VORTEX was initially commissioned in FY16. We request funding to support continuing investigations, perform needed instrumentation improvements, and procure and perform assay on new test samples. These measures will enable design, parameter definition, and interpretation of the LTREX scale test planned at LLO (Task 12).

12. Livingston Tube Recovery EXperiment (LTREX)

Whether intended or accidental, recovery of a beamtube vented fully or partially to ambient could incur extreme costs in both capital and delay (perhaps ~ $10M and years, respectively). We consider it risky to leverage recovery plans solely on modeling, even if supported by benchtop-scale tests like VORTEX (Task 11). For example, steel samples procured recently contain up to 10x greater hydrogen concentration than as-built beamtube steel, despite particular care to match specifications and processing. This highlights the reality that materials with identical specifications can vary significantly in bulk and surface properties. Similarly, scale-dependent diffusion and thermal timescales may introduce discrepancies between otherwise identical processes performed on small and large scales.

During LIGO construction, a 7.5-meter section of beamtube was placed in storage at the Livingston site. This affords an exact match to the material, fabrication process, and dimensional scale of LIGO tubes. It also presents an opportunity to accurately calibrate models at an intermediate test scale. The sample is housed in a surplus section of concrete beamtube enclosure, presenting an ideal simulator for the actual tube's thermal environment. Backfill and recovery scenarios can thus be simulated under highly realistic ambient conditions.

We will clean and prepare the sample tube and add flanged endcaps for evacuation. We will then instrument the tube and initialize it by a conventional heat-tape bake, simulating the original preparation of the real tubes. Residual post-bake gas composition will then be compared with historical data from the Livingston and Hanford tube qualification in the late 1990's and early 2000's.

After evaluating this baseline, we intend to test a prototype dry air plant based on those developed for the semiconductor industry, capable of providing air dried to sub-PPB water vapor concentration. RGA assay will let us establish quantitative correspondence with the benchtop VORTEX results and with models for adsorbed mass, binding energy spectrum, and residency time as a function of exposure.

In future phases we expect to explore alternative bake strategies to address final removal of adsorbed water. One candidate strategy involves simple hot air circulation inside the concrete tube enclosure. For low initial concentrations, this may let us forego the costly electrical power systems, thermal blankets and mobilization needed to perform a conventional tube bake. We plan to simulate, at scale, the equipment and instrumentation that would ultimately be required for a complete tube recovery.

We expect the LTREX apparatus to begin operation and provide initial results during the subject period of performance. Further work under subsequent awards is expected to refine protocols for incursions and equipment service (such as a gate valve exchange, should this prove necessary). The facility will also support large surface area studies of candidate material outgassing, pump optimization, and vacuum compatibility engineering for LIGO instrument payloads. It is expected to become a critical resource for LIGO vacuum system and detector simulation and qualifications.