



Results from Prototype Advanced LIGO Seismic Isolation

Jeffrey Kissel, for the LSC

Denver APS Meeting, May 2 2009

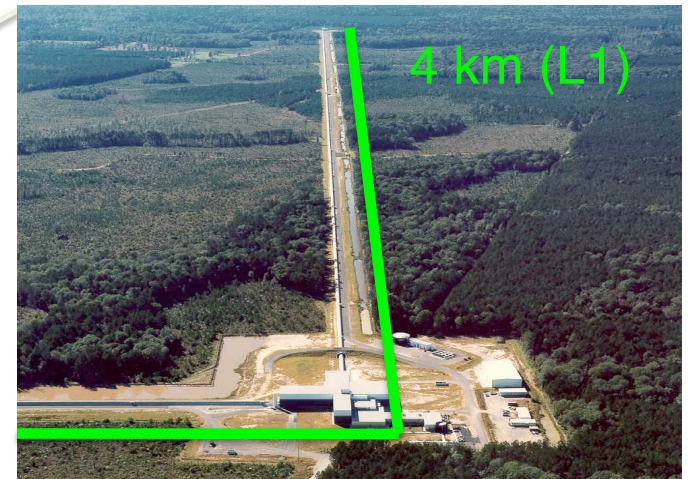
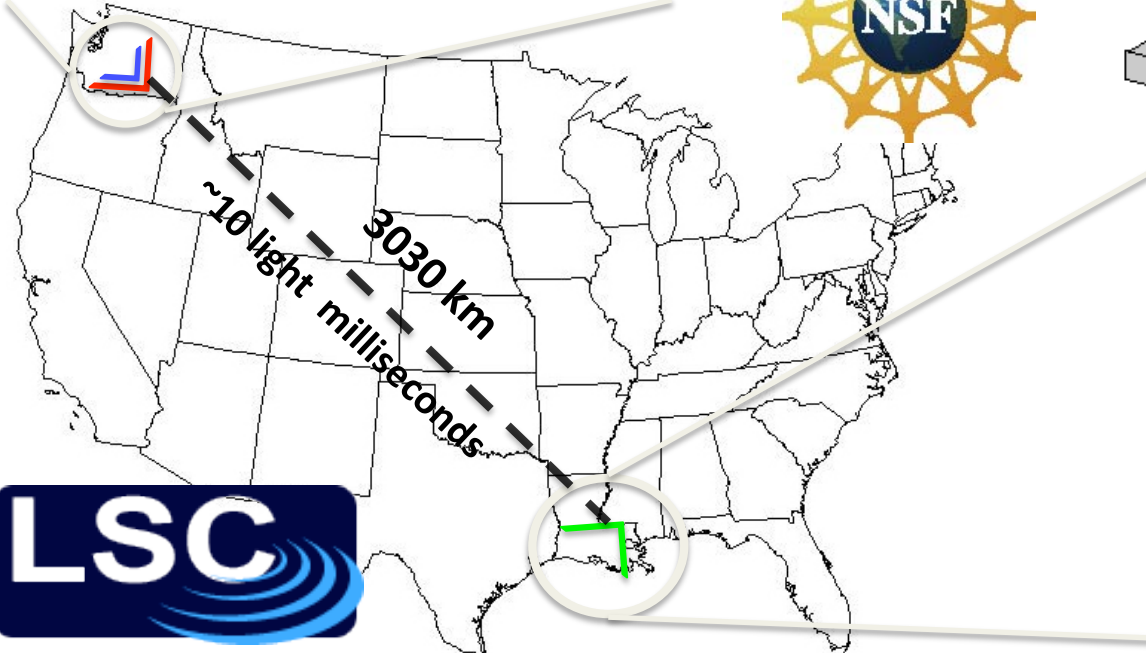
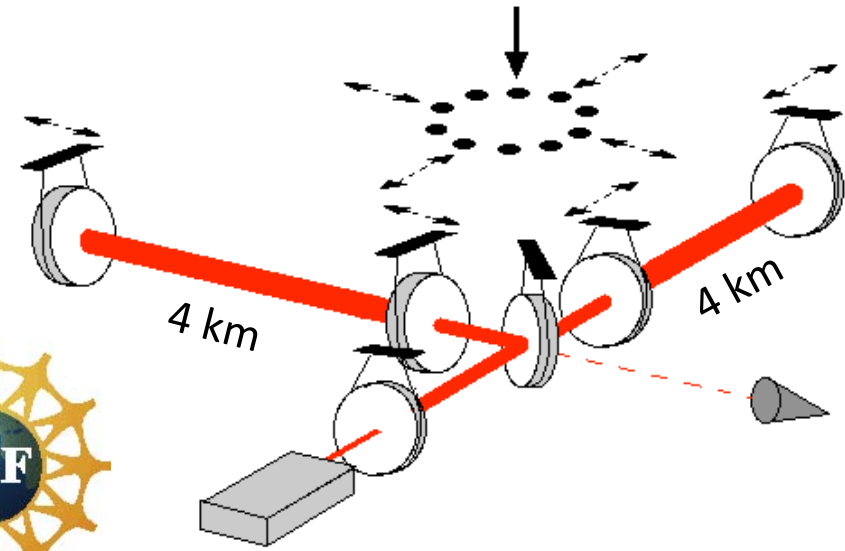
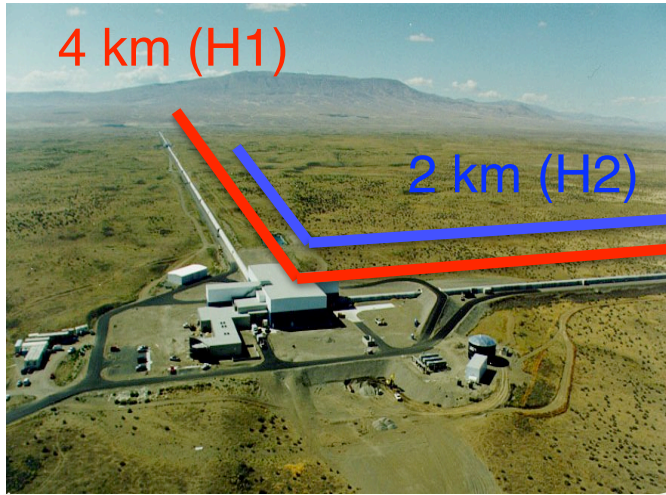
LIGO-G090427-v2



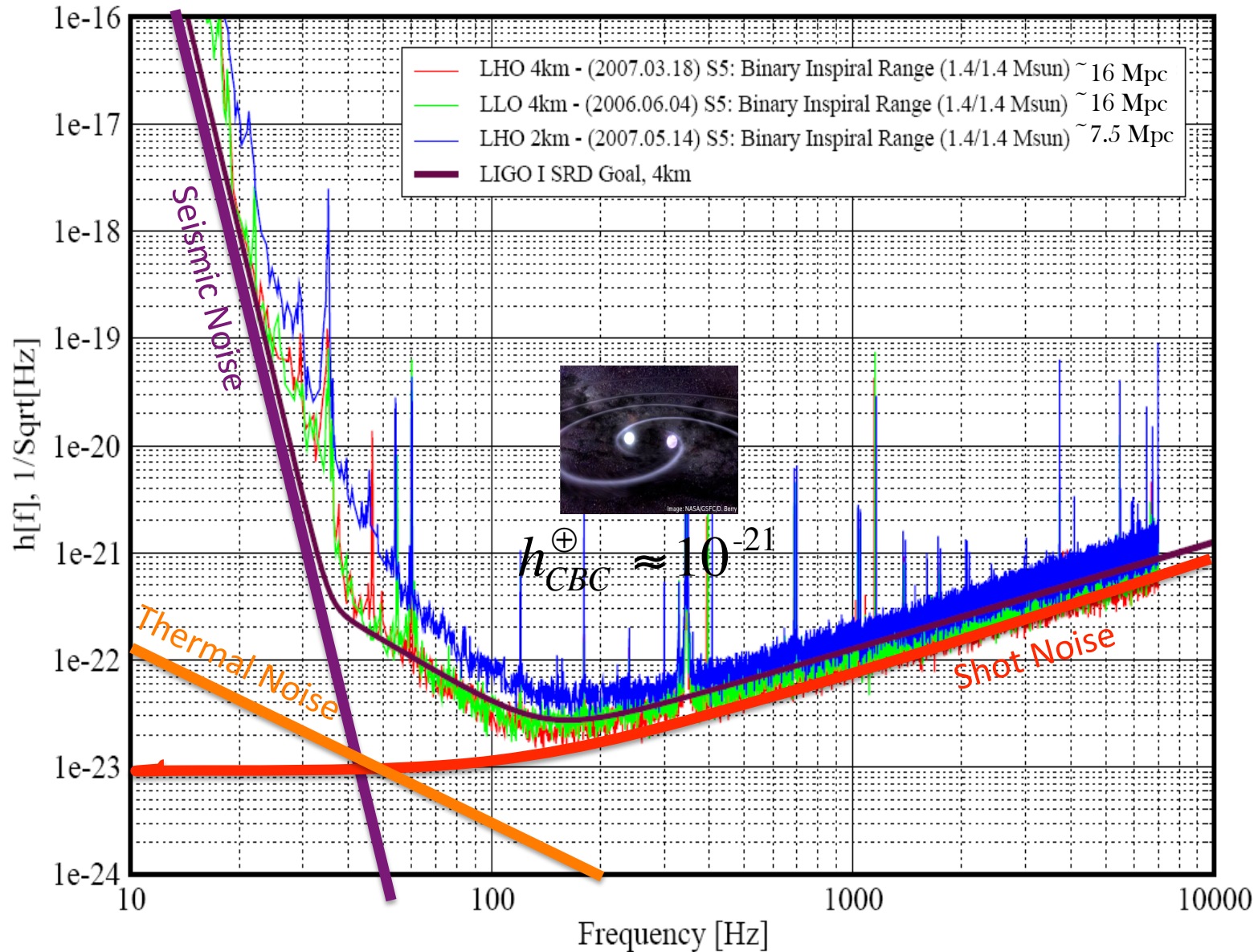
The LIGO Interferometers



Power-Recycled Michelsons with Fabry-Perot Arms



Strain Sensitivity and Fundamental Noise Sources





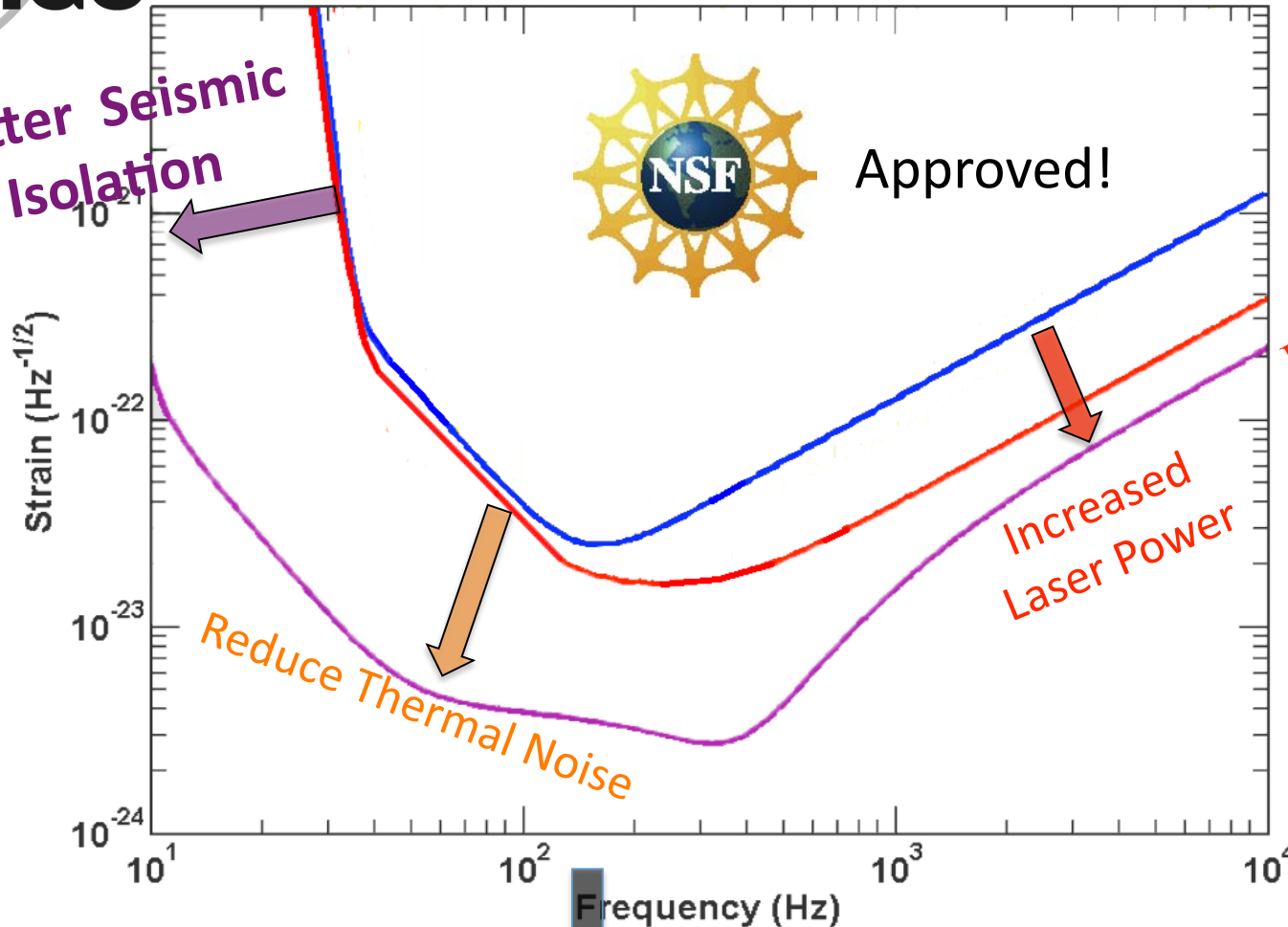
LIGO's Projected Future Strain Sensitivity



Better Seismic Isolation



Approved!



Initial LIGO / S5 ('05 to '07)
 Enhanced LIGO / S6 (Sum '09 to '10)
 Advanced LIGO / S7 (2014 - ??)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Observing	S5		S6					S7 and beyond!	
Upgrading		Enhance!			Advance!				

Advanced LIGO Seismic Isolation

In-vacuum Seismic Isolation (ISI)

Small Optic Isolation "HAM" Chambers

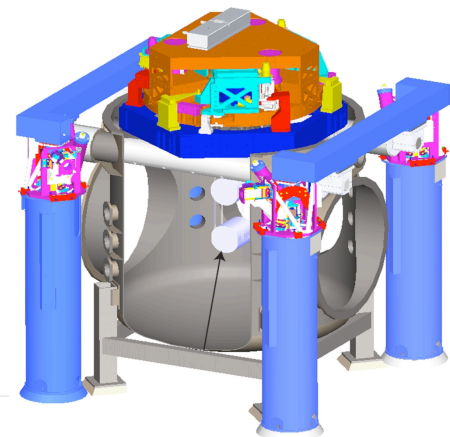
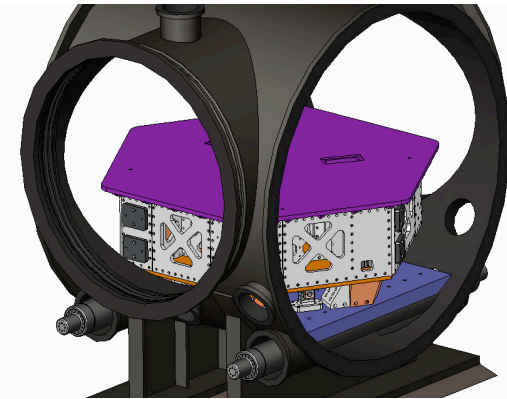
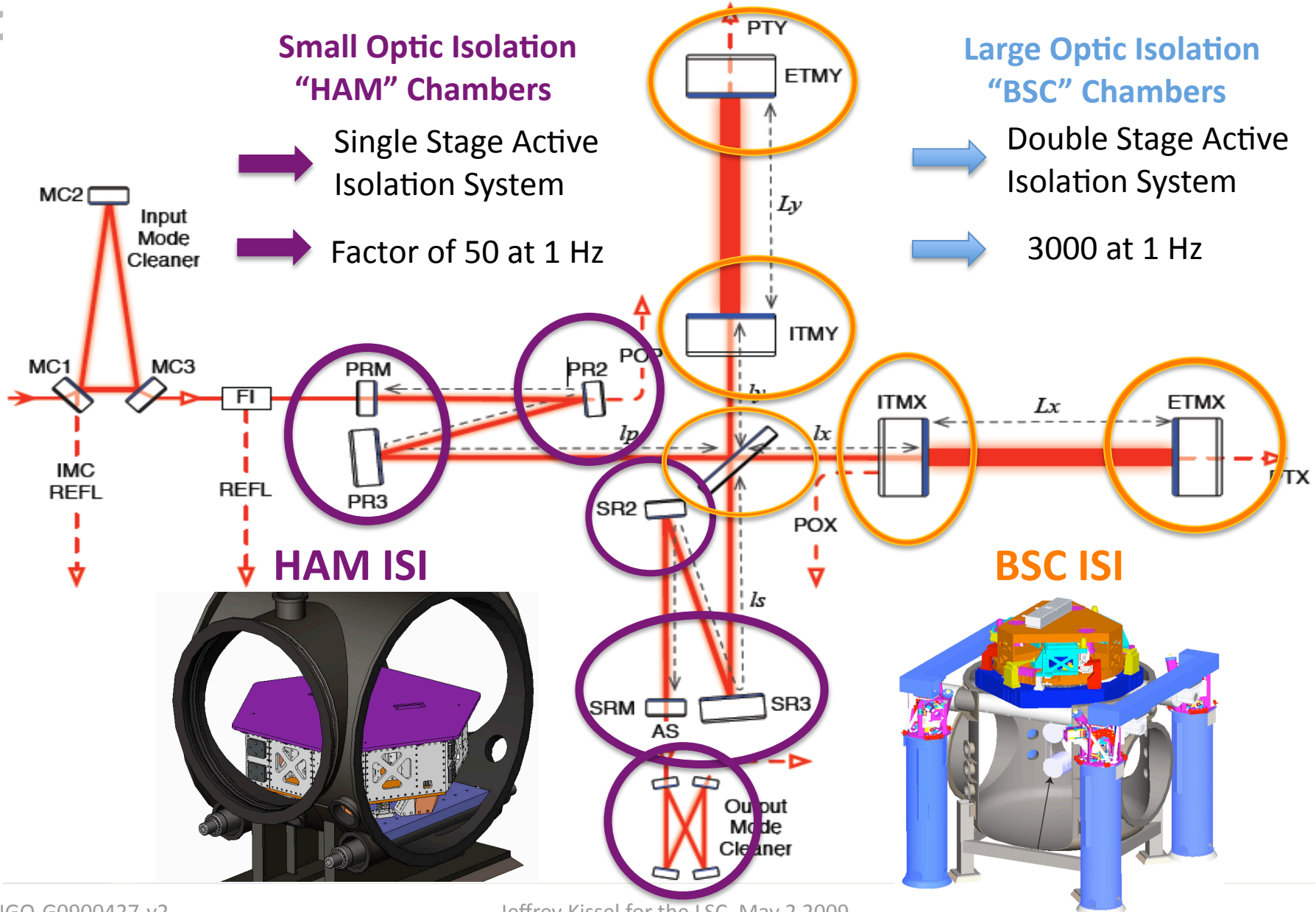
Single Stage Active Isolation System

Factor of 50 at 1 Hz

Large Optic Isolation "BSC" Chambers

Double Stage Active Isolation System

3000 at 1 Hz



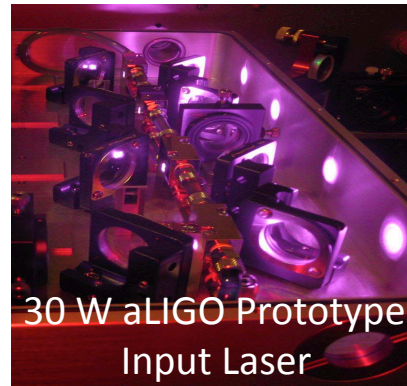
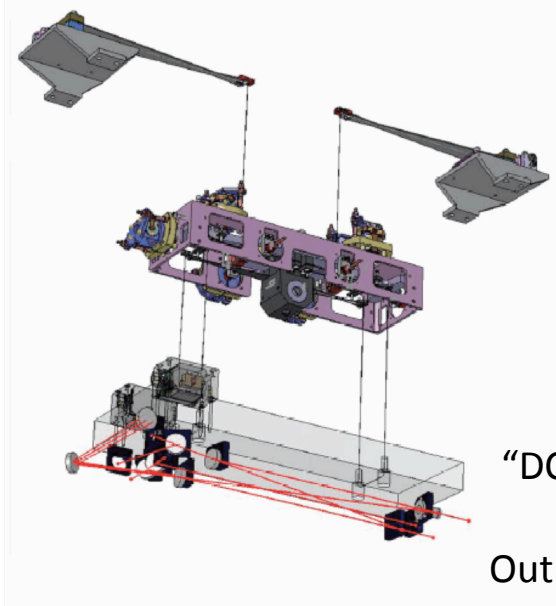


Enhanced LIGO

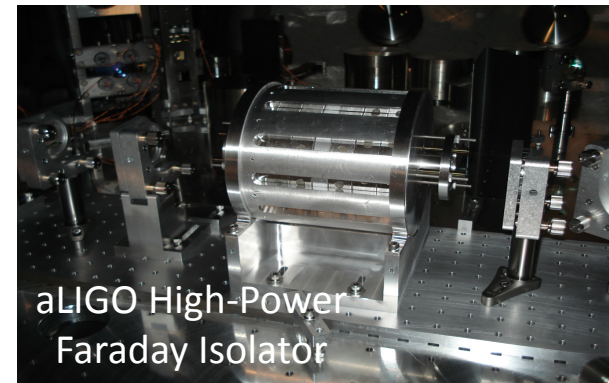


“Minor” Upgrades to the two 4 km interferometers
All components installed as of Jan 2009!

aLIGO Prototype
Double Pendulum Suspension

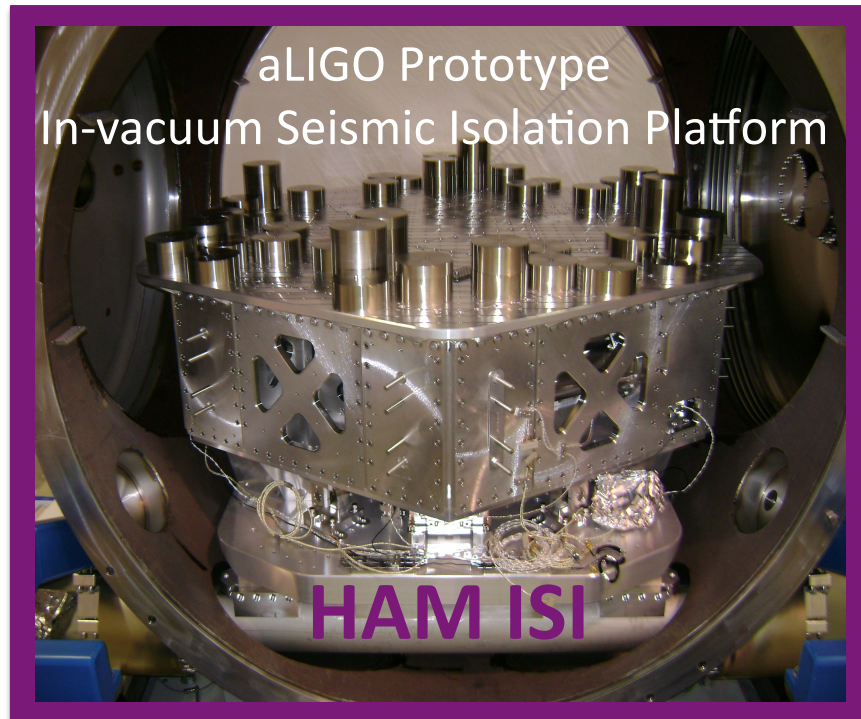


30 W aLIGO Prototype
Input Laser



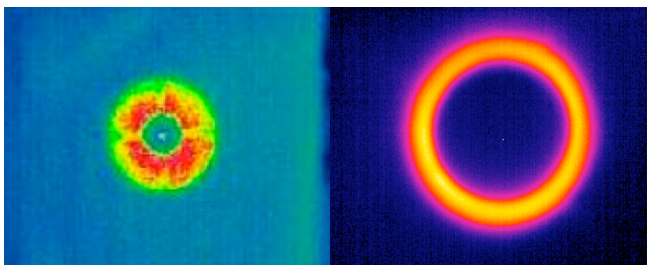
aLIGO High-Power
Faraday Isolator

In-vacuum
“DC” Readout Photo
Diodes and
Output Mode Cleaner



aLIGO Prototype
In-vacuum Seismic Isolation Platform

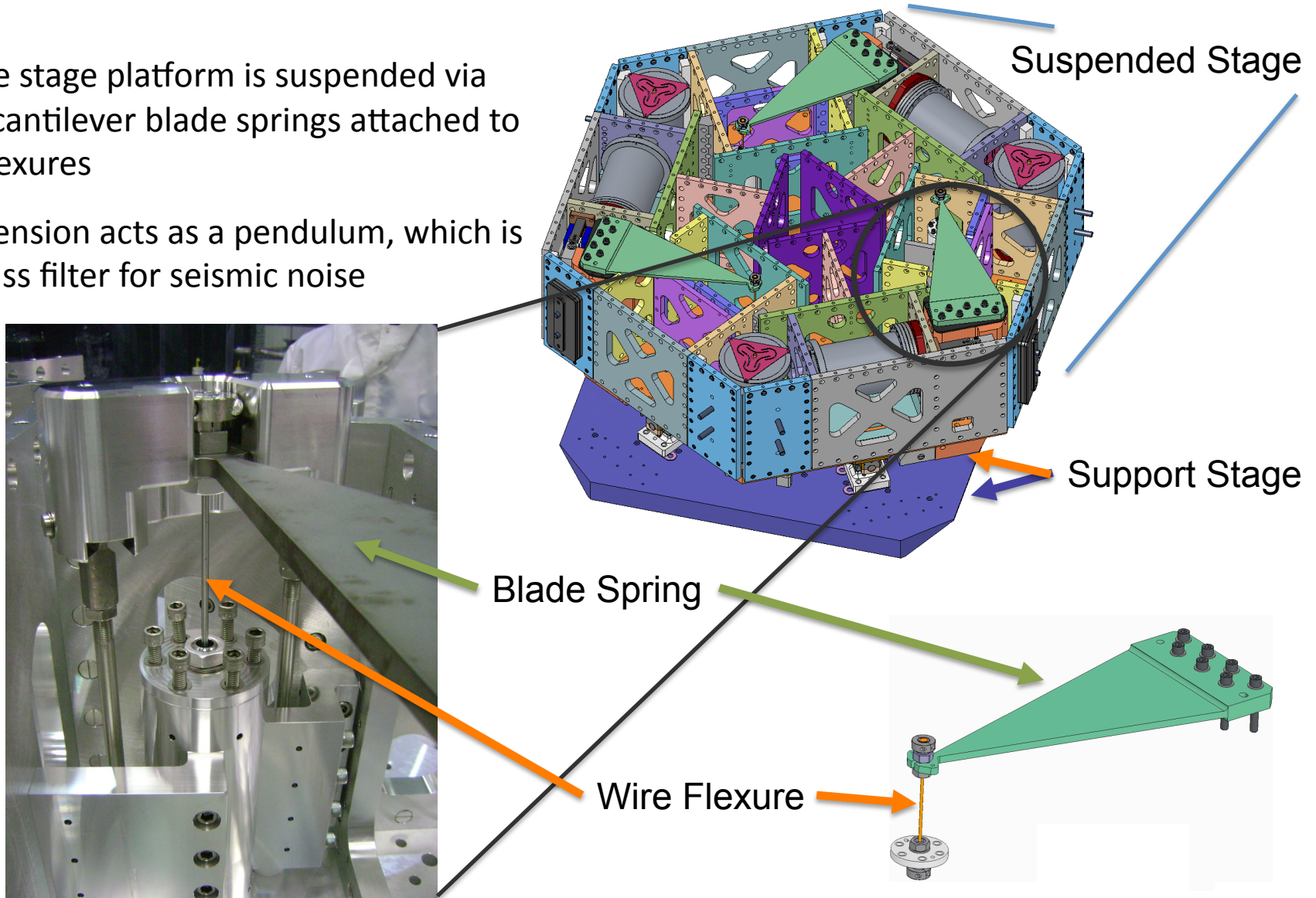
Improved, High Power Thermal
Compensation System



The HAM ISI

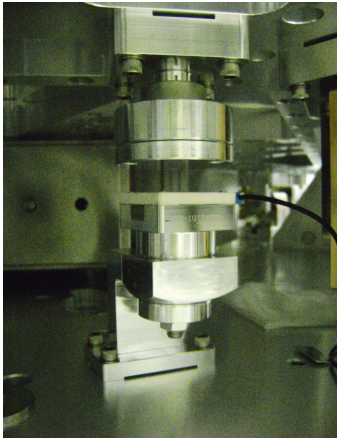
Passive Isolation Components

- Single stage platform is suspended via three cantilever blade springs attached to wire flexures
- Suspension acts as a pendulum, which is low-pass filter for seismic noise



The HAM ISI

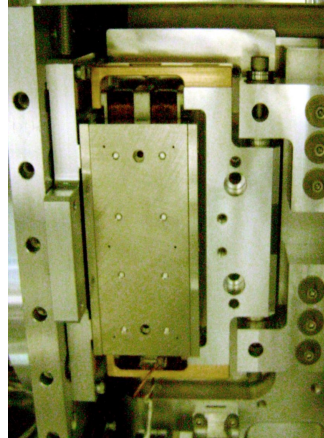
Active Isolation Components



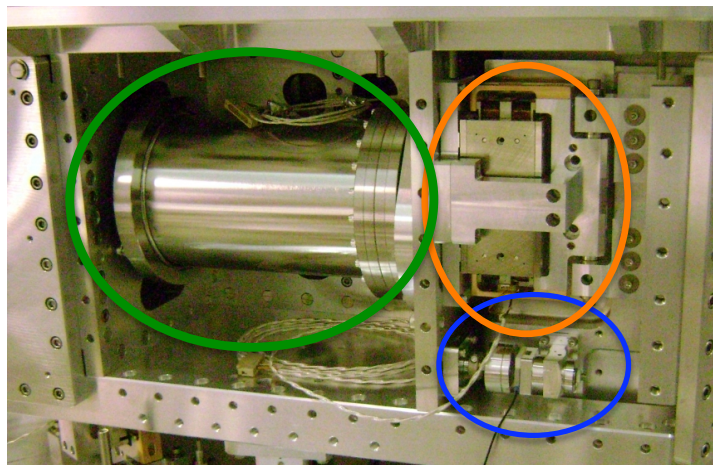
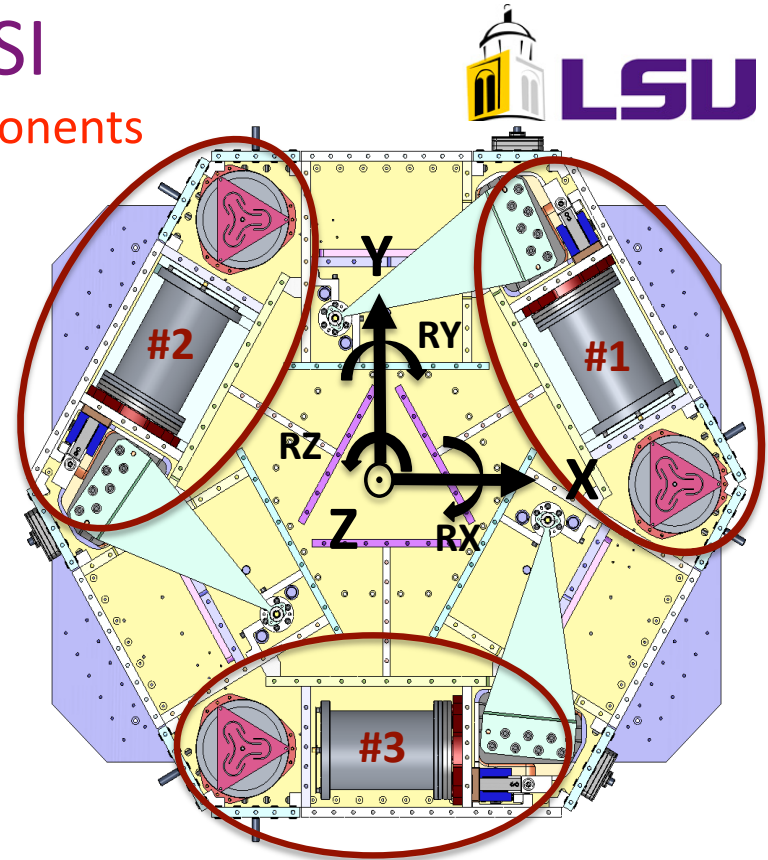
Displacement
Sensors



Inertial Sensors



Electromagnetic
Actuators



- **Displacement sensors** provide alignment and low frequency (10 Hz to DC) information
- **Inertial Sensors** (Geophones) provide high frequency (500 Hz to 0.5 Hz) information
- **Electromagnetic actuators** provide drive and control of the table at all frequencies
- Six sensor and actuator clusters mounted symmetrically on the table control **ALL SIX** degrees of freedom



Enhanced LIGO Seismic Isolation HAM ISI RESULTS!!

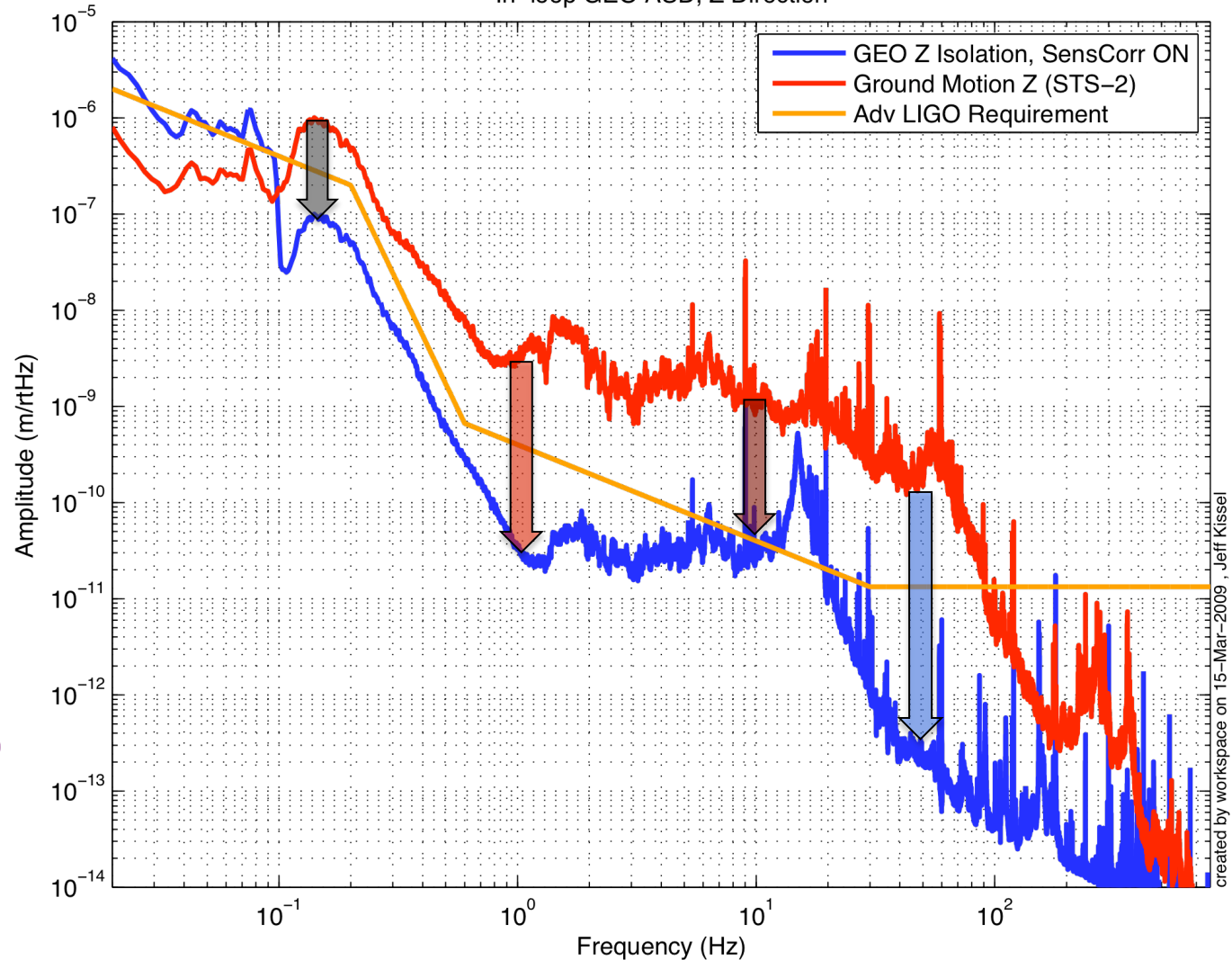


H1HAM6ISI Performance, March 13 2009
In-loop GEO ASD, Z Direction

Isolation from **ground** is

- Factor of 10 at 0.15 Hz
- Factor of **100** at 1 Hz
- Factor of 50 at 10 Hz
- Factor of **1000** at 50 Hz

Meets or beats
Advanced LIGO
Requirements!

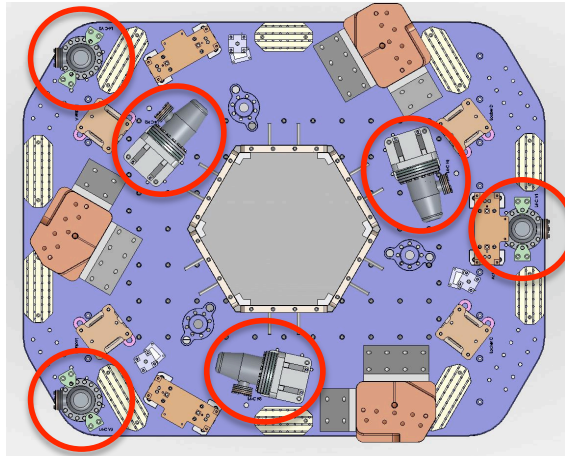
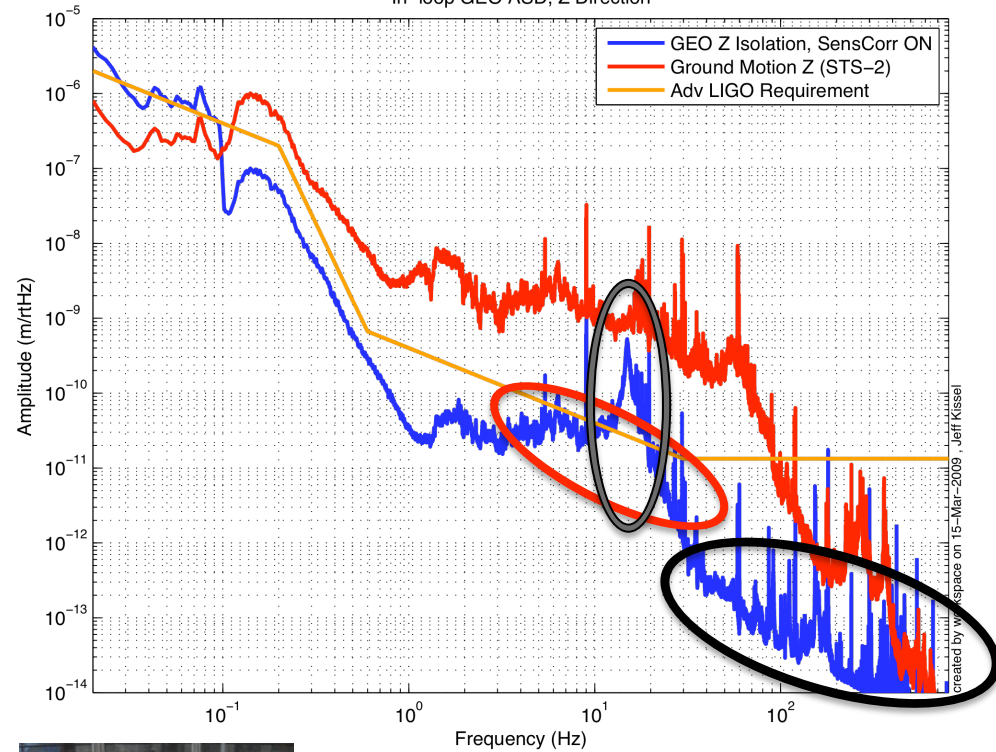




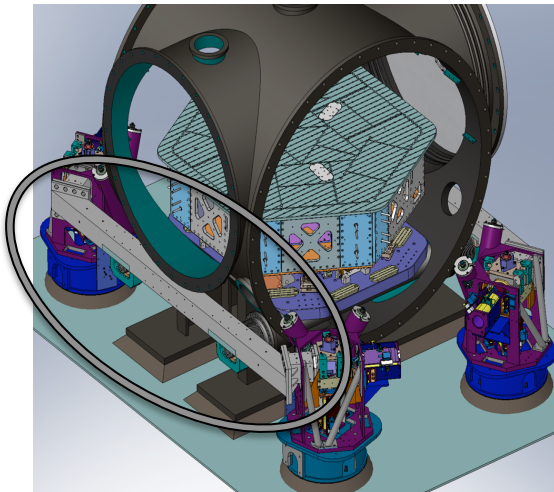
Advanced LIGO Seismic Isolation Planned Design Improvements



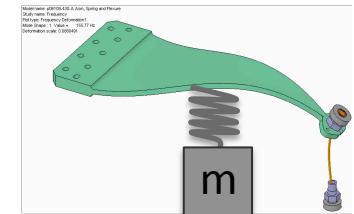
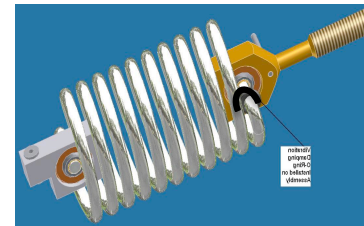
H1HAM6ISI Performance, March 13 2009
In-loop GEO ASD, Z Direction



More feed-forward!



Stiffer support structure, add external pre-isolation!



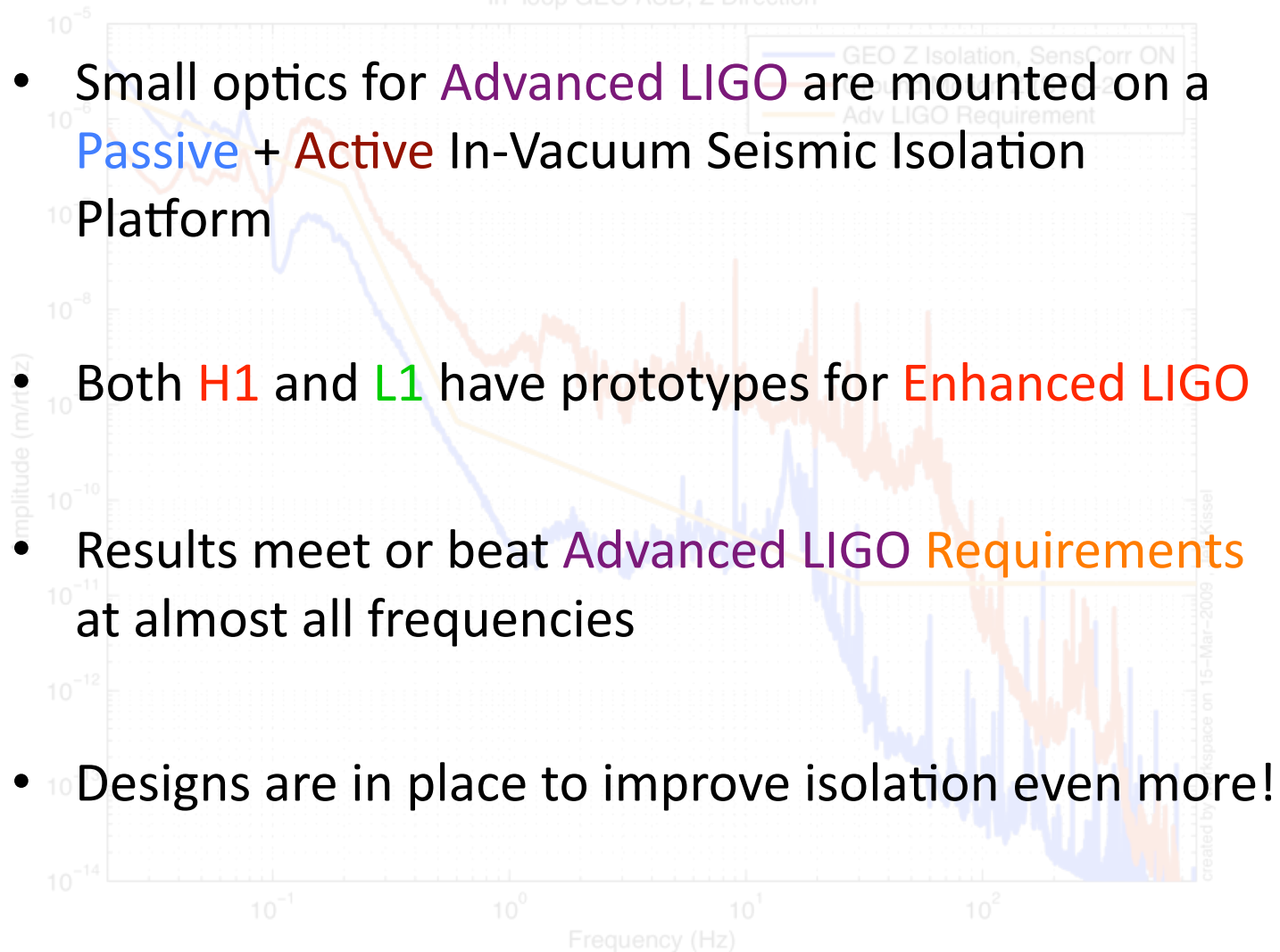
Add constrained layer and tuned mass damping!



Results from Prototype **Advanced LIGO** Seismic Isolation



H1HAM6ISI Performance, March 13 2009
In-loop GEO ASD, Z Direction

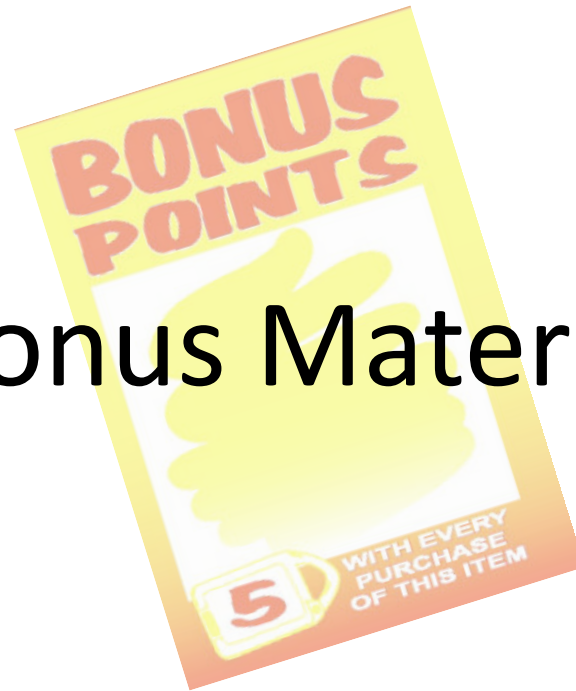


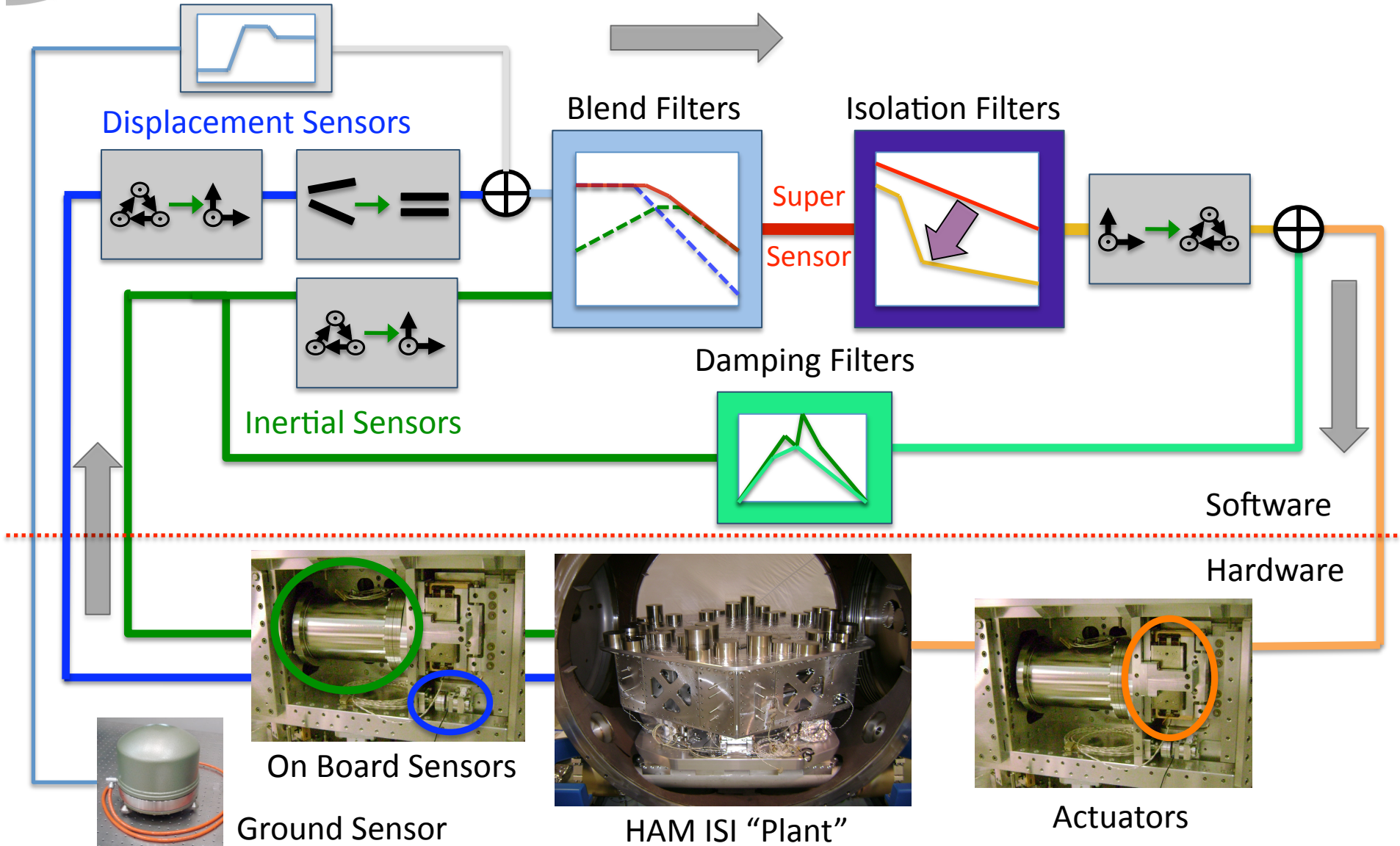
- Small optics for **Advanced LIGO** are mounted on a **Passive + Active** In-Vacuum Seismic Isolation Platform
- Both **H1** and **L1** have prototypes for **Enhanced LIGO**
- Results meet or beat **Advanced LIGO Requirements** at almost all frequencies
- Designs are in place to improve isolation even more!





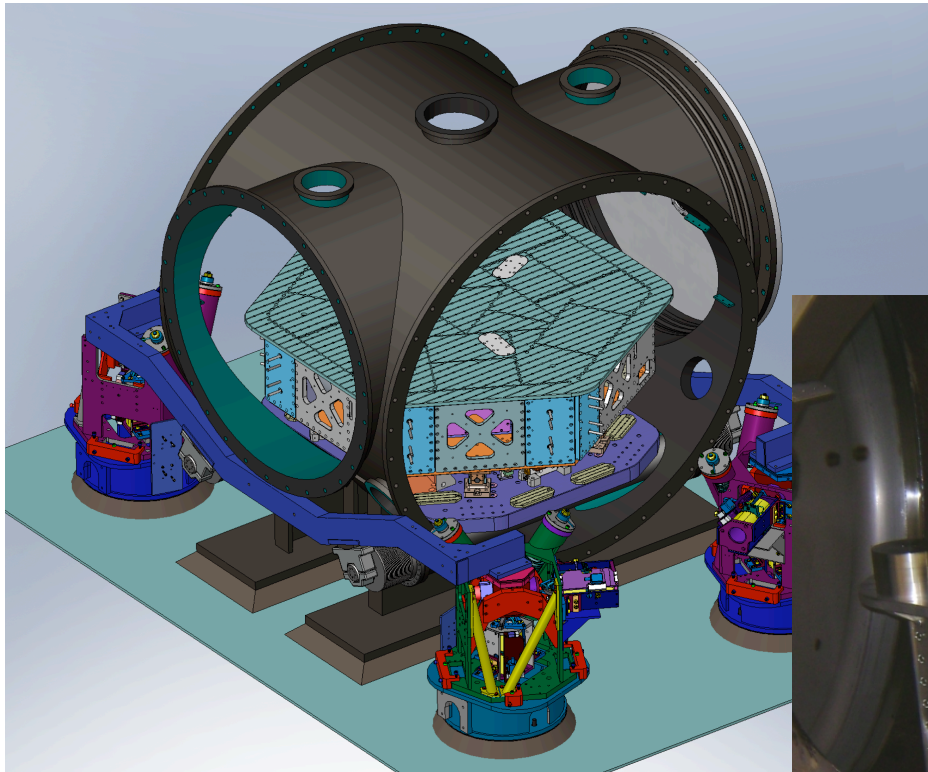
Bonus Material





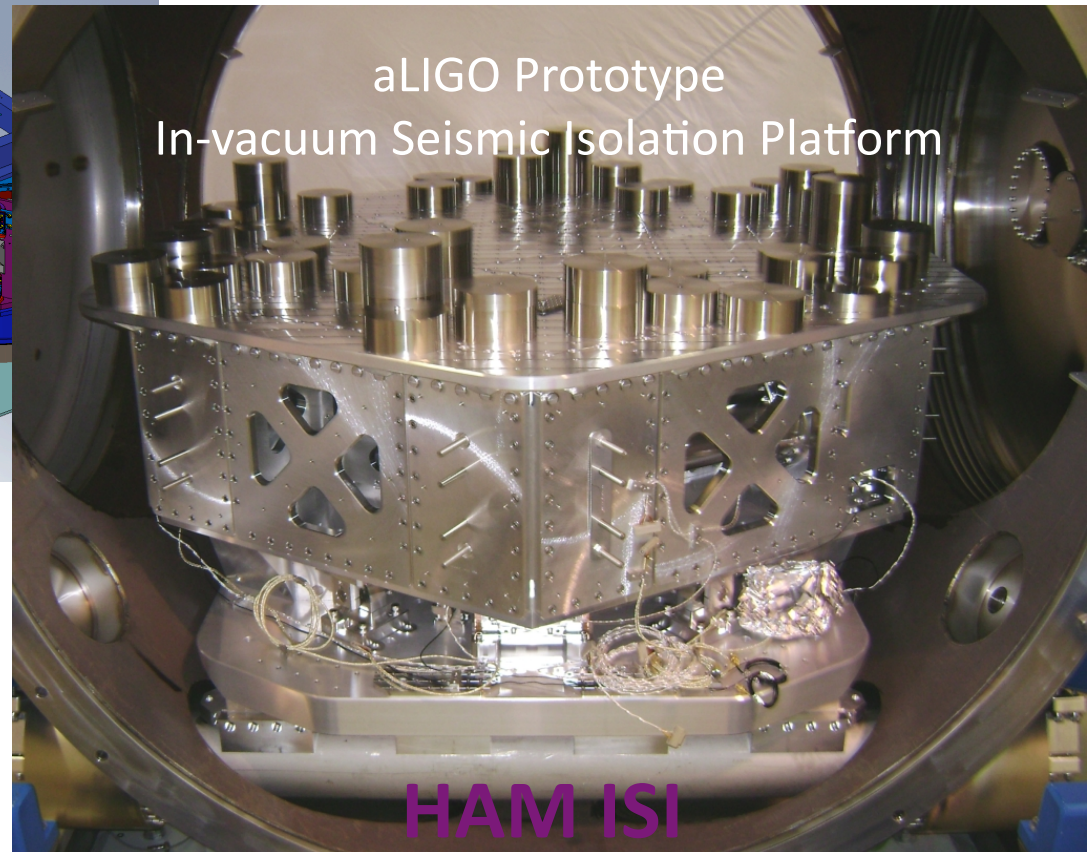


Enhanced LIGO Seismic Isolation Prototype In-vacuum Seismic Isolation (ISI)



L1 HAM ISI built and installed Feb/Mar '08

H1 HAM ISI built and installed Apr/May 2008



H1 HAM ISI commissioning
Jun '08 and Feb/Mar '09

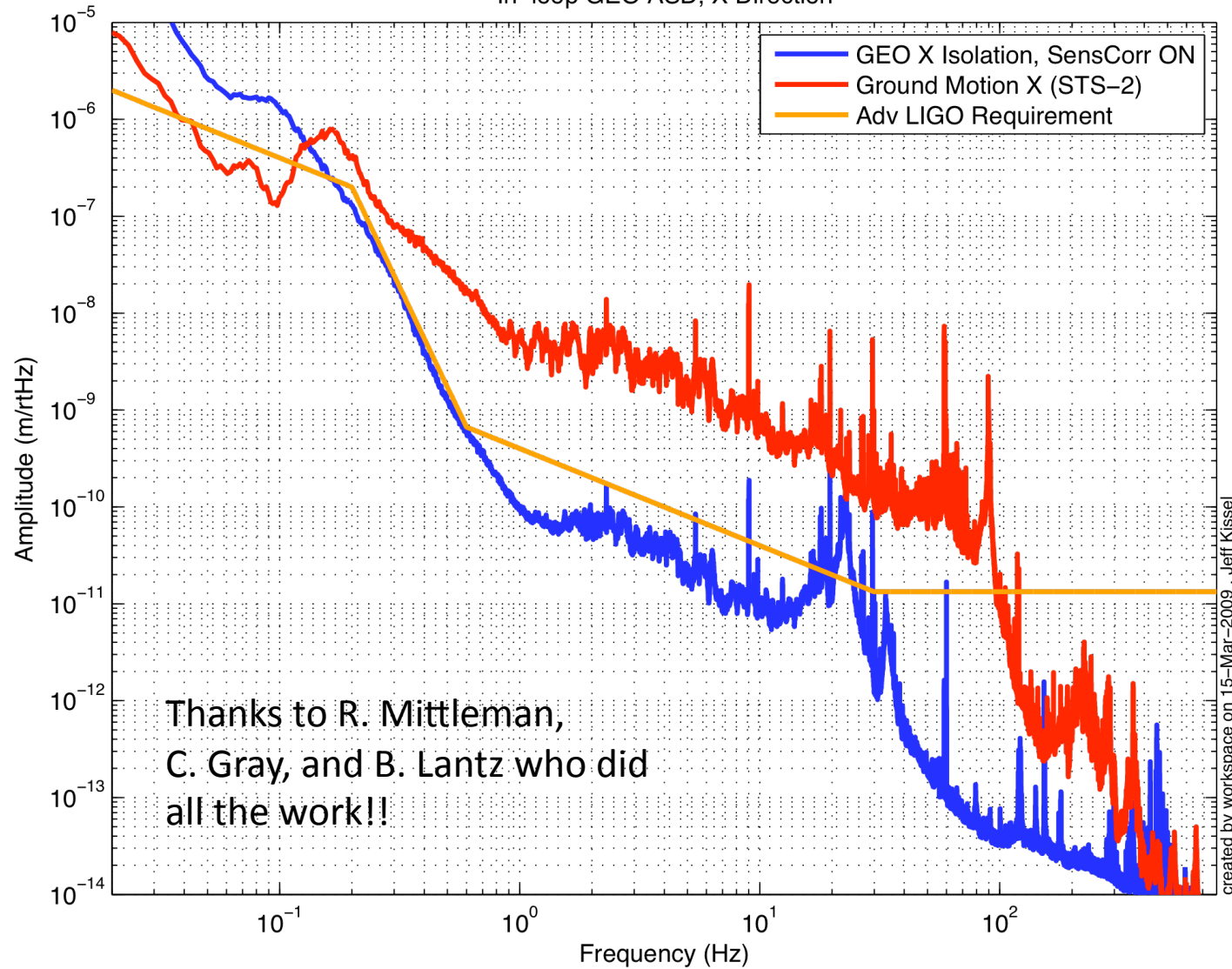
L1 HAM ISI commissioning
Sep/Oct '08 and Jan/Apr '09



Enhanced LIGO Seismic Isolation HAM ISI RESULTS!!



H1HAM6ISI Performance, March 13 2009
In-loop GEO ASD, X Direction

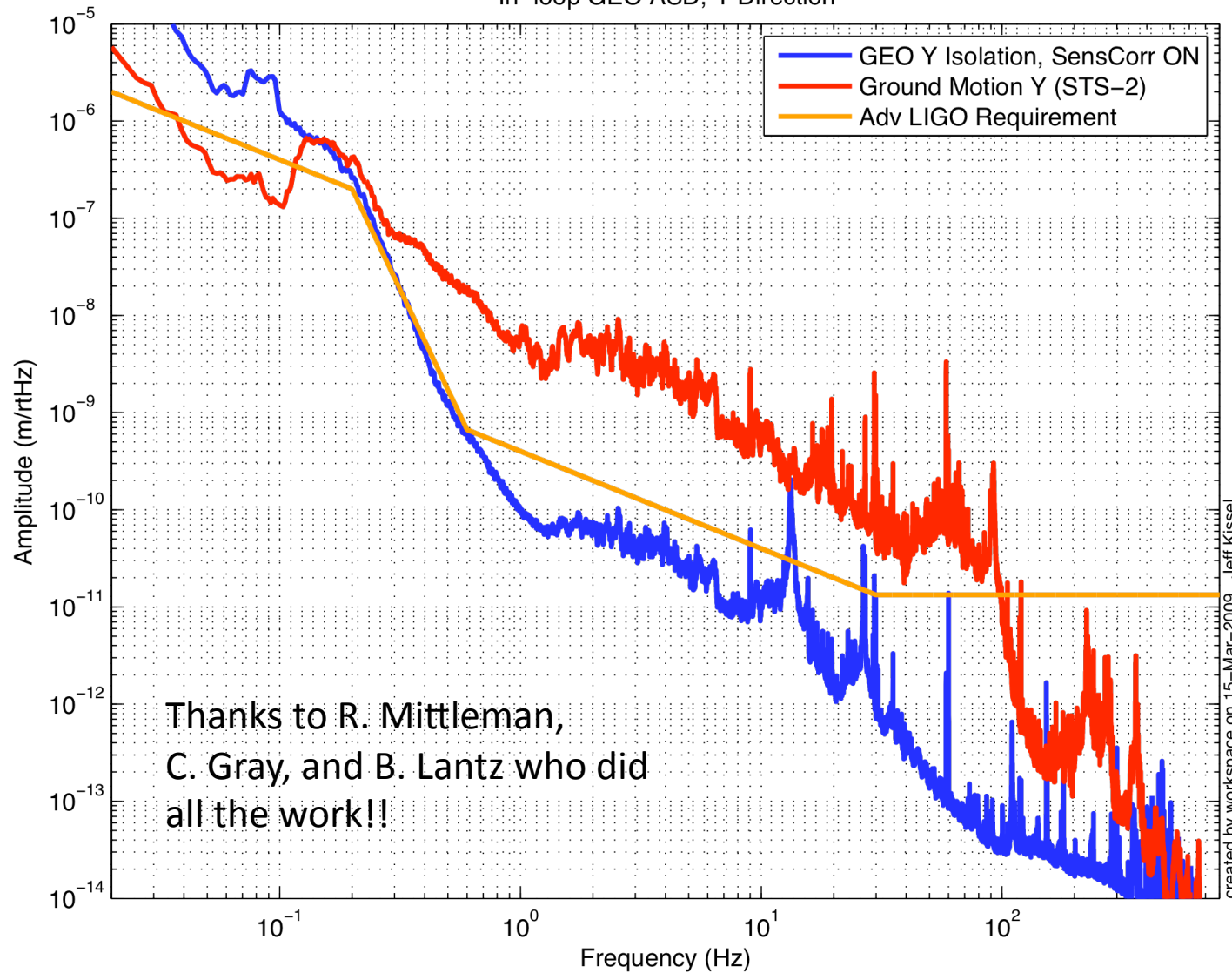




Enhanced LIGO Seismic Isolation HAM ISI RESULTS!!



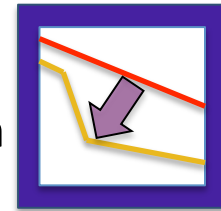
H1HAM6ISI Performance, March 13 2009
In-loop GEO ASD, Y Direction



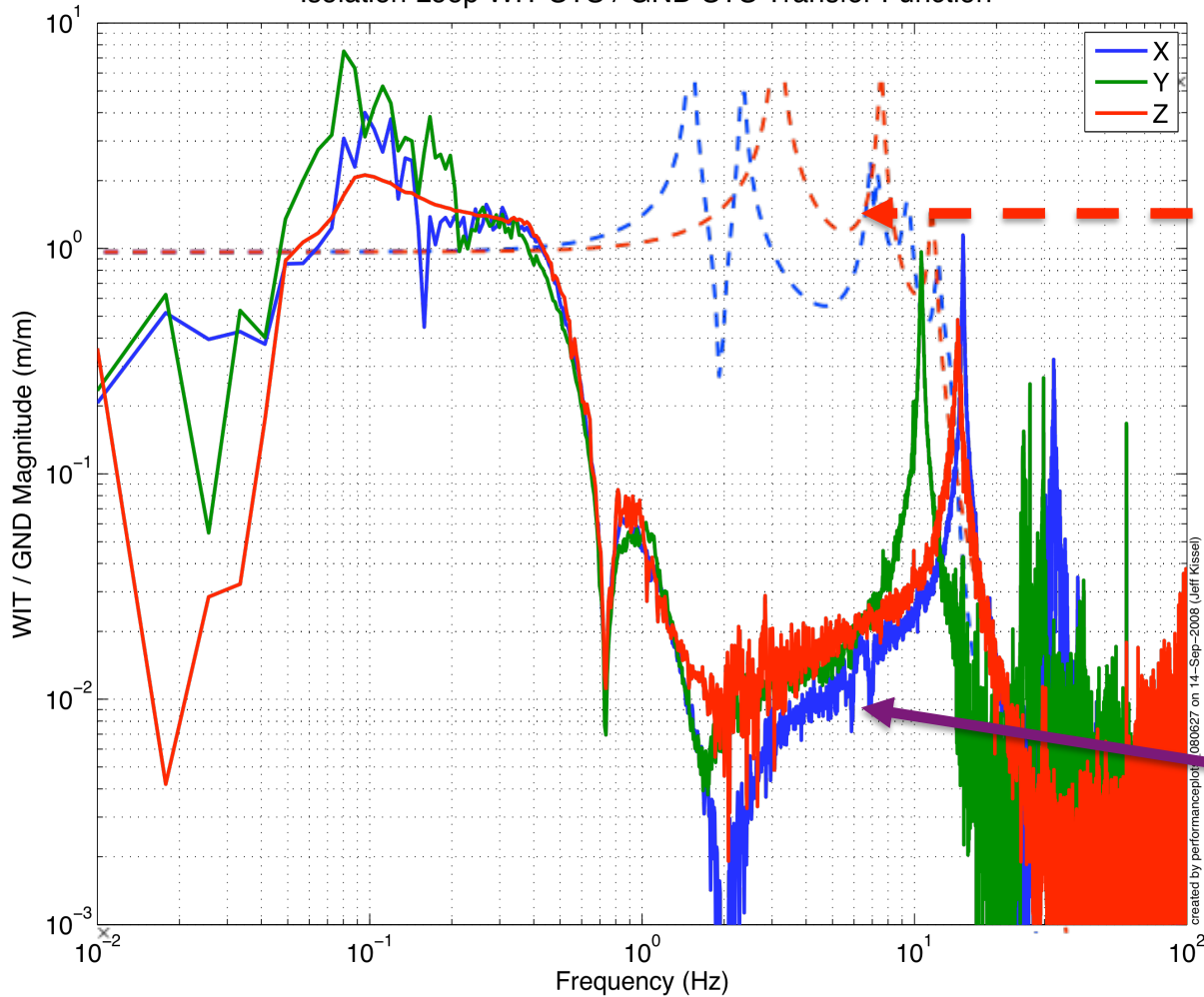


The HAM ISI

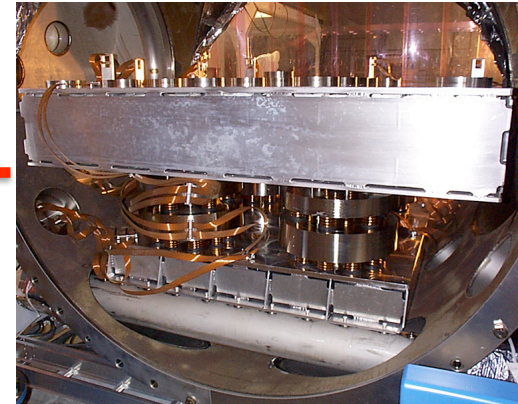
Old vs. New Isolation Comparison



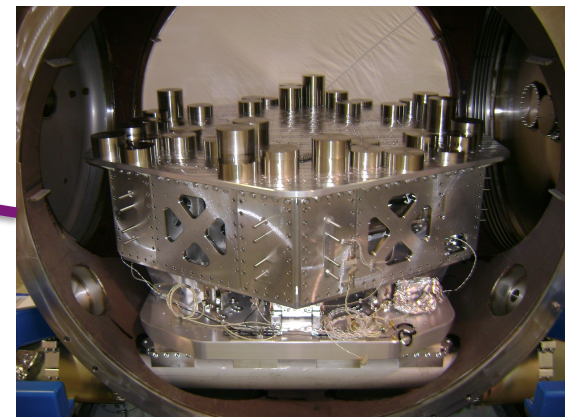
LHO HAM6 ISI, June 27 2008
Isolation Loop WIT STS / GND STS Transfer Function



iLIGO Passive Isolation



eLIGO Passive & Active Isolation





The aLIGO HAM ISI

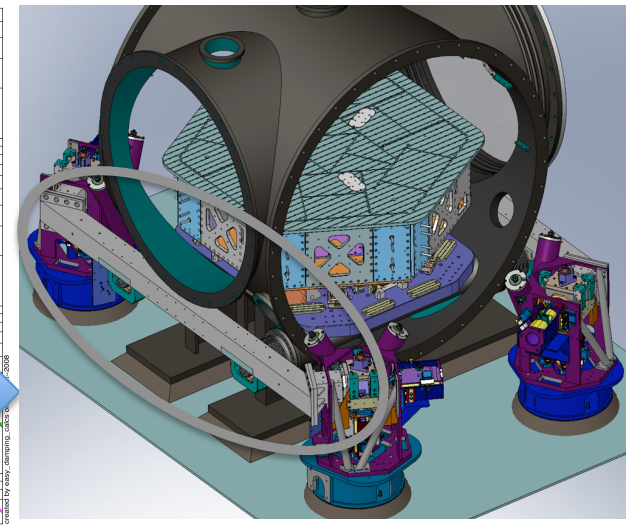
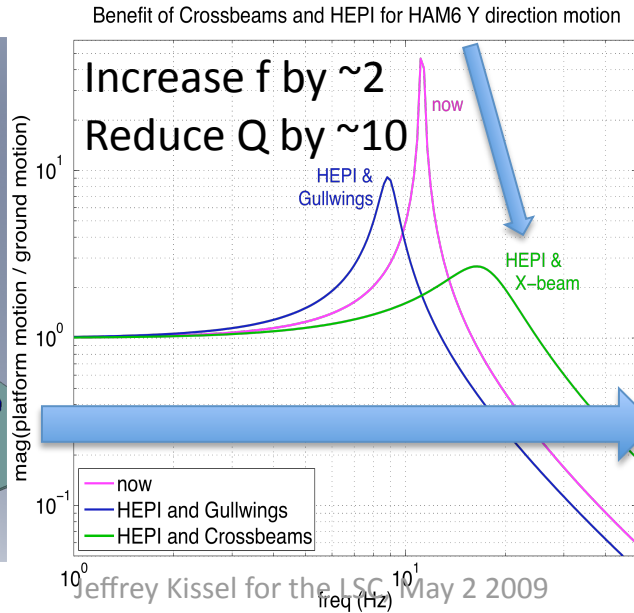
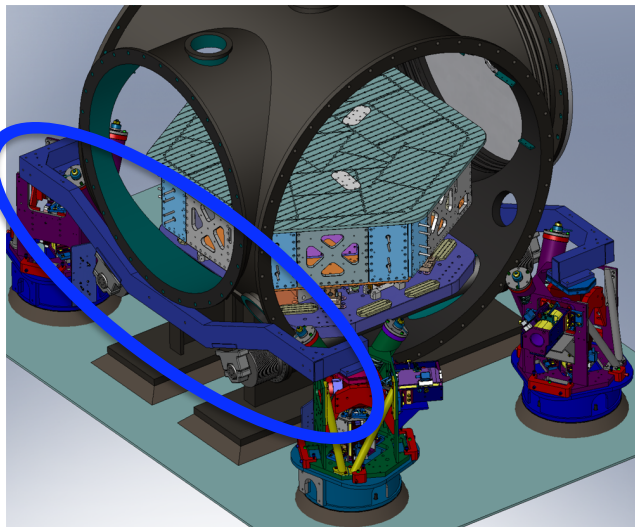
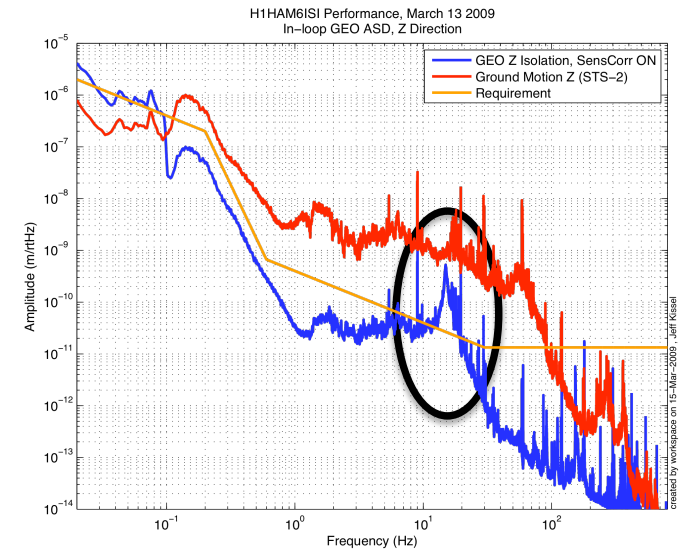
Improving the Performance in Advanced LIGO

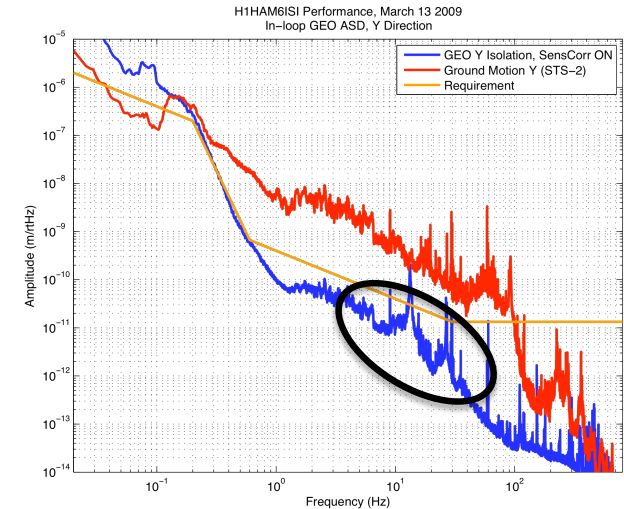
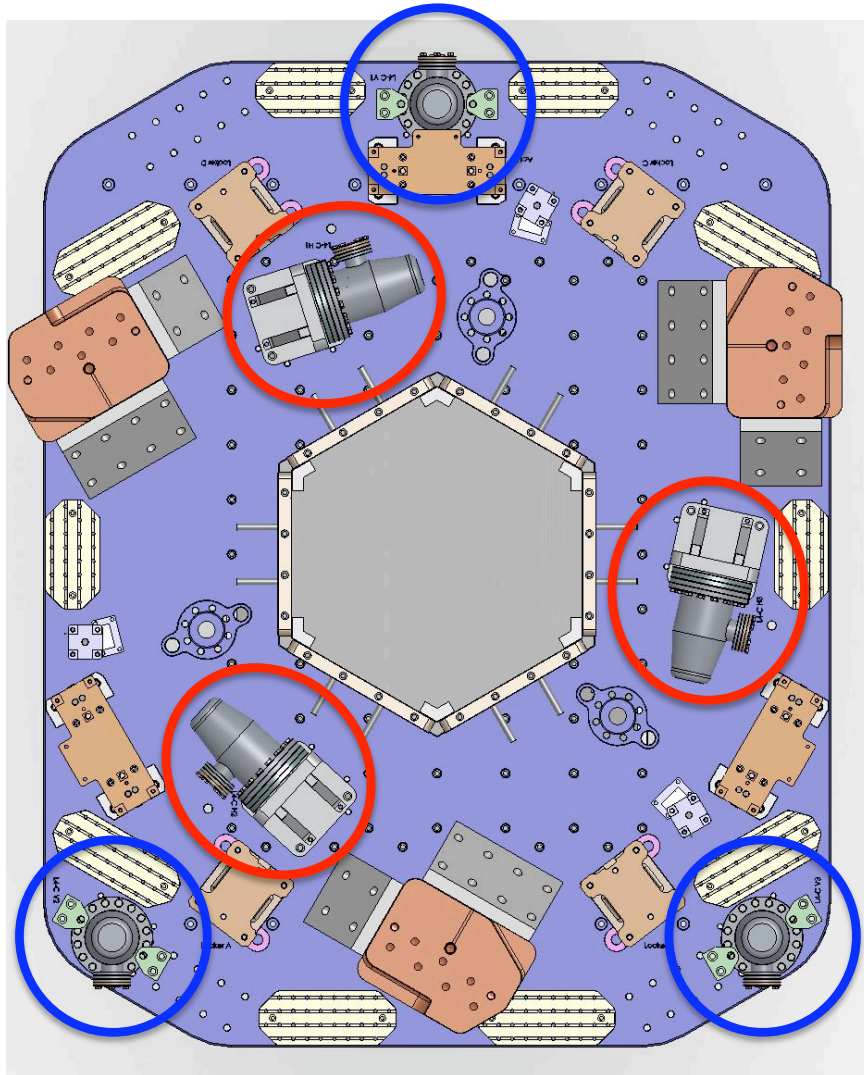


Stiffer support structure, add *external* pre-isolation!

Gullwings → Crossbeams

- Support structure has been redesigned for aLIGO, have already been purchased!
- Hydraulic External Pre-Isolation will be installed, redesigned to use the new crossbeams





More Feed-forward!

- Certain chambers need performance *better than the requirements* between 5 and 20 Hz
- We'll try 6 additional inertial sensors that feed-forward from support stage to suspended stage (Three **Horizontal**, Three **Vertical**)
- Prototyping fall/winter of 2009



The aLIGO HAM ISI

Improving the Performance in Advanced LIGO



Add constrained layer and tuned mass damping!

- Damping ring on vertical inertial sensor restoring springs



Inertial Sensor

