42nd Annual Armament Systems: Gun and Missile Systems Conference

Energetic Materials to Meet Warfighter Requirements: An Overview of Selected US Army RDECOM-ARDEC Energetic Materials Programs

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Outline

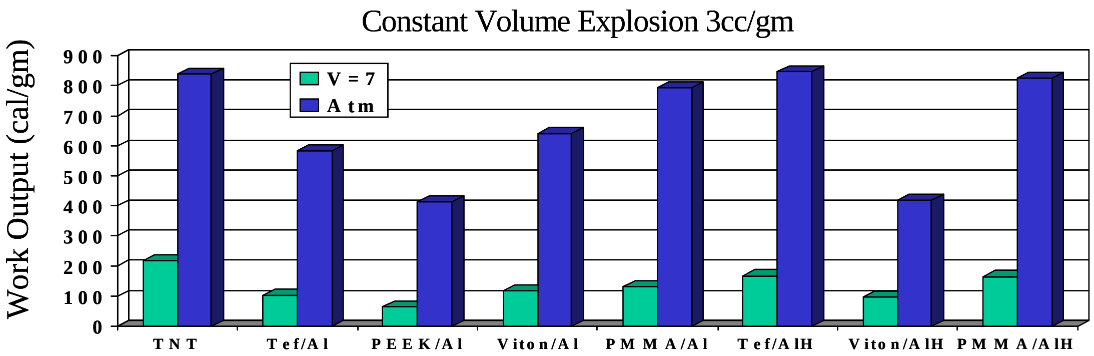
Selected US Army RDECOM-ARDEC Energetic Materials Programs

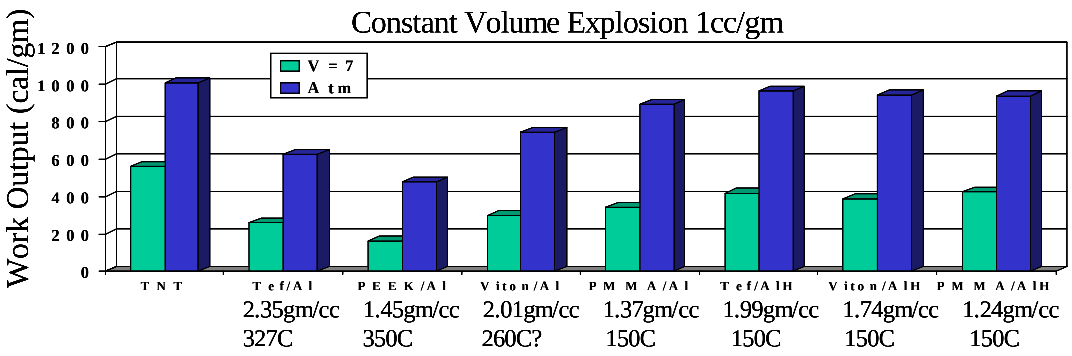
- Reactive Materials
- Insensitive Munitions Technology
- High Energy/High Blast Explosives
- Nanocrystalline Energetics & Nano Composites
- Summary

Reactive Material Applications

- Demolition Shaped Charge (BAM-BAM)
- Reactive Fragmentation
- EFP RM
- EM Splat
- Reactive IM Liners (PIMS)

- Active Protection System
- Low collateral damage
- Structural energetic
- KE Rod
- IED defeat
- Chemical agent defeat

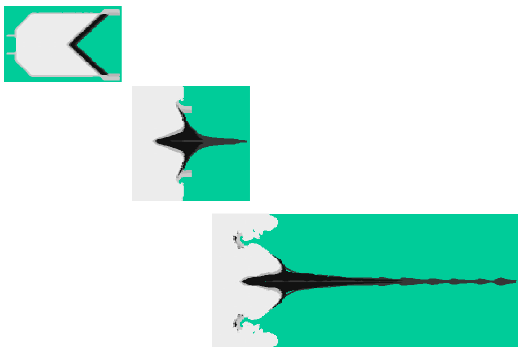




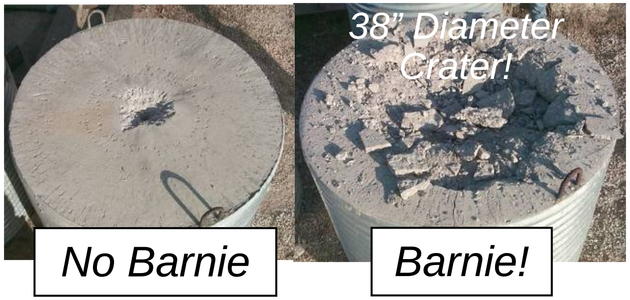
Unitary Demolition Reactive Material Warhead

Barnie SC Concept "The Rubblizer"

High-Rate Dynamic Continuum Modeling



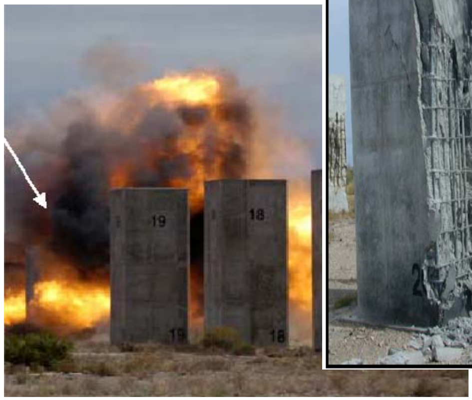
- *Incorporates defeat mechanism of a two stage munition into single unitary warhead concept!*
- *The most effective unitary demolition warhead currently known!*



Scaled up *"Bam-Bam"* Warhead

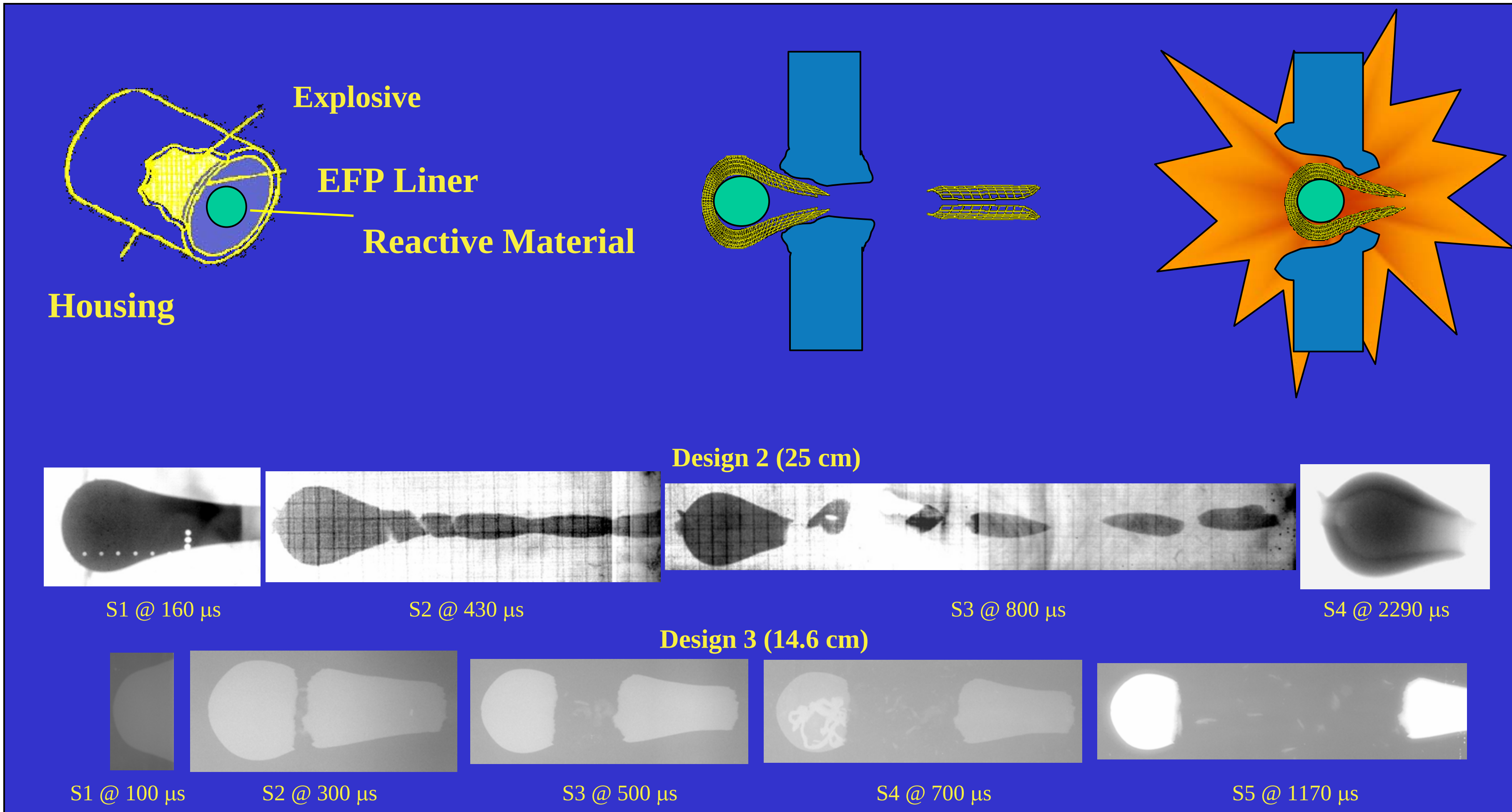
Roadway Cratering Test

PAM Bridge Pier Target Testing



REACTIVE MATERIAL ENHANCED LETHALITY EFP

Explosively formed long penetrator with follow-thru grenade for enhanced behind target effects.



IM TECHNOLOGY

- **IM ATO**
  - **Warhead Venting**
  - **Predictive Technology M&S**
  - **Gun Propellant**

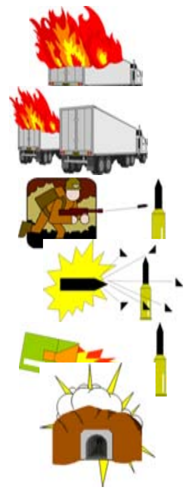
- **PEO AMMO IM Energetics Thrusts**
  - **Explosives**
  - **Gun Propellants**
  - **Warheads**

- **Major Customer Program**
  - **155mm Artillery TNT Replacement**
  - **120 mm Mortar Composition B Replacement**

- **High Performance Computing Software Applications Portfolio Insensitive Munitions (IM) Modeling & Simulation (M&S)**

- **OSD – IM S&T D-Line Program**

Six Threats



Fast cook -off (FCO)

Slow cook -off (SCO)

Bullet impact (BI)

Fragment impact (FI)

Sympathetic detonation (SD)

Shaped Charge Jet Impact (SCJ)

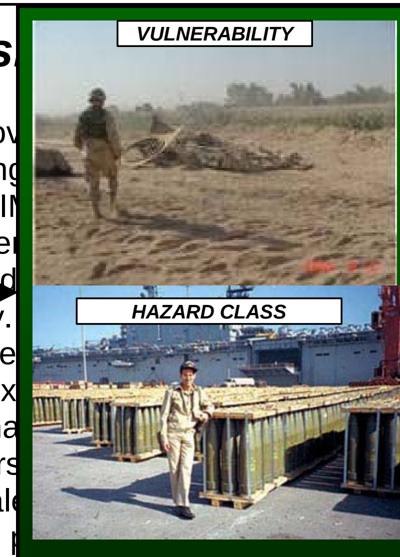
IV.WE.2005.03 IM Technologies for Guns, Miss... s

Responses

I / II	DETONATION/ PARTIAL DETONATION
III	EXPLOSION
IV	DEFLAGRATION
V	BURNING
VI	NO SUSTAINED REACTION

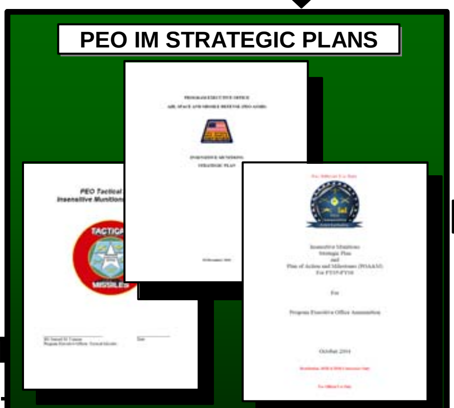
Example Munition Response Profile

FCO	SCO	BI	FI	SD	SCJ
V	III	VI	(IV)	(F I)	P IIII

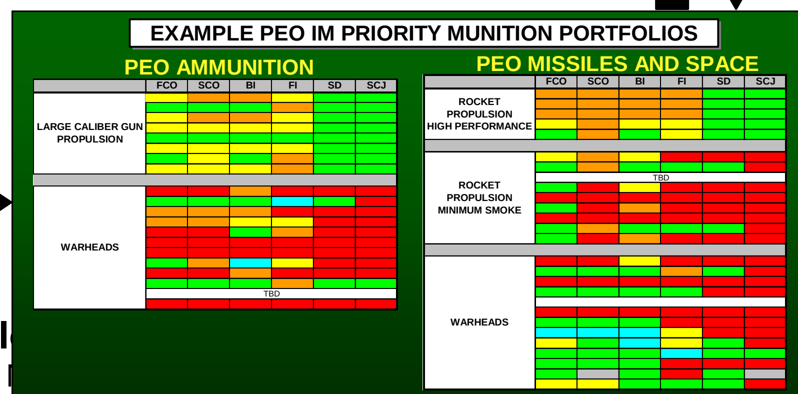


...ce survivability ... g ability, while prov... for Army ...ormance requi... ined with lightening ... nsitivity ...arfighter. Curr... does not enable I... ...frames consist... chnologies, both e... mitigation, will ...designing munition... ...aging weight, ...gistics benefits ... d improved safety. ... getics efforts ...technology devel... dressed. FY05. De... ation the ...e threshold for a ... late benchmark ex... dictive ...4). FY06. Apply/dem... lity to laboratory ha... ential of a ...rmulation (TRL 4). F... addition of barriers ... STD-2105C compliance, (b) a new high-energy propellant provides IM/performance potential equivale... propellant, (c) near tactical design of warhead venting (TRL 5) FY08.Apply venting design to full-scale ... ctive liner materials. Demonstrate slow cook-off burning response (TRL 5.) FY09. Demonstrate IM compliance thro... h testing using barriers, venting and a high-energy IM missile and gun propellant. Demonstrate that prediction metho... y using advanced numerical tools can predict fragment ... e munition (TRL 5). SUPPORTS: PEO Missiles and Space, UAMBL, ... M, NLOS-LS, PGMM, PAC-3 MSE, GMLRS.

IM ATO PROVIDES TECHNOLOGY TO THE ARMY'S MUNITION PORTFOLIO



FY05
1,100
750
4,450



AT...
Dr. ...
ARL-WMRD

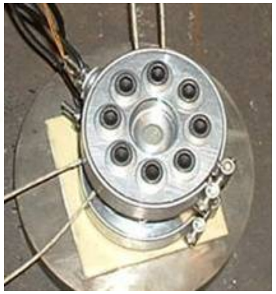
Technol...
Ms. Mary ...
HQDA, SAAL-TT

UAMBL, S&T Division Chief

IM ATO provides technology for reducing the vulnerability and hazard of the Army's future munition portfolio

IM Warhead Venting for Cook-off Response Mitigation
(Tech Base/PEO Ammunition Leveraging)

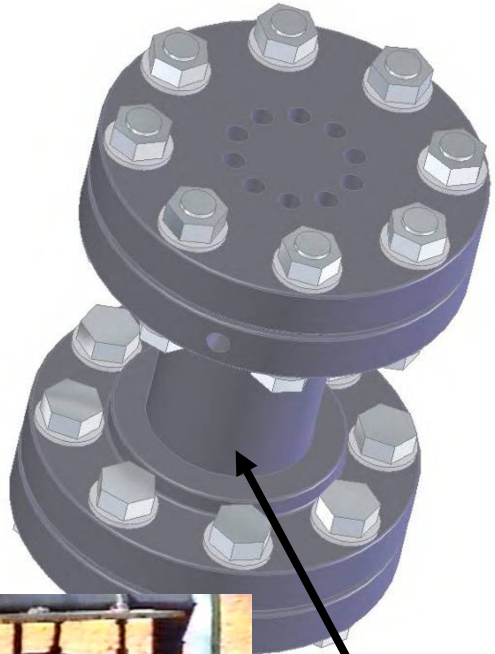
ARDEC Tech Base Small-Scale 1" Test (In-House)

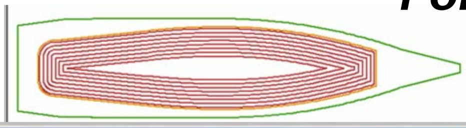


PEO IM Venting Large-scale 3" test

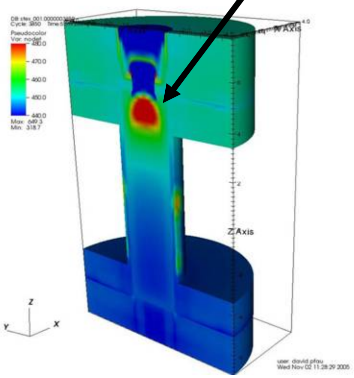
Venting Thrust

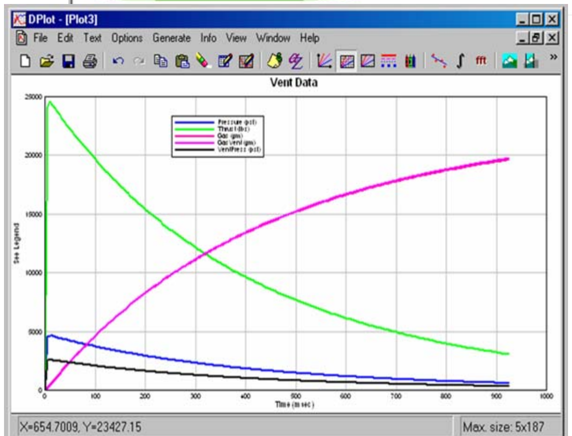
Techbase transfer For PEO Demo

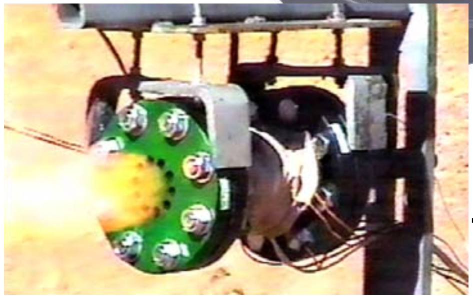




Ignition







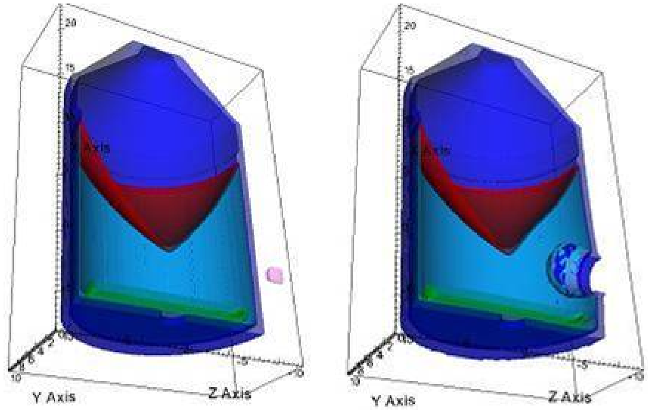
Pressure Transducer Port

Tech base ignition and burn modeling:
Predict and design ignition and required venting calibrated using small scale tests

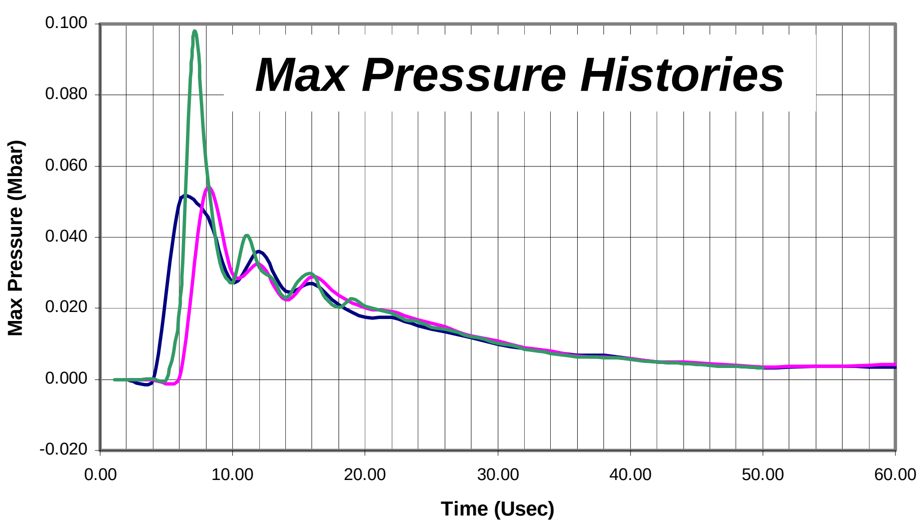
GENERAL DYNAMICS
Strength on Your Side™

Predictive Technology Description
FI/BI/SD IM Warhead Development

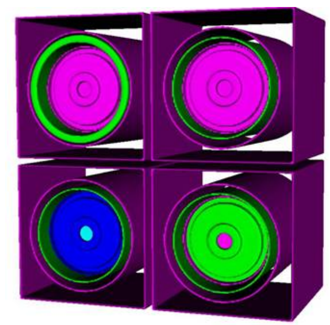
NLOS-LS & MRM Impact Modeling

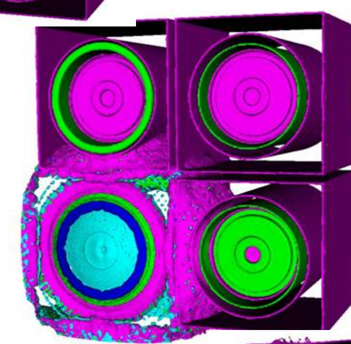


ALE3D

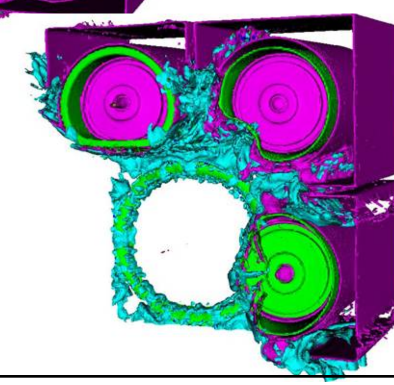


NLOS-LS & MRM SD Modeling





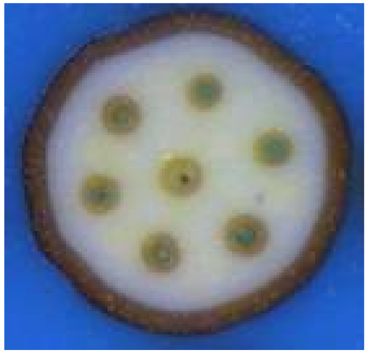
Peak Pressures
Adjacent: 17Kbar
Diagonal: 7Kbar



- *BI/FI/SD Modeling Results Provide Design Capabilities to Mitigate Responses*
- *MRM & NLOS-LS: Being Designed to Pass IM Tests!*

PEO AMMO IM Propellant Thrust
Evaluation of Non-Nitroglycerin Propellants

NG Free Propellant



Description

- Propellant formulations with NG sensitive to ignition from outside stimuli (Poor IM characteristics)
- Potential of a basic non-NG propellant formulation that can be tailored through changes to grain geometry to work with a wide range of munitions
- Feasibility study to test and evaluate non-NG extruded propellants for use in DOD munitions items (medium cal and mortar)

Approach

- **Manufacture various candidates**
- **IM screening tests**
- **Down-select propellants**
- **Granulate verification lots**
  - 500 pound lot each for evaluation in 120mm non-NG main charge propellant and for 30mm MK258)
- **Ballistic testing**
- **IM Testing**

Warfighter Payoff

- Elimination of NG from propellant formulations will reduce propellant sensitivity to shock
- Reduced propellant sensitivity to bullet impact and fragment impact
- Reduced sensitivity will improve propellants response to slow cook-off

Low Cost Common IM Explosives Program
PEO AMMO / PM-CAS

- **Low Cost TNT IM Replacement**
  - 11 candidates tested
  - 3 selected candidates showed significant IM improvements and are low cost
  - All Pass SD in current configuration without barrier
  - Team pursuing insertion into M795 production in FY09
- **Low Cost COMP B IM Replacement**
  - Program on-going
  - Test vehicle is 120mm mortar
  - Multiple candidates under testing

155 mm M795	FCO	SCO	BI	FI	SD	SCJ
A	TBD	IV	V	V	III	TBD
B	TBD	V	V	V	III	TBD
C	TBD	V	IV	V	III	TBD
TNT	III	III	III	III	I	TBD

I / II	III	IV	V	VI
Detonation / Partial Detonation	Explosion	Deflagration	Burn	No Sustained Reaction (Unofficial)

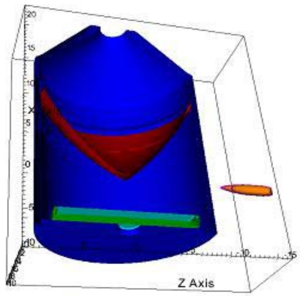
SD

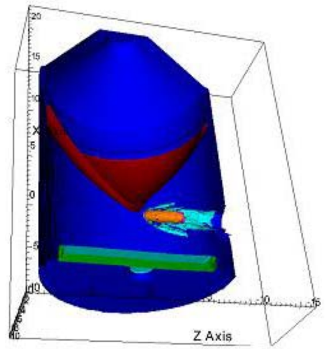
Fragment Impact

Bullet Impact

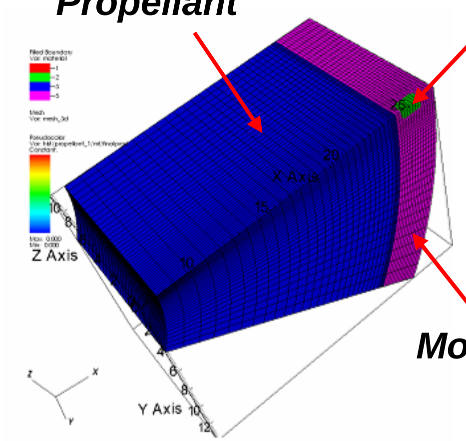
High Performance Computing Software Applications Portfolio Insensitive Munitions (IM) Modeling & Simulation (M&S)

- *ARDEC leading a Tri-Service proposal with National Lab participation (LLNL, SNL, and LANL).*
- *Focused on improving the state of the art in DOE developed codes for modeling of bullet and fragment impact on rocket motors and confined energetic warheads.*
- *A 3 year effort that builds upon the previous CHSSI Multiphase Flow and Target response (MFT) effort and leverages numerous DoD/DOE programs such as prior Joint Munitions Planning (JMP) and Technical Coordination Group (TCG) efforts.*



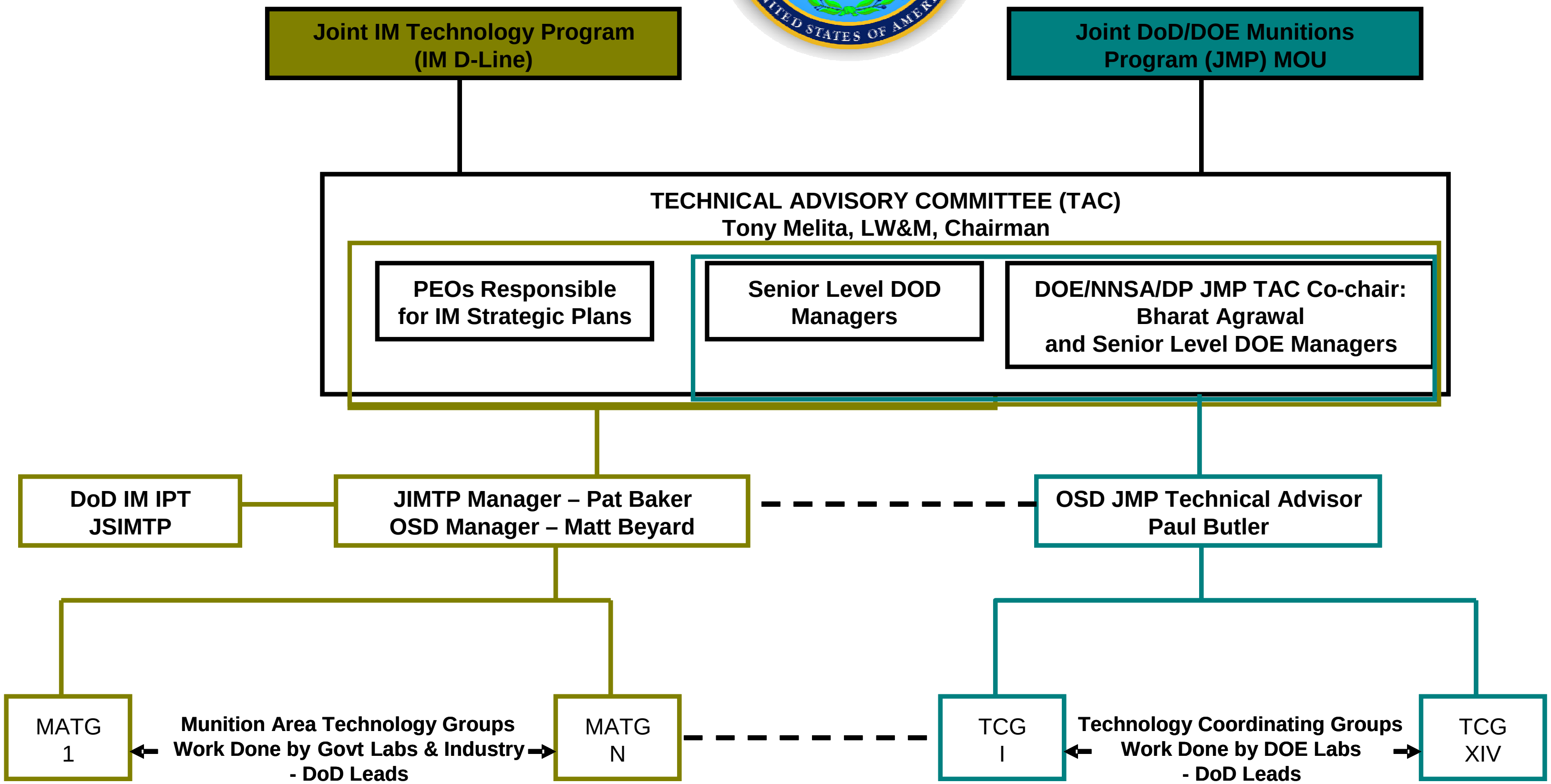


BI on Warheads



FI on Rocket Motors

JIMTP Structure

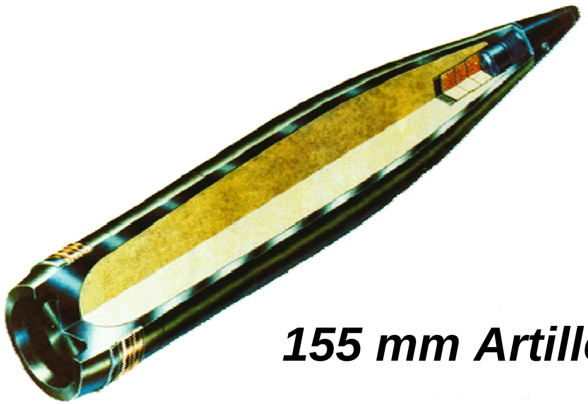


OSD D-Line IM Program
A Joint Service Collaboration & Partnership

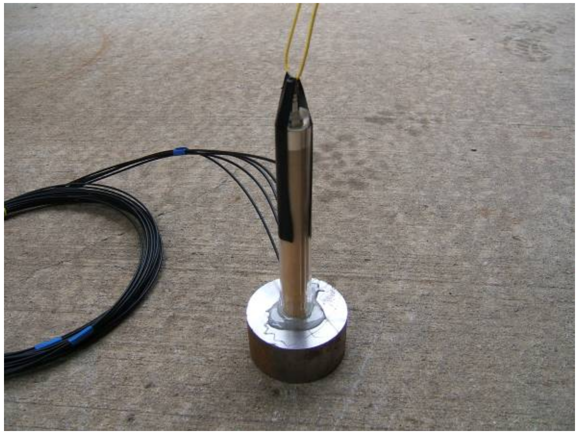
IM Melt-Cast Explosives

- ***New IM Melt-Cast explosive compounds***
- ***Synthesize compounds of interest and evaluate safety, toxicity, compatibility & performance at small scale***

Mortar



155 mm Artillery



Measurement of Detonation Velocity

OSD D-Line IM Program
A Joint Service Collaboration & Partnership

Development of Halogenated Wax Binder Systems for High Power Explosives

- ***Press loaded explosive formulations competitive with or exceeding the performance of top explosives (e.g. LX-14), while gaining insensitivity sufficient to achieve IM requirements***

- ***Chlorinated binder systems have shown improvement in IM properties and have helped maintain performance***

- ***BI Test resulted in Type V Reaction - Burn***
- ***LX-14 resulted in Type IV Reaction - Deflagration***

High Energy / High Blast Explosives

- High Blast
  - PAX-3 transitioned to BDM and demonstrated in LOS-MP
  - Excellent IM Properties

- High Impulse
  - Several Thermobaric type formulations tested and characterized in coordination with ARL TBX test program and DTRA Test Program

- Combined Effects Explosives - High Energy/High Blast
  - PAX-30
  - PAX-42

Explosive Formulation Development

2006 — **PAX-XX, (FCS MP-MRM, JCM)**

PAX-41 (SPIDER)

PAX-AFX-196 (155MM M107, M795)

PAX-28, Aluminized Cast (Unitary)

PAX-31, Improved Comp B Repl (120mm Mortar)

PAX-22, 92% CL-20

PAX-24, TNT Replacement

2000 —

PAX-21, Comp B IM Replacement (60mm mortar)

PAX-23, (AX-1) Future Armor Tile for Abrams Tank Systems TC FY99

PAX-12, 90% CL-20 IM (PM SWMO, LSO Warheads)

1997 — **PAX-11, 94% CL-20**

PAX-3, HMX/Alum. IM (PAM TC'ed FY99)

PAX-2A, 85% HMX IM (M915, M982, MLRS – Grenade Submunitions)

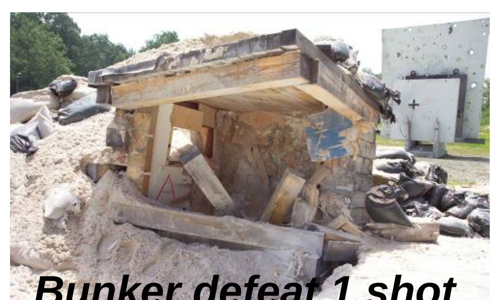
PAX-2, 80% HMX IM (25mm)

1987

PAX 3 Tested in LOS-MP and BDM

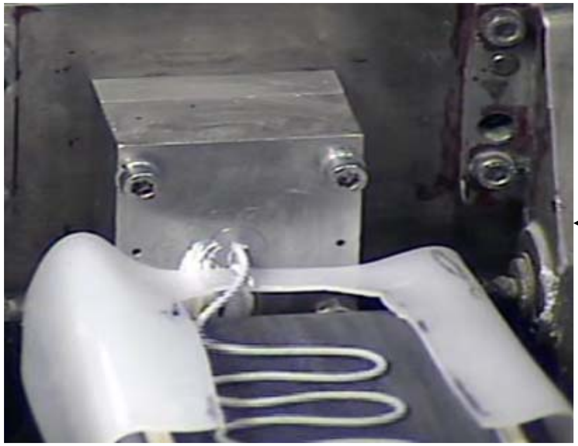
- Warhead design and process
  - PAX 3 has excellent loading and machining characteristics
- Integrated PAX3 warhead fired from M256 gun system at 30,000 g’s
- PAX 3 will not detonate as warhead passes through targets
- PAX 3 warhead performance on target meets exit criteria for LOS-MP ATO
- PAX 3 transitioned to BDM

2 shots defeat DRC

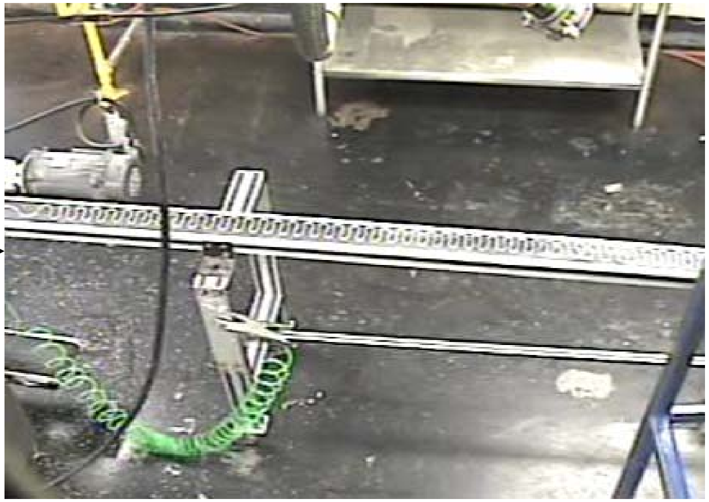


Bunker defeat 1 shot

Twin Screw Extrusion of PAX-3



Extruded
PAX-3



Final End
Product
PAX-3

Granulated
PAX-3

IN-HOUSE Production Capability "A GO"

High Energy Coupled with High Blast
Increased Blast / Maintained Energy for Combined-Effects Warhead

Percent Change in Performance Compared to LX-14			
HE	Cost of Explosive Fill ($)/lb.	Metal Pushing/Unit Volume (Experimental)	Blast (Calculated)
LX-14 (HMX)	18	0 (Baseline)	0 (Baseline)
PAX-29c (CL-20)	600	17 %	43 %
PAX-29n (CL-20)	600	17 %	38 %
PAX-3 (HMX)	18	-28 %	32 %
PAX-30 (HMX)	18	6 %	30 %
PAX-42 (RDX)	7	3 %	24 %

- PAX-30 and PAX-42 maintain metal pushing energy of LX-14 but substantially exceed blast with 18.5% less explosive fill
- Excellent candidates for multi-purpose warhead!
- Excellent Reduced Shock Sensitivity
- Most cost effective

PAX-30 Provides both blast and high penetration

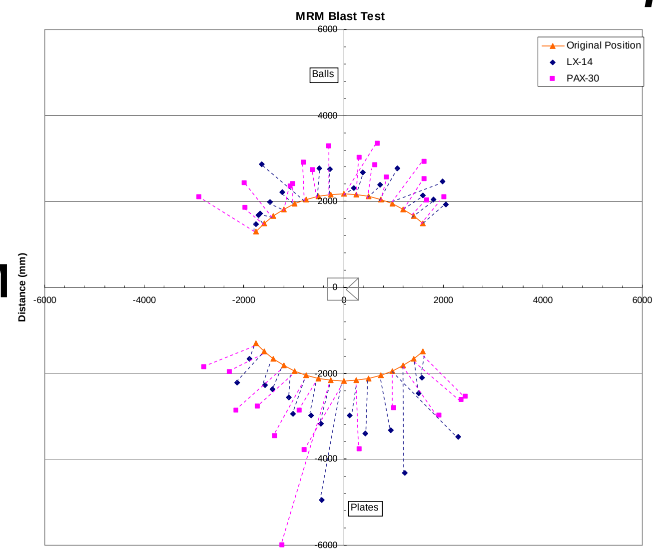
JAVELIN

PAX-30 penetration ~10% better than current production with LX-14 in Javelin

'Stonehenge' Impulse Test Setup

PAX-30 vs. LX-14 Blast Output

MRM



PAX-30 blast outperformed LX-14 in the MRM configuration.

High Blast/Anti-Armor Warheads for Shoulder Fired Munitions

Reduced Solder Burden

CURRENT SOLUTION
1 ARMOR WEAPON
1 BUNKER WEAPON

ONGOING WORK
1 WEAPON FOR ARMOR,
& BUNKER TARGETS

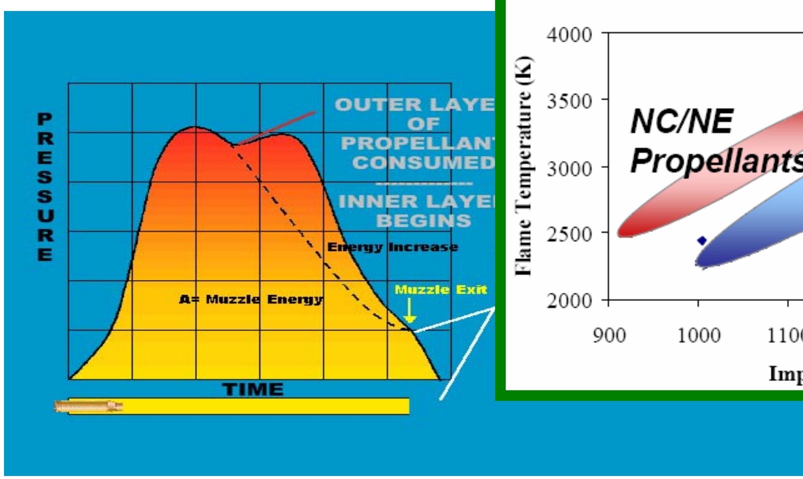
Blast effect for bunker defeat

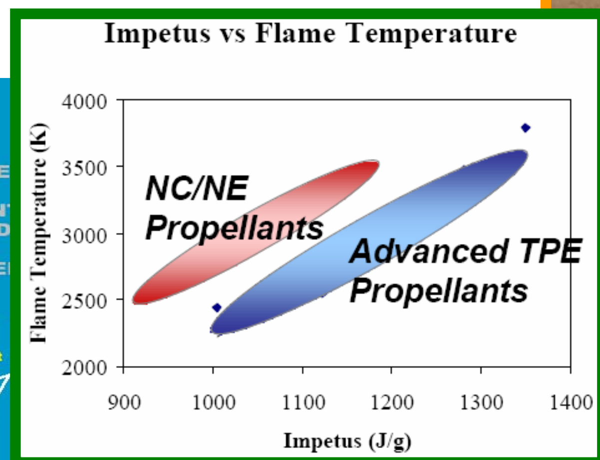
Jet penetration for armor defeat

Novel Energetic Materials ATO – Advanced Gun Propellants

High performance & insensitive propellants

- ETPE layered propellants
- BDNPN, NTO propellants
- High nitrogen propellants





Enhanced gun performance

- ***Tailorable burning rates***
- ***Increased charge weight***
- ***Increased energy density***
- ***Controlled pressurization***

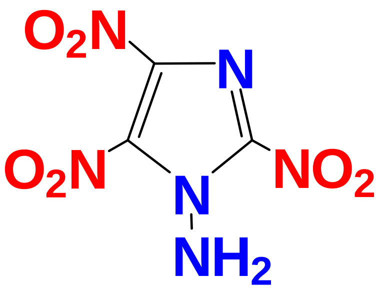
Reduced barrel erosivity

- ***Reduced flame T***
- ***Less erosive propellant combustion products***

Reduced sensitivity/vulnerability

Synthesis Program Target Compounds

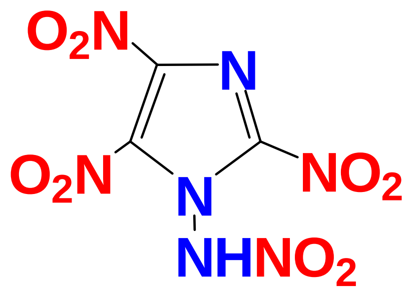
High Density High Energy Compounds



ATNI - Amino Trinitroimidazole

Cal. Density 1.92 g/cc

Performance 10 % better than HMX and Insensitive due to hydrogen bonding

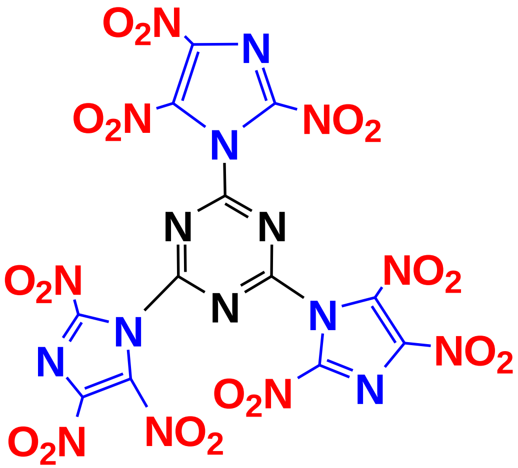


NATN – Nitramino Trinitroimidazole

Cal. Density 1.96 g/cc

Insensitive due to hydrogen bonding

High Energy High Nitrogen Compounds

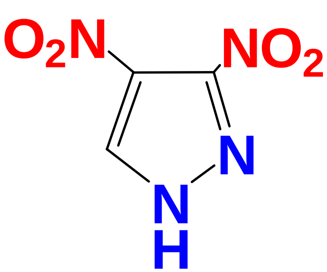


TTIT - Tris(Trinitroimidazole) Triazine

Cal. Density 2.06 g/cc

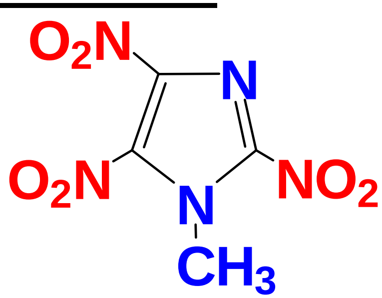
Performance 20% better than HMX

Insensitive Melt-Cast Materials



DNP - Dinitropyrazole

Density 1.76 g/cc;
Performance better than Comp.B Melt cast

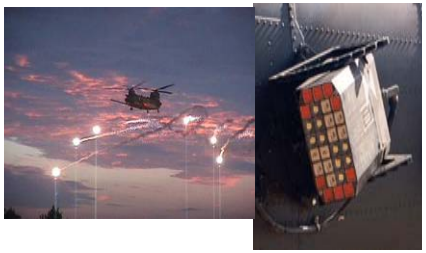


MTNI - MethylTrinitroimidazole

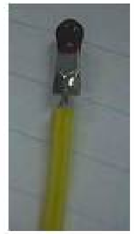
Density, 1.79

Detonation velocity better than Comp. B, Melt cast and Insensitive

Nano-materials / Nano-energetics

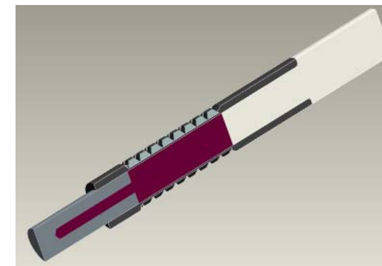


Counter Measures



Igniters

Green LEI Primers

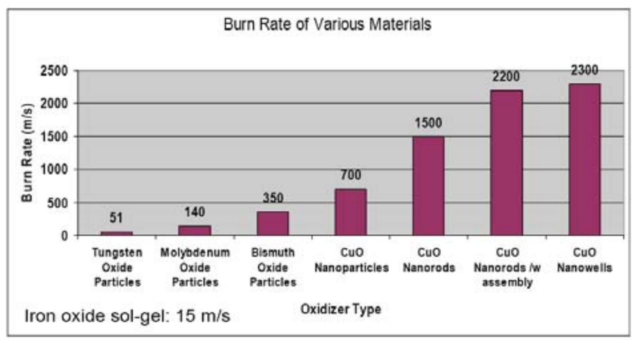


Reactive Tungsten Penetrator

Illum Candles

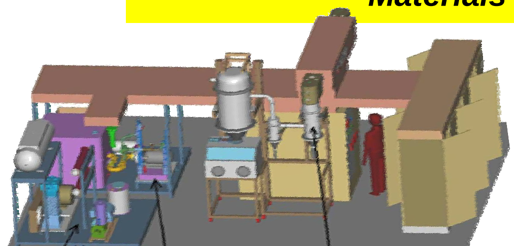
Primers

On-going Efforts

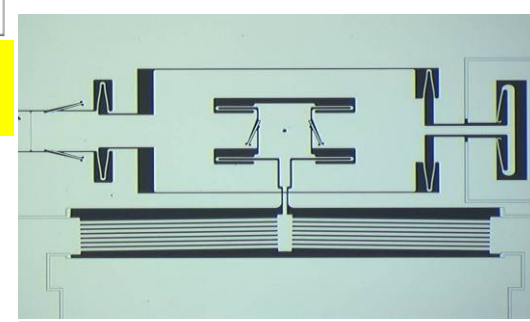


Formulation of New Reactive Materials

Dual Use Composites



Material Fab & Characterization



MEMs S&A Designs

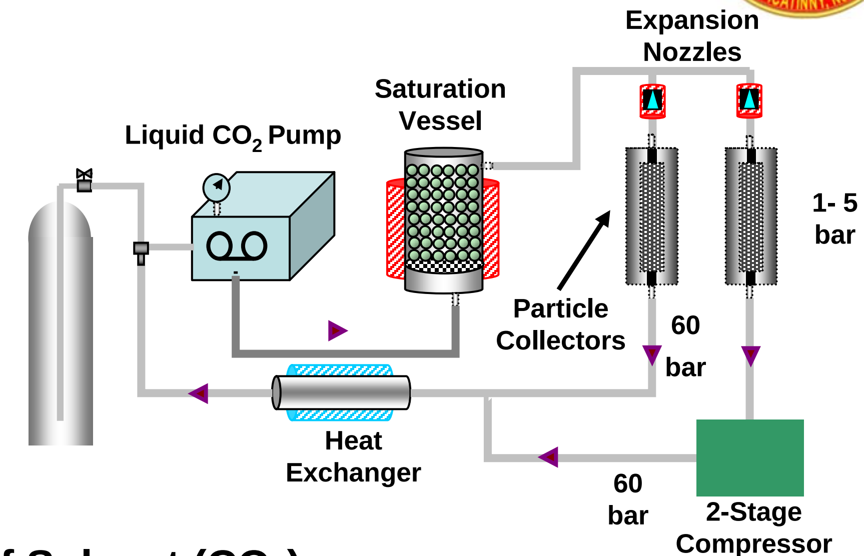
Production of Nano RDX by RESS

RESS Set-up

- Solvent: Carbon Dioxide
- Saturation P\T: 350 bar\85 ºC
- Expansion Pressure: 1 – 60 bar

Current Process Capabilities

- Precise Particle Size Control:100–500nm
- Production Capacity: 10-12 g/hour
- Continuous Operation: > 10 hours
- Contained Operation with Full Recycle of Solvent (CO_2)



Sensitivity Testing

Impact Test

150 nm RDX Pellet: H_{50} – 41 cm

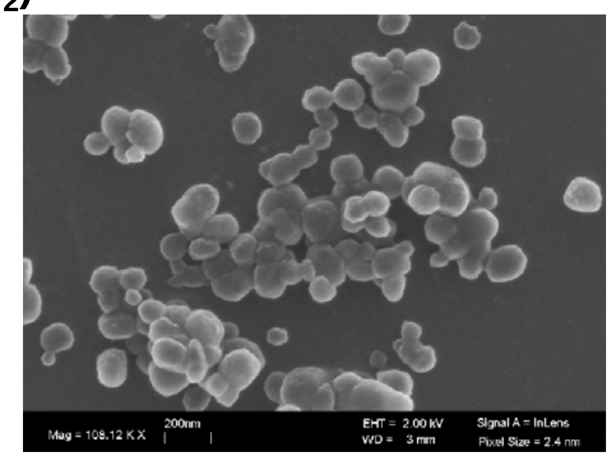
150 nm RDX Powder: H_{50} - >100 cm

Holston C-5 RDX Powder: H_{50} – 23 cm

Small Scale Gap Test

500 nm RDX in 88/12 wax formulation: Gap_{50}- 32 kbar

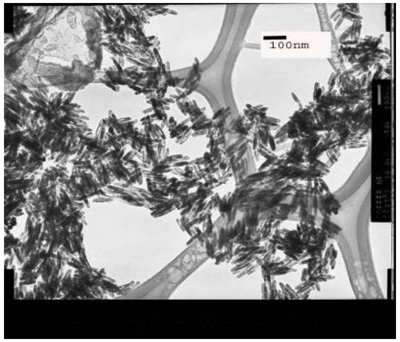
4.8 micron RDX in 88/12 wax formulation: Gap_{50}- 21 kbar



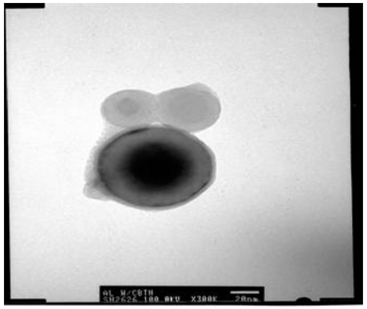
SEM Image of Nano RDX

Nanocomposite Synthesis and Production

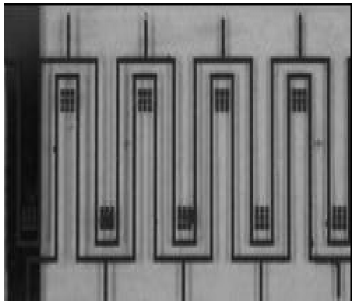
- ***Tunable super-thermites***
- ***Multiple uses, safe to handle***

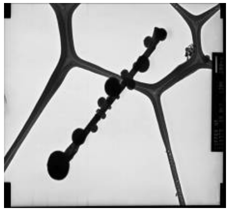


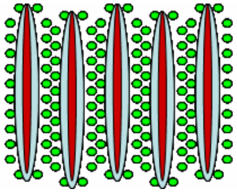
Coated Nanoparticles



Patterned Energetics

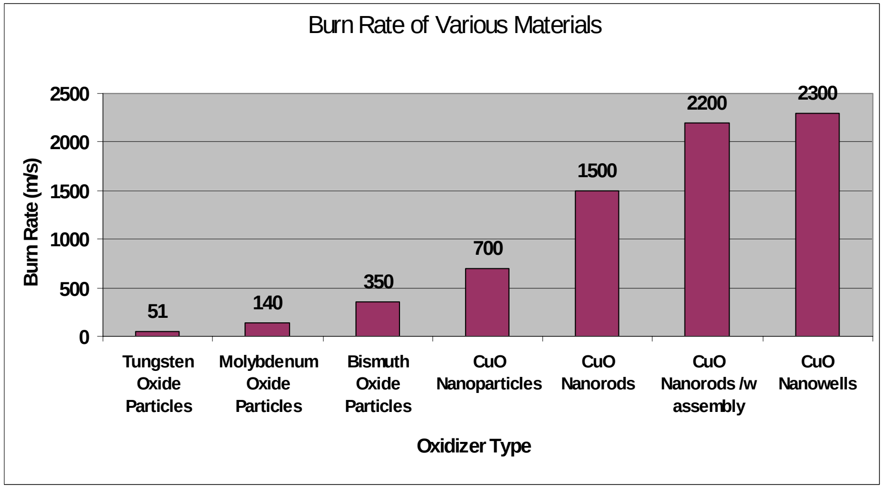






Ordered Energetic Composites

Microencapsulation



Summary

- Army RDECOM-ARDEC Energetic Materials Program focused on meeting goals for transition to Army and Joint Service applications to meet Warfighter needs.
- Reactive materials demonstrated in demolition warheads and as IM liners.
- Actively developing IM Technology for PEO IM Priority Munitions with emphasis on M&S and Partnering in OSD IM S&T D-Line.
- High energy / High blast explosives demonstrated
- Novel Nanocrystalline and Nanocomposite Energetics applications being investigated.