LIGO SURF 2016
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Project Plan
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LIGO Physical Environment Monitoring

As the Hanford team prepares for Advanced LIGO's second run, the O2 PEM injections will be preformed to locate any areas susceptible to vibrations and ambient fields that originate from environmental phenomena. These injections are signals applied to (or created within) different areas along the instrument, which will allow us to measure the impact acoustic vibrations, coupling, etc. have on the test mass motion. The O2 PEM injections have the potential to both identify locations from which noise originates, as well as help the team distinguish between varying types of test mass motions in order to identify motion caused by gravitational wave radiation in a more efficient manner. The injections are hence essential in optimizing the DARM (differential arm movement) sensitivity. There is currently some unidentified noise that is believed to be a result of scattering somewhere within the vacuum chamber. If a fraction of the light is deflected, retro-reflected and then recombined with the main beam, it will produce noise within the gravitational wave channel as a result of phase difference. Hopefully, the injections will help pinpoint and remedy the source of this noise so that LIGO Hanford may achieve its sensitivity goals. The O2 PEM injections will also allow for further analysis of coupling sites that may have a substantial impact on the DARM sensitivity, as well as fill gaps in the data from last year's O1 PEM injections[i] [ii]. The mechanical and electronic alterations made to the instrument since last year's injections may have altered the coupling and ambient levels at certain locations. If there is new noise affecting the test mass motion, it must be accounted for in the processes of vetting possible gravitational waves. Areas that showed to be problematic in last year's O1 PEM injections will be investigated again, such as the satellite amp rack in the VEA, which was believed to be the source of coupling within End X and End Y[i]. Last year's O1 PEM injections did not include the shaker injections at the end stations due to lack of time[i]. Therefore, the schedule of the O2 PEM injections is likely to be altered in order to provide the environmental monitoring team with enough time to conduct all the planned injections at various locations along the instrument.

I will be maintaining and improving a MATLAB code (the foundations of which have already been written by Robert Schofield and his colleagues) that will generate functions demonstrating test mass motion caused by specific types of injections. Using a function of

the DARM noise floor as a reference, this program will demonstrate how different vibration and fields affect the test mass by calculating the magnitude at which they appear among the background DARM signals. Output from this code will look much like the figures presented in Robert Schofield's reports on PEM injections in the aLIGO LHO Logbook[i] [ii]. The data produced from this program will then be cited to conduct specific calibrations, and maybe even mechanical corrections, to minimize significant deviations from the DARM noise floor. My primary aim will be to make this code more efficient and user friendly. When I am finished with this task, my mentor and I will discuss other ways in which the program can be improved. Additionally, I will assist in implementing the injections themselves, and will do so under the instruction of my mentor and his colleagues, in a manner that will be explained to me on site. It is important to note that our project focus is flexible. Working with interferometer performance, it is difficult to predict where our surveillance of the instrument can lead us. It depends on whether a particular kind of injection proves to be more problematic than the rest. If our study shows that environmental coupling is generating a significant amount of noise, then we will focus on improving range to remedy the issue.

Our general project focus is to help improve DARM sensitivity for more efficient detection of gravitational waves. By identifying the noise that various environmental phenomena can create in the DARM background, the LIGO team will then have the ability to make mechanical alterations to reduce the noise and improve calibration procedures to simplify the process of vetting gravitational waves. We want to see how the environment can impact aLIGO at Hanford before the instrument's next run in order to more efficiently differentiate between test mass motion caused by gravitational waves and those caused by background noise when observation begins.

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[i] Schofield, Robert. *PEM injections complete at LHO; report on magnetic coupling, site activity coupling, and preliminary report on other coupling.* Hanford: LIGO, 2015. Accessed April 28, 2016. https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=21272

[ii] Schofield, Robert. *PEM injection report part III: vibration coupling at LHO.* Hanford: LIGO, 2015. Accessed April 29, 2016. https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=22797