Overview

- Current Arena Test Methodology
- Current Data Limitations
- T&E Need
- Use Case Variants
- AWETC Project Description
- Alternatives for Solutions Development
- Technology Development to Watch
- Project Status
Current Arena Test Methodology

- **Number of Fragments Captured**
  - 15% (40 ft. arena)
  - 200-3000 fragments per test captured
  - Weapon must be rotated and retested

- **Number of Tests Required**
  - Small Munitions (<100 lbs)
    - 3 Horiz, 2 Vert ⇒ $732K, 5 mo.
  - Large Munitions (>100 lbs)
    - 2 Horiz, 2 Vert ⇒ $779K, 5 mo.

- **Data Quality**
  - Methods STILL insufficient to:
    - Adequately assess Weapon Effectiveness (Lethality)
    - Prevent over-cautious Collateral Damage Estimation
Current Arena Data Limitations

For Each Polar Zone

50 Frags collected
Masses: ...

7 Velocities measured, no correlation
2500 fps, 3000 fps, ……., 4000 fps, 4500 fps
Which fragment generates which value? Unknown

Max CDE Range (r)
Distance at which largest mass can no longer pierce clothing and skin, assuming it starts at largest observed velocity (4500 fps)

2 Problems with Current Arena Data Acquisition:
Incomplete Data: 7 Velocities vs 50 Frags with 0 Correlation (Quality)
Insufficient Data: Celotex Coverage only captures 5-15% of frags (Quantity)
Weapon Effects Characterization

Current Arena Test Methods do not:
• Capture sufficient weapon fragmentation data (quantity)
• Capture the right fragmentation data (quality)
• Address unique fragmentation characteristics of newer low collateral damage warheads

Resulting In:
• Conservative weapon selection for selected target
• Re-engagement of target – increased risk

New Test Methodologies are Needed to:
• Determine more accurate CDE* distances
• Provide a measure of error on lethality/CDE distances

* - Collateral Damage Estimate
• **Requirement** - Collect sufficient data to properly evaluate weapon effectiveness
  
  • Fragment position over time
  • Fragment velocity vector – per fragment (speed/trajectory)
  • Physical Characterization – per fragment
One AWETC Use Case, Three Variants

- Small Warheads
  - ~10 lbs. NEE*
- Medium Warheads
  - ~100 lbs. NEE
- Large Warheads
  - ~1000 lbs. NEE

Variants based on JMEM**, Site Visits

* - Net Explosive Equivalent Weight
** - Joint Munitions Effectiveness Manual
AWETC Site Visit Summary

- **Aberdeen Test Center (ATC) – 21 Aug 2014**
  - Test Items: Grenades, 60/81/120mm mortars, 105 and 155mm artillery shells
  - Typical Arena Test Set-up: Square (12-15 ft. from munition to bundles)
  - Cameras: 6-7 (velocity measurements)
  - Primary Users: Army Modeling and Simulation Agency (AMSAA) and Army Research Laboratory (ARL)

- **Redstone Test Center (RTC) – 27 Aug 2014**
  - Test Items: Small tactical missiles
  - Typical Arena Test Set-up: 15 ft. radius
  - Cameras: Used for velocity measurements
  - Primary Users: MSIC and AMRDEC

- **China Lake (NAWC-WD) – 17 Sep 2014**
  - Test Items: Can test up to 2000 lbs.
  - Typical Arena Test Set-up: Round (10-50’ radius)
  - Cameras: Used for velocity measurements
  - Primary User: NAWC-WD
Small Warhead Use Case

- Based on JMEM Weapon Classes* (~10 lbs. Net Explosive Equivalent (NEE))
Medium Arena Test Set-up

Medium Weapon Test

- Medium Warhead Use Cases
  - Based on JMEM Weapon Classes (~100 lbs. NEE)

Distribution Statement A: Unlimited Distribution
Large Arena Test Set-up

- Large Warhead Use Cases
  - Based on JMEM Weapon Classes (~1000 lbs. NEE)
Project Description

➢ **Description**
  • Robust data collection system for arena testing
  • Supports warhead fragmentation characterization, calculation of collateral damage distances, lethality

➢ **Technical Objectives**
  • Match individual fragments to corresponding velocity vectors
  • Capability to calculate individual fragment characteristics
  • Reduce use of traditional capture medium

**Core Capabilities To Be Developed**

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<th>Capability 1</th>
<th>Capability 2</th>
<th>Capability 3</th>
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<td>➢ More complete coverage of the arena range (33% of the blast hemisphere)</td>
<td>➢ Ability to correlate individual fragments to their corresponding velocities; ability to determine characteristics such as size and shape on much larger number of fragments</td>
<td>➢ Ability to provide unprecedented robust source data to the Weapons Effectiveness Community</td>
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Alternatives for Solution Development

- **Radar**
  - Signal to noise ratio not favorable
  - Only large fragments (1-2 cm) can be detected
  - Large numbers of systems required for minimal capability
  - Prohibitively expensive (~$24M)

- **Acoustic and Shock Wave Detection**
  - Low TRL
  - Cannot determine fragment size
  - Imprecise location and velocity determination
  - Number of systems required and exposed to high-speed fragmentation environment drives a “disposable instrumentation” solution

- **Multi-Spectral Detection**
  - Multiple wavelength detectors show promise for the ability to look inside a fireball
  - Currently have insufficient data acquisition rates to capture data on individual fragments

- **Optical Solutions**
  - Cameras now possess sufficient resolution, frame rate, and shutter speeds
  - Algorithms now exist to process large amounts of video for determination of position over time, fragment size, and derivation of fragment mass

Distribution Statement A: Unlimited Distribution
Technology Development Efforts

- AWETC Task: Monitor Relevant S&T and SBIR Efforts

- Examples:
  - Fragment Tracking Algorithms
  - Collateral Effects – Secondary Debris
  - High Speed Stereo Shadowgraph Imaging
  - Blast Characterization: Visible and multi-band IR stereo tracking

Distribution Statement A: Unlimited Distribution
AWETC Project Status

- **Enhanced Solutions Phase**
  - All Tasks Complete

- **Phase 0**
  - Working to Gain “New Start” Status
  - Phase 0 work includes PMP*, Acquisition Strategy

- **Coordination**
  - Will continue working with service partners
  - Will maintain connection w/FIT and JTCG/ME

* - Project Management Plan

Distribution Statement A: Unlimited Distribution
BACK-UP
Types of Testing
- Less-than-lethal grenades
- 60/81/120mm mortars
- 105mm and 155 artillery shells
- Most recent testing of less-than-lethal grenades incorporating rubber balls as projectiles.
  - Requires swapping Celotex for foam board to capture “fragments”

Typical Arena Setup
- Square (12-15 feet)
- Setup employs 6-7 cameras, mainly for velocity measurement
- Velocity captured on opposite side of Celotex w/ cameras & modified flash panel setup

Typical Arena Test
- Majority of testing is tank rounds
  - Newest variants are generally multi-purpose (frag and penetrator.)
  - Occasionally frag packs are included with test munitions, but not common
  - Rounds are commonly scored or solid cased
Analysis

Frag Capture:
- Celotex primary for frag capture with 8’ high by 4’ thick bundles
- Fires are usually not a problem since detonation is not close enough to the bundles and/or the fragments aren’t hot enough to be a hazard

Fragment analysis (frag picking)
- Team is assembled under direction/careful oversight of lead fragment engineers
- Depending upon the density of the fragment spray, bundles (4’x8’x4’) can be scored at 1-2 per week or 1-2 per day

Velocity Measurement:
- Frags not expected to generate a flash as they penetrate membrane
  - Flash bulbs illuminate inside arena
  - Cameras outside the measurement membrane document light coming through
  - This timing gives average velocity from the detonation
- Membrane is typically naugahyde or paper (inside of membrane is normally coated with aluminum foil to increase amount of light seen when fragment passes through)
  - Paper allows visualization of smaller fragments
  - Significant advantage over velocity screens which must generally disregard velocity data after shock passage due to instrumentation damage

Primary Customers
- Anti-personnel analysts at Army Modeling & Simulation Analysis Agency (AMSAA)
- Army Research Laboratory (Military Operations in Urban Terrain)
- **Types of Testing**
  - Largely composed of small tactical missile work
  - Capability to perform testing up to and including 50 pounds of explosive equivalent
  - Large amount of sled track testing

- **Typical Arena Setup**
  - Setup is round (15 foot radius)
  - Velocity captured on opposite side of Celotex with cameras and flash panels
  - Pressure transducers used to evaluate shock for ~20% of testing
  - Typical setup uses high-speed cameras for data collection & for timing of flashes from flash panels
  - Fires in these setups are usually not a problem, since the detonation is not close enough to the bundles and/or the fragments aren’t hot enough to be a hazard

- **Typical Arena Test**
  - Small tactical missile work to include Hellfire, Javelin and Longbow -- capable of performing testing up to and including 50 pounds of explosive equivalent
Redstone Test Center
Analysis
- Frag Capture
  - Celotex is primary for fragment capture with 8’ high by 4’ thick bundles
- Fragment analysis (frag picking)
  - Team assembled under direction/careful oversight of lead fragment engineers
  - Frag picking and data analysis are done by the customers (MSIC and AMRDEC, using Dynetics as contract support)
- Velocity Measurement:
  - Velocity captured on opposite side of Celotex with cameras and flash panels
  - Flash panels are 1/15” to 1/8” steel or aluminum
  - As with flash panels in other locations, this yields average velocity per polar zone

Primary Customers
- Primary consumers//MSIC and AMRDEC, using Dynetics as contract support
Types of Testing
- Testing of any size munition up to #2000, but recent work has been primarily AIM-9 warheads (difference between Dahlgren & CL is that Dahlgren primarily handles shipborne gun munitions)
- Analysis group also evaluates dynamic testing data from sled tracks

Typical Arena Setup
- Setup is round (10-50’ radius)
- Celotex is primary for fragment capture 8’ high by 4’ thick bundles
- Occasionally, setups will include bundles up to 12’ in height
- Horizontal weapon tests are typically half Celotex and half flash panels, while verticals are 1/3 Celotex, 1/3 flash panel and 1/3 pressure transducers
- China Lake and Eglin have been the only sites that assess the strength and movement of the blast shock--China Lake does not typically take temperature data during arena tests
- Velocity captured using cameras and flash panels, much the same way as Redstone and Eglin
- Some tests use a spiral flash panel setup to get a better look at how fragment velocities change at different ranges from the blast
  - Relies on symmetry of blast, as no single fragment is tracked
  - Timing derived from flash panel instrumentation is consolidated into average velocity from the detonation for z-data file input
  - High speed cameras used to observe flashes and aid in determining average velocities
Types of Testing
- Testing of any size munition up to 3,000 NEE
  - Will go larger by exception

Typical Arena Setup
- Setup is round and 20’ - 80’ radius
  - Less than 20’ normally square
- Celotex is primary for fragment capture 16’ high by 4’ thick bundles with 2” of plywood behind
  - Supported by steel racks
- Horizontal weapon tests are typically 180° Celotex (no flash panels)
- Vertical weapon tests are typically 90° Celotex (no flash panels & generally no pressure transducers unless specifically requested)
- Normally use velocity screens (VALTS)
  - No flash panels unless specifically requested by customer
- China Lake & Eglin have been the only sites that assess strength/movement of the blast shock

Typical Arena Test
- Recent work has been primarily MK-82-size weapons
Analysis

- Done similarly to other services’ arenas
- Frag Capture
  - Celotex is primary for fragment capture
  - 16’ high by 4’ thick bundles with 2’ plywood backing (on steel stands)
- Fragment analysis (frag picking)
  - Team assembled under direction/careful oversight of lead fragment engineer
  - Frag retrieval capacity = 6 to 7 bundles per day, per crew (2 crews)
    - High density frags = 2 to 3 bundles per week, per crew (2 crews)
- Velocity Measurement
  - Velocity captured on opposite side of Celotex with cameras and flash panels
  - Flash panels are 1/15” to 1/8” steel or aluminum
  - As with flash panels in other locations, this yields average velocity per polar zone

Primary Customers

- Weapon Programs
# Key Performance Parameters

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<tr>
<th>Key Performance Parameter (KPP)</th>
<th>Threshold</th>
<th>Objective</th>
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<tr>
<td><strong>1. Fragment Tracking</strong></td>
<td>Minimum Fragment Size of Interest:</td>
<td>2 mm (all arena / weapon sizes) matched to individual velocity</td>
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<td></td>
<td>7 mm (large weapon test) matched to individual velocity</td>
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</tr>
<tr>
<td></td>
<td>5 mm (medium weapon test) matched to individual velocity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 mm (small weapon test) matched to individual velocity</td>
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<tr>
<td><strong>2. Fragment Velocity</strong></td>
<td>Up to 6000 fps</td>
<td>Up to 8,000 fps</td>
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<td><strong>3. Fragment 3D Position Error</strong></td>
<td>+/- 4% of distance from point of detonation to fragment measurement point</td>
<td>+/- 2% of distance from point of detonation to fragment measurement point</td>
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<td><strong>4. Arena Coverage</strong></td>
<td>33% of the upper hemisphere</td>
<td>50% of the upper hemisphere</td>
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