MSIAC IM Databases
An Efficient Toolbox to Assess IM Signature

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Abstract

To assist the Insensitive Munitions (IM) community, the Munitions Safety Information Analysis Center (MSIAC) began in 2002 to develop a suite of databases collecting information on the six IM tests described in STANAG 4439 Policy For Introduction and Assessment of Insensitive Munitions (MURAT). These tests are: Sympathetic Reaction, Shaped Charge Jet, Fragment Impact, Bullet Impact, Liquid Fuel/ External Fire and Slow Heating.

Till 2009, three MSIAC databases reporting munitions responses to Bullet Impact (BIRD), Fragment Impact (FRAID) and Sympathetic Reaction (SYR) stimuli were available. MSIAC has just completed its IM testing results database suite by adding two other databases, one for munitions exposed to thermal threats such as Liquid Fuel/ External Fire or Slow Heating (HEAT) and the other one for shaped charge jet impact (DARTS).

These databases have been developed in electronic format under Excel2003 to ease their use and take advantage of Excel search features. Test set-ups, results and analyses are also reported in detail and interpretation of results is made easier by the inclusion of pictures, graphs, comments and references.

Together these databases compile data from 500 publications and comprise more than 4,000 test configurations. They represent an opportunity for the IM community to easily and quickly assess for instance the IM relevance of an explosive for a particular application, the achievable IM signature for a certain type of warhead.

Information provided by these databases can be combined with other MSIAC products to get a full set of parameters on energetic material performance, sensitivity and munition vulnerability:

- EMC Energetic Material Compendium that compiles information on more than 1,200 energetic materials
- NEWGATES database that includes 1,450 gap test results
- TEMPER software that takes into account two IM threats (STANAG 4496 conical-ended fragment and sympathetic reaction) and helps to assess the influence of various parameters (body thickness, EM shock sensitivity, etc) to avoid a detonation.

The paper describes the IM databases and illustrates on particular examples the information that can be collected or used as input for TEMPER simulations. These examples also show that these databases are not only useful for design and modelling but also for munitions procurement and testing.

1 Introduction

To assist the Insensitive Munitions (IM) community, the Munitions Safety Information Analysis Center (MSIAC) began in 2002 to develop a suite of databases collecting information on the six IM tests described in STANAG 4439 Policy For Introduction and Assessment of Insensitive Munitions (MURAT).

Till 2009, three MSIAC databases reporting munitions responses to Bullet Impact (BIRD), Fragment Impact (FRAID) and Sympathetic Reaction (SYR) stimuli were available. MSIAC has just completed its IM testing results database suite by adding two other databases, one for munitions exposed to thermal threats such as Liquid Fuel/ External Fire and Slow Heating (HEAT) and another one for Shaped Charge Jet Impact (DARTS).

Together these databases compile data from 500 publications and comprise more than 4,000 test configurations. They represent an opportunity for the IM community to easily and quickly assess for instance the IM relevance of an explosive for a particular application, the achievable IM signature for a certain type of warhead.

The paper describes the IM databases and illustrates on particular examples the information that can be collected or used as input for other software like TEMPER. These examples also show that the use of these databases is wider than design and modelling.

2 IM Database Suite

2.1 General Characteristics

Other the years, MSIAC staff has created databases that collect test results for the six types of threats used to evaluate the vulnerability of munitions to thermal and mechanical aggressions: Fast Cook-off (FCO), Slow Cook-off (SCO), Bullet Impact (BI), Fragment Impact (FI), Sympathetic Reaction (SR) and Shaped Charge Jet Impact (SCJI).

These databases have been developed in electronic format under Excel2003 to ease their use and take advantage of Excel search features. Test set-ups, results and analyses are also reported in detail and interpretation of results is made easier by the inclusion of pictures, graphs, comments and references.

The IM databases are updated on a regular basis so that the user may find the most recent data available in the open literature. Table 1 gives an overview of the contained information. Together these databases compile data from over 500 publications and comprise more than 4,000 test configurations.

Table 1: General Information on the IM Databases

	Fast cook-off	Slow cook-off	Bullet impact	Fragment impact	Sympathetic reaction	Shaped charge jet impact
Database name and version	HEAT v1.0	HEAT v1.0	BIRD v1.2	FRAID v1.10	SYR v1.2	DARTS v1.0
Number of energetic materials	100	100	200	111	101	86
Number of test configurations	239	223	601	2003	670	354
Number of references	96	40	141	175	109	53
Number of pictures	0	0	0	120	200	93
Database size (Mo)	2	2	14	27	40	24

Each database comes with a comprehensive user guide document that gives information on the database structure, the taxonomy and ways of improving search. Examples of advanced searches with Excel Autofilters are given so that the user can train using this feature.

To illustrate the content of the databases, two of them, BIRD and SYR, are briefly presented in the next paragraphs.

2.2 BIRD

MSIAC staff has gathered information related to bullet impact tests in a single database called BIRD. This database provides more than 2,000 bullet impact results on 600 test configurations with 5.56 mm, 7.62 mm, 12.7 mm, 20 mm and 30 mm bullet calibres.

This database can be used to compare or predict bullet impact response of systems, subcomponents or energetic materials. It has also been designed to provide statistics (number of test results for the different reaction types) in order to increase the confidence in the test results.

A first version of BIRD (v1.0) was distributed in 2005 and updated in 2007. A new version will be released at the end of 2010.

2.2.1 Database Content

BIRD database is divided into several datasheets, each of them being dedicated to one bullet calibre (figure 1). A specific datasheet has also been created to describe Generic Test Units (GTU).

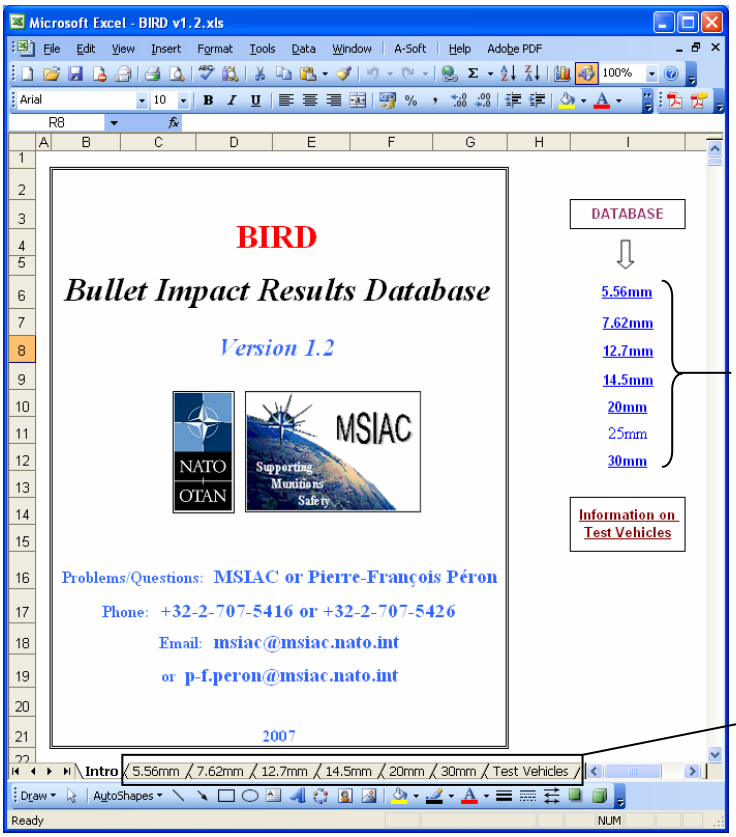

Figure 1: BIRD Excel Workbook

2.2.2 Test Results

Each results datasheet comprises four categories (figure 2):

- Tested System, i.e. munition, component or GTU with available information on explosive composition, envelop and impact point,
- Threat, i.e. bullet designation, velocity, type of firing (single or burst) and delay between shots in case of burst,
- Test procedure, i.e. STANAG, MIL Standard, etc,
- Reaction Level(s), i.e. type I to V or No Reaction (NR) with the number of test results for each reaction level if several tests have been carried out in the same configuration.

12.7 mm bullet impact

	TESTED SYSTEM									THREAT						TEST	REACTION LEVEL					
	System Designation	Country of Test	Tested Item	Config	Aim point	Aim Point Design.	Energetic Material at Aim Poin	Case thickness at Aim Point (mm)	Case Material at Aim Poi	Design.	Vo (m/s)	Firing range (m)	V impact (m/s)	Burst or Sing	Burst Timing (m	Proc.	Type I	Type II	Type III	Type IV	Type V	NR
408	STD MIS 2 ER (RIM-G/N/J)	US	RM	B	Center	MK 104 Mod 1 (S)	TP-N-1205C (S) TP-N-1206 (B)	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A				1		
409	STD MISSILE	US	W	B	Center	MK-90	H-6	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A				1	2	
410	STD MISSILE	US	W	B	Center	EX-115	PBXN-106	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A					2	1
411	STINGER	US	W	B	Center	FIM-92A	HTA-3	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A	1				1	
412	Storm Shadow	UK	PC	B	Center	Precursor Charge	PBXN-110	-	-	AP	-	-	850	S	-	STANAG 4241				1		
413	Swingfire	UK	RM	B	Center	-	CDB	-	Al. Alloy	AP	-	-	850	S	-	STANAG 4241					1	
414	TACID RBO	US	W	B	Center	-	PBXC-116M	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A					1	
415	TDW GTU	GE	GTU	B	MS	-	KS33	-	-	AP	-	-	850 +/-60	S	-	MIL-STD-2105B					1	
416	TDW GTU	GE	GTU	B	MS	-	P31	-	-	AP	-	-	850 +/-60	S	-	MIL-STD-2105B					1	
417	TERRIER	US	W	B	Center	MK-51	APLEX-2	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A					2	
418	TOMAHAWK (R/UGM-109 B/C/D)	US	W	B	Center	WDU-25B	PBXW-109	-	Steel	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A			2			
419	TOMAHAWK (R/UGM-109 B/C/D)	US	RM	B	Center	MK 106 Mod 0	Arcadene	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A					1	
420	TOMAHAWK (R/UGM-109 B/C/D)	US	RM	B	Center	MK 111 Mod 0	UTP-25201C	-	-	AP	-	-	840 +/-60	B	50 +/-10	MIL-STD-2105A			1			
421	TAURUS	GE	W	B	Art	Mephisto penetrator	KS22a	-	Steel	AP	-	-	850 +/- 60	S	-	MIL-STD-2105						1
422	TAURUS	GE	W	B	Art	Mephisto precursor charge	KS33	-	Steel	AP	-	-	850 +/- 60	S	-	MIL-STD-2105					1	

Figure 2: Partial Screenshot of 12.7 mm Bullet Datasheet (BIRD v1.2)

2.2.3 Generic Test Units

A worksheet (figure 3) has been dedicated to Generic Test Units (GTU). These units are generally used to perform comparative tests between compositions. The worksheet comprises twenty-four GTU with their dimensions and pictures or drawings (figure 4).

Designation	Acronym	Country	Shot Line	Impact Case Material	Impact Case thickness (mm)	Overall length (mm)	External diameter (mm)	Internal Diameter (mm)	Ref
3.2 inch Generic Shaped Charge Test Unit	GSCTU	USA	Radial	tbd	7	193	95	81	
Chinese Generic Test Unit	CGTU	China	Axial	Steel	tbd	127	56	-	
Chinese Pipe Nipple Bomb	PNB-C	China	Radial	Steel	3	102	58.5	52.5	14
GEMO 3 liters thick wall Test Unit	GEMO 3 I KW	France	Radial	Steel	10	260	143	123	
Heavy Wall Test Unit	HWTU	USA	Radial	Mild Steel	12.7	406.4	203.2	177.8	
Large Scale Rocket Motor Generic Unit	LSRMGU	France	Radial	Metal	tbd	500	165	-	31
Naturally Fragmenting Test Unit	NFTU	USA	Radial	Steel	9.525	381	203.2	-	95
Pipe Nipple Bomb	PNB	USA	Radial	Iron	3.175	76.2	-	50.8	
Small Scale Rocket Motor Generic Unit	SSRMGU	France	Radial	Metal	tbd	100	152	-	31
UN Steel Tube	EIDS	UN	Radial	Steel	4 +/-10%	200	-	45+/-10%	

Figure 3: Partial Screenshot of Datasheet on GTU (BIRD v1.2)

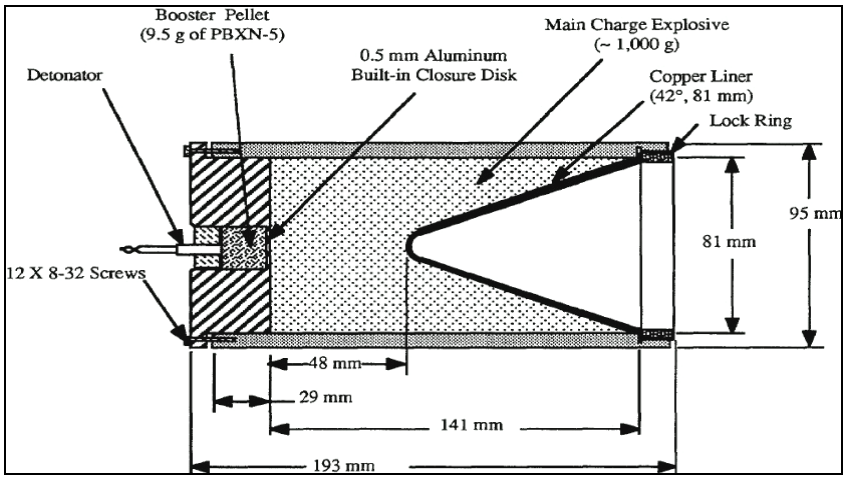

Figure 4: Example of GTU Drawing - 3.2" Generic Shaped Charge Testing Unit (BIRD v1.2)

2.2.4 Database Key Figures

In BIRD v1.2, more than 140 open publications (symposia proceedings, unclassified reports, scientific reviews, etc) are used for a total of 601 tested configurations and 2,336 bullet impact results (table 2). Most tests have been performed with 7.62 mm and 12.7 mm bullets.

Table 2: Information Available in BIRD v1.2

	Bullet calibres (mm)						
	5.56	7.62	12.7	14.5	20	30	Total
Number of test configurations	7	122	447	2	20	3	601
Number of test results	21	1194	1035	2	38	46	2336

2.3 SYR

MSIAC staff has gathered information related to sympathetic reaction (SR) tests in a single database called SYR. This database provides more than 670 sympathetic reaction results on 83 munitions.

This database can be used to estimate the SR response of systems, to compare the response of different energetic materials or to estimate the influence of various parameters such as distance between munitions, mitigation thickness or shape, etc. Pictures of test configurations and test results have also been included to ease their comprehension.

The first version of SYR (v1.0) was distributed in 2007 and has been updated in 2009.

2.3.1 Database Content

Sympathetic reaction test results are gathered in the main SYR datasheet called “Database” (figure 5). A “Test set-up diagram” datasheet has also been included to give an example of a generic SR test configuration and to indicate how distances between donor, acceptor and mitigation are reported. Papers used to populate the database are listed in the “References” datasheet.

These datasheets can be directly accessed from the SYR Front Page (figure 5). Direct links to the following documents have also been added in this page:

- STANAG procedure related to sympathetic reaction test (STANAG 4396 edition 2);
- User Guide;
- Help to fix possible graphics viewer issue on opening picture links.

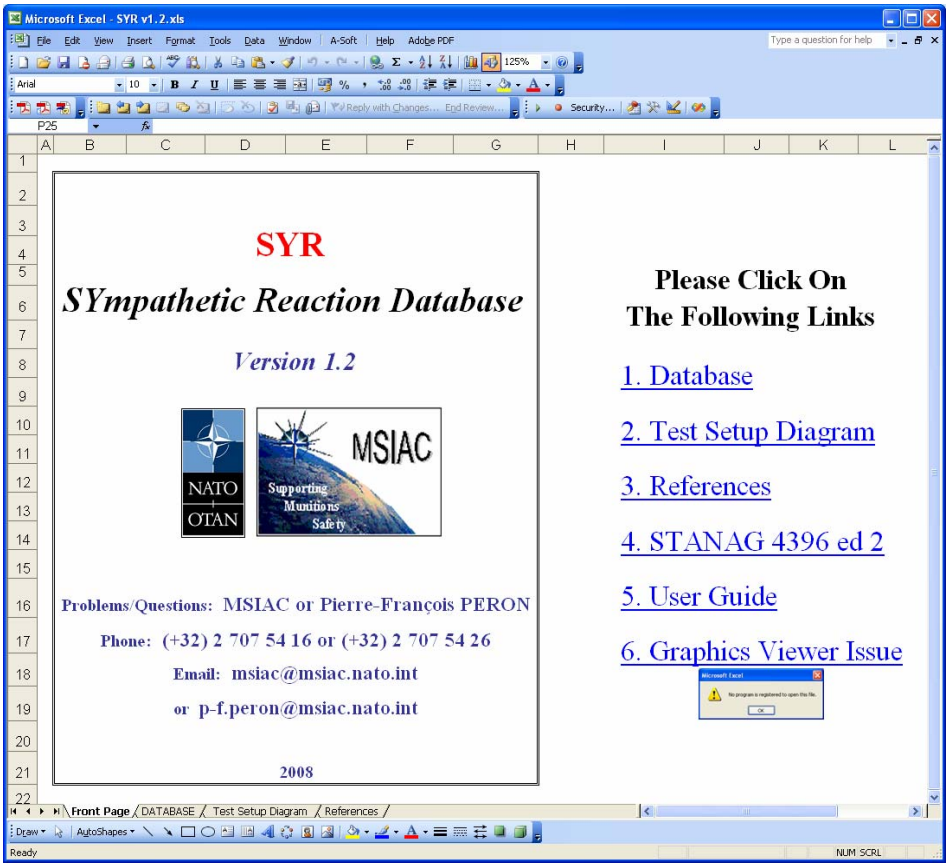

Figure 5: SYR Excel Workbook

2.3.2 Test Results

The results database comprises six categories (figure 6):

- munition name;
- donor and acceptor main features, i.e. explosive compositions, charge diameter, case thickness, length and material (characteristics put in the same columns for both donor and acceptor to see at one glance all the data concerning each test);
- mitigation, i.e. material, thickness and density;
- test set-up, i.e. distances between munitions and mitigation;
- results:
  - o warhead test configuration, i.e. one-on-one, one-on-many or many-on-many and for each case buffered or unbuffered;
  - o initiation mechanism (shock-to-detonation transition, diagonal effect, unknown-to-detonation transition);
  - o reaction type according to STANAG 4439;
- information, i.e. references and general comments on the test configuration, the munition particularities and the results.

Pictures describing the set-up and the munitions after tests (figure 7) can be seen by clicking on the hyperlink in the warhead test configuration cell.

Munition	Donor (D) and Acceptor (A) Charge Features					Mitigation			Test Set up			Results			Information		
Name	Energetic Material	Composition	External Diameter (mm)	Case Thickness (mm)	Case Material	Mitigation Material	Mitigation Thickness (mm)	ρ (g/cm³)	Distance Donor Skin to Acceptor Skin (mm)	Distance Skin of Donor to Mitigation (mm)	Distance Skin of Acceptor to Mitigation (mm)	Initiation Mechanism	Reaction Type	Configuration	References		General Comments
155 mm M795 Shell	IMX-101	DNAN NTO NQ	155		Steel	-	-	-	29 29 105	0	0	DSDT	ND	One on Many Unbuffered	80		Test in pallet configuration with 1 donor, 1 acceptor (diagonal) and 2 inerts (adjacents)
175 mm shell	Comp B	60RDX 40TNT	175	14.2 - 17.5	Steel	-	-	-	1987.55			SDT	I (x1) ND (x3)	One on One Unbuffered	16		Case thicknesses refer to the most vulnerable part of the shell as claimed by the author
175 mm shell	Comp B	60RDX 40TNT	175	14.2 - 17.5	Steel	-	-	-	2336.8			SDT	ND (x2)	One on One Unbuffered	16		Case thicknesses refer to the most vulnerable part of the shell as claimed by the author
BLU-109	PBXN-109	64RDX 20Al 16HTPB	370	25	Steel	-	-	-	108			SDT	I	One on One Unbuffered	73		Test in a 2 bomb pallet Distance between bombs measured on a drawing
BLU-109	AFX-931	32RDX 37AP 15Al 16HTPB	370	25	Steel	-	-	-	108			SDT	ND	One on One Unbuffered	74		Test in a 2 bomb pallet Distance between bombs measured on a drawing
GTU	PBXN-109 (ADI RS-RDX)	64RS-RDX 20Al 16HTPB	120.66	9.53	Mild-Steel	-	-	-	240			SDT	II, III, IV	One on One Unbuffered	6		Sympathetic Reaction Tests with GTU Warheads Filled with PBXN-109 Influence of RS-RDX Source on Acceptor Reaction containers
Hellfire I	LX-14	95.5HMX 4.5Estane 5702	177.8	2.6	Al	Al.	69.85	2.7		44.5	44.5	SDT	I	One on One Buffered	6		
Hellfire I	LX-14	95.5HMX 4.5Estane 5702	177.8	2.6	Al	Al.	101.6	2.7		44.5	44.5	SDT	III	One on One Buffered	6		
Hellfire I	LX-14	95.5HMX 4.5Estane 5702	177.8	2.6	Al	Al.	101.6 (plate) 63.5 (rod)	2.7				SDT	ND (x5 tests)	One on Many Buffered	6		

Figure 6: Partial Screenshot of Sympathetic Reaction Results (SYR v1.2)

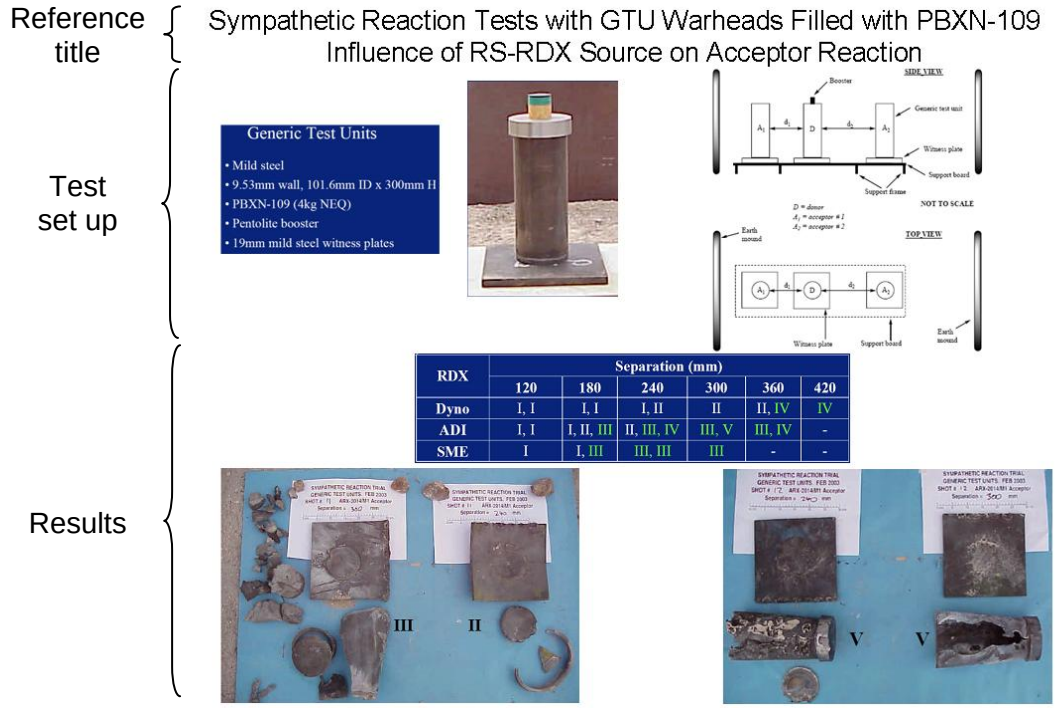

Figure 7: Example of Pictures Describing Test Set-Up and Results (SYR v1.2)

2.3.3 Database Key Figures

In SYR v1.2, 109 open publications (symposia proceedings, unclassified reports, scientific reviews, etc) are used for a total of more than 6700 results on 83 munitions and 101 explosive compositions.

3 Examples of IM Database Use

Potential applications of the databases are illustrated in the next paragraphs through three examples. These examples intend to show that the use of these databases is not limited to munition design or modelling and can also be interesting for procurement and testing purposes.

3.1 First Example: Procurement of Low Vulnerability Artillery Shells

A procurement agency is interested in purchasing 155 mm artillery shells that do not sympathetically detonate in pallet configuration and would like to have at short notice an overview on shells that meet this requirement and the implemented IM technologies.

For this query, the quickest and easiest way is to use SYR and the Excel Autofilter feature that is activated in SYR. The user will select the following criteria (figure 8):

- External Diameter (mm) = 155;
- Reaction Type = ND (No Detonation), Type III, Type IV, Type V and NR (No Reaction).

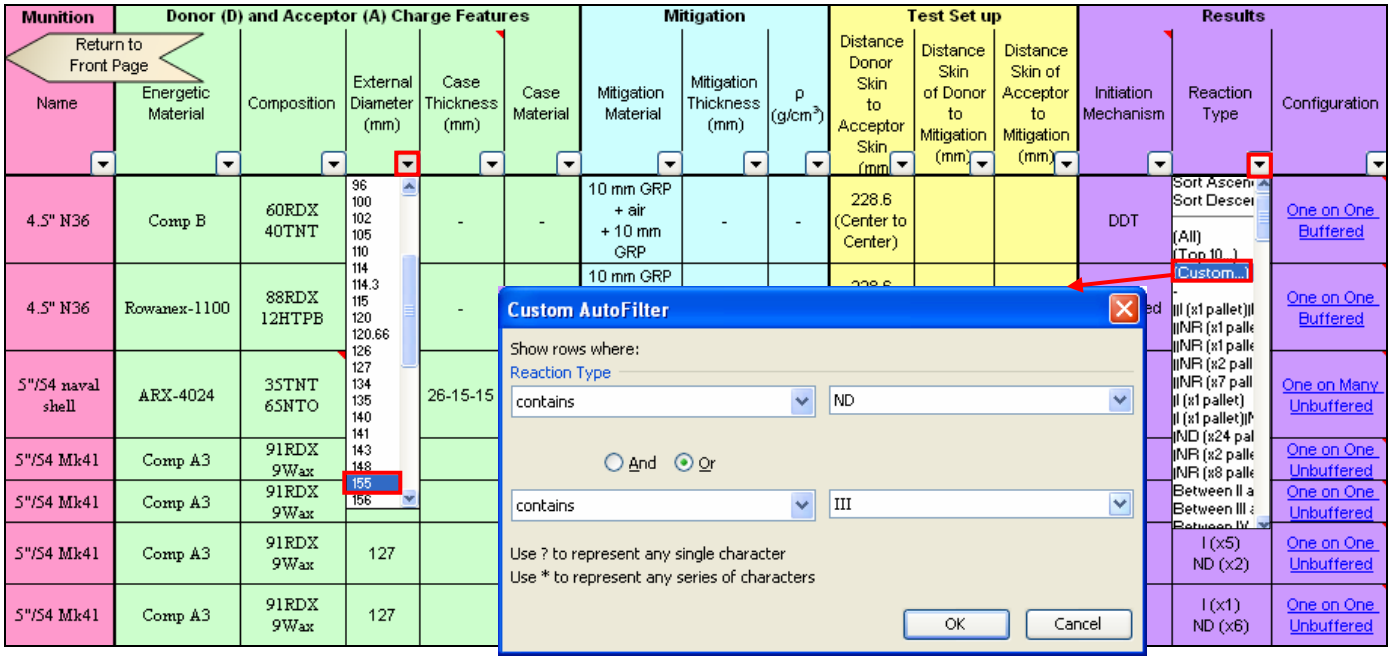

Figure 8: Input of Search Criteria Values Using Excel Autofilters (SYR v1.2)

The final search output is presented in figure 9. It comprises twelve test results on six different shells (some shells tested with different explosive fillings).

This search reveals that there are two possibilities to achieve the requirement. The first one consists in a low shock sensitivity filling (mostly NTO-based formulations) to pass the test without mitigation. The second one uses RDX- or HMX-based compositions (more shock sensitive) and SR is prevented by adding a barrier that fits in the gaps between shells. According to the search results, High Density PolyEthylene (HDPE) barrier is widely used and only relatively thin layers are required to prevent detonation transmission.

In addition to the technical information, the references linked to the results will enable the user to make a list of potential suppliers and points of contact.

Munition	Donor (D) and Acceptor (A) Charge Features					Mitigation			Test Set up			Results			
Return to Front Page Name	Energetic Material	Composition	External Diameter (mm)	Case Thickness (mm)	Case Material	Mitigation Material	Mitigation Thickness (mm)	ρ (g/cm³)	Distance Donor Skin to Acceptor Skin (mm)	Distance Skin of Donor to Mitigation (mm)	Distance Skin of Acceptor to Mitigation (mm)	Initiation Mechanism	Reaction Type	Configuration	Ref
155 mm Shell	TNT (D) RDX/TNT (A)	(D) 100TNT (A) 50TNT 50RDX	155		Steel	Poly-ethylene	40	-	40			SDT	IV	One on One Buffered	32
155 mm Shell	TNT (D) TNH (A)	(D) 100TNT (A) TNT HNS	155		Steel	Poly-ethylene	40	-	40	0	0	SDT	IV	One on One Buffered	32
155 mm Shell	TNT (D) TT (A)	(D) 100TNT (A) 40TNT 60NTO	155		Steel	Poly-ethylene	40	-	40	0	0	SDT	NR	One on One Buffered	32
155 mm LU-211M	XF-13333	48NTO 31TNT 14Al 7Wax	155	16.4 15 8	Steel	-	-	-	35 35 114			SDT SDT DSDT	IV	One on Many Unbuffered	15
155 mm M107	PAX-196	RDX Wax	155	20 to 23	Steel	Possibly HDPE						SDT DSDT	III	One on Many Buffered	81
155 mm M107	PBXW-108 mod	82RDX 18Wax binder	155	20 to 23	Steel	HDPE	9.53	0.95				SDT DSDT	III	One on Many Buffered	84
155 mm M795 Shell	IMX-101	DNAN NTO Other	155		Steel	-	-	-	29 29 105			DSDT	ND	One on Many Unbuffered	80
155 mm M795 Shell	IMX-102	TNT NTO Chlorinated Wax	155		Steel	-	-	-	29 29 105			DSDT	ND	One on Many Unbuffered	80
155 mm M795 Shell	IMX-103	NQ RDX DETN EDD MeNQ HBNQ	155		Steel	-	-	-	29 29 105			DSDT	ND	One on Many Unbuffered	80
155 mm M795 Shell	PAX-196	RDX Wax	155		Steel	Possibly HDPE			29 29 105	0	0	SDT DSDT	III	One on Many Buffered	81
155 mm XM0121A18 Shell (Assegai)	SPX-1 (Filling) DPX-2 (Sup. charge)	SPX-1 (Pres.) RDX Binder DPX-2 92HMX 2Hytemp 6DOA	155		Steel	Polyethy-lene	#12.7 tube around each shell	0.95	29 29 105	0	0	SDT DSDT	III	One on Many Buffered	82
155 mm XM982 Shell (Excalibur)	PBXN-9	92HMX 2Hytemp 6DOA	155		Steel	Packaging						SDT DSDT	ND	One on Many Buffered	85

Figure 9: Search Results for 155 mm Shells that Pass Sympathetic Reaction Test (SYR v1.2)

3.2 Second Example: Bullet Impact Testing of Mortar Warheads

A proving ground has been tasked to evaluate the response of mortar warheads to 12.7 mm bullet impact. The mortars have calibres between 60 mm and 120 mm and the bullet has an Armour Piercing (AP) core. Prior to the tests, this proving ground would like to estimate the mortar reaction for the trial preparation, especially the selection of the sensors and the protection of the test equipments.

For this query, BIRD can be useful to have an overall estimation of the mortar reactions recorded with various fillings. The user will select the following criteria in BIRD (figure 10):

- 12.7 mm worksheet;
- System Designation = contains mortar.

The test results that match the search criteria are reported in figure 11. They show that no mortar detonated, either fully or partially, even with Composition B or TNT fillings.

The number of mortar responses per reaction level is indicated at the bottom of the table. In most cases, tests resulted in a type V or no reaction and only one type III has been recorded.

A closer look shows that tested 60 mm mortars did not react (x 5) or only exhibited a type V reaction (x 7). 81 mm mortars tests mostly resulted in no reaction (x5) and in one case in a type IV. 120 mm mortars responses are type III (x1), type IV (x1) and type V (x2).

The number of tests is of course insufficient to draw statistics but the results give a reasonable impression that the mortar warhead to be tested would not detonate.

This information should help to design the test setups and even refine them based on the mortar calibres.

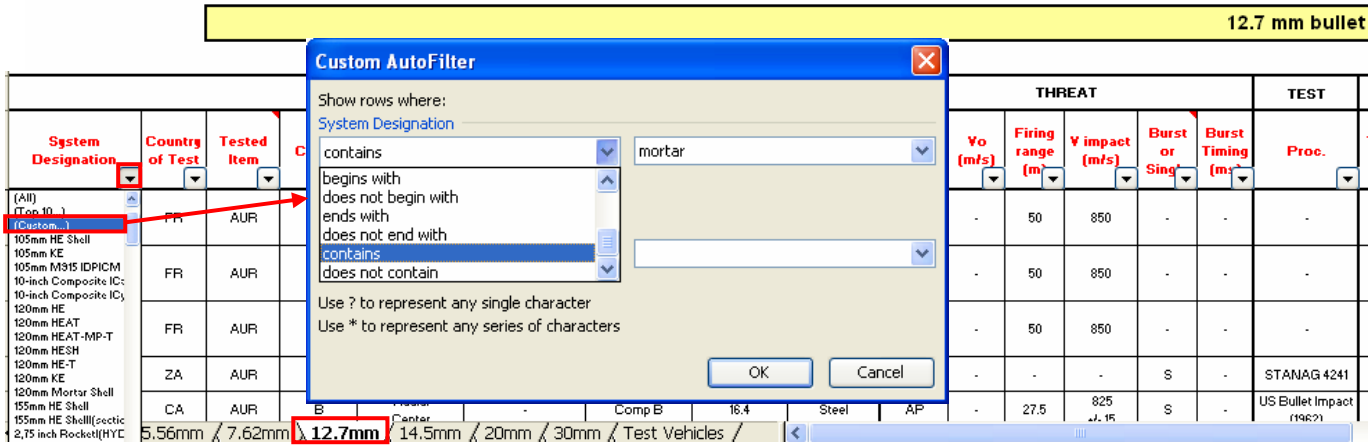

Figure 10: Input of Search Criteria Values Using Excel Autofilter (BIRD v1.2)

TESTED SYSTEM									THREAT			TEST	REACTION LEVEL					
System Designation	Country of Test	Tested Item	Config	Aim point	Aim Point Design.	Energetic Material at Aim Poin	Case thickness at Aim Point (mm)	Case Material at Aim Poi	Design.	V impact (m/s)	Burst or Sing	Proc.	Type I	Type II	Type III	Type IV	Type V	NR
60mm Mortar Shell	CH	AUR	B	Warhead Center	MAPAM	PBXN-110	-	Steel	AP	850 +/-60	S	MIL-STD-2105B					2	
60mm Mortar Shell	CH	AUR	B	Warhead Booster	MAPAM	PBXN-110 PBXN-5	-	Steel	AP	850 +/-60	S	MIL-STD-2105B					2	
60mm Mortar Shell	CA	AUR	B	Radial Center	-	Comp B	-	Steel	AP	825 +/- 15	S	US Bullet Impact (1962)					1	1
60mm Mortar Shell	CA	AUR	B	Radial Center	-	Comp B/ETPE 90/10	-	Steel	AP	825 +/- 15	S	US Bullet Impact (1962)						2
60mm Mortar Shell	CA	AUR	B	Radial Center	-	Octol/ETPE 90/10	-	Steel	AP	825 +/- 15	S	US Bullet Impact (1962)						2
60mm Mortar Shell	US	AUR	B	Radial Center	M720	Comp B	-	Steel	AP	-	S	-					1	
60mm Mortar Shell	US	AUR	L ship. cont.	Radial Center	M720E1	PBXN-5 PAX-21	-	HF-1 Steel	AP	-	S	MIL-STD-2105B					1	
81mm Mortar Shell	FR	AUR	L	Radial Center	-	TBI-60	-	cast iron	AP	-	S	STANAG 4241						3
81mm Mortar Shell	US	AUR	B	Radial Center	-	Comp B	-	Steel	AP	-	S	-				1		
81mm Mortar Shell	AU	W	B	Warhead Center	-	TNT	9	Steel	AP	850 +/-60	S	STANAG 4241						1
81mm Mortar Shell	AU	W	B	Warhead Center	-	ARX-4024	9	Steel	AP	850 +/-60	S	STANAG 4241						1
120mm Mortar Shell	US	AUR	B	Radial Center	M934A1	Comp B CH-6 booster	15 (estimated)	Steel	AP	-	S	MIL-STD-2105B			1			
120mm Mortar Shell	US	AUR	T	Main Charge	M934A1E1	HBU88B	15 (estimated)	Steel	AP	919-871	S	STANAG 4241				1	1	
120mm Mortar Shell	US	AUR	L	LQ	Main charge EFSS	PBXW-128	8 (estimated)	Steel	AP	850 +/- 60	B	STANAG 4241					1	
												Total			1	2	9	10

Figure 11: Search Results for Mortar Warheads Impacted by a 12.7 mm Bullet (BIRD v1.2)

3.3 Third Example: Warhead Design

A design team is developing a new warhead that has an external diameter of 130 mm and a steel case with a thickness between 8 and 12 mm. PBXN-110 composition (88% HMX and 12% HTPB) has been selected with few other compositions as potential fillings based on their performance.

Before going further in the development, the design team is looking for IM signatures of munitions that are loaded with this composition and the added mitigations. It would also like to estimate which IM signature is achievable with PBXN-110 in the warhead being designed.

For this query, two searches will be performed in all the test results databases. For the first one, the criterion is PBXN-110 as an Energetic Material. For the second one, two more criteria will be added:

- Case Material = steel;
- Case Thickness = 8 mm to 12 mm.

An example of Slow Cook-off results is shown in figure 12 for the first search (munitions warheads filled with PBXN-110). It will not be easy in this paper to show database by database the search entries as spreadsheets contain a lot of information and are not easy to read in the reduced format of a Word document. The results of this first search are thus synthesized in table 3.

SCO

Acronyms description can be reach by clicking on the comment symbol associated with each column title cells
Data can be sorted by clicking on the downward arrow associated with each column title cells

SYSTEM								THREAT							RESPONSE	
Munition Type	Munition Designation	Type of Item	Nb. Of Item in a Test	Cfg.	Item Pos.	Main Energetic Materials (Link to EM)		Mitigation Device/ Thermal Liner	Heating Rate (°C/hr)	Heat	Nb. of TC	TC Loc.	Air Space Width (mm)	Type of Support	Test Proc. (Link to Proc.)	Nb. of Test	Level (Link to Detailed Response
60 mm Mortar	60 mm Mortar MAPAM	AUR	1	B	V	PBXN-110	PBX	Fuse-body connection designed to break to release pressure Low confinement with the plastic resin matrix of the body	3.3	EOF	6	50 mm			MC	2	V
2.75 in Rocket	2.75 inch rocket warhead (Mk146 Mod 0)	W	1	L		PBXN-110	PBX	Meltable base and fuze warhead adaptors	22.2	EI			200		MB		V
Missile Air to Air	AMRAAM AIM-120	AUR				PBXN-110 in WDU/41B Warhead	PBX	Vented fuse							MB	2	IV V
Missile Air o Surface	Storm Shadow /Scalp EG	O (Precursor charge)	1	B	H	PBXN-110	PBX	Body lined with insulating material Detaching closure fixings in cook-off									V

Figure 12: Slow Cook-off Search Results for Munitions Warheads Filled with PBXN-110 (HEAT v1.0)

Table 3: IM Signature of Munitions Warheads Filled with PBXN-110

Munitions	IM Test Results					Mitigations
	FCO	SCO	BI	FI	SR	
60 mm MAPAM Mortar	V^u	V^u	V^P	V^P	IV^P	Fuse-body connection designed to break to release pressure Low confinement with the plastic resin matrix of the body
2.75" Mk 146 Mod 0 Rocket	V^T	V^T	V^u	I^u	I^P	Polymer nose and base adapter
AMRAAM AIM-120	IV	IV		V	$Pass^P$	Vented fuse
Storm Shadow/ SCALP EG (Precursor Charge)	V^u	V^u	V*	V**	IV^P	Body lined with insulating material Detaching closure fixings in cook-off

^{U}: Unpacked ^{P}: Packed ^{T}: Tactical (in launcher)
* Bare charge ** by analysis

PBXN-110 has been used in various in service munitions that have very different calibres (60 mm to more than 200 mm) and applications (blast/fragment to shaped charge). The IM tests generally resulted in a pass or were close to it. The detonation observed for the 2.75" rocket are due to the warhead thin steel body that is not sufficient to attenuate fragment impact shock waves.

For the second search, only fragment impact results are available (figure 13) on Rowanex 1001, a PBXN-110 analogue. These results are very interesting as they enable to calculate a set of parameters (figure 13) for the modified Jacobs-Roslund model [1]. This set of parameters can be used in TEMPER software to estimate the detonation threshold of PBXN-110 to the fragment impact defined in STANAG 4496 for IM testing.

Detonation threshold curves calculated with TEMPER are presented in figure 14 for four steel body thicknesses between 6 mm and 12 mm. These calculations can be very helpful for the warhead body design to avoid a detonation to this fragment. According to TEMPER calculations, the required casing thickness would be around 12 mm for a fragment velocity of 2530 m/s (standard test procedure) and around 6 mm for 1830 m/s (alternate procedure # 1).

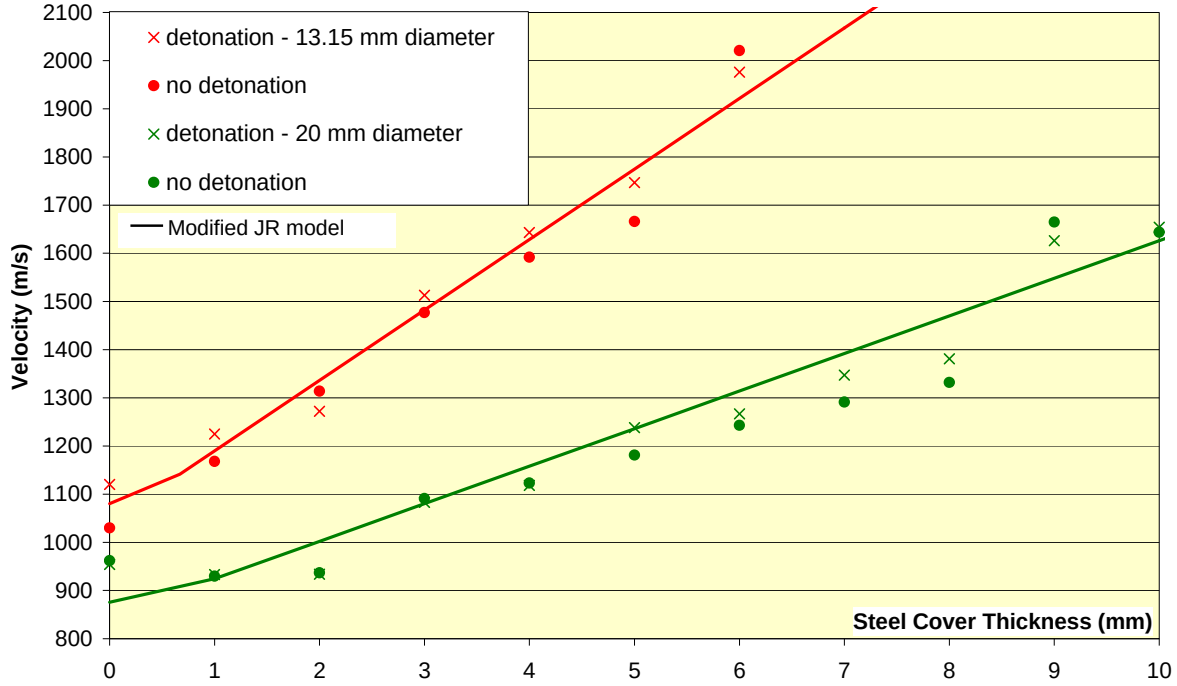

Figure 13: Flat-Ended Fragment Impact Tests on Steel Covered Rowanex-1001 Blocks Modified Jacobs-Roslund Modellisation Calculated from these Tests

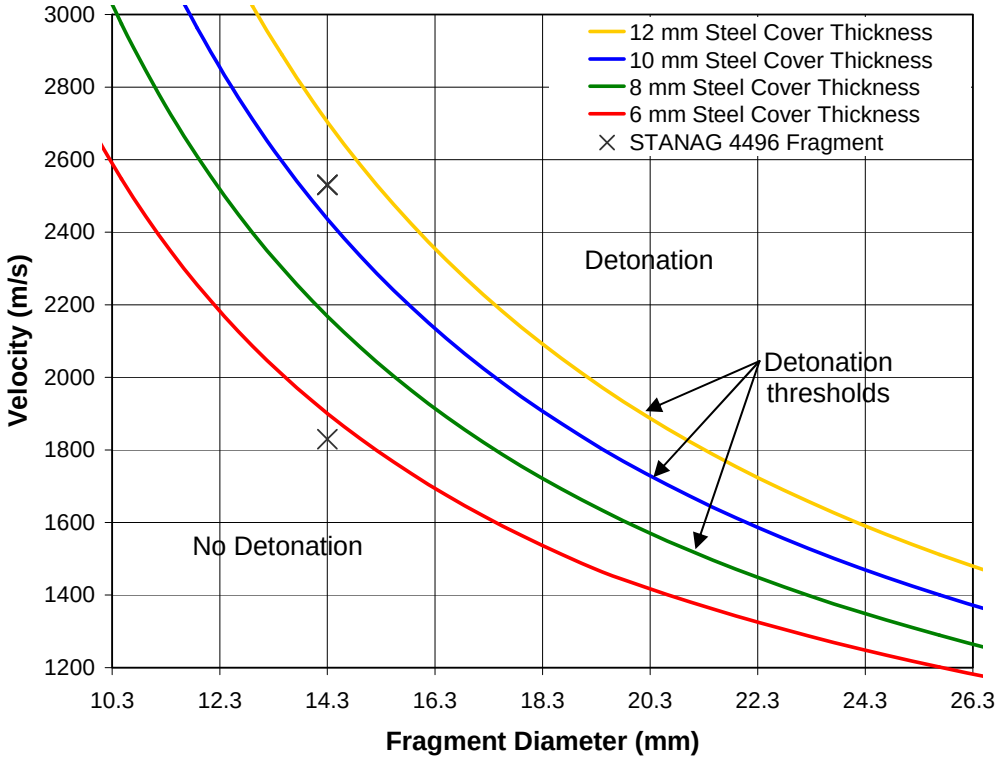

Figure 14: TEMPER Simulation of STANAG 4496 Fragment Impact on PBXN-110 Blocks Covered with Steel

4 Conclusions

MSIAC has created six Excel databases that compile available munition responses to slow cook-off, fast cook-off, bullet impact, fragment impact, sympathetic reaction and shaped charge jet impact.

These databases contain information on tests carried out on numerous explosive compositions and in various munitions configurations. Test set-ups, results and analyses are reported in detail and interpretation of results is made easier by the inclusion of pictures, graphs, comments and references. The large variety of results enables the user to find relevant data in a configuration close to the one under study and to carry out parametric evaluations on the projectile or the munition characteristics. All databases are updated on a regular basis.

These database have been developed to:

- enable users to populate the database themselves with their own data and to optimize their use thanks to Excel sorting, filter and chart capabilities;
- provide scientists and engineers with easy to use tools whose large variety of results enable them to find relevant data for a configuration close to the one being studied;
- provide information to facilitate the comparison of charge response with different explosive formulations and/or to carry out parametric studies on the effect of the threat or the munition characteristics such as projectile calibre, target confinement thickness, etc;,
- provide modellers with flexible research tools containing data and references required to validate models;
- provide the IM and Munitions Safety (MS) communities with a tool from which statistics can be derived when possible in order to increase the confidence in test results.

Application examples illustrated in the present paper show that these databases are not reserved to designers and modellers and can be a useful tool for procurement and testing.

These databases are available to MSIAC Nations organisations or to individuals in accordance with the MSIAC release of information policy. They can be downloaded from the MSIAC secure website (https://sw.msiac.nato.int/SecureWeb).

5 Planned Improvements

MSIAC is currently planning to migrate all these databases in a unified web-based environment. This migration offers significant advantages. Searches should be simplified as a unique search engine will be created and will allow to look in all the databases with a few clicks. The databases in their web-based environment will also be available from any PC connected to the internet and will not require installation of software on to the user's machine. It will also allow easy central updating of the tool and the test results.

The feasibility of this project has been demonstrated by migrating SYR database. The web-based version is shown in figure 15. All the Excel features used in SYR (like picture visualization) have been recreated and a more comprehensive and user-friendly interface has been developed. The work started with SYR will go on next year with the progressive migration of all the databases and the creation of links with the other MSIAC products like Energetic Material Compendium (EMC) that is already available on-line.

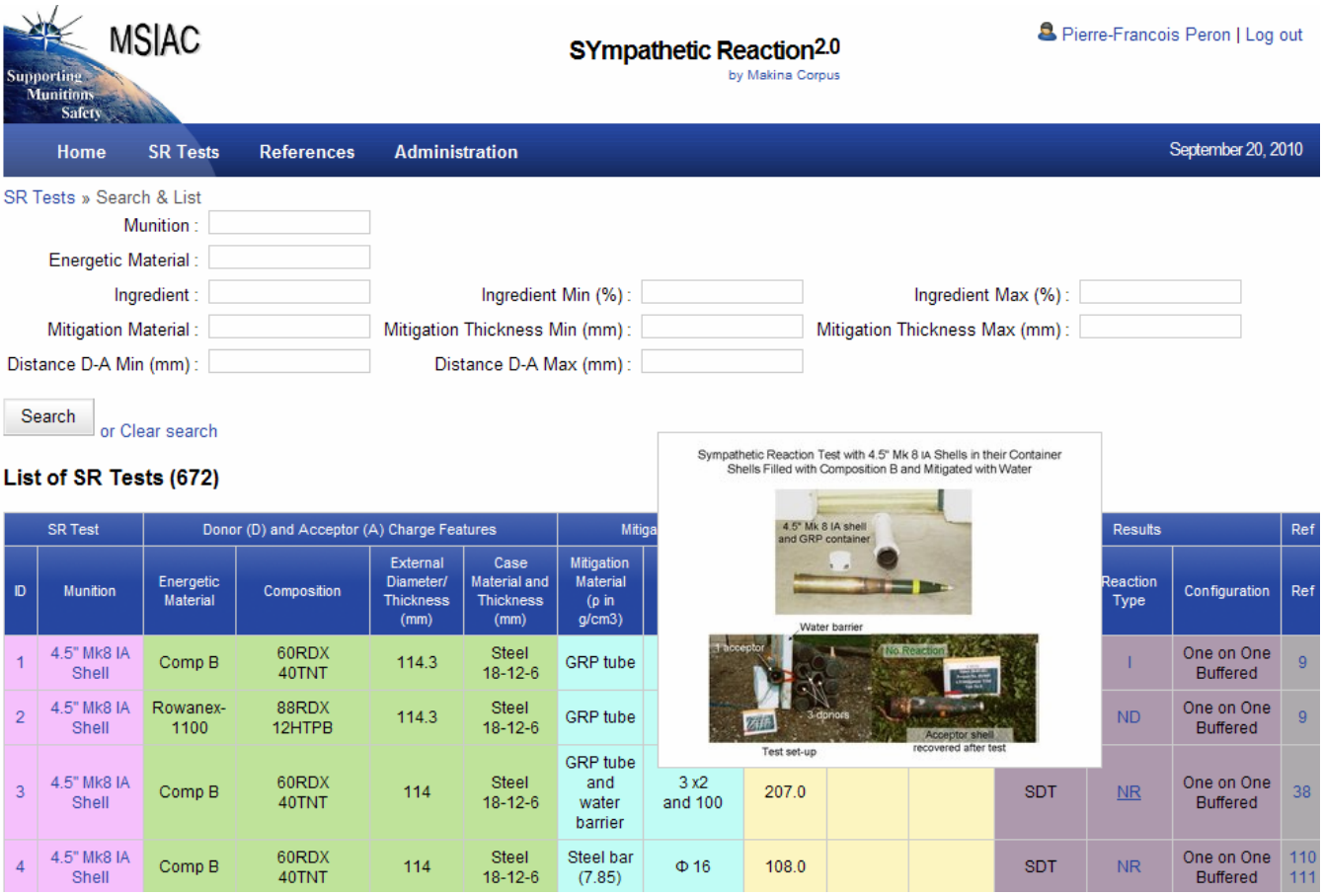

Figure 15: SYR Web-Based Environment

6 Bibliography

[1] “Modelling of Warhead Response to Projectile Impact with TEMPER Software”, Lapébie E, Grannec F., Péron P-F, IMEMTS (2009)