ARC Centre of Excellence for Gravitational Wave Discovery

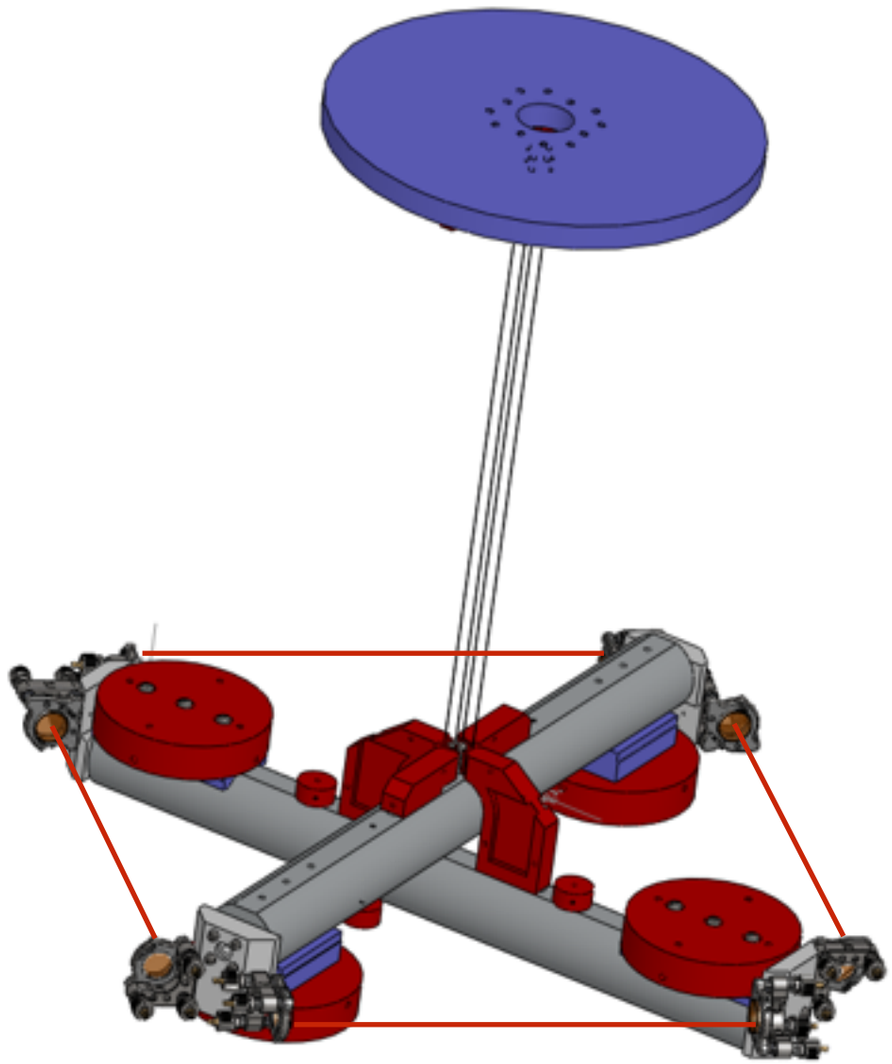
TorPeDO

David McManus,[1] Perry Forsyth,[1] Giles Hammond,[2] Ayaka Shoda,[3]
Robert Ward,[1] Daniel Shaddock,[1] David McClelland,[1] Bram Slagmolen[1]

1 Department of Quantum Science, Australian National University
2 School of Physics and Astronomy, University of Glasgow
3 National Astronomical Observatory of Japan

TorPeDO

Torsion Pendulum Dual Oscillator



TorPeDO is a gravitational force sensor

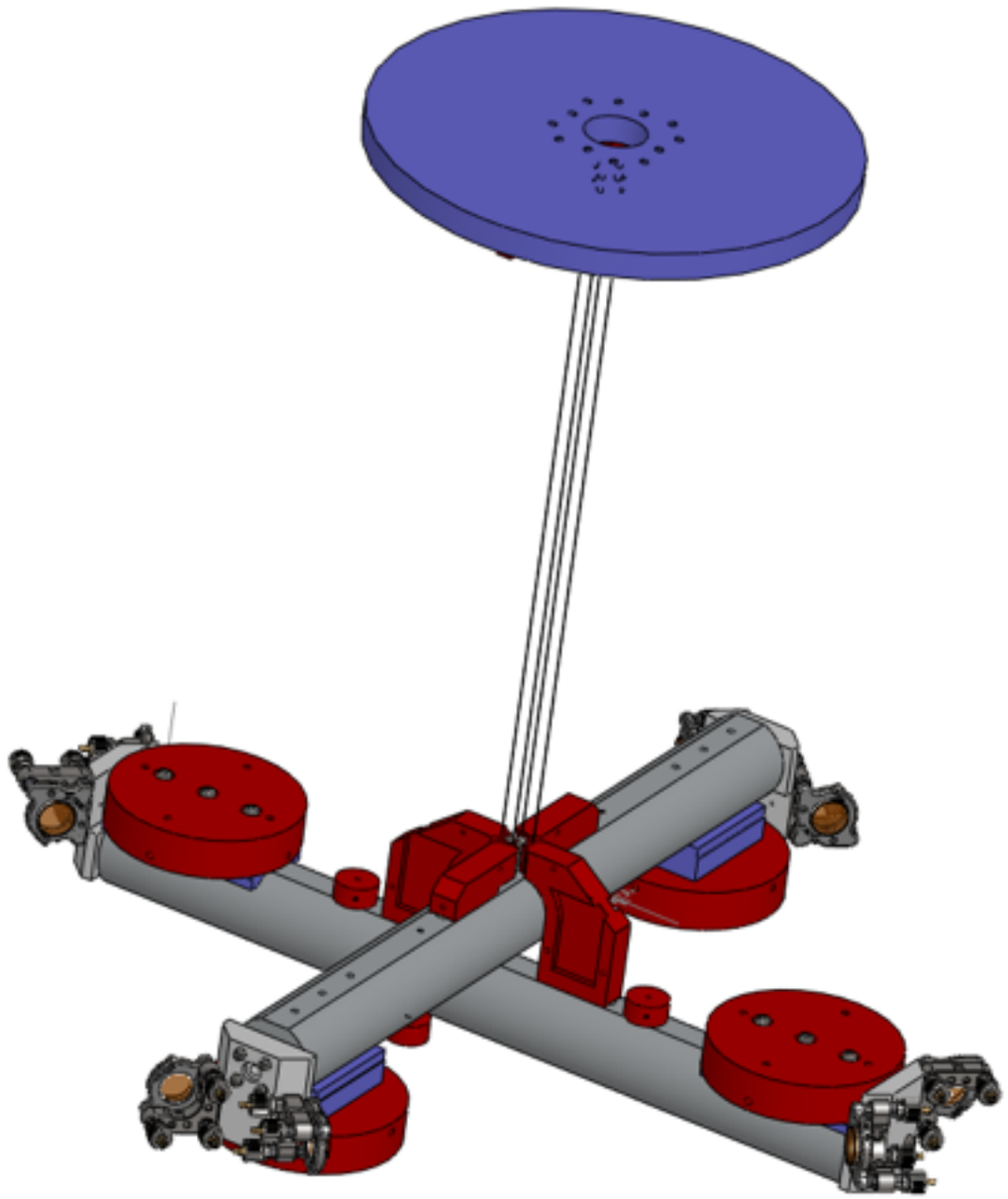
OzGrav

TorPeDO

Torsion Pendulum Dual Oscillator

Based on the TOBA concept by Ando et. al

TorPeDO measures gravitational forces by accurately measuring the differential rotation between two torsion pendulums.



Applications:

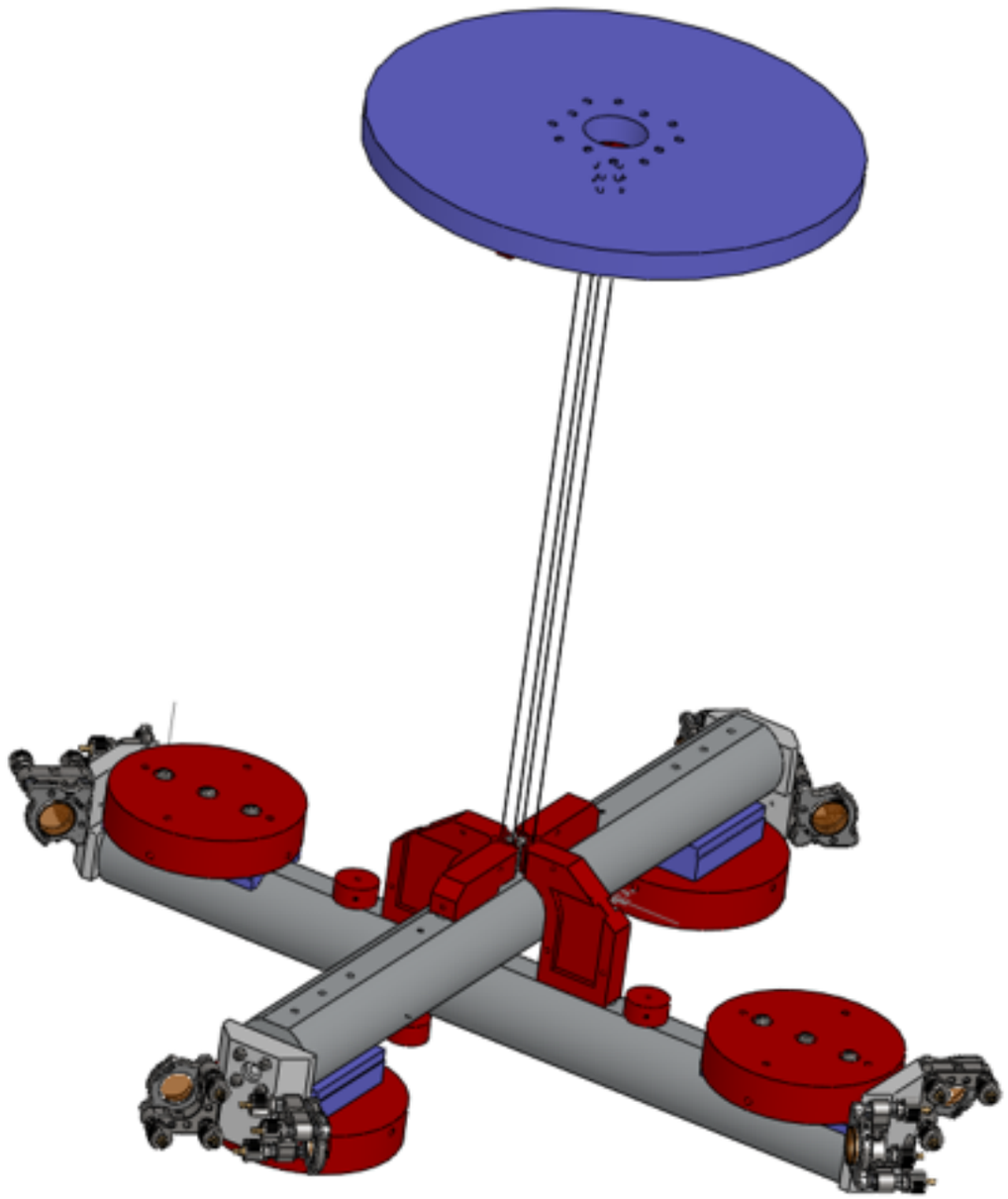
- Measuring Newtonian noise
- Early earthquake detection
- Measuring Quantum Radiation Pressure Noise
- Testing semi-classical gravity
- Low Frequency Gravitational Wave Detector

TorPeDO

Torsion Pendulum Dual Oscillator

Based on the TOBA concept by Ando et. al

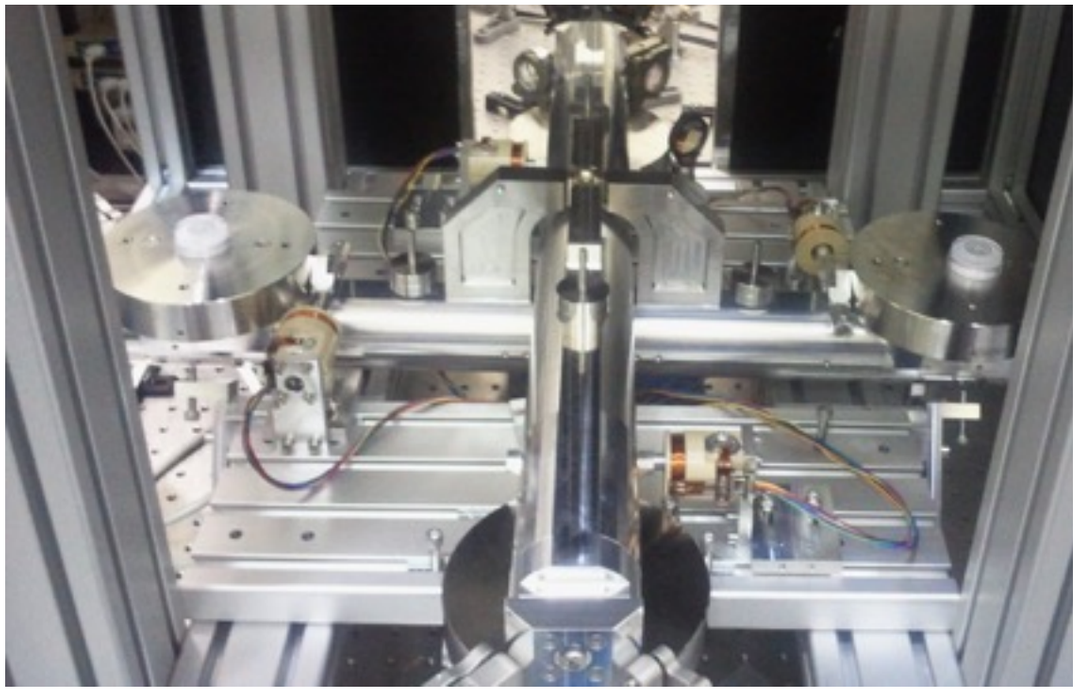
TorPeDO measures gravitational forces by accurately measuring the differential rotation between two torsion pendulums.

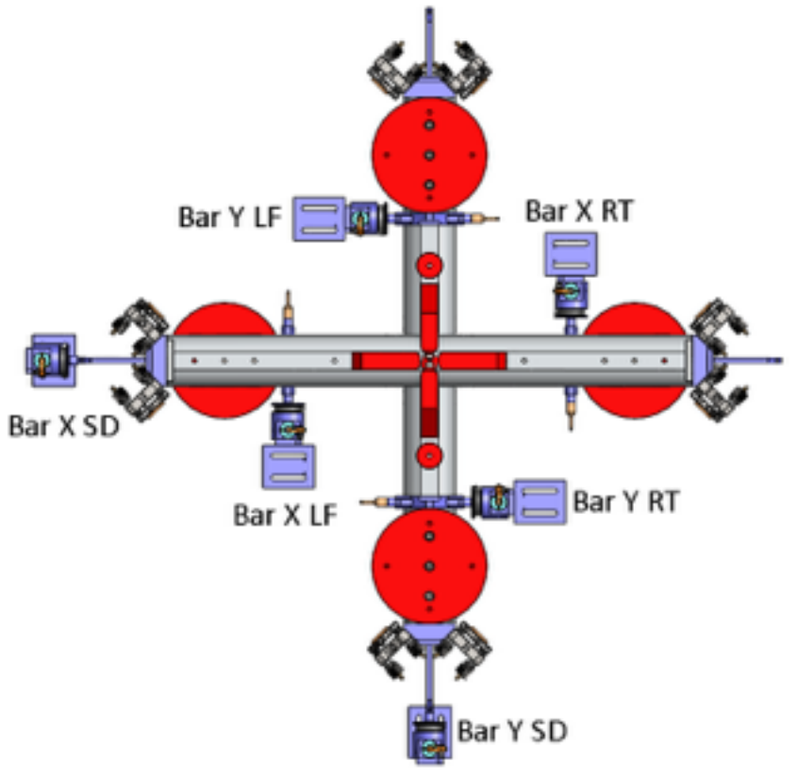


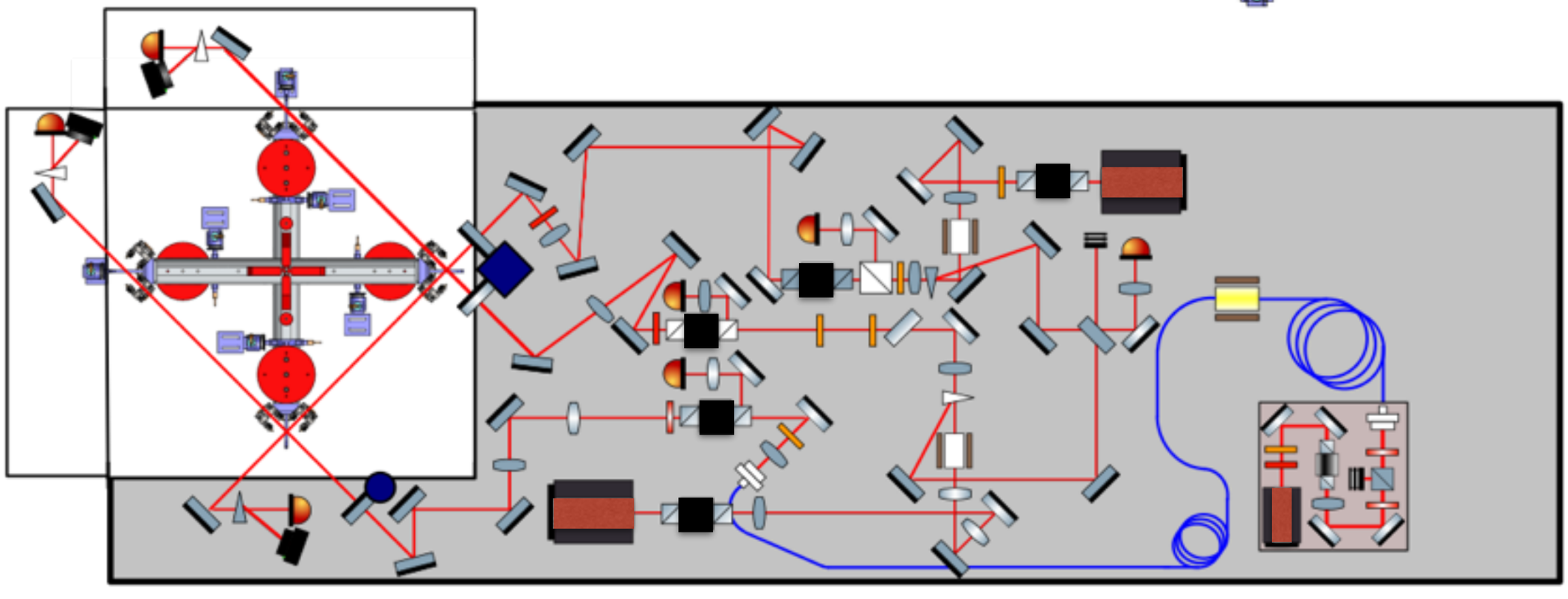
Applications:

- Measuring Newtonian noise
- **Early earthquake detection**
- Measuring Quantum Radiation Pressure Noise
- Testing semi-classical gravity
- Low Frequency Gravitational Wave Detector

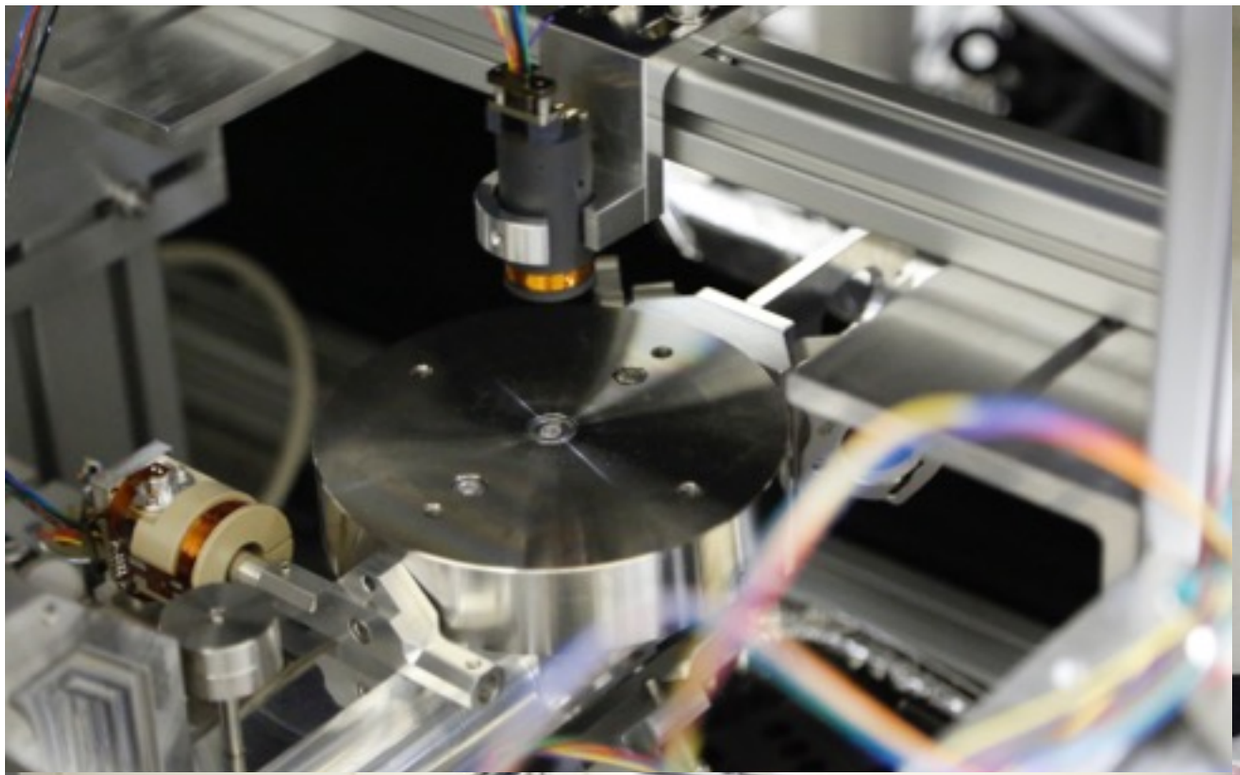
TorPeDO (recently)

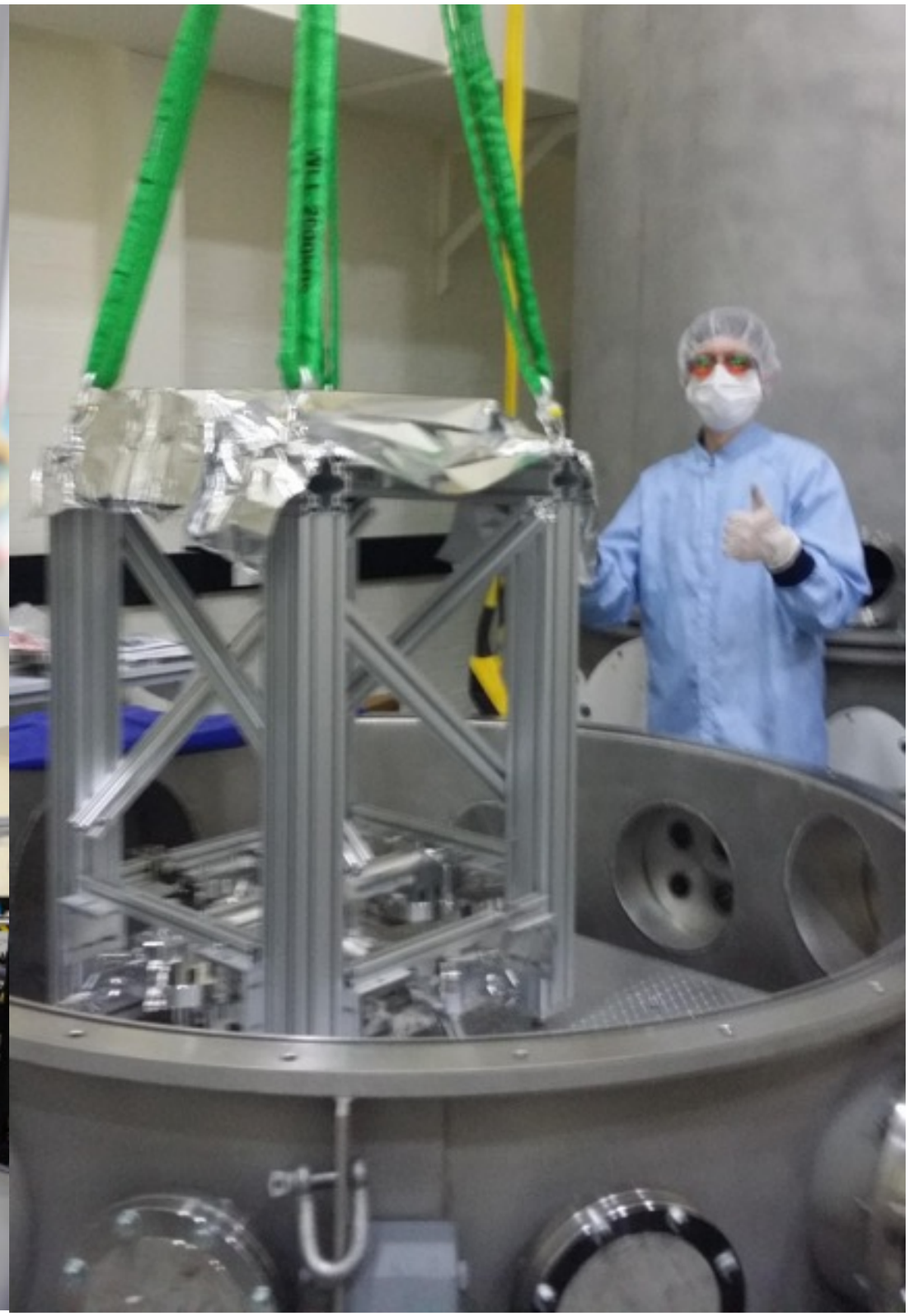




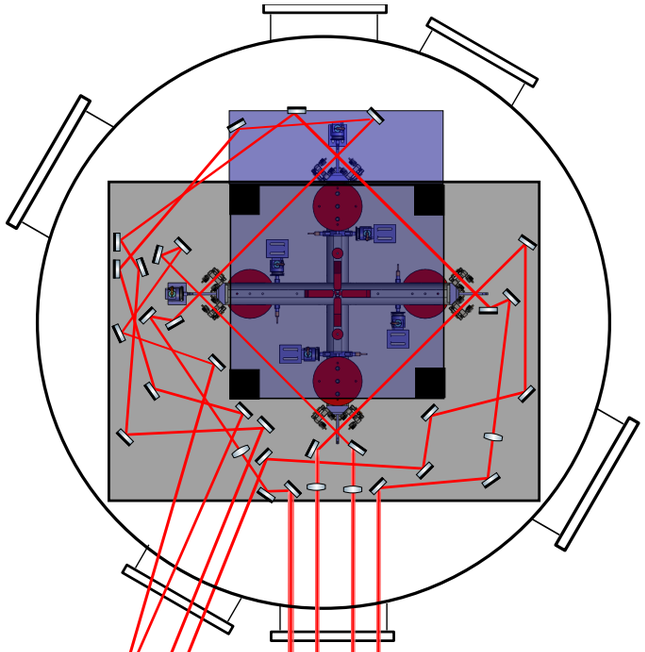


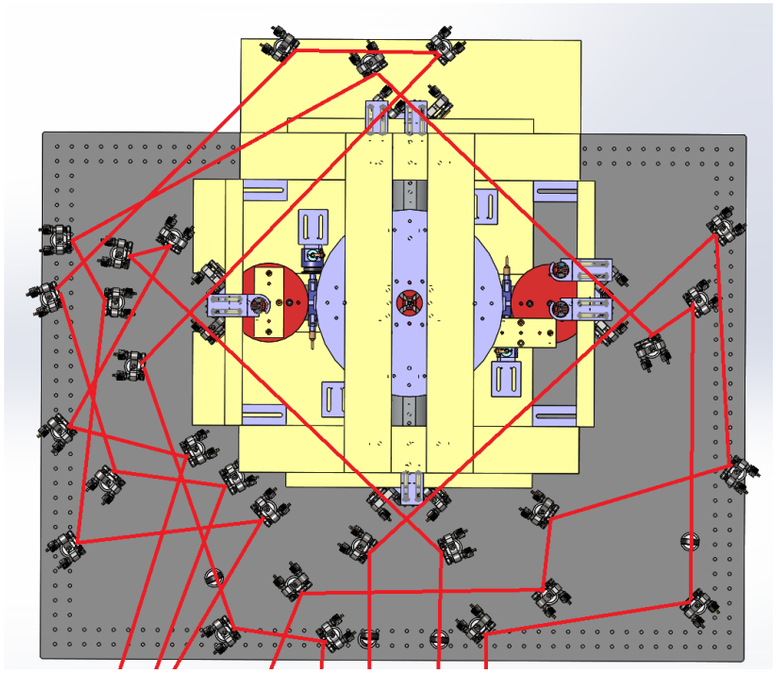
TorPeDO (right now)



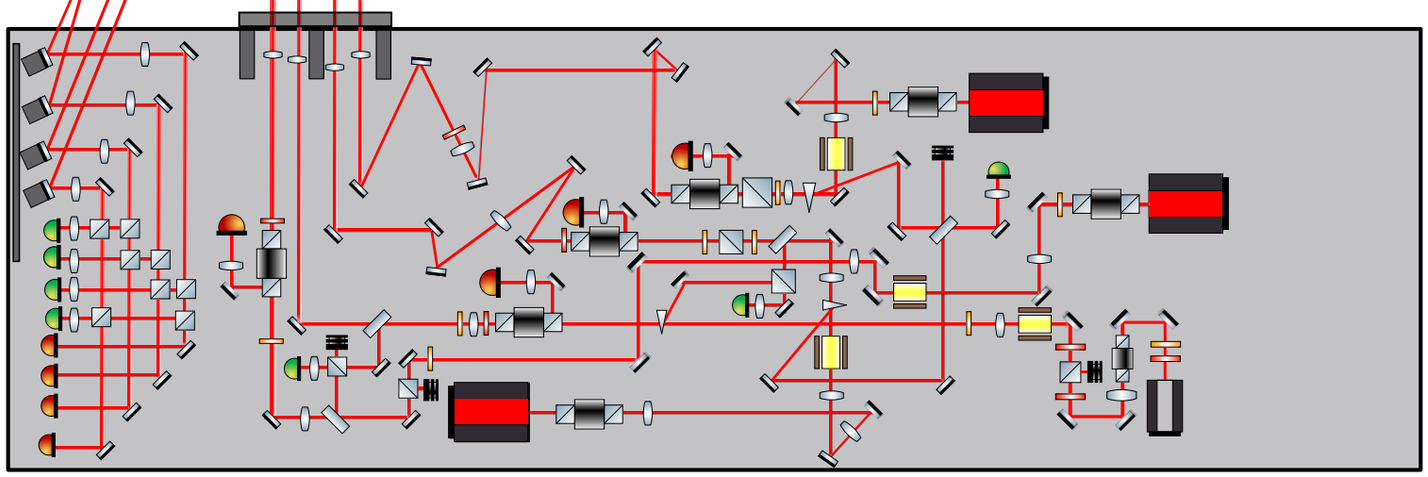


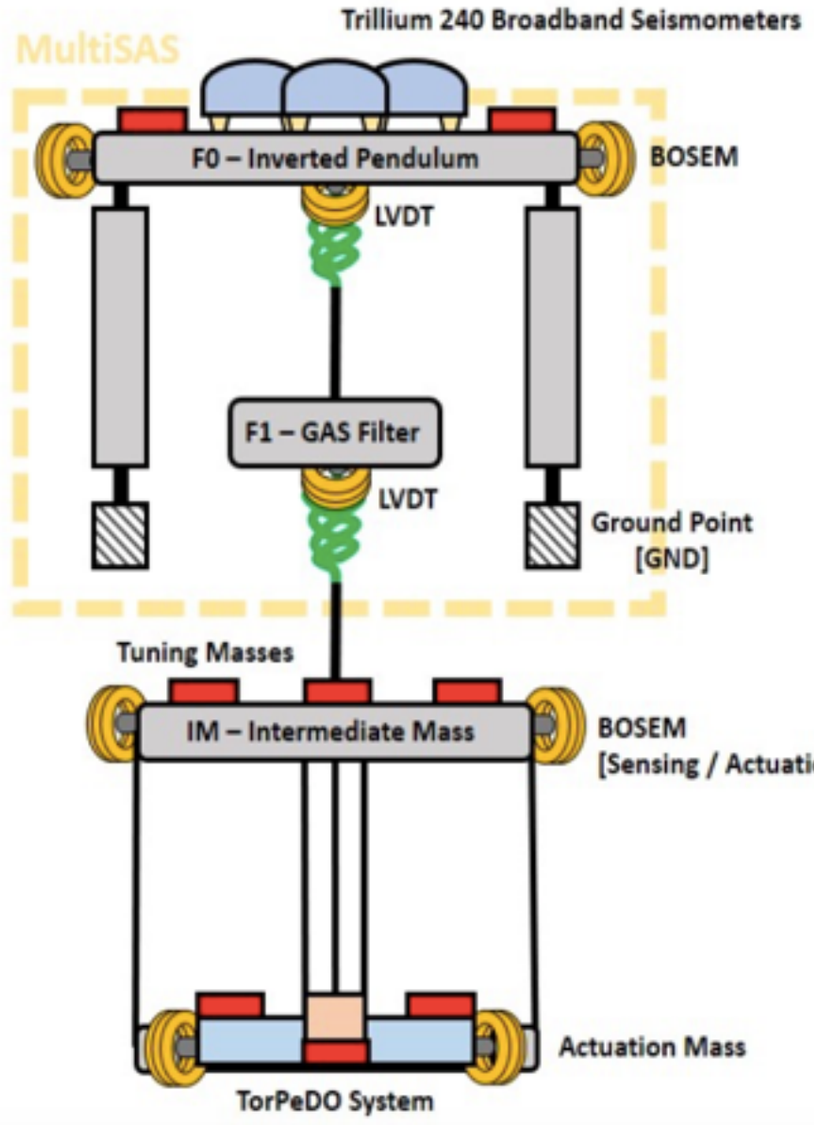
TorPeDO (Soon)





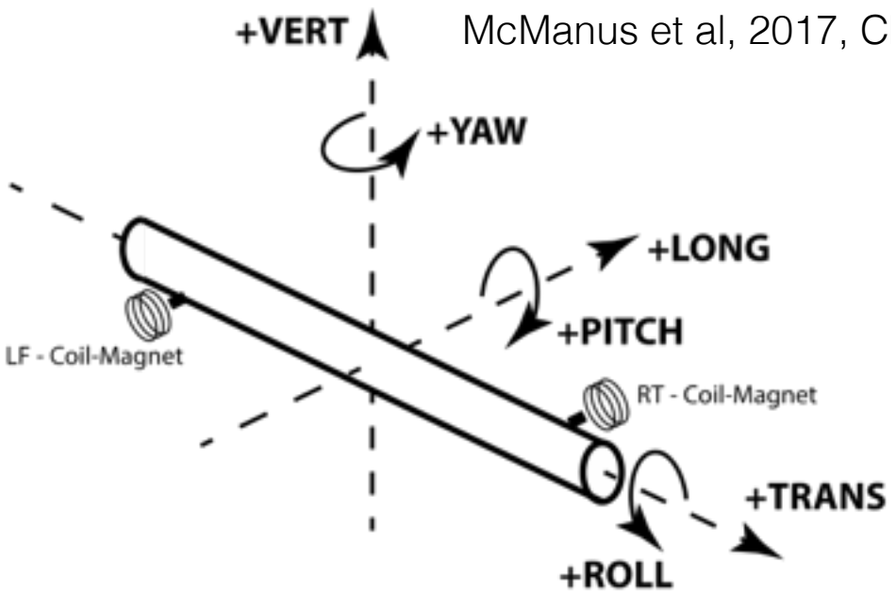
Scale: 1m





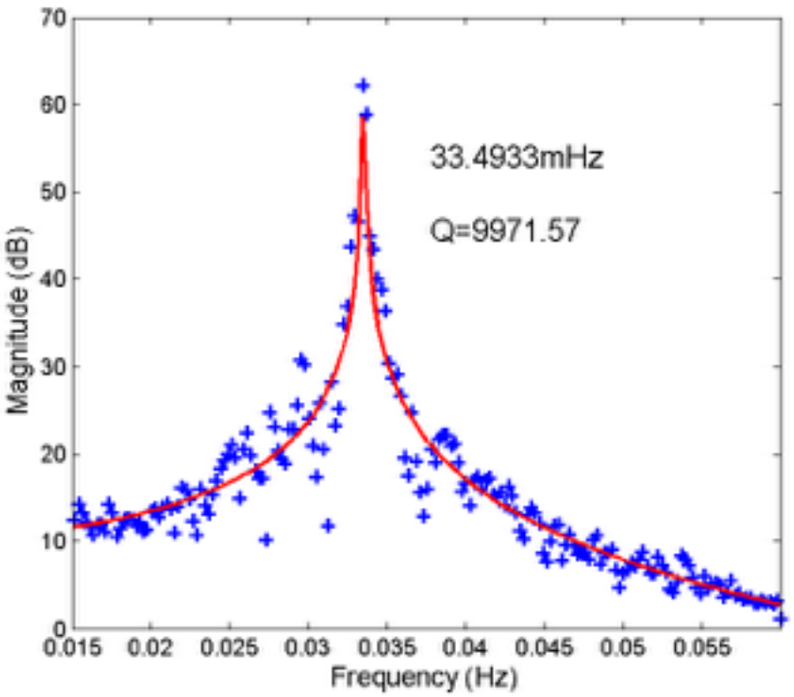
Mechanical Properties

McManus et al, 2017, Class. Quantum Grav.https://doi.org/10.1088/1361-6382/aa7103

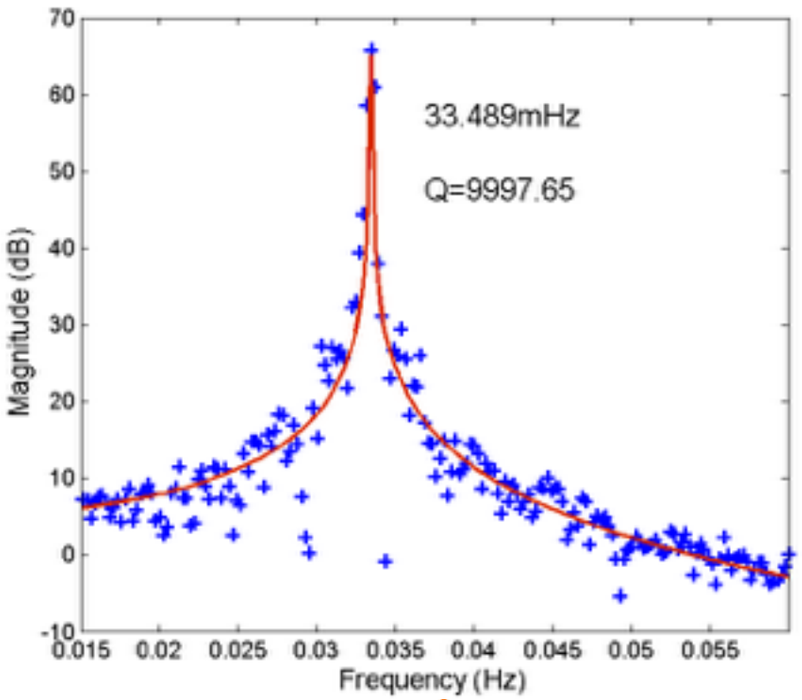


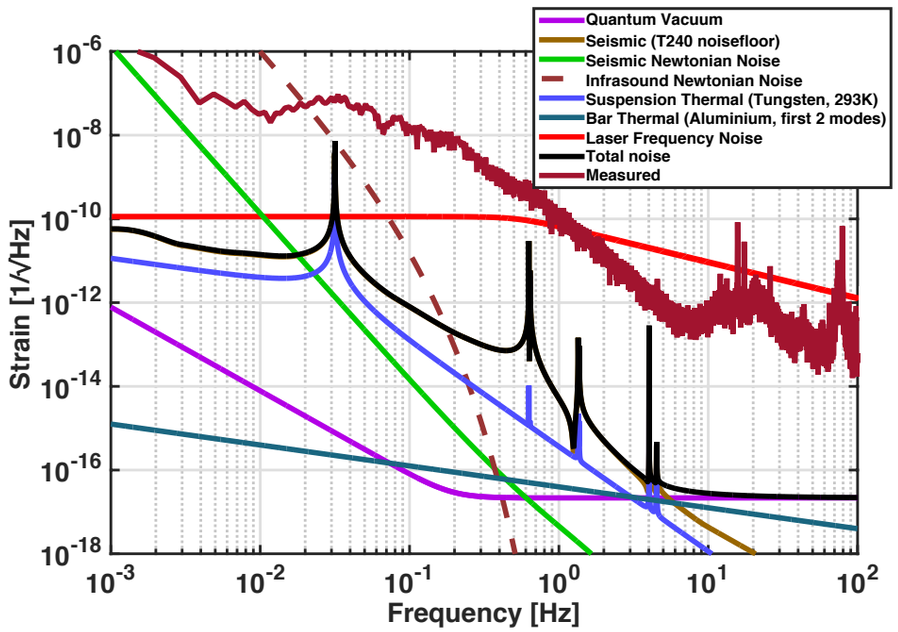
Mode	Bar 1	Bar 2	Difference
Yaw	33.4933 mHz	33.489 mHz	4.3 μHz
Longitudinal	0.6072 Hz	0.6077 Hz	0.53 mHz
Transverse	0.65465 Hz	0.653 Hz	1.6 mHz
Pitch	1.16286 Hz	1.14326 Hz	0.0196 Hz
Roll	4.334 Hz	3.853 Hz	0.481 Hz

Bar 1 Tuned Yaw Mode



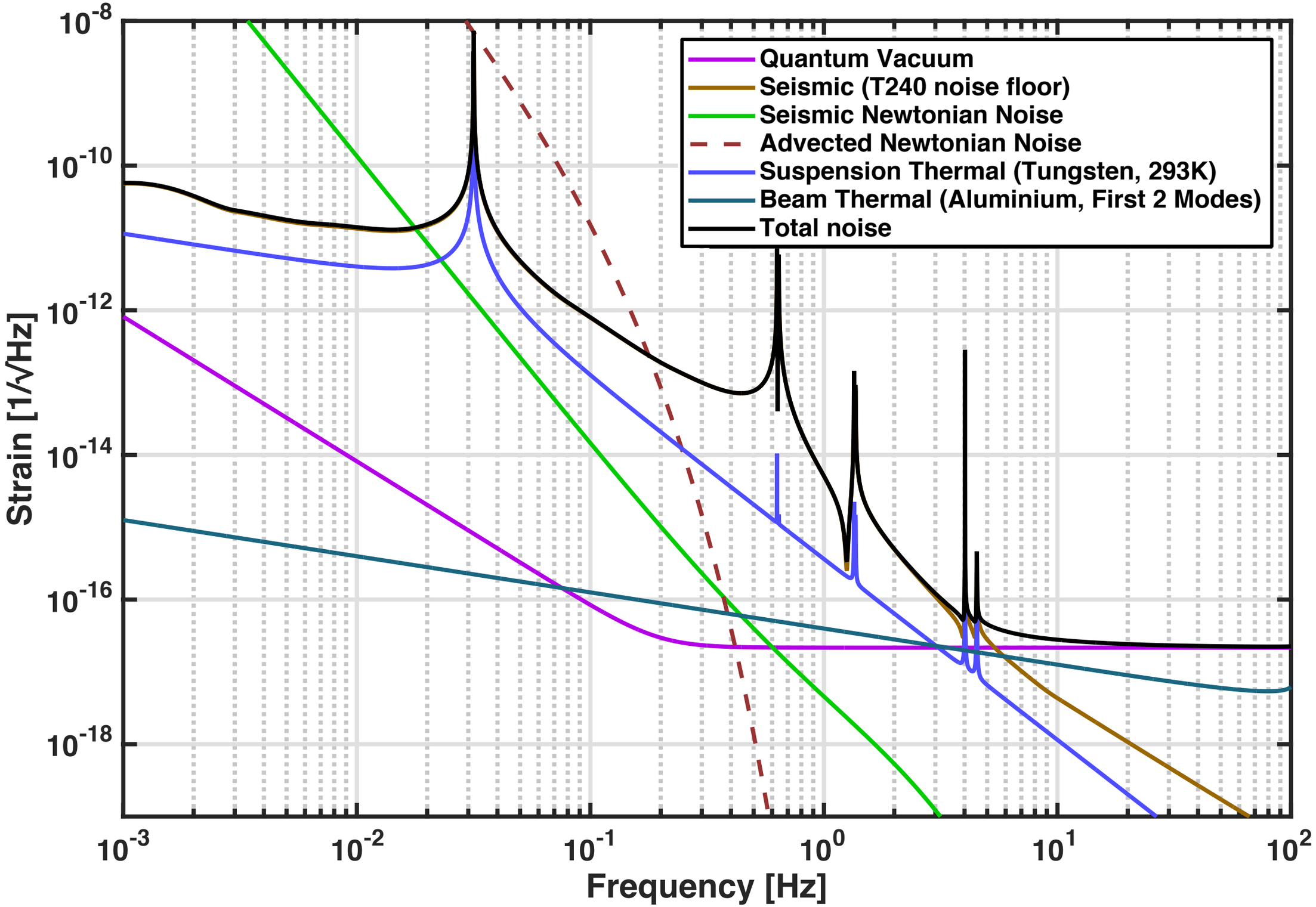
Bar 2 Tuned Yaw Mode





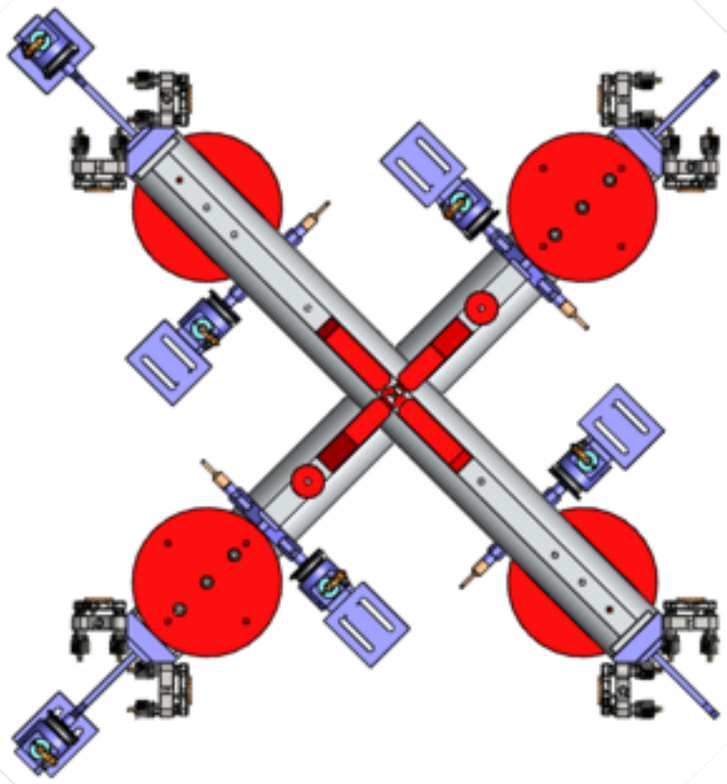
OzGrav

TorPeDO Prototype Noise Budget

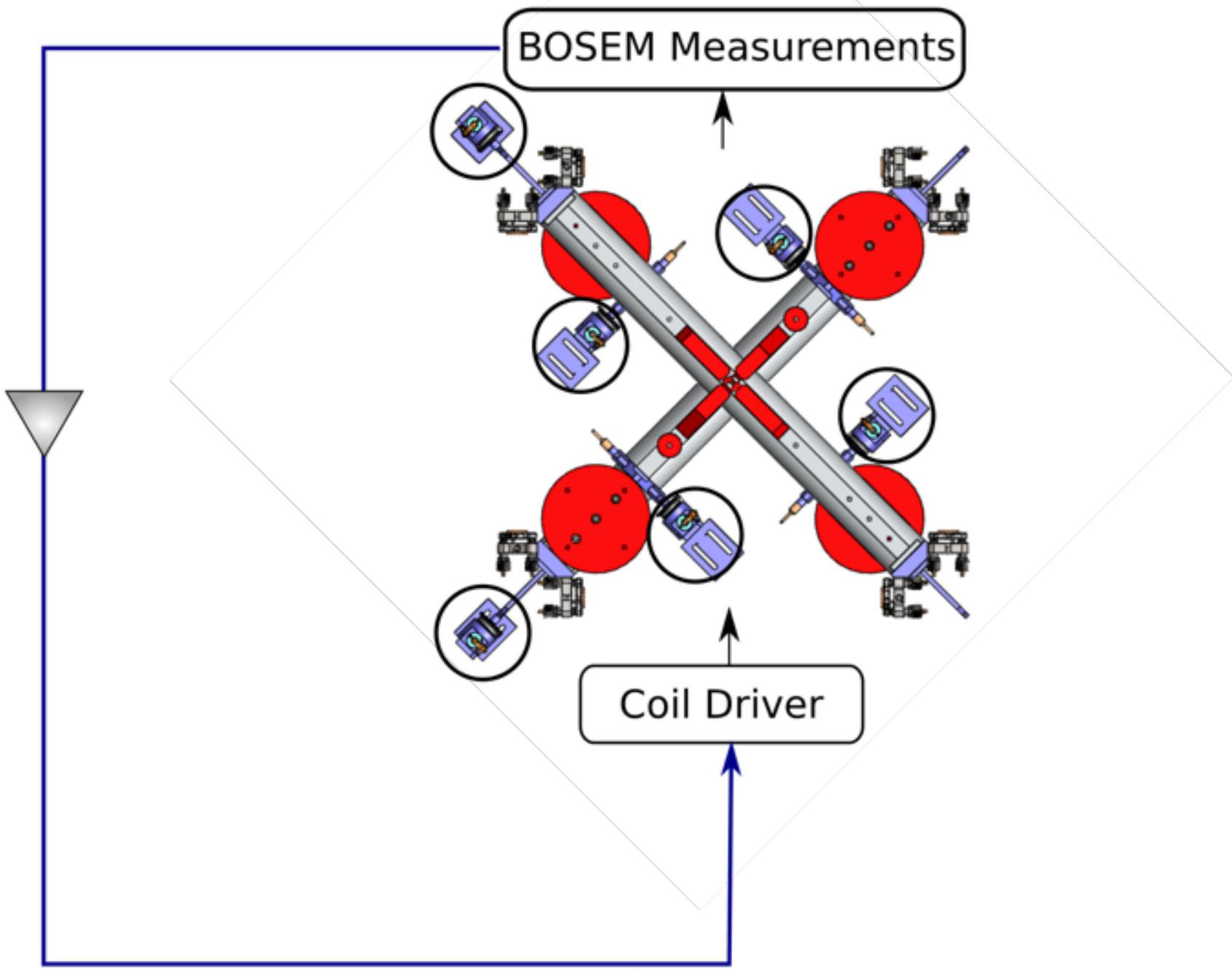


OzGrav

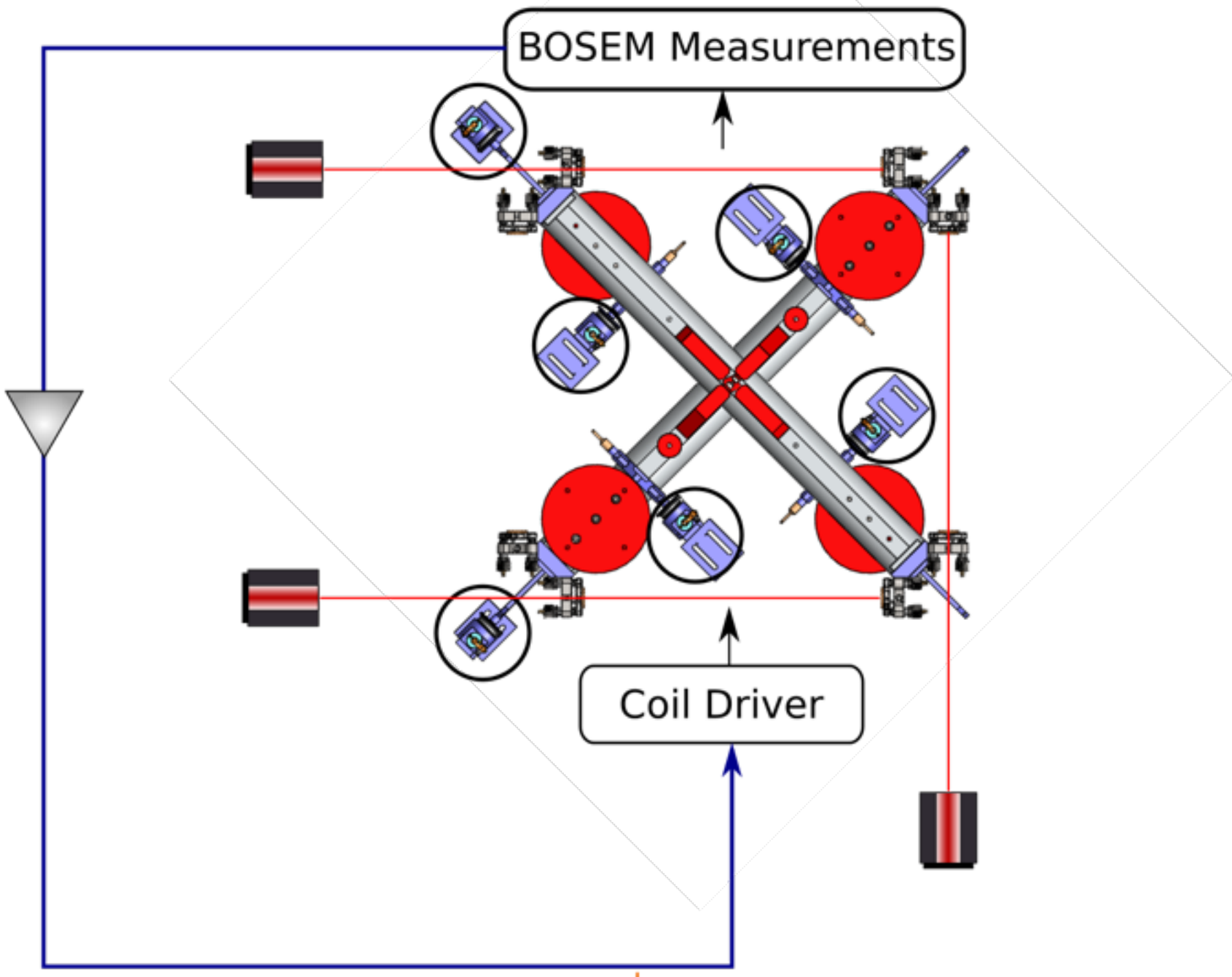
System Control



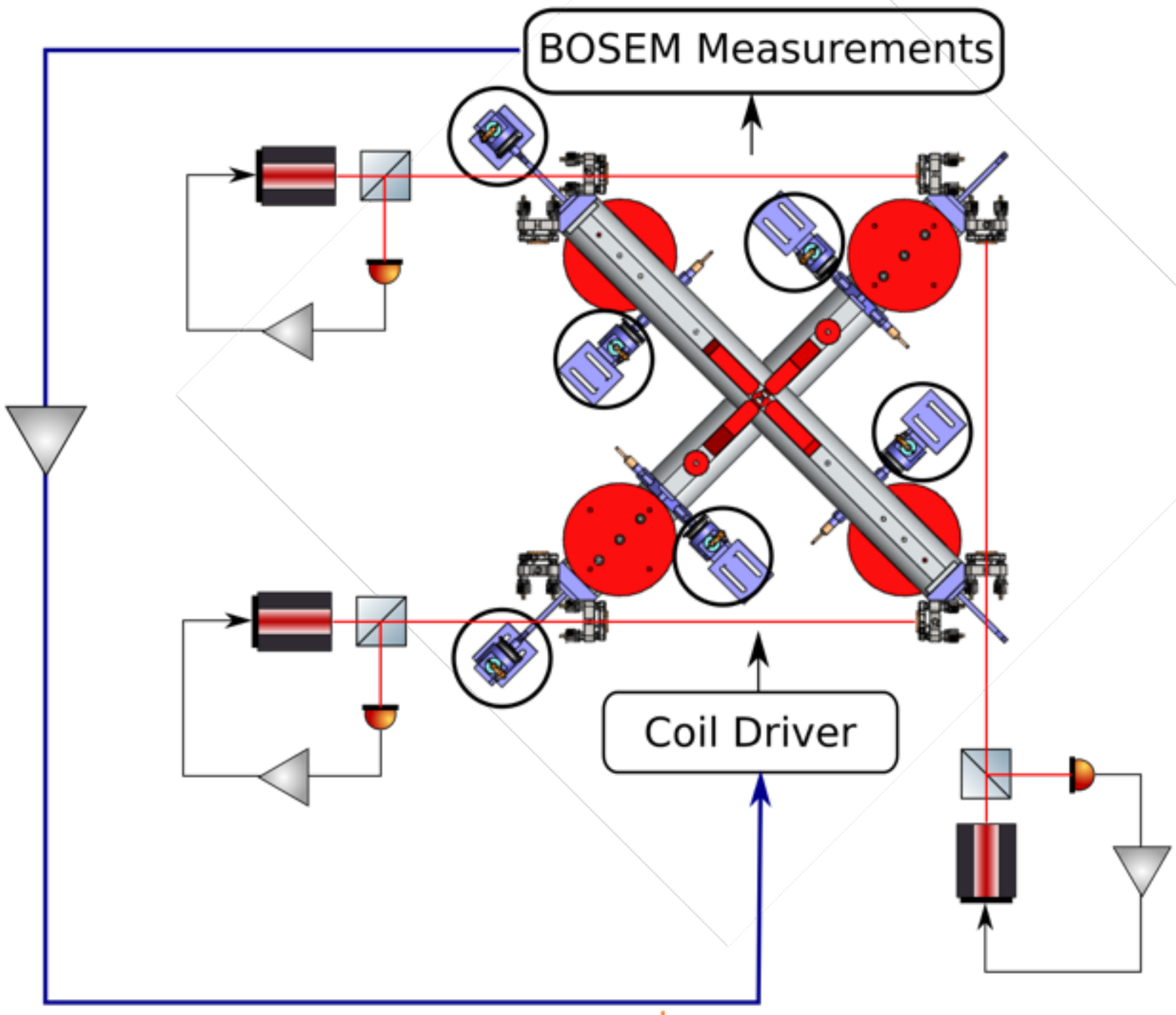
System Control



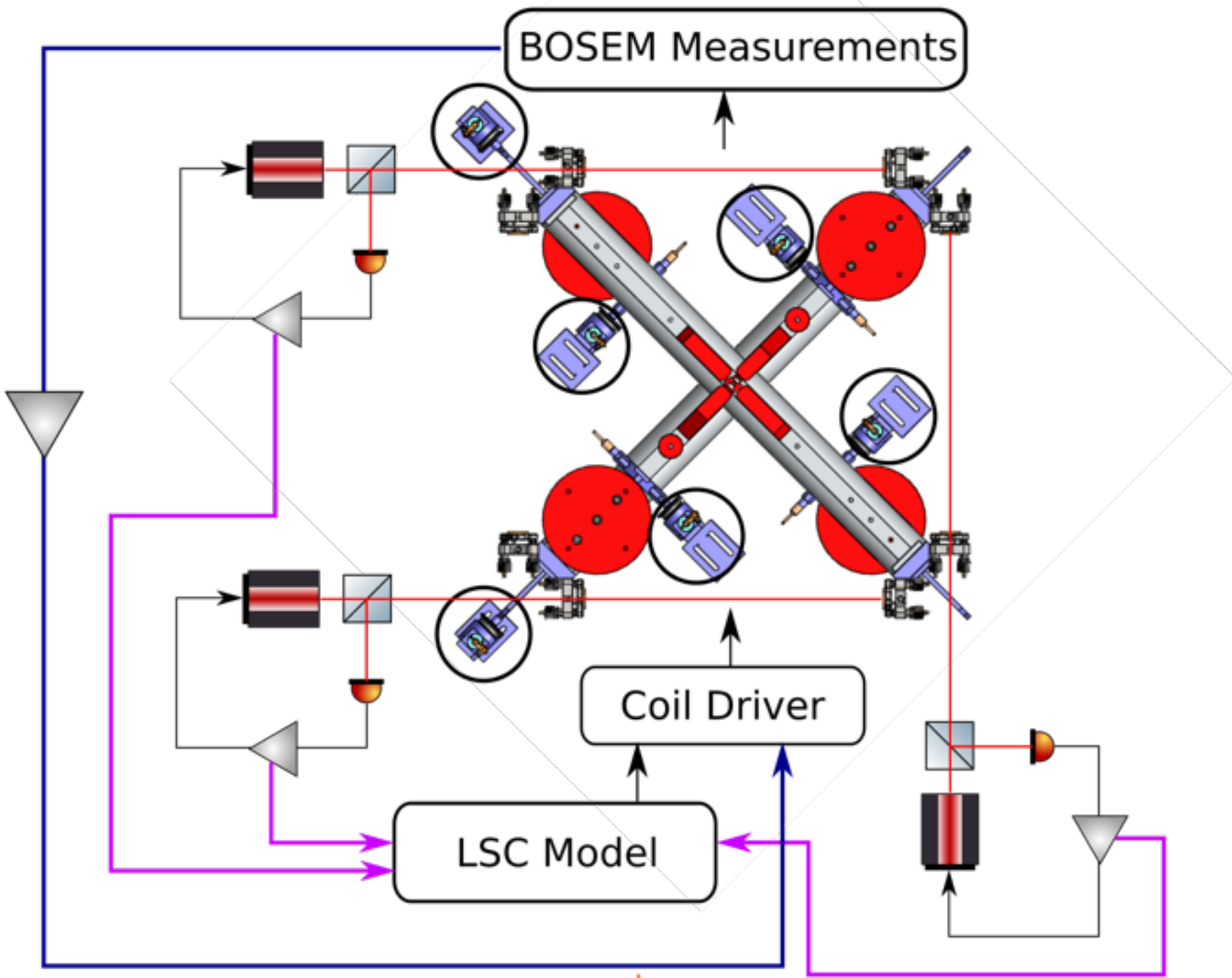
System Control



System Control



System Control

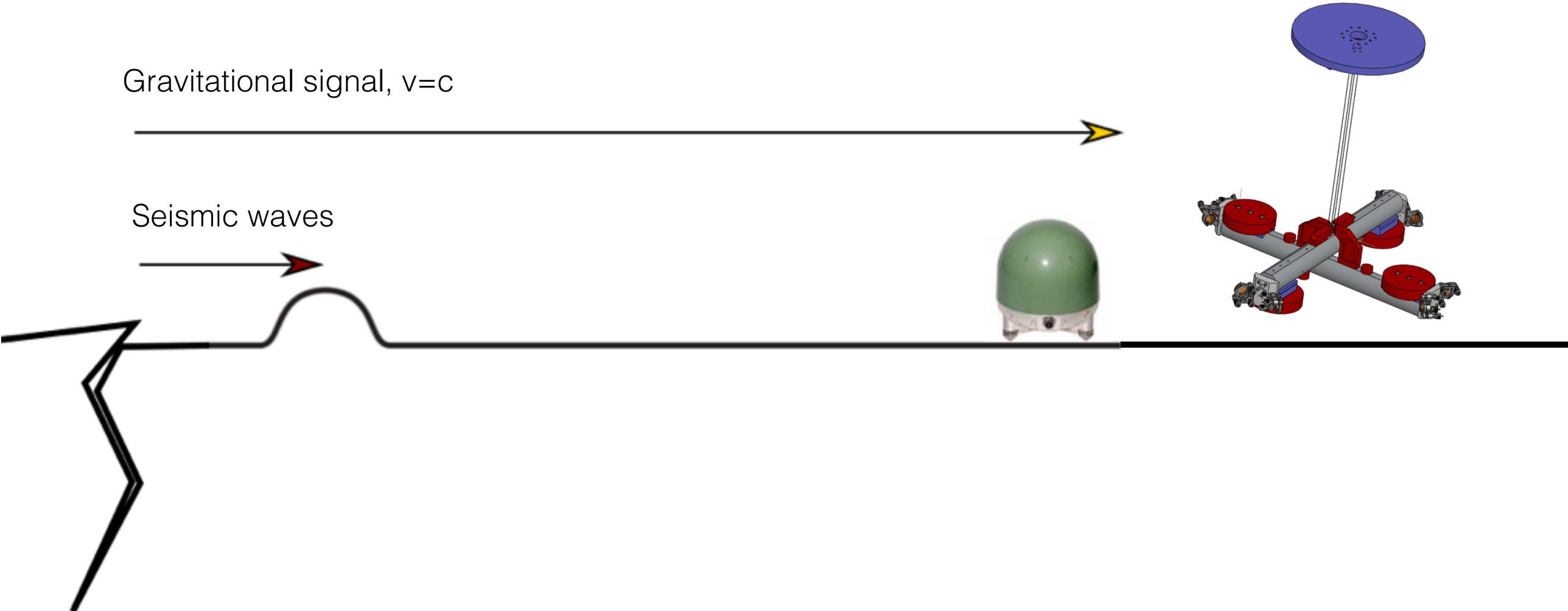


Lock Acquisition with Guardian

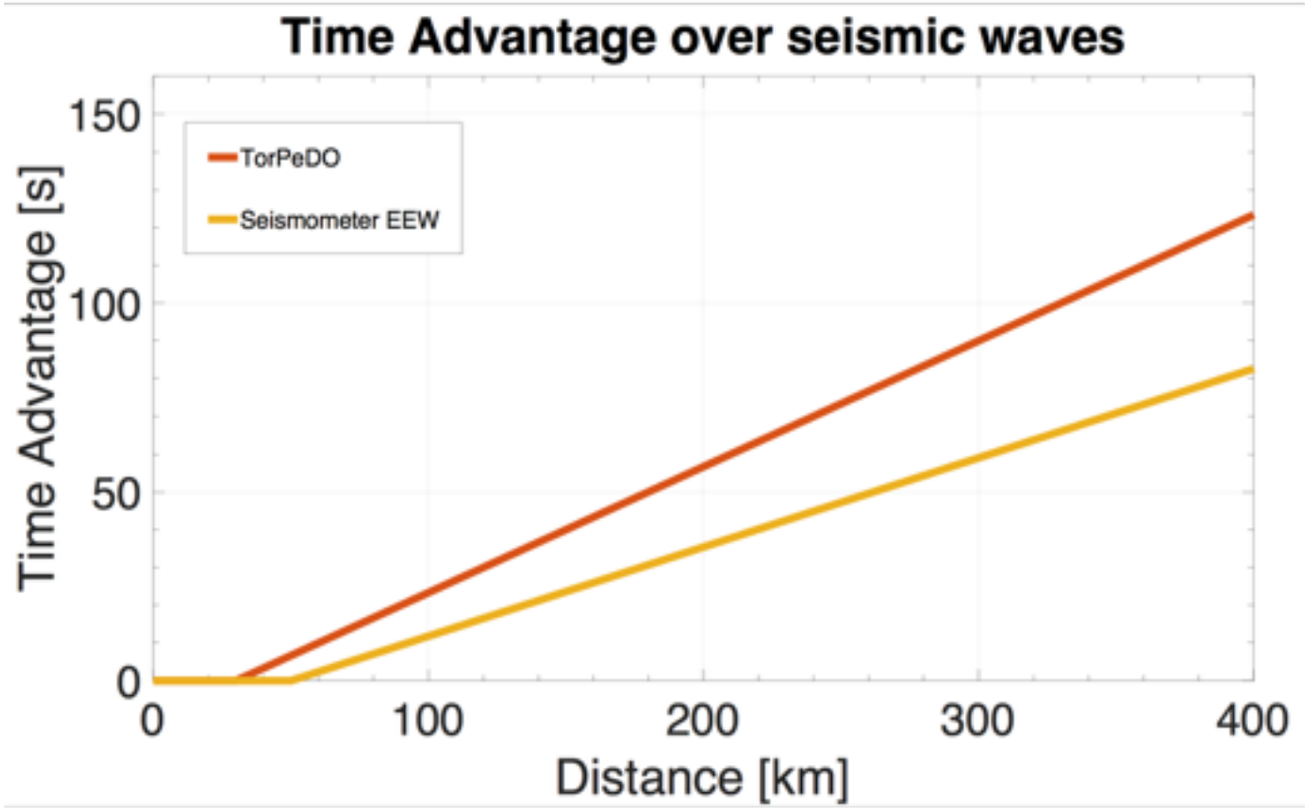
Early Earthquake Detection

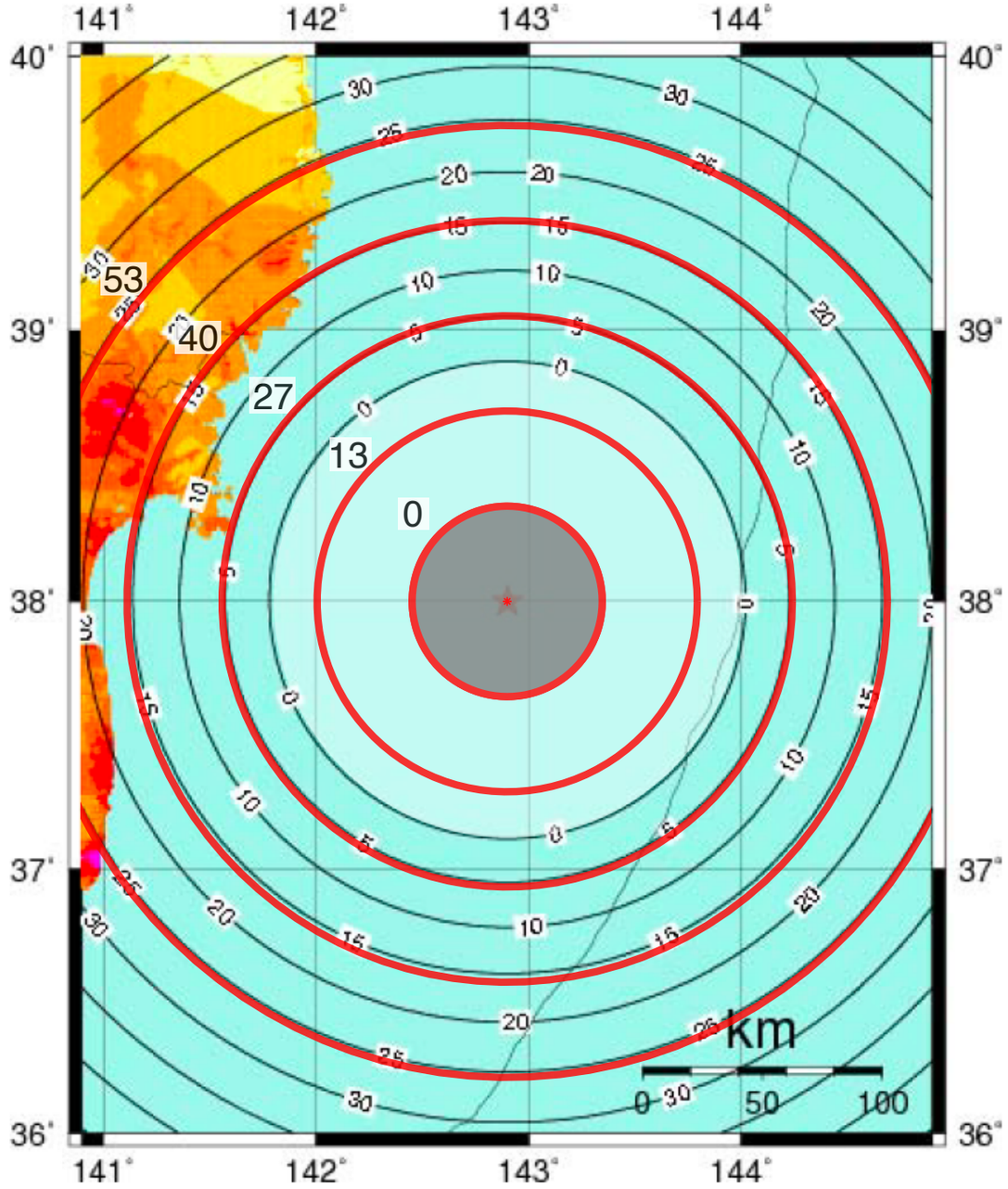
- Gravity travels faster than seismic waves

- In some cases this extra warning could allow for crucial systems to be shut off or put in a safe operating mode that may prevent injury, death, or damage to assets and infrastructure.



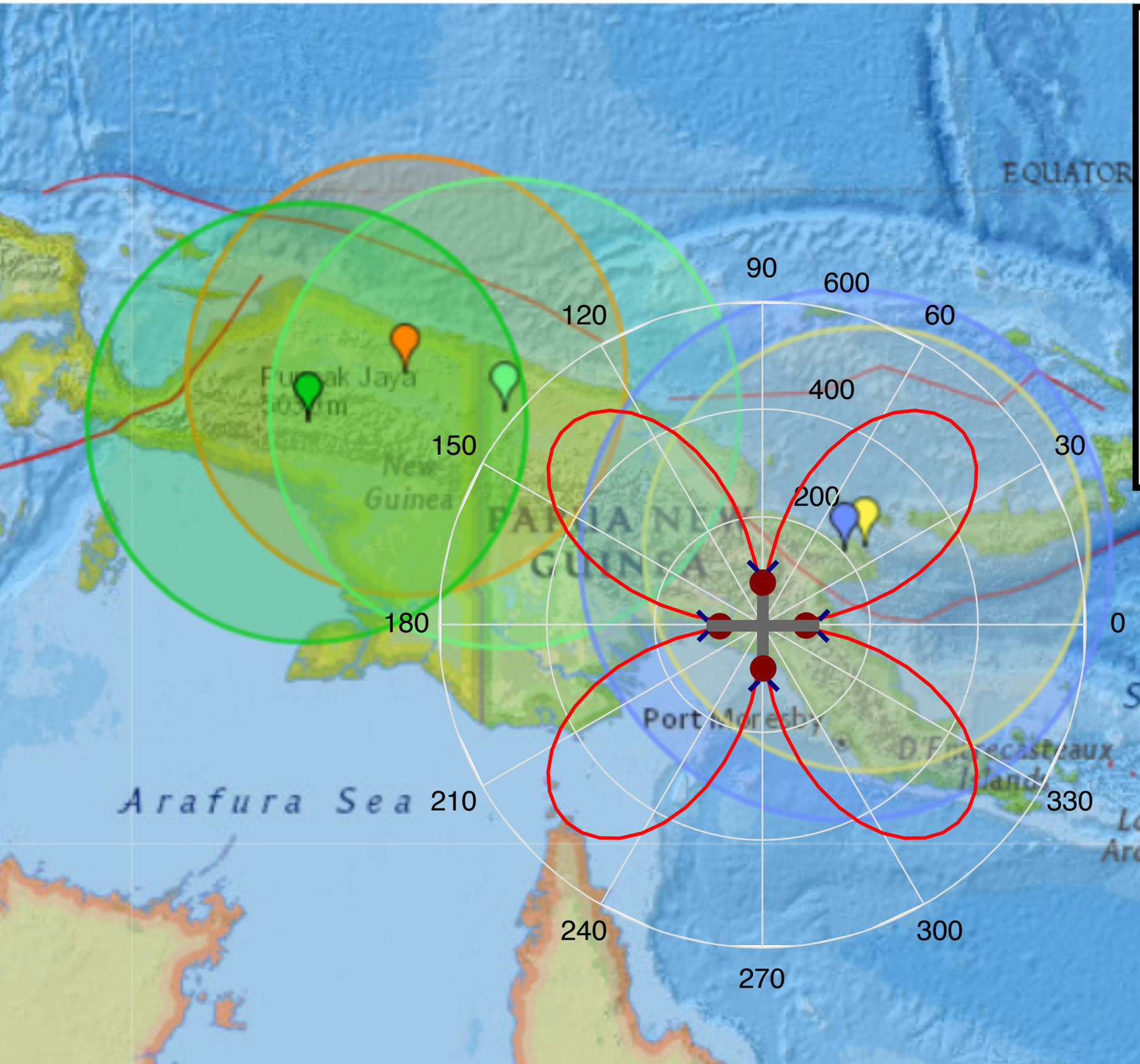
Early Earthquake Warning





OzGrav

Early Earthquake Warning



47 years ago 7.7 magnitude, 30 km depth
Abepura, Papua, Indonesia

80 years ago 7.7 magnitude, 35 km depth
Finschhafen, Morobe, Papua New Guinea

82 years ago 7.8 magnitude, 30 km depth
Aitape, Sandaun, Papua New Guinea

102 years ago 7.7 magnitude, 35 km depth
Nabire, Papua, Indonesia

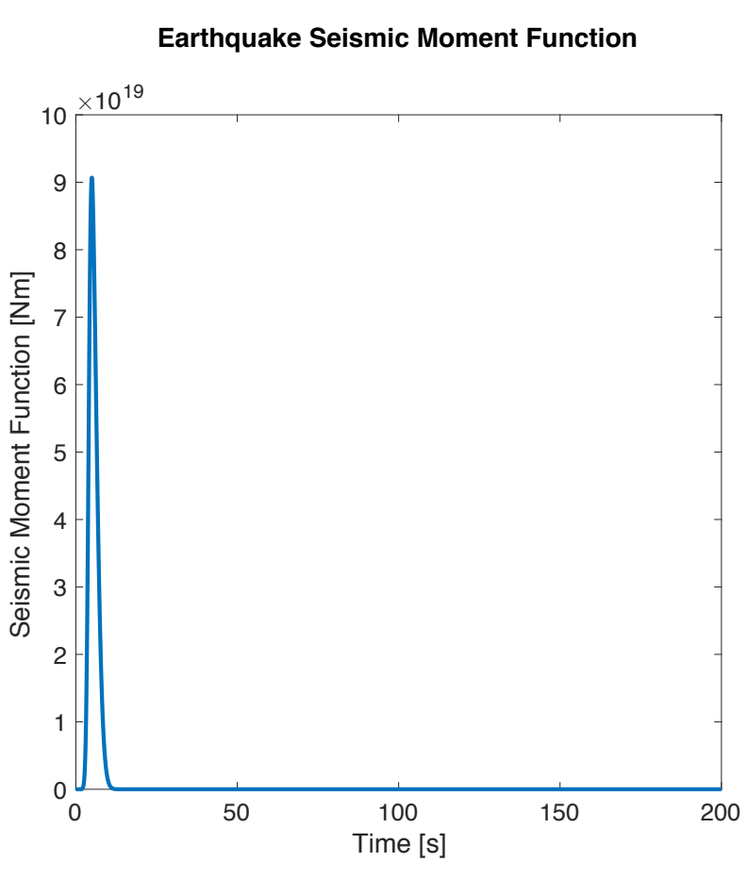
111 years ago 8.0 magnitude, 35 km depth
Lae, Morobe, Papua New Guinea

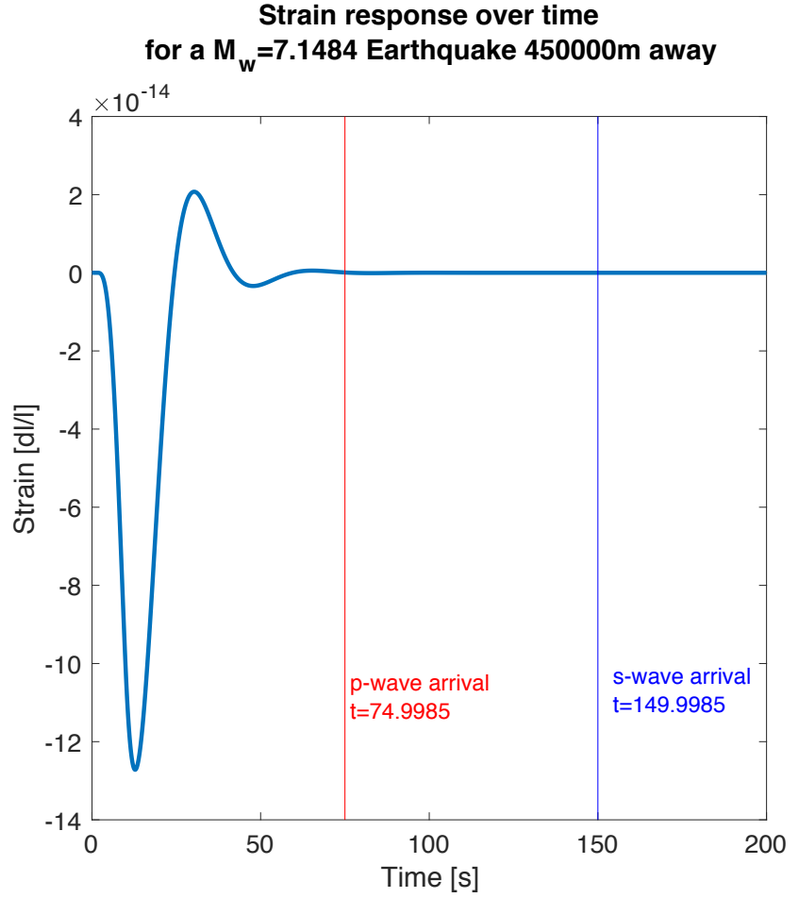
Simulated time-domain response

Preliminary

$$\ddot{\mathbf{h}}(r_0, t) = -\frac{6G}{r_0^5}\,\mathbf{S}(\theta,\phi)\int_0^t \mathrm{d}u\, u M_0(t-u)$$

J. Harms, et al. Geophys. J. Int. (2015) 201, 1416–1425





Things I'd like to look at

- Localisation accuracy and sensor placement
- Matched filtering / Signal triggering
- Parameter Estimation

Conclusions

- The initial TorPeDO configuration allowed us to test our control scheme
- The sensor is now offline and we are upgrading to a more advanced configuration
- The applications of the TorPeDO as an early earthquake detector appear promising.