MSIAC Engineering Tools and Databases

2009
Electronic Library 50,000+ references

- Technical Reports
- Journal Articles
- Points of Contact
  - >4,500
- Questions
- Accidents
- Books
- Presentations, Videos, Technical Software, etc...
- Company Literature

Products & Services are based on staff expertise, library, and Points of Contact
MSIAC Products - Tools & Databases

- Energetic Materials Compendium (EMC) – 1997
- Mitigation Methods for Munitions (M³) – 2000
- IM State-of-the-Art (IM SoA) – 2002
- Fragment Impact Database (FRAID) – 2002
- Gap Tests Information Worksheets (NEWGATES) – 2002
- Cost Benefit Analysis Model (CBAM) – 2003
- Safety Assessment Software (SAS) – 2005
- Bullet Impact Results Database (BIRD) – 2005
- Sympathetic Reaction Database (SYR) – 2007
- Cook-off Aggression Database (HEAT – Beta Version) – 2008
Energetic Material Compendium: EMC V3.4

- Current version (V3.4) released in April 2007
- Focus on adding more data and formulations (including current, in-service formulations)
  - >1000 formulations (~800 in V3.2)
  - >450 references (~350 in V3.2)
  - Double number of ingredient datasheets
- New IM suppliers catalog
- Inclusion of NEWGATES and BIRD
- NATO AOP-26 Ed 2
- Updated version of FRAID

345 ‘registered’ users

MSIAC Ingredients Data Sheets

New Datasheets can be downloaded from the internet
Information Included in EMC

Database Browsing

Name: B-2214
Lookup Formulation: B-2214

References for Selected EM:

UIN 10
Title: The interest of Cast Platic Bonded High Explosives for Inensitive Munitions: State of the Art at SNPE
Authors: Isler, J.
Journal or Proceedings: International Seminar on the Defense Technology, Pakistan
Date: December 1991
Volume: N/A
Page Number(s): N/A

INFORMATION RESERVED FOR MSIAC NATIONS ONLY
Mitigation Methods for Munitions - M³

A compendium of technologies/techniques for mitigating the hazard presented by munitions

- Version 1.04 was released in 2005
  - Increase in the number of examples
  - More and improved quality images (75% more)
  - 20% more references used
- Enhanced search capability and key wording
- Review of all data to eliminate inconsistencies
- 61 days have been devoted to developing an updated version of M3 in 2008
- 165 registered users
Mitigation Methods for Munitions - M³

Sympathetic Reaction Of Adjacent Munitions

Search In M³ For Potential Design Solutions

Input Component

Input Configuration

Input Threat

MUNITION

PACKAGED

SYMPATHETIC REACTION
Mitigation Methods for Munitions - M³

Using buffers to mitigate shock/impacts and prevent sympathetic detonation (storage facilities or containers).

Example 9 of 18
(For the method shown above)

Use of pumice as a buffer material. Pumice is a foamed volcanic glass (also defined as a white volcanic rock with no odour) that comes from granitic volcanoes. Pumice is a relatively lightweight, porous, shock absorbing material which can be mixed with a binder to provide a castable composite. It can be used to absorb the dynamic shock of an explosion and prevent sympathetic detonation of adjacent munitions. A series of tests were conducted on a variety of munitions (155-mm Comp B filled projectiles, MK-82 and MK-84 bombs) to evaluate the feasibility of using a pumice-filled container as a barrier to prevent sympathetic detonation and propagation. Most of the large tests were conducted using pumice in its natural form with no bonding material. The munitions were placed inside a container and surrounded by pumice. When a bonding agent was used, the agent served to shape the pumice and hold it in place within the container. Both methods proved effective for preventing sympathetic detonation. [47] [220]
• Large fragment impact database (~1700 results)
  • Wide range of
    ▪ explosive compositions
    ▪ munitions
    ▪ tested parameters

FRAID

Fragment Impact Database

Version 1.8

Problems/Questions: MSIAC or Pierre-François Péron
Phone: +32-2-707-5416 or +32-2-707-5426
Email: msiac@msiac.nato.int
      or p-fperon@msiac.nato.int

V1.8 released in December 2007

<table>
<thead>
<tr>
<th>Version</th>
<th>Number of compositions</th>
<th>Number of results</th>
<th>Number of references</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1.8</td>
<td>86+Systems</td>
<td>1716</td>
<td>136</td>
</tr>
</tbody>
</table>
Fragment Impact Database - FRAID

- Tests:
  - Scale 1 (Full Scale)
  - Small scale
  - Numerical simulations

- Covered and bare configurations

- Different types of impactors

- Variation in angle of incidence
# FRAID Datasheet Examples

## TETRYL

### Steel

<table>
<thead>
<tr>
<th>EXPLOSIVE</th>
<th>COVERING-CASING</th>
<th>PROJECTILE</th>
<th>RESULTS</th>
<th>REMARKS</th>
<th>REFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>density (g/cm³)</td>
<td>process</td>
<td>state</td>
<td>thickness (mm)</td>
<td>diameter (mm)</td>
<td>length (mm)</td>
</tr>
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<td>1.5</td>
<td>porous</td>
<td>solid</td>
<td>2.54</td>
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<td>-</td>
</tr>
<tr>
<td>1.54</td>
<td>-</td>
<td>solid</td>
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<td>76</td>
<td>76</td>
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<td>1.52</td>
<td>-</td>
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<td>2.68</td>
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<td>solid</td>
<td>6.35</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>1.48</td>
<td>pressed</td>
<td>solid</td>
<td>7.8</td>
<td>136</td>
<td>30</td>
</tr>
</tbody>
</table>

**Flat projectile (tetryl covered with steel)**

- Detonation threshold: 7.62 mm - ref. 23
- Detonation threshold: 12.7 mm - ref. 23
- Detonation threshold: 12.7 mm - ref. 4

**Diagram:**

- Fragmentation and blast shielding
- Explosive
- Cover
- Standoff tube
- Detonator
- Film and Casings
- MRL 36 mm shaped charge
- Bow shock initiation

**Reference 21**
Bullet Impact Results Database: BIRD

- Current Version (V1.2) released in December 2007
- Large database of BI results (>2300)
  - wide range of composition
  - wide range of systems
  - fully searchable
- Comes with a Generic Testing Vehicle Database

<table>
<thead>
<tr>
<th>Version</th>
<th>5.56mm</th>
<th>7.62mm</th>
<th>12.7mm</th>
<th>14.5mm</th>
<th>20mm</th>
<th>25mm</th>
<th>30mm</th>
<th>Ref.</th>
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</thead>
<tbody>
<tr>
<td>V1.2</td>
<td>21</td>
<td>1194</td>
<td>1035</td>
<td>2</td>
<td>38</td>
<td>0</td>
<td>46</td>
<td>141</td>
</tr>
</tbody>
</table>
SYmpathetic Reaction Database - SYR

- Excel database
- > 650 results
- Wide range of
  - explosive compositions
  - munitions / barriers
  - tested parameters
- Fully searchable

SYR v1.2 released in December 2008

<table>
<thead>
<tr>
<th>Version</th>
<th>Number of compositions</th>
<th>Number of results</th>
<th>Number of references</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>101</td>
<td>670</td>
<td>109</td>
</tr>
</tbody>
</table>

Problems/Questions: MSIAC or Pierre-François PERON
Phone: (+32) 2 707 54 16 or (+32) 2 707 54 26
Email: msiac@msiac.nato.int
or p-f.peron@msiac.nato.int
### SYR – Database Content

<table>
<thead>
<tr>
<th>Donor (D) and Acceptor (A) Charge Features</th>
<th>Mitigation</th>
<th>Test Setup</th>
<th>Results</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energetic Material</td>
<td>External Diameter (mm)</td>
<td>Case Thickness (mm)</td>
<td>Case Length (mm)</td>
<td>Case Material</td>
</tr>
<tr>
<td>GTU</td>
<td>PXE0-159 (Dynex RDx)</td>
<td>120.85</td>
<td>9.53</td>
<td></td>
</tr>
<tr>
<td>GTU</td>
<td>PXE0-159 (ADT RDx)</td>
<td>120.85</td>
<td>9.53</td>
<td></td>
</tr>
<tr>
<td>GTU</td>
<td>PXE0-159 (Dynex RDx)</td>
<td>120.85</td>
<td>9.53</td>
<td></td>
</tr>
<tr>
<td>GTU</td>
<td>PXE0-159 (Dynex RDx)</td>
<td>120.85</td>
<td>9.53</td>
<td></td>
</tr>
<tr>
<td>GTU</td>
<td>PXE0-159 (Dynex RDx)</td>
<td>120.85</td>
<td>9.53</td>
<td></td>
</tr>
<tr>
<td>IOS 70M1 shell</td>
<td>Comp 8 (D)</td>
<td>105</td>
<td>17.10</td>
<td>-</td>
</tr>
<tr>
<td>4.5&quot; NS6</td>
<td>Roman 1100</td>
<td>114.3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>60 mm MAPM</td>
<td>PXE0-110</td>
<td>50</td>
<td>10</td>
<td>153 resin and ø 4 mm steel spheres</td>
</tr>
<tr>
<td>LU-211M</td>
<td>X13339</td>
<td>165</td>
<td>16.4</td>
<td>16.8</td>
</tr>
<tr>
<td>LU-211M</td>
<td>X13339</td>
<td>165</td>
<td>16.4</td>
<td>16.8</td>
</tr>
</tbody>
</table>
**SYR – Application Example**

- **Influence of mitigation width on munition response**
  - 127 mm US Navy shells filled with Composition A3
  - Steel mitigation - 38 mm or 76 mm width
  - Shell response evaluation for various mitigation thickness

<table>
<thead>
<tr>
<th>Lateral dimensions (mm)</th>
<th>Thickness (mm)</th>
<th>Number of detonation results/Number of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 mm</td>
<td>3</td>
<td>0/4</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0/1</td>
</tr>
<tr>
<td></td>
<td>9.5</td>
<td>0/1</td>
</tr>
<tr>
<td>76 mm</td>
<td>3</td>
<td>2/3</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>2/4</td>
</tr>
<tr>
<td></td>
<td>9.5</td>
<td>0/3</td>
</tr>
</tbody>
</table>
Shaped Charge Impact Database - DARTS

- Excel database
- Additional databases on
  - Shaped charges
  - Generic test units
- Pictures describing the setup and the results for most reported tests
- Fully searchable

V1.0 to be released in May 2009

<table>
<thead>
<tr>
<th>Version</th>
<th>Number of compositions</th>
<th>Number of results</th>
<th>Number of references</th>
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</thead>
<tbody>
<tr>
<td>Beta</td>
<td>18</td>
<td>50</td>
<td>10</td>
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</tbody>
</table>

DARTS

Database of Ammunition Reaction Trials to Shaped Charge Aggression

Version Beta

Problems/Questions: MSIAC or Pierre-François PERON
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Email: msiac@msiac.nato.int or p-f.peron@msiac.nato.int

2008
Database Searching Tool

- Available databases for all IM tests in 2009
- Another database related to gap test results (NEWGATES)
- All databases in Excel format with similar architectures

Next step
- Development of a search tool to gather quickly information available in all the databases
- Search with one or several keywords, headings
- Results in an Excel workbook (one or several worksheet per database)
Toolbox of Engineering Models for the Prediction of Explosive Reactions (TEMPER)
• MSIAC in conjunction with DGA (French MOD) have been offering access to a French software program called TEMPER.

• A library of empirical and analytical models dedicated to ammunition safety. It has the potential to become a reference tool if resources allocated.

• MSIAC acts as a focal point to ensure coherence and availability. Users can develop custom models or enhance existing ones.

• TEMPER is flexible to afford multiple developers and therefore save time and money.

• TEMPER is documented to ensure ease of further developments and ensure consistency.

• TEMPER main features include:
  - Library of threats, models and parameters to run the models
  - Ability to select threat/mitigation/structure/model
  - Ability to perform parametric or stochastic simulation:
  - Ability to draw curves and save results
Example of Database Use for Engineering Work

- PBXN-110 has been selected as a candidate for the development of a new warhead with a steel envelop.
- Which IM level can be achieved with this explosive?
## Example of Database Use for Engineering Work

### Table:

<table>
<thead>
<tr>
<th>Substance</th>
<th>mmoI</th>
<th>CB</th>
<th>S</th>
<th>Gap length</th>
<th>Incident Initiation Pressure (GPa)</th>
<th>Critical Initiation Pressure (GPa)</th>
<th>&gt;</th>
<th>Number of cards</th>
<th>Gap length (mm)</th>
<th>Incident Initiation Pressure (GPa)</th>
<th>Critical Initiation Pressure (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBXN-110</td>
<td>1.60</td>
<td>2.470</td>
<td>1.270</td>
<td>7.0</td>
<td>3.3</td>
<td>2.541</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110</td>
<td>1.60</td>
<td>2.470</td>
<td>1.270</td>
<td>7.0</td>
<td>3.3</td>
<td>2.541</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110 (Dyno RS-H100)</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110 (Dyno)</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>PBXN-110 (Bolos)</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110 (HNAP)</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110 (HNAP-6 months old)</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110 (HNAP-6 months old)</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PBXN-110 (HNAP-6 months old)</td>
<td>1.60</td>
<td>1.906</td>
<td>2.700</td>
<td>16.0</td>
<td>2.7</td>
<td>3.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Example Data:

#### 60 mm MAPAM
- **Munition**: PBXN-110
- **Energetic Material**: MAPAM
- **External Diameter (mm)**: 60
- **Case Thickness (mm)**: 10
- **Case Length (mm)**: 153
- **Case Material**: Plastic resin and 34 mm steel sheath
- **Mitigation**: Not indicated or close
- **Test Set Up**: One on Many Buried
- **Configuration**: Undetermined
- **Inhalation Mechanism**: LV
- **Reaction Type**: 14

---

### Diagram:

**12.7 mm bullet impact**

#### Tested System

<table>
<thead>
<tr>
<th>System Designation</th>
<th>Count of Test</th>
<th>Tested Rem.</th>
<th>Config.</th>
<th>Aim Point Design.</th>
<th>Energetic Material at Aim Point</th>
<th>Case Distance at Aim Point (mm)</th>
<th>Case Material at Aim Point</th>
<th>Design</th>
<th>Yo (m/s)</th>
<th>Y Impact (m/s²)</th>
<th>Burst or Expl.</th>
<th>Burst Time (sec)</th>
<th>Prog.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2R90 Direct Hit</td>
<td>US</td>
<td>V</td>
<td>B</td>
<td>Varyed</td>
<td>MAPAM</td>
<td>180</td>
<td>Steel</td>
<td>AP</td>
<td>-</td>
<td>+600</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2R90 Direct Hit</td>
<td>US</td>
<td>V</td>
<td>R</td>
<td>Varyed</td>
<td>MAPAM</td>
<td>180</td>
<td>Steel</td>
<td>AP</td>
<td>-</td>
<td>+600</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2R90 Direct Hit</td>
<td>US</td>
<td>V</td>
<td>R</td>
<td>Varyed</td>
<td>MAPAM</td>
<td>180</td>
<td>Steel</td>
<td>AP</td>
<td>-</td>
<td>+600</td>
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<td>-</td>
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<tr>
<td>2R90 Direct Hit</td>
<td>US</td>
<td>V</td>
<td>R</td>
<td>Varyed</td>
<td>MAPAM</td>
<td>180</td>
<td>Steel</td>
<td>AP</td>
<td>-</td>
<td>+600</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

---

### Other

- **Reaction Level**: 1
### Example of Database Use for Engineering Work

#### Determination of Jacobs-Roslund Model Parameters

- **Steel Flat Projectiles (Steel Covered ROWANEX-1001)**

<table>
<thead>
<tr>
<th>Steel Thickness (mm)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>900</td>
</tr>
<tr>
<td>1.0</td>
<td>1000</td>
</tr>
<tr>
<td>1.2</td>
<td>1100</td>
</tr>
<tr>
<td>1.3</td>
<td>1200</td>
</tr>
<tr>
<td>1.4</td>
<td>1300</td>
</tr>
<tr>
<td>1.5</td>
<td>1400</td>
</tr>
<tr>
<td>1.6</td>
<td>1500</td>
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<td>1.7</td>
<td>1600</td>
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<td>1.8</td>
<td>1700</td>
</tr>
<tr>
<td>1.9</td>
<td>1800</td>
</tr>
<tr>
<td>2.0</td>
<td>2000</td>
</tr>
</tbody>
</table>

- **Test Procedure**:
  - Detonation - 13.15 mm diameter
  - Detonation - 20 mm diameter

#### System Information

<table>
<thead>
<tr>
<th>System Name</th>
<th>System Designation</th>
<th>Class</th>
<th>Tested Item</th>
<th>Tested Item Design</th>
<th>Caliber (mm)</th>
<th>Energetic Material</th>
<th>Burst of Single</th>
<th>Proc.</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
<th>NR</th>
<th>Other</th>
<th>Ref</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65mm Mortar</td>
<td>MAPAM</td>
<td>MGA</td>
<td>AUR</td>
<td></td>
<td>60</td>
<td>RDXN-110</td>
<td>S</td>
<td>2102B</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>AMFAM</td>
<td>120A</td>
<td>ARV</td>
<td>F</td>
<td>VOCH-41/86/8-Mod-9</td>
<td>127</td>
<td>RDXN-110</td>
<td>B</td>
<td>2102B</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>2504</td>
<td>2530</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Determination of Jacobs-Roslund Model Parameters

- Detonation - 13.15 mm diameter
- Detonation - 20 mm diameter
- Jacobs-Roslund 13.15 mm
- Jacobs-Roslund 20 mm

---

**Detonation**
- No detonation
- Jacobs-Roslund 13.15 mm
- Jacobs-Roslund 20 mm

---

**Steel Thickness (mm)**

- Detonation
- No detonation

---

**Velocity (m/s)**

- 800
- 900
- 1000
- 1100
- 1200
- 1300
- 1400
- 1500
- 1600
- 1700
- 1800
- 1900
- 2000
- 2100
Example of TEMPER Simulation Result with FRAID Input Data

Use of Jacobs-Roslund model parameters to estimate fragment detonation threshold

- Jacobs-Roslund Vlim : Dimension - Velocity - Cover Plate Thickness = 0.014
- Jacobs-Roslund Vlim : Dimension - Velocity - Cover Plate Thickness = 0.012
- Jacobs-Roslund Vlim : Dimension - Velocity - Cover Plate Thickness = 0.01
- Jacobs-Roslund Vlim : Dimension - Velocity - Cover Plate Thickness = 0.008

Initial Stimulus
Residual Stimulus
M Munitions
S Safety
I Information
A Analysis
C Center

Web site http://www.msiac.nato.int
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SAS is a tool for the development of Safety and Suitability for Service assessment of munitions. It assists the user to:
- define the common threats to the munition
- The life cycle of the munition is developed using AOP 15 Annex A
- Environmental constraints are input based upon the user requirements
- SAS will identify relevant standards and make them available
- A report of all identified trials documentation can be exported in Word Excel or TXT formats.
- An electronic document database of international (UN, NATO) and several national standards applicable to munitions is included.

Current version released January 2007
Cost Benefit Analysis Model: CBAM v2.0

A tool to help calculate the cost differences of introducing IM into service

• It can also be used to calculate the cost of ownership of a munition

• CBAM calculates cost differences by:
  – Aiding in the creation of a life cycle for a munition type
    • Life-cycle Tree creation component
  – Providing a structured method for compiling cost data
    • Modules to account for cost differences arising from:
      – Risk Assessment & Direct cost
  – Calculates cost by means of a Monte Carlo Simulation
    • Takes into account the uncertainties