Combustion, Detonics & Shock Wave (CDSW) Panel

A Panel of ARMREB

Dr P K Soni
Scientist 'F'
Panel Coordinator

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Thrust Areas for Research CDSW:

National Program on :

- **Modelling and simulation facility for detonation, blast mitigation, blast material interaction and related phenomena.**
- **New Energetic materials meeting requirement of performance and insensitiveness**

Covering -

3.Equation Of State of Explosives- for reacted & un-reacted explosive.

4.Hazard Assessment, Sensitivity and Safety-Related Responses- IM testing methodology and simulation

5.Advanced and Novel Experimental Techniques, Modelling and simulations- Evaluation of detonics parameters and simulation of various phenomenon

6.Dynamic Shock Loading of Materials- Equation of state of materials under high pressure, mechanical & metallographic properties, equation of state.

7. Shock Waves Blast Damages, Effects & Scaling- Blast and shock mitigation

8.Response toward mechanical insult and Properties of Explosives- Safety issues in machining, casting and pressing, high strain rate behavior of explosives.

9.Detonics and Micro-Detonics- Nano-energetics, metastable intermolecular composites.

10. **IM compliance Testing and protocols** – for future Insensitive Munitions and warheads.

Other Areas:

- Shear Thickening Fluids – Body Armour
- Blast and Shock Mitigation
- Advanced Fuze Technology
- Nano Energetics
- Material Characterization
- Laser Initiation of High Explosives

Areas for Further Collaboration

1.Equation Of State of Explosives- for reacted & un-reacted explosive.

2.Hazard Assessment, Sensitivity and Safety-Related Responses- IM testing methodology and simulation

3.Advanced and Novel Experimental Techniques, Modelling and simulations- Evaluation of detonics parameters and simulation of various phenomenon

4.Dynamic Shock Loading of Materials- Equation of state of materials under high pressure, mechanical & metallographic properties, equation of state.

5.Blast Damages, Effects & Scaling- Blast and shock mitigation

6.Mechanical Properties of Explosives- Safety issues in machining, casting and pressing, high strain rate behaviour of explosives.

7. Detonics- Nano-energetics, metastable intermolecular composites.

Armament Design, Mechanism and Ballistics (ADMB Panel)

ARDE, Pune

Chairman: Dr Mahendra Jha, Retd. Sc ‘G’, ARDE, Pune

Co-ordinator: Shri Prem Y Borse, Sc ‘G’, ARDE, Pune

ADMB Panel

✓Vision

✓Mission

✓Thrust Area

✓About ADMB

✓On-going Projects of ADMB

✓Prospective Problem Statements

✓ADMB Panel Constitution

Vision

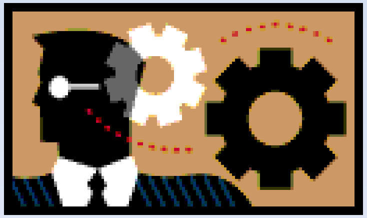
To expand the technological advancement of the country in the field of Armament Design, Mechanism and Ballistics by promoting research talent available in the academic/research institutions.

To develop expertise/technologies in the field of Armament Design, Mechanism and Ballistics to meet the defence and security needs of the country.

Mission

To enhance scientific knowledge, physical infrastructure and technical understanding in the field of Armament Design, Mechanism and Ballistics to counter the future challenges of defence and national security.

To develop technological advancement in warfare domain that boast superiority of nation in defence strategies and war like situations.

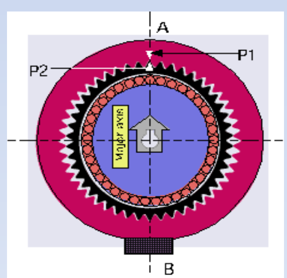


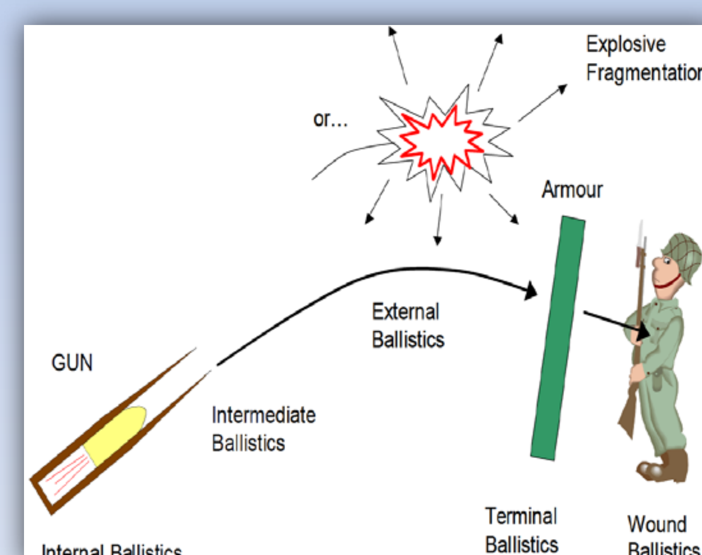
Thrust Area

A-Armament
D-Design
M-Mechanism
B-Ballistics

Thrust Area

- **Armament Design & Mechanism**
  - **Infantry Weapon & Ammunition**
  - **Artillery Gun & Ammunition**
  - **Warheads**
  - **Tank Gun & Ammunition**
  - **Air Delivered Munitions**
  - **Land Munitions**
  - **Rockets**
- **Ballistics**
  - **Internal Ballistics**
  - **External Ballistics**



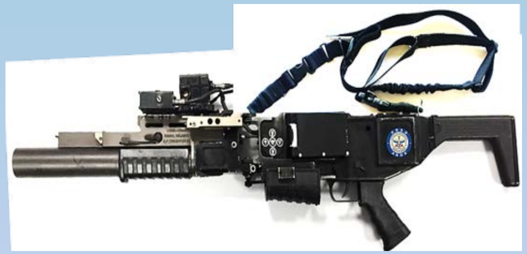


Infantry Weapons

5.56 X 30 mm Joint Venture Protective Carbine (JVPC)	
Specifications	
Caliber	5.56x30 mm
Weight(without magazine)	3.1 kg
Length	• 745 mm(butt extended) • 552 mm (butt folded)
Operation	Gas operation
Magazine capacity	30 rds
Rate of fire	700-800 rpm
MV	650 m/s
Accuracy at 50 m	• SS mode: 9/10 hits < 10x10 cm • SB Mode: 18/30 hits < 36x30cm
Effective range	100 m (capable to defeat 3.5 mm MS plate)
Reliability	Less than three Class1/Class-2 stoppages in 1200 rd of firing
Mode of fire	Single & auto
Sights	Iron, Reflex, Laser, IR
Safety	Mechanical & applied
Accessories	Silencer, bayonet, Muzzle cap, Sling
User	DG Infantry & CAPFs
Industry Partner	a) Small Arms Factory Kanpur for Weapon b) Ammn factory, Kirkee, Pune for Ammn

Infantry Weapons

Corner Shot Weapon System (CSWS)	
Specifications	
Weapon	9 mm Pistol /40 mm UBGL
Effective Range	25m with Pistol 100 m with UBGL
Max length w/o Weapon	< 860 mm < 700 mm with Butt Folded
Overall weight	3.8 - 3.9 kg without Weapon
Firing Orientations	+65°, 0° & -65°
Trigger Pull	2.5 - 3.5 kg
Sighting System Modules	Day & Night camera Tactical Torch IR Illuminator, Red LASER
Day Camera	Digital zoom Up to 10X D/R/I : 50/30/15 m in Day Light
Identification Range	LASER : 15 m in Clear Starlight IR : 15 m in No Light Torch : 15m in No Light
Colour Display	3.5 inch LCD (Res 640 X 480)
Battery	Li-Ion Battery Pack (BMS Protection) 2.5 - 3.5 hrs endurance
Temp Range	Operating : -20^{0}C to +45^{0}C Storage : -25^{0}C to +50^{0}C
User	DG RR, CAPFs
Industry Partner	a) Bharat Electronics, Pune b) Zen Technologies, Hyderabad



Infantry Weapons

5.56 X 45mm CQB Carbine	
Specifications	
Calibre	5.56x45 mm
Ammn	In-service 5.56 mm INSAS & NATO
Length with extended Butt	800 mm
Length with Retracted Butt	650 mm
Weight	3.04 kg
MV	880 m/s
Accuracy in SS mode (9/10 hits)	< 15 X 15 cm
Accuracy in SB Mode (18/30 hits)	< 24 X 24 cm
Effective range	200 m range : Penetration of 3.5 mm MS Plate
Rate of fire	700-800 rpm
Reliability	Less than 3 Class-I/Class-II stoppages and Nil Class-III stoppage in 2000 rds of firing as per TOP-3-2-045
User	DG Infantry & CAPFs
Industry Partner	a) Small Arms Factory Kanpur for Weapon b) Ammn Factory, Kirkee, Pune for Ammn

Infantry Weapons

7.62x51mm Belt Feed LMG	
Specifications	
Calibre	7.62 x51mm
Ammn	In service M80 NATO
Effective Range	800m
Max length	< 1200 mm
Overall weight (with bipod)	9.6 kg
Automation	Gas Operated
Mode of Fire	Single (SS), Auto (SB)
Belt Capacity	250 Rounds in one belt
Muzzle velocity	>800 m/s
Accuracy SS mode (9/10 rds)	<12x12 cm at 100 m
Accuracy SB Mode (18/30 rds)	<30x30 cm at 100 m
Reliability	Less than 3 Class-I/Class-II stoppages and Nil Class-III stoppage in 2400 rds of firing as per TOP-3-2-045
Rate of Fire	600- 650 Rds/min
Safety	Applied , Mechanical
Sights	Iron sight with luminous tip, PNS
Picatinny rail	12 O' Clock
Accessories	Spare Barrel, Bipod, Sling, BFA
User	DG Infantry & CAPFs
Industry Partner	a) Small Arms Factory Kanpur for Weapon b) OF Varangaon for Ammn

Infantry Weapons

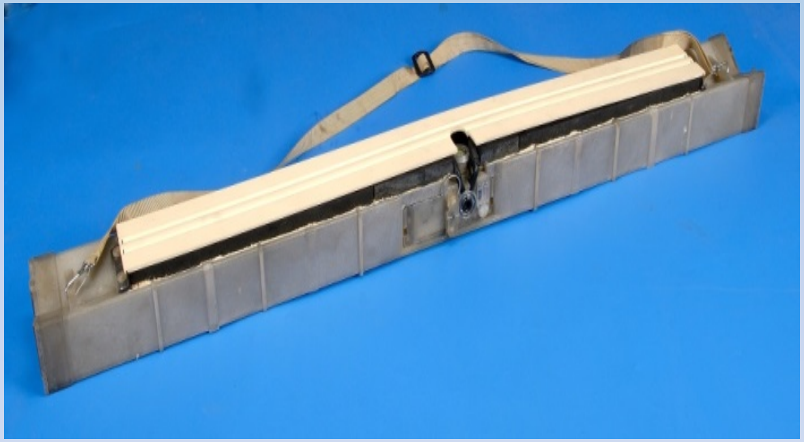
9x19 mm Machine Pistol	
Specifications	
Caliber	9x19 mm
Ammunition	9x19 mm in-service & NATO
Operation	Blowback
Effective Range	100 m
Weapon Mass	< 2.1 kg
Barrel Length	7.2 inch & 6.5 inch
Overall Length	Butt Folded – 382 mm Butt Extended – 612 mm
Butt Operation	Side folding
Picatinny rail	Full length at 6' O clock & 12' O clock
Construction	- Aircraft grade Aluminum alloy with hard coating - Carbon fibre polymer Pistol Grip & Butt
Accessories	- Magazine (32 rds) - 3 point Sling - Silencer - Reflex Sight
User	DG Infantry & CAPFs
Industry Partner	Yet to decided

Guided Pinaka

Guided Pinaka	
Specifications	
Accuracy	60 – 80 m (with GPS aid)
Range	75 km
Improved hit angle	> 50 deg
Guidance	INS + GPS guidance(MEMS INS & GPS + GLONASS + GAGAN)
Control	Canard based
User	DG Artillery
Industry Partner	OFB, BEML, TATA, L&T, EEL

NFM (New Family Munitions)

Vishal (Anti Tank Blast Type Munition)	
Specifications	
Size	1200 x110x 90 (in mm)
Pressure Pad	950 mm
Actuation Load	140-250 kg on 250mm of pressure pad
Anti-Tilt Device	Built-in Electronic (Modular)
Fuze	Timer based 60±5 min. delay
Actuation	Single and Double action
Explosive	6.5 kg (RDX/TNT)
Munition Weight	11.75 kg
User	Engineers
Industry Partner	BFL



NFM (New Family Munitions)

Vibhav (Anti Tank Blast Munition)	
Specifications	
Weight of munition	7.5 kg
Major Dimensions	Ø 280mm & Height 150mm
Fuze	Pressure actuated ,Single & Double action
Arming Delay	Arming delay of 60 ± 10 min
Anti Removal device	Inbuilt electronic Module
Actuation load	140 -250 kg
Explosive weight	5.0 kg (RDX/TNT)
User	Engineers
Industry Partner	BFL

Nipun (Soft Target Blast Munition)	
Specifications	
Mass	190 g
Actuation load	11-30 kg
Major Dimensions	Ø 90 mm, Ht : 50 mm
Actuation Area	Ø60mm
Fuze Type	Mechanical fuze
Explosive	36 g
Package	Plastic Roto-molded
No of Munition in a Package	60 Nos.
User	Engineers
Industry Partner	EEL Nagpur and PEL Hyderabad

Artillery Gun & Ammunition

155 mm x 52 Cal Advanced Towed Artillery Gun System (ATAGS)	
Specifications	
Elevation	-3 to 72 degree
Traverse	+/-30 degrees
Accuracy &Consistency	0.6% in R, 0.2 % in L
Rate of Fire	1.Burst of 5rd/1 min 2.Intense 10rd/2.5 min 3.Sustained 60rd/60min
Direct Fire	2 km
Gun Laying	ILNS in loop
Communication	SDR, VDCU, DIS
Automation	All electric
Compactness	Back Pack
SP mobility	> 18 km/hr
User	DG Artillery
Industry Partner	BFL, Pune & TPSED, Bengaluru

Tank Ammunition

125MM FSAPDS PRACTICE AMMUNITION FOR T72/T90 TANKS	
Specifications	
Consistency	Px ≤0.64m (0.40mils) at +27°C. Py≤ 0.64m (0.40mils) at at +27°C
Ballistics	Ballistic matching with AMK-339 APFSAPDS ammn when fired from T-90 and T-72 tanks fitted with TPDK1, TIAS and TI ESSA.
Barrel Wear	≤0.9 EFC
Chamber Pressures	< 600 MPa@ +55°C
Recoil	Between 270mm-320mm (max 340 mm)
Hit Indication	Use of Tracer (Burning time 2-3 sec)
Lethality/Penetration	Nil
Physical Attributes	Commensurate to AMK 339
Safety	As per in- service Amn
Toxicity	As per DIPAS standards
Shelf Life	Ten years
User	Indian Army

Tank Ammunition

120 MM HESH AMMUNITION FOR MBT ARJUN TANKS	
Specifications	
Lethality	Scab on 120 mm RHA
Consistency	≤ 0.3 mils
Max Effective Range	~ 1600 m
Max Chamber Pressure	≤ 160 MPa
Toxicity	As per DIPAS standards
Shelf Life	Ten years
User	Indian Army

Grenades

Family of 40x46mm Grenades for UBGL/MGL	
Specifications	
Variants under development	(i) High Explosive Anti-Personnel(HEAP) (ii) High Explosive Dual Purpose(HEDP) (iii) Red Phosphorus(RP) (iv) Target Marker (TM)
Weapon Compatibility	In-service 40mm UBGL & MGL Weapons
Effective range	375 to 400 m
Functioning of Fuze/Grenade	(i) Impact (ii) Self Destruction
Arming distance	28m
Muzzle Velocity	76±3 m/s
Shelf life	10 years
Reliability	93-95%
HEAP Lethal Radius	5m
HEDP Penetration	50mm Armour / 65mm Mild Steel Plate
RP Scatter Radius	1.5m
TM Smoke Duration	20 to 50s
User	CAPFs and Indian Army (Infantry)
Industry Partner	(i) Ordnance Factory (ii) Private Industry (being identified)

About ADMB

Established in:

1997

Projects sanctioned in last 3 years:

No.: 17

at Cost: ₹ 12.24 Cr

Collaborating Institutes :

IITs, NITs, DIAT, CSIR Labs

Govt. & Private Universities, etc.

Ongoing Projects:

No.:14

at cost: ₹ 9.21 Cr

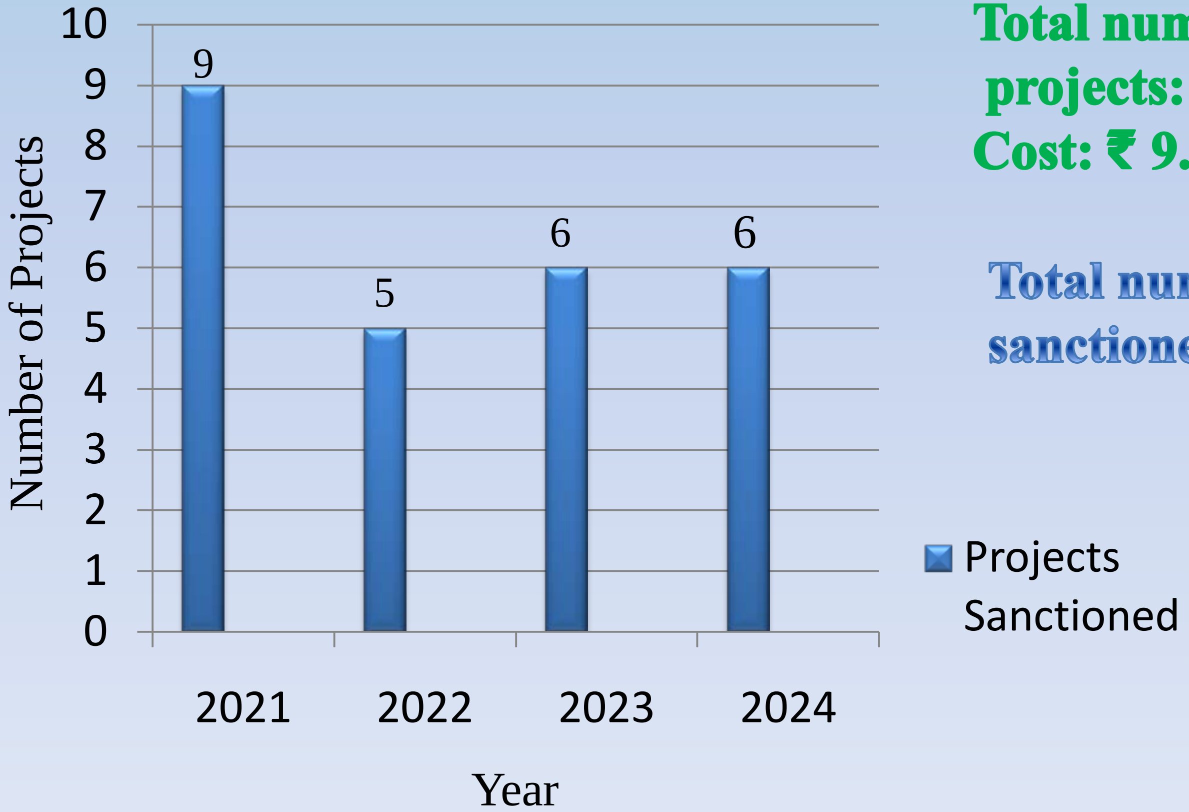
Completed, ADMB Projects

Projects completed in last three years:

- ✓ Modification of conventional artillery rocket to a guided rocket with freely spinning tail
- ✓ Feasibility study for design, manufacturing & testing of CRDi Fuel Injection System(FIS) of diesel engine for Armored Fighting Vehicle
- ✓ Characterization and validation of schlieren technique for capturing shock wave
- ✓ High speed fragment launcher by rotary mechanism for impact test
- ✓ Use of thermal autofrettage for defence Application
- ✓ Machine vision based adaptive quality assurance system for aerospace vehicle assembly unit
- ✓ Design and development of laser seeker
- ✓ Development of hard chrome replacement Ni based alloy coating for gun barrel application using pulse current electro deposition
- ✓ Dynamic characterization of Aluminum and Tungsten alloy
- ✓ Development of a technique for visualization of preformed fragment in detonation gas cloud
- ✓ Hypervelocity impact simulation
- ✓ Numerical analysis on effect of fragment shape on damage of targets in ballistic application

On-going projects ADMB

❖ Armament Design, Mechanism and Ballistics (ADMB) Panel is one of the mediums which facilitate academia to offer an opportunity of research with DRDO.



Total number of on-going projects: 14
Cost: ₹ 9.21 Cr

Total number of projects sanctioned in last four years: 26

Prospective Problem Statements

- Design and development of portable X-ray system for visualization shot seating inside the gun barrel
- Development of a fast algorithm for 3D flow simulation (and drag estimation) around a supersonic projectile for dynamic estimation of the trajectory
- Development of optical technique for visualization of orientation and motion of FSAPDS shot along with sabot during internal ballistic phase.
- To assess low temperature and high temperature altitude effect on gun structural and automotive system
- To assess the reliability and availability of gun structural and automotive system in all environmental conditions
- Feasibility study of determination of the impact point of bombs, rockets and/or artillery rounds using image or video processing
- Selection of optimum projectile size to defeat multi layered target
- Investigate various techniques to neutralise hypersonic targets
- 3 Dimensional numerical code for Internal Ballistics (IB)

Prospective Problem Statements

- Automatic calibration of ignition & growth model for a DNAN based melt-cast explosive
- Experiments & simulation on Cook-off characteristics of a DNAN based cast explosive
- Ignition growth characteristics of JEOL explosive during cook-off tests
- Development of a design methodology against cast Cook-off threat for insensitive munitions
- Multi- scale modeling of shock initiation of a pressed energetic material III: Effect of Arrhenius chemical kinetic rates on macro-scale shock sensitivity

Prospective Problem Statements

Estimation of Yaw and Pitch angle generated due to In-bore Motion of Projectiles.

Problem Statement:

To develop generic mathematical model of in-bore motion model of projectile to obtain Yaw and Pitch angle and their rates. The major inputs of model will be
(a)Geometry and dimension of projectiles
(b)Geometry and dimension of the barrel
(c)Internal ballistics forces/profiles

The model should be generic for 105mm, 120mm, 125mm, 155mm or 200mm Projectile and barrel.

ADMB Panel constituents

Dr M Jha, Retd. Sc ‘G’, ARDE
Chairman ADMB

Shri A Raju, Director ARDE
Co-Chairman ADMB

Shri Ashish Jauhari, Secy. ARMREB
Member ADMB

Dr M Kulkarni, IIT Mumbai
Member ADMB

Dr G Chandekar, Cummins College of Engineering
Member ADMB

Dr Srikrishna N Joshi, IIT Guwahati
Member ADMB

Shri Amit K Manglik, Sc ‘F’, R&DE
Member ADMB

Shri V V Jagirdar, Sc ‘F’, VRDE
Member ADMB

Dr A Banerjee, Sc ‘F’, PXE
Member ADMB

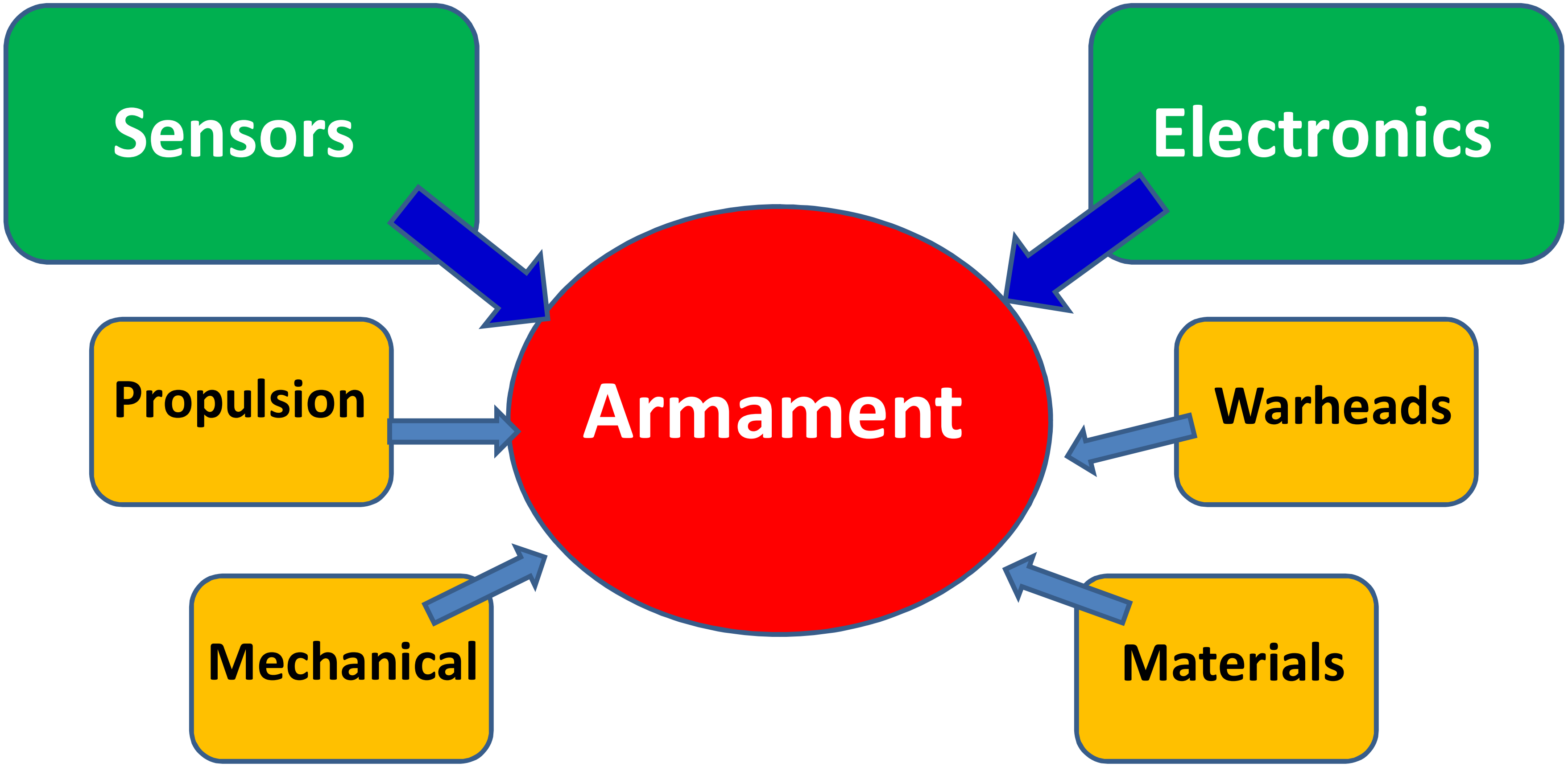
Shri Prem Y Borse, Sc ‘G’, ARDE
Co-ordinator ADMB

Thrust Areas

for

Armament Sensors & Electronics (ASE) Panel

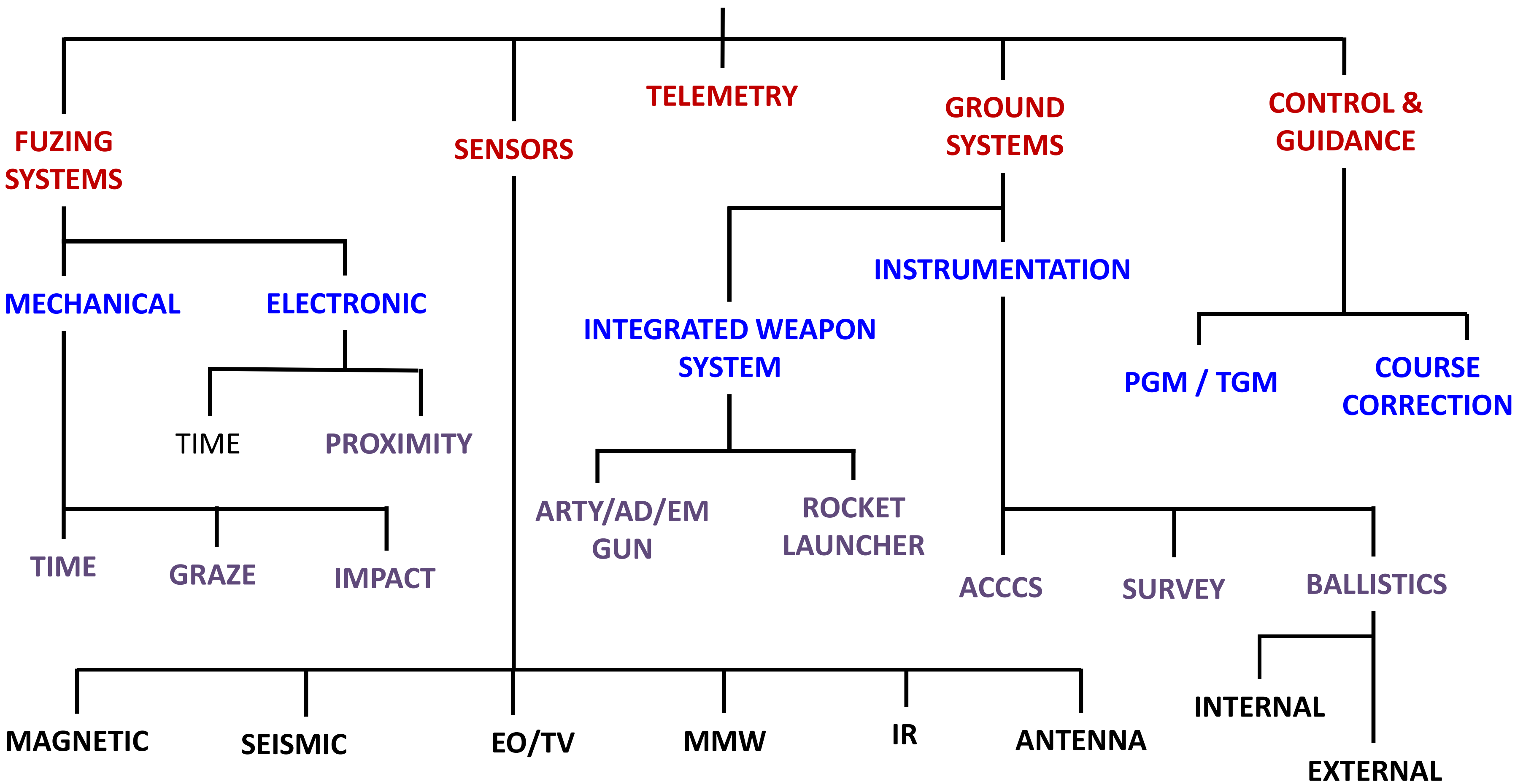
Introduction



ASE Panel activities are related to Design, Development, Realization, Testing (instrumentation), Implementation and Applications of Sensors and Electronics for Military Weapons and Equipments.

Technology Spectrum

SCOPE OF ARMAMENT ELECTRONICS



Constraints in Armament Electronics Design

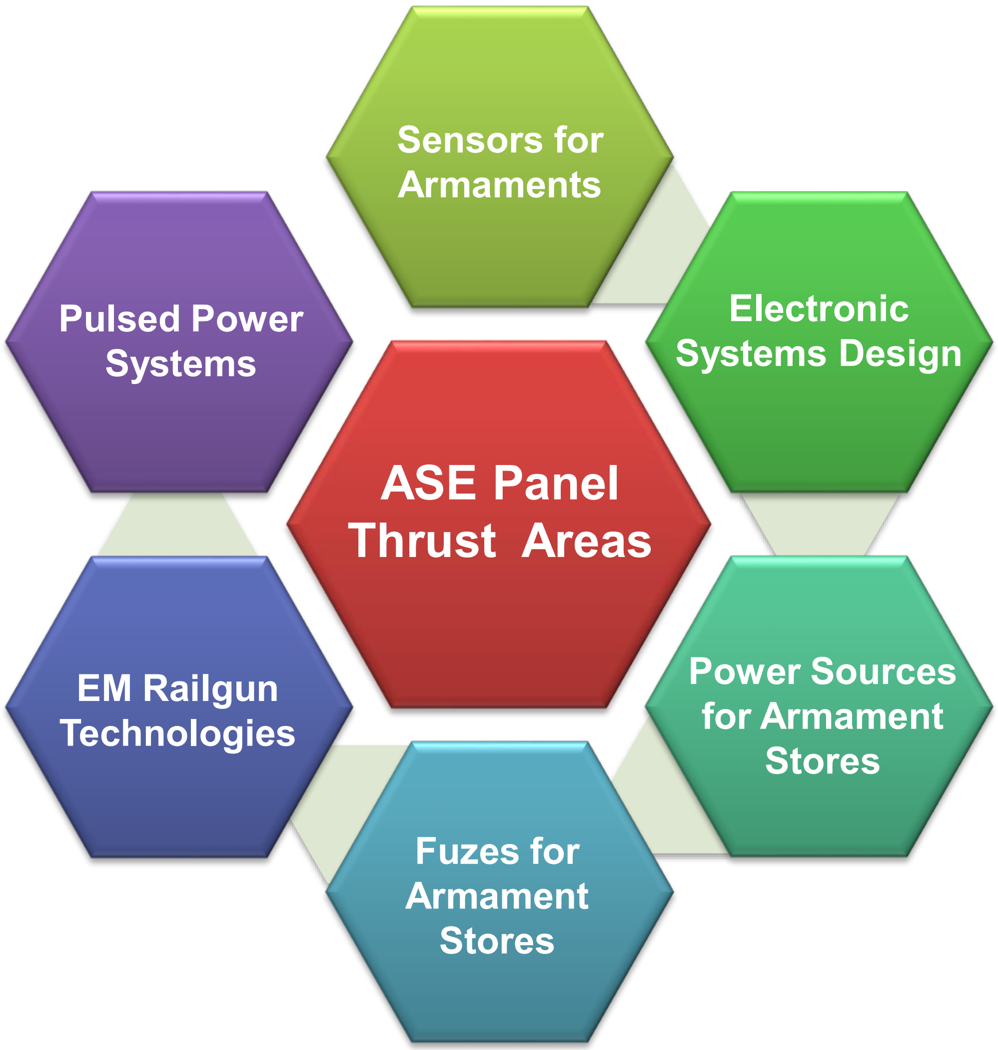
• Parameters	• Degree of Variation
• Acceleration	10,000 g to 60,000 g
• Spin	30,000 rpm
• Muzzle Velocity	200 m/s to 1000 m/s
• Temperature	- 40 To 55 ºC
• ECCM	State of the Art
• Power Source	Reserve / Primary / Turbo Generator
• Caliber / Munitions	30 - 150 mm Projectiles / Rockets
• Space / Size / Weight	Minimum Possible
• Height of Burst / Miss Dist.	3 to 30 mtrs

What Makes Armament Electronics Different!

- Very high ‘g’ functional environment
- Reliable performance under extreme climatic conditions of storage / operation
- Different range of constraints for different types of ammunitions
- Wide variety of technologies
- Very high density packaging
- Fail safe system
- Mass production with high functionality (e.g. AQL 5 or better)
- Single-shot functional reliability over a storage life of 10 years or more

Introduction

Areas of Interest



Ballistic Data instrumentation and sensors

1. **Pressure Sensors**
   a. 50 to 350 MPa, Temperature: 10 to 350°C Application: Pinaka Rocket, ERR, ATGM
   b. Gun chamber pressure sensor: ~800 MPa
2. **Blast Measurement Sensors**
   a. Free field Pencil type blast sensors, 500 psi, sub µsec response time, Wireless sensors required
   b. Application : Air blast measurement, peak pressure and total impulse, shock wave velocity and time of arrival determination
3. **Meteorological sensor package (Artillery application)**
   1. Temperature, crosswind velocity, moisture, barometric pressure, position estimate with RF transmitter(g-hardened with small form factor)
4. **Accelerometers ~ 10,000g, Strain Gauges and Magnetic sensors**
5. **Tactical grade MEMS based IMU**
6. **Sensors for survey instrumentation-** Thermal sights, navigation and communication equipment

Sensors for Armament Applications

1. Electro Mechanical Sensors

- **Pressure Sensors-** Range: 50 to 350 MPa, Temperature: 10 to 350°C. (Eg. Long Range Artillery Rockets, 122 mm ERR, Anti-Tank Guided Missiles etc.)

Pressure Sensor

Sensors for Armament Applications

Proposed Pressure Sensors

- **Indigenous : Based on Artificially Engineered Smart Materials.** (Split-ring resonators, nano-materials and artificially engineered sensor)
- **Miniaturized : 40 mm length; 20 mm diameter**
- **Range : 50 to 300 bar**
- **OperatingTemperature : Up to 200°C**

Sensors for Armament Applications

1. Electro Mechanical Sensors

- **Acceleration Sensors-** Should be small size and support up to 1000 ‘g’ for use in Rockets and ATGMs.

- **High ‘g’ Sensors-** Acceleration sensors with high ‘g’ up to 30,000 ‘g’ for use in gun and shell environments.

Proposed Spin Sensors –

- MEMS based Gyros for spin measurement up to 3000 rpm.
- Should be suitable for use under high launch shock (~ 30,000 ‘g’) environments.

Sensors for Armament Applications

1. Electro Mechanical Sensors

- **Seismic Sensors- (a)** For various Mines. The mines should not be initiated due to seismic vibrations. Identification of signature of Tanks or real targets should be ensured.

  (b) For Detection of Tanks, B-Vehicles, Trucks using signatures for identification of the vehicle.

- **Temperature Sensors-** For measurement of temperature profile in Rockets like PINAKA Mk-II and Guided PINAKA to ensure proper functioning of Electronics, Guidance and Navigation system.

Sensors for Armament Applications

Proposed Temperature Sensors :

- Indigenous
- Miniaturized & flexibility to be adopted to the ogive design
- Range (up to 200°C)
- Good linearity
- Should be suitable for use under high launch shock (~ 30,000 ‘g’) environments.

Sensors for Armament Applications

2. Optical Fiber Sensors for Gun-barrel Wear Measurement

- Non-contact, accurate (up to 1 µm) and over the entire length wear measurement in gun barrels by using appropriate optical fiber displacement sensors capable of operating in harsh/field environments.

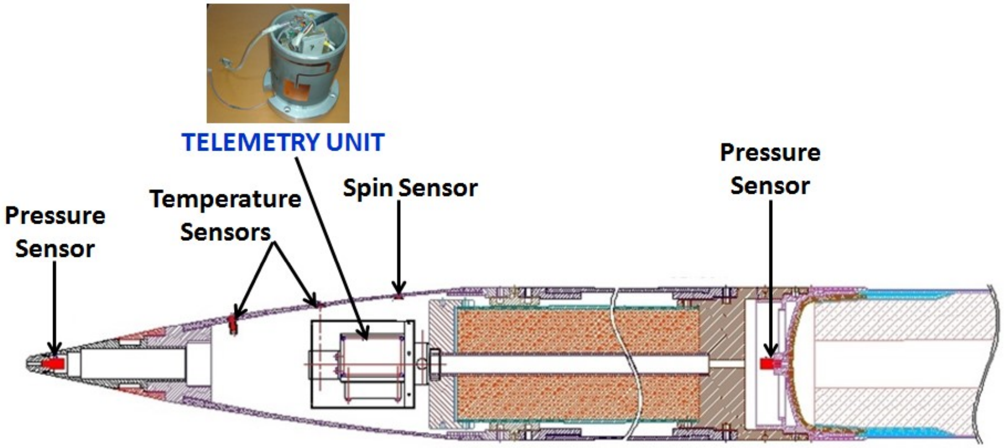
Proposed Wear Measurement Sensors :

- Operation Range (up to 200°C)
- Self-referencing to overcome power fluctuations
- Should be suitable for use in field conditions

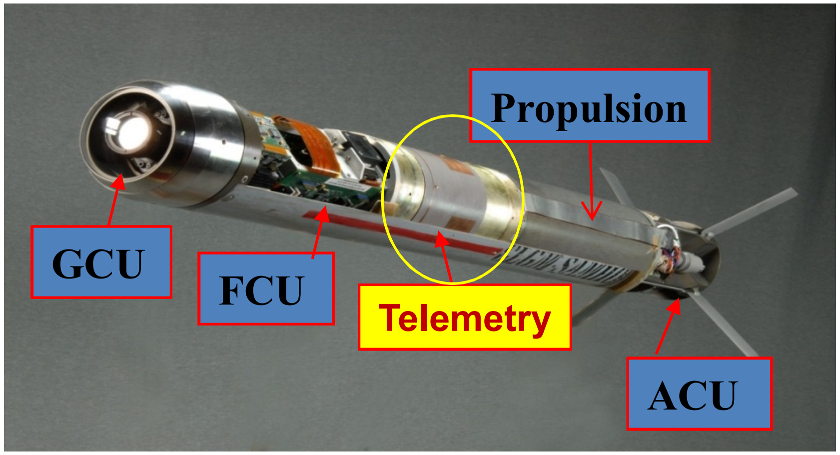
Electronic Systems Design for Armaments

1. On-board Telemetry for Armaments

➢ **Telemetry for Rockets, Missiles and Bombs.**



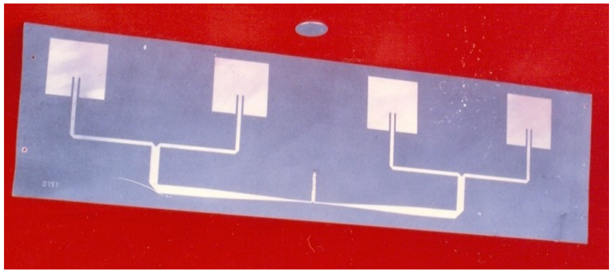
Aim: To validate design parameters and evaluate performance of various subsystems.



Electronic Systems Design for Armaments

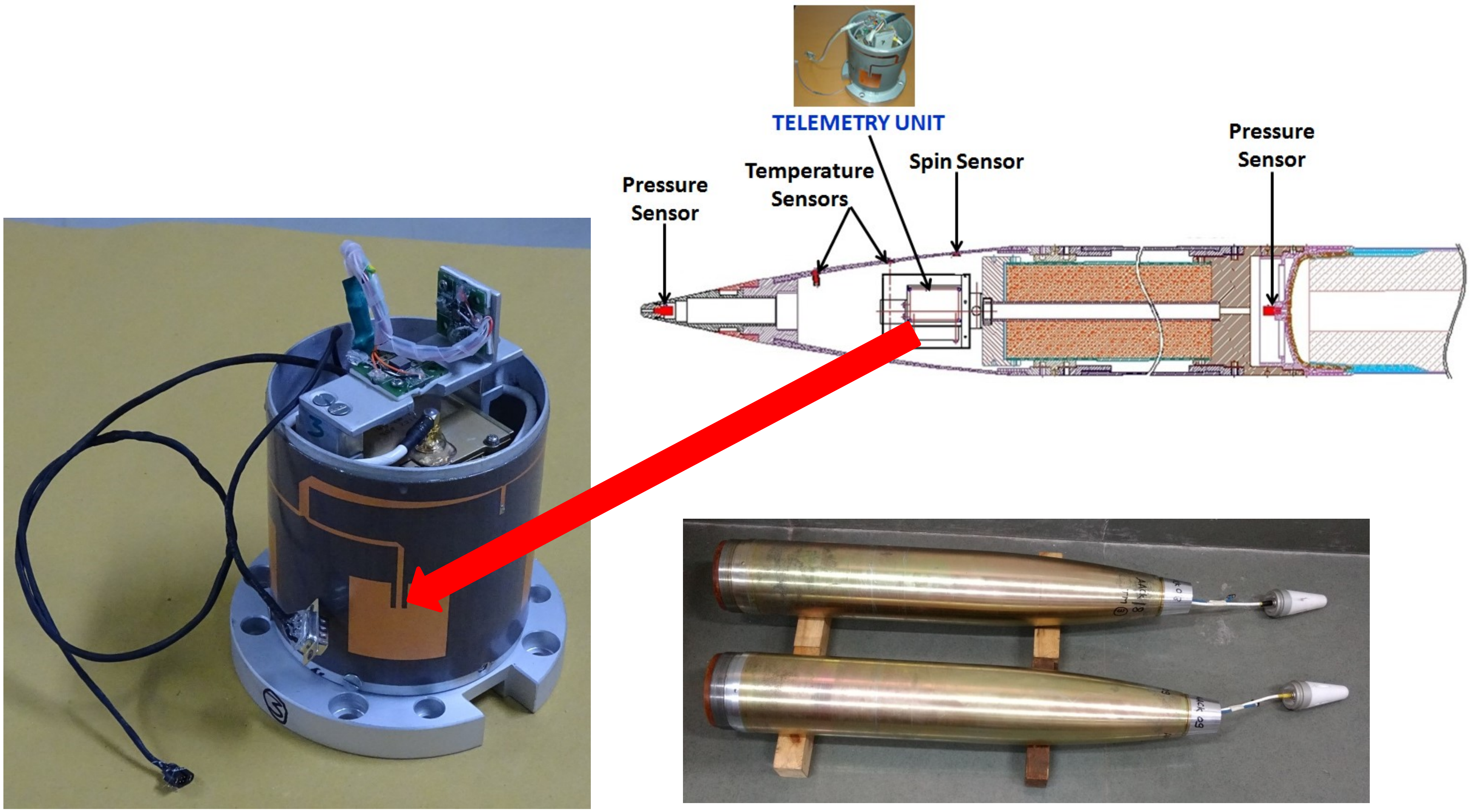
2. Proposed Antenna for On-board Telemetry

- Single antenna for Telemetry Transmission (S-band) and GPS reception (L-band).
- Constraints: Space available, Type of ogive, Cross-talk.



Microstrip Patch Antenna

Monopole Antenna
(for metallic ogive)



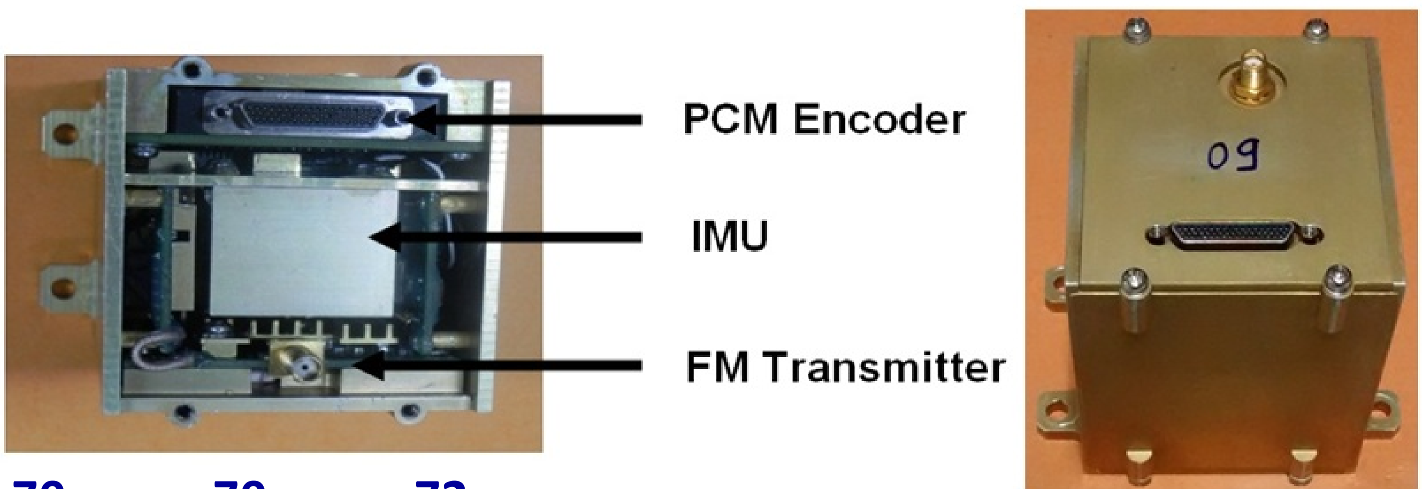
Wraparound antenna for Rocket with FRP ogive

Monopole antenna for Rocket with metallic ogive

Electronic Systems Design for Armaments

3. Proposed On-board Telemetry

- Miniaturized.
- Remote Activation possibility.
- Cost-effective.
- In-built power source for longer duration (2 hrs).



70 mm x 70 mm x 72 mm

A typical Integrated Telemetry Module

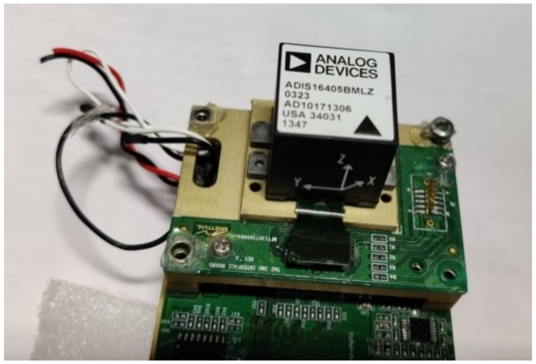
Electronic Systems Design for Armaments

4. Proposed High 'g' On-board Telemetry

- Ruggedized On-board Telemetry for 30,000 'g' (as in guns/shells).
- Space constraint – To suit dimensions of gun/shells.
- Cost-effectiveness

5. Proposed IMU for Navigation

- Tactical grade Acceleration and Gyro.
- Assembled in miniaturized and rugged package.
- Capable of operation up to 30,000 'g'.
- Method: Off the shelf Chip with mounting, assembly and packaging.



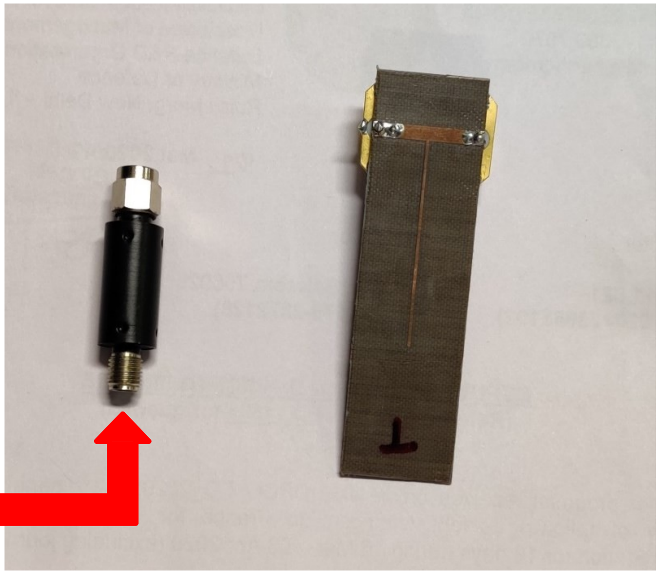
Electronic Systems Design for Armaments

6. Proposed high dynamics GPS based navigation

- GPS system for higher 'g' operation.
- GPS system for higher velocity operation.
- Software algorithms for improving the data rate up to 10 Hz.

7. Proposed GPS Notch Filter

- Insertion loss < 1 dB.
- Rejection better than -40 dB.
- Power handling capacity ~ 10 W
- Imported = Rs. 60,000/-



8. Proposed LNA for Telemetry Antenna

- Noise figure ~ 0.6 dB
- Gain > 30 dB
- Operating Frequency: 2.2 - 2.3 GHz
- Dynamic Range: -10 dBm to -80 dBm.
- Preferably remotely controlled.
- Variable gain to avoid saturation of Rx system.

Electronic Systems Design for Armaments

Additional Proposed Thrust Areas:

(a) Terminal Phase data reception with Telemetry:

- Compact/Mobile Telemetry ground receiving stations suitable for telemetering of long range projectiles.

(b) Target point and fall of shot detection:

- AI/ML based algorithm for fall of shot detection, terminal velocity measurement with help of video of terminal phase of projectile.

Electronic Systems Design for Armaments

(c) Miniaturized SDR for Telemetry and video data transmission:

- Use of COFDM (Coded orthogonal FDM) based modulation scheme along with Diversity for reliable & robust data communication against fading.

(d) Digital beam steering antenna:

- These antennae can be employed for RF signal reception from a highly manoeuvrable projectile.

Electronic Systems Design for Armaments

(e) Tri-band Micro-strip patch Antenna :

- These antennae can be useful for reception of GPS and IRNSS and transmission of Telemetry data in s-band.

Power Sources for Armament Stores

1. Turbo generator based Power sources for Fuzes

- Current up to 250 mA.
- Voltage up to 30 Volts.

2. Reserve batteries (for spin & non-spin projectiles)

- Development of a reserve battery that will be initiated by launch shock which can be in the region of 1000 - 50000 ‘g’ depending on the ammunition.
- These batteries should withstand temperatures from -40 to +65 °C and should have life in excess of 10 years.

Power Sources for Armament Stores

3. Ultra capacitors

- Ultra capacitor to provide bursts of high power during short duration events such as acceleration of azimuth and elevation drives of rocket launcher and 155 mm guns.
- The specifications: Ultra capacitor of 63 farad, 125 V with peak current 1800 A and RMS 140-240 A current.

4. Primary/Secondary batteries

- For use as compact and efficient power source for on-board Telemetry for Artillery rockets, Anti-Tank Guided Missiles (ATGM) and Guided Bomb etc.

5. Setback generators/PZT crystals/ Rotary generator based power generation

Fuzes for Armament Stores

Development of compact ET & VT Fuzes

- Use of same antenna for Tx and Rx.
- If different antenna are used, isolation to be ensured using proper polarization techniques.
- Antenna should be as small as possible (since there is space constraint).
- Fuzes should be with ECCM feature (so can not jammed by the enemy).
- Reduced time of RF Transmission (so not detected).
- Proper coding scheme for jam-proof operation.

Safety & Arming for Fuzes

Safety Arming Devices for Fuzes

- **MEMS based Safety & Arming for Fuze applications:**
  - <u>Arming mechanism</u> helps in an out-of-line position to align the explosive fuze train after the delay required. Actuator is activated when delay period is completed, arming the munition.
  - Safety and Arming mechanisms protect users from premature or accidental detonation.
  - Artillery fuzes may be initiated by a timer mechanism, impact or detection of proximity to the target, or a combination of these.

Precision Guided Munitions/Smart Artillery

1. MEMS based IMU (Packaged)
2. Integrated Hybrid navigation- Multi sensor(MEMs IMU with IRNSS+GPS+GAGAN)
3. Smart Fuzes/Course correction Fuzes
4. Self Correcting and Autonomous Target recognition and engagement based Sub-munitions
5. Multiple void sensing and delayed Detonation MEMS based fuze
6. Rugged LASER/IR seeker
7. High bandwidth actuators with high torque capacity in minimum size

Artillery Guns/MBT/Munitions

1. Low power rugged IR detectors with signal processing for top attack munitions.
2. Robust Networking Technology for inter module control and comm. - Network based Anti vehicle munitions.
3. Sensor Development- Rugged EO/IR sensors which can withstand arty firing, Setback, PZT and rotary generators.
4. Use of AI in best weapon selection and autonomous engagements.
5. Robotic arm based autonomous Round identification, pickup and loading for arty guns.
6. AI based predictive maintenance and health monitoring for Artillery guns.
7. Multi Function fuze tech with Proximity, time and impact setting for Artillery guns.

Mines (Anti-Tank/Anti-personnel)

1. **Communication:**
    a) Cryptography for Secure communication with mines
    b) Non-GPS based geo-location
    c) Algorithms for adaptation to environment and Geo-tagging
2. **Networking**
    a) Inter mine communication
    b) Wireless power harvesting and Power management techniques
3. **Sensor Development**
    a) Compact & Power efficient acoustic sensor development
    b) Seismic sensors for signature based target identification

Mines(Anti-Tank/Anti-personnel)

4. AI/ML

a) Mine reorganisation gap filling for greater stopping power

b) Breach attempt detection and breach vulnerability assessment algorithms

c) Target detection and interception in mines

Pulsed Power and EM Rail gun (10/100MJ)

1. **Indigenization of HED capacitors for high current pulsed power**

- **Ultra high density capacitors (2.1J/cc) with small ESR and large pulse current capability (5 MA) could provide a compact solution.**

2. **Indigenization of Semiconductor Crowbar switch for railgun**

- **Operating Voltage - 11 kV Peak switch current - > 250 kA peak**
- **High efficiency inductance coils**
- **Snubber circuit design for equal current and voltage sharing under dynamic conditions**

Pulsed Power and Railguns

3. High power and energy compensator based Power system design

- Liquid metal switches for Rail gun - Liquid metal conductor based current injectors
- Li-Si based battery bank for HVDC power augmentation

4. Hypervelocity Projectiles

- Design of hypervelocity projectiles and hypervelocity impact models that can be used in design optimization.

5. Magnetic and Electric Field Calculation

- Study of EMI/EMC and magnetic effects in the surrounding of railgun.
- Simulation/Program for calculation of electric and magnetic field with variation of current in the current conducting railgun.

AI/ML

1. Real-time Battlefield Translation
2. Threat Assessments
3. Logistics Management
4. Mission Planning and Execution
5. Tactical Decision-making Support
6. Situational Awareness
7. Develop new materials for armament applications using AI
8. Autonomous USV & UGV Patrolling techniques and Collaborative System for Over the Horizon Surveillance
9. Fault Tolerant Control System with Artificial Intelligence and accelerator hardware
10. AI & Machine learning approach for condition monitoring of hydraulic system
11. Development of Smart Minefields and associated technologies like reconfigurable mines, autonomous mines.
12. Quantum ML Technology
13. AI algorithms verification/validation

Mountain Geo Hazard Management in Indian Himalayas (DGRE)

1. Development of technologies for Data gathering, forecasting, monitoring, control and mitigation of Landslides and Avalanches
2. Research in Geoinformatics and Hyper spectral systems
3. Digital Atlas of different terrains
4. State-of-the-art Data acquisition and dissemination systems and networks
5. Rugged sensor and instrumentation for mountain hazards
6. Avalanche event and victim detection and rescue system
7. Multi sensor Geo hazard Early warning and mitigation system
8. AI/ML based Multi-hazard mapping and modeling methods

On Going Projects (ASE Panel)

1. “Design of a portable high gain receiving telemetry antenna array for S band applications” VIT Bhopal
2. “Development of Laser Surface Modified Triboelectric Nano generator for Harvesting Energy from Shoe Sole” IIT, Indore
3. Design and Development of Doppler Radar system for in-bore projectile velocity measurement IIT, Bhubaneswar
4. “Design, Simulation, Fabrication, Packaging and Characterization of MEMS based Sound Source Localizer for Gunshot Events” NMIT Bangalore

Recommended By Panel

1. “Development of high dynamics high accuracy baseband and navigation processing for GNSS receiver” IIT Mumbai
2. “Modeling and control of plasma observed in rail gun” IIT Mumbai
3. “Development of Height of burst measurement system for airburst munitions” IIT Kanpur

THRUST AREAS

High Energy Materials Panel

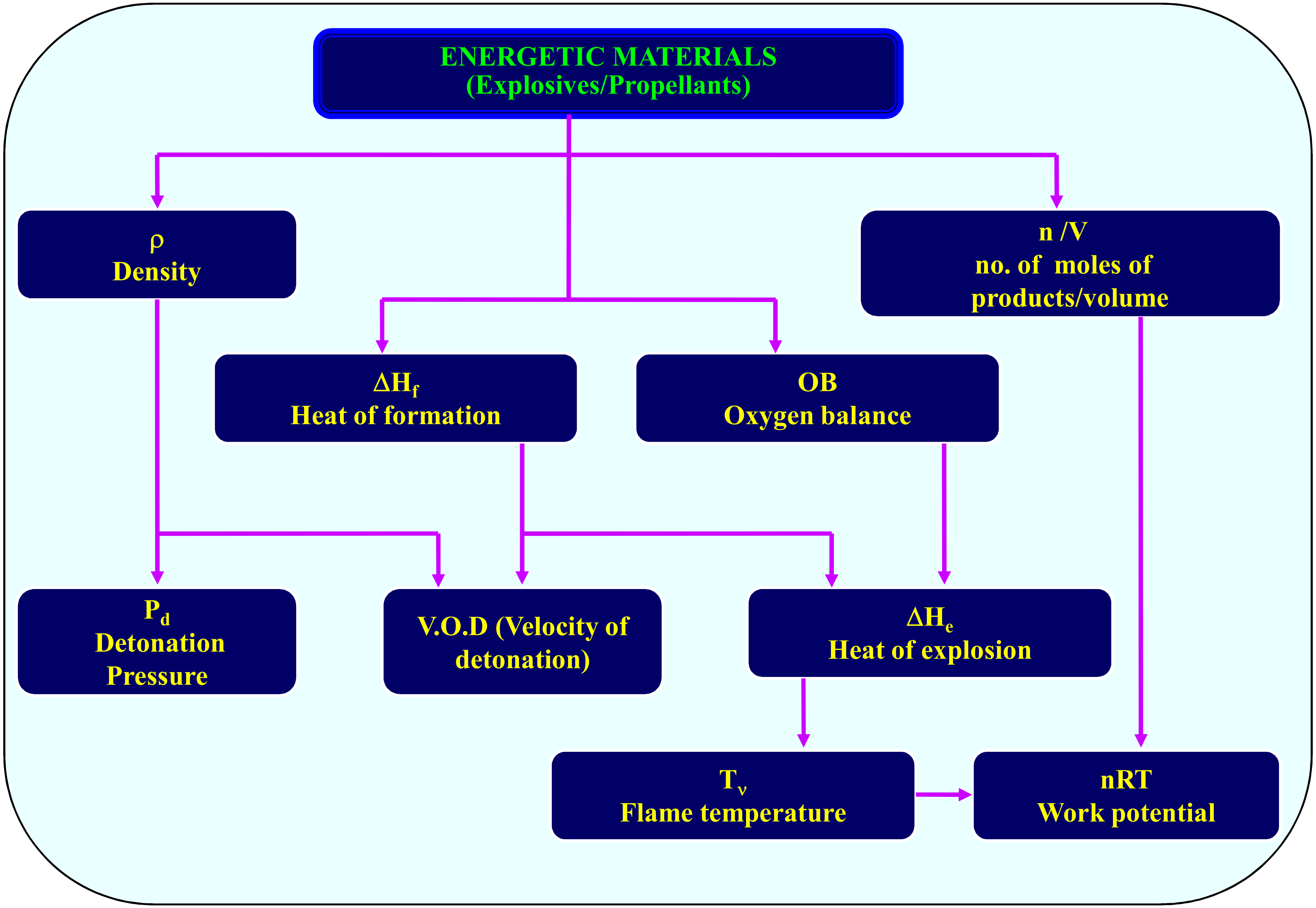
High Energy Materials Panel

- **Research in the field of High Energy Materials and related technologies**
  - **Initiator & Pyrotechnic devices**
  - **HIgh Explosives**
  - **Gun Propellants**
  - **Solid Rocket Propellants**

Thrust Areas of High Energy Materials Panel

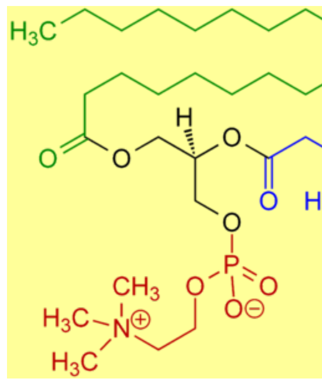
- **Synthesis and scale up**
- **Allied Materials**
- **New Technologies**
- **Mathematical Modelling**

Physico-chemical parameters that recognize HEMs



Viscosity Reducers

- **Composite propellants are based on HTPB binder loaded with 80-85 % solid ingredients**
- **After mixing operation, highly viscous propellant slurry is to be cast in to rocket motors under vacuum**
- **Usually composite propellant, slurry viscosity at the end of mixing (EOMV) is in the range of 4000–6000 Poise at 40-45^{o}C**
- **However, some of the compositions slurry viscosity are in the range of 50,000- 1,00,000 Poise at the end of mixing**
- **High propellant slurry viscosity pose difficulties in casting and also offer limited pot-life for casting due to viscosity build-up**
- **Presently Lecithin is being used as process aid to bring down the viscosity**



Lecithin

Viscosity Reducers

- Aim is to develop effective viscosity reducing agent to bring down propellant slurry viscosity below 12000 Poise
- It will facilitate the casting of large size rocket motors as well as motors having smaller annular space/ web thickness by providing-
  - Lower slurry viscosity
  - Sufficiently longer pot-life to get flawless propellant after curing

Requirements:

- To be effective only in minor quantity (preferably 0.1 %)
- Must be compatible with all the ingredients
- Should not affect mechanical, ballistic and ageing properties of the propellant

Thin Polymeric liner / insulation material for shock attenuation from 100 kbar to 15 kbar

Scope of work:

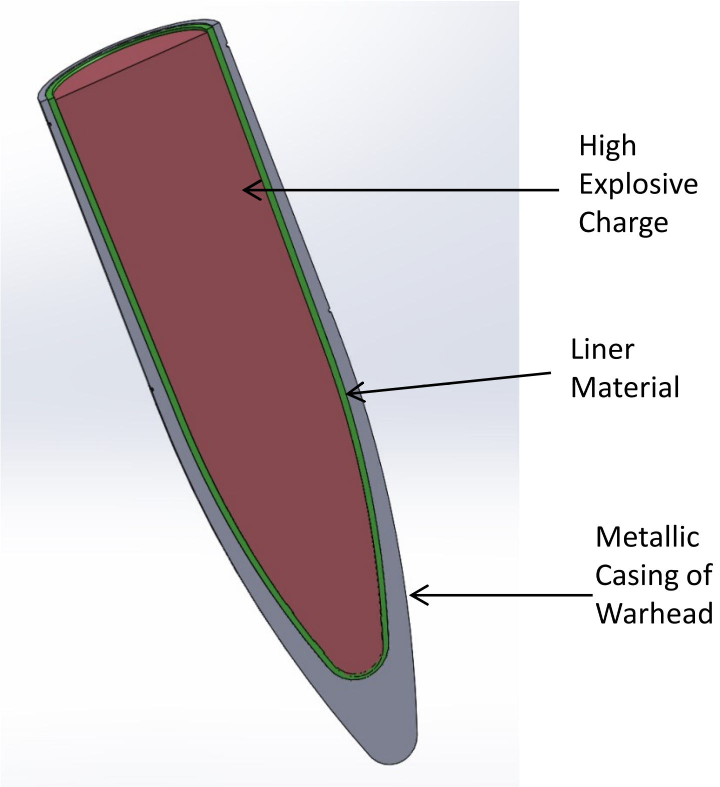
Development of internal liner between energetic material and metallic casing for attenuation of shock stimuli

Background:

- **During storage/use, high explosive filled warheads are required to withstand extreme environments / threats generated due to high temperature and shock**
- **Threats caused by fire, explosion of adjacent stored ammunition or impact of high velocity projectiles (bullet, fragment, etc.)**
- **Incorporation of suitable liner material capable to attenuate the shock can provide improved insensitivity for the warhead**

Thin Polymeric liner / insulation material for shock attenuation from 100 kbar to 15 kbar

- **Desired characteristics for polymeric shock insulation material / liner**
  - **Flexible**
  - **Compatible with high explosives**
  - **Ease of placing and/or pasting to casing**
  - **3 mm thickness maximum**
  - **Pressure attenuation from applied pressure**
    ~ 100 kbar to 15 kbar
  - **Withstand temperature of ~200°C**
  - **Useful life (after use/application) ~25 years**



Necessary support for field testing of the material will be provided by HEMRL

Requirement: **50 sq.m. of material in initial lot**

Self Healing Polymers in Solid Rocket Propellants

What are self Healing Polymers?

- Self healing polymers are a class of novel polymers possessing the ability to heal or repair damage automatically and autonomously
- Most of the biological materials are self healing in nature e.g. Merging of broken bones, closure and healing of blood vessels, repair of DNA, skin regeneration etc.
- Self healing polymers are man-made attempt to replicate the natural mechanism
- Potential applications include concrete, tyres, coatings, electronics, medicine etc.

Why do we need them?

- Major failure modes of propellant grain are crack, void and de-bonding
- Crack formation is the most severe form of defect and can cause catastrophic failure thereby leading to complete rejection of motors
- If self healing of cracks can be applied to propellant grains successfully, it can virtually eliminate the rejection of motors thereby saving considerable cost and improving safety drastically

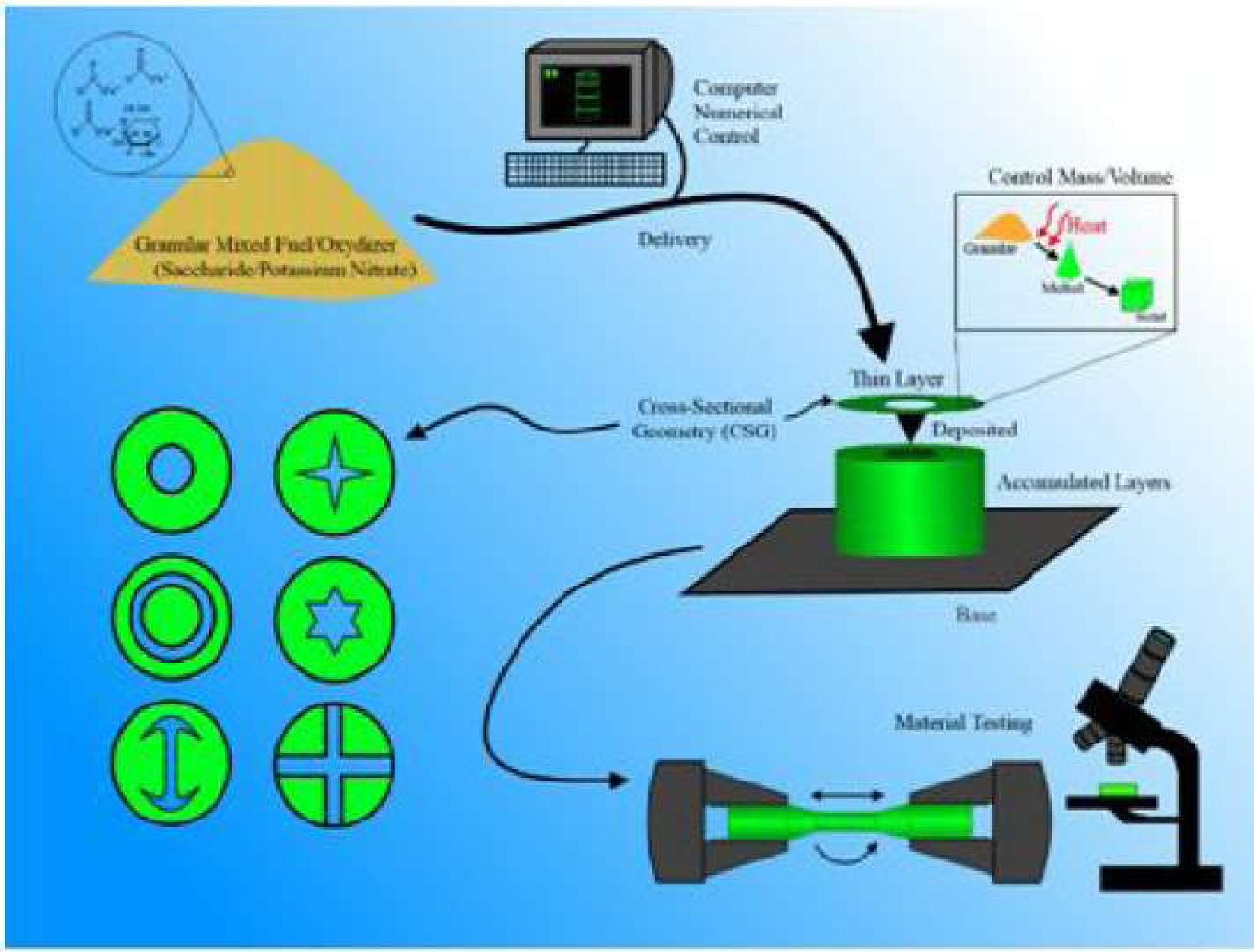
SCOPE OF DEVELOPMENT:

Development of Self Healing Polymer as binder system

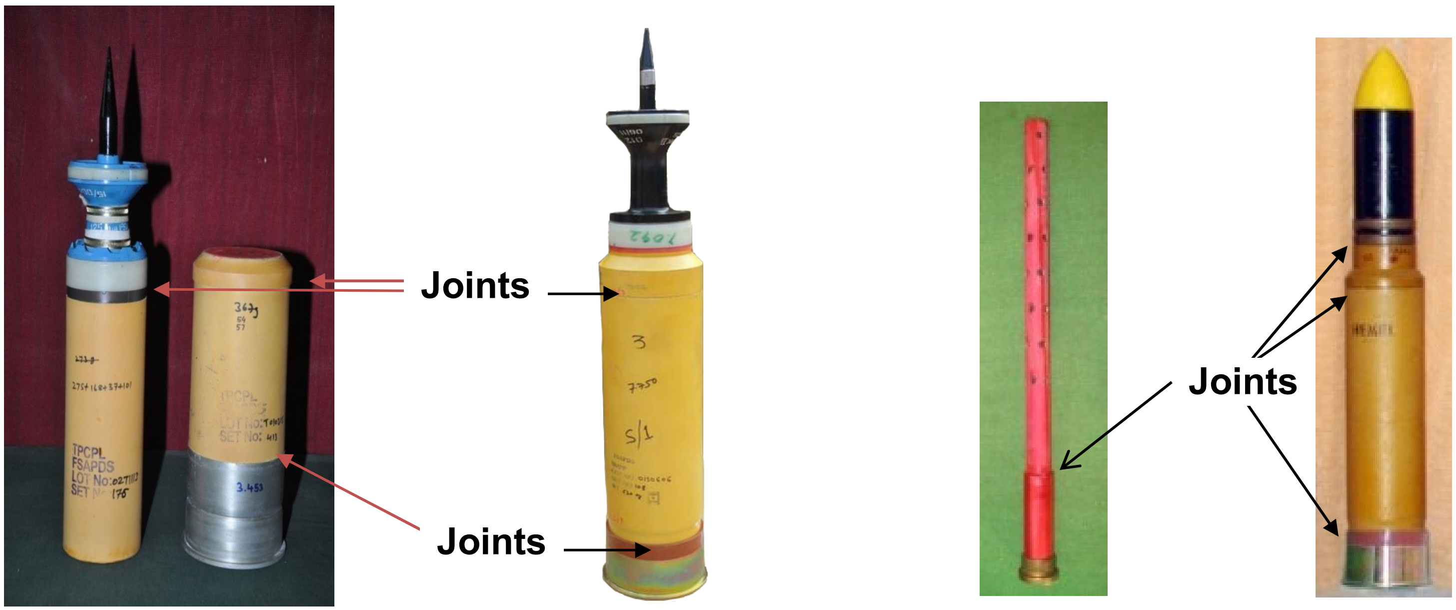
3D Printing of Propellants

- Casting of complex geometry propellant grains has been highly tedious task using either segmented mandrel technology or melt alloy mandrel technology
- In addition, these technologies are not production friendly
- 3D printing of propellant may facilitate ease of manufacturing for all kind of propellant geometry
- Enhance the volumetric loading of the propellant in rocket motor case significantly
- Major bottleneck - instantaneous curing of propellant in 3D printing
- development of suitable binder system which cures instantaneously under UV light

Steps in 3D Printing



Development of High Bond Strength Combustible Adhesive for Gun Ammunition



125 mm Practice Ammunition

120 mm FSAPDS Ammunition

Primer for 120 mm Ammunition

120 mm HESH Ammunition

Limitations of existing NC based Adhesive

- Shelf life of adhesive is only 6 months
- Bonding strength (Adhesive strength) is 50 kgf only between CCC to CCC

Limitations of Epoxy based Adhesive

- Debris of adhesive is observed on firing of ammunition occasionally

Specifications of existing NC based Adhesive

Sr. No.	Characteristic	Passing standard	Test method
1.	Viscosity at 25 °C (CPS)	Min 3500 Max 6500	Brokfield Viscometer (Spindle No 2 or 3)
2.	Acidity as H_2SO_4 (%)	Max 0.05	Titration method by using N/10 NaOH solution and 1% alcohol solution of Phenolphthalein as indicator
3.	Solid content (%)	25 - 30	Weight loss method
4.	pH of water extract	5.5-7.5	pH meter
5.	Adhesive Strength / Bond strength) (kgf)	Min 50	Tensometer / UTM

Objectives for development of new adhesive:

- To develop Adhesive for assembly of gun ammunitions with debris / residue free combustion on firing
  - ✓ Operational temperature range -40 to +65°C
  - ✓ Gun Chamber pressure ≥ 40 MPa
  - ✓ Adhesive should completely consume within 10 ms
- It should have 2 years (min) of shelf life & 10 years (min) of service life
- It should have bond strength of 100 kgf (min) between CCC to CCC

Gel Propellants and its Atomisation

- Gels are liquids whose rheological properties have been altered by adding gellants and their behaviour resembles that of solids
- The compositions are modified in such a way that the viscosity is reduced during feeding process (Shear thinning) & these burn as liquids (after atomization).
- Various advantages of Gel propellants are :
  - Reduced leakage rate
  - Reduced toxicity hazards
  - Insensitive to impact, friction & ESD
  - Controllable combustion in case of accidental ignition
  - On – Off capability; variable thrust profile management
  - No effect of cracks in the gel structure
  - High Specific Impulse (~ Liquid Prop), increase when metalized (450 – 500 s)
  - High Density Impulse
  - Long term storage capability (> 10 years)

Gel Propellants and its Atomisation

- Various problems with the development which include atomization, lower combustion efficiency, particle sedimentation, increased feed pressures, etc.
- Development of Anti Gelling agent is highly essential to resolve problem of nozzle clogging
- Serves as enabler for smoother discharge of the gel propellant to be burnt appropriately in the mixing chamber with the oxidizer
- The general composition of gel propellant is as follows:

Ingredient	Content (%)
Kerosene or Dimethyl amino ethylazide (DMAZ)	60 to 90
Solids (Aluminium, Carbon)	25 to 35
Fumed Silica (gelling agent)	5 to 10
Surfactant (Polyoxyethylne sorbitan trioleate)	0.5 to 1

Sensors and Technology for Stand-off Detection of Concealed Bulk Explosive

Background

- Detection of concealed bulk explosive is the need of the hour considering the requirement of security agencies for use in Public places like Airport, Railway Stations, Malls etc
- Various techniques are available for trace explosive detection but not useful for standoff detection or if available but with higher rate of false alarm which seriously limits their use for online surveillance
- Although not a single technique will detect all the explosives but many developed techniques has capability to detect only limited numbers explosives or explosives of few classes

Requirements

- Data generation and capturing of fingerprint of various explosives for online identification of explosives using SORS / UMARS techniques
- Bulk concealed explosive detection by SORS / UMARS techniques
- Explosive detection by Mass Spectrometry from Solid, Liquid and Gaseous phases of explosives
- Understanding of underlying physics and Data Generation of Mass Spectrometry from various explosives for online identification of explosives using Mass Spectrometry method
- Sensors / materials development for online standoff detection of bulk concealed explosive in solid and liquid

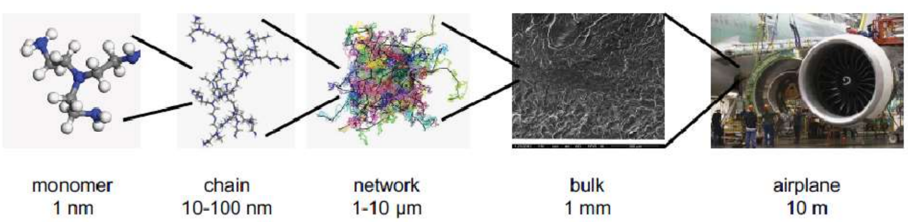
Stand-off Distance: 500 mm or more

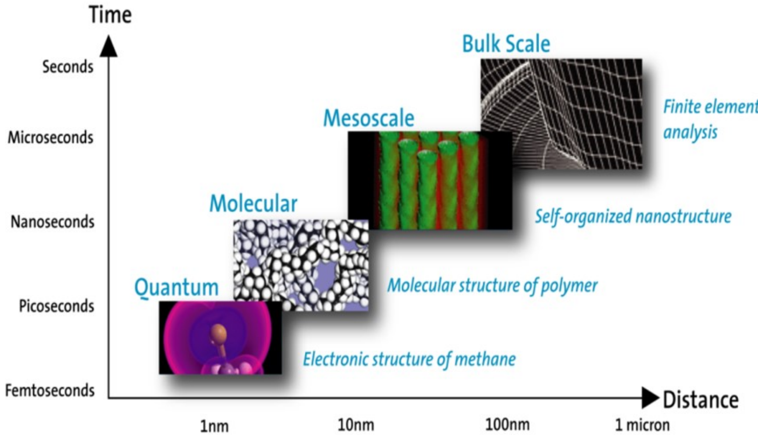
Minimum Concealed Material thickness for detection

- Steel: 2mm
- Aluminum: 3 mm
- Plastic: 6 mm
- Card board: 10 mm
- Glass : 8 mm

Multiscale Modeling on Energetic Materials

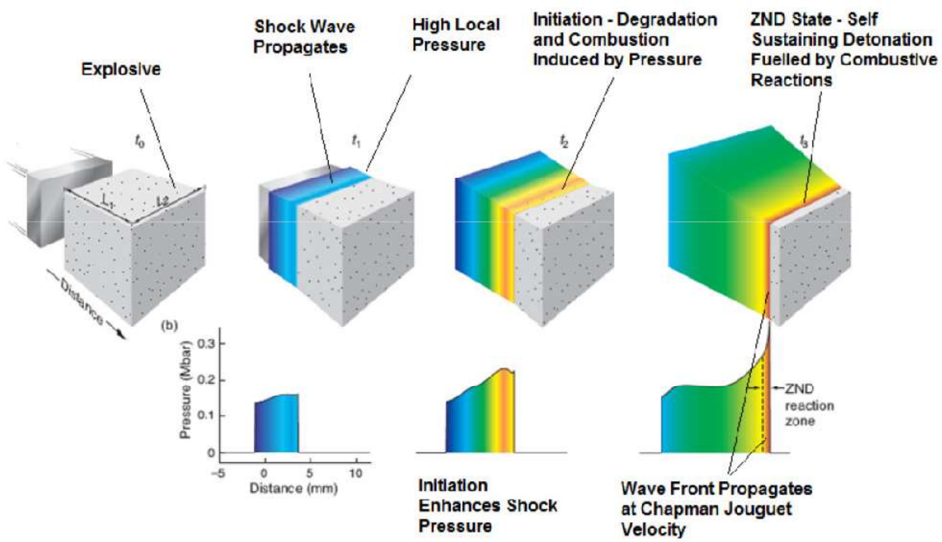
- **Multi-scale modeling includes simulations at**
  - **electronic scale (by quantum mechanics)**
  - **atomic-molecular scale (molecular mechanics)**
  - **meso-scale level (Dissipative Particle Distribution)**
  - **Macro scale (Continuum mechanics)**
- **Multi-scale simulation methodology helps to generate reliable data to predict the fundamental properties of HEMs as well as bulk behaviour.**
- **The response of an energetic material to insult is perhaps one of the most difficult processes to model due to concurrent chemical and physical phenomena occurring over scales ranging from atomistic to continuum.**
- **Unraveling the inter-dependencies of these complex processes across the scales through modeling can only be done within a multiscale framework**



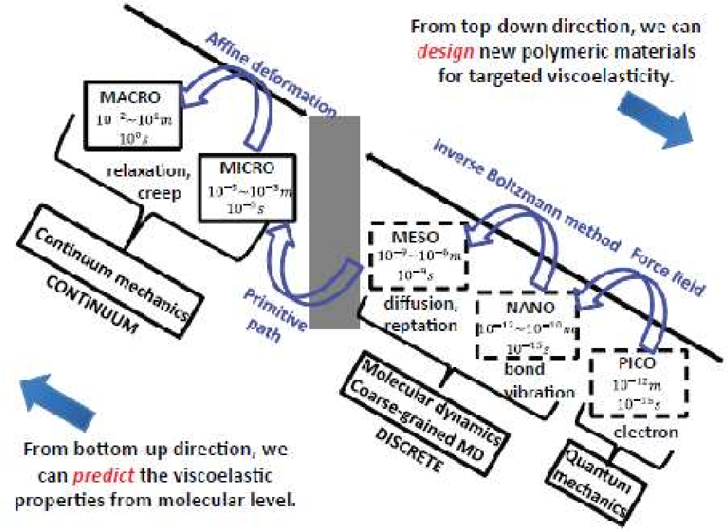


Multiscale Modeling on Energetic Materials

Detonation: The Zeldovich, von Neuman, Doring Model



Bdzil, J. B.; Aslam, T. D.; Henninger, R.; Quirk, J. J. *Los Alamos Science* 2003, *28*, 96.



Areas of Interest:

- Particle packing and microstructure modelling of energetic materials
- Multiscale multiphase modelling of detonations in condensed energetic materials
  - The explosion model includes a shock-to-detonation transition in a condensed phase, which is then allowed to propagate into a surrounding gaseous mixture. Shock initiation and detonation behavior are attributed to reaction changes in the microstructure of condensed materials. Challenges emerge in the coupling of the corresponding equations of state due to the multiphase nature of the problem, as well as resolving the different spatial and time scales
- Development of improved techniques to predict their performance and sensitivity.
- Computational strategies for simulating the thermal response of high explosives

Code for Prediction Infrared Radiation Intensity of MTV Flares

- MTV (Magnesium-Teflon-Viton) based Infrared (IR) Flares are used as expendable cheap decoy to protect aircrafts, by diverting 1st and 2nd generation of heat seeking missiles.
- The MTV-Flares generate higher Infrared Radiation intensity, as compared to aircrafts in the field of view of heat seeking missiles and shifts the lock from aircrafts to flares.

Appraisal:

- Currently, radiation intensity in temporal and spectral modes are measured by Spectro-radiometer and the same is reported in different wavebands.
- At present, there is no method to predict the radiation intensity of a typical IR flare in ground and flight conditions
- There are codes available to predict product of combustion of MTV composition, but technology-gap is present to predict radiation intensity from product of combustion.

Code for Prediction Infrared Radiation Intensity of MTV Flares

Requirement: To predict radiation intensity of various MTV flare compositions in 3-5, 2-3, 1-6, and 8-14µm waveband

Deliverable must include a software code (GUI based), where following inputs are perceived:

- **Percentage of Magnesium, Teflon and Viton or Mole fraction of Product of combustion**
- **Particle size details of Magnesium and Teflon**
- **Density of pellets**

The output expected from the code is as follows:

- **IR Radiation intensity in specified wave bands in ground and flight conditions**

Development of mathematical model / software for theoretical evaluation of gun barrel wear / erosion

Introduction

- Erosion / wear results in enlargement of gun bore
- The major contributors to wear/erosion of gun barrels are:
  - ✓ Thermal factors
  - ✓ Chemical factors
  - ✓ Mechanical factors

Objective

- To develop a model to predict gun barrel erosion w.r.t. propellant composition, material of construction of barrel, gun parameters, projectile type, temperature, pressure, etc.
- Creation of experimental set-up & data to be acquired
- Model verification procedure
- Validation of model with actual trial results.

Development of mathematical model / software for theoretical evaluation of gun barrel wear / erosion

Input parameters

- Propellant composition
- Burn rate & peak pressure from Closed Vessel firing
- Material of construction of barrel
- Gun parameters (Calibre, chamber volume & chamber pressure limit) and projectile type
- Operational temperature

Output parameters

- Composition of combustion products
- Enlargement of gun bore
- Effective Full Charge (EFC) (Maximum nos. of rounds that can be fired up to maximum allowable enlargement)
- Contribution of different factors on barrel erosion

Thrust Areas

Materials for Armament Applications (MAA) Panel

Domains of Interest

- **Materials for Armours**
- **Materials for Combat Vehicle Application**
- **Materials for Ammunition/Kinetic Energy Projectiles**
- **Materials for Gun barrel applications**
- **Advanced Manufacturing Processes**
- **Modelling and Simulation studies**

Scope of Work

- New material relevant to defence
- New technology pertaining to defence
- Better properties/ Increased performance
- Reduction in manufacturing cost
- Shorter routes (lesser manufacturing time)
- Lower density to have significantly lighter weight/smaller size
- Enhancing the “know why” on the subject

Materials for Armour

Armour

Anti-tank Threats

KE projectiles 

> 650mm

S/C HEAT projectiles 

> 750mm

RPGs 

> 500mm

ATGMs 

> 1200mm

HESH

Bottom attack Mines 

> 200mm

Explosive blast >10 kg

Top attack munitions 

> 200mm

Directed Energy Weapons ?? 

Tank Armours

- **Metals**
  - Steels
  - Ti-alloy
  - Al-alloy
  - BMG
- **Ceramics**
  - Al_2O_3 & ZTA
  - SiC, B_4C
  - TiB_2, AlN, AlON
  - Glass ceramics
- **Composites**
  - PMCs, MMCs, CMCs
  - Nano Polymers

- Fracture Toughness
- Hardness
- Compressive strength

Metals:

- Rolled homogeneous armor (RHA) steel, Medium hardness steels, High hardness steels
- Superbainitic steels (SBS): A high performance steel with a ballistic performance at least twice that of conventional Rolled Homogenous Armour (RHA). It is both ultra-hard (600 Brinell) and highly effective against small arms fire)

- High nitrogen steels, Ti-alloys and Al-alloys,Ultra- high hardness amour steels (600 BHN and above).
- Dual hardness armour (Base non-ferrous and upper ferrous-Lightweight application for turret),
- Materials for Adaptive Camouflage Armour

Ceramics:

- Alumina, ZTA, Boron Carbide, Silicon carbide, Ti-diboride Glass ceramics, Al Nitride,
- Functionally Graded Materials and Transparent crystalline ceramics
- High-performance tough ceramics for impact resistance applications

Inter-metallics and other materials:

- High temperature inter-metallics such as Nb-Si and Mo-Si-B, Ternary and quaternary eutectics with intriguing microstructures with complex interfaces. 3D printed and lattice structural systems for lightweight structural systems
- Self-healing FRP composite systems, High energy absorbing and damage mitigating FRP composite systems for impact and blast resistance,
- Metal Matrix Composites, Carbon Matrix Composites, Metal intermetallic laminates and Nano-Composites

Materials for Ammunition

FSAPDS- Penetrators

Current Material: Tungsten alloy (powder metallurgy process)

Density – 17 g/cc, UTS- 1100 MPa, elongation – 8%

Requirements: UTS ~ 1500 Mpa, elongation > 8%,

High density, high fracture toughness

FSAPDS Penetrator

Nano: Tungsten alloy- Mechanical Alloying, Depleted Uranium

Bimetallic Penetrators: Rhenium core with tungsten alloy cover

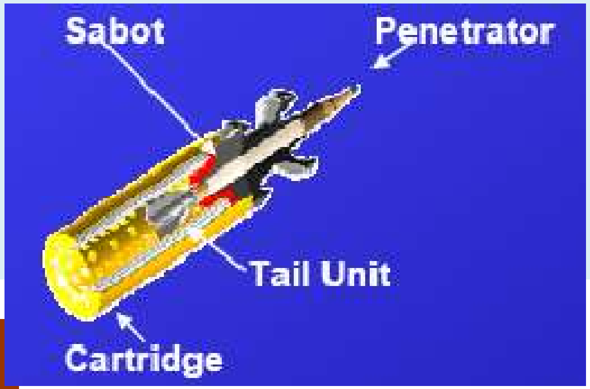
Metal matrix composite: Amorphous metal alloy of Be, Zr, Cu, Ti & Al with W

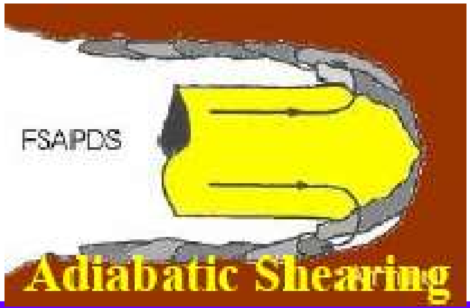
Advantages

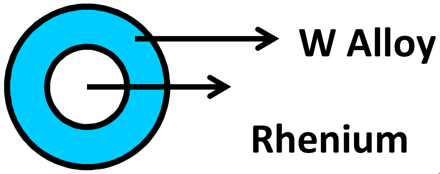
High density and ultimate tensile strength

Adiabatic shear deformation

High fracture toughness







- Development of advanced alloys, W-bulk metallic glass composites.
- Establishment of Microstructure-mechanical properties correlations, investigations on high strain rate flow behaviour.
- Tungsten heavy alloys: W-Ni-Fe, W-Ni-Co, W-Ni-Fe-Co, W-Ni-Mn

Gun Barrel Technologies

Challenges

- Reduced Gun Barrel Erosion & Enhanced Fatigue Life
- Improved Gun Barrel Thermal & Ballistic Performance
- Reduced Life Cycle Costs

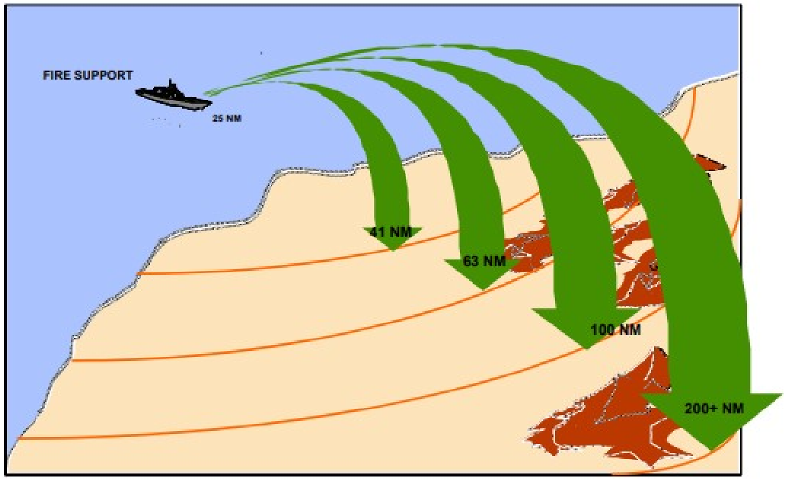
Current Material - ESR / VAR / Combination of VIM & VAR/ESR Steels

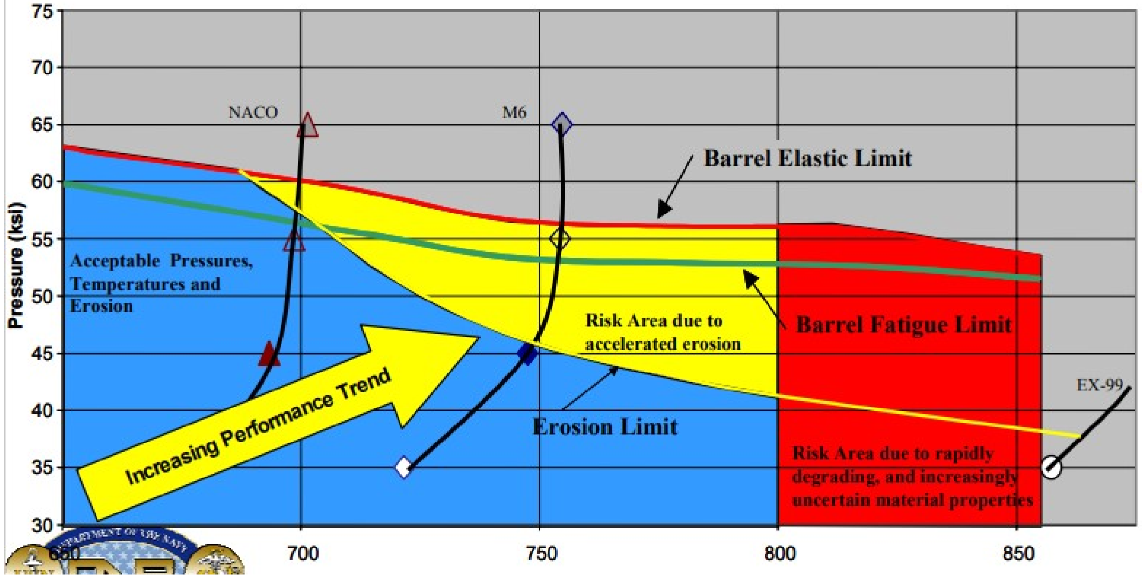
- Rotary / Centrifugal forgings followed by thermo-mechanical treatments

New Technologies

- Refractory Coatings With Steel Barrel
  - Reduced barrel wear & longer fatigue life
- Composite Material Barrel Technology
  - Improved thermal management
  - Enhanced ballistic performance
  - Metal Matrix Composites / Ceramic composites

- The trend of gun performance requirements has been for increased range and rate of fire for centuries
- Wear and thermal management limit system performance
- Highest energy propelling charge and advanced projectile solutions are precluded by barrel limitations
- Improving wear, erosion or thermal management yields increased system performance





- **Barrel Design Space Limits**
  - Elastic strength
  - Fatigue strength
  - Max bore temperature
  - Wear and erosion

1- Refractory / Steel Barrel : Focus on the technologies providing longer barrel erosion and fatigue life.

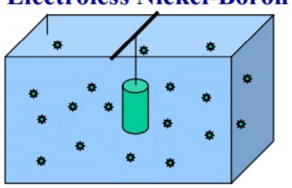
- Develop and apply alternate coating / liner material and processing to the existing Chromium plating.

2- Composite Barrel : Develop Composite gun Barrel for improved thermal management and wider design space for enhanced ballistic performance for current and future gun barrels

- Technologies such as Metal Matrix Composites that provide more flexibility in achieving desired material properties in radial and axial directions in the barrel

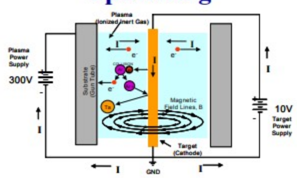
Refractory coatings on artillery and tank gun barrels and Strip lamination process for rocket motor tubes

Electroless Nickel-Boron



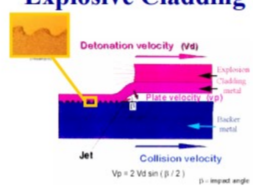
Catalytic plating process produces extremely uniform coating even on complex geometries

Sputtering



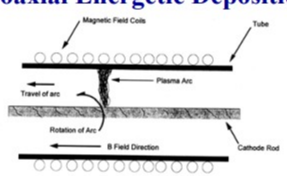
Material is sputtered, from a coaxial target, uniformly over the inside diameter of the barrel

Explosive Cladding



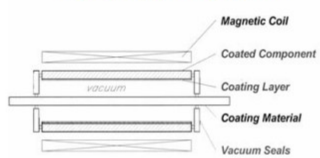
Tube of cladding material is mechanically bonded with the gun barrel in a collision driven by an explosive detonation

Coaxial Energetic Deposition



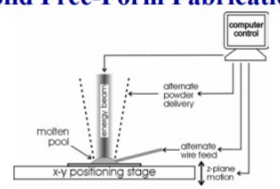
Plasma arc rotates around center conductor and travels along its length depositing material

Electromagnetically Enhanced Physical Vapor Deposition



Electrically controlled magnetic fields enhance the plasma environment of the physical vapor

Solid Free-Form Fabrication



Engineered material is created by alloying of powdered and/or wire-fed metals

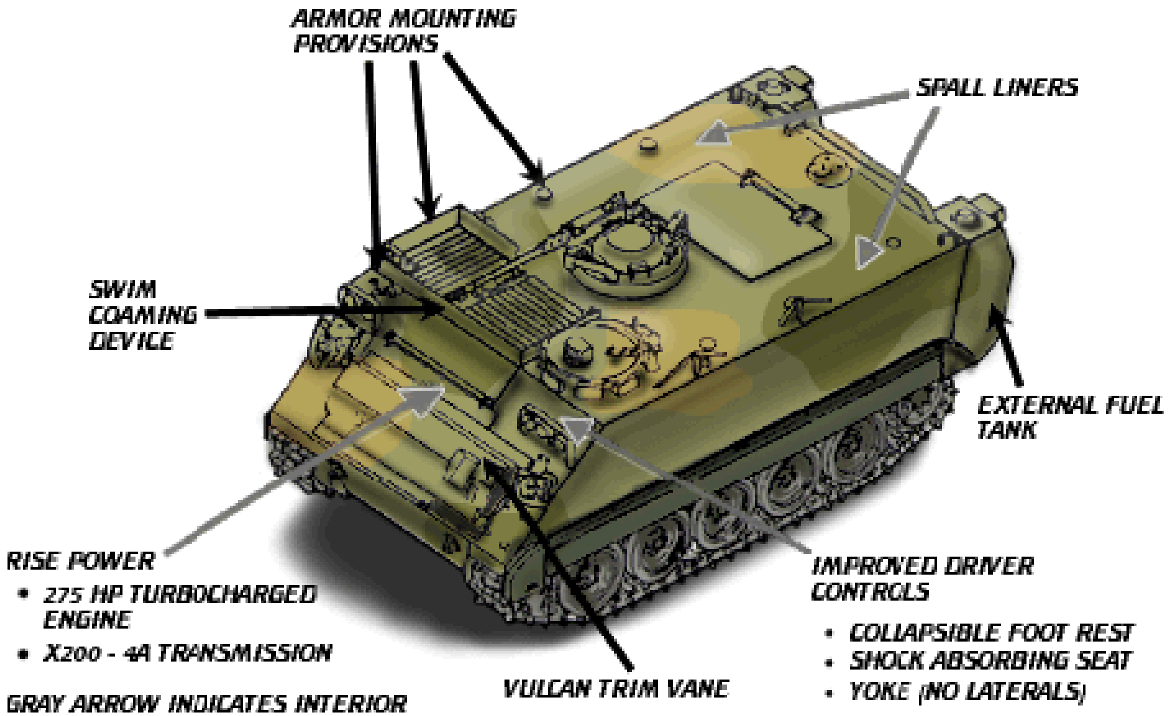
- Wear and fatigue studies for high Ni-Cr steels
- High temperature materials for rocket nozzles and Thermal protective coatings
- Study on Stellite based coatings for barrels

Advanced Manufacturing Processes

- Near net shape forming of metals and ceramics
- *Shape deposition manufacturing*– 3D printing, machining, deposition of electronics in cycles
- Smart composite microstructure
- *3D multi-material printing*, direct ink writing (robocasting) – printing silicone actuators with in-built fluidics
- 3D Ceramic printing

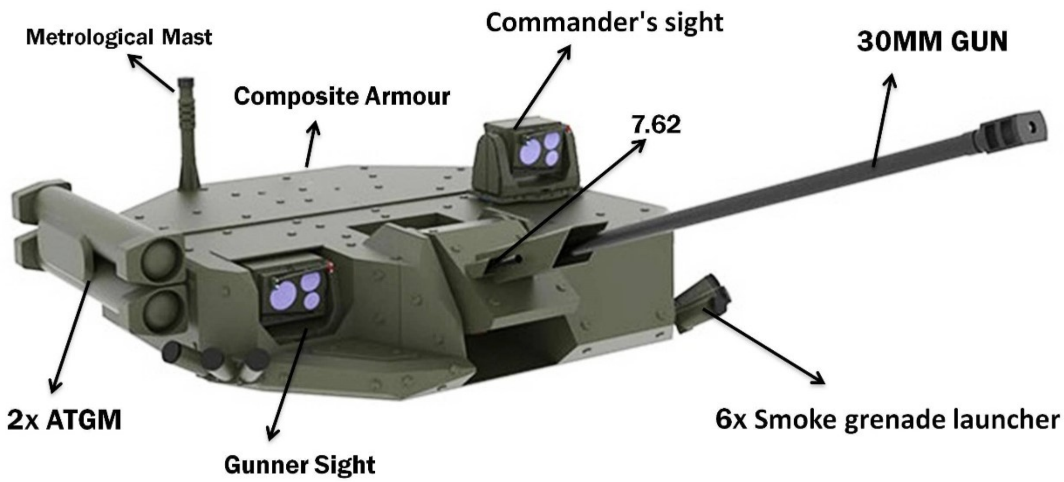
- Additive manufacturing of add-on armour for both ballistic and blast protection
- Additive manufacturing of Damper for Armoured Fighting Vehicles (AFV)
- Weldability Studies of RHA using non-conventional methods such as Plasma Arc Welding, Electron Beam Welding, Laser Beam Welding etc.

Materials for combat vehicles applications



- Non – metallic materials for AFV fuel tanks (in lieu of exciting SS Fuel tanks for weight reduction and obviation of maintenance issues.
- Impact resistant AFV Fuel tanks (Fuel tanks with penetration resistant / absorption materials without fuel leakage)
- Non-ferrous alloy pistons for AFV Suspension (in-lieu of existing steel pistons in existing hydrogas suspension for weight reduction)

- Blast resistant materials for AFV tracks including wheels
- MR & ER Fluids for AFV Active Hydrogas Suspension
- Graphene based materials for AFV applications



Materials for Structural application

- Joining/welding of dissimilar materials
- Metal composites joints
- Nano-composites
- Additive manufacturing/3D printing of thick structures including continuous fibre composites with large complex topologies
- Self-healing materials
- Auxetics (Materials with negative Poisson's Ratio)

- Metamaterials
- Functionally graded materials
- Bio-inspired materials
- Fatigue and life assessment of complex welded structures
- Structural health monitoring
- Smart materials
- High Entropy Alloys
- Powders for additive manufacturing & metal injection moulding

Modelling studies

- Modelling for development of armor materials & penetration behaviour
- Multi-scale damage modelling of ceramics and FRP composites, especially when subjected to high-rate dynamic loading such as, impact and blast
- Modelling of wear, Modelling of fatigue and fracture
- Modelling of welding process
- Constitutive relations for smart materials

- Modelling and simulation studies for electro-magnetic rail gun

Safety, Test and Evaluation Panel

Armament Research Board

Areas of interest: -Fire, Explosive and Environment Safety

Explosive safety

Safe storage / siting / processing of explosives and ancilliaries (Regulatory)

Structures for storage of Advanced weaponry/ missile systems

Fire safety

Fire safety in military platforms/ storage/ process buildings.

Environment safety

Determination of environmental impact of the next generation systems and mitigating their environmental damage effects

Explosive Safety

Explosive Safety

Regulatory activities

Deterministic approach :Storage and Transport of Explosive Committee (STEC)

Probabilistic approach :Quantitative Risk Assessment

- **Development of QRA methodology based on probabilistic techniques**
- **Development of blast and fragment prediction models**
- **Integration of Predictive Tools with GIS**

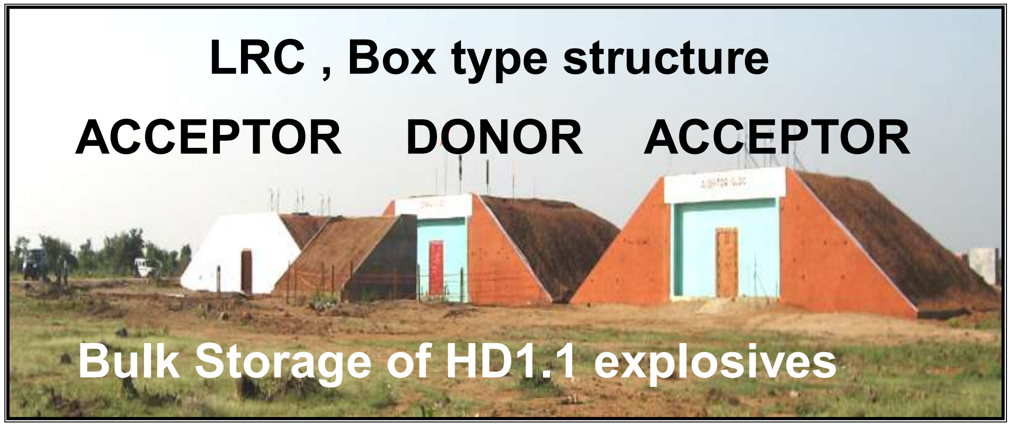
DESCRIPTION	Catastrophic >100	Critical 10-100	Marginal 1-10	Negligible <1
FREQUENT 0.1	A	A	A	C
PROBABLE 0.01	A	A	B	C
OCCASIONAL 0.001	A	B	B	D
REMOTE E-04	B	B	C	D
IMPROBABLE E-06	C	C	C	D

Areas of collaboration with academic partners

- Development of consequence model for effects due to fragmentation
- Integration of predictive tools using GIS

Explosive Storage Structure

IGLOO (HD1.1)



Unit Risk Principle (HD1.1)

High Performance Magazine (HD1.1)

Unit Risk Principle (HD1.3)

Modeling and simulation: Development of codes.

Safe Explosive Storage structures

- **Portable storages for forward areas**
- **Blast resistant materials/ protective wall based on composite materials.**
- **Underground explosive/ ammunition storage facility.**
- **Blast-structure Interaction: Simulation and Modeling of structures subjected to extreme loads: Development of Codes**

Areas of collaboration with academic partners

- Development of sandwich blast mitigating structures
- Development of Numerical codes

Risk Reduction

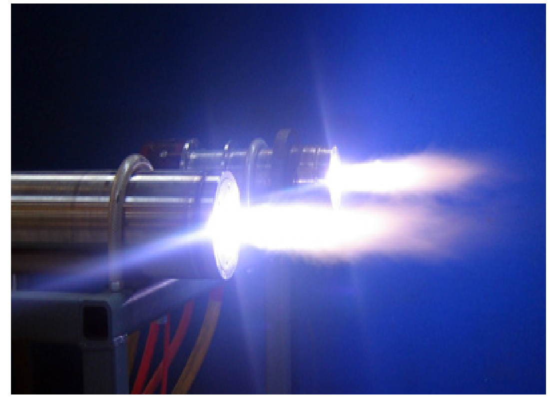
- **Development of special packaging for reducing hazard class of HE**
- **Safe Technologies for disposal of unserviceable explosives/ ammunitions**
- **Life Cycle analysis (LCA) of munitions**

Areas of collaboration with academic partners

- Development of retrofitting polymeric formulations
- Development of model for polyurea
- Scale up of models

Demilitarization Techniques, Disposal of Aged Propellants and Explosives





- **Design of air cushions for minimization impacts during transportation**

- **Design, development and validation of explosive containment vessels/structures for safe transportation of initiatory and for scaled down testing**

Area of collaboration with academic partners

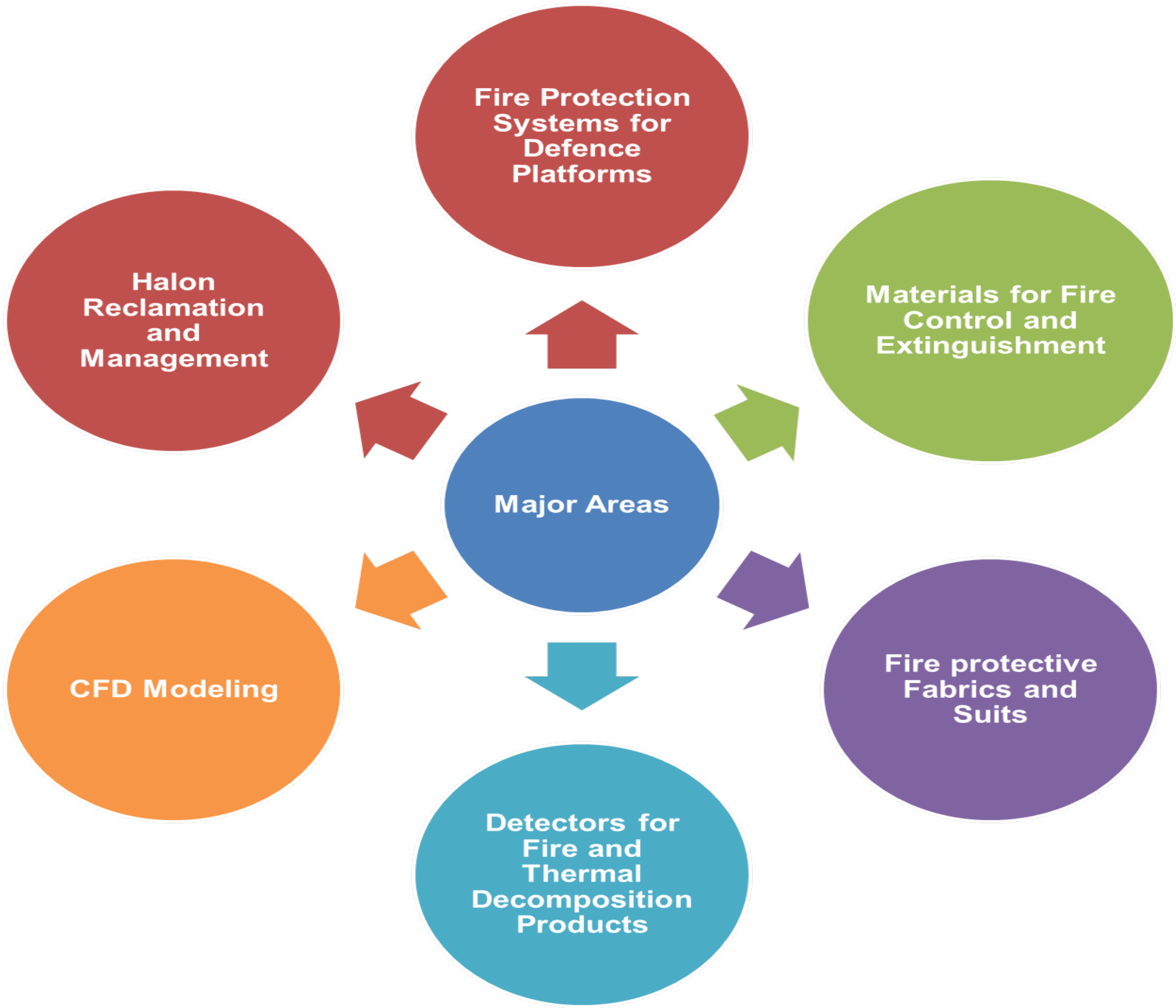
- Modeling of explosive containment vessels/structures
- Methodology for scale up of models

Additional thrust areas (Explosive safety)

- ***Thermal cracking of explosives***
- ***Non sparking materials***
- ***Meta-materials for explosive storage***
- ***Developing material models for Laced reinforced concrete (LRC) and Reinforced Cement Concrete (RCC)***
- ***Modelling of Secondary fragmentation: Based in the distribution data generated from previous trials***

Fire Safety

Fire Safety – Core Competencies



Chemicals for Fire Protection

On-going Research Areas

- Design, Development & Process Scale-up of organo-fluorine compounds to be used as halon alternatives
- Analysis of Thermal Decomposition Products of materials
- Toxicity Evaluation of fire extinguishing agents
- Development of fluorosurfactants for fire-fighting foam applications

Areas of Collaboration

- Development of Next Generation Halon Alternatives/ Non-chemical routes
- Development of eco-friendly fluoro-surfactants for fire fighting foam
- Evaluation of Thermal Decomposition Products of Fluorinated Compounds
- Development of methodology for evaluation of Environment Impact Parameters such as ODP and GWP
- Toxicity Evaluation of Fire Suppression Compounds & Bio-accumulation of surfactants

Fire Dynamics

On-going Research Areas

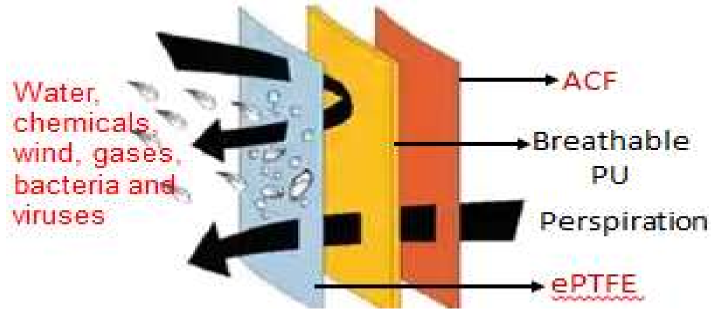
- CFD & Molecular Modelling of Fire Interaction
- Miniaturized and Embedded Fire & Toxicity sensor development

Areas of Collaboration

- Development of Fire Sensor Network and multi-signature fire detection algorithm
- Development of CFD Solver for Fire Dynamics
- Numerical Model for fire suppression agent interaction with fire
- Numerical Model for water mist interaction with hot gas plume
- Molecular Modeling for interaction of fire suppression agent with fire

Fire Protective Textiles

Indigenous Aluminized Suits



Components of Light Weight Suits

On-going Activities

- Development of Multifunctional Moisture barrier Fabric for Fire suits

Areas of Collaboration

- Modelling & Prediction of Fire Retardancy of Fire Protective Fabrics
- Development of CBRN layer to be integrated in Fire Protective Suits
- Development of light weight cylinders for Breathing Apparatus Set
- Biaxial stretching of polytetrafluoroethylene as breathable layer
- Development of reflective aluminised layer

Additional thrust areas in Fire safety

- Fiber development program.
- Inherently fire retardant fabrics

Polymer synthesis

Melt Processing

Fiber Processing

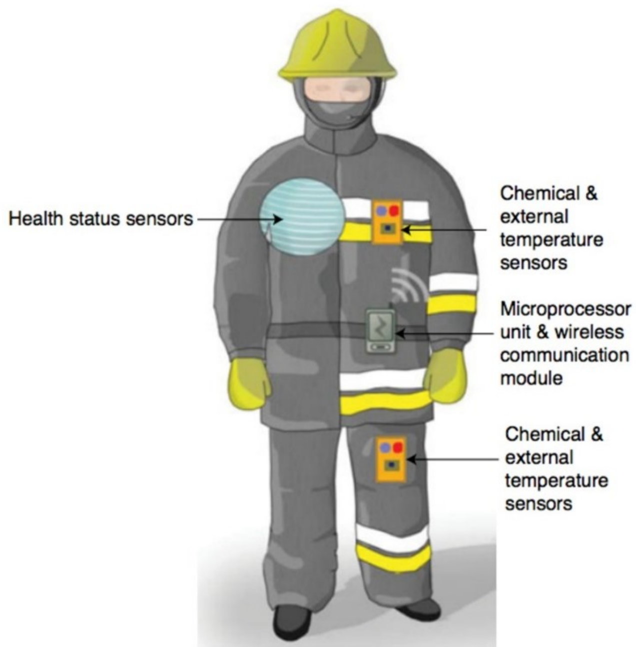
Additional thrust areas in Fire safety

- Thermally stable foams

- Molecular modelling of fire extinguishing agents
- Development of Augmented Reality based Fire Training Simulator
- Development of Breathable polyurethanes through environment friendly routes
- Fire extinguisher media for Lithium battery fire

New Areas in Fire safety

- Smart fire fighter
  - Wearable sensors
  - Drones to assist firefighter as well as firefighting



Environment Safety

Environment Safety

Collaboration areas with academic partners

- **Technology Development for waste Management at High altitudes**

- **Catalyst development : Waste to fuel**
- **Pyrolytic reactors: Development of Compact and portable pyrolytic reactors, which are operational even at low temperatures**

Nano safety research

Environment fate and toxicity studies of nanomaterials (for formulating guidelines / regulations for nano material safety)

- Determination of factors influencing fate, transport and transformation of nanomaterials

  Physical: particle size and concentration, flow velocity, heterogeneity

  Chemical: pH, ionic strength, particle surface chemistry

- Development of standardized test methods for evaluating key transformation processes in the environment

- Determination of mechanism and forms of engineered NM transition from one environmental media to another

- Impact of size, morphology, charge and surface coatings on reactivity and mobility.

Environment safety

Life Cycle analysis

Develop a suitable or specific methodology to evaluate the impacts of improvements (during explosive production/ use) and rank the different alternatives from an environmental point of view.

New areas: Environment Safety

Traverse remediation: Flora

Pollution abatement (during firings)

Plastic eating microbes

Carbon capture

Desalination (halophilic bacteria)