MSIAC Workshop 2018:
Improved Explosives and Munitions Risk Management

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- Unclassified workshop open at no cost to government, industry and academia representatives from all MSIAC member nations
- Limit of 70 participants almost reached
IEMRM workshop features:
- Sun: Welcome reception
- Mon: Plenary session
- Tue – Thu: Parallel sessions (focus areas) and plenary sessions (back briefs)
- Tue: Workshop dinner
- Wed: Visit to GDELS
- Fri: Conclusions

IEMRM preparations:
- 15 MSIAC papers and/or presentations
- 34 papers and/or presentations from participants
- MSIAC Sharefile repository with papers and references
- Webinar
- Site survey
Improved Explosives and Munitions Risk Management

This workshop seeks to exploit an improved understanding of munitions vulnerability and consequences to deliver improvements in munitions risk management.
Objectives

- **Support** the IM and HC harmonization initiative
  - Identify how response descriptors can be introduced in HC testing
  - Identify whether there’s a need for a revised definition of Hazard Divisions (HD) and Storage sub Divisions (SsD)

- **Develop** improved methods for explosives and munitions risk management
  - Exploit results from small- and full-scale testing
  - Manage risk with sufficient detail and granularity
  - Realize benefits of IM
  - Efficiently manage munitions presenting the greatest hazard

- **Recommend** improved methods for explosives and munitions safety risk standards
  - Ensuring they reflect the changing nature of the munitions stockpile
  - Balancing complexity versus ease of user application
**Workshop structure**

**Mon**
- Registration Welcome and Plenary Session

**Tue**
- 1A Improved HC and IM Assessment
- 1B Applicability of HD Assignment to Storage Part 1
- 2A Internal Blast and Debris
- 2B Fragmentation

**Wed**
- 1A Improved Criteria for HD Assignment Part 2
- 1B Applicability of HD Assignment to Storage Part 2
- 2C External Blast
- 2D Thermal Effects

**Thu**
- Implementation of IEMRM
- 3A Deployed Missions and Operations
- 3B Storage in Home Country
- 2E Probability of Event

**Fri**
- Conclusions and Way Forward

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1. Improved HC and IM Assessment
2. Improved Consequence and Risk Analysis
3. Implementation of IEMRM
Workshop structure

Mon
- REGISTRATION WELCOME AND PLENARY SESSION
- 1A IMPROVED CRITERIA FOR HC and IM Assignment Part 1
- 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE Part 1
- 2A INTERNAL BLAST AND DEBRIS
- 2B FRAGMENTATION

Tue
- 1A IMPROVED CRITERIA FOR HD ASSIGNMENT PART 1
- 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE PART 1
- 2A INTERNAL BLAST AND DEBRIS
- 2B FRAGMENTATION

Wed
- 1A IMPROVED CRITERIA FOR HD ASSIGNMENT PART 2
- 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE PART 2
- 2C EXTERNAL BLAST
- 2D THERMAL EFFECTS

Thu
- 3A DEPLOYED MISSIONS AND OPERATIONS
- 3B STORAGE IN HOME COUNTRY
- 2E PROBABILITY OF EVENT

Fri
- CONCLUSIONS AND WAY FORWARD
Current HC system loosely defines explosive effects

Differences in Hazard Divisions (HD) between nations possible

Q: Can IM test responses be introduced into HC assessment* and what would be the assessment criteria?

*this was already done for test series 7 used to classify HD1.6
### Improved criteria for HD assignment

#### Support for Munitions Safety

<table>
<thead>
<tr>
<th>Response Level Type</th>
<th>Energetic Materials (EM)</th>
<th>Case</th>
<th>Blast</th>
<th>Fragment or EM projection</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type I</strong> (detonation)</td>
<td>Prompt consumption of all EM once the reaction starts</td>
<td>(P) Rapid plastic deformation of the metal casing contacting the EM with extensive high shear rate fragmentation</td>
<td>(P) Shock wave with magnitude &amp; timescale — to a calculated value or measured value from a calibration test</td>
<td>Perforation, fragmentation and/or plastic deformation of witness plates</td>
<td>Ground craters of a size corresponding to the amount of EM in the munition</td>
</tr>
<tr>
<td><strong>Type II</strong> (partial detonation)</td>
<td>(P) Rapid plastic deformation of some, but not all, of the metal casing contacting the EM with extensive high shear rate fragmentation</td>
<td>(P) Shock wave with magnitude &amp; timescale &lt; than that of a calculated value or measured value from a calibration test</td>
<td>Perforation, plastic deformation and/or fragmentation of adjacent metal plates. Scattered burned or unburned EM.</td>
<td>Ground craters of a size corresponding to the amount of EM that detonated.</td>
<td></td>
</tr>
<tr>
<td><strong>Type III</strong> (explosion)</td>
<td>(P) Rapid combustion of some or all of the EM once the munition reaction starts</td>
<td>(P) Extensive fracture of metal casings with no evidence of high shear rate fragmentation resulting in larger and fewer fragments than observed from purposely detonated calibration tests</td>
<td>Observation or measurement of a pressure wave throughout the test arena with peak magnitude &lt;&lt; than and significantly longer duration that of a measured value from a calibration test</td>
<td>Witness plate damage. Significant long distance scattering of burning or unburned EM.</td>
<td>Ground craters.</td>
</tr>
<tr>
<td><strong>Type IV</strong> (deflagration)</td>
<td>(P) Combustion of some or all of the EM</td>
<td>(P) Rupture of casings resulting in a few large pieces that might include enclosures or attachments.</td>
<td>Some evidence of pressure in the test arena which may vary in time or space.</td>
<td>(P) At least one piece (casing, enclosure or attachment) travels beyond 15m with an energy level &gt; 20J based on the distance/mass relationship used for HC. Significant scattered burning or unburned EM, generally beyond 15 m.</td>
<td>(P) There is no primary evidence of a more severe reaction and there is evidence of thrust capable of propelling the munition beyond 15m. Longer reaction time than would be expected in a Type III reaction.</td>
</tr>
<tr>
<td><strong>Type V</strong> (burn)</td>
<td>(P) Low pressure burn of some or all of the EM</td>
<td>(P) The casing may rupture resulting in a few large pieces that might include enclosures or attachments.</td>
<td>Some evidence of insignificant pressure in the test arena.</td>
<td>(P) No item (casing, enclosure or EM) travels beyond 15m with an energy level &gt; 20J based on the distance/mass relationship used for HC.</td>
<td>(P) No evidence of thrust capable of propelling the munition beyond 15m. For a rocket motor a significantly longer reaction time than if initiated in its design mode.</td>
</tr>
<tr>
<td><strong>Type VI</strong> (no reaction)</td>
<td>(P) No reaction of the EM without a continued external stimulus. (P) Recovery of all or most of the unreacted EM with no indication of a sustained combustion.</td>
<td>(P) No fragmentation of the casing or packaging greater than that from a comparable inert test item.</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

**Primary evidence** (P), shown in Bold text, would almost always be observed and would be definitive of the reaction type.  
**Secondary evidence** could be observed, but its lack would not preclude that reaction type.

Note: (1) Fragment energy relationship shown in the Figure I-1

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NATO/PFP UNCLASSIFIED
Observations from MSIAC HC database

- HD1.5 and 1.6 absent
- SsD1.2.3 only 61 assignments

Current HD & SsD not an ideal representation of munitions stockpile

Q: Is it necessary to revise the definitions of HD and SsD and what would be the implications?
HC (UN orange book) for transport also adopted for storage

Confinement example: US propellant testing in reinforced concrete magazines, Farmer, et al. 2015
Applicability of HD to storage

Scaling example: 105 mm HE IM shells, Edwards (2011), single shell detonation (left), two shell detonation (right)

Q: Can we develop improved guidance to clarify the applicability of HC assessments?

Q: What complementary information (related to scale and confinement) is needed to make a reliable estimate of munitions response in storage conditions?

Q: What information from the explosive (storage) safety community is needed?

Q: What is a sufficient number of test repetitions?

Q: Are there best practices?
Workshop structure

**Supporting Munitions Safety**

**REGISTRATION WELCOME AND PLENARY SESSION**
- 1 Improved HC and IM Assessment
- 2 Improved Consequence and Risk Analysis

**TUESDAY BRIEFINGS**
- 1A Improved CRITERIA FOR HD ASSIGNMENT PART 1
- 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE PART 1
- 2A INTERNAL BLAST AND DEBRIS
- 2B FRAGMENTATION

**THURSDAY BRIEFINGS**
- 1A IMPROVED CRITERIA FOR HD ASSIGNMENT PART 2
- 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE PART 2
- 2C EXTERNAL BLAST
- 2D THERMAL EFFECTS

**FRIDAY BRIEFINGS**
- 3A DEPLOYED MISSIONS AND OPERATIONS
- 3B STORAGE IN HOME COUNTRY
- 2E PROBABILITY OF EVENT

**CONCLUSIONS AND WAY FORWARD**
Current risk management

Hazard Classification

AASTP-3

Guidelines for safe storage of ammunition

AASTP-1

Deployed operations:
Field Distances (FD)

AASTP-5

Home country:
Quantity Distances (QD)

Explosives Safety Risk Analysis

If these cannot be met:

AASTP-4

Detailed models

Complicated

Simple

Explosives Safety and Munitions Risk Management (ESMRM)

ALP-16

Hazard Identification

Risk Tracking

Risk Analysis

Risk Approval

Risk Control Plan

Continuous process
To be conducted by ESO
As Low As Reasonably Practicable (ALARP)
Level of authority for risk approval
**Quantity Distances**

- **Interior QDs**
  - Inter Magazine Distance (IMD)
  - Explosive Workshop Distance (EWD)
  - Intra Line Distance (ILD)

- **Exposed Sites (ES)**
  - Potential Explosion Site (PES)
  - Explosive Workshop Distance (EWD)
  - Inhabited Building Distance (IBD)

- **Exterior QDs**
  - Public Traffic Route Distance (PTRD)

- **Net Explosive Quantity (NEQ, Q)**
- **Maximum Credible Event (MCE)**
- **Compatibility Group (CG)**
  - A-N
- **Sensitivity Group (SG)**
  - SG1-SG5
- **Hazard Division (Storage Subdivision)**
  - HD1.1
  - HD1.2 (SsD1.2.1, SsD1.2.2, SsD1.2.3)
  - HD1.3 (SsD1.3.1, SsD1.3.2)
  - HD1.4
  - HD1.5
  - HD1.6

*Earth Covered Magazine (ECM)*

*Heavy Structure*

*Light Structure*
Consequence and risk analysis

Current models primarily available for (mass) detonations

Benefits of less violent munitions responses cannot always be exploited

<table>
<thead>
<tr>
<th>Munitions response descriptors (AOP-39)</th>
<th>Models available for consequence and risk analysis, e.g. AASTP-4?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Detonation</td>
<td>Yes</td>
</tr>
<tr>
<td>II Partial Detonation</td>
<td>Yes/No (fraction that will detonate uncertain)</td>
</tr>
<tr>
<td>III Explosion</td>
<td>No</td>
</tr>
<tr>
<td>IV Deflagration</td>
<td>No</td>
</tr>
<tr>
<td>V Burn</td>
<td>Yes</td>
</tr>
<tr>
<td>VI No Reaction</td>
<td>NA</td>
</tr>
</tbody>
</table>

Q: What experimental data and models are required to quantify consequences and risks based on the response descriptors, in particular for Deflagration (type IV) and Explosion (type III)?
Various sessions on:

- Internal blast and debris
- Fragmentation
- External blast
- Thermal effects
- Probability of event

840 g steel fragment from a M107 155 mm artillery shell that reached 1824 m after a sub-detonative response. (Baker)

Detonation in RC magazine (Applied Simulations, Inc)

High speed frame from Kasun test (Grønsten)

Klotz Group Engineering Tool v 1.5.3
Workshop structure

Mon

REGISTRATION WELCOME AND PLENARY SESSION

1 Improved
HC and IM Assessment

2 Improved
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Tue

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3 Implementation of IEMRM

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CONCLUSIONS AND WAY FORWARD
Increased granularity and detail more complex QD tables and consequence and risk analysis methods.

• In some areas this is very necessary, think about AASTP-5 where all munitions are to be aggregated as HD1.1. As a result benefits of any HD other than HD1.1 are currently not seen.
• In other areas (AASTP-1, already 100 pages of QD tables in current version) standards may become difficult to use. What is still acceptable?

Alternate approach: introduction of computer-based tools

• Easier application, less prone to error
• But also leads to a dependency on IT equipment which may be an issue e.g. during operations. Is this acceptable?
Munition-specific consequence and risk analysis

- Improves reliability of the results
- But limits range of applicability. Is this acceptable?

Development of holistic approach

- Cost and benefits of simplistic and conservative assessment methods versus more detailed quantitative assessment methods.
- Most suitable approach dependent on the lifecycle phase

Exploitation of smaller QDs and risks has issues:

- Reducing distances is often not possible (stationary infrastructure).
- Increasing quantities is also often not possible (in case of fully loaded storage buildings).
Conclusions

The envisaged results of the workshop are:

• Revised approach to munitions hazards and risks in light of development and introduction of IM

• Improved methods for consequence and risk analysis

• Improved understanding of the true nature of hazards and risks and how this can improve ownership and associated costs

See related presentation on Wednesday:
“Explosion Effects and Consequences from Detonations and Less Violent Munitions Response”
Questions?