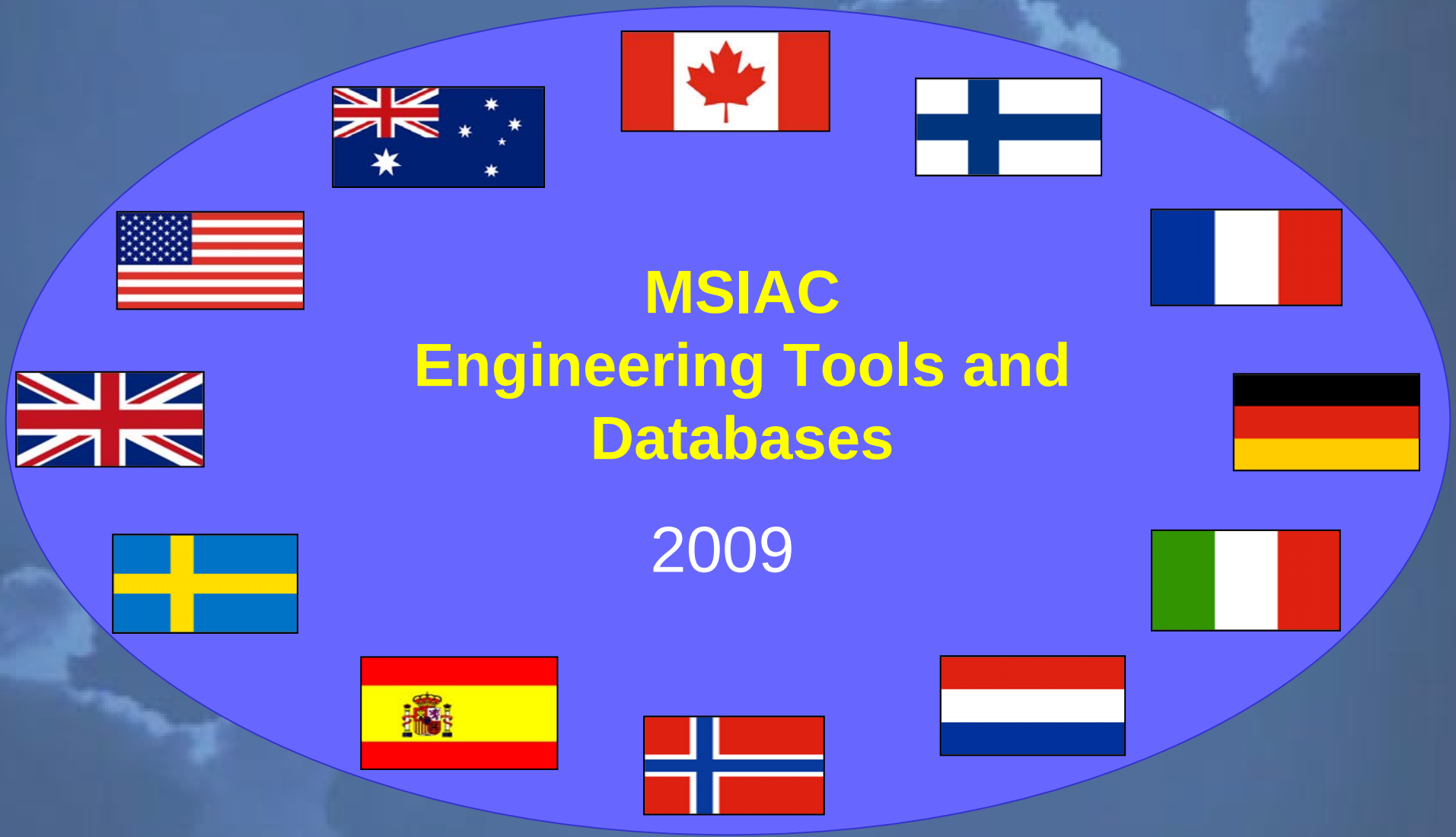
MUNITIONS SAFETY INFORMATION ANALYSIS CENTER

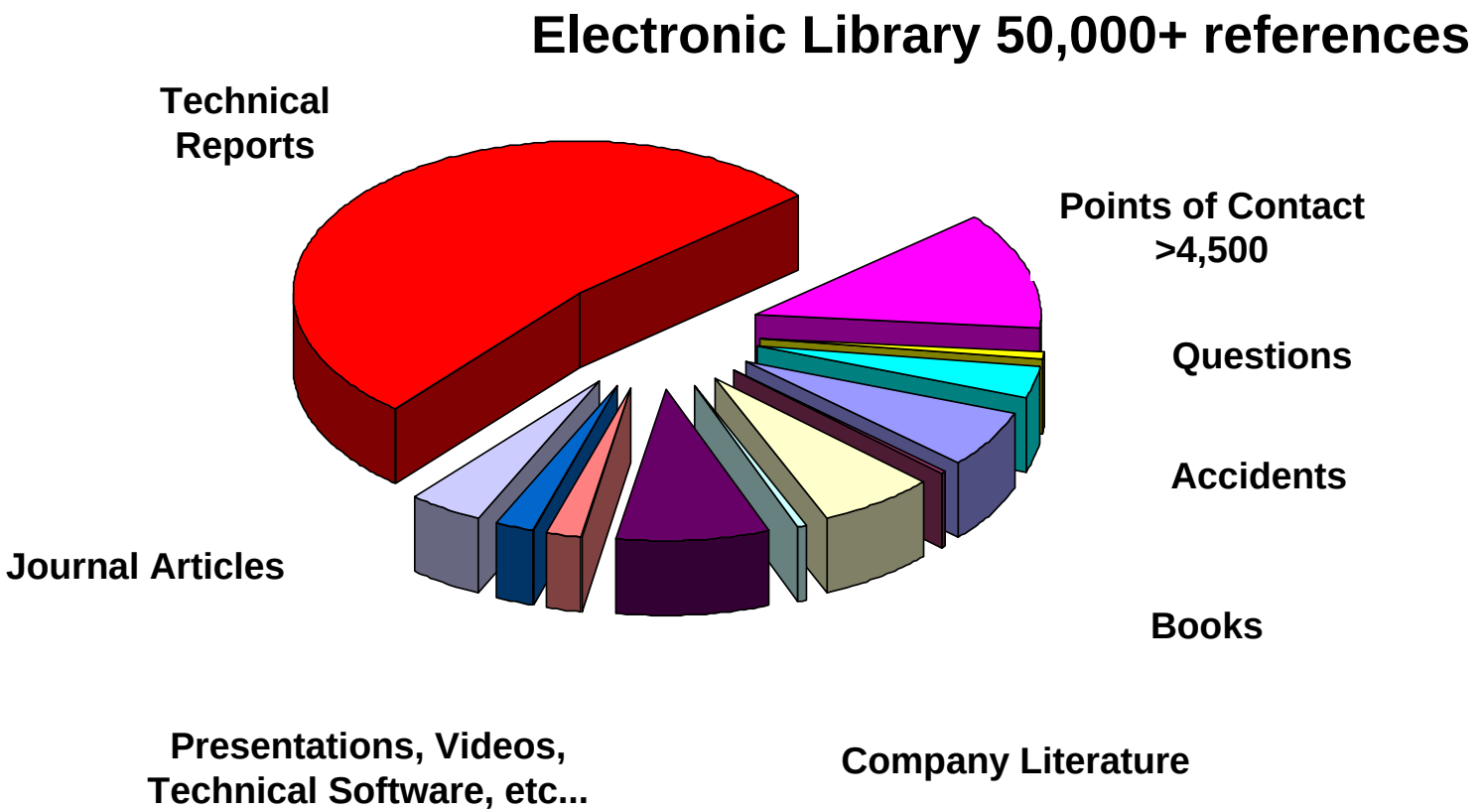


MSIAC
Engineering Tools and Databases

2009

MSIAC Unclassified

Products & Services are based on staff expertise, library, and Points of Contact

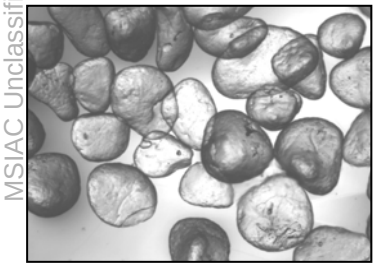


MSIAC Products - Tools & Databases

- Energetic Materials Compendium (EMC) – 1997
- Mitigation Methods for Munitions (M^3) – 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
- Toolbox of Engineering Models for the Prediction of Explosive Reactions (TEMPER) – 2005
- Safety Assessment Software (SAS) – 2005
- Bullet Impact Results Database (BIRD) – 2005
- Sympathetic Reaction Database (SYR) – 2007
- Cook-off Aggression Database (HEAT – Beta Version) – 2008
- Shaped Charge Impact Database (DARTS – May 2009) – 2009

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



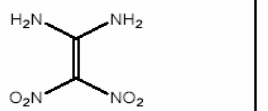
(Fox-7)

Synonyms: DADE, DADNE, 1,1-diamino-2,2-dintroethylene, 2,2-Dinitro-ethene-1,1-diamine.

General

Fox-7 is a simple nitro-amine compound based upon ethylene. Laytpov et al first published the method to synthesis Fox-7 in the open literature in 1998[1]. Synthesis of Fox-7 involves nitration of a heterocyclic compound, commonly with mixed acid, followed by hydrolysis. Other alternative methods are available.[2]

FOX-7 exhibits a greater thermal stability and lower shock, impact and friction sensitivity than other common explosive ingredients (RDX, HMX, CL-20). Therefore, it is an interesting candidate for reduced vulnerability formulations.



1,1-diamino-2,2-dinitroethylene (FOX-7)

MSIAC

Ingredients Data Sheets

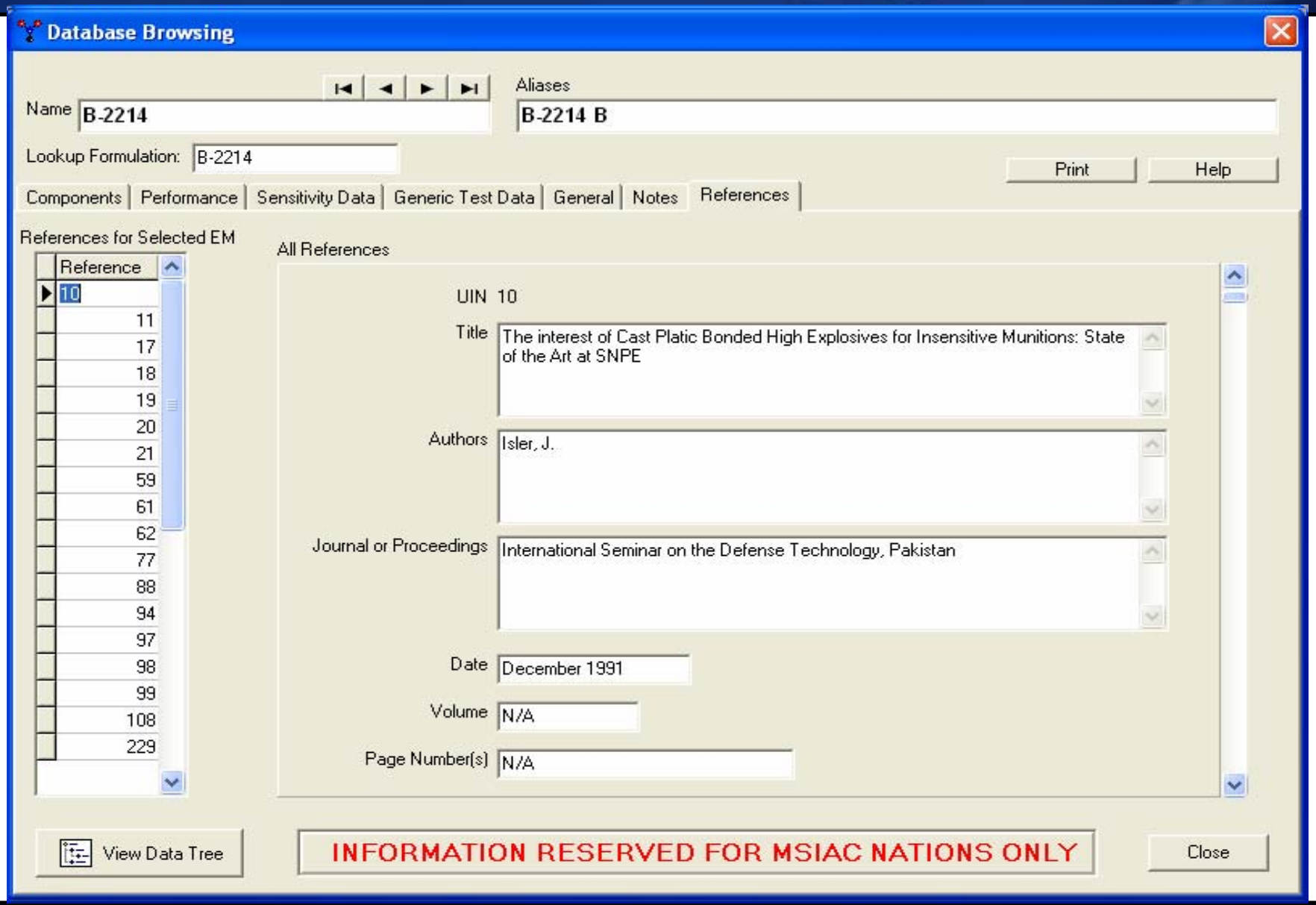
New Datasheets can be downloaded from the internet

ADN.pdf
BuNENA.pdf
CL-20.pdf
DMDNB.pdf
DNAN.pdf
Fox-7.pdf
HNF.pdf
HTPE.pdf
LLM-105.pdf
NTO.pdf
polynimmo.pdf

- **New IM suppliers catalog**
- **Inclusion of NEWGATES and BIRD**
- **NATO AOP-26 Ed 2**
- **Updated version of FRAID**

345 'registered' users

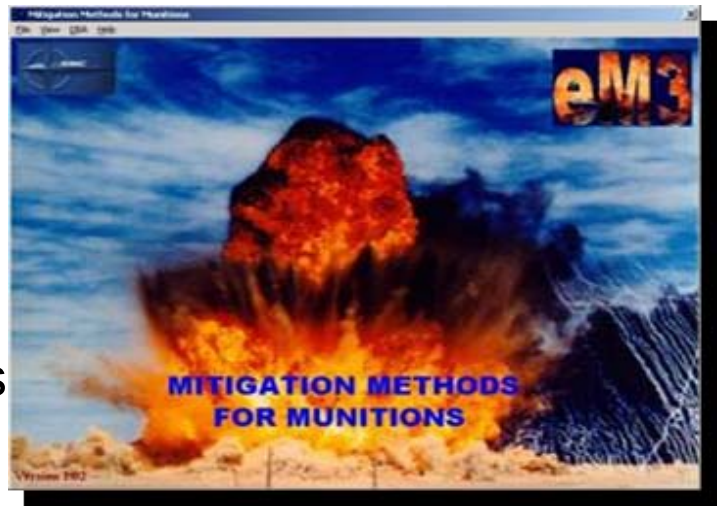
Information Included in EMC

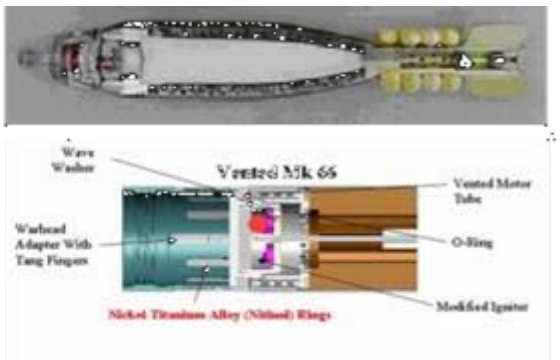


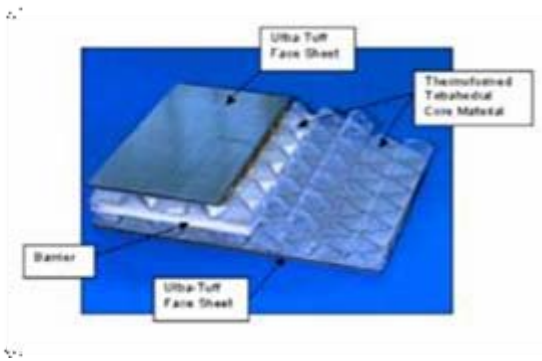
Mitigation Methods for Munitions - M^3

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





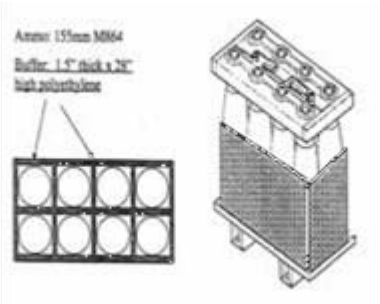


Mitigation Methods for Munitions - M³

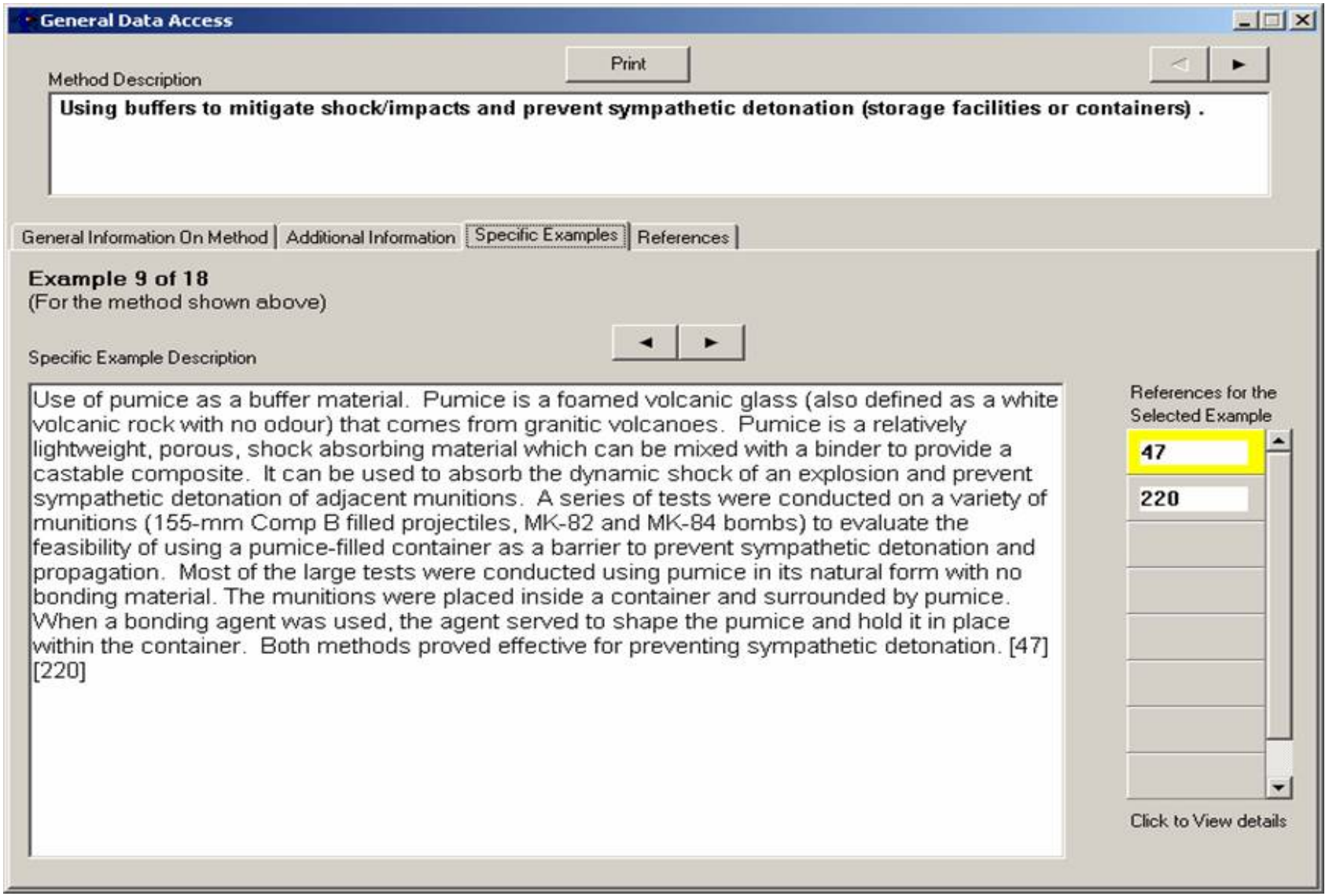
Sympathetic Reaction Of Adjacent Munitions

Search In M³ For Potential Design Solutions

- Input Component → MUNITION
- Input Configuration → PACKAGED
- Input Threat → SYMPATHETIC REACTION

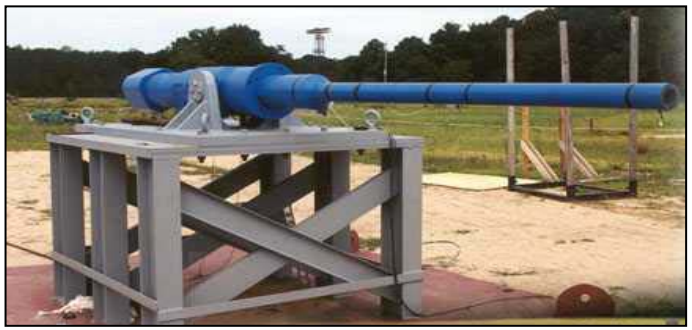


Mitigation Methods for Munitions - M^3



FRAgment Impact Database - FRAID

- 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-f.peron@msiac.nato.int

2007

REFERENCES

MSIAC would like to acknowledge the contribution of the following organizations

Select your Explosive & Click on it

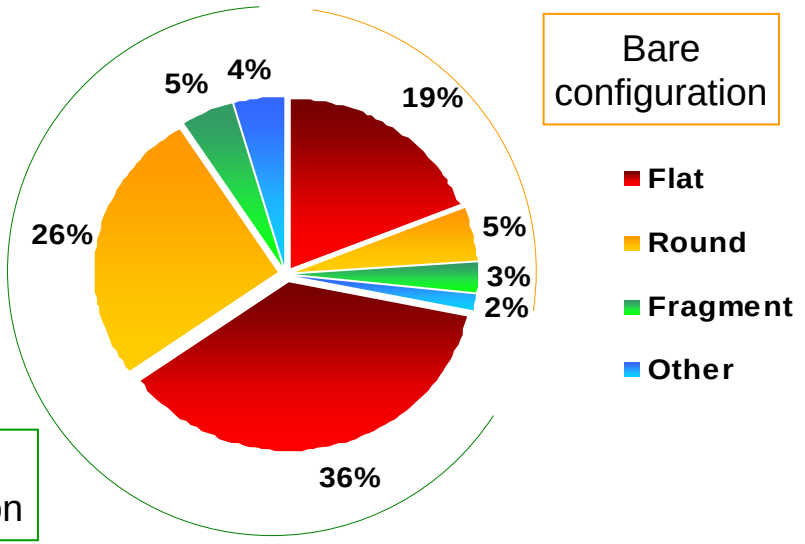
SYSTEMS

V1.8 released in December 2007

Version	Number of compositions	Number of results	Number of references
V1.8	86+Systems	1716	136

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

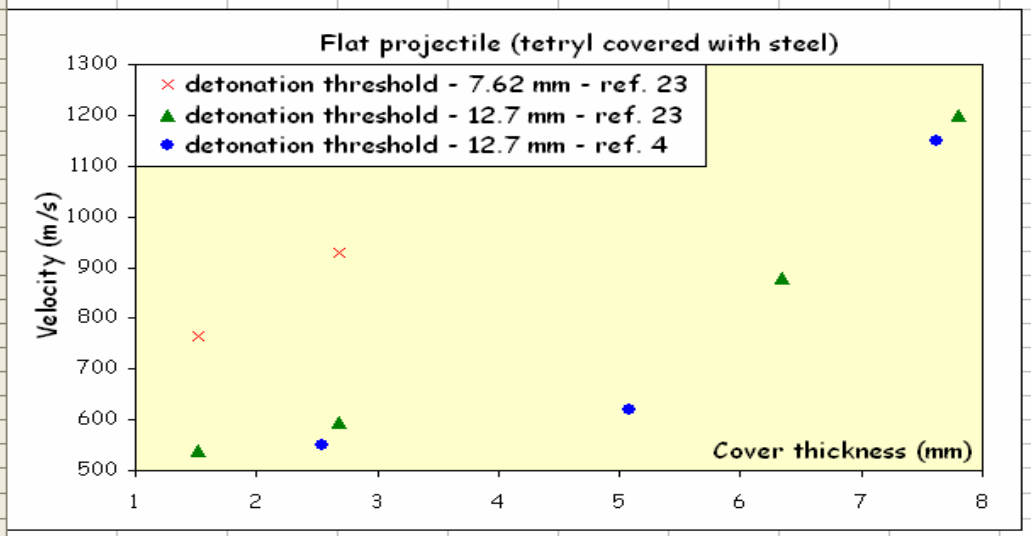


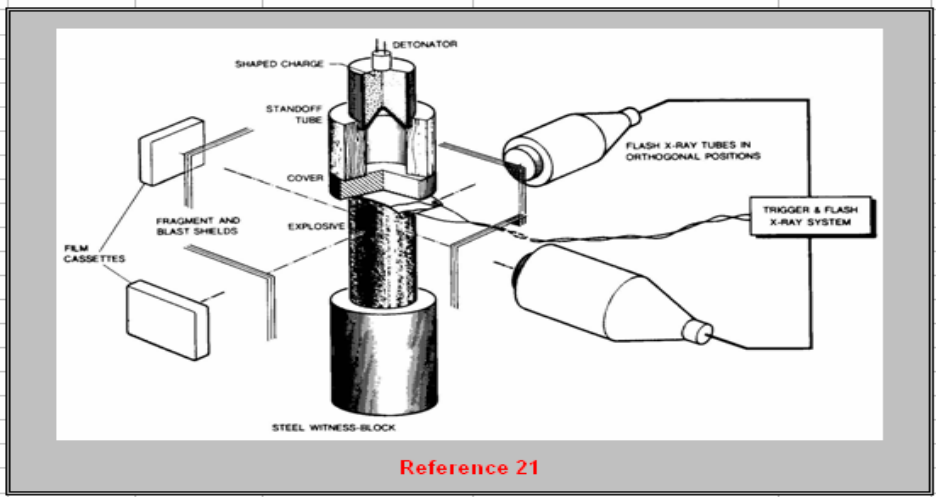
FRAID Datasheet Examples

TETRYL

Steel

EXPLOSIVE			COVERING/CASING				PROJECTILE					RESULTS (detonation no detonation type III, IV, V, XDT, ...)	REMARKS	REFERENCES
density (g/cm^3)	process	state	thickness (mm)	diameter (mm)	length (mm)	nature	shape	nature	incidence (°)	velocity (m/s)	diameter or side (mm)			
1.5	porous	solid	2.54	-	-	-	flat	steel	0	550	12.7	detonation threshold	Data from reference 109	4 109
			5.08							620	12.7	detonation threshold		
			7.62							1150	12.7	detonation threshold		
1.54	-	solid	1.52	76	76	steel	flat	steel	0	766	7.62	detonation threshold	6.4 mm thick brass casing Data used for the determination of Jacob-Roslund model parameters	23
			2.69							929	7.62	detonation threshold		
1.54	-	solid	1.52	76	76	steel	flat	steel	0	539	12.7	detonation threshold	6.4 mm thick brass casing Data used for the determination of Jacob-Roslund model parameters	23
			2.69							595	12.7	detonation threshold		
			6.35							878	12.7	detonation threshold		
			7.8							1200	12.7	detonation threshold		
1.48	pressed	solid	136	38	< 100	-	shape charge jet	copper	0	3500	1.5	detonation threshold	MRL 38 mm shaped charge Bow shock initiation	21 (see below)



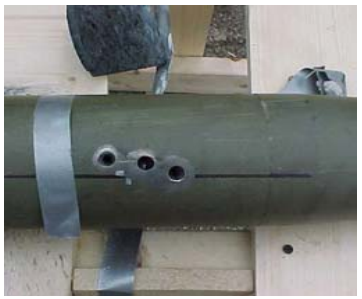


Reference 21

Bare | Steel

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



Version	5.56mm	7.62mm	12.7mm	14.5mm	20mm	25mm	30mm	Ref.	
V1.2	21	1194	1035	2	38	0	46	141	2336

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

SYR

SYmpathetic Reaction Database

Version 1.2

NATO OTAN

MSIAC Supporting Munitions Safety

Problems/Questions: MSIAC or Pierre-François PERON

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Email: msiac@msiac.nato.int

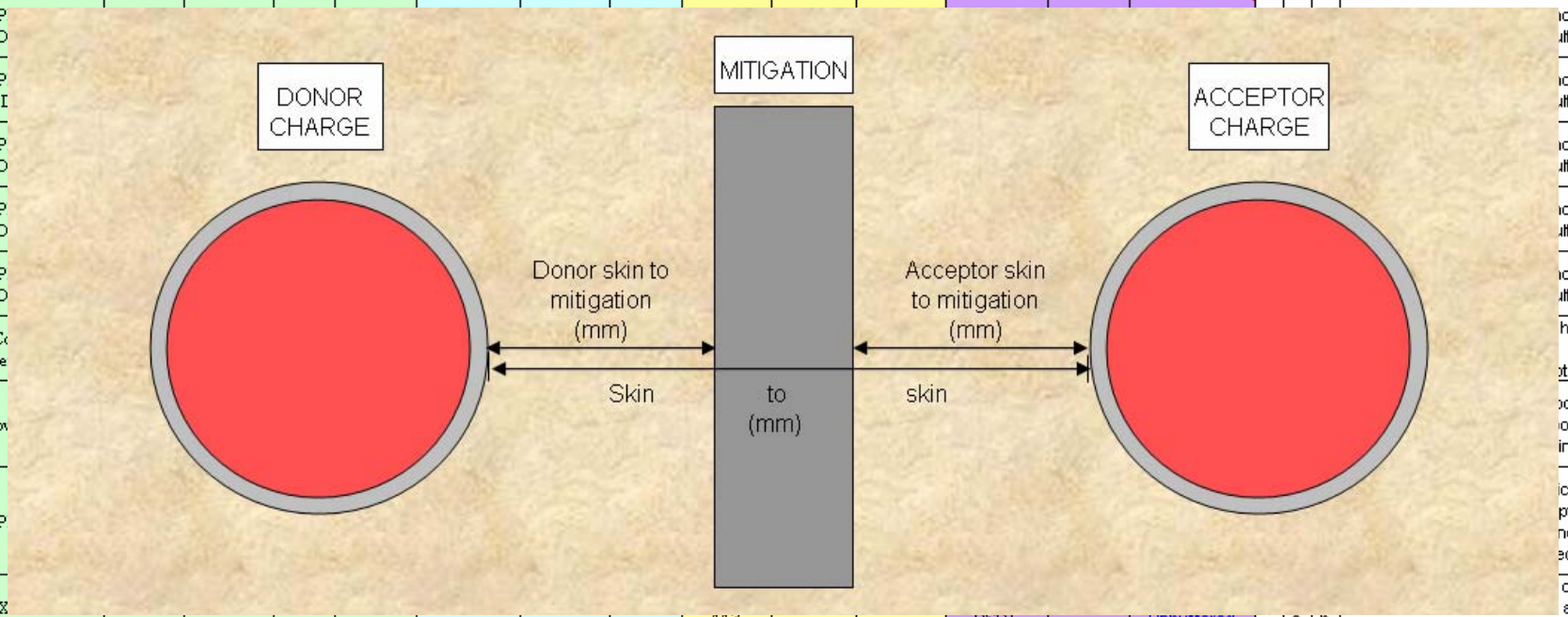
or p-f.peron@msiac.nato.int

2008

Version	Number of compositions	Number of results	Number of references
1.2	101	670	109

SYR – Database Content

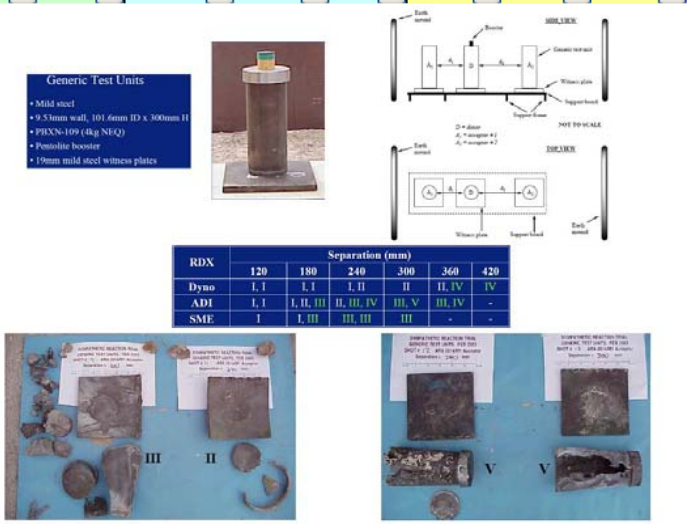
	Munition	Donor (D) and Acceptor (A) Charge Features: Energetic Material	External Diameter (mm)	Case Thickness (mm)	Case Length (mm)	Case Material	Mitigation: Mitigation Material	Mitigation Thickness (mm)	ρ (g/cm³)	Test Set up: Distance Donor Skin to Acceptor Skin (mm)	Distance Skin of Donor to Mitigation (mm)	Distance Skin of Acceptor to Mitigation (mm)	Results: Initiation Mechanism	Reaction Type	Configuration	References	General Comments
41	GTU	P (D															ce on sympethetic lts
42	GTU	P (AI															ce on sympethetic lts
43	GTU	P (D															ce on sympethetic lts
44	GTU	P (D															ce on sympethetic lts
45	GTU	P (D															ce on sympethetic lts
60	105 mm M1 shell	C Pe															high and 203 mm tor (confinement)
76	4.5" N36	Rov															booster osite side to donor in the acceptor
102	60 mm MAPAM	P															ic box (6 mortars) ptor - 1 diagonal nert ed on drawings
103	LU-211M	X		8						113			DSDT		Unbuffered	a	b configuration acceptors Distance measured on a picture
104	LU-211M	XF 13 333	155	16.4 15 8	560	Steel	-	-	-	35 113			SDT DSDT	IV	One on Many Unbuffered	15	15 a 15 b 16 rounds in a pallet configuration 1 donor and 2 active acceptors inside the pallet Distance measured on a picture



Front Page | DATABASE | Test Setup Diagram | References

SYR – Database Content

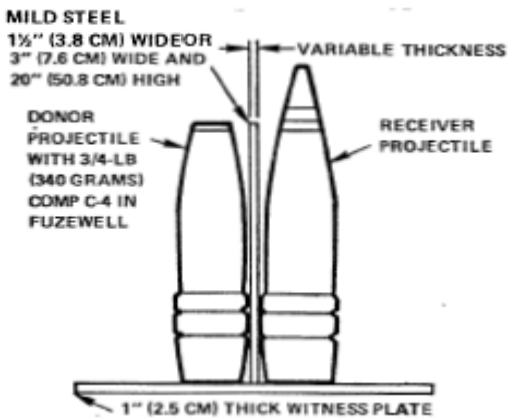
	Munition	Donor (D) and Acceptor (A) Charge Features: Energetic Material	External Diameter (mm)	Case Thickness (mm)	Case Length (mm)	Case Material	Mitigation: Mitigation Material	Mitigation Thickness (mm)	ρ (g/cm³)	Test Set up: Distance Donor Skin to Acceptor Skin (mm)	Distance Skin of Donor to Mitigation (mm)	Distance Skin of Acceptor to Mitigation (mm)	Results: Initiation Mechanism	Reaction Type	Configuration	Information: References			General Comments
41	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	II, IV	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
42	GTU	PBXN-109 (ADI RS-RDX)	120.66	9.53									SDT	III, IV	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
43	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	IV	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
44	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	V	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
45	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	V	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
60	105 mm M1 shell	Comp B (D) Pentolite (A)	105	17-10.2-10.5									SDT	I (x1) ND (x1)	One on One Buffered	56			Polyethylene plate 510 mm high and 203 mm wide Steel plate behind the acceptor (confinement)
76	4.5" N36	Rowenex 1100	114.3	-									Undefined	-	One on One Buffered	9			Rowanex 3601 booster Shell burst open one the opposite side to donor No fragment penetration in the acceptor
102	60 mm MAPAM	PBXN-110	60	10	153	resin and ϕ 4 mm steel spheres	-	-	-	indicated but few mm for adjacent			Undefined	IV	One on Many Buffered	14	14 a		Test performed in the logistic box (6 mortars) 1 donor - 1 adjacent acceptor - 1 diagonal acceptor - 3 inert Charge features measured on drawings
103	LU-211M	XF 13 333	155	16.4 15 8	560	Steel	-	-	-	35 113			SDT DSDT	IV	One on Many Unbuffered	15	15 a	15 b	8 rounds in a half pallet configuration 1 donor and 2 active acceptors Distance measured on a picture
104	LU-211M	XF 13 333	155	16.4 15 8	560	Steel	-	-	-	35 113			SDT DSDT	IV	One on Many Unbuffered	15	15 a	15 b	16 rounds in a pallet configuration 1 donor and 2 active acceptors inside the pallet Distance measured on a picture

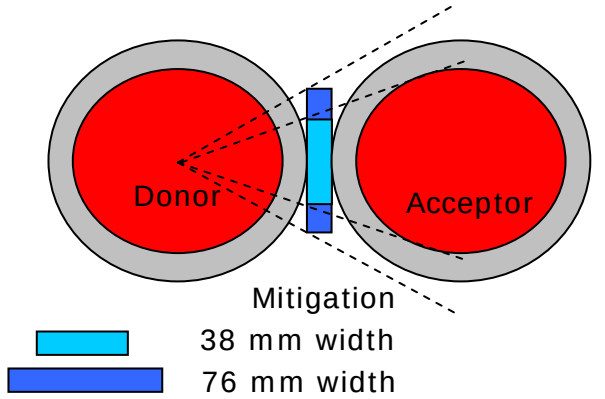


Front Page | DATABASE | Test Setup Diagram | References

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





Lateral dimensions (mm)	Thickness (mm)	Number of detonation results/ Number of tests
38 mm	3	0/4
	6	0/1
	9.5	0/1
76 mm	3	2/3
	6	2/4
	9.5	0/3

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

DARTS

Database of Ammunition Reaction Trials to Shaped Charge Aggression

Version Beta

NATO OTAN

MSIAC Supporting Munitions Safety

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

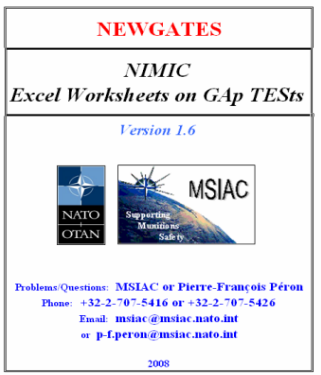
2008

Version	Number of compositions	Number of results	Number of references
Beta	18	50	10

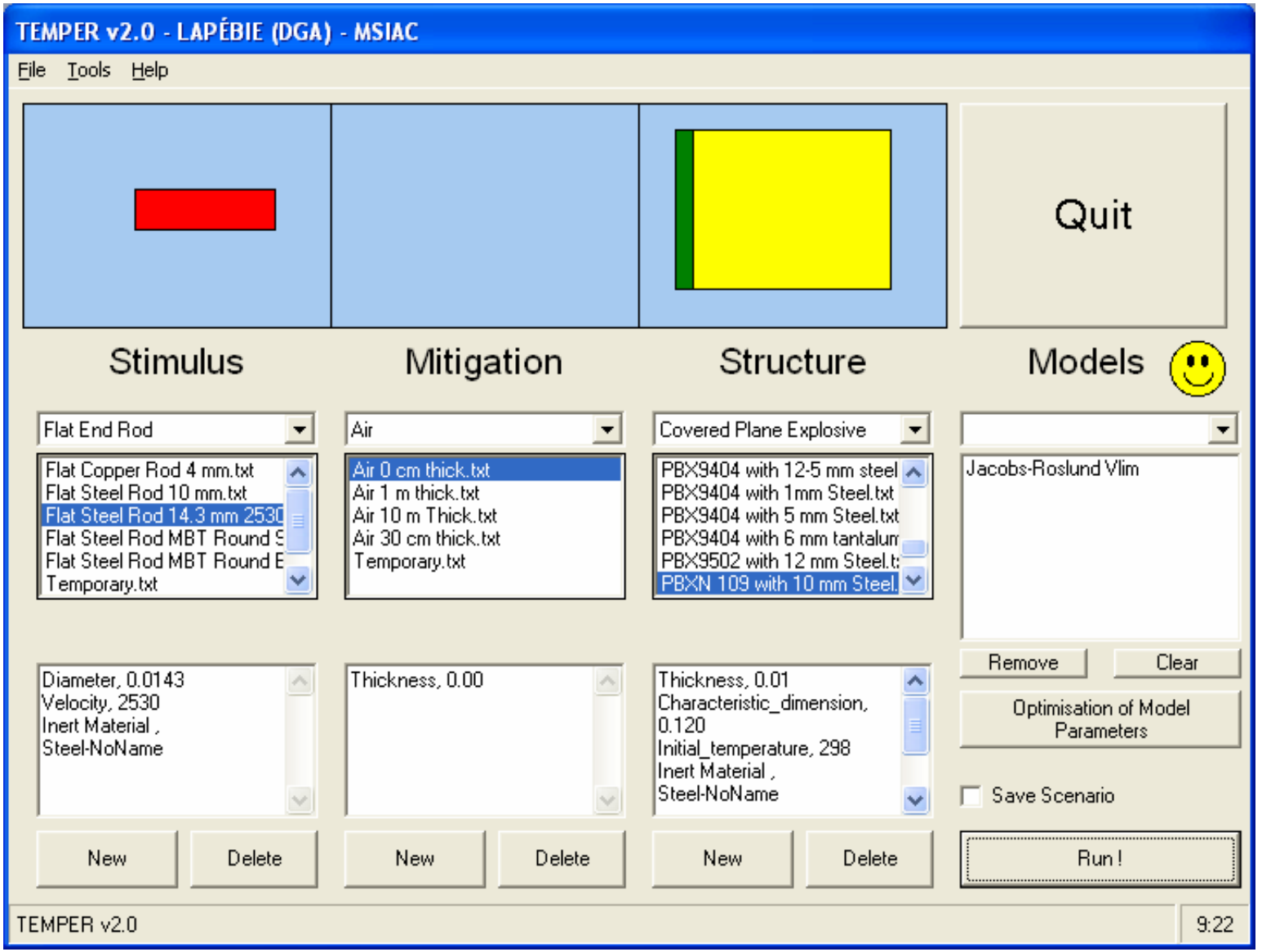
Database Searching Tool

- 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)

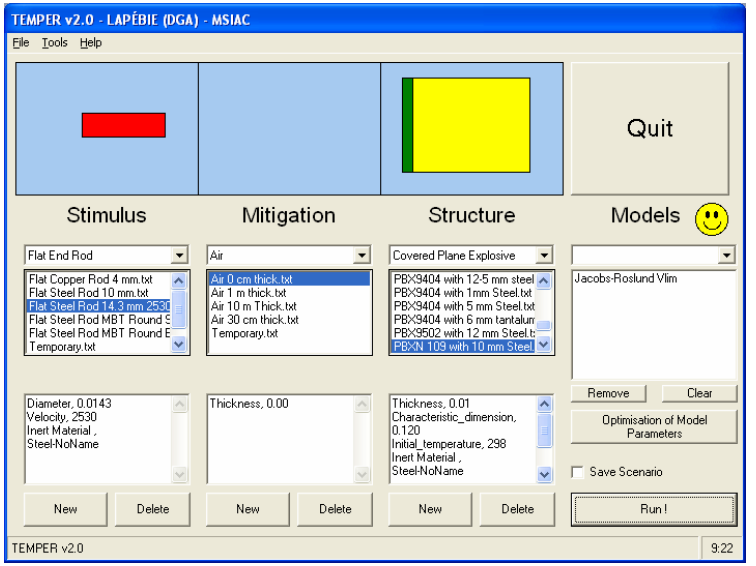


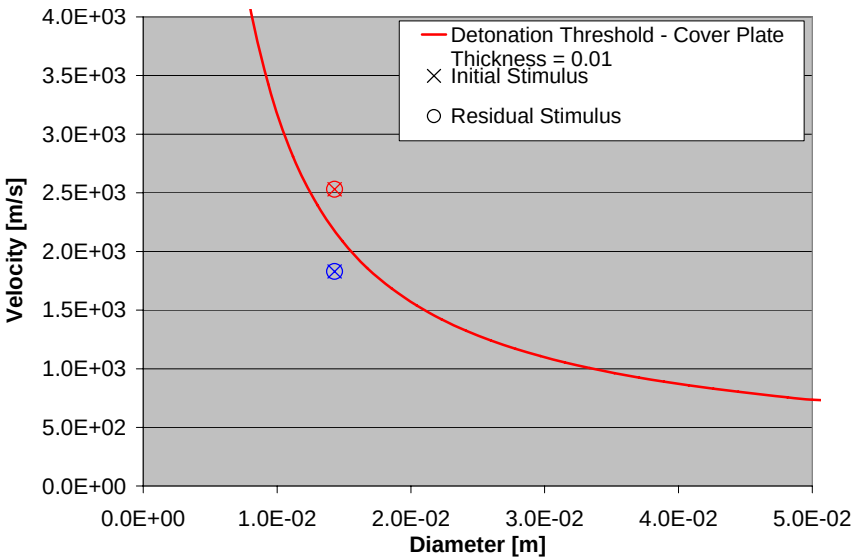
Toolbox of Engineering Models for the Prediction of Explosive Reactions (TEMPER)



TEMPER

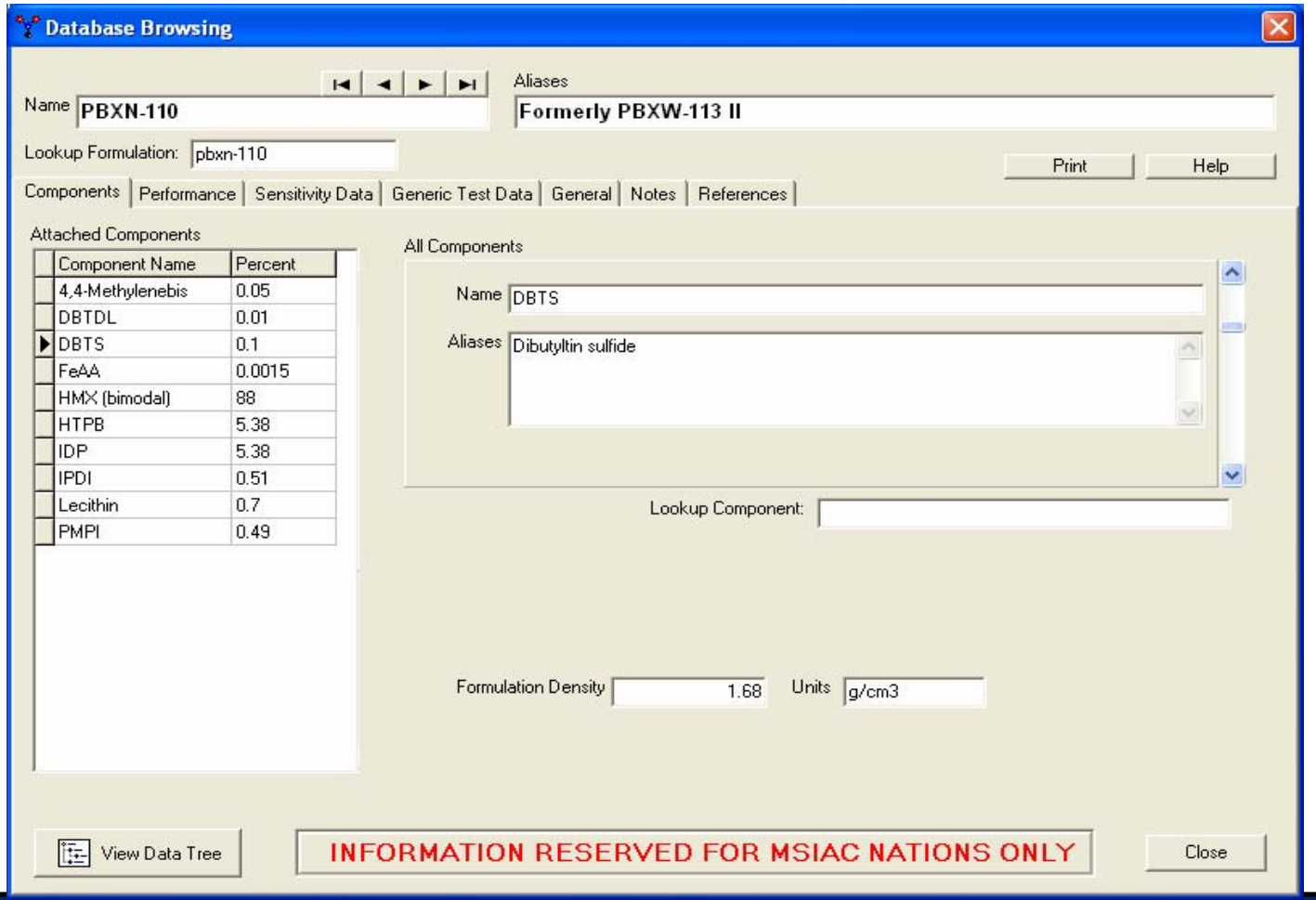
- MSIAC in conjunction with DGA (French MOD) have been offering access to a French software program called TEMPER
- A library of empirical and analytical models dedicated to ammunition safety. It has the potential to become a reference tool if resources allocated
- MSIAC acts as a focal point to ensure 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 simulations
  - 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?



EMC

Example of Database Use for Engineering Work

NEWGATES

Number of available gap tests results	508			SSWaterGT results			ISGT results				NOL-LSGT results			
INTRO / Substance	rho0 [g/cm3]	C0 [km/s]	S	gap length (mm)	Incident Initiation Pressure (Gpa)	Critical Initiation Pressure (Gpa)	number of cards	gap length (mm)	Incident Initiation Pressure (Gpa)	Critical Initiation Pressure (Gpa)	number of cards	gap length (mm)	Incident Initiation Pressure (Gpa)	Critical Initiation Pressure (Gpa)
PBXN-110	1.680	2.470	1.270		-	-			-	-	154	39.12	3.67	4.15
PBXN-110	1.680	2.470	1.270	17.0	2.3	3.21			-	-	178	45.21	2.69	3.06
PBXN-110	1.600	1.905	3.700	15.0	2.7	4.01			-	-			-	-
PBXN-110 (Dyno RS-HMX)	1.650	1.905	3.700	11.0	3.6	5.47			-	-			-	-
PBXN-110 (Dyno)	1.650	1.905	3.700		-	-			-	-	172	43.69	2.90	3.61
PBXN-110 (Bofors)	1.660	1.905	3.700		-	-			-	-	150	38.10	3.87	4.94
PBXN-110 (HAAP)	1.670	1.905	3.700		-	-			-	-	159	40.39	3.43	4.35
PBXN-110 (HAAP- 6 months old)	1.620	1.905	3.700		-	-			-	-	156	39.62	3.57	4.49
PBXN-110 (Bofors- 6 months old)	1.620	1.905	3.700		-	-			-	-	158	40.13	3.48	4.36
PBXN-110 (Dyno- 6 months old)	1.640	1.905	3.700		-	-			-	-	173	43.94	2.86	3.55

SYR

	Donor (D) and Acceptor (A) Charge Features					Mitigation			Test Set up			Results			Information		
Munition	Energetic Material	External Diameter (mm)	Case Thickness (mm)	Case Length (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)	Configuration	Initiation Mechanism	Reaction Type	References		General Comments
60 mm MAPAM	PBXN-110	60	10	153	Plastic resin and ϕ 4 mm steel spheres	-	-	-	Not indicated but close			One on Many Buffered	Undefined	IV	14	14 b	Mortars in their logistic container Charge features measured on drawings

BIRD

12.7 mm bullet impact

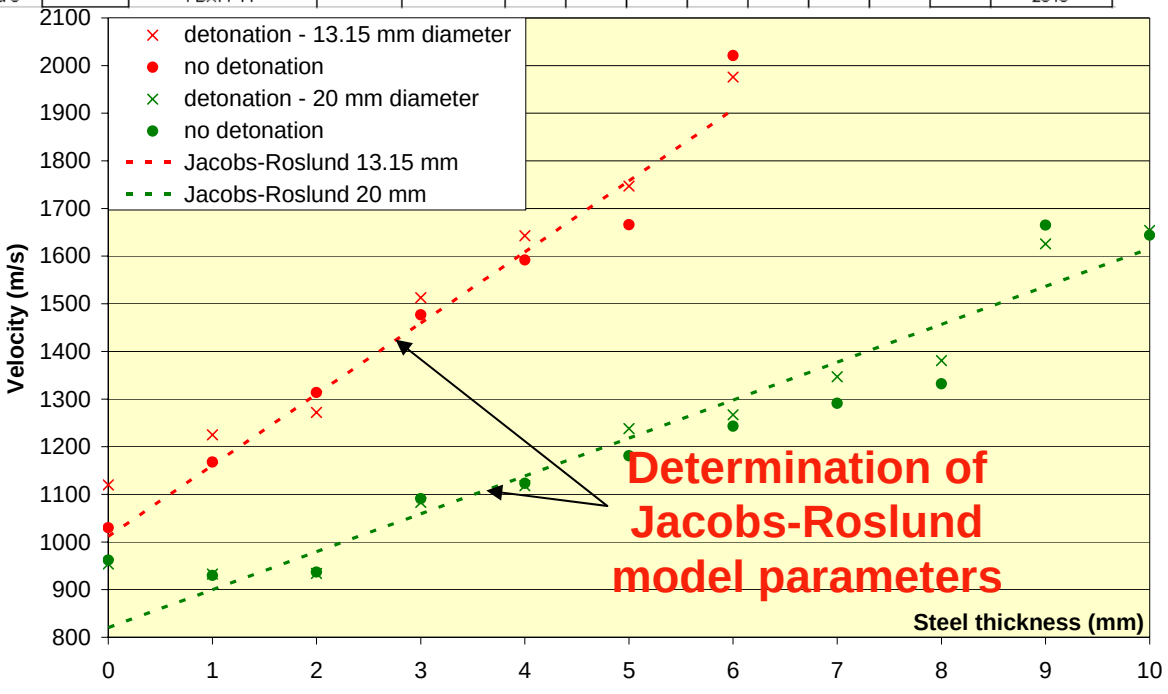
TESTED SYSTEM									THREAT						TEST	REACTION LEVEL						
System Designation	Country of Test	Tested Item	Config	Aim point	Aim Point Design.	Energetic Material at Aim Point	Case thickness at Aim Point (mm)	Case Material at Aim Point	Design.	Vo (m/s)	Firing range (m)	V impact (m/s)	Burst or Single	Burst Timing (ms)	Proc.	Type I	Type II	Type III	Type IV	Type V	NR	Other
2,75 inch Rocket (HYDRA-70)	US	W	B	Warhead Fuze Booster	MK 146 Mod 0 MK 435 Mod 0	PBXN-110 PBXN-7	-	Steel	AP	-	-	850 +/-60	B	-	MIL-STD-2105B					1		
2,75 inch Rocket (HYDRA-70)	US	W	B	Warhead Center	MK 146 Mod 0	PBXN-110 (Cast)	-	Steel	AP	-	-	850 +/-60	B	-	MIL-STD-2105B					1		
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		
UN Steel Tube	NW	GTU	B	Center	-	PBXN-110	4	Steel	AP M2	840 +/-40	-	-	S	-	EIDS 7(d)(i) Test						3	

Example of Database Use for Engineering Work

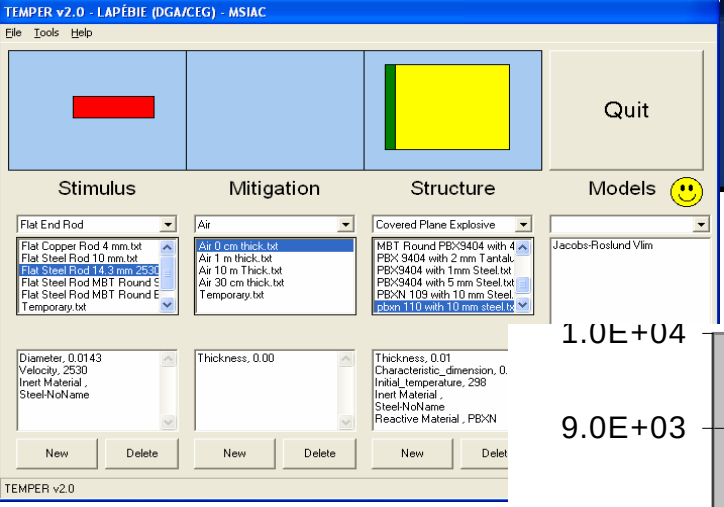
EXPLOSIVE			COVERING/CASING				PROJECTILE					RESULTS	REMARKS	REFERENCES
density (g/cm³)	process	state	thickness (mm)	diameter (mm)	length (mm)	nature	shape	nature	incidence (°)	velocity (m/s)	diameter or side (mm)	(detonation no detonation type III, IV, V, XDT,		
99.8% TMD	cast-cured	solid	4.06	55.12	199.90	steel	conical 140° (16 g)	steel	0	1829	12.7	type IV	Test according to MIL-STD-2105 B (alternate test procedure #1) Target: UN steel pipe for EIDS bullet impact test Worst result over 2 tests Shaped charge application	46 47 48 (see below)
-	cast-cured	solid	5.1	76	-	steel	conical 160° (18.6 g)	steel	0	2050	14.3	type V	Test performed to replace the explosive composition of the HYDRA-70 rocket STANAG 4496 fragment	128 (see below)
										2266	14.3	type I		
-	-	solid	9.5	203.2	406.2	steel	≤ 2 cubes	steel	0	2530	12.7	type III (x3)	Test conducted in accordance with MIL-STD-2105 B Modified Naturally Fragmenting Test Unit (NFTU) used as a target	123

SYSTEM INFORMATION							THREAT	TEST	REACTION LEVEL								
System Name	System Designation	Clas.	Tested Item	Tested Item Design	Caliber (mm)	Energetic Material	Burst or Single	Proc.	Type I	Type II	Type III	Type IV	Type V	NR	Other	Ref	Velocity (m/s)
60mm Mortar	MAPAM	GMA	AUR	-	60	PBXN-110 PBXN-5	S	2105B					1			70	
AMRAAM	AIM-120A	AAW	F	WDU-41/B Mk 80 Mod 0	127	PBXN 110 PBXW-11	B	2105B					2			100	2504 2540

FRAID

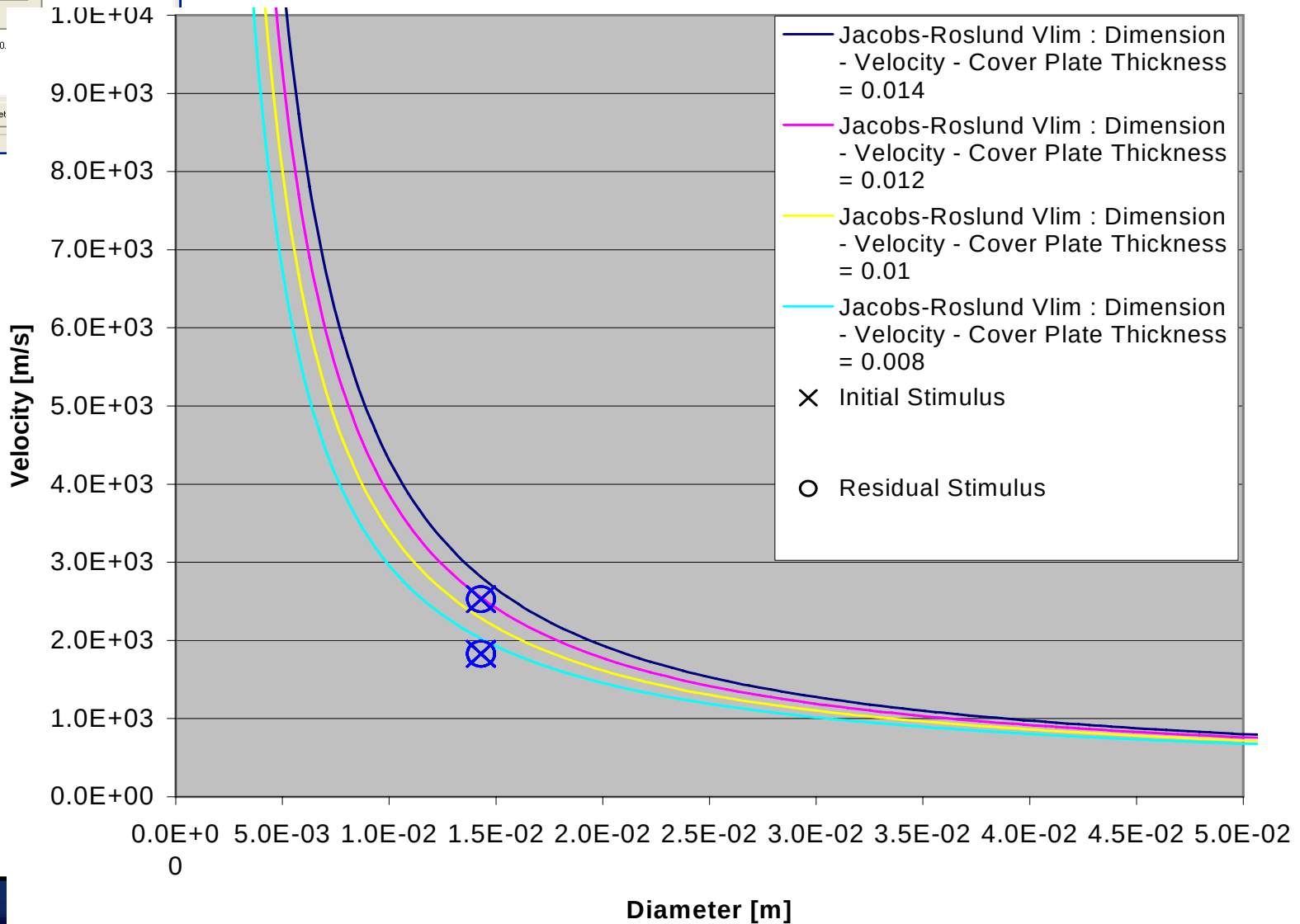


Example of TEMPER Simulation Result with FRAID Input Data



TEMPER

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



MSIAC
Supporting Munitions Safety

M **Munitions**
S **Safety**
I **Information**
A **Analysis**
C **Center**

Web site **http://www.msiac.nato.int**

e-mail **msiac@msiac.nato.int**

Safety Assessment Software - SAS

- 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