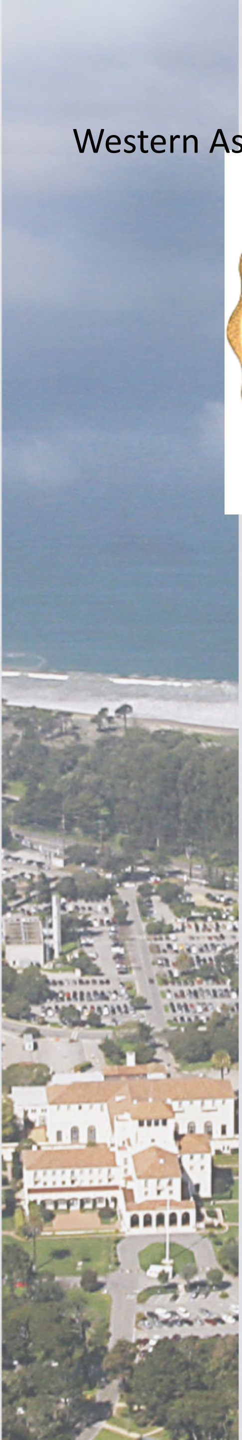

WASC

Western Association of Schools and Colleges

NAVAL POSTGRADUATE SCHOOL

ABET

Accreditation Board for Engineering and Technology

Combat Systems Engineering and Directed Energy Weapons Systems Capabilities

12 August 2015

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Purpose

Familiarize with the Combat Systems Engineering process, professional experience and educational opportunities in the Systems Engineering Department.

Introduce system level and detailed work in support of directed energy initiatives in the DoD.

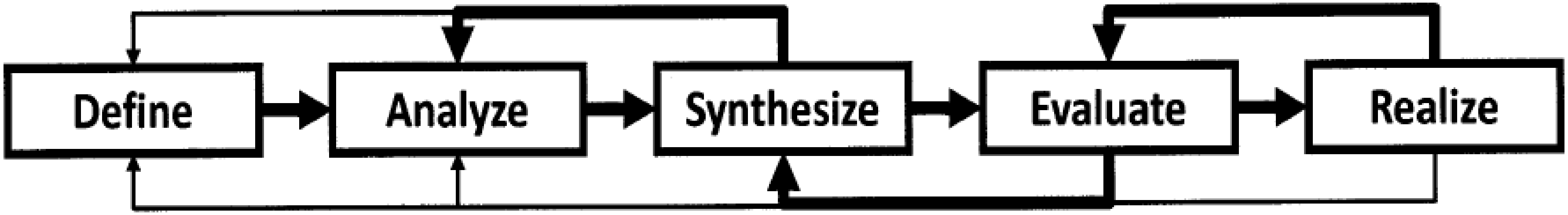
Outline

- Combat Systems Engineering Approach
- Examples of Student Work
- Ongoing Effort

Combat Systems Engineering

The design, development and realization of combat systems that perform the military missions for which they are developed.

Given a thorough grounding in the principles of sensors, weapons and command & control elements, the systems engineering process is a workable guide to the activities of combat systems engineering.



Overarching Systems Engineering Process

- **Consider the "big picture" and the "long view"**
- **Define and bound the problem**
- **Analyze the problem**
- **Establish the requirements of acceptable solutions**
- **Synthesize alternative solution concepts**
- **Compare the "performance" of all alternatives**
- **Select the best solution**
- **Document the process and the results**
- **Make the solution happen!**

Everything else is tools, techniques and details.

A Combat Systems Engineering Approach

Step	Activity	Tasks
Define	Mission Definition	* User input * Context definition * Identification of constraints * Mission concept of operations * Scenario generation
Analyze	Mission Analysis	* Mission functional analysis * Mission timeline analyses * Design reference mission * Operations analyses * Performance requirements definition
	System Analysis	* System functional and timeline analyses * Functional allocation (to element types)
Synthesize	Concept Synthesis	* Identification of alternatives * Technology assessment * Generation of schematic block diagrams * Selection of major alternative system suites
Evaluate	Analysis of Alternatives	* Selection of measures of performance and measures of effectiveness * Trade studies * Performance analyses * Cost-effectiveness analyses * Selection of preferred alternatives
Realize	Concept Refinement/ Optimization	* Architecture * Integration concept * Preliminary system layout * System concept of operations * Documentation of decisions

Some Examples of Student Work

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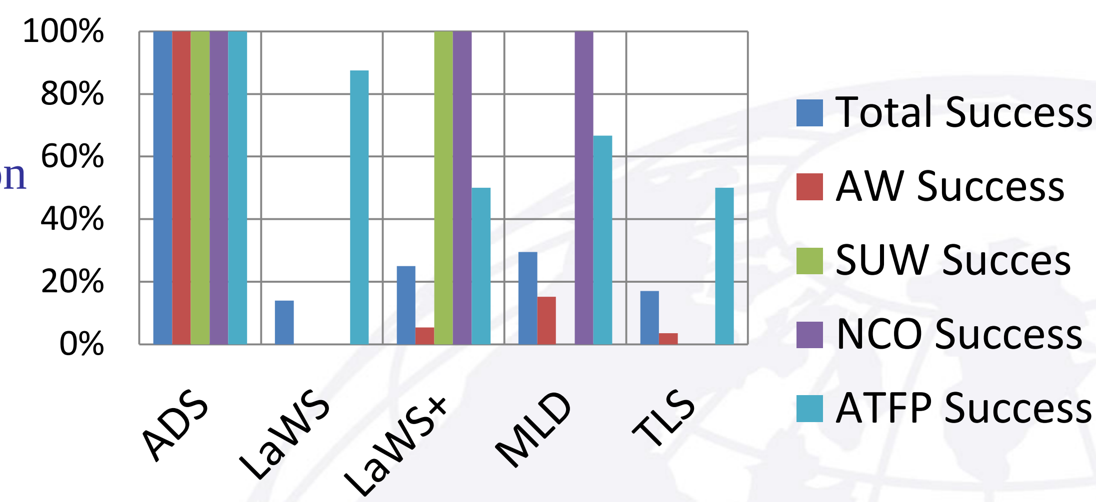
VIABLE SHORT-TERM DIRECTED ENERGY WEAPON NAVAL SOLUTIONS: A SYSTEMS ANALYSIS OF CURRENT PROTOTYPES (SEA 19B)

- DEW can and will be "game changing," just not in the next 4 years
- Current DEW tech levels inadequate for "one for one" weapon replacement
- Aggregate estimate for shipboard fuel cost associated with a DEW shot is less than $1
  - Compare to $800K to $3.6M AD interceptors
- Tactical Laser System (TLS) currently offers the best "bang for the buck"
- Active Denial System (ADS) has potential to fill unique capability gap for Anti-Terrorism and Force Protection
- Both TLS and ADS are significantly cheaper than other alternatives of comparable performance

Weapon-Warfare Area Mission Sucess Rates



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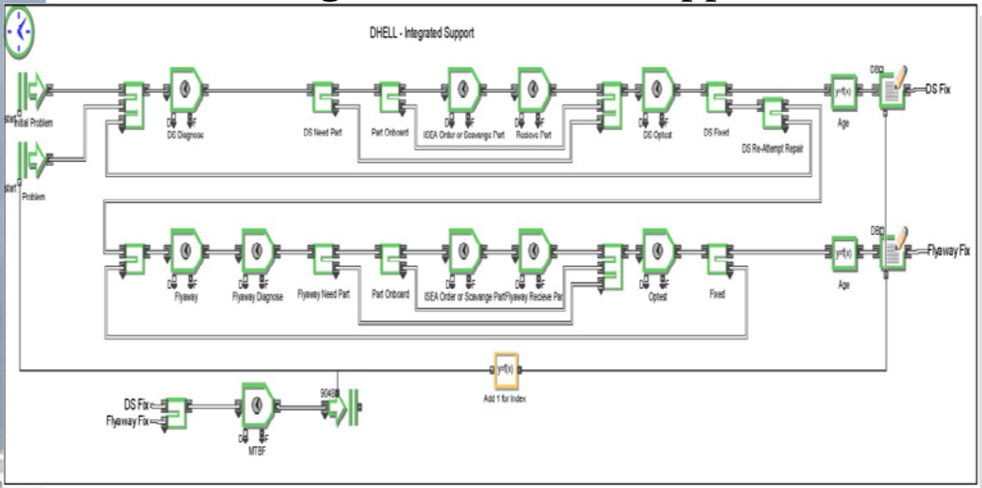
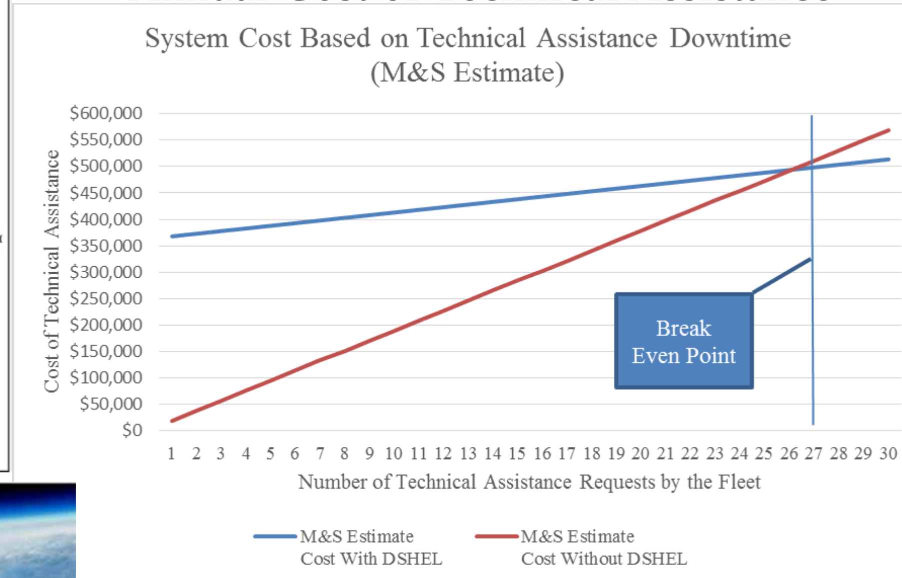
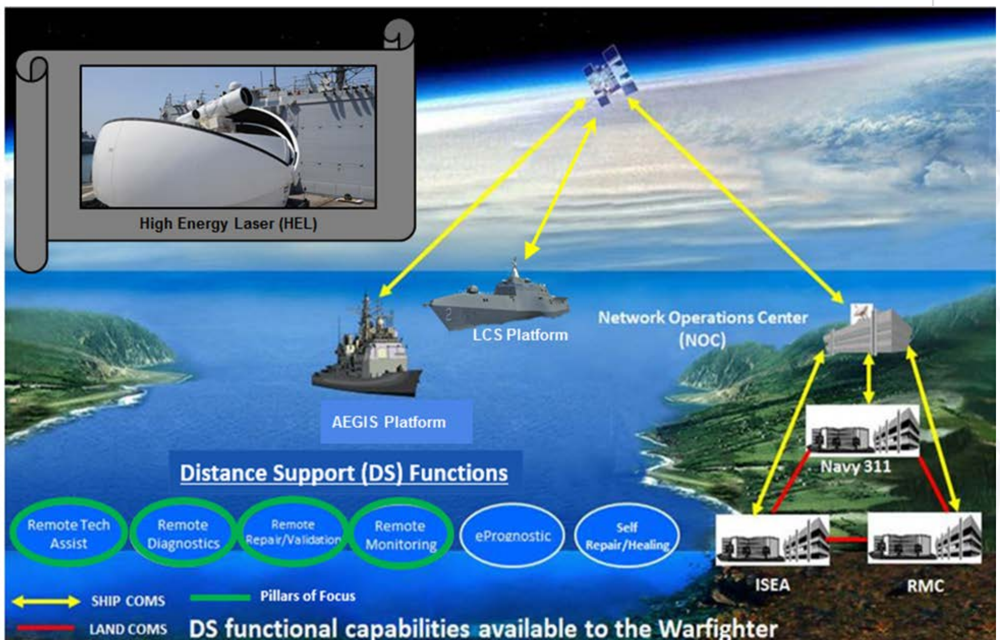
DISTANCE SUPPORT IN-SERVICE ENGINEERING FOR THE HIGH ENERGY LASER (DSHEL Team 311-133O)

DSHEL – Integrated Distance Support Model

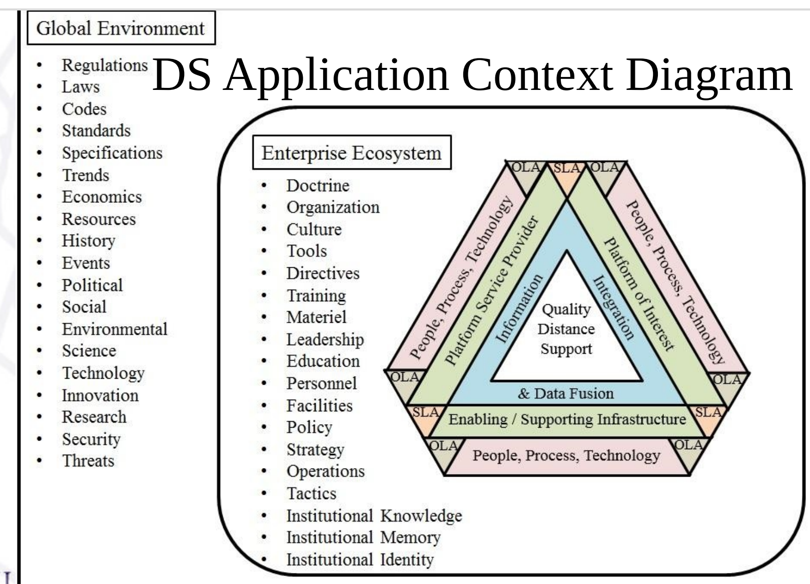


Annual Cost of Technical Assistance



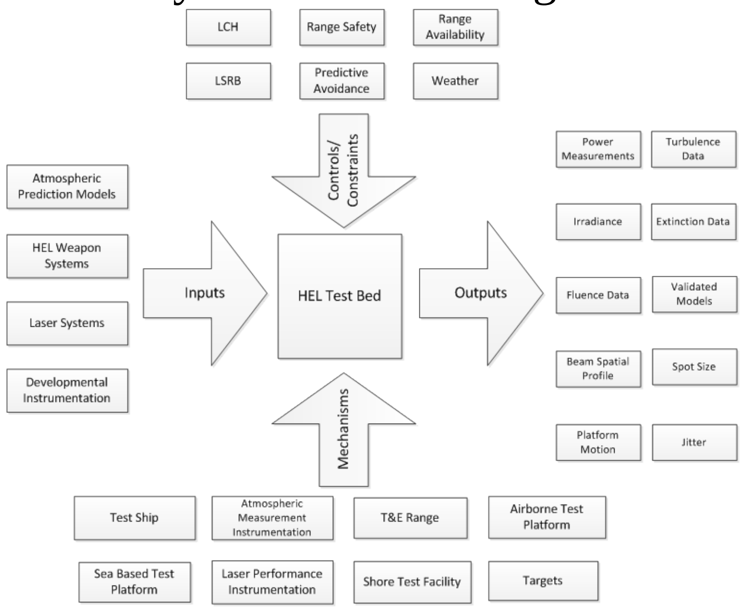


DS Application Context Diagram

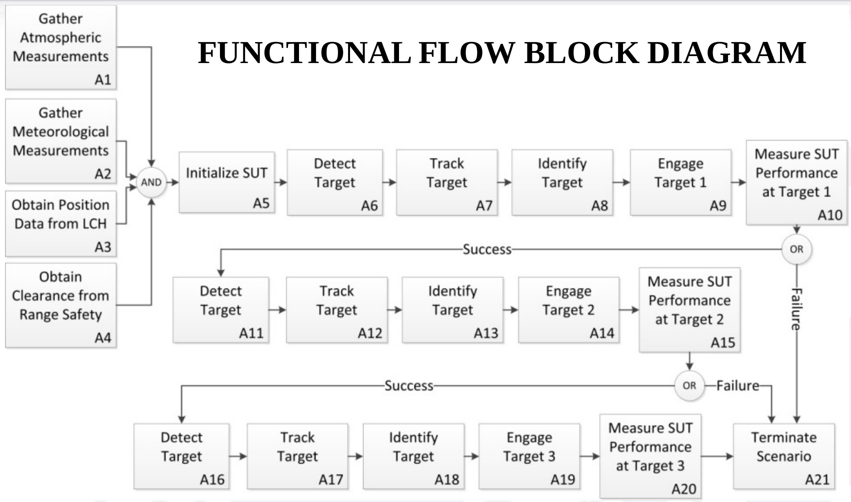


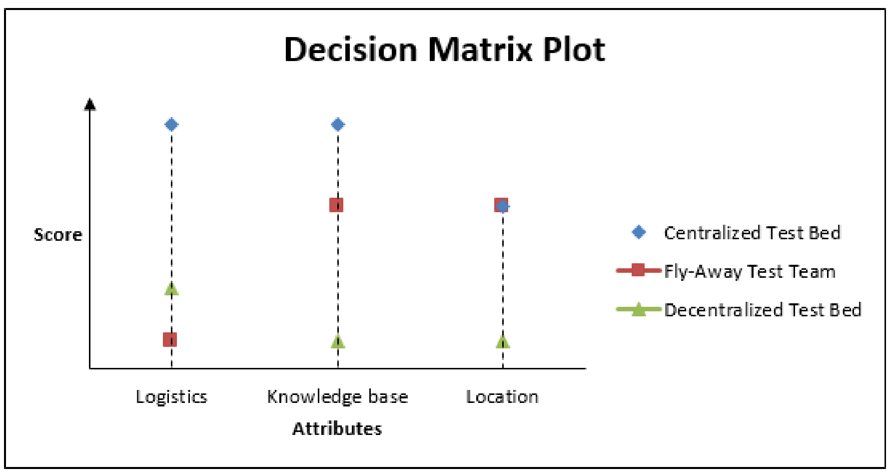
COMPREHENSIVE SYSTEM BASED ARCHITECTURE FOR AN INTEGRATED HIGH ENERGY LASER TEST BED (Testbed Team 311-133O)

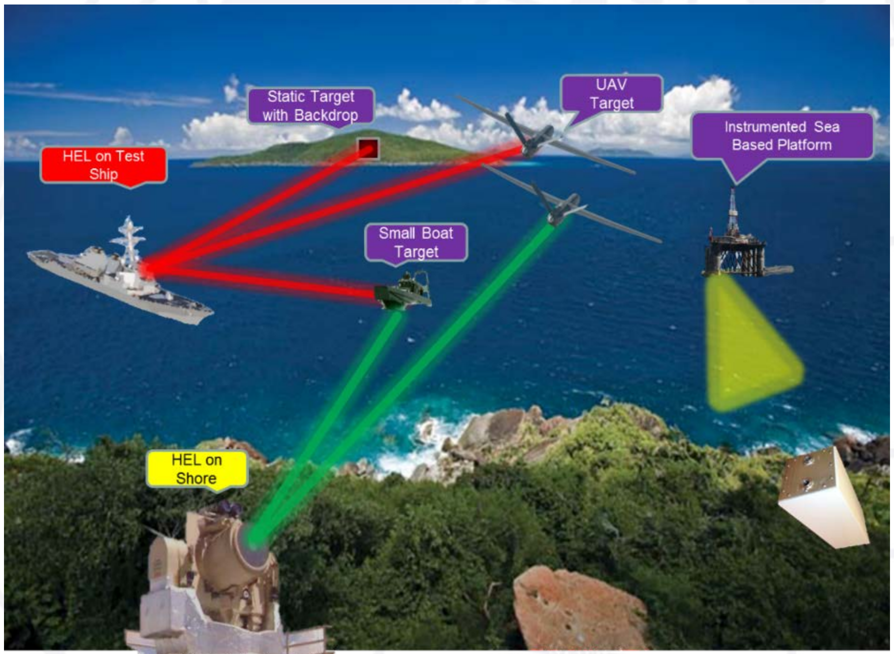
HEL System Context Diagram



FUNCTIONAL FLOW BLOCK DIAGRAM







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Mission Definition & Analysis

LT Patrick Stone (December 2015 Graduation)

Define and clarify potential mission sets in which a future submarine may find itself, it will then be possible to determine the driving factors and effectiveness of the benefit of a HELWS.

Analyze to determine HELWS mission effectiveness.

Functions of the submarine and the HELWS will be examined including a timeline analysis to help determine and analyze metrics that the submarine and HEL will need to meet in order to be effective in accomplishing the defined mission set.

Summary

- **Combat Systems Engineering approach is well suited for today's challenges**
- **Experience of the SE team brings a unique perspective**
- **Previous and current student work is addressing warfighter needs**

Systems Engineering has a distinctive capability

Backup

Mission Definition

Process of understanding all relevant aspects of the mission under consideration.

Essential first step in any mission analysis and for any system design.

Involves four major activities:

- **Context definition**
- **Identification of constraints**
- **Mission concept of operations**
- **Scenario generation**

All should be based on user input as well as any knowledge or intelligence that is available.

No matter how logically conceived and technically executed, if a design is not what the user wants it will usually not be used, even if it is what the user needs.

Mission Analysis (1/2)

Systems engineering analyses to determine critical requirements that will drive system design.

Identify future system needs and system requirements.

Examine military utility of systems and operational concepts along with the performance of candidate systems.

Determine impact of threat developments on mission capabilities and the effects of countermeasures on system performance.

Forms a framework for developing and assessing concepts of operations.

Can be used to identify and prioritize issues for decision makers.

Mission Analysis (2/2)

Specific analyses associated with mission analysis include:

*** Functional analysis**

*** Timeline analyses**

*** Functional allocation (to element types)**

*** Operations analyses**

*** Performance requirements definition**

Concept Synthesis

- Arguably the hardest part of system design.
- Creative process as opposed to the other mostly analytical parts of the process - difficult to describe generically.
- References the earlier work on defining the mission functions and ultimately the system functions.
- Usually begins by identifying alternatives for performing the most important functions.
- Available technologies must be reviewed and their ability to meet or evolve to meet requirements must be assessed.
- Schematic block diagrams are developed which relate the system elements to each other – each slightly different depending on the technology alternatives included.
- Two or three different system concepts should be explored and evaluated.

Analysis of Alternatives

Thorough design synthesis results in multiple alternatives.

Analysis of alternatives is both a generic and specific term.

- **Generic - analysis of alternatives compares and contrasts the alternative candidates with the aim of deciding which candidate is preferred (aka trade study).**
- **Specific - analysis of alternatives is the activity previously known as cost-benefit analysis, cost-effectiveness analysis, or cost & operational effectiveness analysis (COEA).**

Trade studies compare the performance, benefits or costs of alternatives over some limited range of quantities (trade space).

Commonly used to narrow the design space to manageable limits.

Trade studies may be qualitative or quantitative.

A selection is difficult without some judgment as to which advantages and disadvantages are more important.

Sometimes one alternative may be clearly superior to others.

Concept Refinement & Optimization

Concept refinement - process of reviewing earlier decisions in light of knowledge obtained as the project proceeds and making alterations as needed to improve the definition of the system.

Optimization - process of making decisions that improve the performance or reduce the cost of the system.

Primary tasks involved in concept refinement and optimization:

*** Selection of an architecture for the combat systems elements**

*** Establishing a concept for integration of the elements**

*** Developing a preliminary system layout**

*** Formalizing a concept of operations for the system (vice the mission)**

*** Documentation of decisions.**

As with all of the steps in the combat systems engineering process, each of these is iterative and may need to be revisited as more information becomes available.

NPS SE Atmospheric Optical Turbulence Characterization at Lazer Bay (San Nicolas Island)

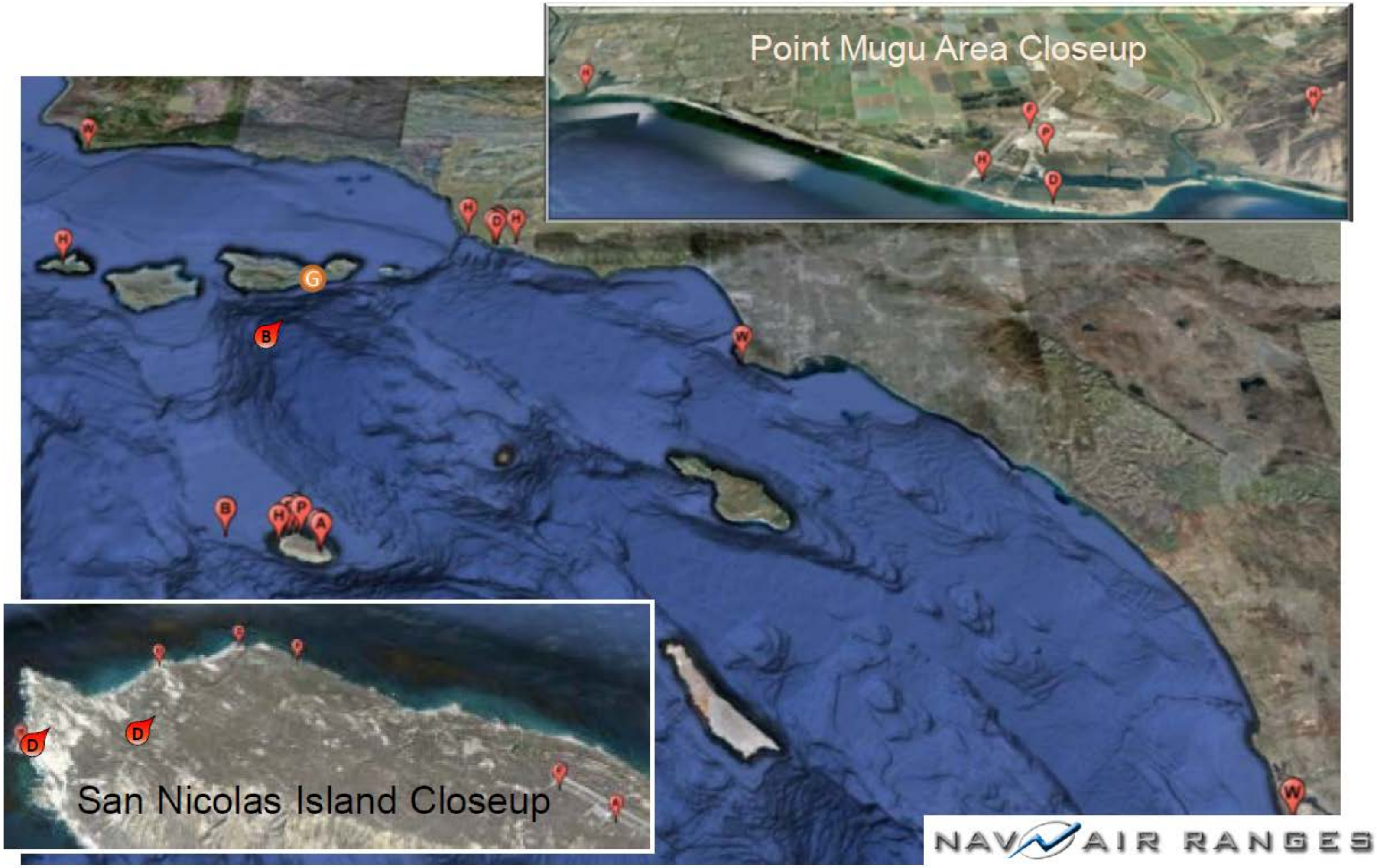
- Conducting extended-duration measurements of Atmospheric Optical Turbulence
- Characterize the local environment at "Lazer Bay" of San Nicolas Island
- Reasonable analog to maritime environment
  - Measurements over the ocean
  - Winds incident from over water, measured prior to significant land interference

Background & Motivations

- Understanding the atmosphere's impact on optical propagation is critical to developing HEL systems.
- Data from maritime environments is needed to:
  - Validate predictive atmospheric models
  - Corroborate HEL test results
  - Increase understanding of maritime atmospheric turbulence
  - Improve prediction methodology from varying meteorological inputs

Sea Range Weather Station Locations

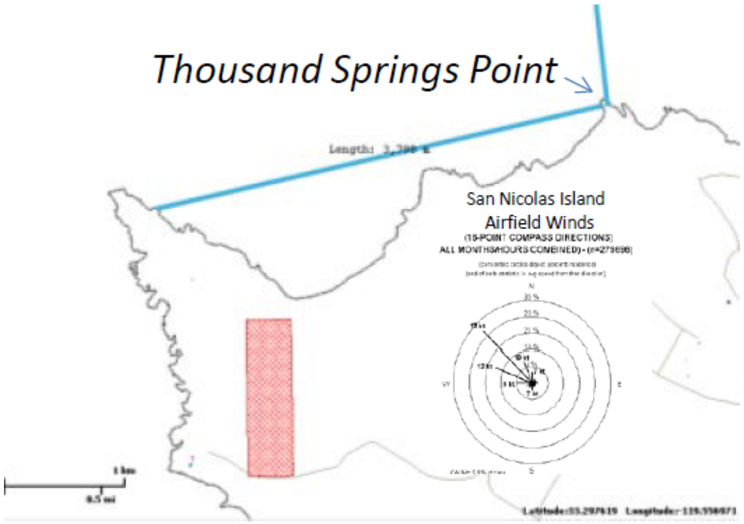
Legend: H = Handar, D = Nomad Davis, W = Weatherflow, B = Anchored Buoy, P = Wind Profiler, A = ASOS, F = Field Mill, G = Planned Addition, 2014

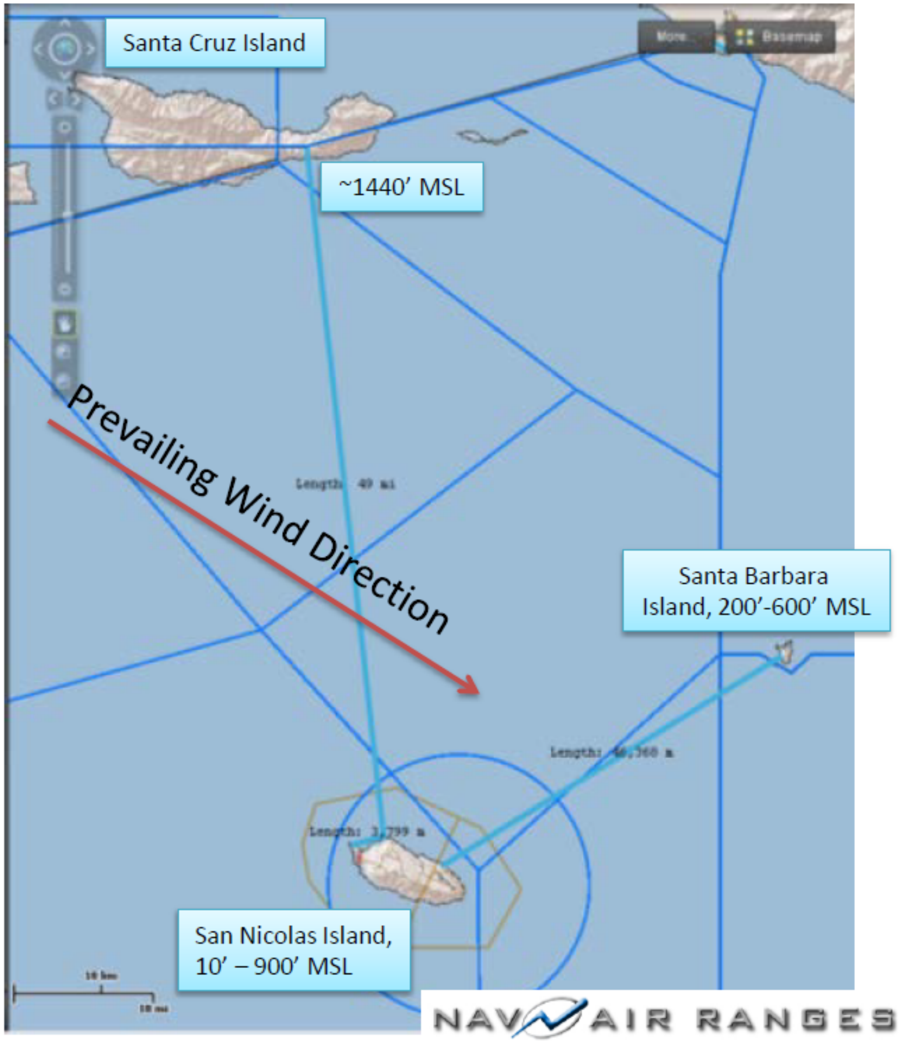


01 April 2014

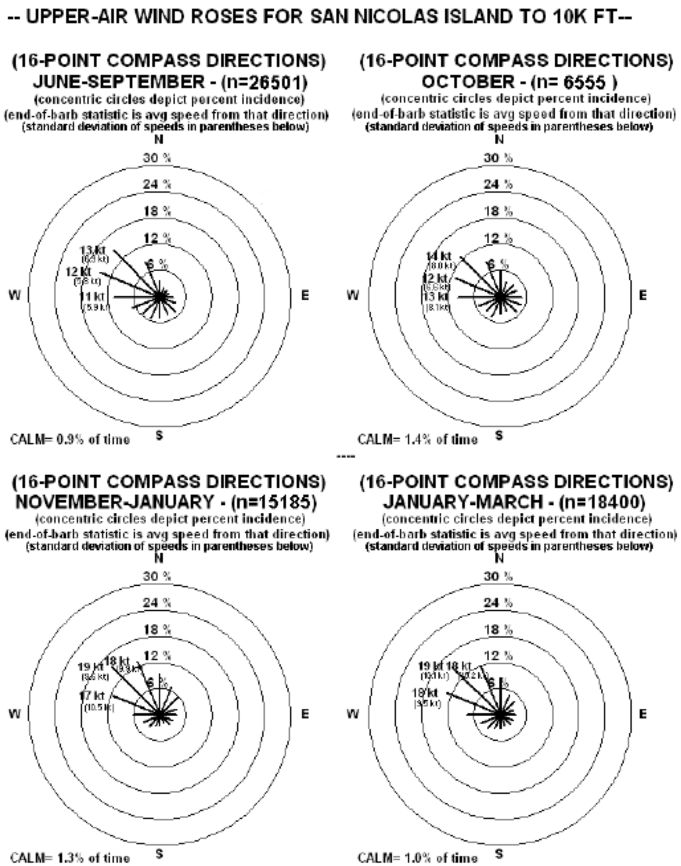
NAVAIR-WD Sea Range Geography

NAVAIR-WD Sea Range can install targets and sensors on many offshore islands, with optical paths across a marine environment.





Wind direction can minimize the littoral effects of the island topography



TAS site, Thousand Springs Pt, looking North

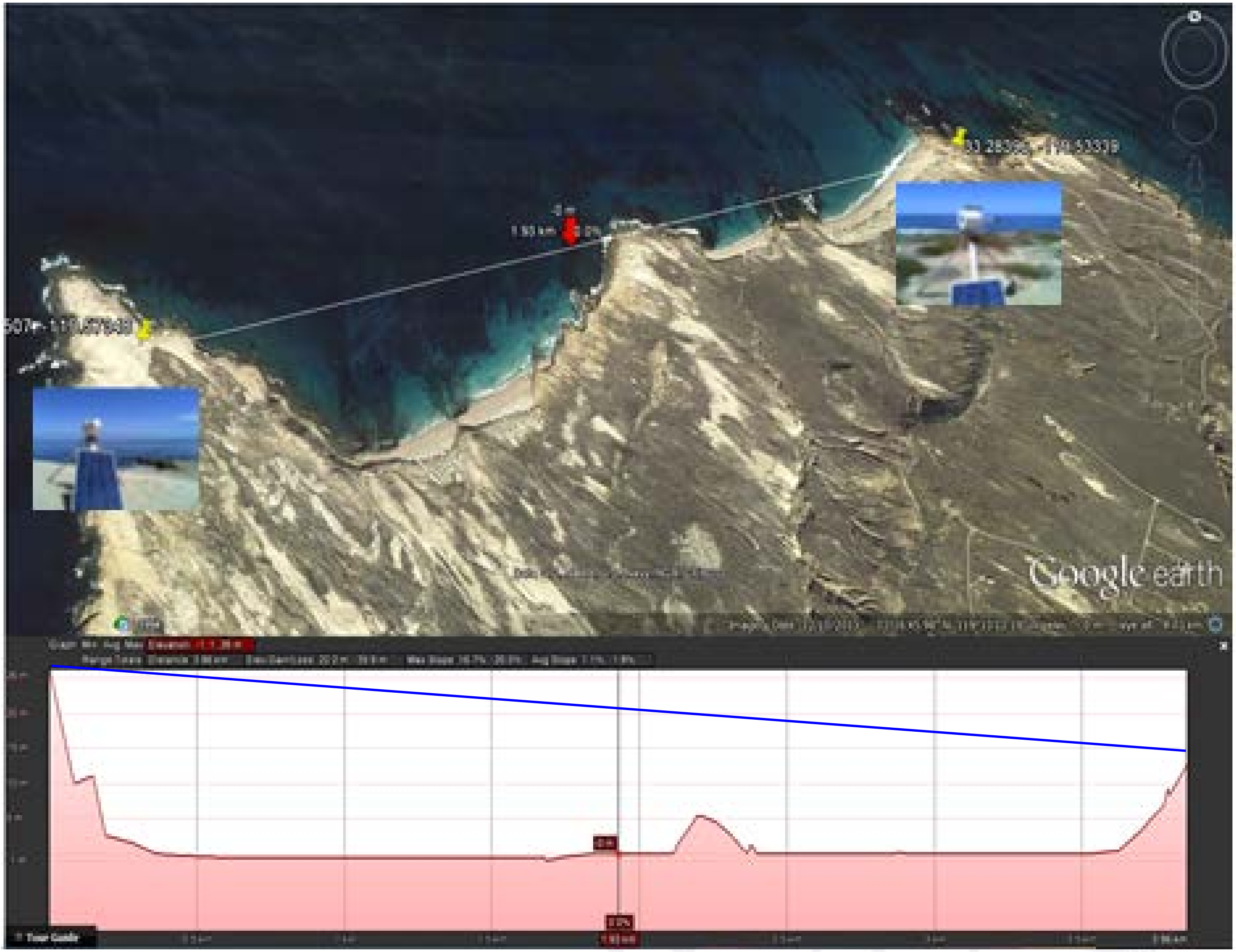
NAVAIR RANGES

San Nicolas Island Setup

BLS 2000 Scintillometer System set up across “Lazer Bay” on San Nicolas Island, approximate 3.9 km path.

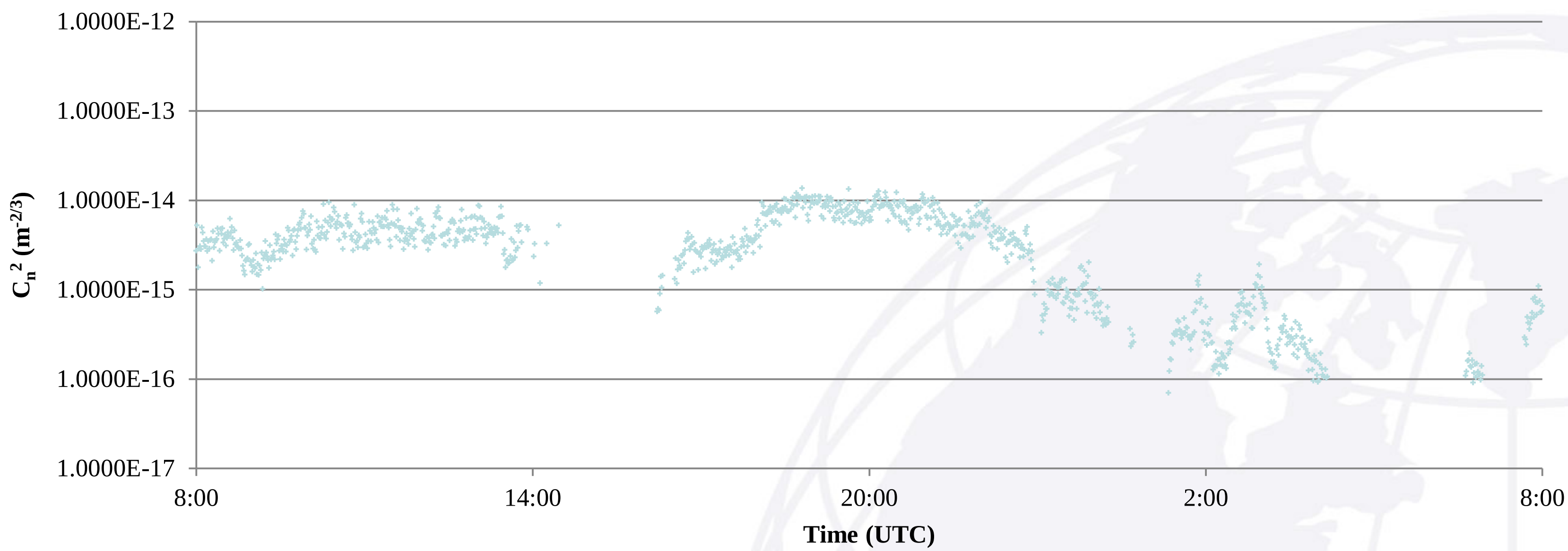
Measurement Path Geometry

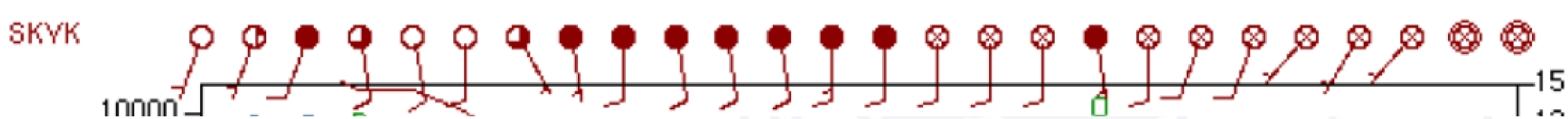
Measurement Path Elevation



Land Influence Data

07 Feb 2015 (Local)

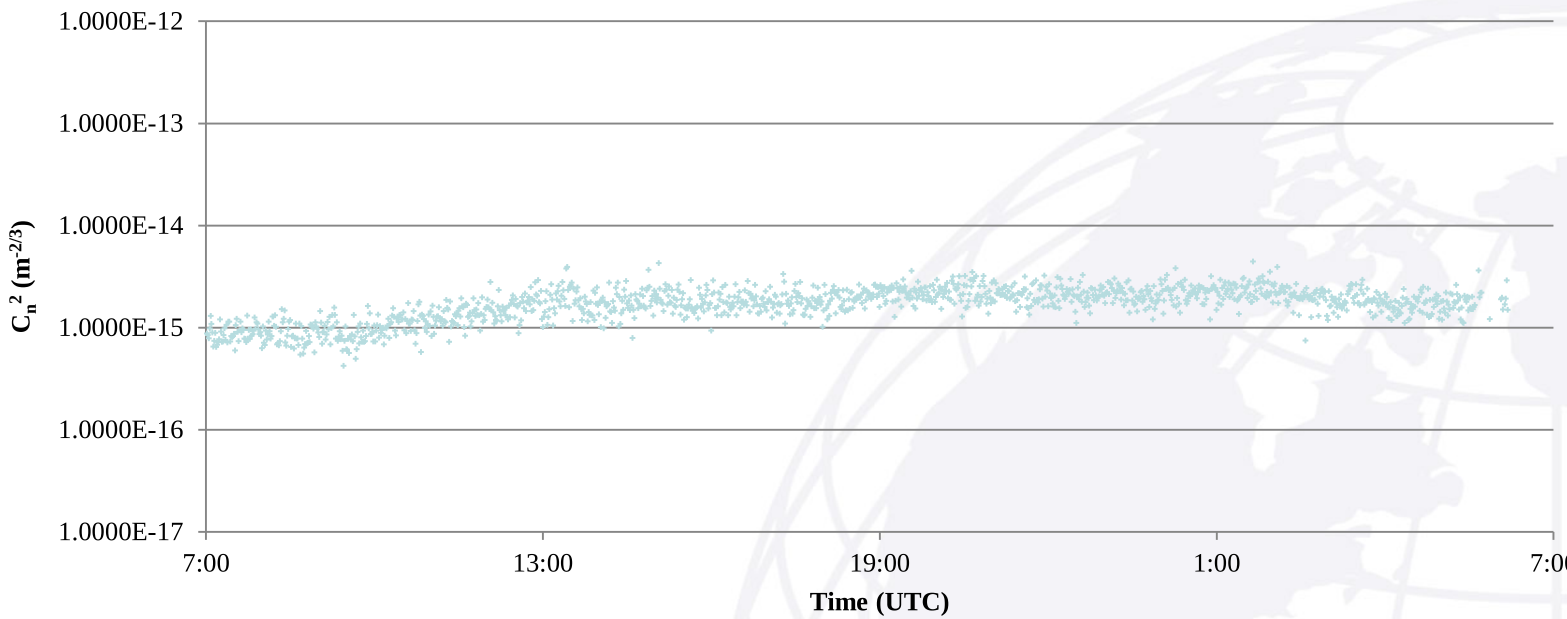


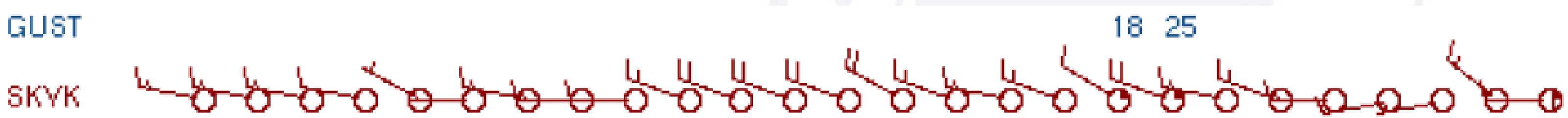


C_n^2 measurements integrated over the path with weighting toward the center (approximately 20m above the surface of the ocean)

“Near” Maritime Data

17 Aug 2014 (Local)





C_n^2 measurements integrated over the path with weighting toward the center (approximately 20m above the surface of the ocean)

Challenges

- Atmospheric optical turbulence effects are only part of propagation
- Limitations of the Scintec BLS 2000
- Range accessibility / geographical / environmental challenges

The Next Steps

- Compare to NPS C_n^2 model in collaboration with Peter Guest and Paul Frederickson
- Compare to other measurement and modeling methods in collaboration with Steve Fiorino, Kevin Keefer and Lee Burchett, AFIT
- Collaborate in modeling and measurements with Tariq Manzur of NUWC
- Collaborate in modeling and measurements with Steve Hammel of SPAWAR

Future Measurement Work

- Include other turbulence sensors in addition to the BLS 2000
  - Dual height scintillometer measurements
  - C_T^2 measurements
- Introduce sensor systems beyond turbulence
  - Transmissometers (Absorption/Extinction)
  - Profilers (Turbulence/Scattering)
  - Increased Weather Monitoring (Surface Temperature, Water Temperature Profile)
- Other propagation paths beyond Lazer Bay
  - San Nicolas Island to Santa Barbara Island?
  - Port Hueneme Oil Platforms?

Big Picture

- Synergies with other characterization work
  - Maritime Atmosphere Refraction Study (MARS)
  - Directed Energy Test Bed
  - Atmosphere Characterization Effort (ACE)
  - NUWC Measurements
- Collaboration
  - M&S Communities
  - HEL Test and Evaluation
  - Naval Postgraduate School Initiatives
- Opportunity to assess prediction capabilities with meteorological data that varies in availability and fidelity
- Characterization of a potential laser test range

Acknowledgements

- Robi Garcia, Kyle Edwards, Michael Saadati, Dan Addison, Don Wilson, Debra Mott and the NAVAIR-WD Sea Range Geophysics crew
- Grace Smith, Lisa Thomas and John Ugoretz, NAVAIR Range Sustainability
- Mike McHenry of the SNI Sea Test Range
- Terry Robinson - Navsea PHD
- NAVAIR & San Nicolas Island support

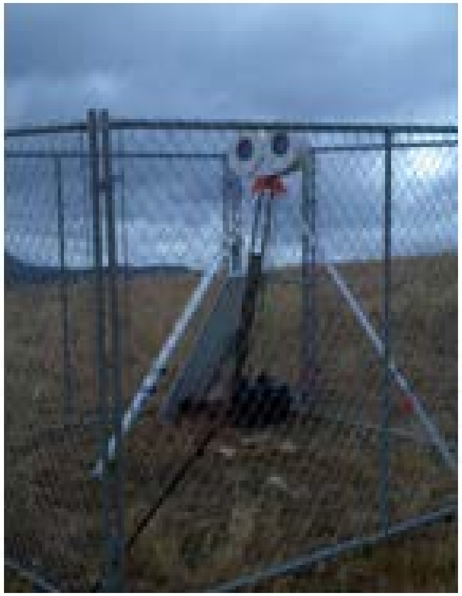
Conclusions

Combat Systems Engineering provides a solid framework for the design, development and realization of combat systems.

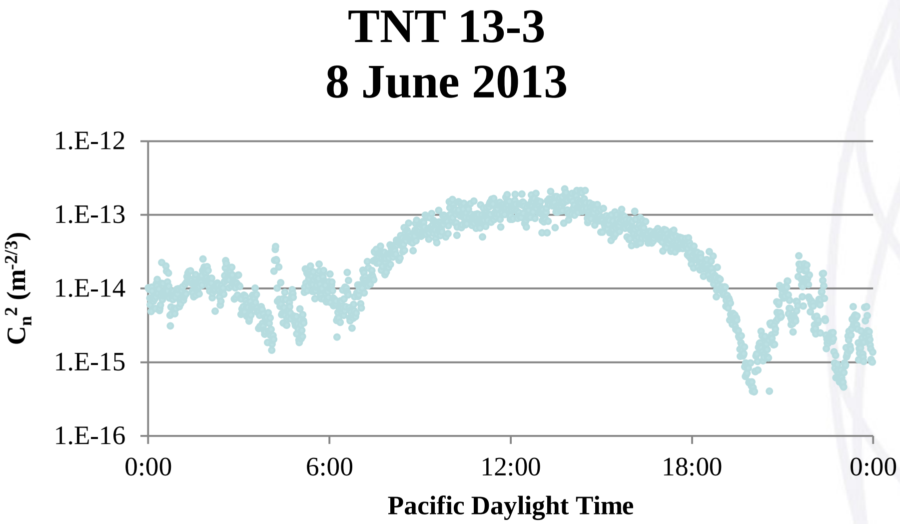
Student research in Systems Engineering at the Naval Postgraduate School is providing valuable insight into further development of the activities of combat systems engineering.

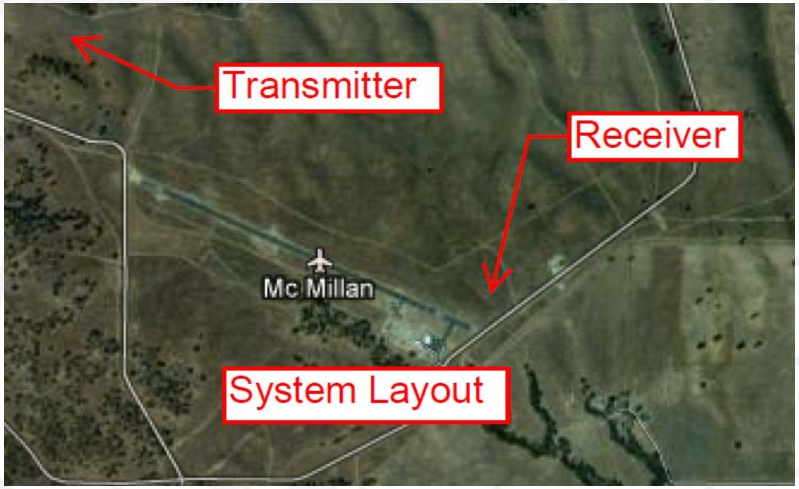
Questions?

Land Measurement – Camp Roberts



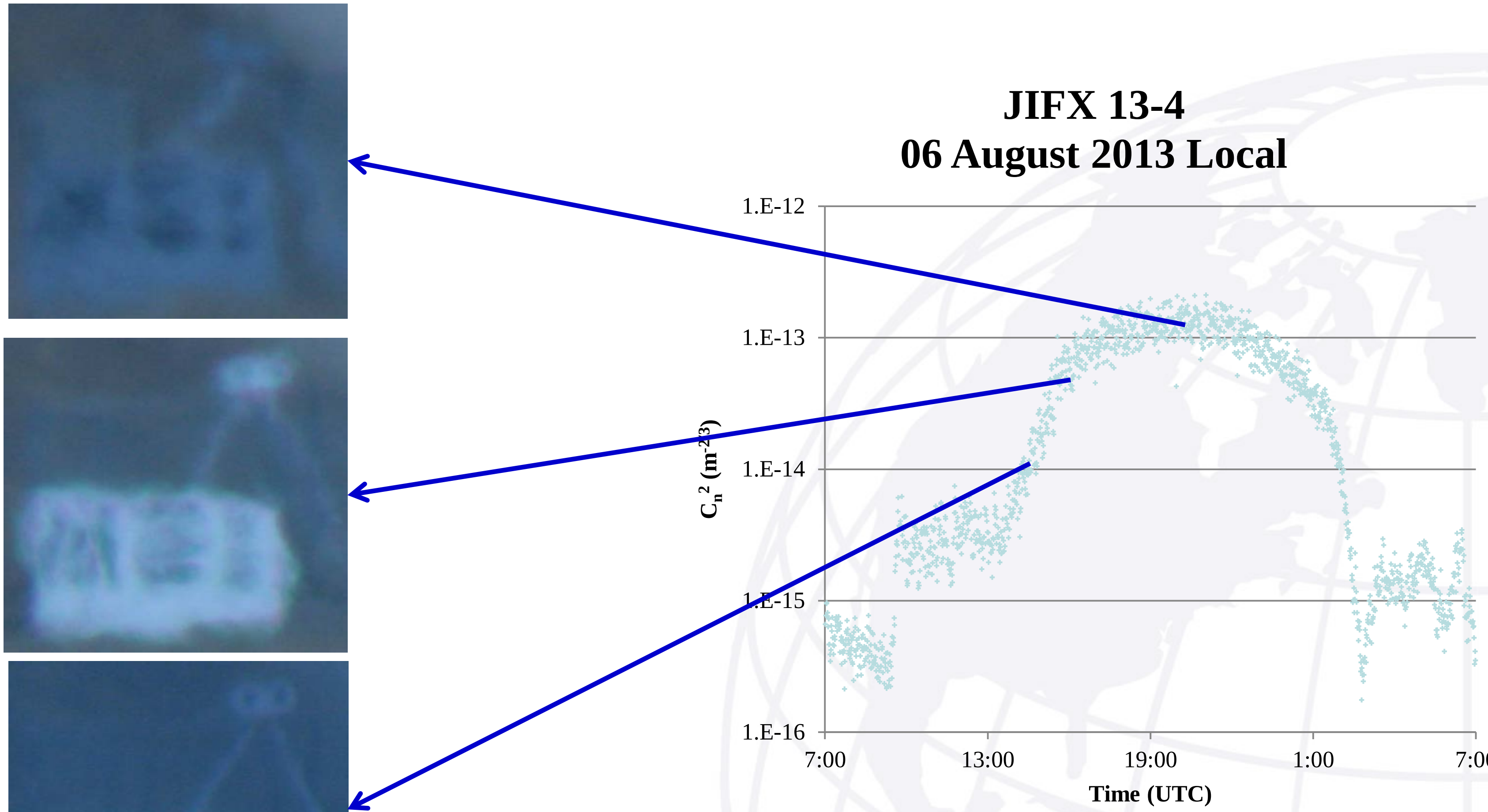
~ 1600+ m





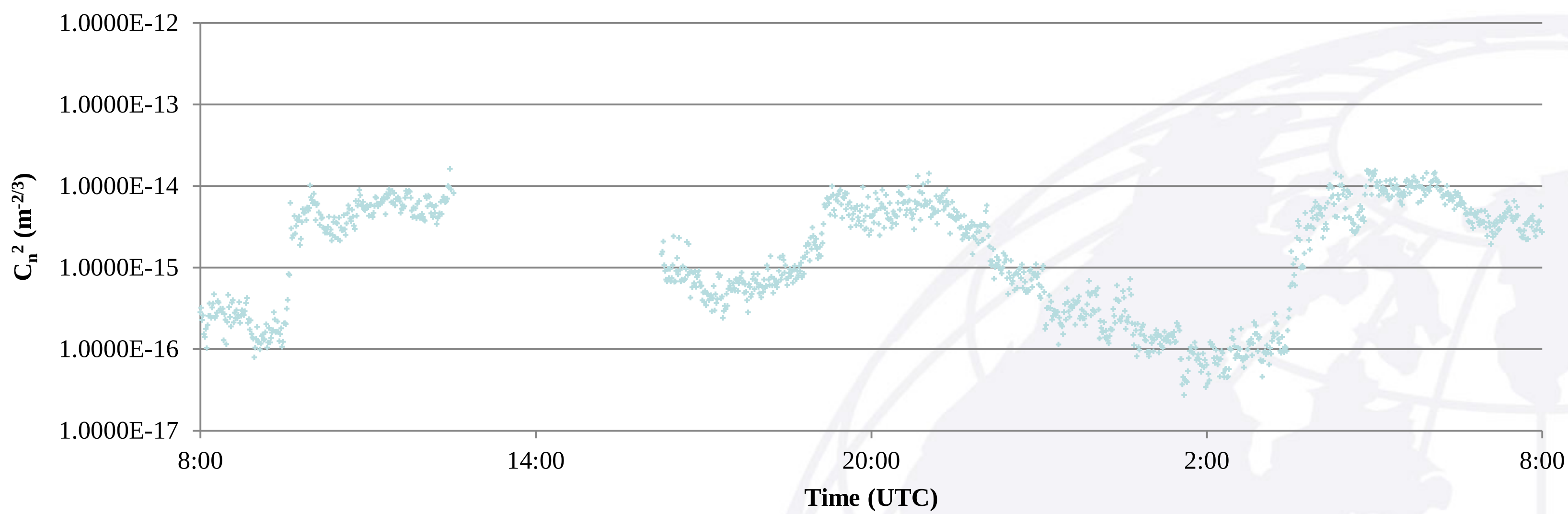
Target Board – JIFX 13-4

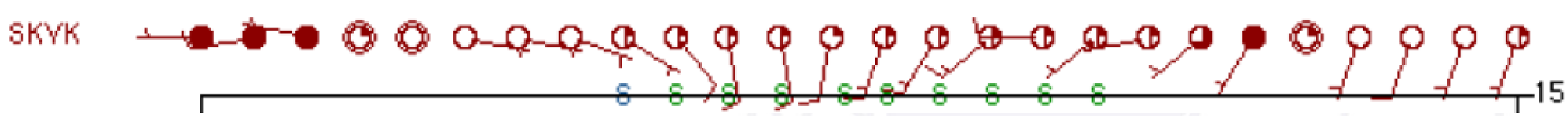
Photo Correlation



Partial Land Influence Data

06 Feb 2015 (Local)





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