

Recent Industry Applications of the CREATE Ships NESM Project

Weidlinger Associates[®], Inc.

HPC User Forum
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NESM



Acknowledgements

- ◆ **Naval Surface Warfare Center, Carderock Division**
- ◆ **Navy Small Business Innovation Research Program**
 - ◆ **SBIR Topic Number: N03-051**
 - ◆ **Contract Number: N00167-08-D-0026**

Overview

- ◆ **What is NESM?**
- ◆ **Who is Weidlinger Associates, Inc.**
- ◆ **Full-Ship Shock Trial Alternative Program**
- ◆ **How has the HPC made a difference**
 - ◆ **Source modeling non-explosive testing alternatives for the US Navy**
 - ◆ **UQ studies**
- ◆ **Key advantages of the HPC**

NESM

Navy Enhanced Sierra Mechanics

- ◆ **Physics-based capabilities to predict ship response to weapons effects**
- ◆ **Coupled media-structure interaction**
 - ◆ **DYSMAS / Gemini – fluid dynamics**
 - ◆ **Sierra Suite – structural dynamics**
 - ◆ **Standard Coupler Interface (SCI)**
- ◆ **Developed by**
 - ◆ **Naval Surface Warfare Center, Carderock**
 - ◆ **Naval Surface Warfare Center, Indian Head**
 - ◆ **Sandia National Laboratories**



Weidlinger Associates, Inc.

- ◆ **300+ engineering firm with 65 years experience**
- ◆ **Buildings, bridges, infrastructure, applied science**
- ◆ **Expertise**
 - ◆ **Design, analysis, testing, and qualification support for US navy systems to UNDEX**
 - ◆ **Integration of novel technology with M&S experience**
 - ◆ **Airgun technology**
- ◆ **Longstanding relationship with US Navy Agencies**
 - ◆ **NAVSEA, NSWCCD, NSWCIH, ONR**



First of Class Shock Trials

- ◆ **Ship tested prior to first refit**
- ◆ **Charges deployed in offshore tests**
- ◆ **Testing ties up ship and support facilities**
- ◆ **Live Fire Testing & Evaluation (LFT&E) requirement**
- ◆ **Trial total:
Tens of millions \$**



FSSTA Program Objective

- ◆ **Develop an affordable, technically sound process capable of replacing Full Ship Shock Trial at-sea testing that supports:**
 - ◆ **Validation of ship shock hardening and**
 - ◆ **Assessment of ship survivability to expected threats**



Seismic Airguns

- ◆ **COTS Technology**
 - ◆ **Non-explosive full-ship shock trial alternative for shock testing**
US Patent # 6,662,624
 - ◆ **Testing can be conducted rapidly, repeatedly in littoral environment, in any weather conditions**

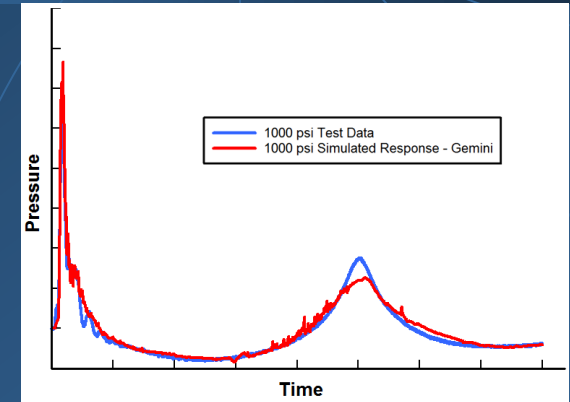


WAI Use of HPC

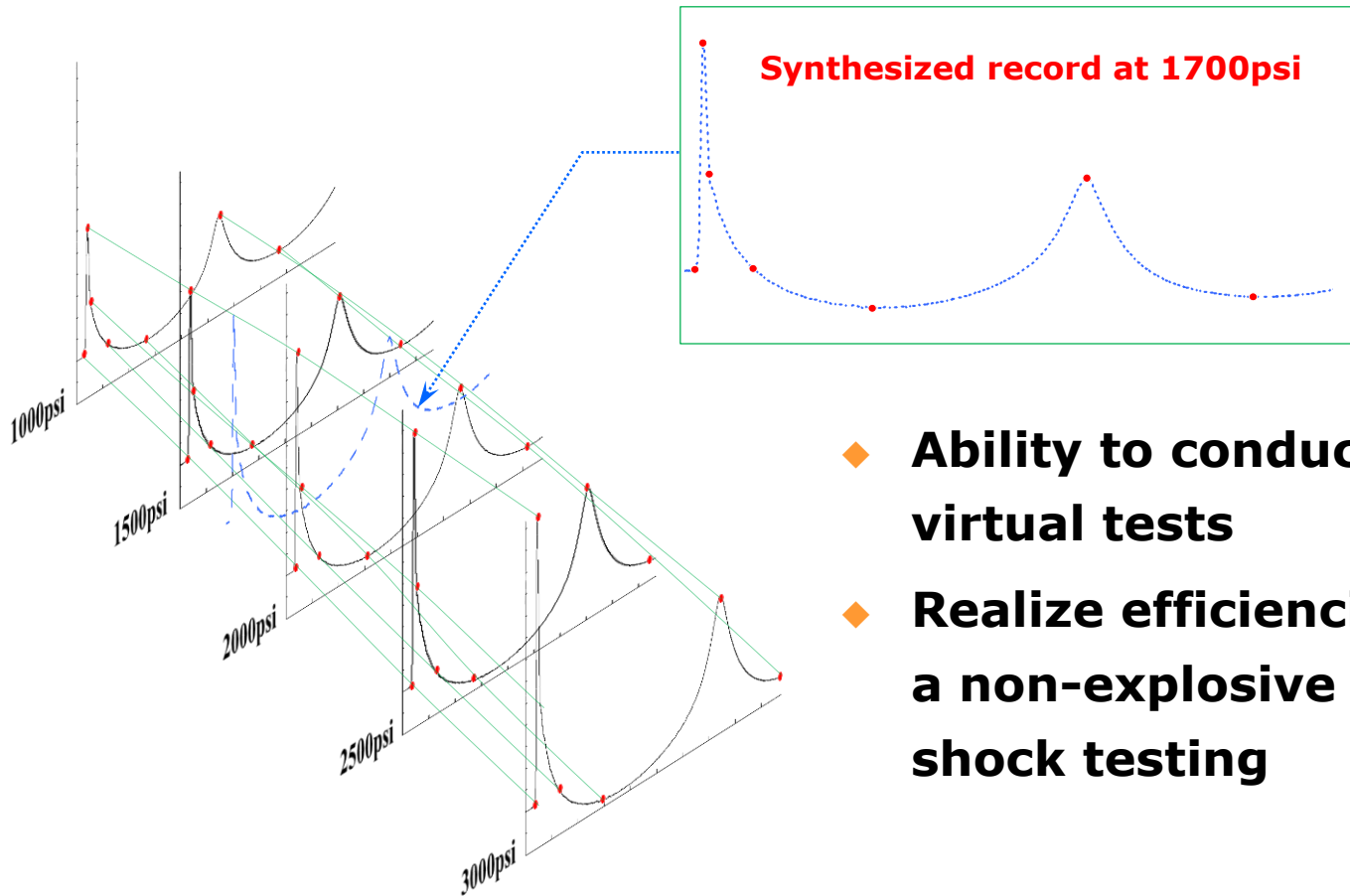
- ◆ **Airgun Source Modeling**
 - ◆ **Automated calibration of source loading parameters**
 - ◆ **Stochastic optimization algorithm**
- ◆ **Uncertainty quantification (UQ) studies**
 - ◆ **Coupled fluid-structure interaction simulations**
 - ◆ **Refined-Stratified Sampling - Bootstrap Monte Carlo (RSS/BMC) Methodology**
 - ◆ **Polynomial Chaos Expansion (PCE) methodology**

Airgun Source Modeling

- ◆ **Loading parameter calibration**
 - ◆ **Nonlinear inverse problem solving airgun bubble dynamics using pressure gage data**
 - ◆ **Propagation of candidate loading in fluid media**
 - ◆ **DYSMAS / Gemini**
- ◆ **Parameter optimization**
 - ◆ **Automated source model parameter optimization**
 - ◆ **Calibration algorithm compiled and executed on HPC**
 - ◆ **Capitalized on HPC compiler features**
 - ◆ **Capitalized on scripting options**



Source Model Calibration Motivation



- ◆ **Ability to conduct virtual tests**
- ◆ **Realize efficiencies of a non-explosive ship shock testing**

Automated Calibrations on HPC Platforms

- ◆ **Basic calibration statistics**
 - ◆ **Single source model calibration: 48,000 CPU hours**
- ◆ **Source model library development**
 - ◆ **10 sets of parameters**
 - ◆ **~0.5M CPU hours of unattended optimized calibrations**

**54 CPU years of calibrations
Conducted with Gemini
on HPC platforms: Harold¹, Diamond², Riptide³**

1. U.S. Army Research Laboratory
2. ERDC DoD Supercomputing Research Center
3. Maui HPCC



Uncertainty Quantification of Large Scale FE Simulations

- ◆ Full-scale coupled fluid-structure interaction simulations
 - ◆ Millions of elements and DOF
- ◆ Use of traditional Monte Carlo methods are intractable for quantifying uncertainty
 - ◆ Size/scale of coupled FSI response simulations exceed computational resources
- ◆ WAI implemented a methodology
 - ◆ Refined Stratified Sampling
 - ◆ Bootstrap Monte Carlo Simulation

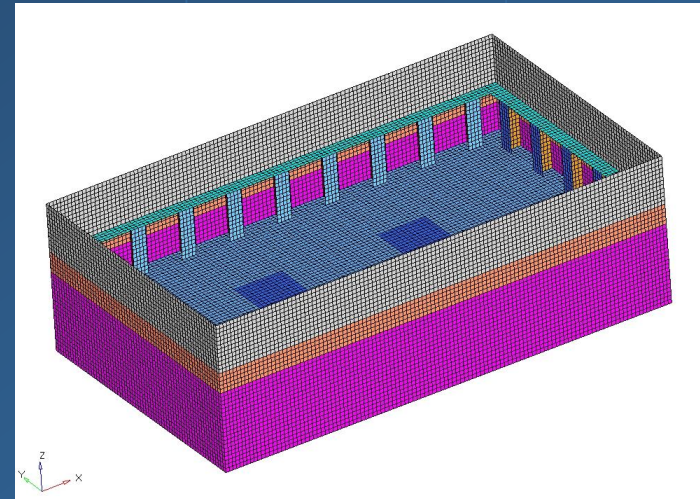
This methodology allows for an optimally small sample size given some desired level of statistical convergence

UQ Studies

- ◆ **WAI conducted 12 complete UQ studies performed in conjunction with 2012 test series**
- ◆ **Uncertain parameters in the UQ studies based on a pooling of practical Navy UNDEX and Airguns experience**

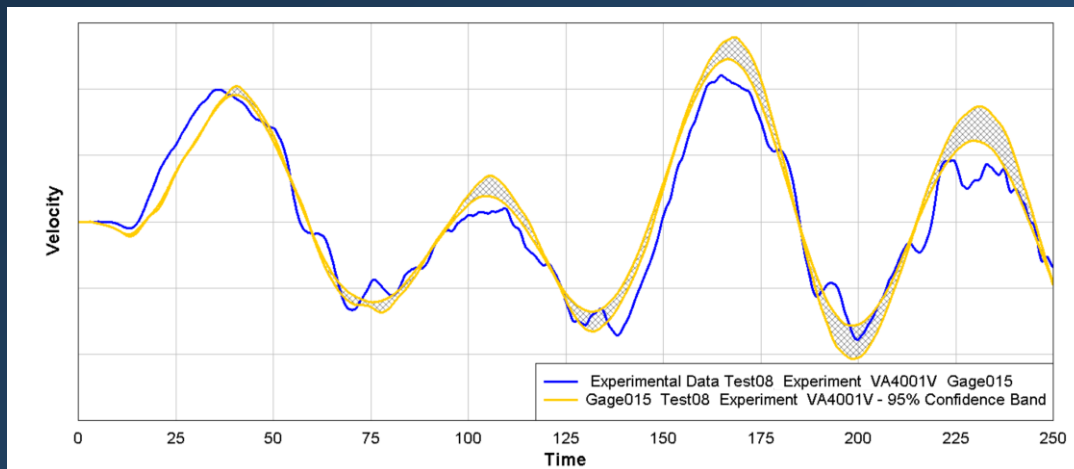


MIL-S-901D Heavyweight Shock Test

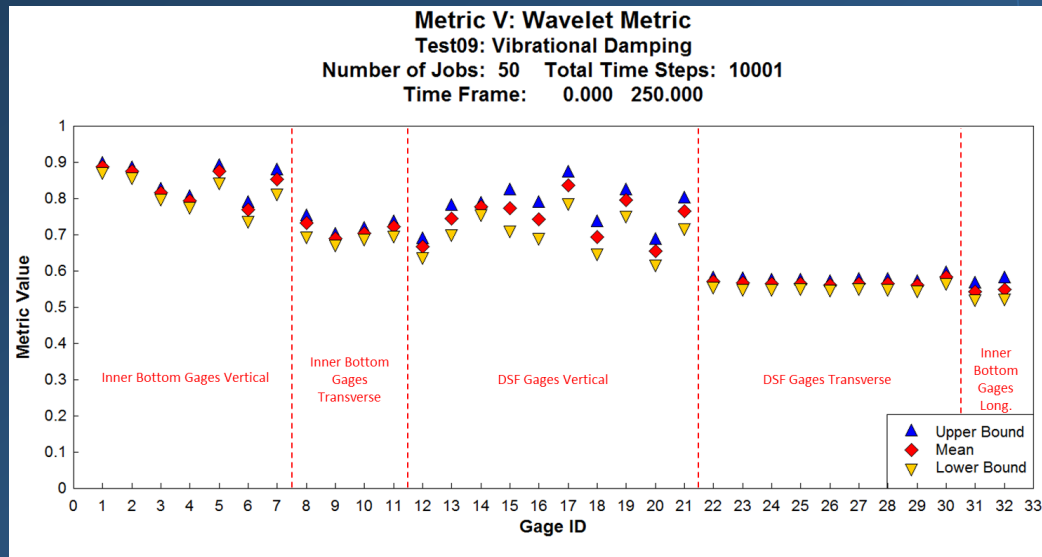


Floating Shock Platform (FSP)

Output Sought in UQ Studies



Confidence Bands
for Statistics of UQ
studies



Correlative Metrics –
“Goodness- of – Fit”

UQ Studies

- ◆ **WAI conducted 12 complete UQ studies**
 - ◆ **7 Airgun loading scenarios against a FSP**
 - ◆ **5 Underwater explosion scenarios against a FSP**

**410 fully-coupled simulations
Conducted with NESM
on HPC Platforms : Harold¹, Diamond²**

56 CPU-years of calculation time

1. U.S. Army Research Laboratory
2. ERDC DoD Supercomputing Research Center



Observations

- ◆ **HPC resources permit solutions to problems which were intractable a decade ago**
- ◆ **Critical asset for automated parallelized processes**

Key Benefits Offered by HPC

- ◆ Instrumental in helping WAI to deliver on Phase III SBIR contract
- ◆ Will realize savings in future test planning and test support

