DEFENCE R&D DÉFENSE

Ballistic Performance Assessment of Lightweight Body Armour Material Systems Against IED Threats

by

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Overview

- Background
- Goal/approach
- Threat comparison
- Protection levels options
- Test results
- Summary
- Future work
- Questions

Background

- Military soft armors mainly designed to defeat lower mass/velocity fragments from warheads detonating at large distances
- Bullet resistant rigid armors mainly designed to defeat standard rifle bullets fired at close distances, with no fragment resistance specified
- Ballistic threat spectrum wider and more complex
- PPE (soft & hard) not designed and neither specified to protect against blast effects and fragments impacts from IEDs

Goal

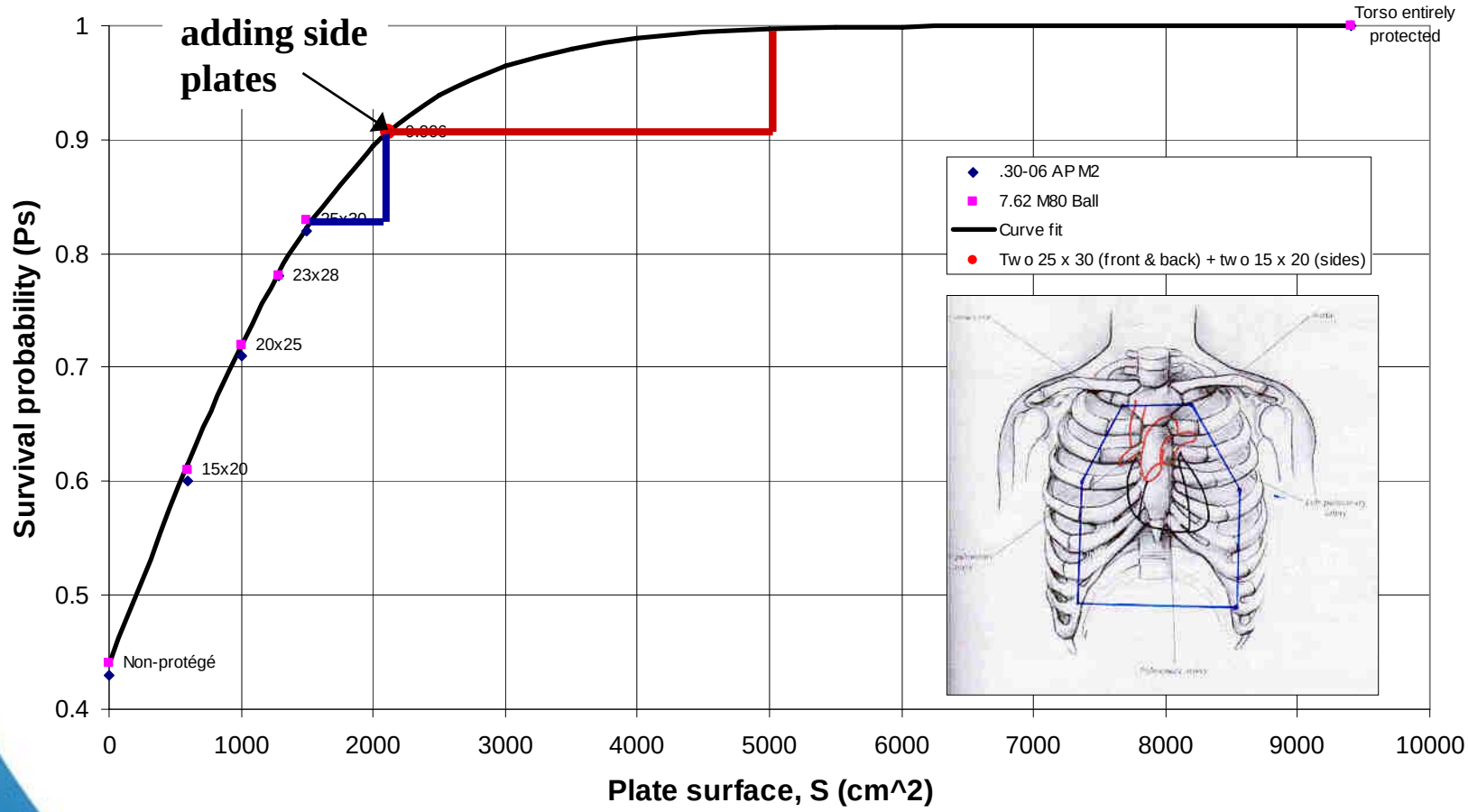
- Increase soldier survivability against IED threats at no extra PPE weight

Approach

- Reduce current PPE weight:
  - Soft Armour:
    - 20% weight saving with same requirements
    - 30% weight saving with lower requirements
  - Hard Armour:
    - 20% weight saving with same requirements
    - 30% weight saving with lower requirements
- Apply weight savings to better match the threat
  - Provide novel IED specific armour components

Torso Coverage Study

- Desirable: uniform coverage of vital organs



Threat Review: Fragments

- Natural fragmenting munitions
  - Large number of fragments (7000-14000) of all sizes (0.5 to 500 gr)
  - Made of steel typically, 30 Rc hardness
  - Initial velocity from 1000 to 1800 m/s
  - L/D or shape factor variable typically 0.5 to 1.1
- Pre-formed fragmenting munitions
  - Spheres:
    - Mines: 7/32 in sphere (0.7 grams)
    - Grenades: 2.5-3.0 mm sphere (0.12 grams)
  - Cubes, steel or tungsten
- Controlled fragmentation

IED Threat Implications

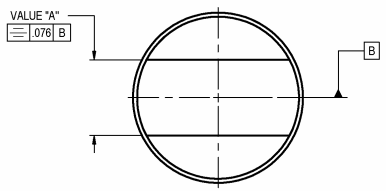
- **Closer proximity from detonation**
  - Higher fragment density & velocity
  - At short range: blast arrive before fragments thus the need for live field tests
  - Fragment impact about simultaneous
  - More frequent negative impact angle
  - Larger fragment variability
    - Size, shape, material

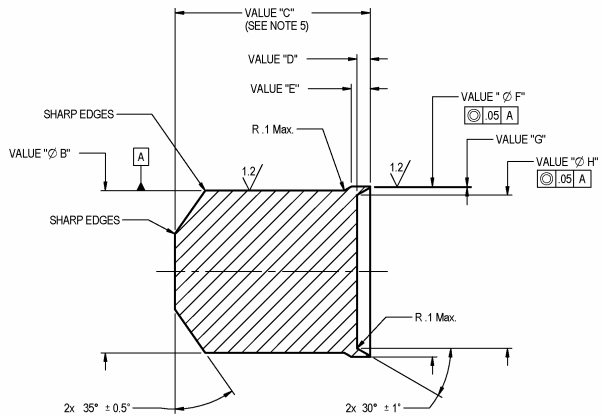
Fragment Surrogates

- Primary fragments:
  - FSP 1.1-g chisel nose, L/D = 1
    (MIL-P-46593 & Stanag 2920 & 4569)
    - Skirted vs unskirted versions
  - RCC flat nose (L/D = 1 or L/D < 1)
    - Required for CRA (Vs-Vr data)
    - Std sizes: 2, 4, 16 and 64-gr, (128-gr)
    - Based on DeLuca work at AAMRC (Vs/Vr match)
- Secondary fragments:
  - Behind armor debris FSP, shorter, L/D = 0.4 (rarely used)
- Possible to design special size for custom threats using homogeneous scaling

Fragment Simulating Projectiles (FSP)
(STANAG 4569)

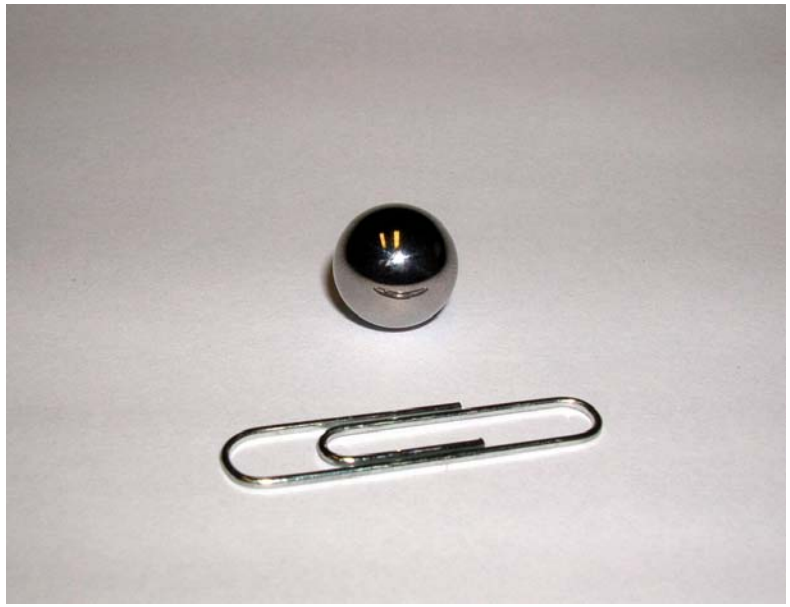
Fragment Simulator	Weight (grains)	A (mm)	Ø B (mm)	C (mm)	D (mm)	E (mm)	Ø F (mm)	G (mm)	Ø H (mm)
FSP 1: 5.56 mm	17±0.5	2.54-0.3	5.46±0.02	6.52	0.4±0.05	0.6±0.05	5.72+0.05	0.08±0.04	5.0±0.1
FSP 2: 7.62 mm	44±0.5	3.45-0.3	7.52±0.02	9.30	0.73±0.05	0.86±0.05	7.87+0.05	0.12 max	6.93±0.25
FSP 3: 9 mm	64±0.5	4.03-0.3	8.69±0.05	9.17	0.4±0.05	0.6±0.05	9.04+0.05	0.12 max	8.42±0.05
FSP 4: 12.7 mm	207±2	5.69-0.4	12.83±0.05	15.24	1.15±0.05	1.47±0.05	12.75+0.08	0.13 max	11.43±0.05
FSP 5: 14.5 mm*	322±2	655-0.4	14.40±0.05	18.00	1.36±0.05	1.68±0.05	15.01+0.08	0.15 max	13.25±0.12
FSP 6: 20 mm	830±4	9.27-0.4	19.89±0.05	24.00	1.62±0.05	2.31±0.05	20.83+0.08	0.2 max	18.80±0.12



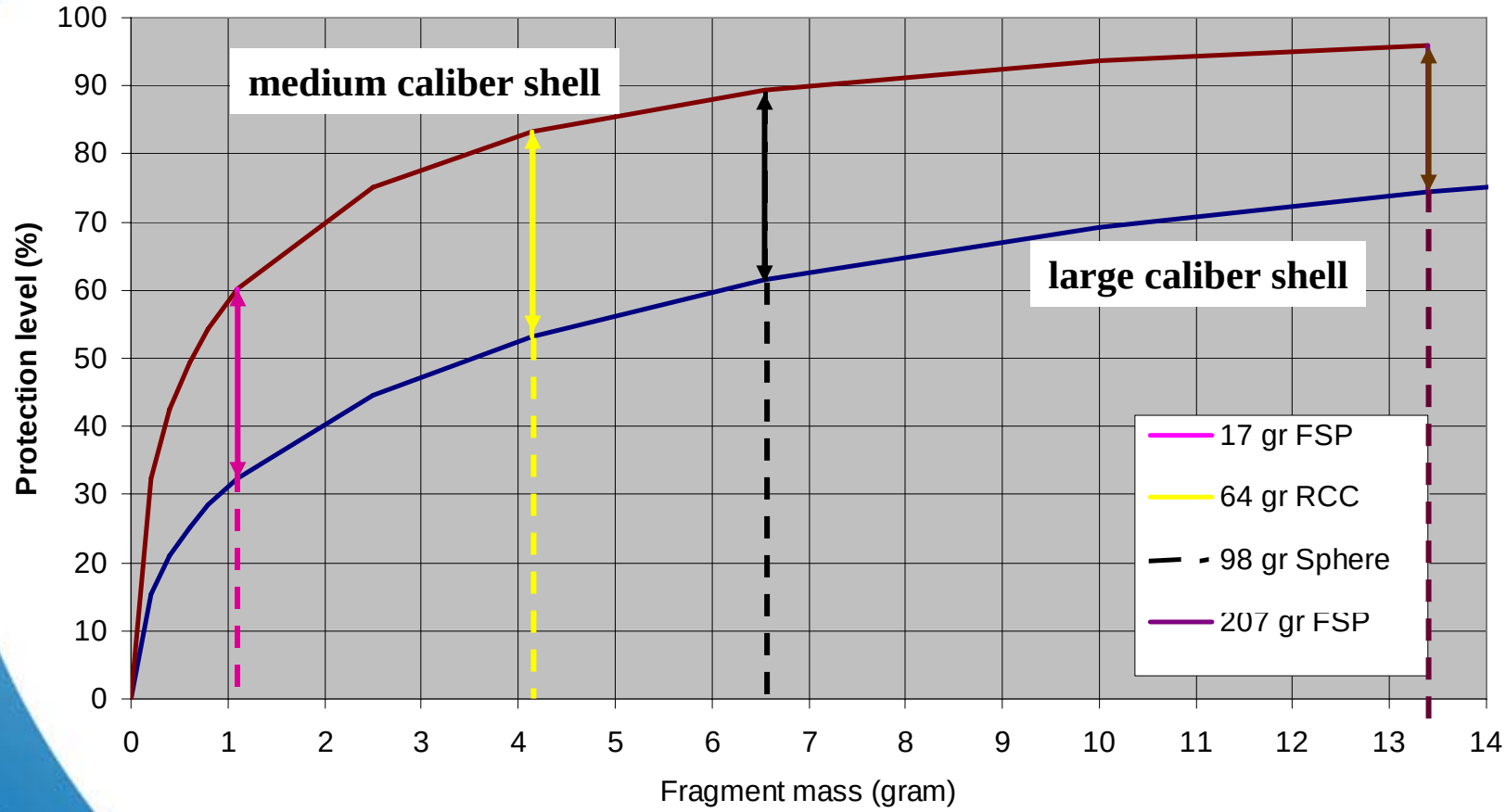


96-gr Sphere Fragment

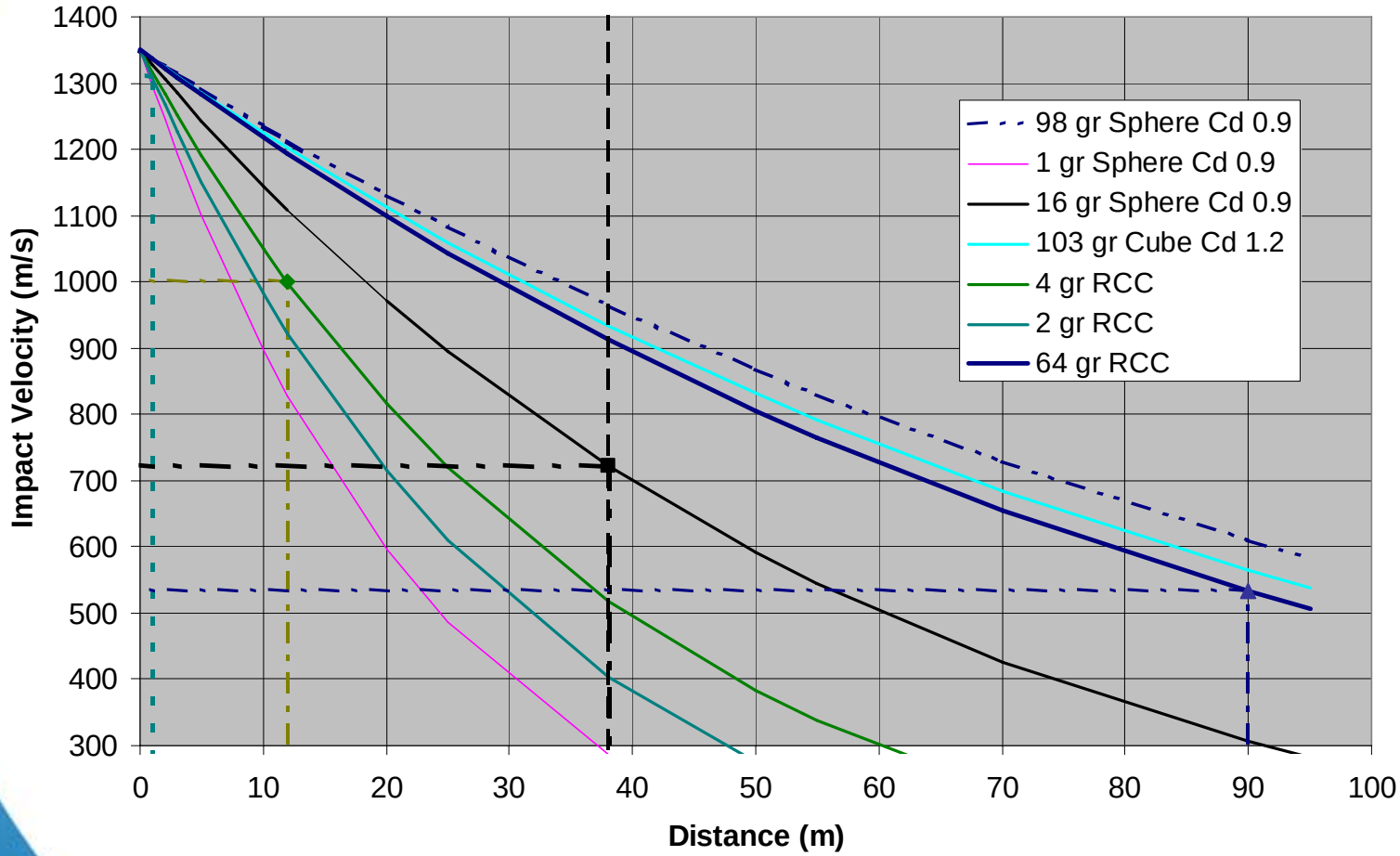
- 11.5 mm diameter, steel HRC 60
- Dimensions, shape & weight very consistent
- Easily available at low cost
- Easily launchable, i.e.: no issues with:
  - sharp edges & hardness
  - flight stability (no yaw)
- More relevant to IEDs & controlled fragment munitions:
- Fill weight gap between 64 gr RCC & 207 gr FSP



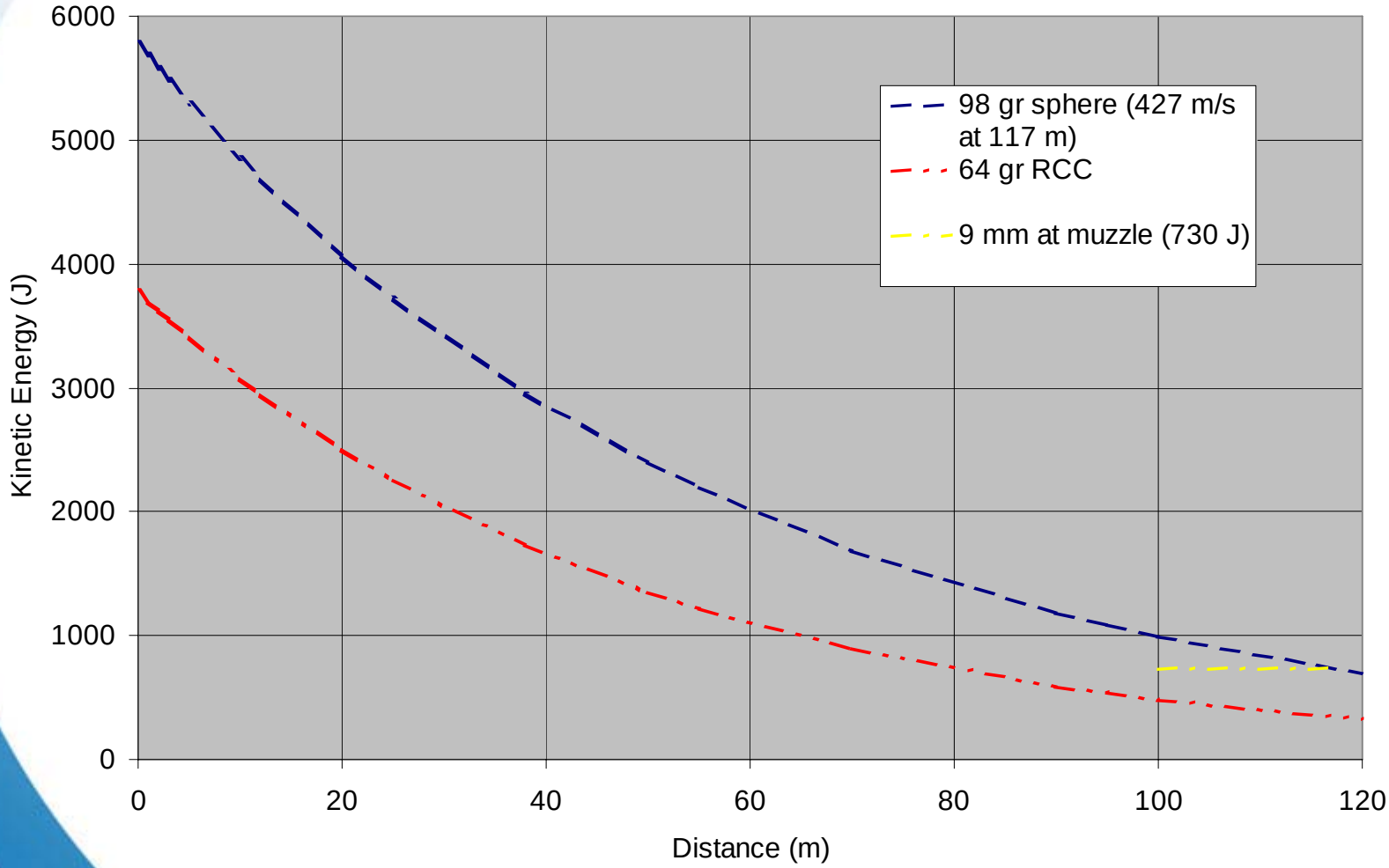
Protection Level vs Fragment Size



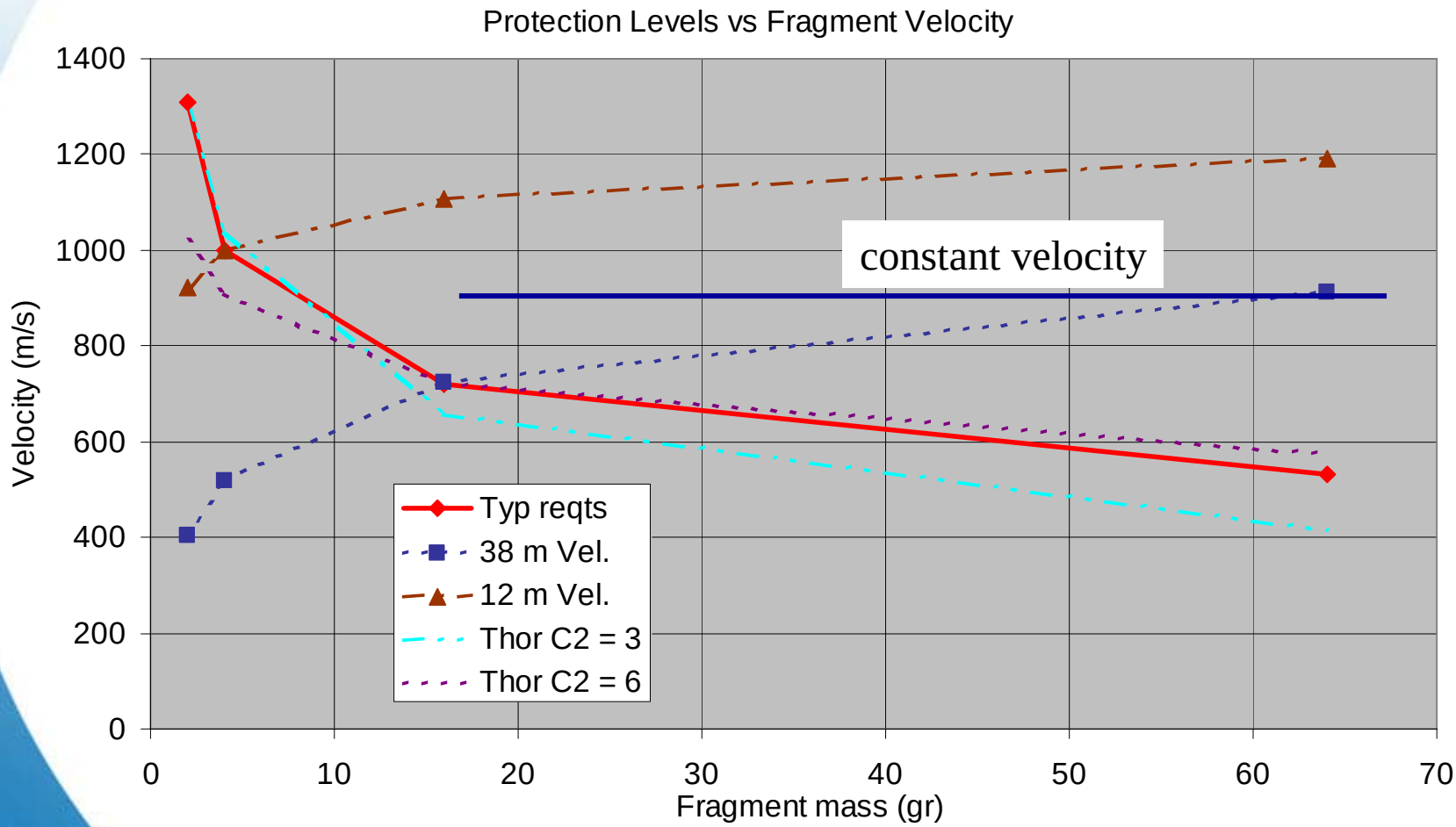
Velocity Decay vs Fragment Mass & Shape



Kinetic Energy Comparison

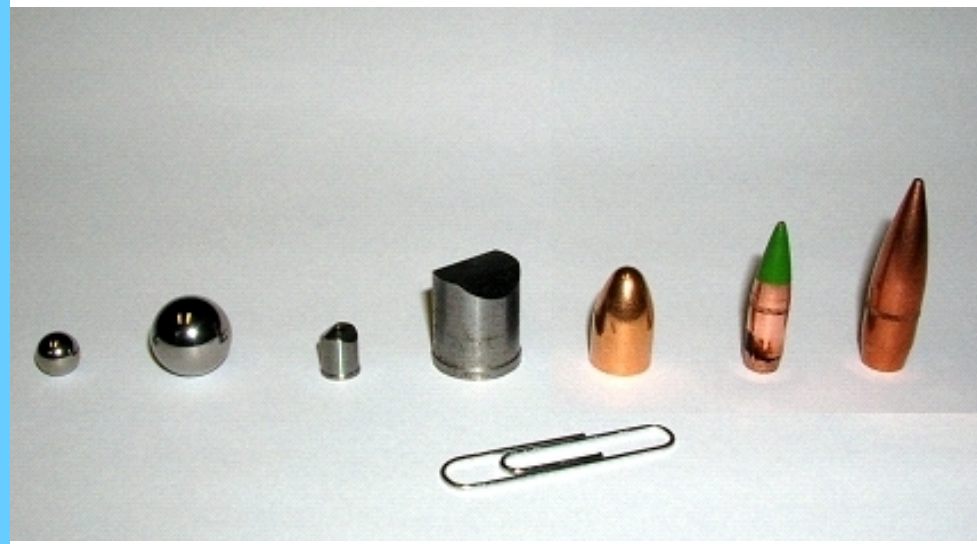


Threat Velocity Specifications



Test Projectiles

- **Fragments:**
  - 16 gr sphere
  - **96 gr sphere 1000 m/s**
  - 17 gr FSP
  - (207 gr FSP)
- **Bullets:**
  - 9 mm FMJ NIJ level 2
  - 5.56x45 SS109 STANAG level 1
  - 7.62x51 M80 NIJ level 3



Soft Armor Targets
(AD 2.5 kg/m^2)

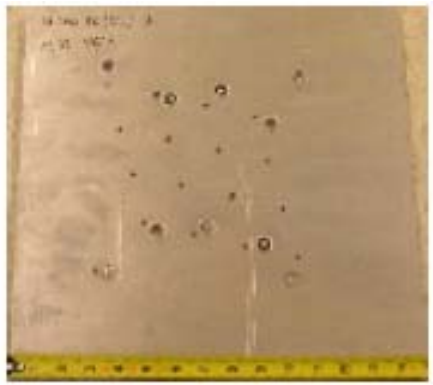
- Polyethylene (PE) felt
- Aramid fabrics
  - K129
  - KM2
  - Special
- Hybrids



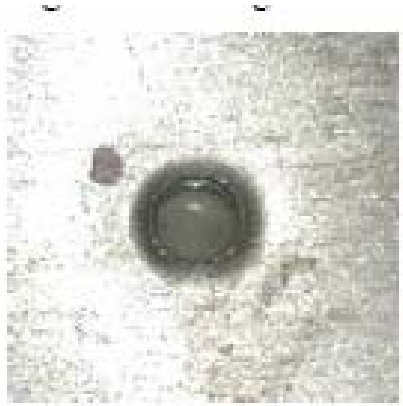

Typical samples photos

Hard Armor Targets
(AD 20 kg/m^2)

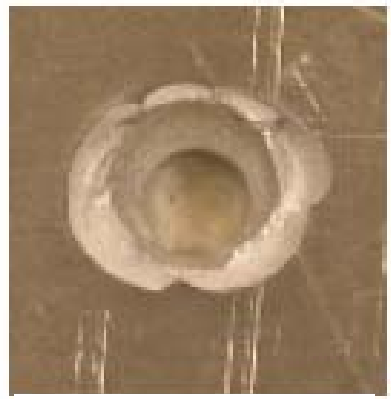
- Metallic
  - Aluminum (6061 & 7075-T6)
  - Magnesium (AZ31B-H24)
  - Titanium (Ti-6Al-4V)
- Polyethylene unidirectional composites (PEA, PEB, PEC)
- Metallic/composite
- Ceramic/composite (Plates)
- Hybrid (S-Glass, PE, Aramid + Ti & Al)



Metallic plate



Aluminum (front)



Magnesium (back)

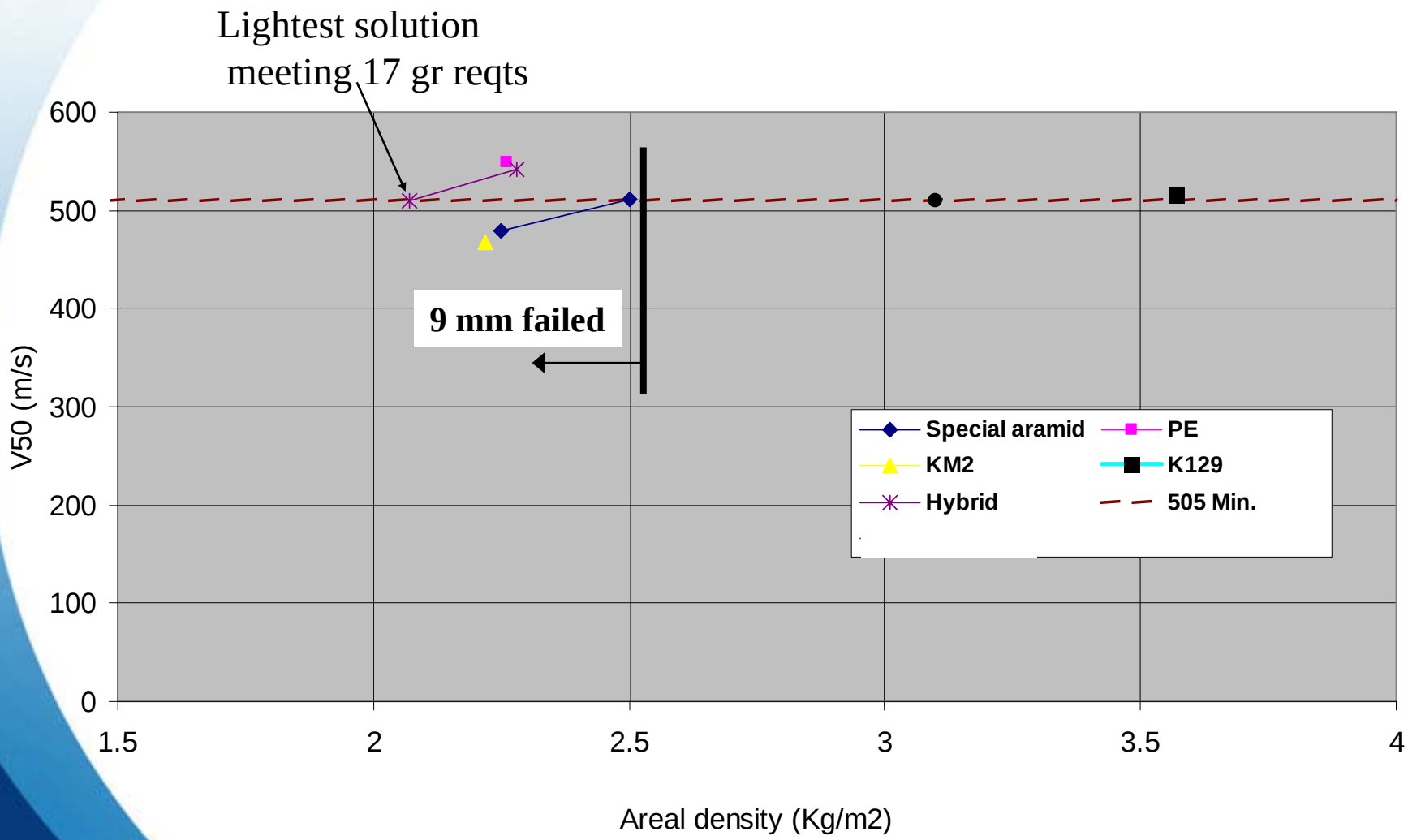
Test Conditions

- 38 x 38 cm samples
- Rigid armour targets tested stand-alone
- Some combinations tested in conjunction with soft armour
- Limited tests done at obliquity

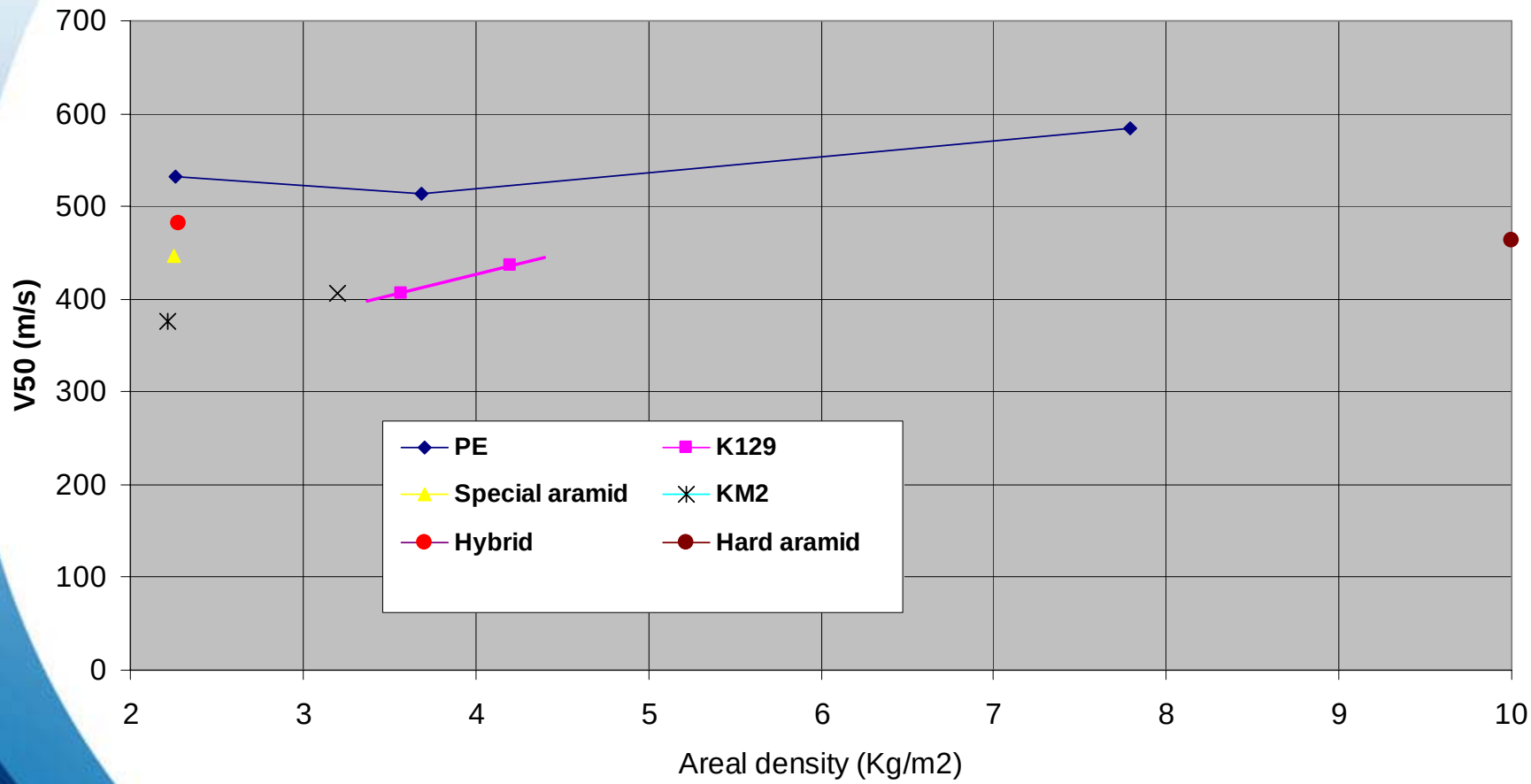
Test Types

- V50 (6 shots)
- Teta 50
- Vproof and backface
- Targets supported on Minicell foam support except for Vbfs using plastilina block

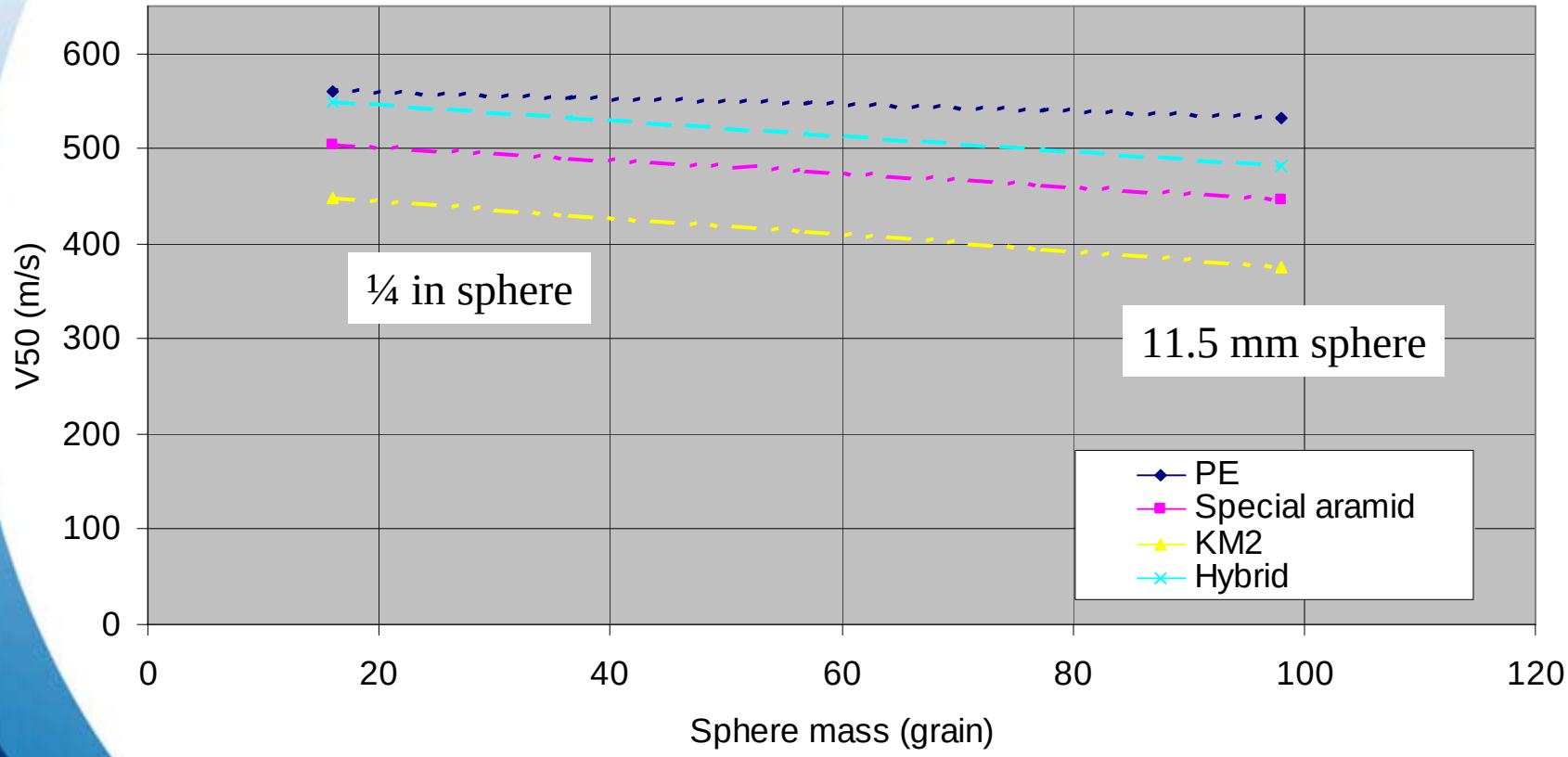
Soft Armor Performance (17-gr FSP)



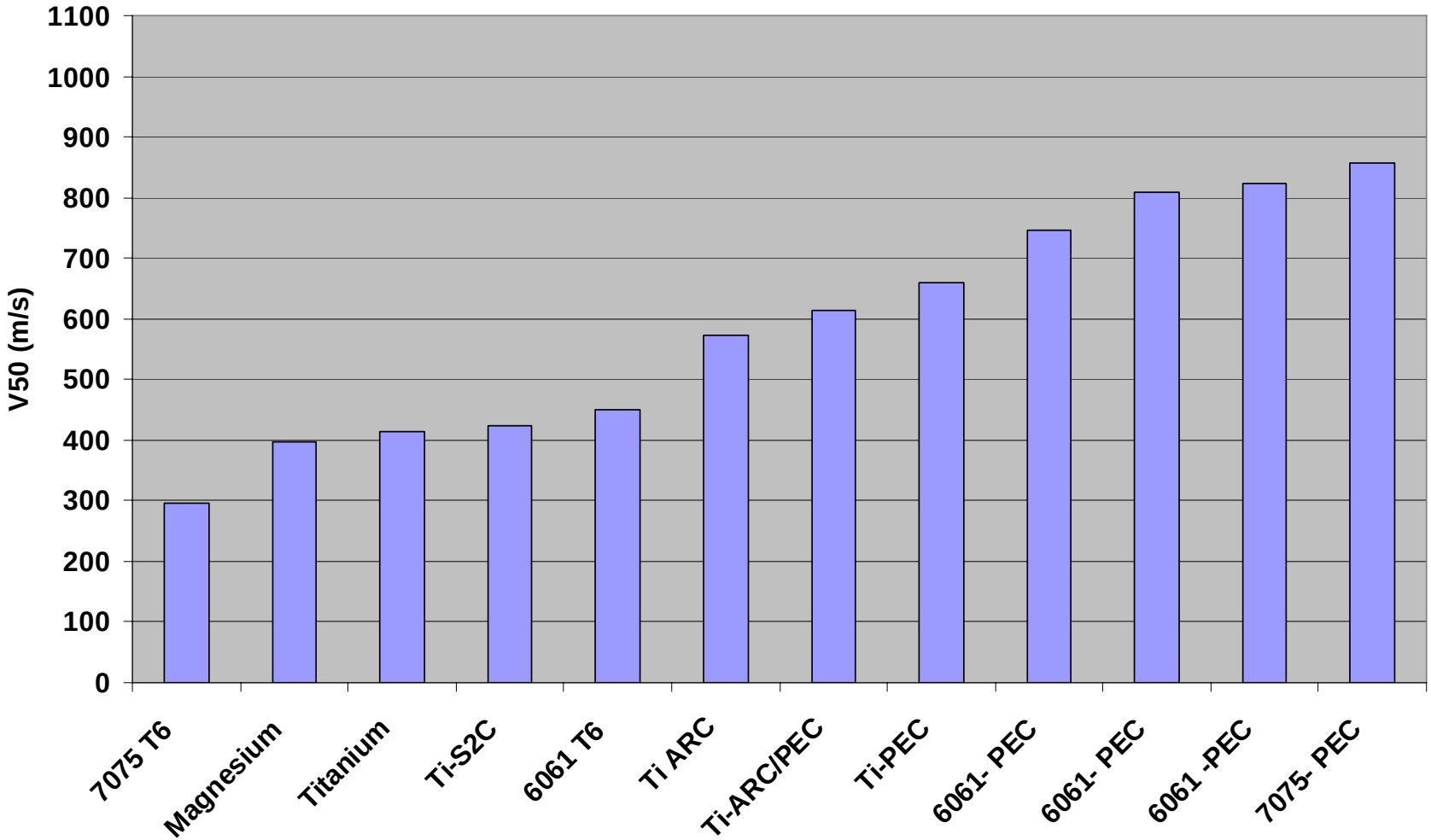
Soft Armor Performance
(96-gr Sphere)



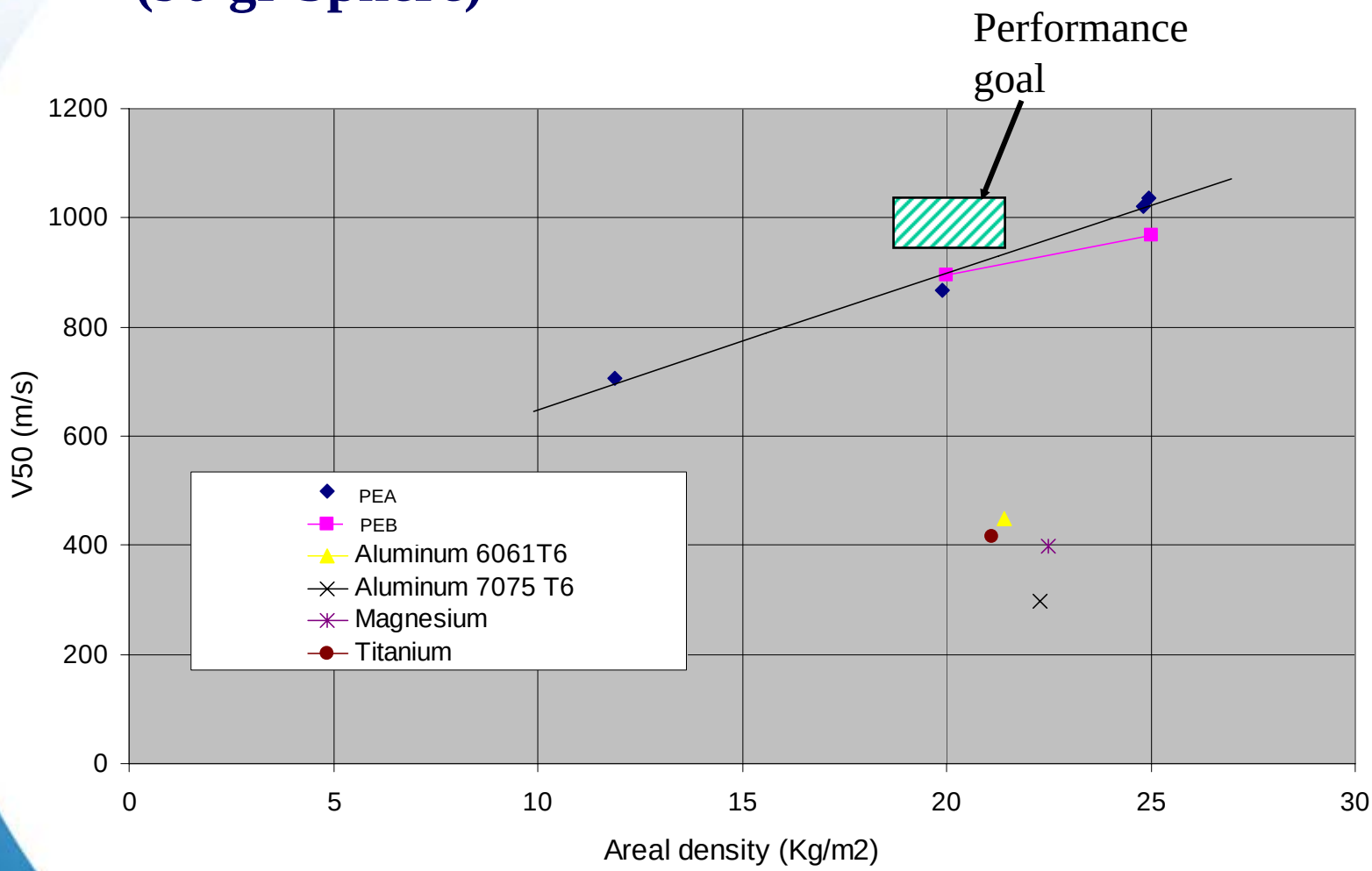
Soft Armors Results vs Sphere Mass



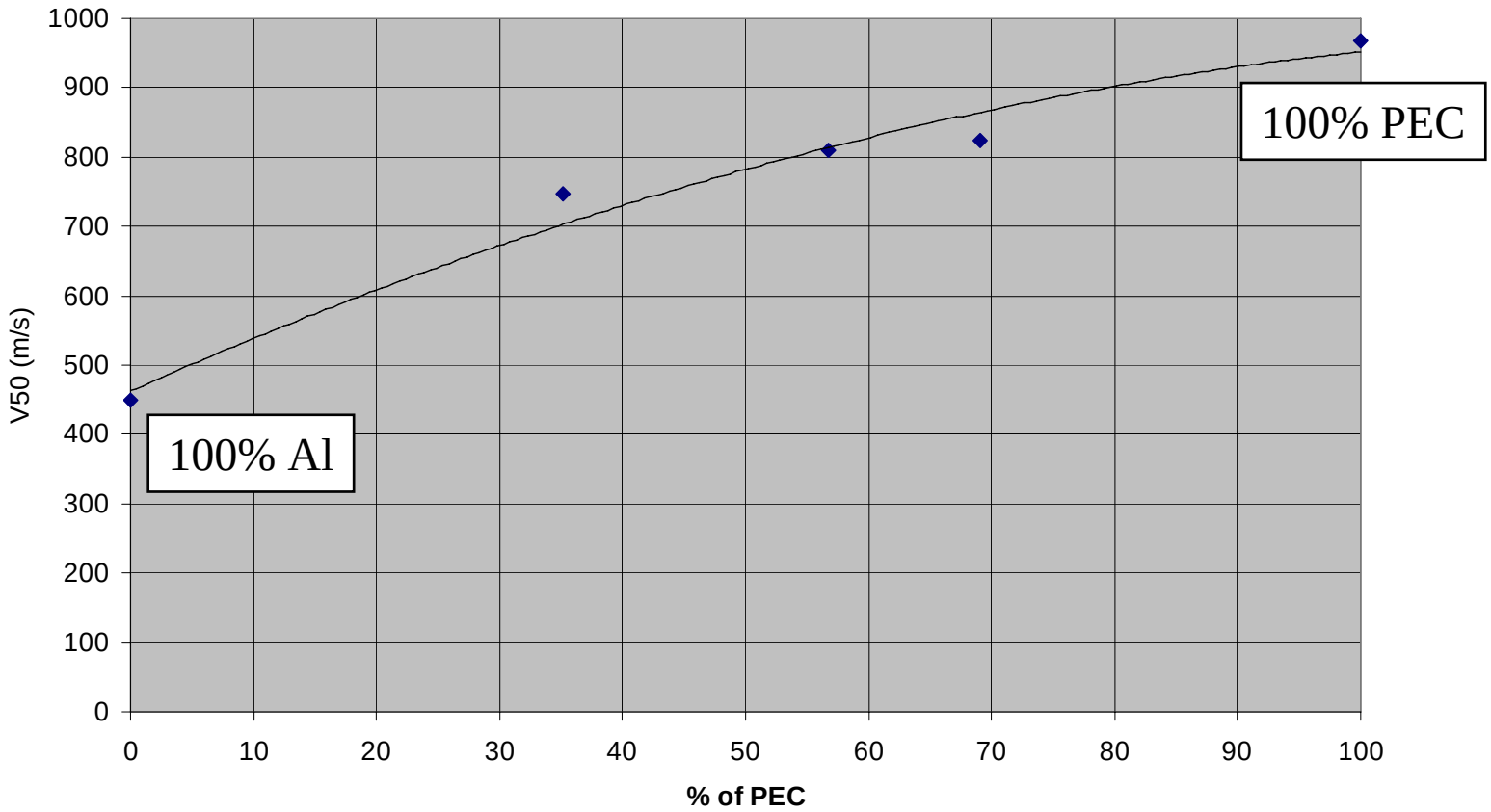
Hard Armor Performance Comparison
(AD 20 Kg/m2)



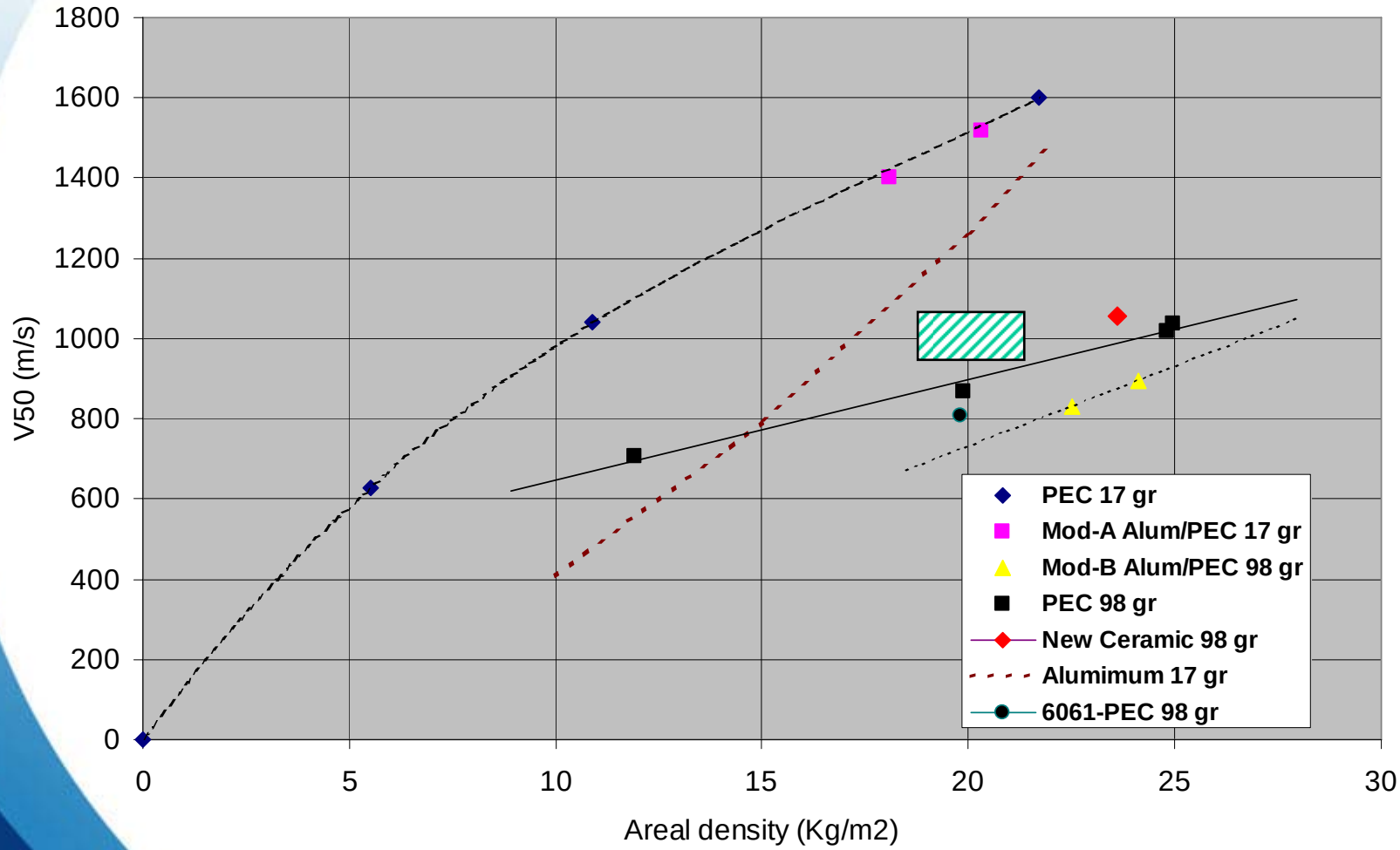
Hard Armour Performance
(96-gr Sphere)



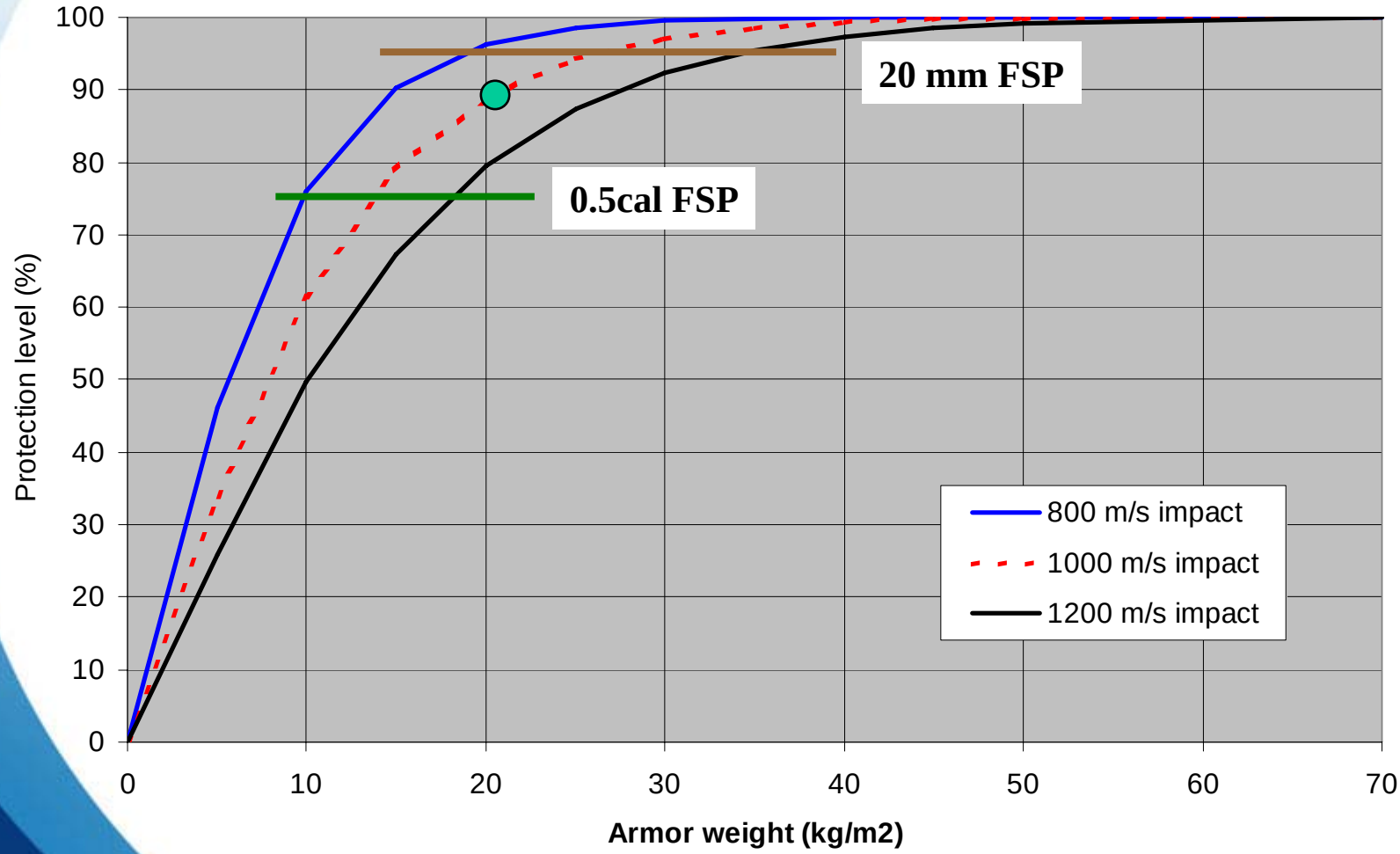
Aluminum/PEC Ratio Study
(96-gr sphere)



Special Hard Armor Configurations
(17-gr and 96-gr fragments)



Protection Level vs Weight & Velocity



Summary

- The 96-gr sphere demonstrated as a viable IED laboratory fragment
- Promising results obtained with some novel armor systems
- Large effects of protection level selected on resulting armour weight
- Level 3+ plate performed quite well vs. fragments & bullets
- Lighter material solutions needed for allowing greater armor coverage & higher protection with no weight penalties
- Trade-off analysis not trivial as many parameters involved

Future work

- Validate performance goals & metrics
  - threat parameters
  - protection/survivability level(s)
  - body coverage
- Conduct detailed trade-off analysis (integrated vs modular vs scaleable)
- Study resulting blast mitigation capabilities
- Further explore new materials and concepts
- …

Key Performance Parameter:
Soldier Acceptance

Biography

Mr. Pageau joined Defence R&D Canada in 1981. He graduated from University of British Columbia with a master degree in Materials Science. He currently works as the scientific advisor for the Integrated Soldier Systems Project within the Directorate of Soldier Systems Program Management in Ottawa. He was exchange scientist at the Natick Soldier Center for two years.