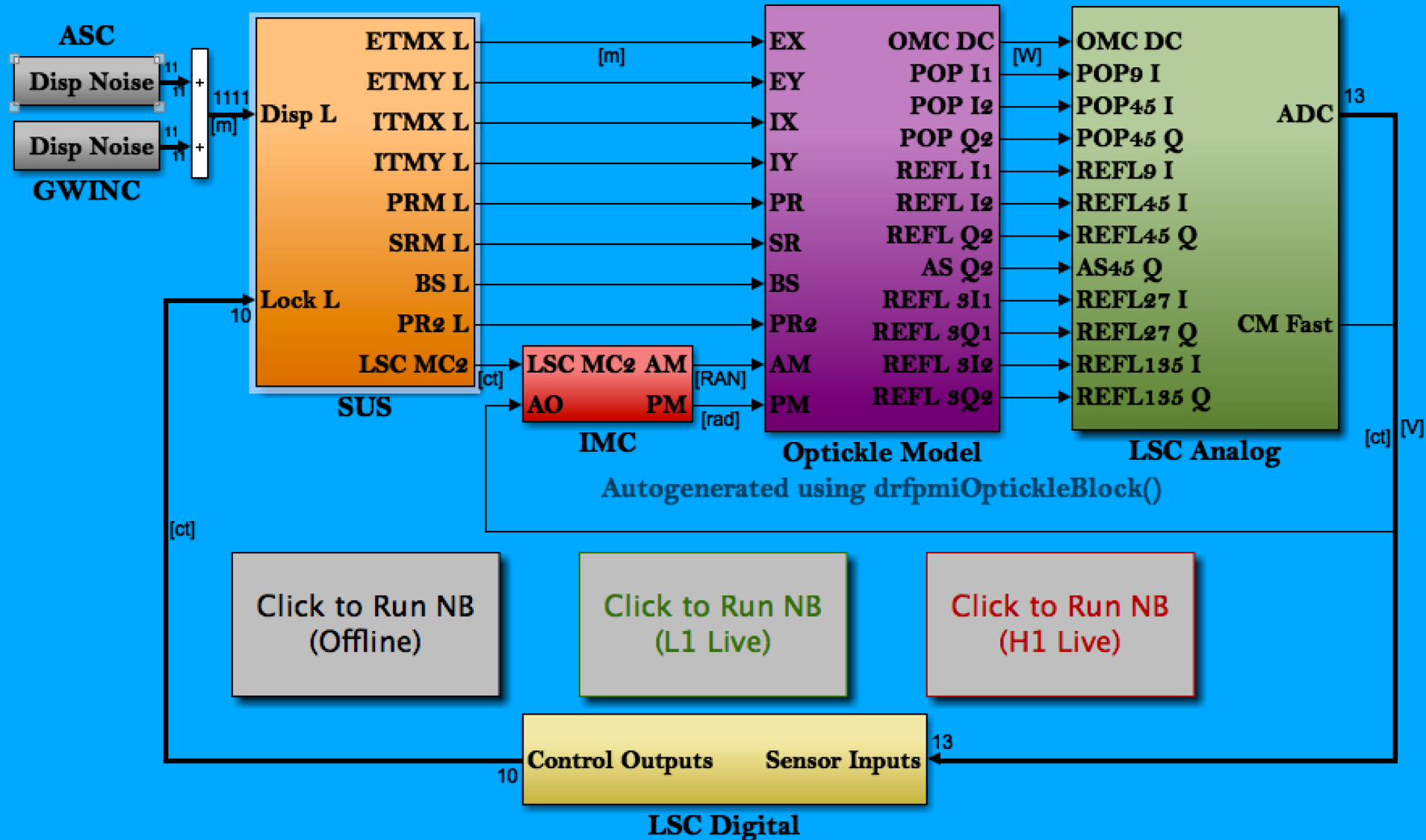
Locate each point in the model where noise couples. This determines calibration TFs.

3

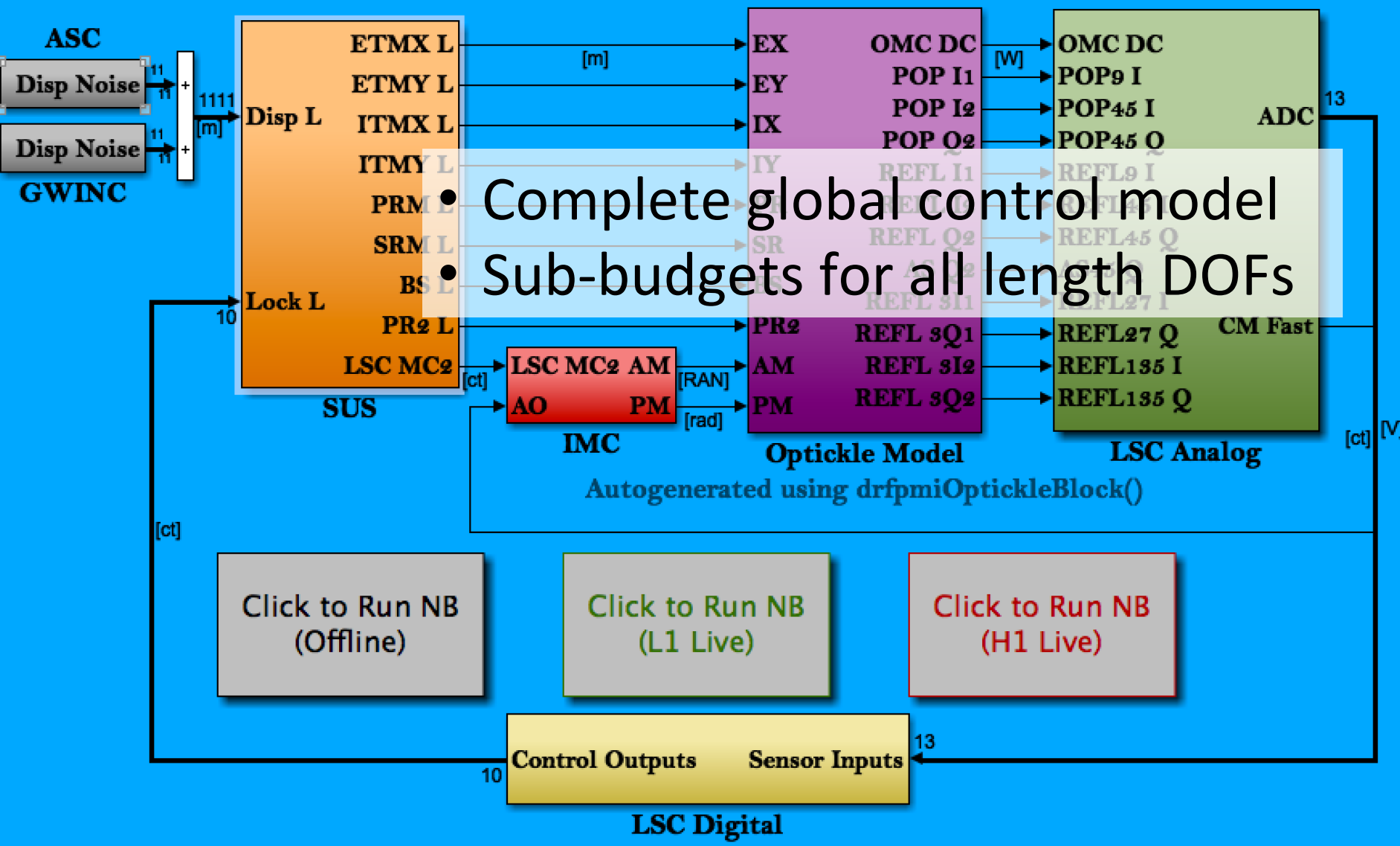


Make spectra and project through the model

# LIGO NOISEBUDGET MODEL



# LIGO NOISEBUDGET MODEL



- Complete global control model
- Sub-budgets for all length DOFs

Click to Run NB  
(Offline)

Click to Run NB  
(L1 Live)

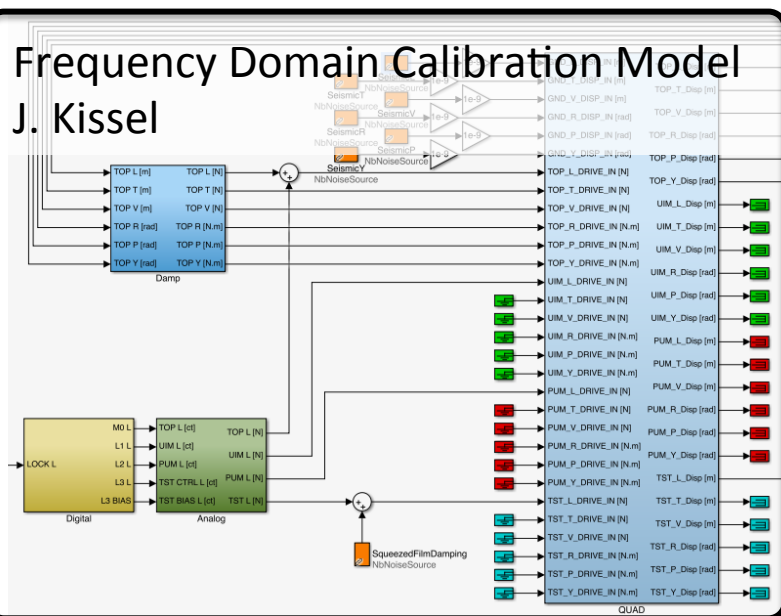
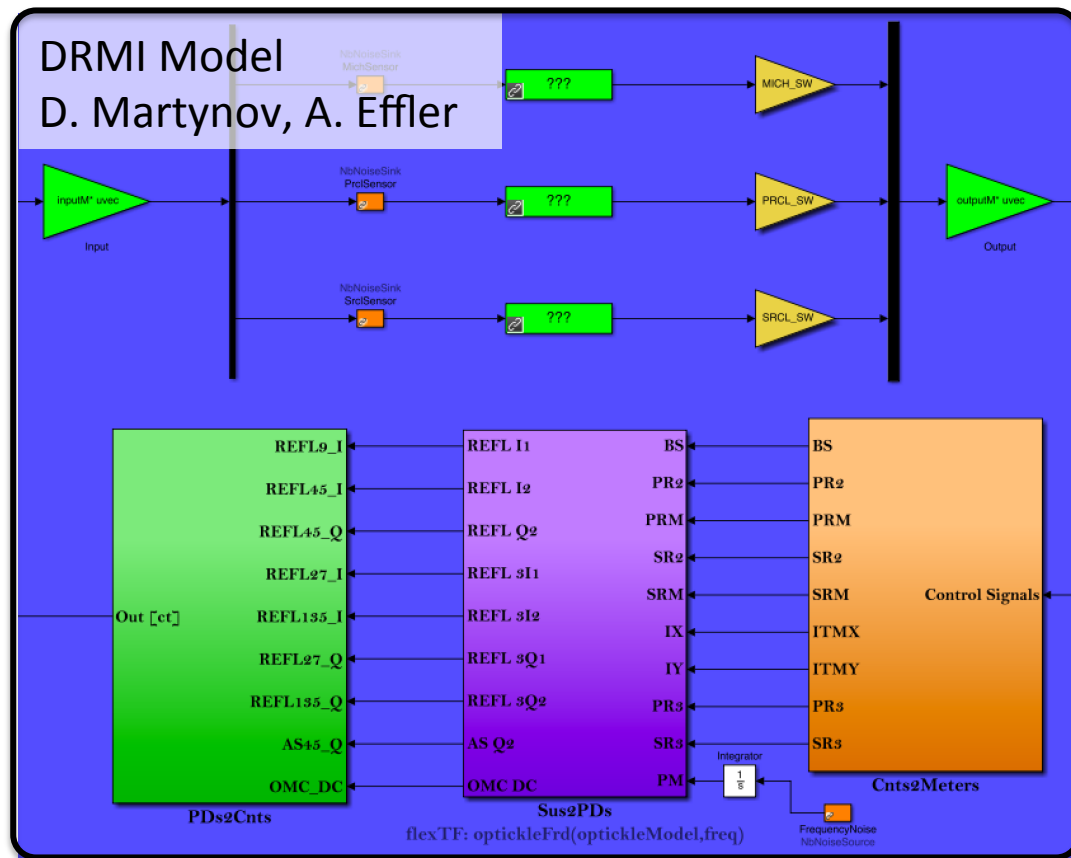
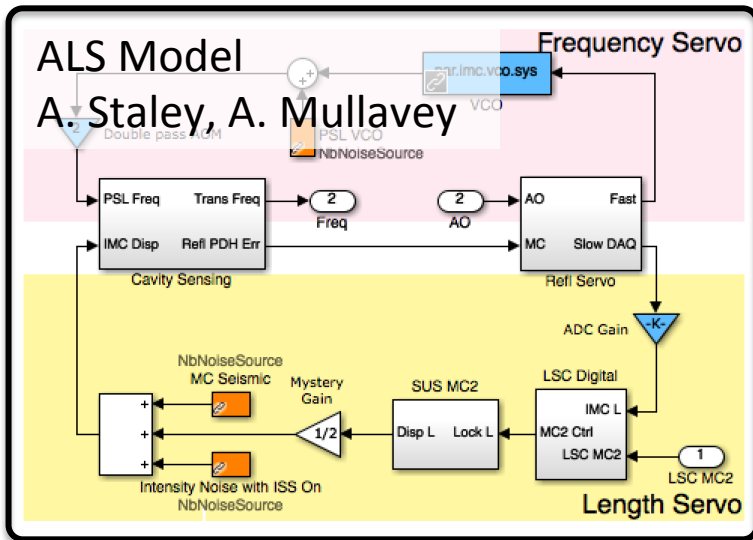
Click to Run NB  
(H1 Live)

Control Outputs    Sensor Inputs

LSC Digital



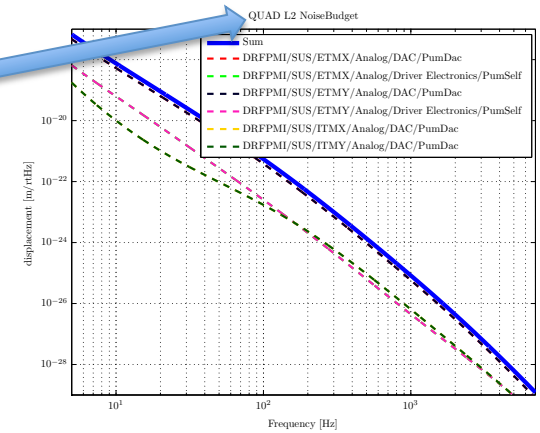
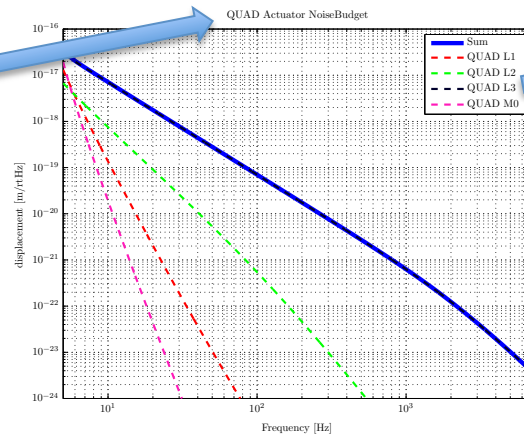
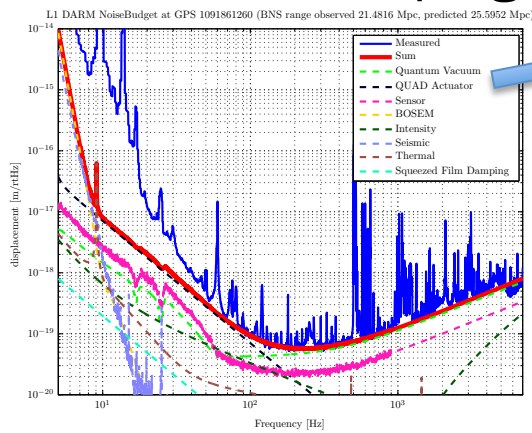
# Building Blocks



- Optickle/Lentickle
- LISO/Elektrotickle
- GWINC
- State-space suspension models

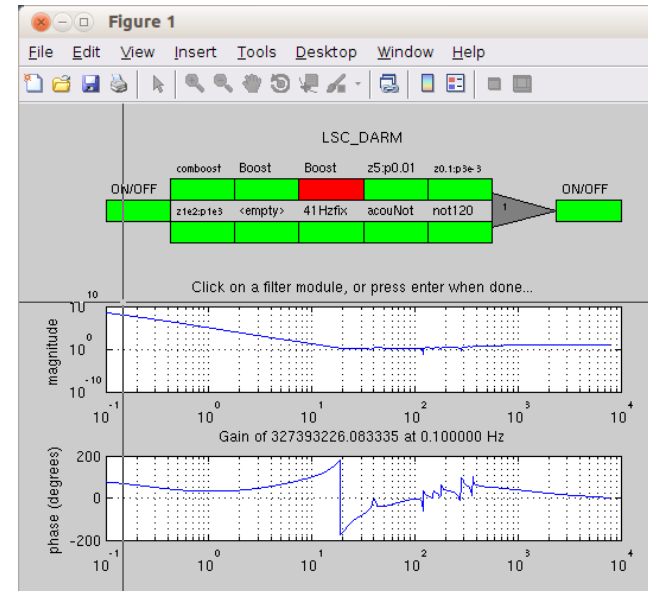
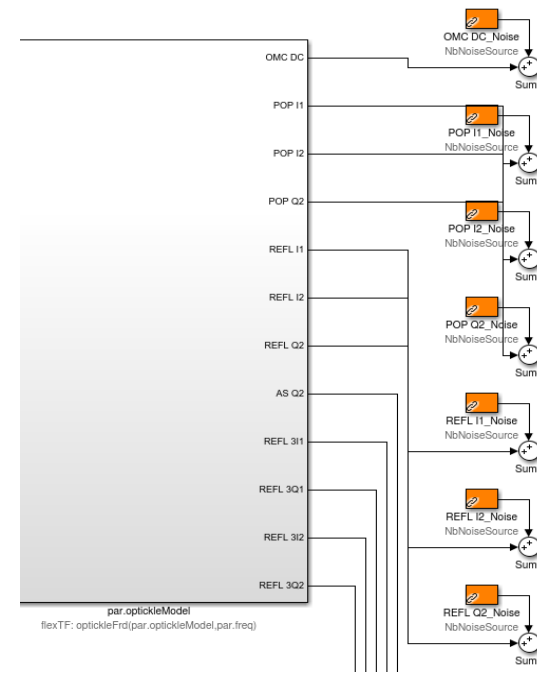
# Simulink Noise Budget Toolbox

- “FlexTF” pluggable frequency responses
  - Replace any block with a numerical TF (no need to fit time-domain models)
- “LiveParts” constants, matrices, and filters
  - Parameters automatically sync from the digital control system at specific GPS time
- Drill-down hierarchical plots
  - Organize noise curves to highlight what matters while keeping full detail



# Simulink Noise Budget Toolbox

- Optickle-Simulink bridge
  - Input: Optickle model
  - Output: auto-generated Simulink block
  - Includes all TFs and quantum noises
  - Contributed by Nicolas Smith-Lefebvre
- Filter module GUI
  - Visualize and edit filter states as in MEDM
  - contributed by Matt Evans

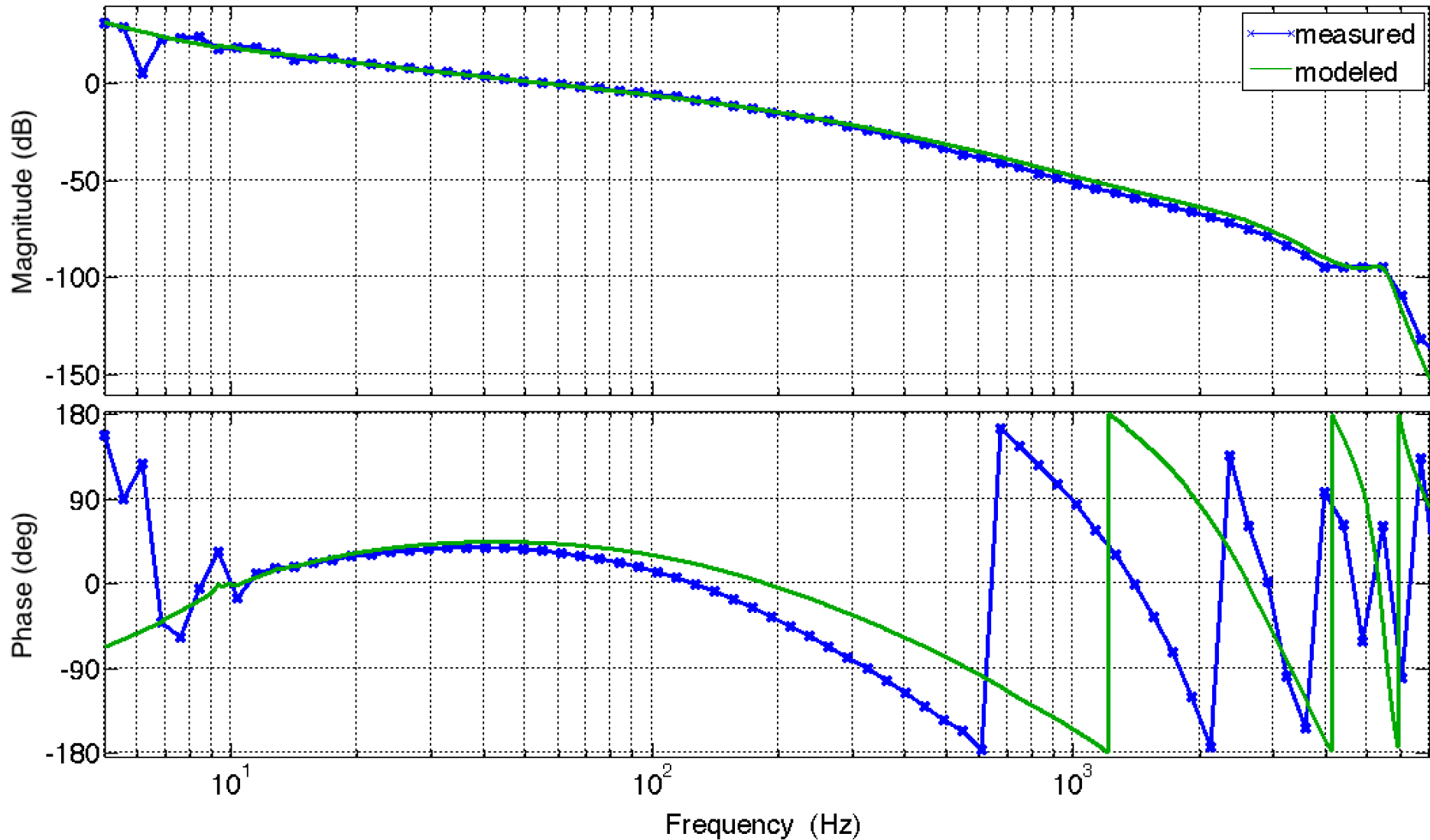


# Noise Budget Status Update

- Runs at both sites
- Runs remotely, with some hand-holding (grabbing filter files from DAQ SVN)
- 126 noise terms calibrated to displacement
- 436 live parameters loaded from digital system
- Still early days — plenty of commissioning and SimCommissioning left to do

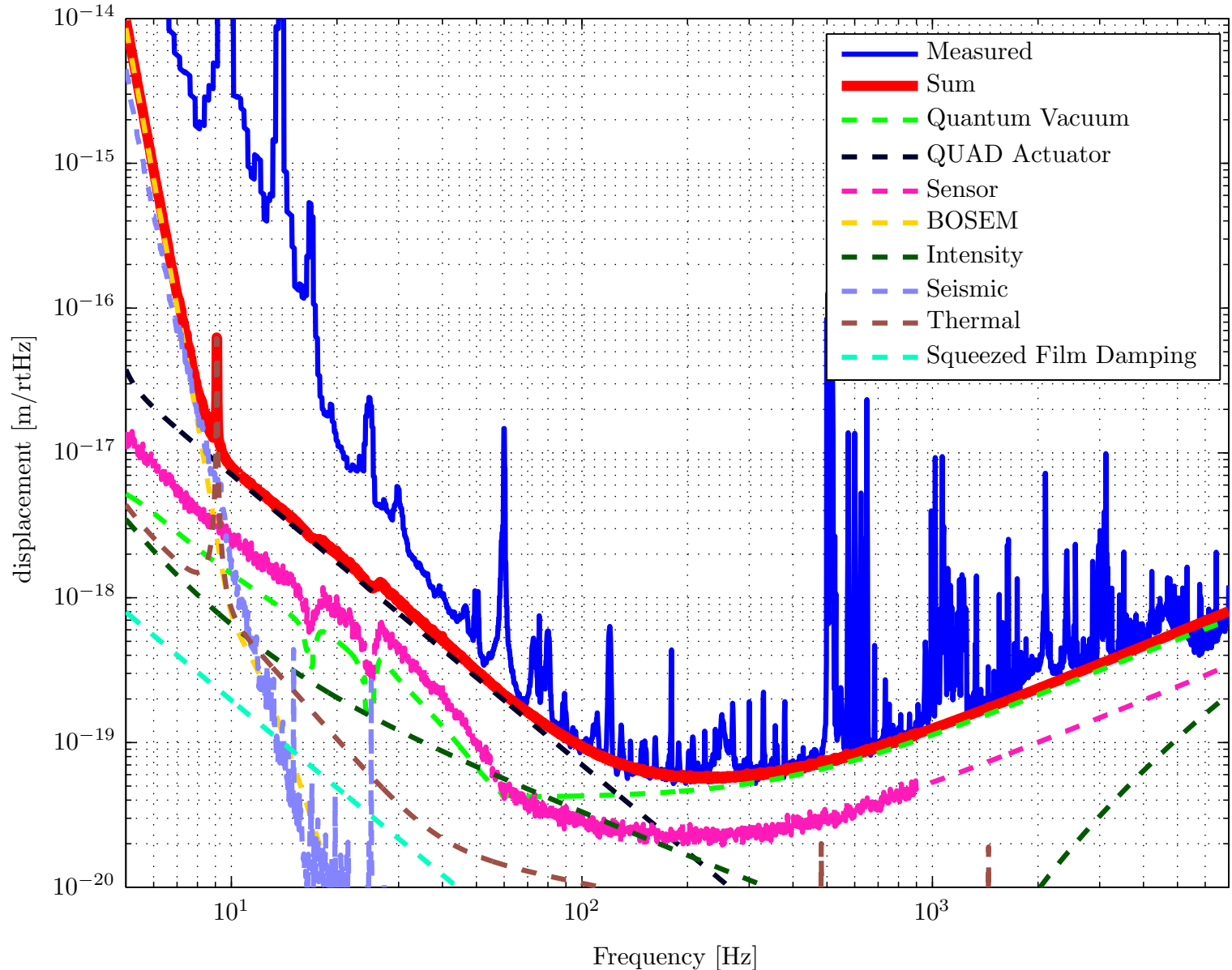
# Model Validation

DARM open loop gain (LLO alog 13789)  
[unexplained gain factor 0.3]



# DARM — Top Level

L1 DARM NoiseBudget at GPS 1091861260 (BNS range observed 21.4816 Mpc, predicted 25.5952 Mpc)



# Assessment / What's Next

Feature	Rating	Ways to Upgrade
Quantum noise	OK	Optickle model
Actuator noise	OK	SUS model; use measured DAC noise
Sensor noise	OK	Optickle model
Local damping noise	Start	Live update damping filters
Intensity noise	Start	Better modeling or use measured
Seismic noise	OK	Add sensor noise of GS13s
Thermal noise	Good	Distribute GWINC thermal noise onto all optics
Squeeze film damping	Start	Wrong for ITMs
Frequency noise	Start	Auxiliary DOF (IMC)
SUS model	OK	Check ESD; quads/triples inconsistent style
Auxiliary DOFs + ASC	Start	General modeling and validation
Optickle model	OK	Check sensor light levels; live update DARM offset
LSC analog/digital	Good	CM servo modeling
Validation	Start	TF measurements to localize errors

# Summary

L1 DARM NoiseBudget at GPS 1091861260 (BNS range observed 21.4816 Mpc, predicted 25.5952 Mpc)

- New noise budgets for Advanced LIGO: design-based, and centered on the control model
- Successful ALS, DRMI models built – and they still live on as part of the aLIGO model
- Noise budget toolkit for Simulink  
<https://svn.ligo.caltech.edu/svn/aligonoisebudget>
- Models and measurements starting to match up
- Exciting days ahead!

