Advanced LIGO

and the bright future of Gravitational Wave Observation

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on behalf of the
LIGO Scientific Collaboration

LIGO - G1301287

Sunrise on Kerala's backwaters

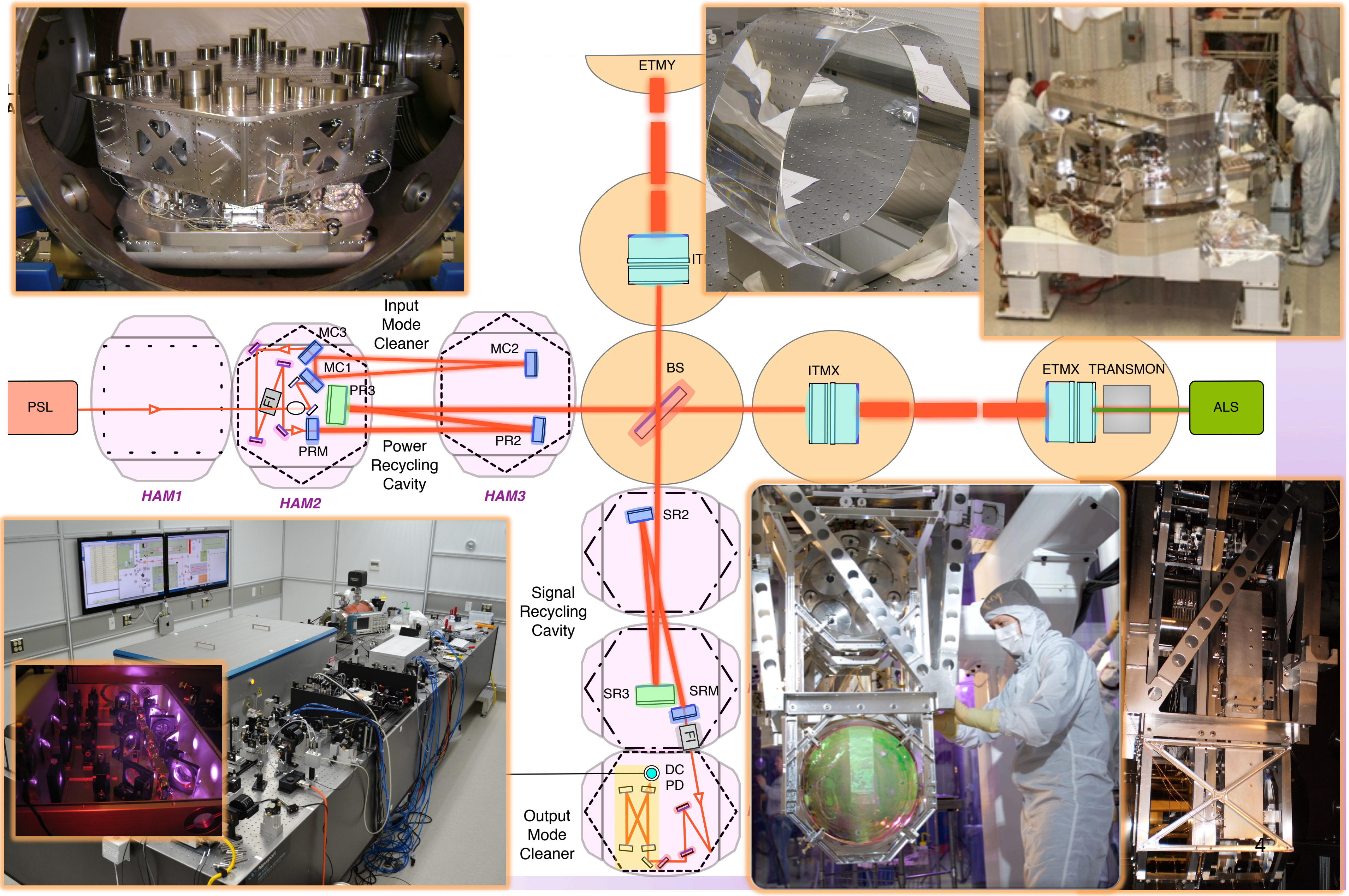
Upcoming Network in the Advanced Detector Era

Credit: C. Mayhew & R. Simmon (NASA/GSFC), NOAA/ NGDC, DMSP Digital Archive

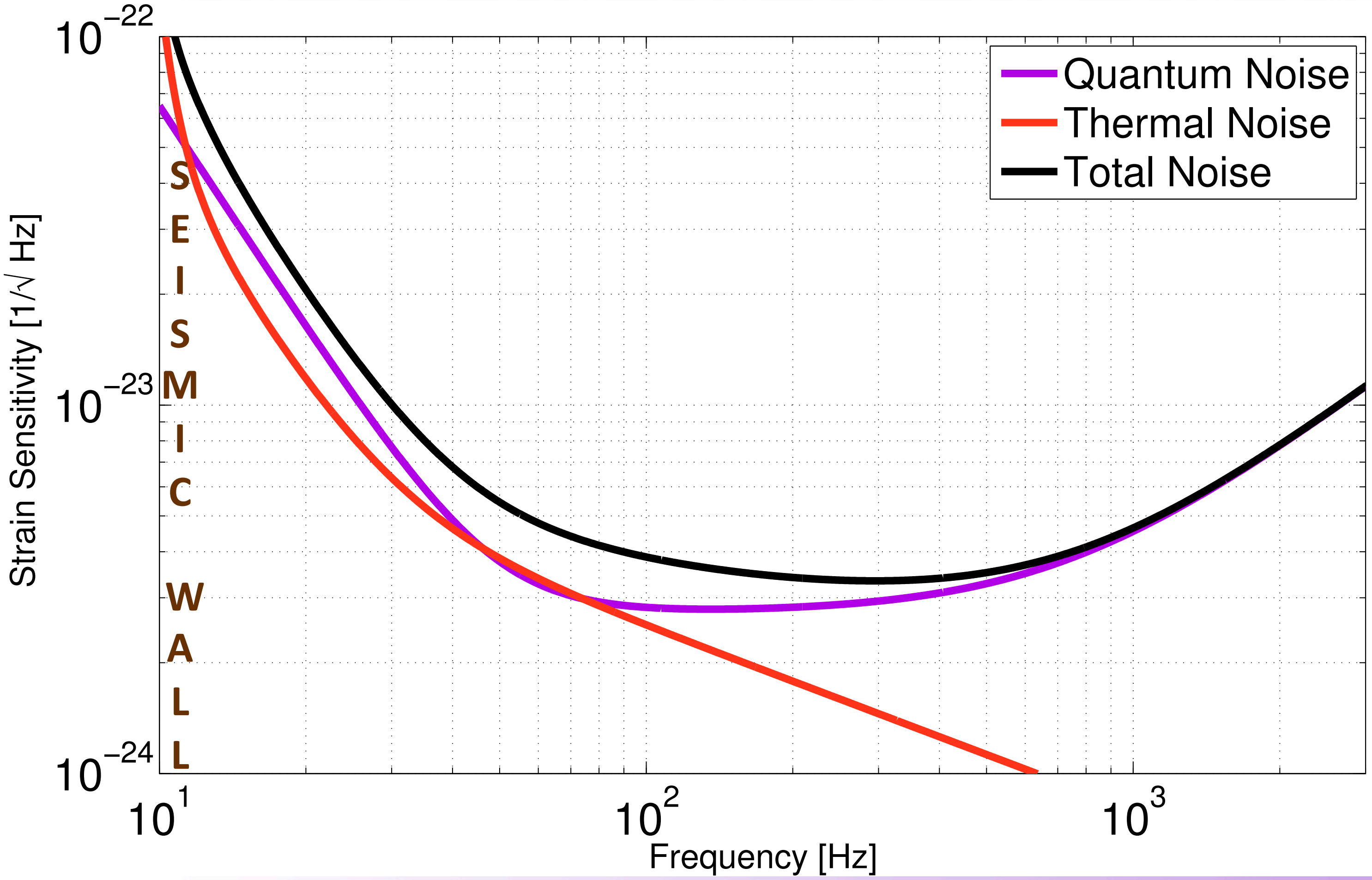
LIGO Hanford Observatory (WA)
H1 – in the desert

LIGO Livingston Observatory (LA)
L1 – in the jungle

Advanced LIGO: L1 & H1



Advanced LIGO Design Sensitivity..



..but what about technical noises? How about data quality?
And, by the way…how do we get to the design sensitivity?

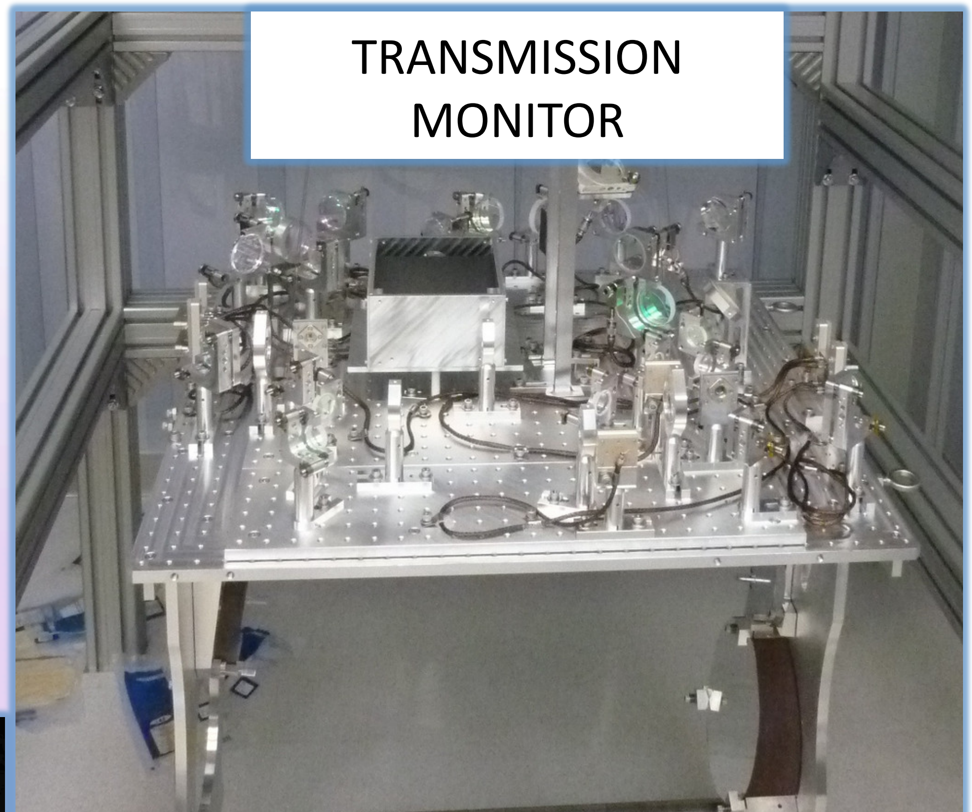
"EVERYTHING is better in Advanced LIGO!"

Incorporated lessons learned from initial detectors to:

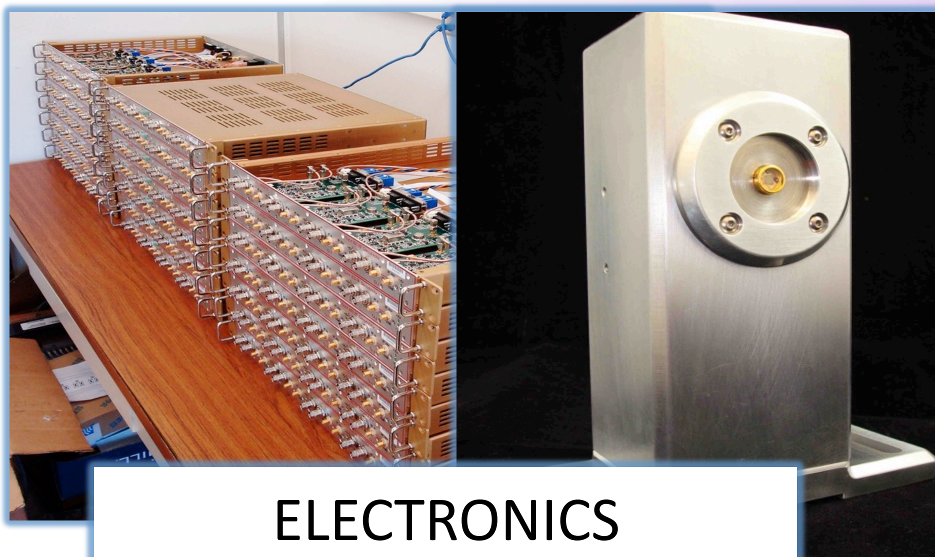
✓ reduce impact of technical noises

✓ reduce causes of glitches

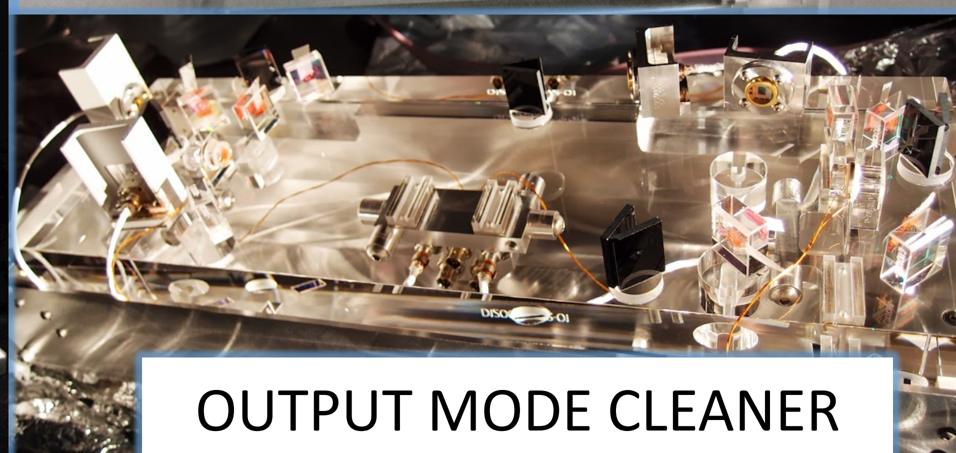
✓ reduce commissioning time



TRANSMISSION MONITOR



ELECTRONICS



OUTPUT MODE CLEANER

Advanced LIGO Status

<u>Installation and integration inspiring "principles"</u>:

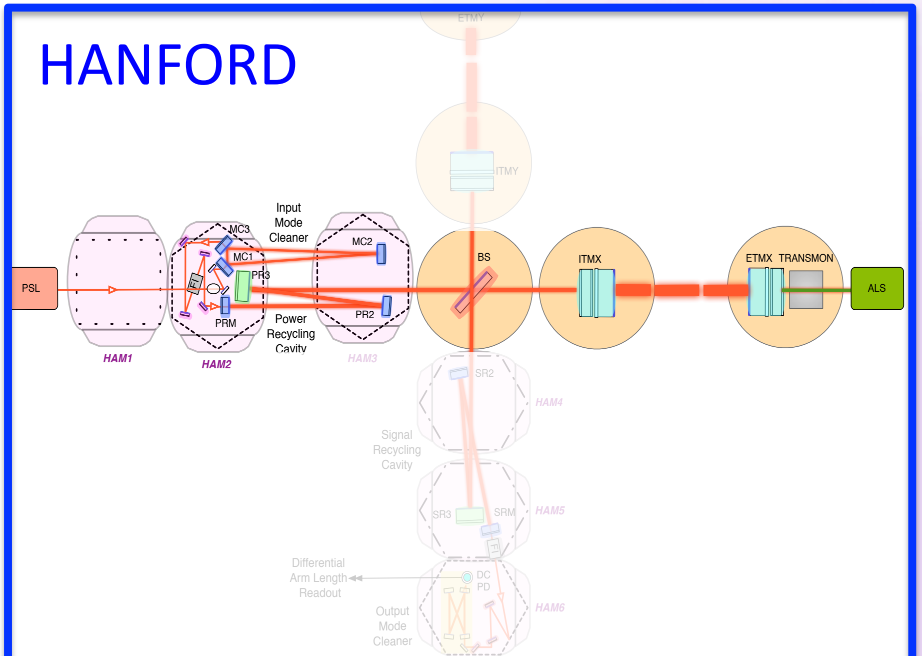
✧ Parallel effort between Hanford and Livingston

✧ Installation of "new" things as soon as possible

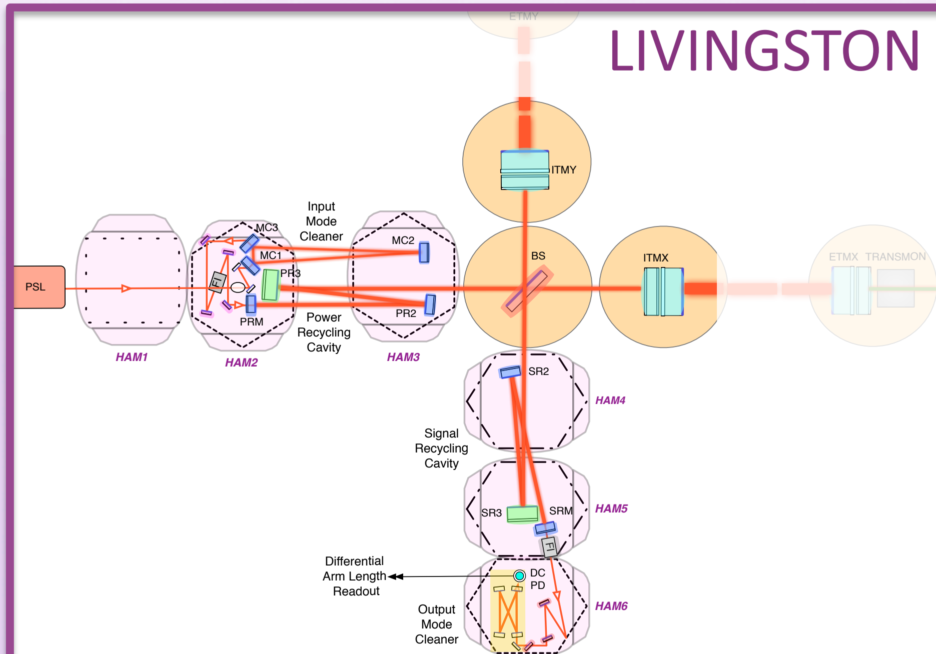
✧ Test configurations of increased complexity

Advanced LIGO Status

HANFORD



LIVINGSTON

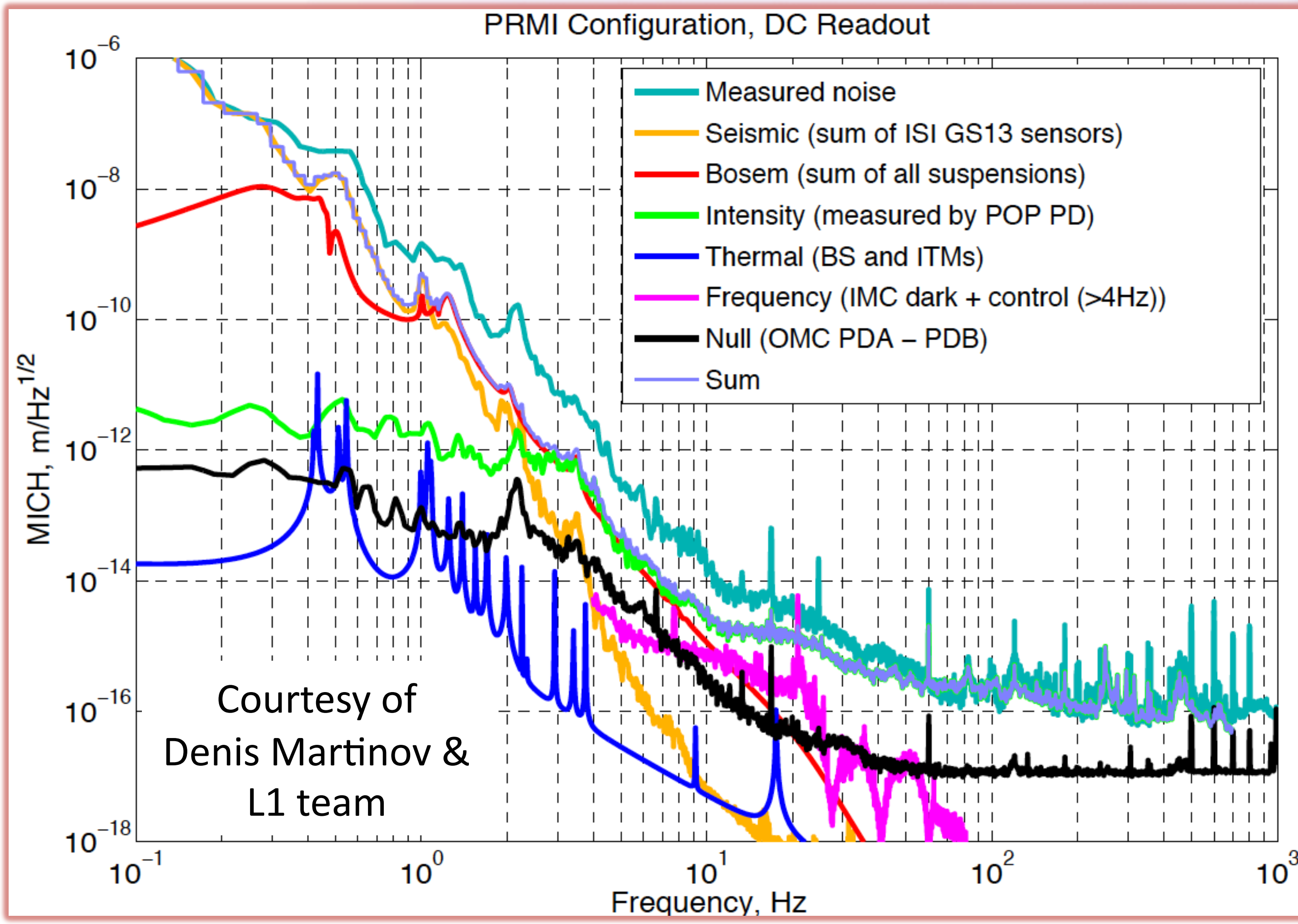


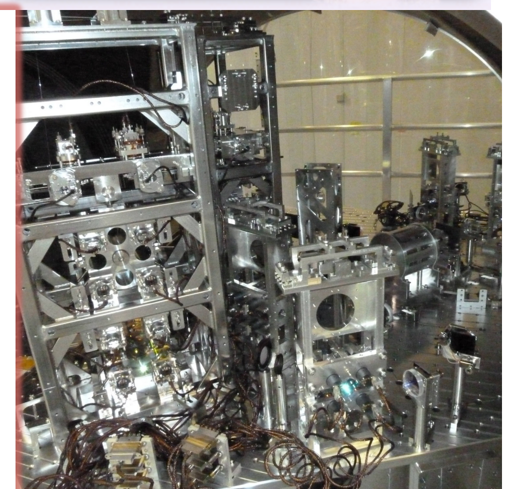
✓Completed first tests on one arm
✓Other arm + central interferometer under installation

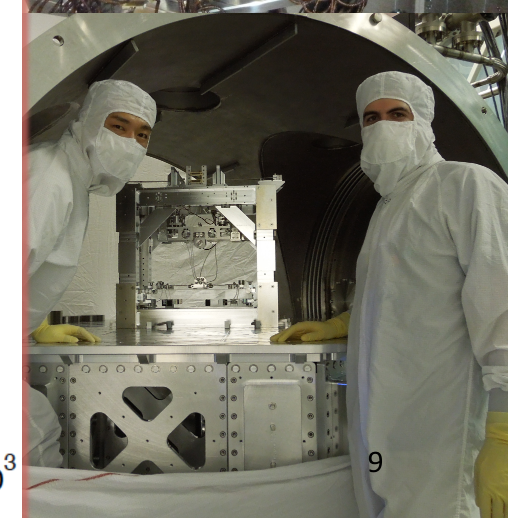
✓Completed first tests on central interferometer
✓ Both arms under installation

Advanced LIGO Status: LIVINGSTON

Noise Budget for the central part of the interferometer (no arms)

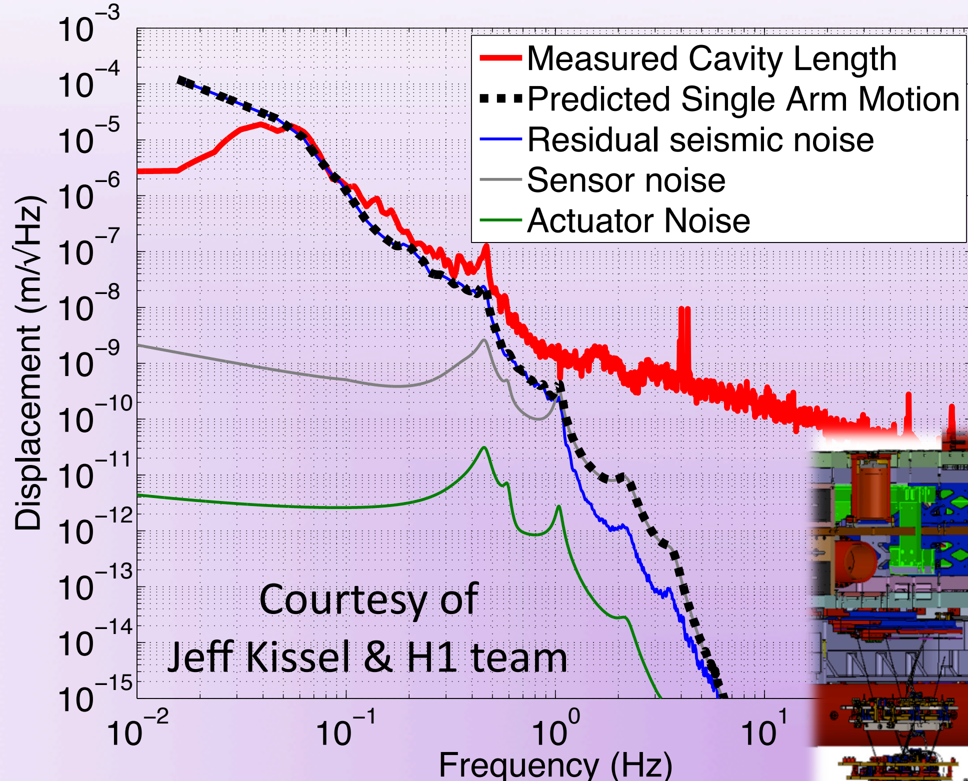




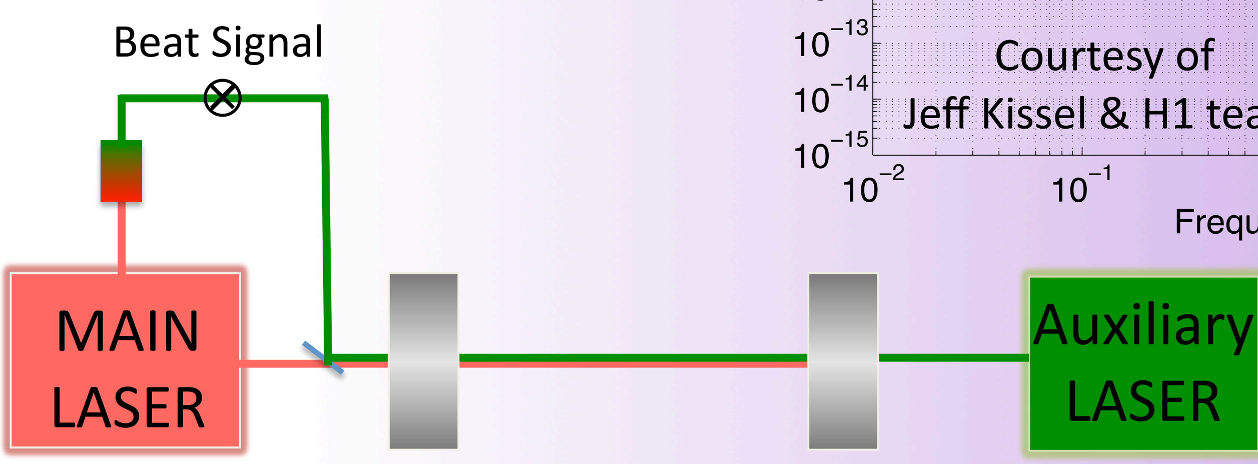


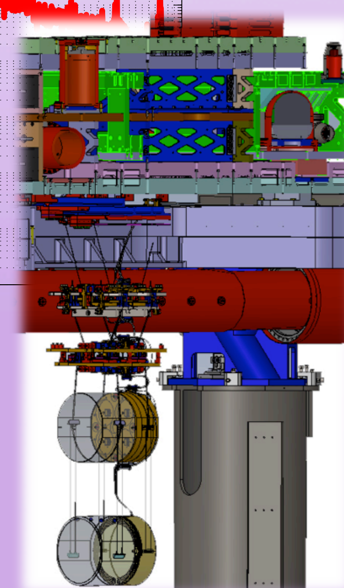
Advanced LIGO Status: HANFORD

✧ First measurement of 4 km arm cavity motion with new seismic isolation



✧ New "Arm Length Stabilization System" for lock acquisition tested for one arm, performing as expected





Advanced LIGO Timeline

2014 --- both detectors "locked" on operating point

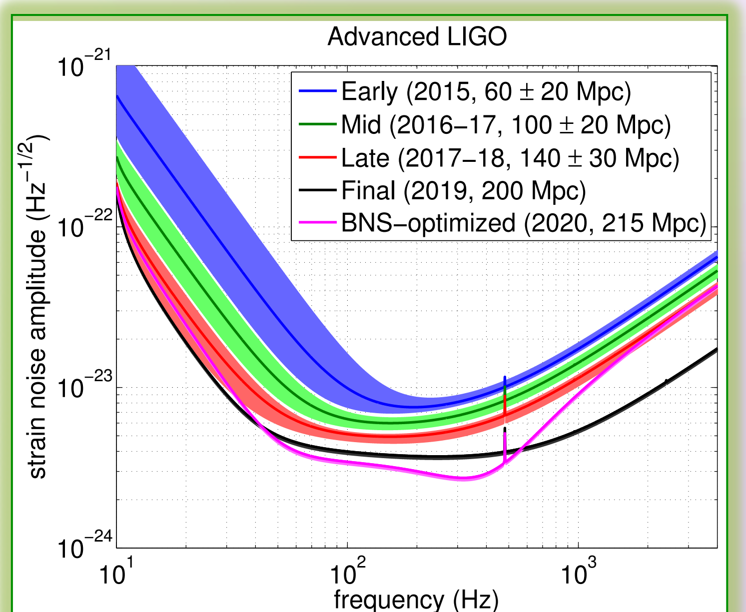
2015 --- "commissioning phase": noise reduction

2016

2017

2018

2019



GW detection events

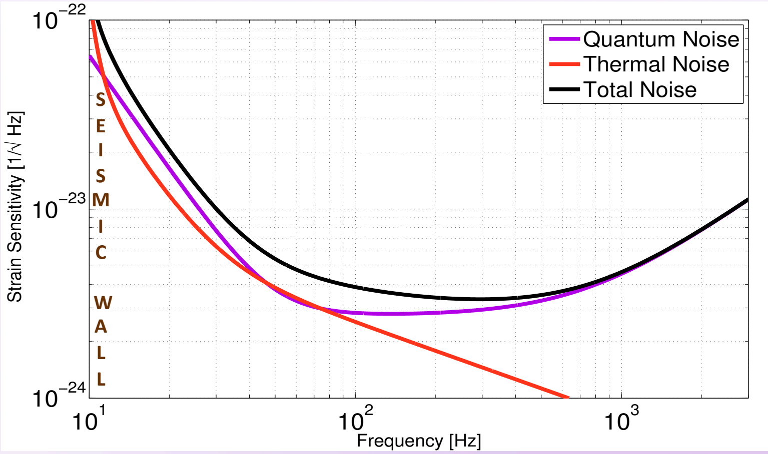
$$\propto \text{(obs time)} \times \text{(sensitivity)}^3$$

➔ Strategize between "observing" and sensitivity improvements

Potential complications

❖ **Required displacement noise levels not verified directly**

(for a good reason… essentially impossible to test in subscale setups!)



❖ **High power operations**

✓ Up to 1 MW stored inside the arm cavity (absorption, thermal compensation, etc)

❖ **Increased complexity**

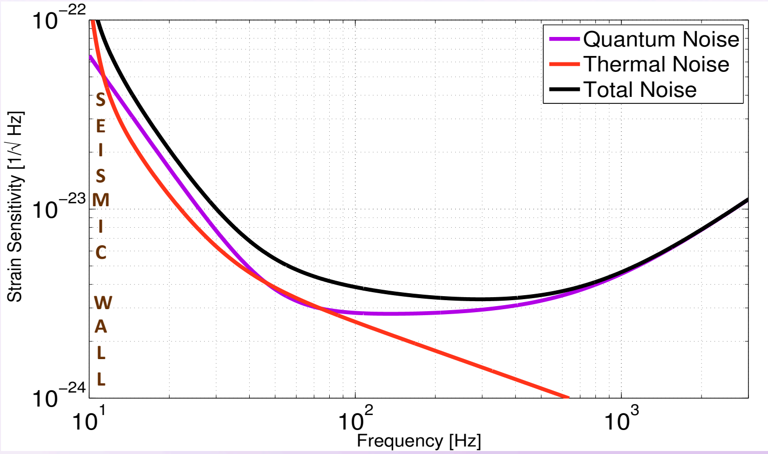
✓ Number of control loops x10 larger than in initial LIGO

✓ Mechanical systems have many more degrees-of-freedom (Test Mass suspension has 48 DOF vs. 6 in initial LIGO)

Potential complications
(according to me, today)

❖ **Required displacement noise levels not verified directly**

(for a good reason… essentially impossible to test in subscale setups!)



❖ **High power operations ➔ Still true, but less scary than before**

- ✓ Up to 1 MW stored inside the arm cavity (absorption, thermal compensation, etc)

❖ **Increased complexity ➔ Acted on, a lot of work happening**

- ✓ Number of control loops x10 larger than in initial LIGO
- ✓ Mechanical systems have many more degrees-of-freedom (Test Mass suspension has 48 DOF vs. 6 in initial LIGO)

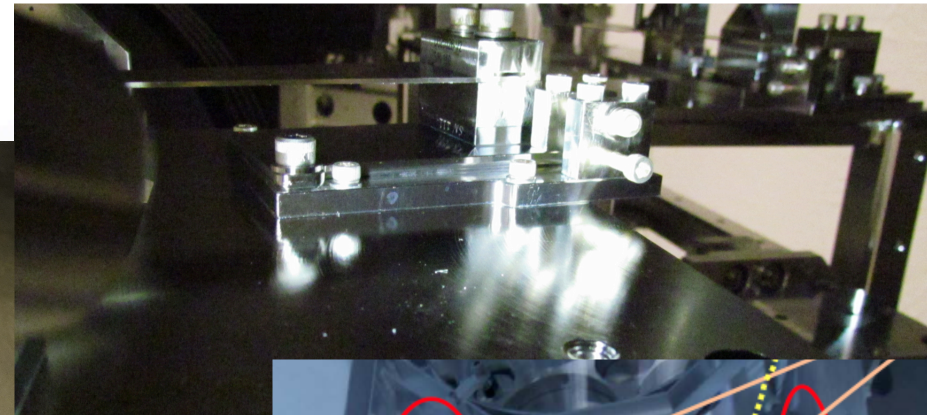
Summary & Outlook

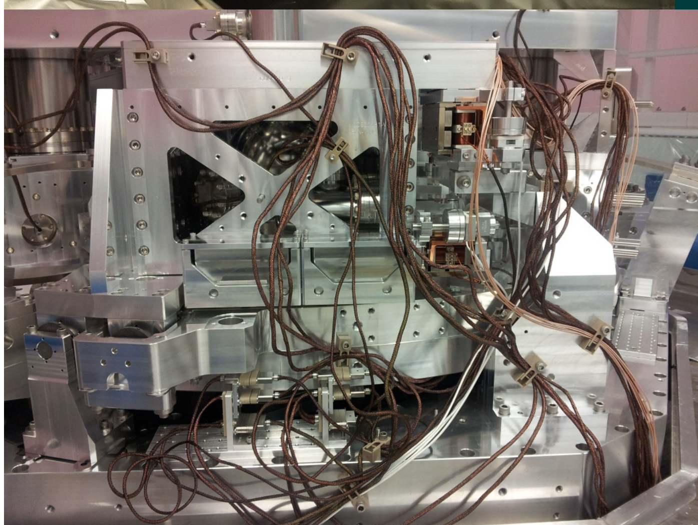
- ✧H1 & L1 are being installed and tested, problems are found and fixed, so far no showstoppers
- ✧Goal is to go as quickly as possible to two interferometers locked: on target for end of 2014 at both sites
- ✧All the 2015+ projected curves that you see are “plausible”, they won’t be exactly like that
- ✧Good data are coming, be ready! ☺

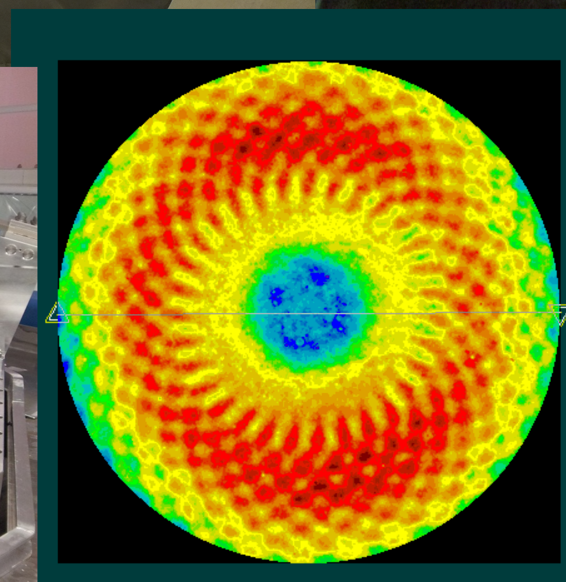

Thanks!
Sunset on Marari Beach

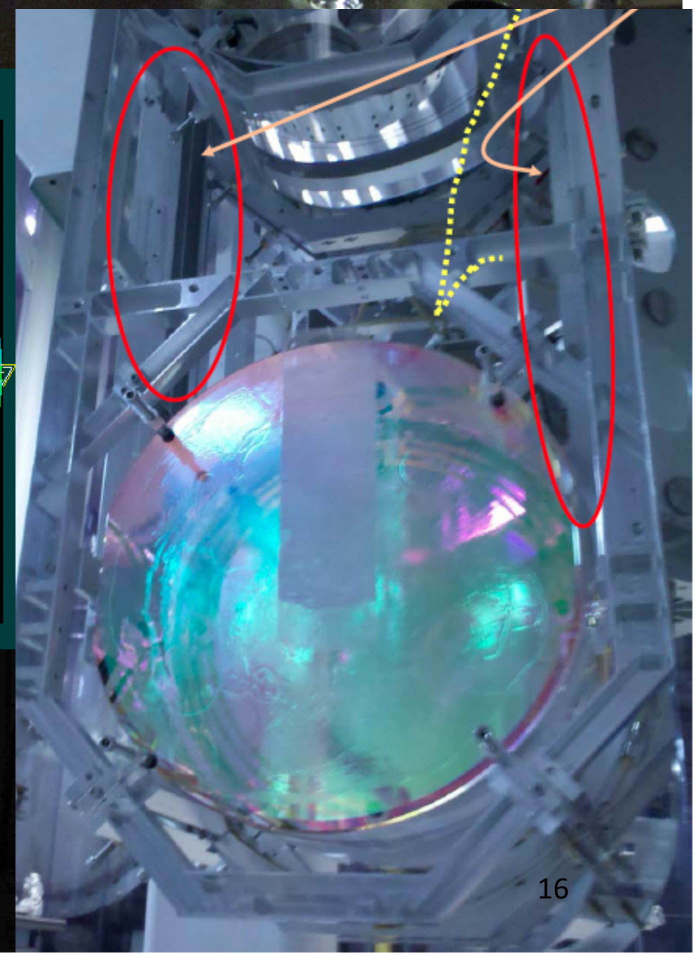
Several bumps in the road, no showstoppers so far

Pick your favorite "bump"!

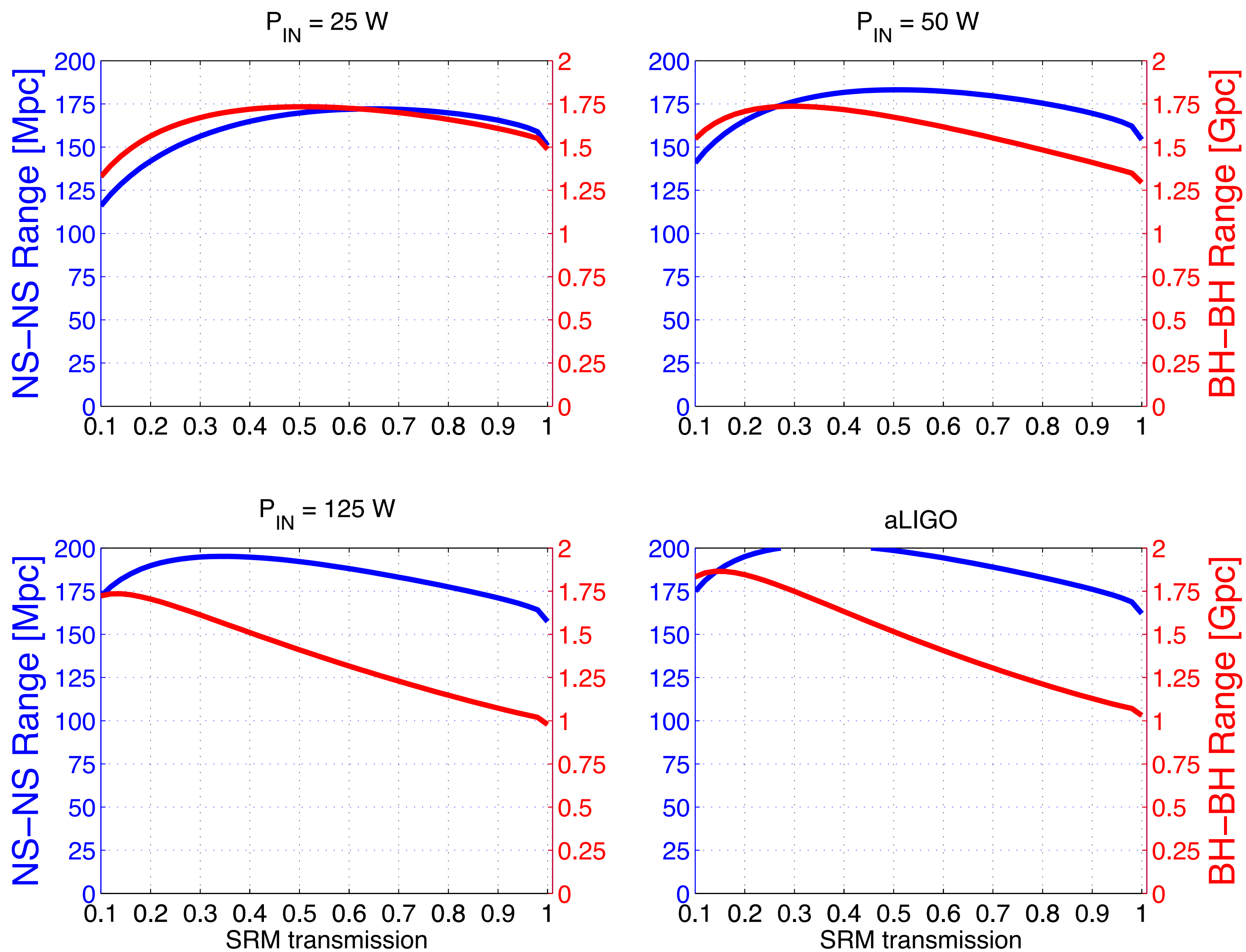




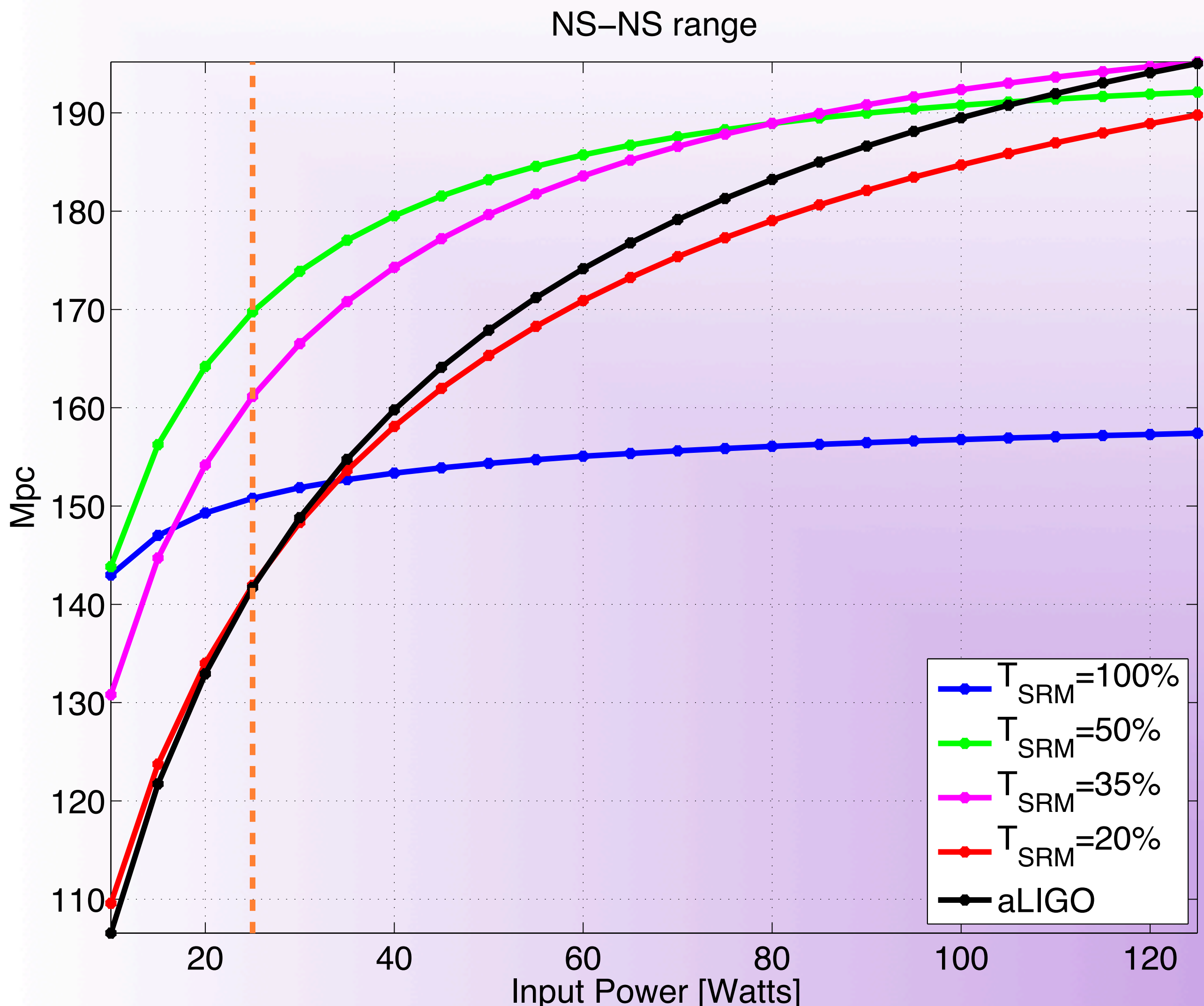




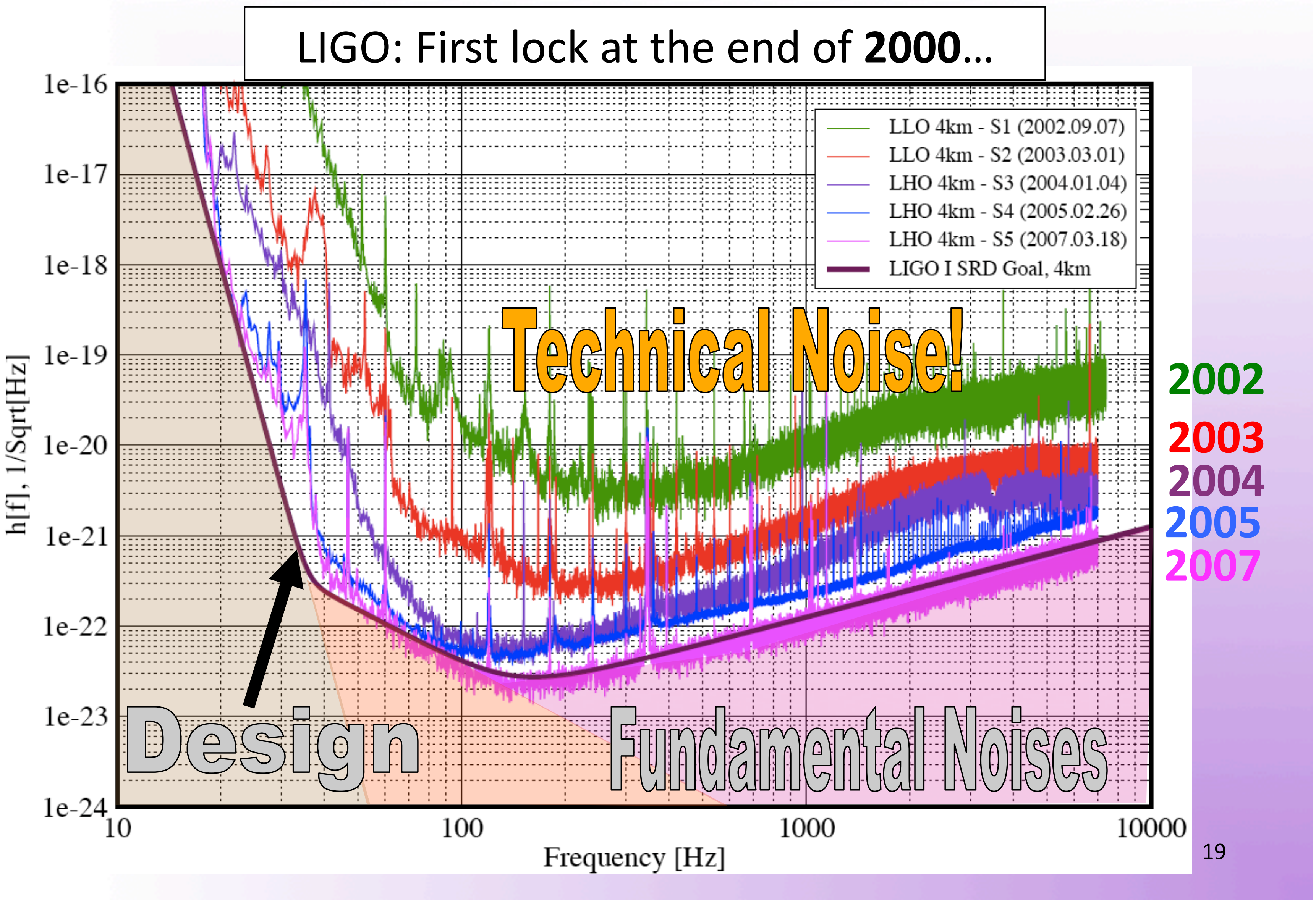
Optimization of SRM transmission



Optimization of SRM transmission

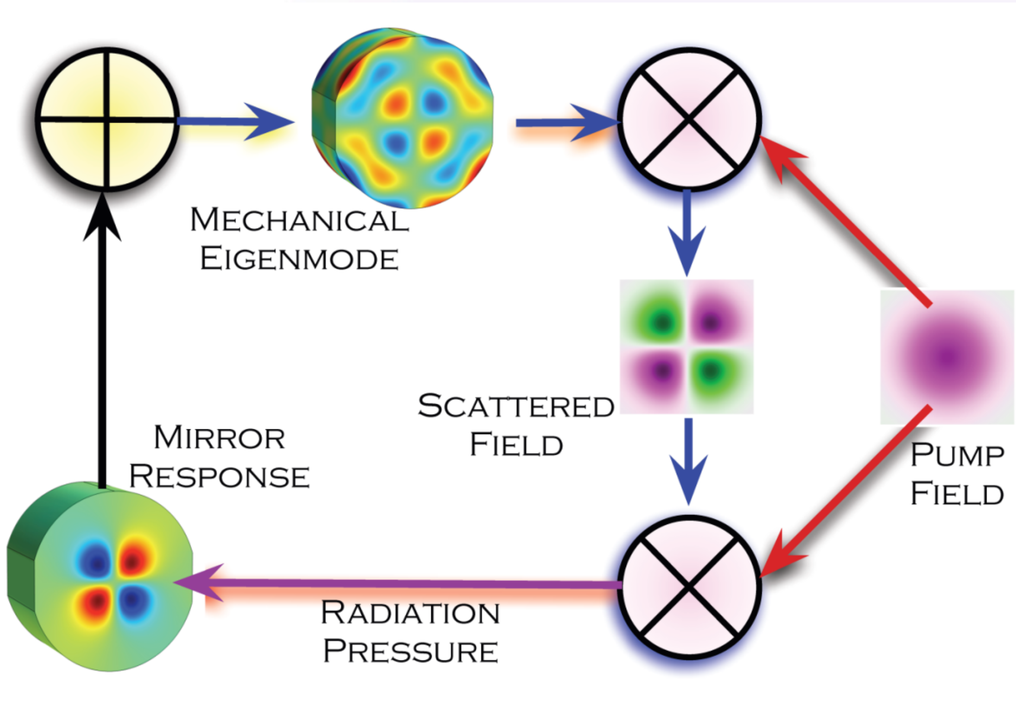


Initial LIGO Sensitivity improvement



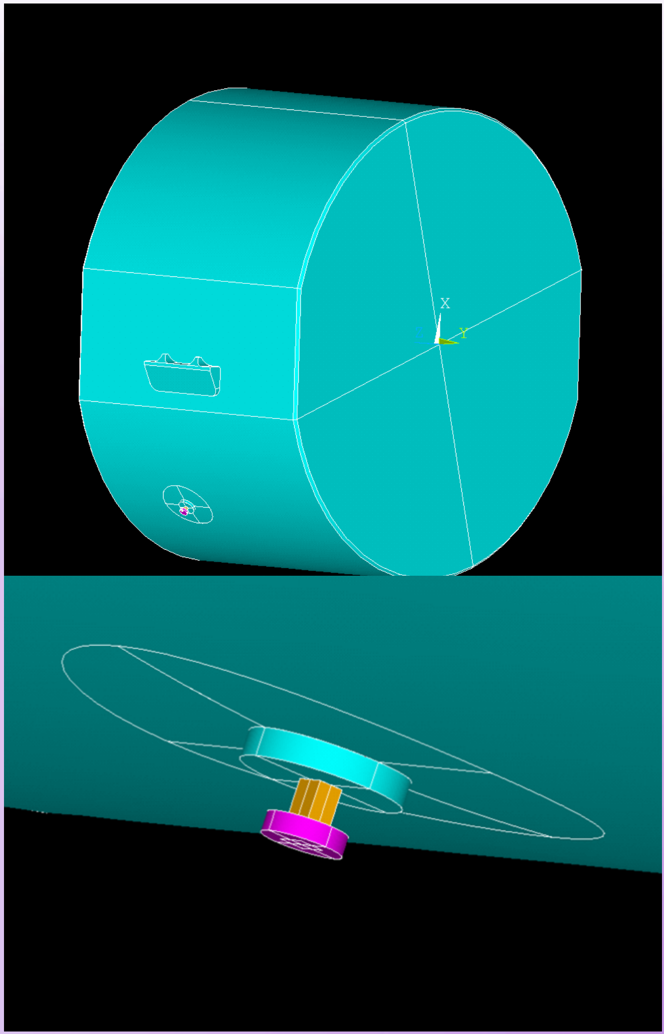
Parametric Instabilities

Slawek Gras (LIGO-MIT)



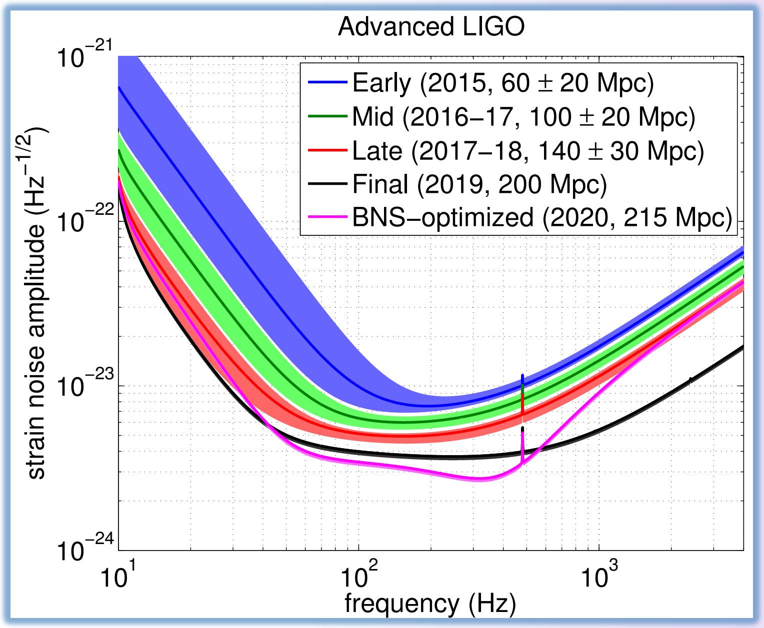
1. Test mass mechanical mode scatters fundamental mode (pump) into the higher order mode

2. After round trip scattered mode returns to the test mass and couples via radiation pressure into the mechanical mode



Detection Rates

Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc) LIGO	Virgo	BNS Range (Mpc) LIGO	Virgo	Number of BNS Detections	% BNS Localized within 5 deg^2	20 deg^2
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48



Neutron Star Binaries:

Advanced LIGO: ~ 200 Mpc

"Realistic rate" ~ 40/year

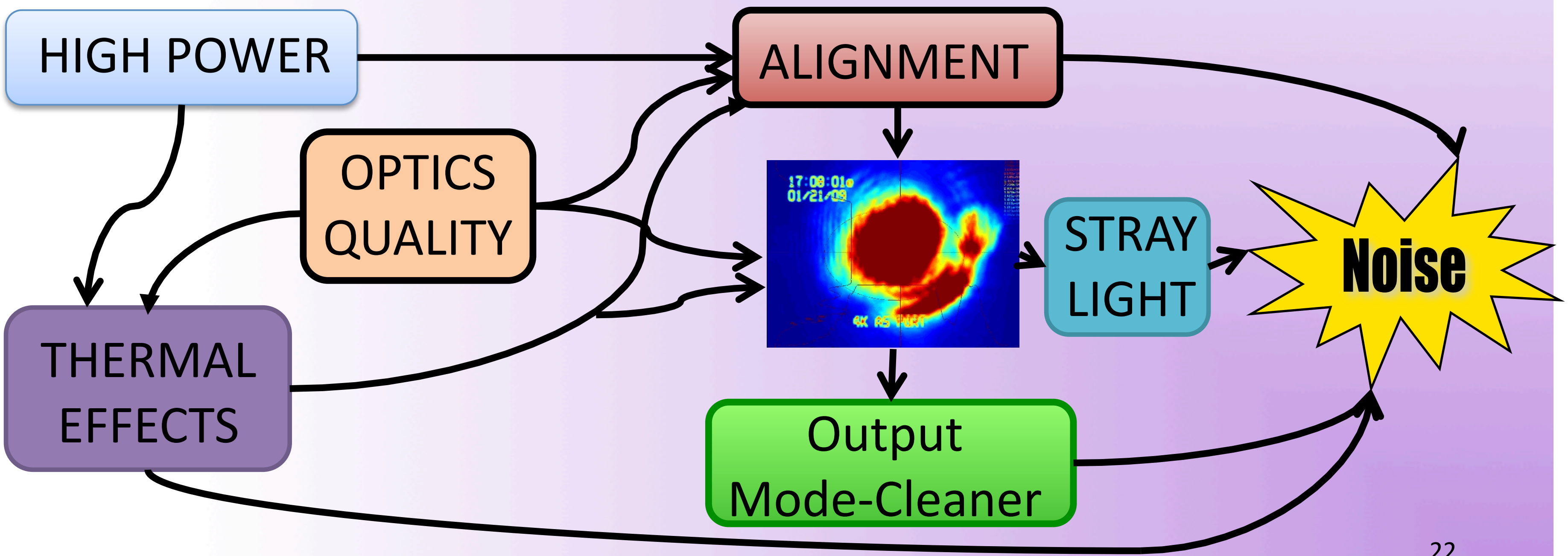
Class. Quant. Grav. **27**, 173001 (2010)

(Initial LIGO: ~15 Mpc, Rate ~1/50years)

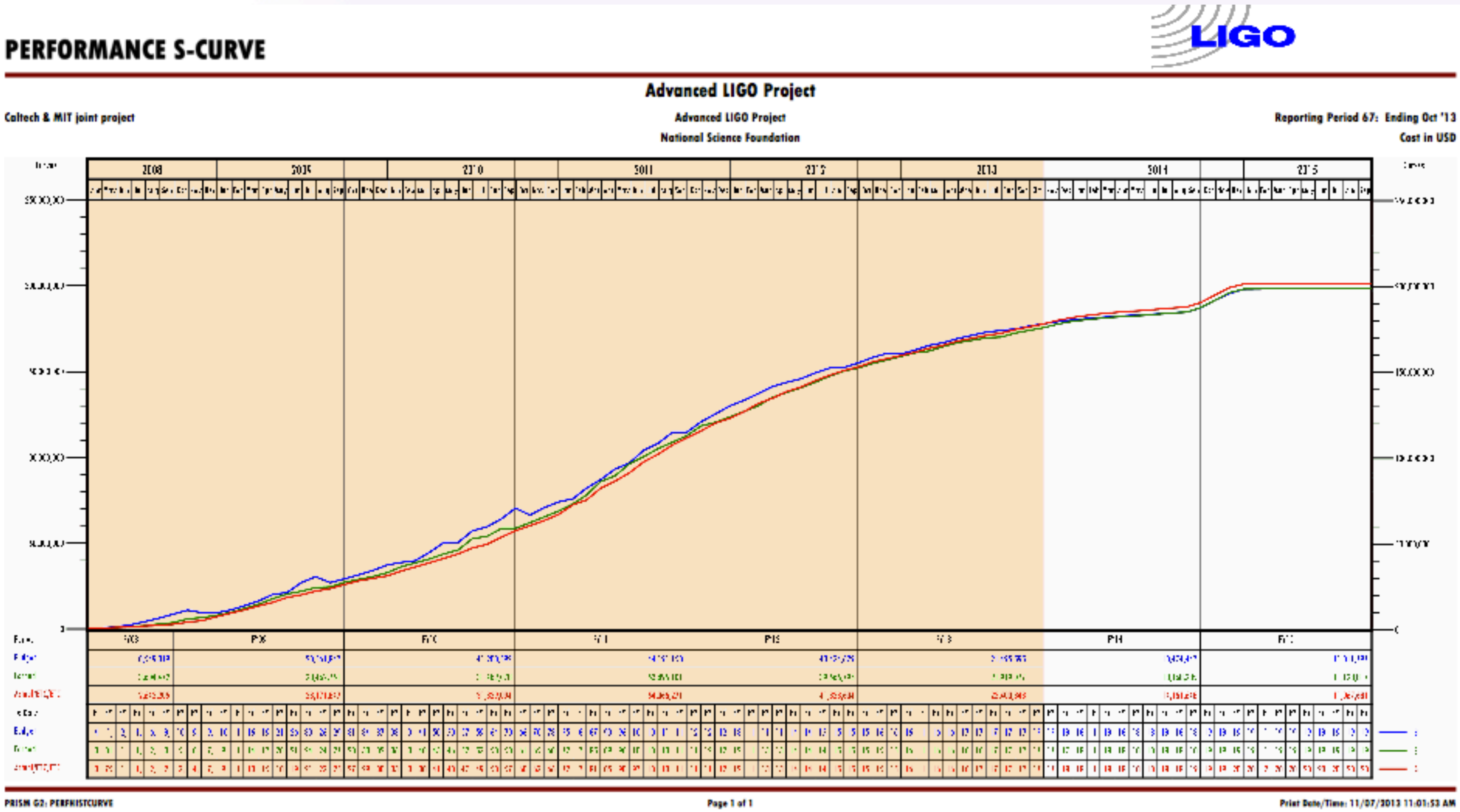
What we call "commissioning":

Understand and fix an entanglement of noise coupling mechanisms

Example from Enhanced LIGO

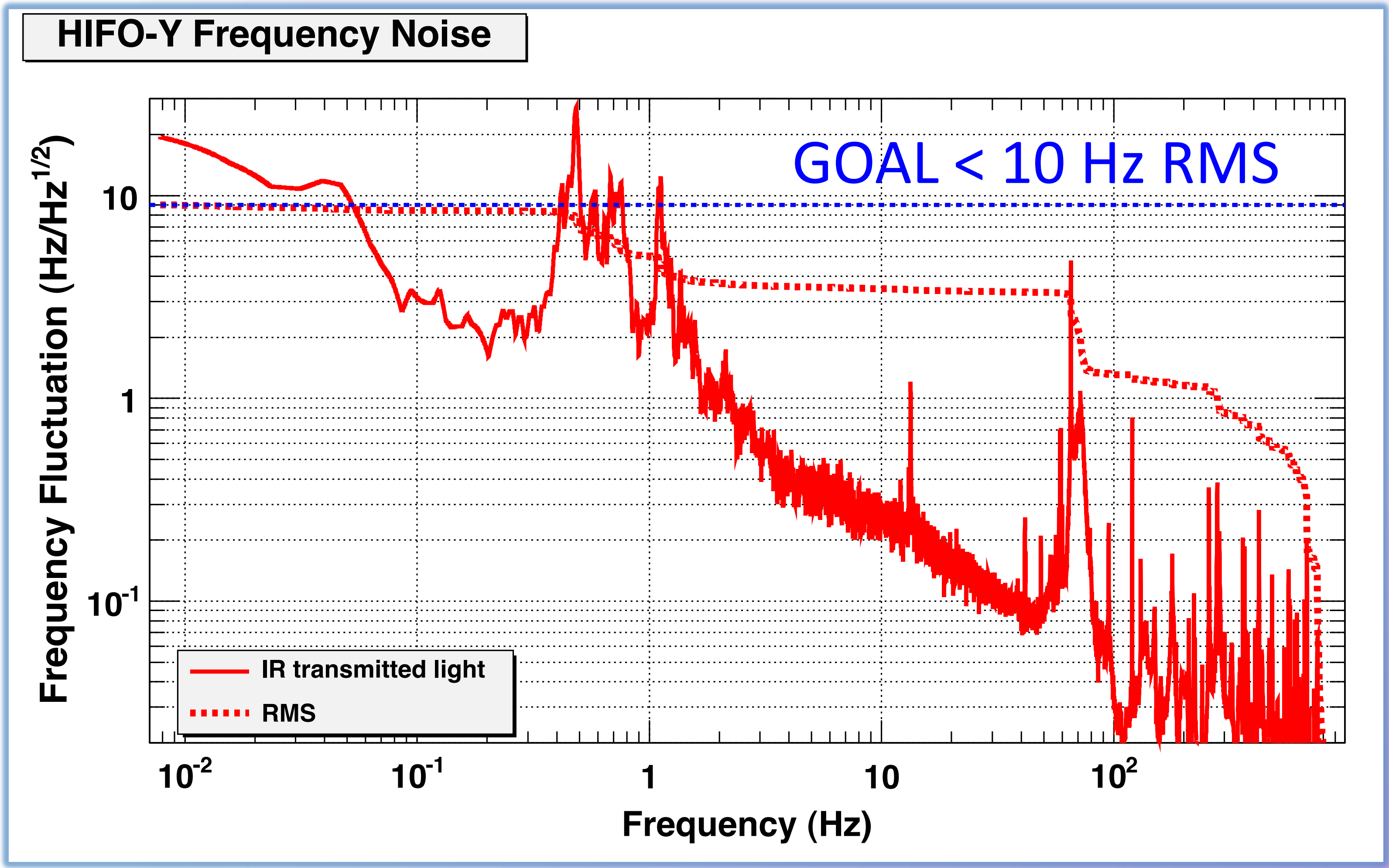


Advanced LIGO is 85.4% complete (@ July 2013)



“Arm Length Stabilization” System

Frequency fluctuations of main laser light is already “good enough” (1/10 of the cavity linewidth), “noise hunting” still in progress



Seismic isolation performance