LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Design Documentation for SOW, LHO Wind Fence

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1 Introduction

This document is intended as a node for referencing and aggregating design information for the LHO Wind Fence SOW C1801957. The information contained herein will be released publicly to vendors as a reference document during the RFP process.

This is a document which expands upon the work done by LIGO to this point in the process. As indicated within the RFP and SOW associated with this procurement, LIGO is not looking to "reinvent the wheel" with any significant R&D effort. The details shared within this document are intended to inform vendors regarding LIGO design decisions. The requirements put forth within the procurement documentation stand as the requirements which govern this procurement.

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2 Site Information

2.1 Site Overview and Map

Site engineering drawings for the LIGO Laboratory site are publically available at:

- https://labcit.ligo.caltech.edu/LIGO_web/docs/asbuilts_lho.html

The following drawings have been utilized within visualizations presented in the RFP package:

Civil, Drawing Index, Location & Vicinity Maps

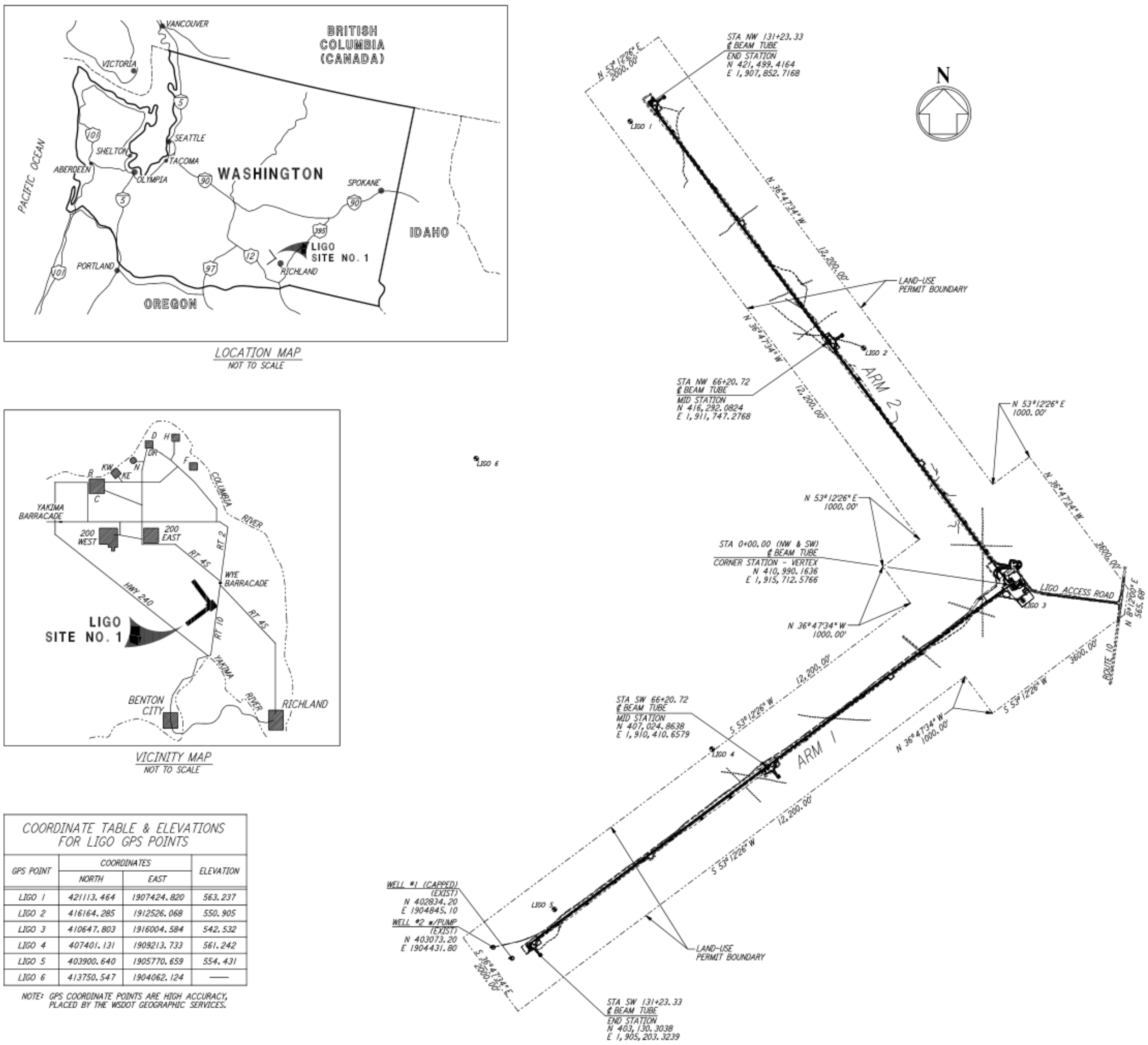

Figure 1: Civil, Drawing Index, Location & Vicinity Maps D960196-01

- Figure 1 Source: https://dcc.ligo.org/LIGO-D960196/public

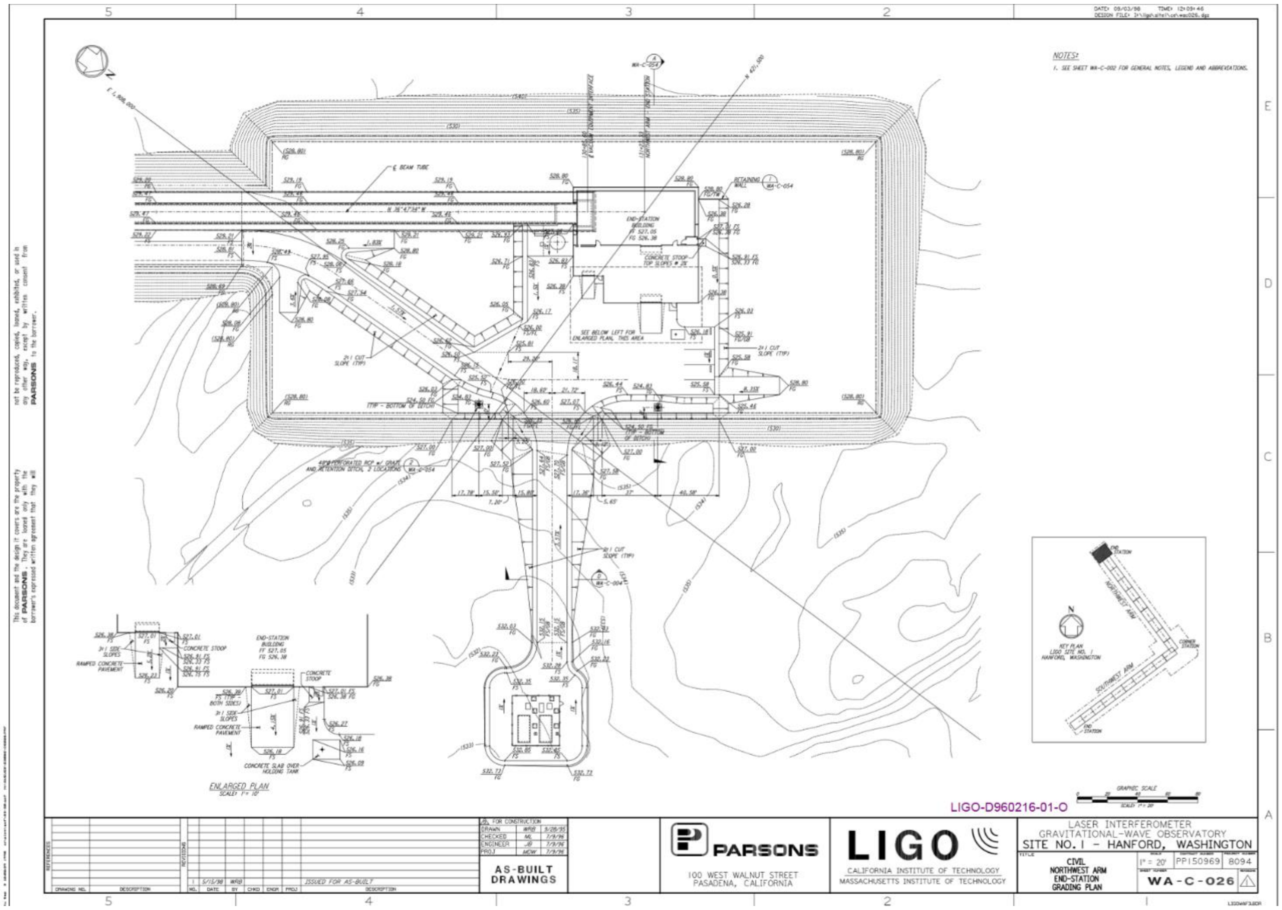

Figure 2: Civil, Northwest Arm, End-Station, Grading Plan D960216-01

- Figure 2 Source: https://dcc.ligo.org/LIGO-D960216/public

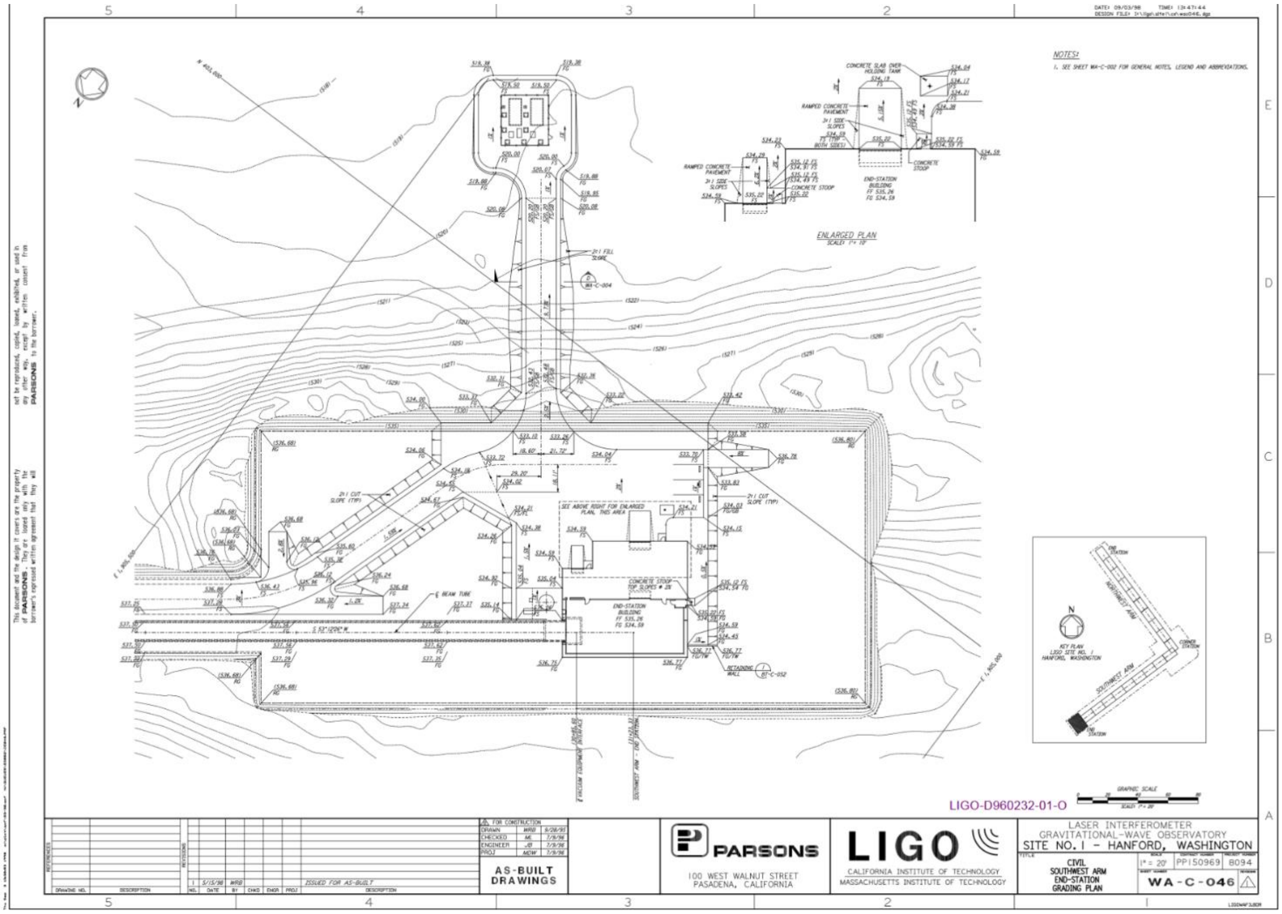

Figure 3: Civil, Southwest Arm, End-Station, Grading Plan D960232-01

- Figure 3 Source: https://dcc.ligo.org/LIGO-D960232/public

2.2 Wind Fence Locations

The below Figure 4 and Figure 5 indicate the prescribed zones for the respective base scope and optional scope wind fences at End X and End Y, respectively.

Figure 4: End X Wind Fence Location overlaid onto Google Maps aerial view

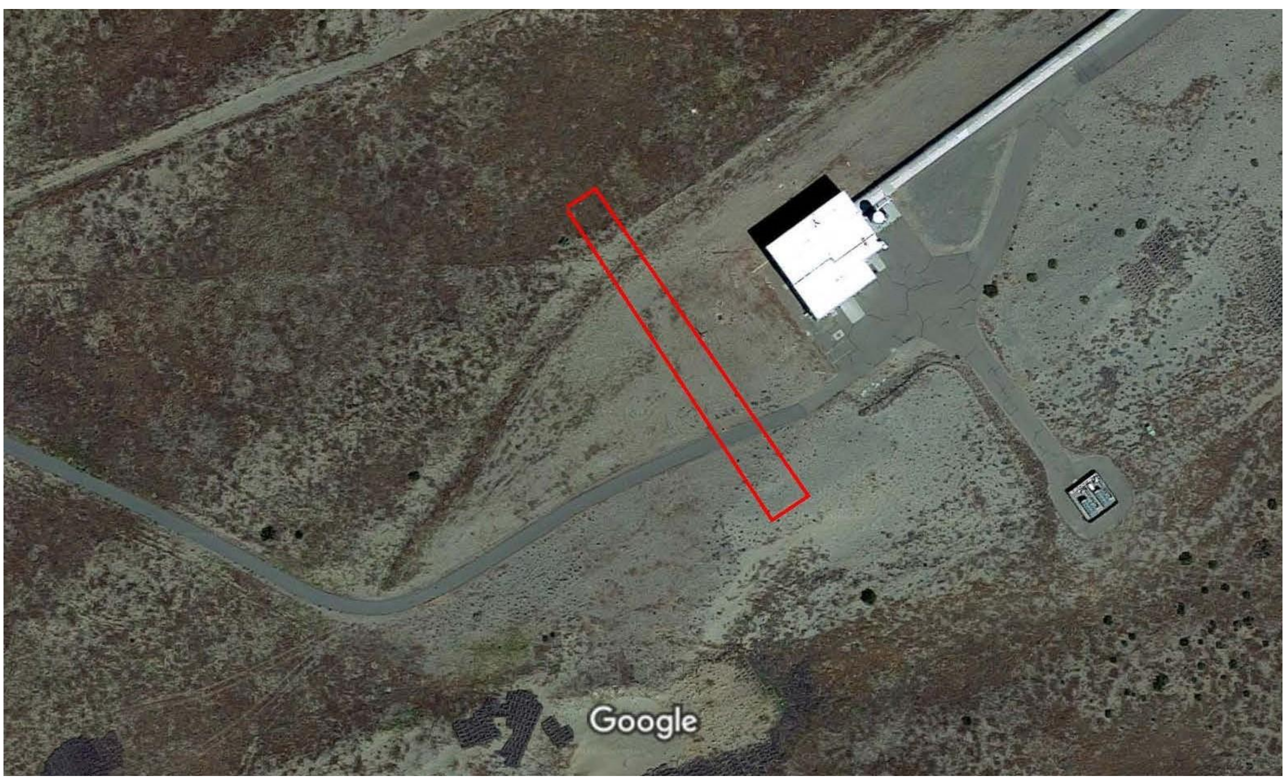

Figure 5: End Y Wind Fence Location overlaid onto Google Maps aerial view

Figure 4 and Figure 5 source: Q&A - LHO Wind Fence Design and Construction

2.3 Site Terrain and Topology

The geotechnical report conducted at the site of LIGO Hanford Observatory, prior to construction, is presented in internal document LIGO-C930032, which has been released along with the initial Q&A.

- https://dcc.ligo.org/LIGO-C930032/public
  - Section 4.1 GEOLOGIC SETTING
  - Plates 2 through 6, Site Plan and Cross Sections
  - Other sections may have relevance

As part of this report, the overall site topology is characterized. Topology of the area under the planned locations of the two, 4 km arms was mapped.

The final planned grading is available within the as-built drawing package for the LIGO Laboratory site which are publically available at:

- https://labcit.ligo.caltech.edu/LIGO_web/docs/asbuilts_lho.html

Of particular relevance to the wind fence build is the earthwork that has taken place to bring the site from the initial state to the as built state. In particular, the following two topological complications exist:

End X wind fence is to be built upon a berm of about 12 feet above the End X station terrain. The authors do not know the full extent of the earthwork that was undertaken to create this berm.

End Y wind fence is likely to run along a plateau at the same height as the End Y station terrain, but the span of the End Y wind fence may necessitate that the span extend off of this plateau, at a level of about 6 feet below. The authors do not know the full extent of the earthwork that was undertaken to create this plateau.

2.4 Site Soil Conditions

The geotechnical report conducted at the site of LIGO Hanford Observatory, prior to construction, is presented in internal document LIGO-C930032, which has been released along with the initial Q&A.

- https://dcc.ligo.org/LIGO-C930032/public
  - Section 4.2 SITE SPECIFIC SUBSURFACE CONDITIONS
  - Section 4.3 FIELD TESTING
  - Plate 7, Seismic Design Data Typical Soil Profile
  - Appendix A, Field Investigations
  - Other sections may have relevance

The earthwork mentioned in Section 2.3 is of relevance to the actual soil conditions at the sites for the constructed wind fence(s). No geotechnical survey known to the authors have captured the site soil conditions following construction.

3 Local Wind Conditions

3.1 Temporal Distribution of “High” Winds > 10 m/s at End Y, End X, and Corner Station

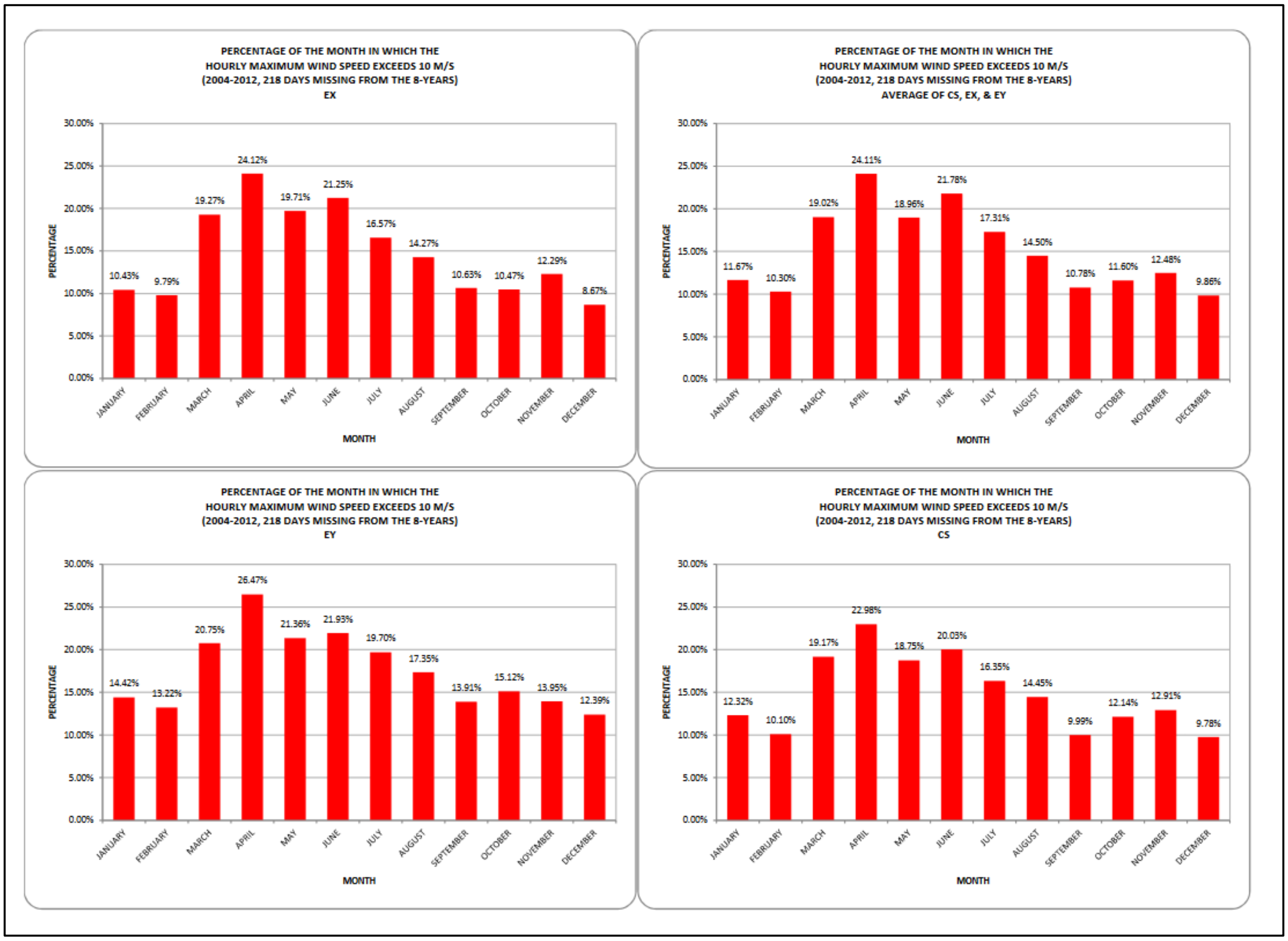

Figure 6: Temporal Distribution of “High” Winds > 10 m/s at End Y, End X, and Corner Station

Figure 6 Source: LHO aLOG 12996

3.2 Wind Rose at Tri Cities Airport, with Site overlays

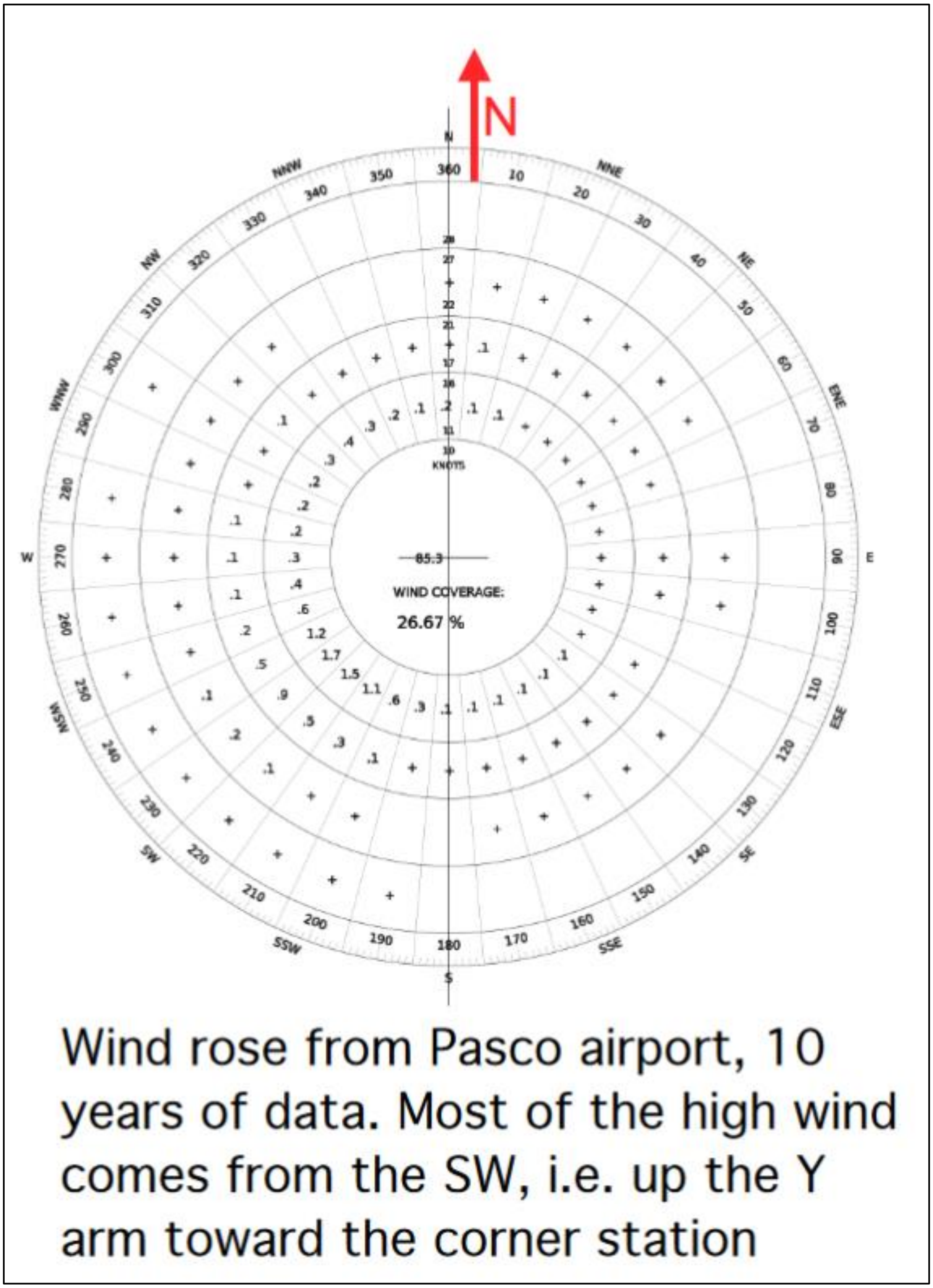

Figure 7: Wind Rose at Tri Cities Airport

Figure 7 Source: G1800148 slide 4

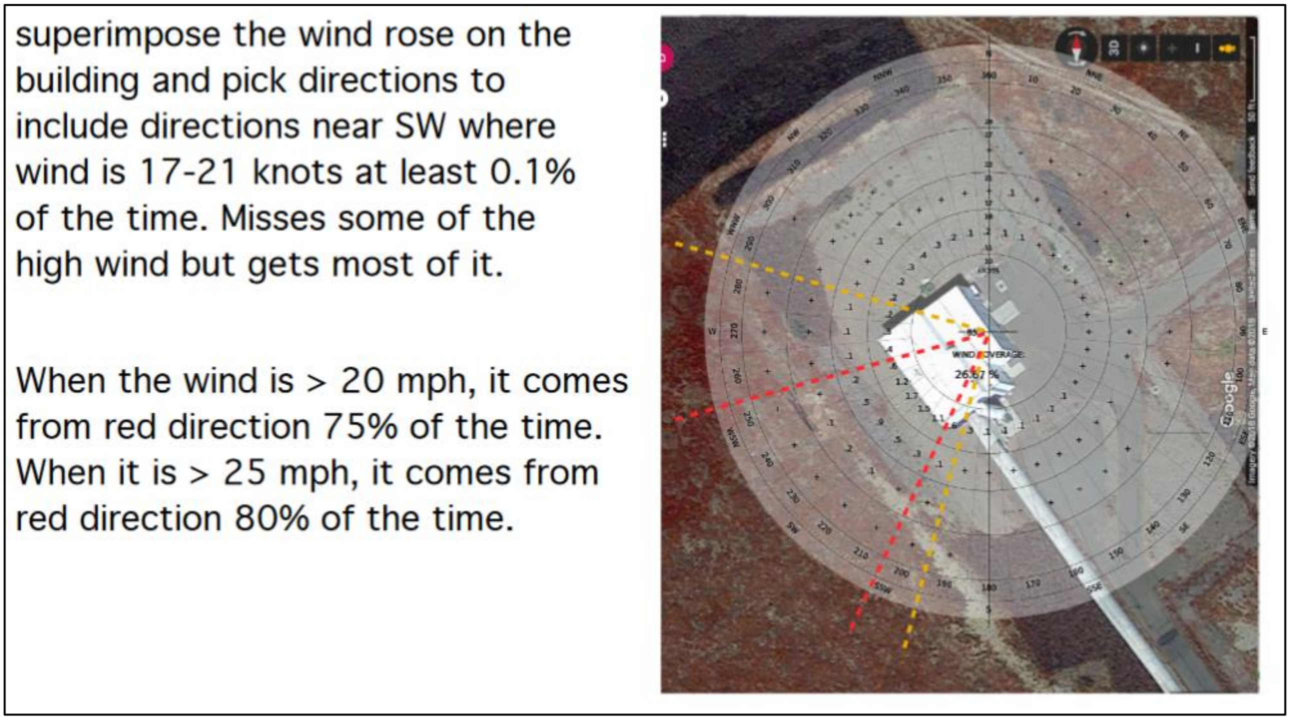

Figure 8: Wind Rose at Tri Cities Airport, overlaid onto End X

Figure 8 Source: G1800148 slide 5

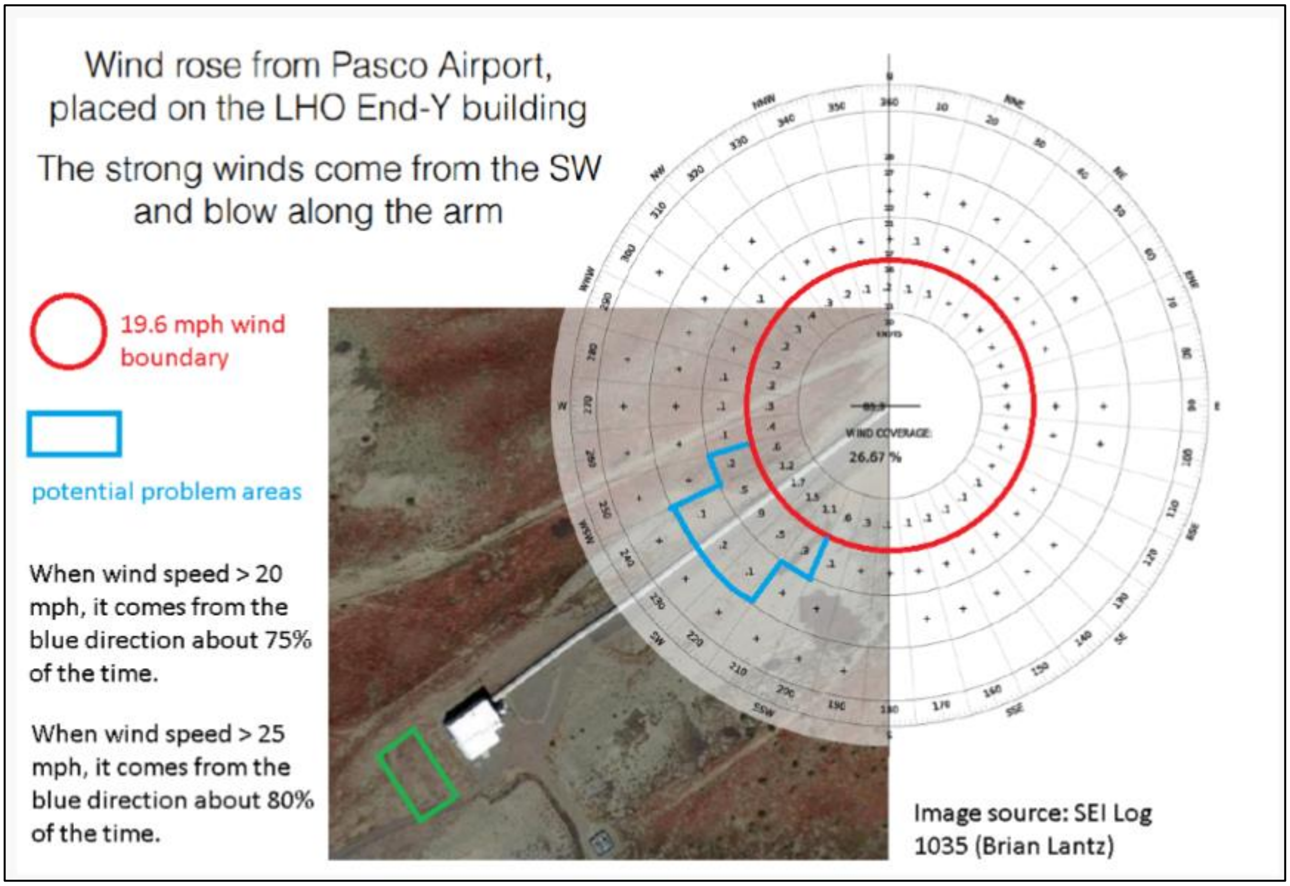

Figure 9: Wind Rose at Tri Cities Airport, overlaid onto End Y

Figure 9 Source: G1800148 slide 8

3.3 Wind Speed Histogram

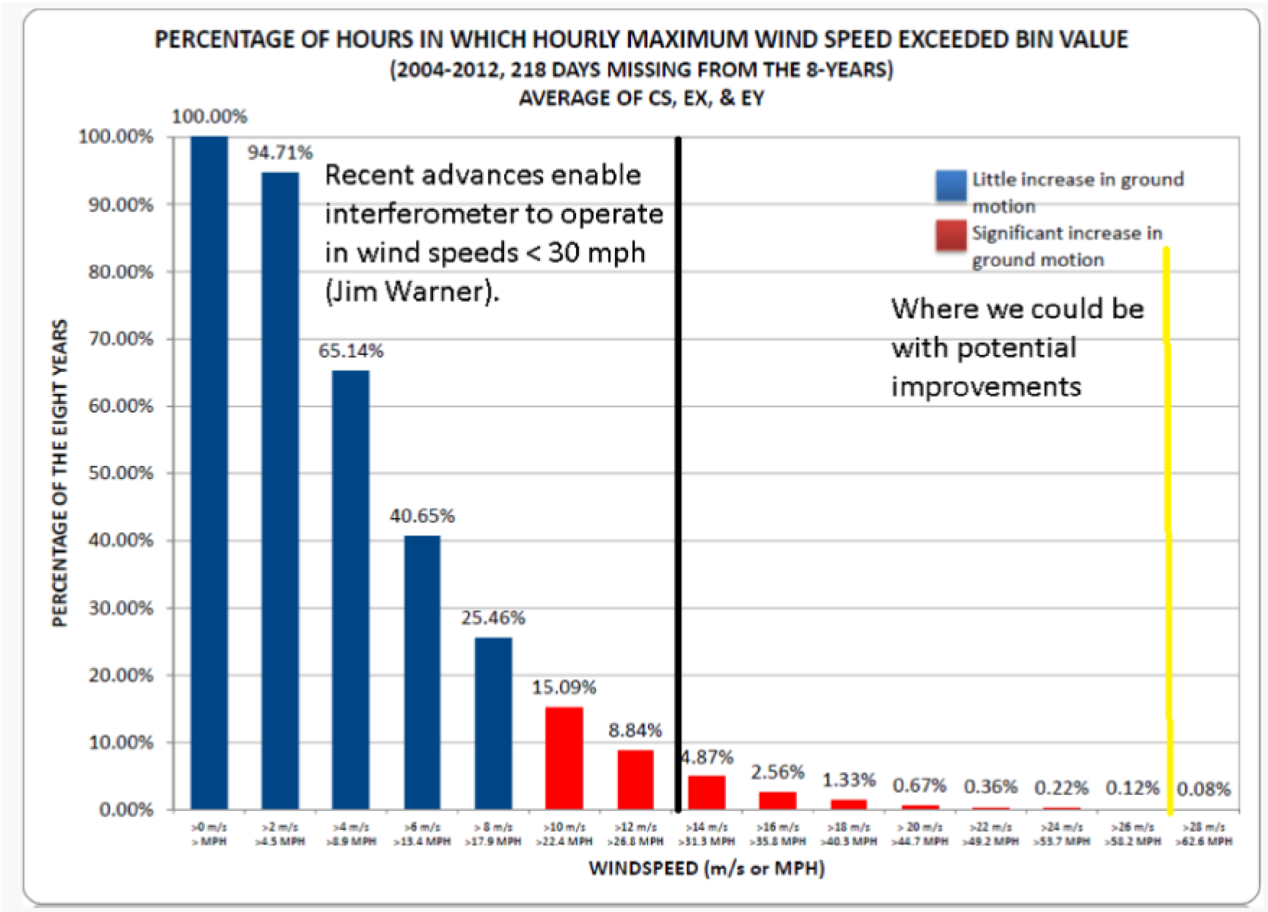

Figure 10: Wind Speed Histogram

Figure 10 Original Source: G1501371-v3 slide 23 / LHO aLOG 12996

Figure 10 Source of Markup: G1800148 slide 9

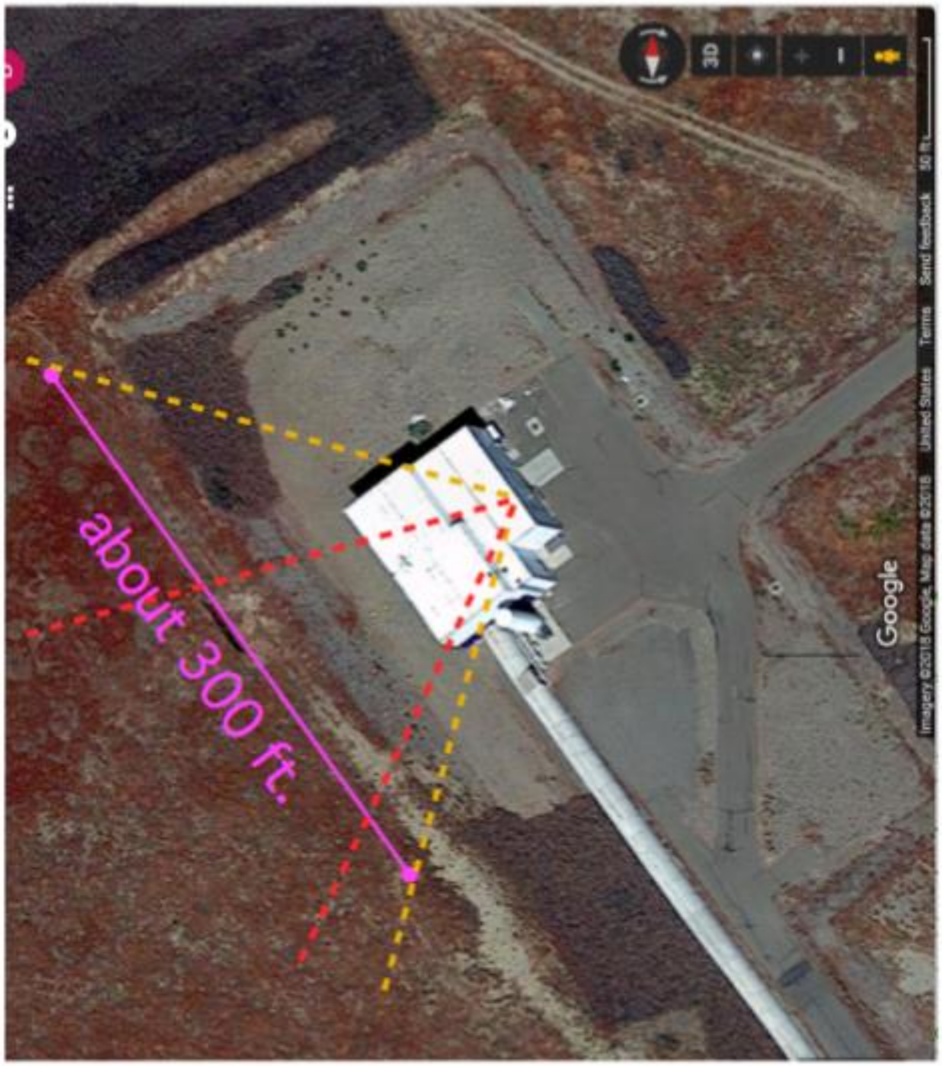

Figure 11: Sketch of different Wind Fence coverage cases at End X

Figure 11 Source: G1800148 slide 6

Figure 12: Sketch of different Wind Fence coverage cases at End Y

Figure 12 Source: Q&A - LHO Wind Fence Design and Construction

4 Local Environmental Conditions

4.1 Meteorological Information

Meteorological Data for the DOE Hanford Reservation is available at:

https://www.hanford.gov/page.cfm/HMS

The setting of the LIGO Hanford site is an arid desert with low annual rainfall, typically less than a couple of feet, and one to a few feet of annual snowfall.

4.2 Tumbleweed

Particularly during high wind weather conditions, tumbleweed travels across the surrounding terrain and accumulates along site facilities.

The bottom edge of the windscreen material of the Prototype Wind Fence was raised 4’ off the ground, which seemed to provide sufficient clearance to avoid tumbleweed accumulation.

5 Prototype Implementation

Figure 13: Prototype Wind Fence Location

Figure 13: Source: G1800148 slide 4

Figure 14: Landscape View of Prototype Wind Fence (Initial Porous Material)

Figure 14 Source: LHO aLOG 27949

Figure 15: Setting a Post for Prototype Wind Fence

Figure 15 Source: LHO aLOG 27759

Figure 16: Close-up View of Prototype Wind Fence Lathing

Figure 16 Source: LHO aLOG 27949

Figure 17: Prototype Wind Fence (Improved 50% Porosity Material)

Figure 17 Source: LHO aLOG 43358

5.1 Prototype Wind Screen Material

Tenax 5.6x150ft Green Wind Screen, Home Depot Internet #205358753 (not available as store stock SKU.) This material is available at other suppliers as well.

We utilized a grommeted run of wind screen for ease of use of this fabric, which required 3 segments run horizontally to provide the intended vertical coverage. Just a prototype all in all.

We have evaluated the breaking strength using a few different pull test variations and our analytical calculations suggest that it would survive in the high wind conditions we expect to ride through.

Sources: T1800386, T1800323

We understand that this material is frequently used with a backing material such as chicken wire, but we did not explore any such implementation in any context.

Initially, we used some less porous fabric with less satisfactory results.

5.2 Prototype Dimensions

30’ in length. Cladding extends from 4’ to 20’ above ground level. These dimensions were selected because of material availability and construction considerations – analyses clearly show the need for greater extents in all directions.

5.3 Prototype Wind Speed Reduction

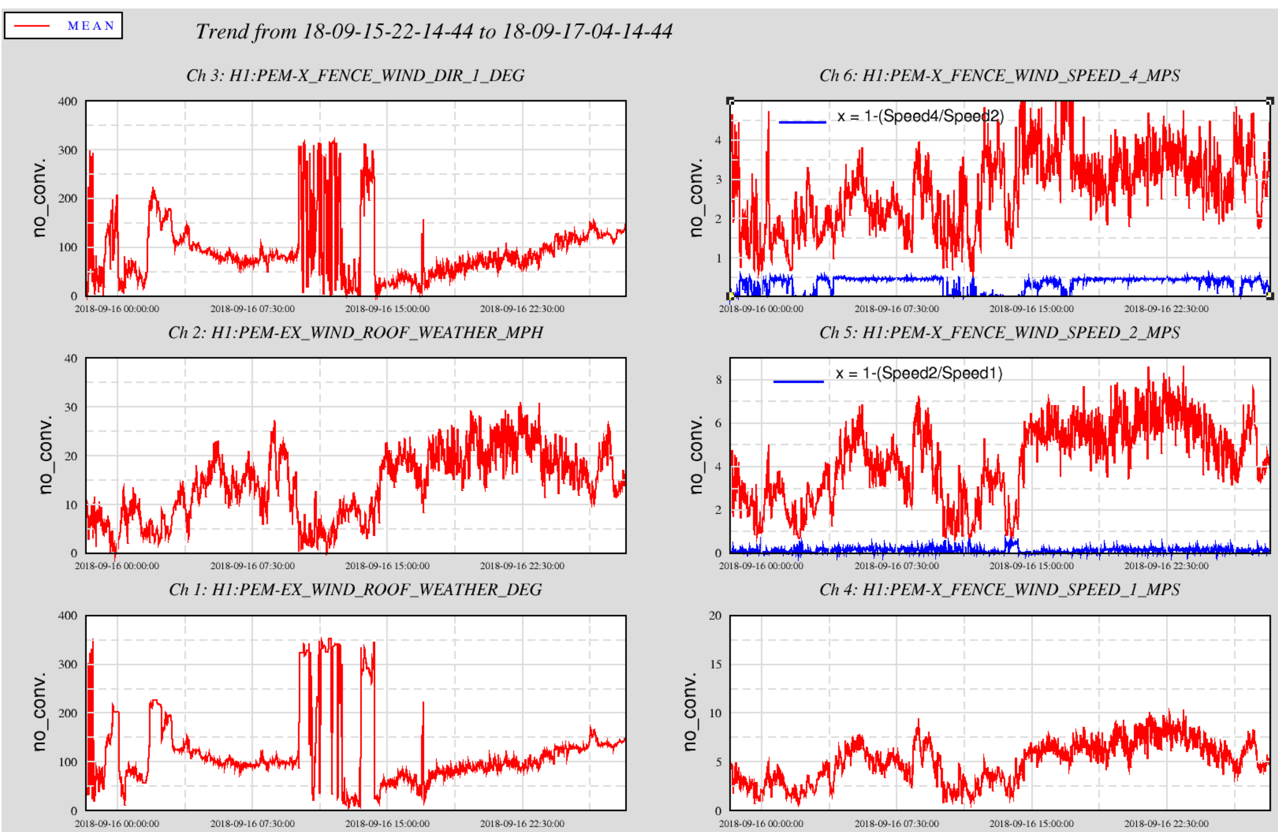

Figure 18: Example of Wind Monitoring Screen showing 50% Wind Speed Reduction

Figure 18 Source: documented in LHO aLOG 44021

5.4 Modeling for Prototype Development

In depth and successful modeling efforts were undertaken by collaborators at LIGO group at Stanford University.

The below results of Figure 19, Figure 20, and Figure 21 capture a small subset of the results, indicating Total Force and Total Moment loading reduction of 70%-80%, without compromised turbulence in front of building.

The model was compared with the performance of the prototype Wind Fence within Figure 22 and Figure 23.

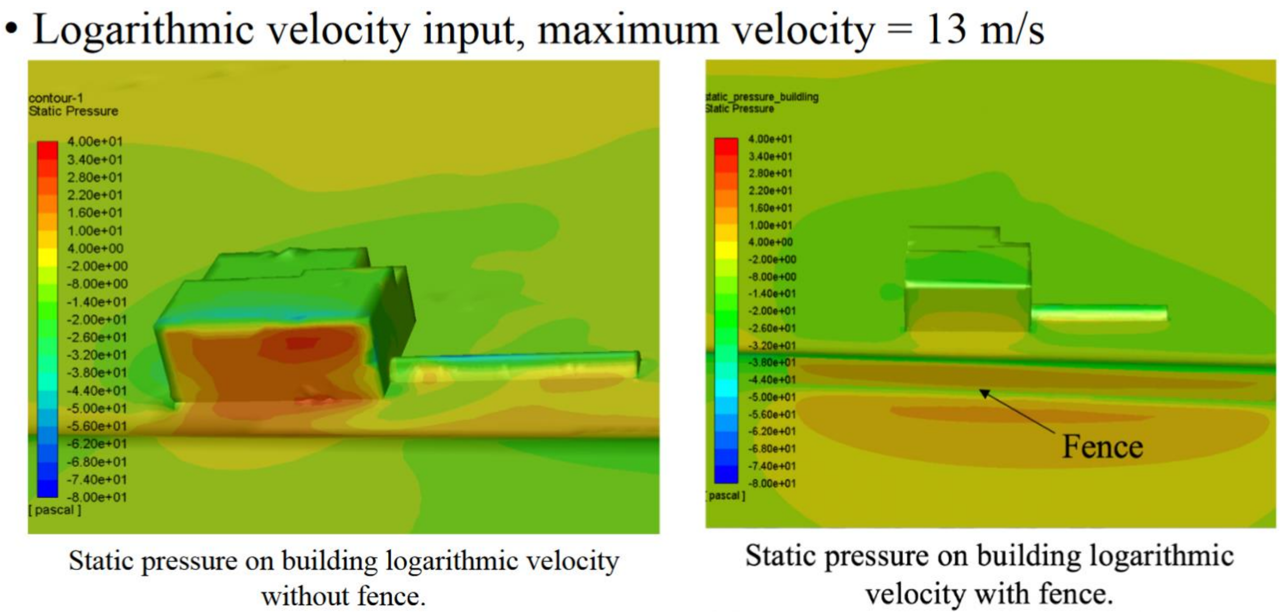

Figure 19: Loading on Building without/with Wind Fence

Figure 19 Source: G1801954

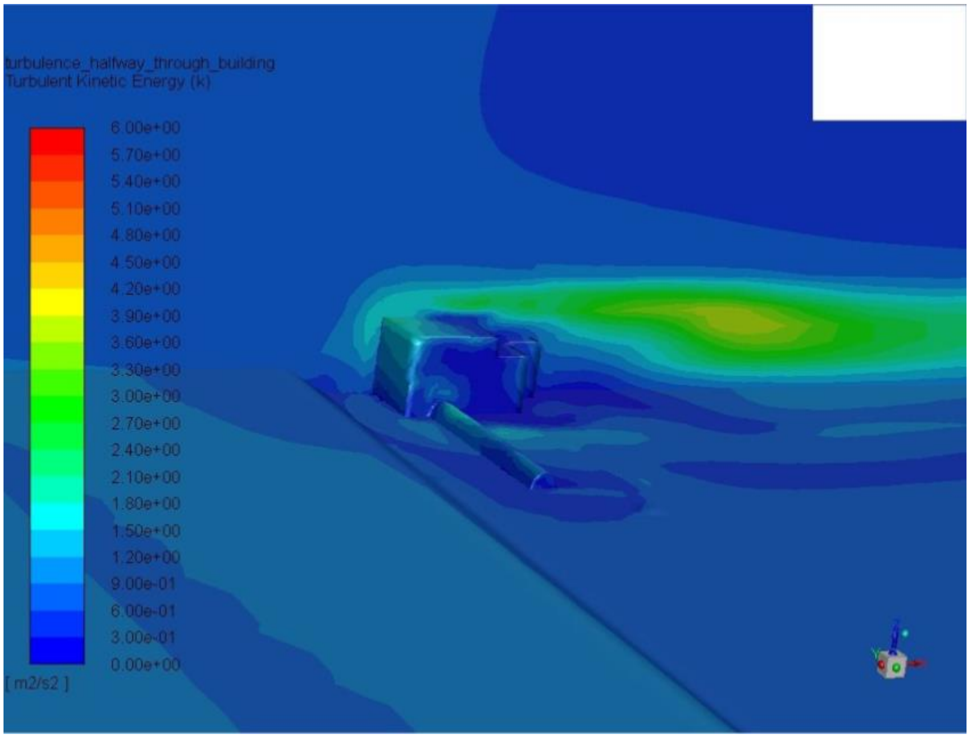

Figure 20: CFD Turbulence on Center Plane, without Wind Fence

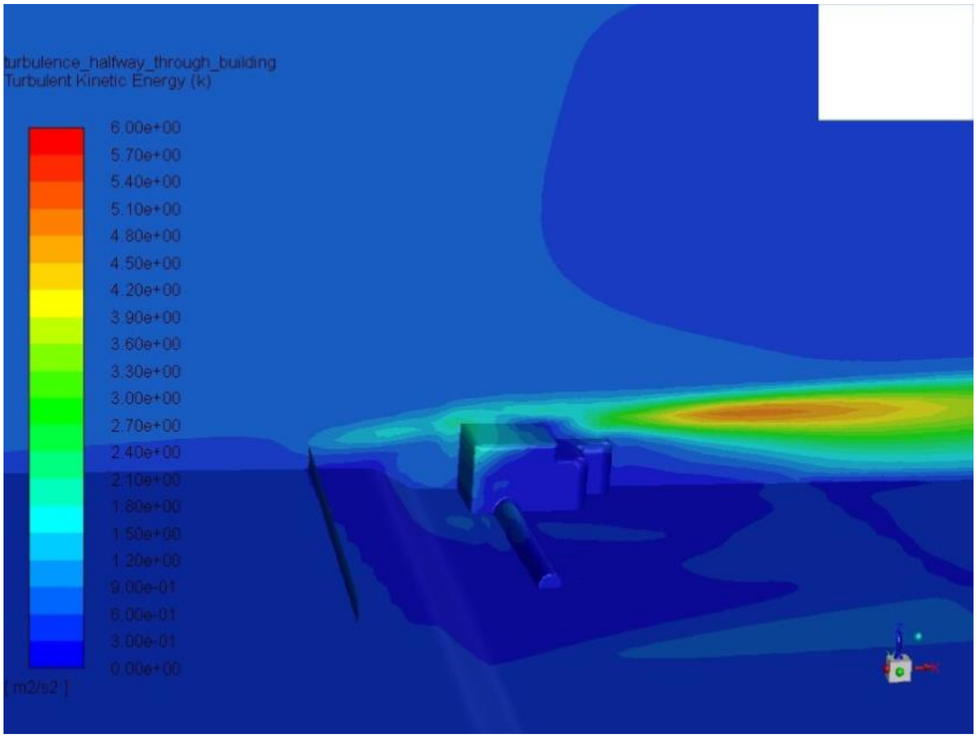

Figure 21: CFD Turbulence on Center Plane, with Wind Fence

Figure 20 and Figure 21 source: T1800360

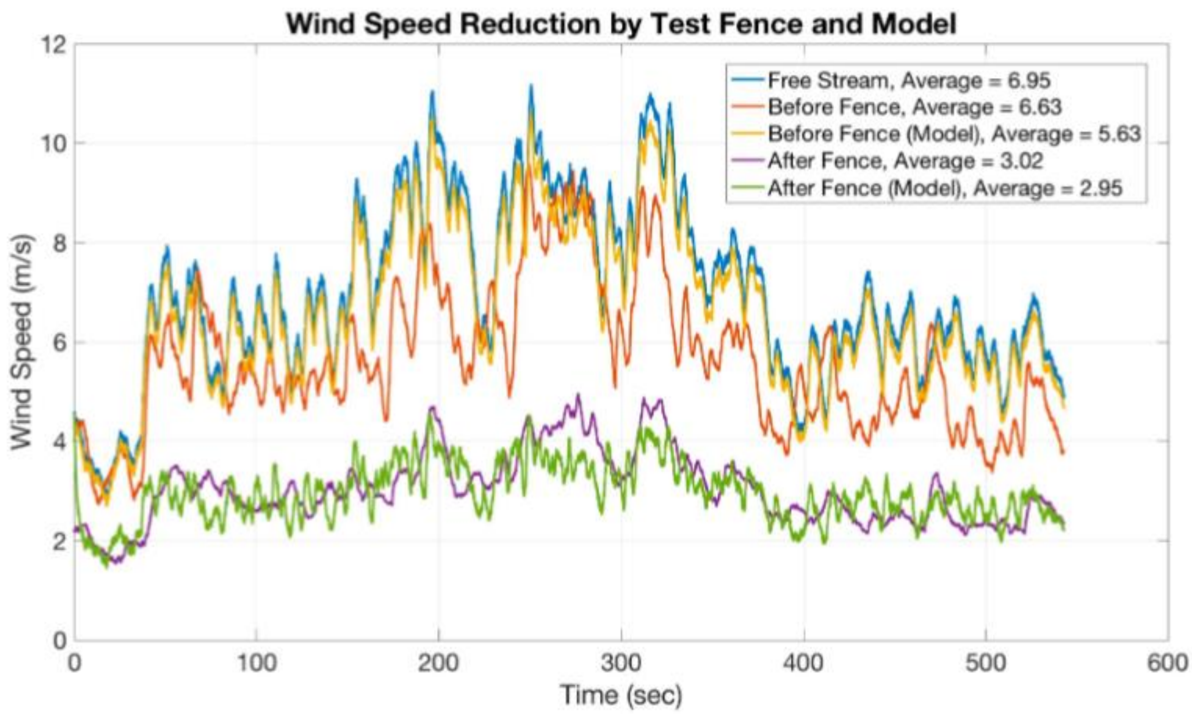

Figure 22: Comparison between CFD Model and Prototype Wind Fence (Time Series)

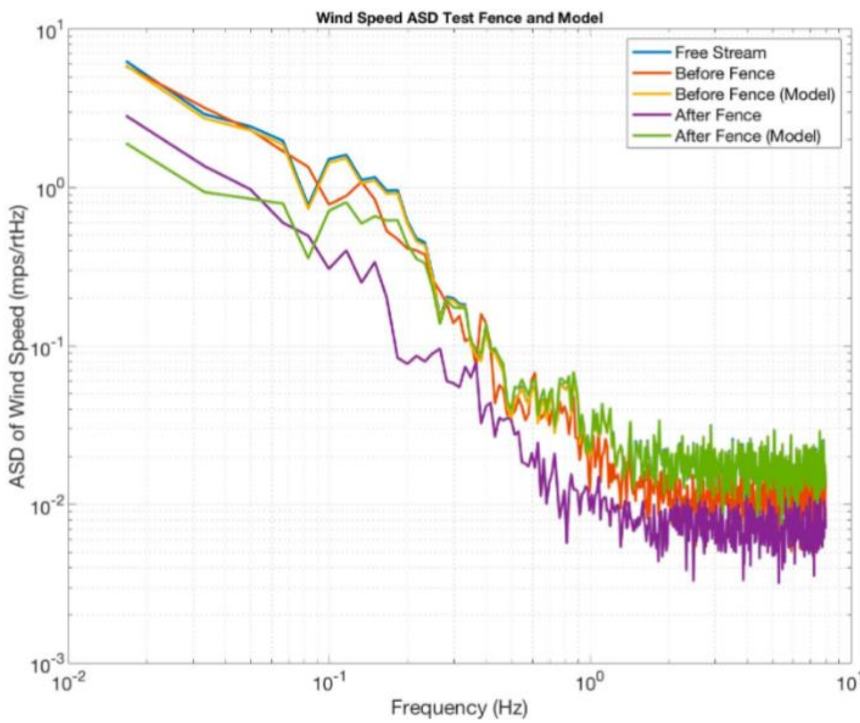

Figure 23: Comparison between CFD Model and Prototype Wind Fence, ASD (Frequency)

Figure 22 and Figure 23 source: G1801954