Multi-Threat

# Performance Evaluation of Multi-Threat Body Armour Systems


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22nd International Symposium on Ballistics
Vancouver, Canada, November 14-18, 2005


Biokinetics

# The Problem

- Is it possible to find light-weight and flexible body armours capable of defeating multiple threats?

# Why should we care?

- Common threats to military and law enforcement personnel:
  - *Small arm projectiles*
  - *Fragmentation from explosive devices (e.g. IEDs)*
  - *Knife, spike, flechette*
- Can they be protected against all these threats with a single body armour system?

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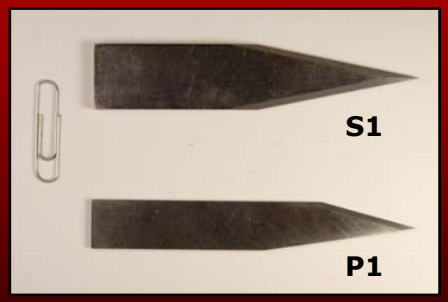
# Our Strategy

- Established multiple performance requirements
- Select appropriate test methods
- Contact mfgs to propose solutions and provide test samples
- Evaluate armour materials

# Performance Requirements & Test Methods

| Threat | Stab<br>S1, P1 |
|---|---|
| Test Standard | NIJ 0115.00 |
| Performance Requirement (necessary) | Level 1<br><br>24J / 36J |
| Performance Requirement (desired) | Level 2<br><br>33J / 50J |



# Performance Requirements & Test Methods

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# Performance Requirements & Test Methods

| Threat | Stab S1, P1 | Spike | Flechette Artillery |
|---|---|---|---|
| Test Standard | NIJ 0115.00 | NIJ 0115.00 | STANAG 2920 |
| Performance Requirement (necessary) | Level 1<br>24J / 36J | Level 1<br>24J / 36J | $V_{50} \geq$<br>250 m/s or equivalent |
| Performance Requirement (desired) | Level 2<br>33J / 50J | Level 2<br>33J / 50J | $V_{50} \geq$<br>400 m/s or equivalent |

artillery flechette simulator

- Ballistic method
  - *flight stability problem*
- Drop mass method equivalent?
  - *based on NIJ 0115.00*

# Performance Requirements & Test Methods

| Threat | Stab S1, P1 | Spike | Flechette Artillery | 17gr FSP |
|---|---|---|---|---|
| Test Standard | NIJ 0115.00 | NIJ 0115.00 | STANAG 2920 | STANAG 2920 |
| Performance Requirement (necessary) | Level 1<br>24J / 36J | Level 1<br>24J / 36J | $V_{50} \geq$<br>250 m/s or equivalent | $V_{50} \geq$<br>600 m/s |
| Performance Requirement (desired) | Level 2<br>33J / 50J | Level 2<br>33J / 50J | $V_{50} \geq$<br>400 m/s or equivalent | $V_{50} \geq$<br>750 m/s |


17gr FSP

# Performance Requirements & Test Methods

| Threat | Stab S1, P1 | Spike | Flechette Artillery | 17gr FSP | 1gr Sphere |
|---|---|---|---|---|---|
| Test Standard | NIJ 0115.00 | NIJ 0115.00 | STANAG 2920 | STANAG 2920 | STANAG 2920 |
| Performance Requirement (necessary) | Level 1<br>24J / 36J | Level 1<br>24J / 36J | $V_{50} \geq$<br>250 m/s or equivalent | $V_{50} \geq$<br>600 m/s | $V_{50} \geq$<br>850 m/s |
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1gr sphere

# Performance Requirements & Test Methods

| Threat | Stab S1, P1 | Spike | Flechette Artillery | 17gr FSP | 1gr Sphere | 9x19 mm FMJ |
|---|---|---|---|---|---|---|
| Test Standard | NIJ 0115.00 | NIJ 0115.00 | STANAG 2920 | STANAG 2920 | STANAG 2920 | NIJ 0101.04 |
| Performance Requirement (necessary) | Level 1<br>24J / 36J | Level 1<br>24J / 36J | $V_{50} \geq$<br>250 m/s or equivalent | $V_{50} \geq$<br>600 m/s | $V_{50} \geq$<br>850 m/s | $V_{proof} \geq$<br>367±9 m/s (Level 2) |
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# Performance Requirements & Test Methods

| Threat | Stab S1, P1 | Spike | Flechette Artillery | 17gr FSP | 1gr Sphere | 9x19 mm FMJ | 9x19 mm Bofors HP |
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# Test Samples

| Armour Sample | Description | Protection | Areal Density ($kg/m^2$) |
|---|---|---|---|
| 1 | Steel sheets and woven fabric, 15 layers total | PSDB Level KR1 | 6.0 |
| 2 | Coated woven aramid, 30 layers | NIJ Stab Level 2 | 10.2 |
| 3 | Coated woven aramid, 30 layers | NIJ Stab Level 2 | 9.9 |
| 4 | Coated woven polyethylene, 27 layers | NIJ Stab Level 2 | 9.9 |
| 5 | 2 types of woven aramid, 32 layers total | Custom | 9.9 |
| 6 | 2 types of woven aramid, 31 layers total | Custom | 8.4 |
| 7* | Multi-layers of dense woven aramid, 18 layers | NIJ Spike Level 2 | 2.2 |
| 8 | Woven aramid and laminated polyethylene, 26 layers total | NIJ Ballistic Class II<br>NIJ Stab Level 2 | 6.3 |
| 9 | Woven PBO and aramid, laminated polyethylene, 50 layers total | NIJ Ballistic Class IIIA<br>NIJ Spike Level 2 | 6.6 |
| 10** | Woven PBO, 20 layers | Custom | 2.7 |
| 11** | Coated woven aramid, woven aramid, laminated polyethylene, 41 layers total | Custom | 11.9 |
| 12** | Coated woven aramid, woven PBO, laminated polyethylene, 51 layers total | Custom | 12.3 |
| 13** | Woven PBO, unidirectional aramid, 38 layers total | Custom | 6.3 |

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# Stab Resistance (Level 2)

Areal Density (kg/m $^2$)

20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0

Level III
18 kg/m2

Level IIIA
5.5 kg/m2

Level II
3.5 kg/m2

Fail
Pass

S1 Knife
P1 Knife
Spike

7 1 8 9 6 4 5 3 2

Armour Sample

* Sample 1 tested at Level 1



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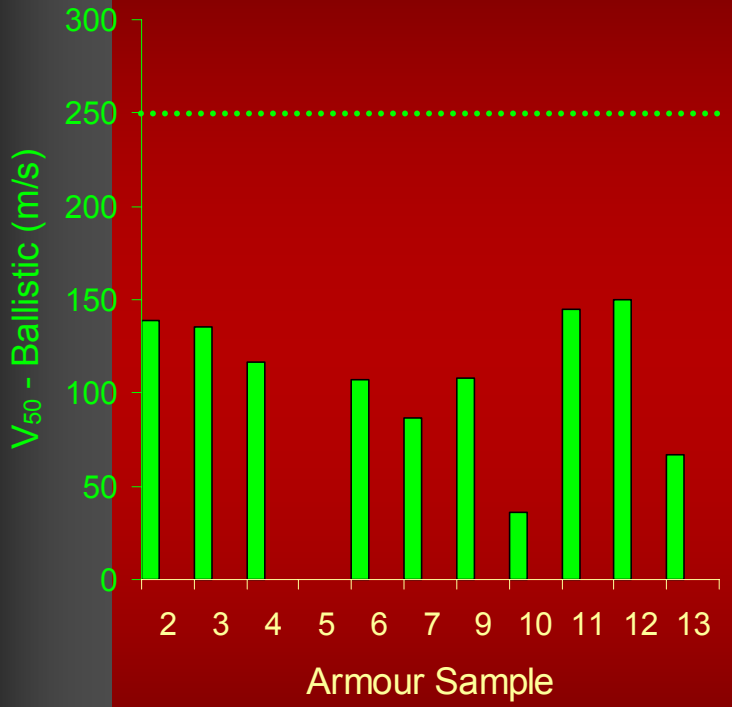
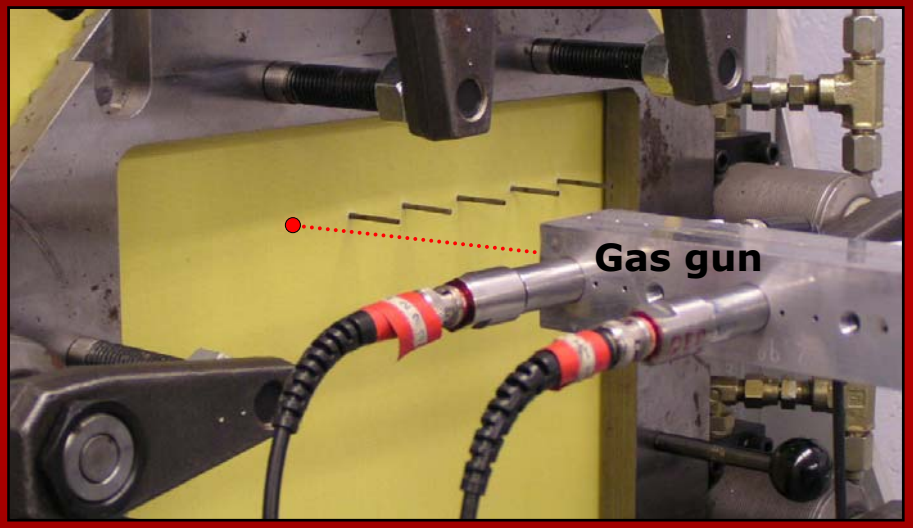
# Flechette Resistance

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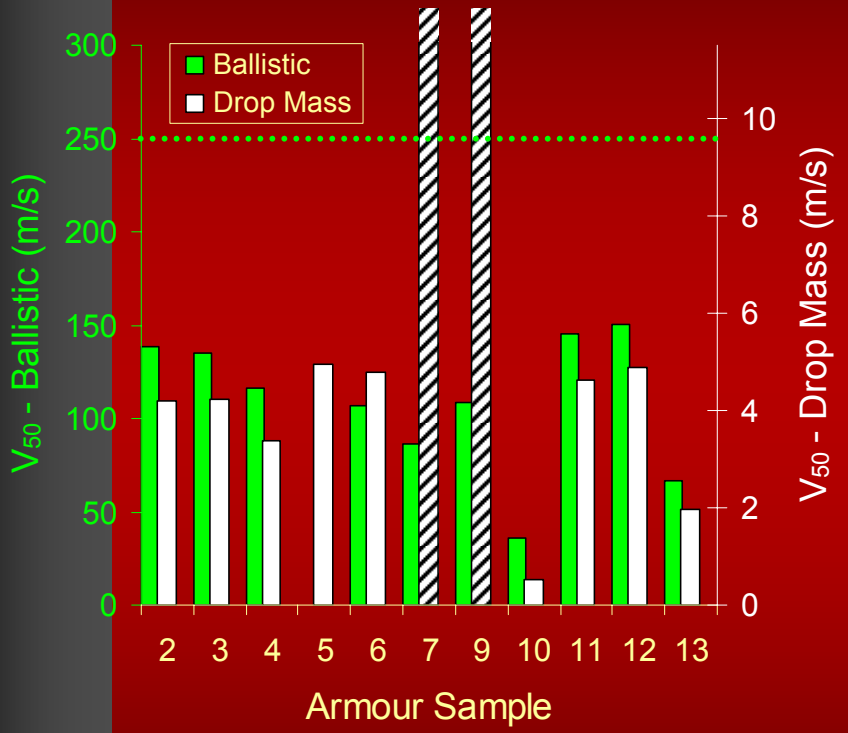


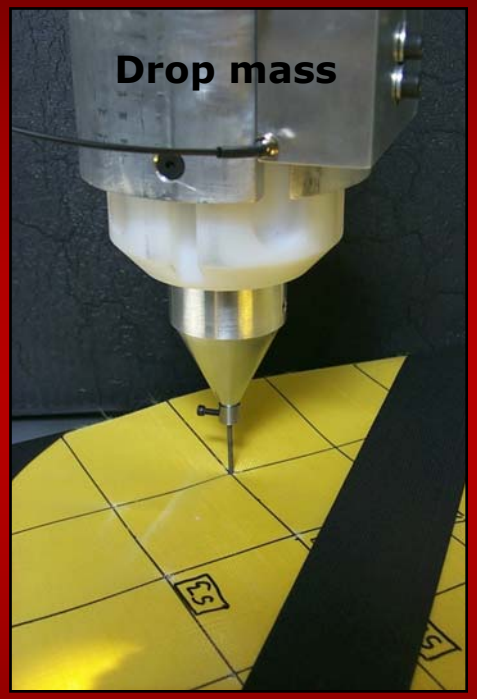

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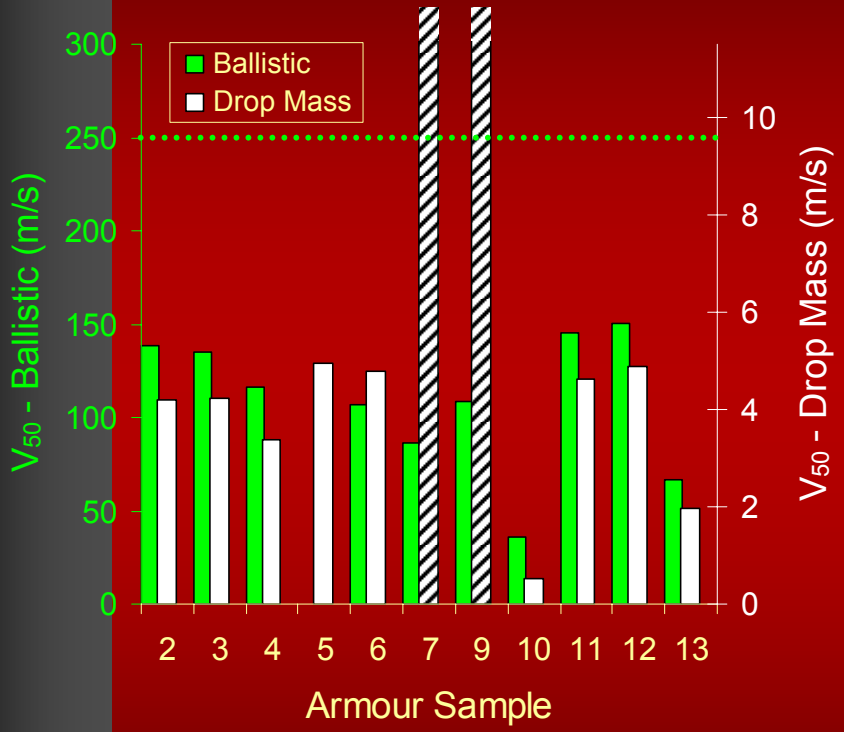
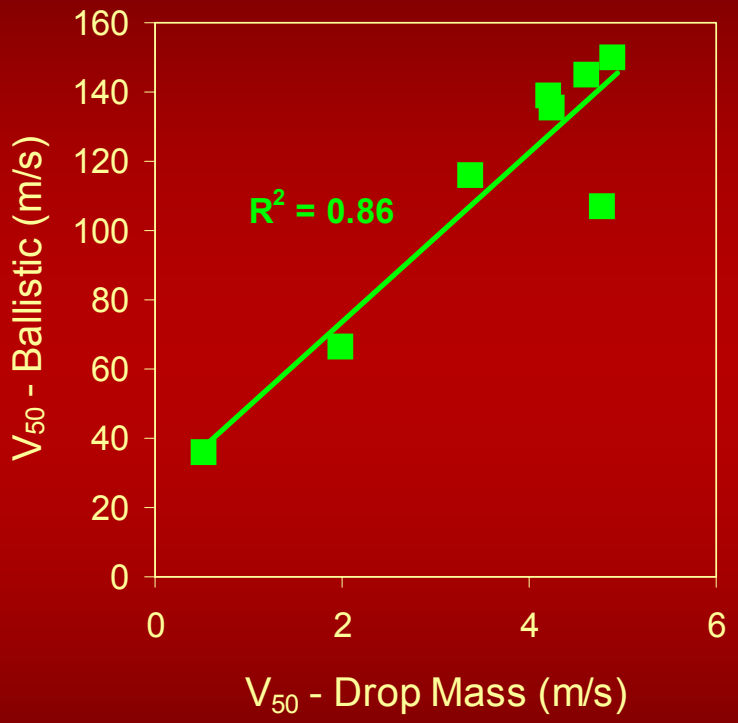
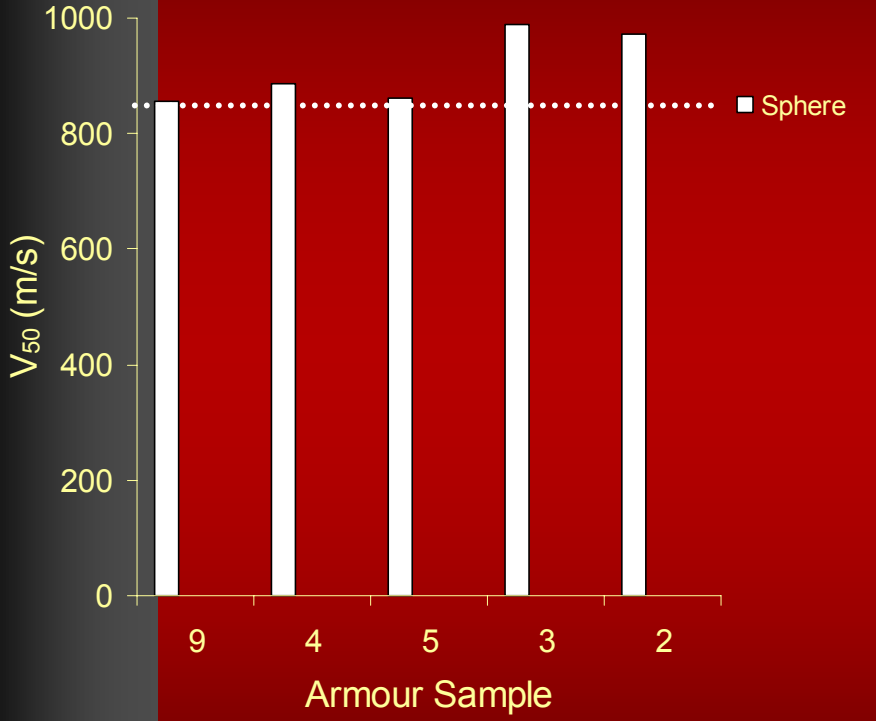


# Fragmentation / Bullet Resistance

## Ballistic Limit

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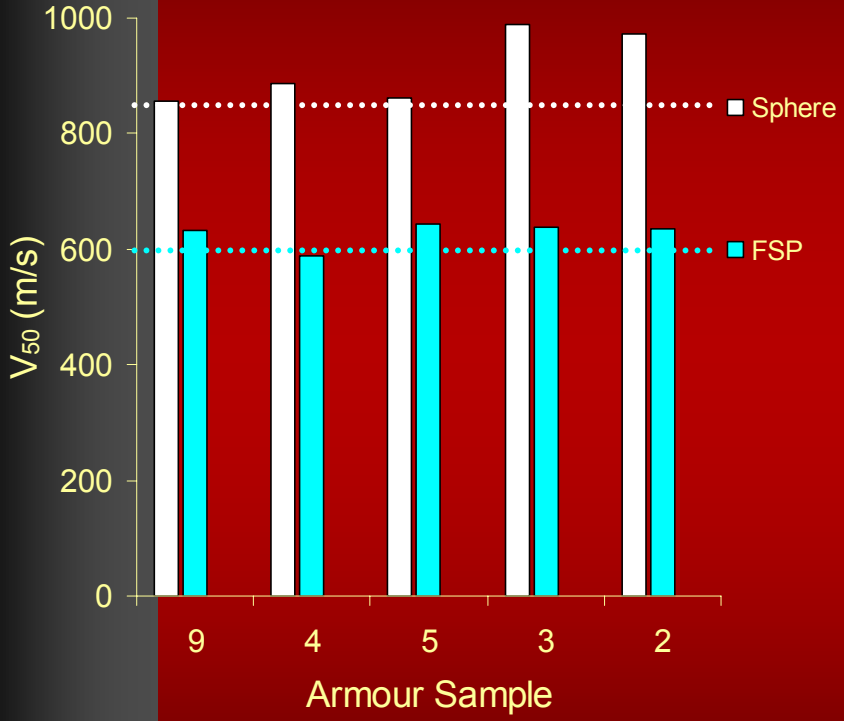


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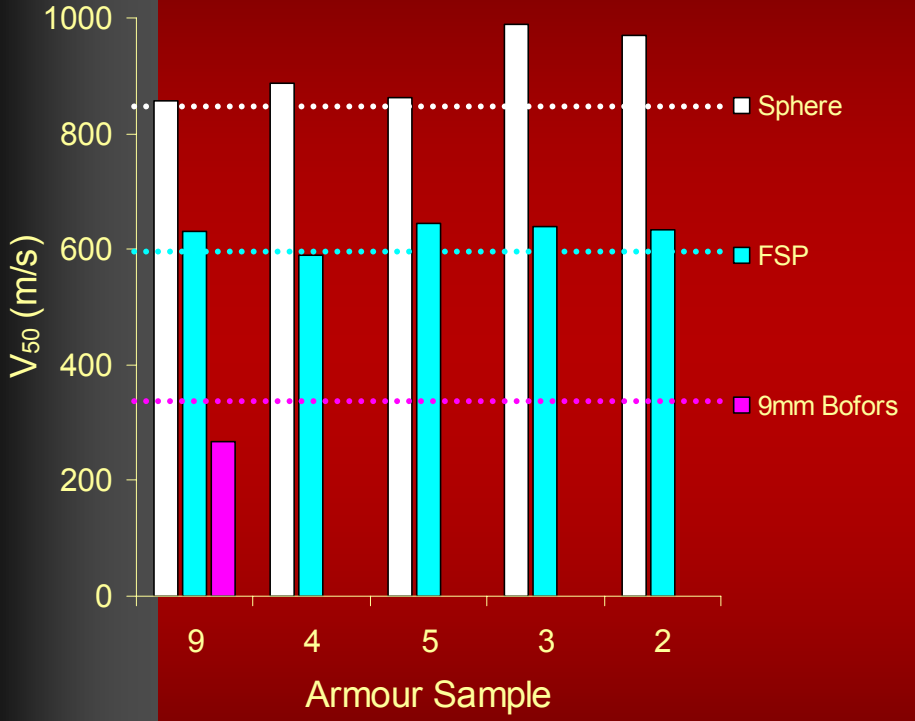


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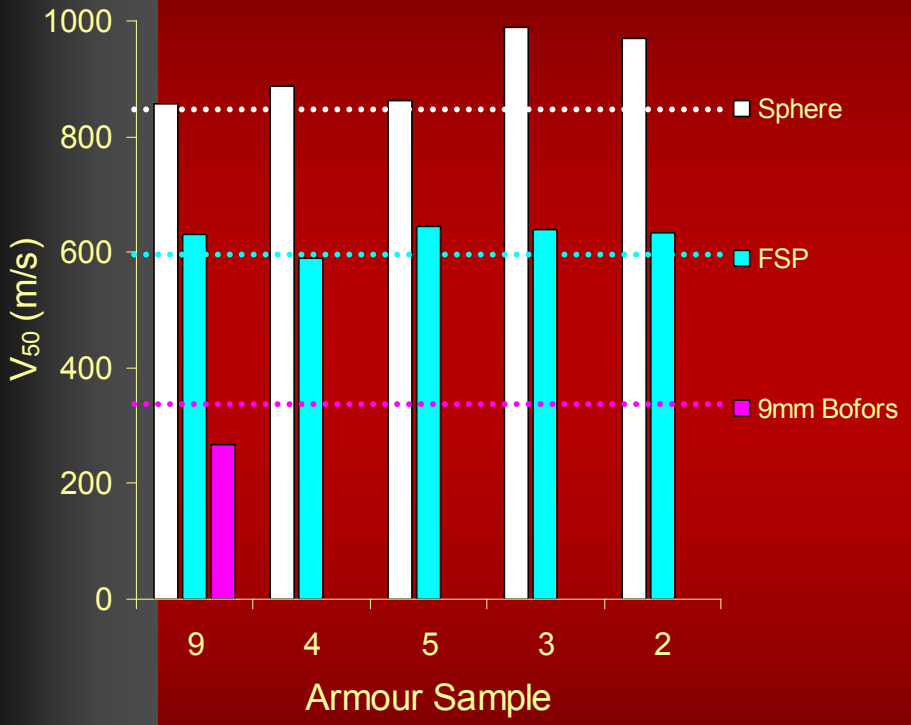
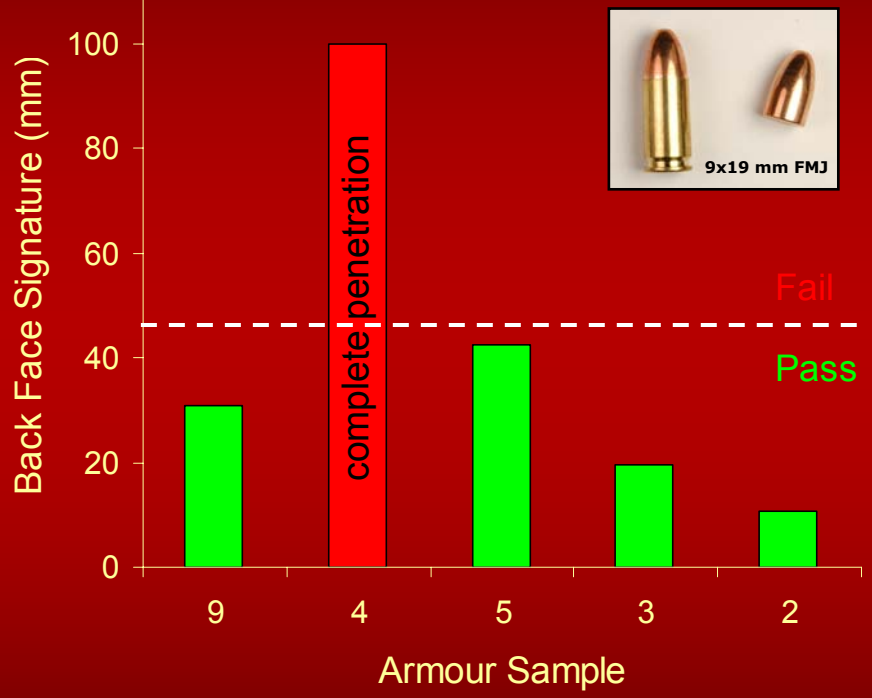
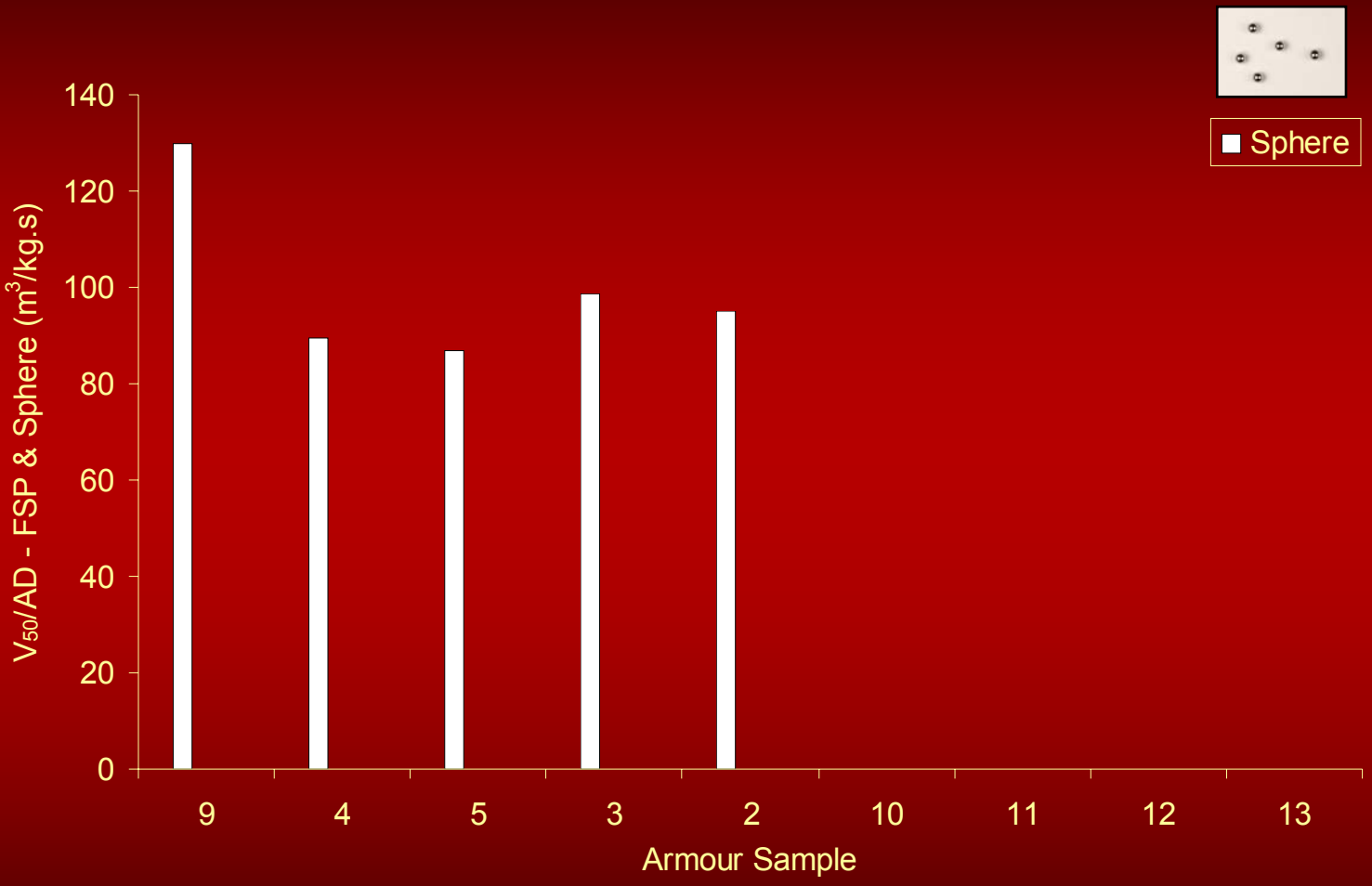



## Back Face Signature



# Performance Comparison – Ballistic Limit



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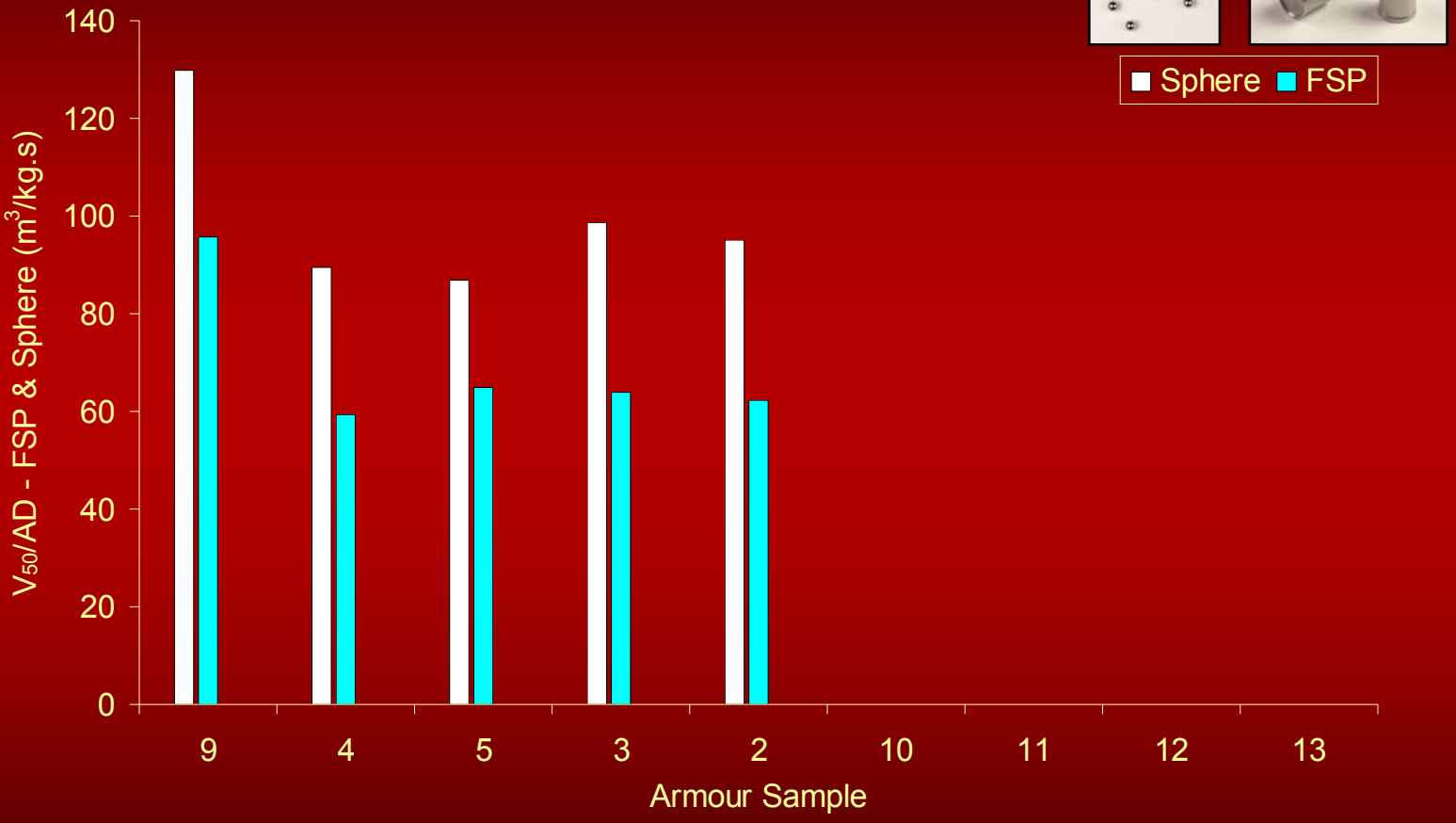

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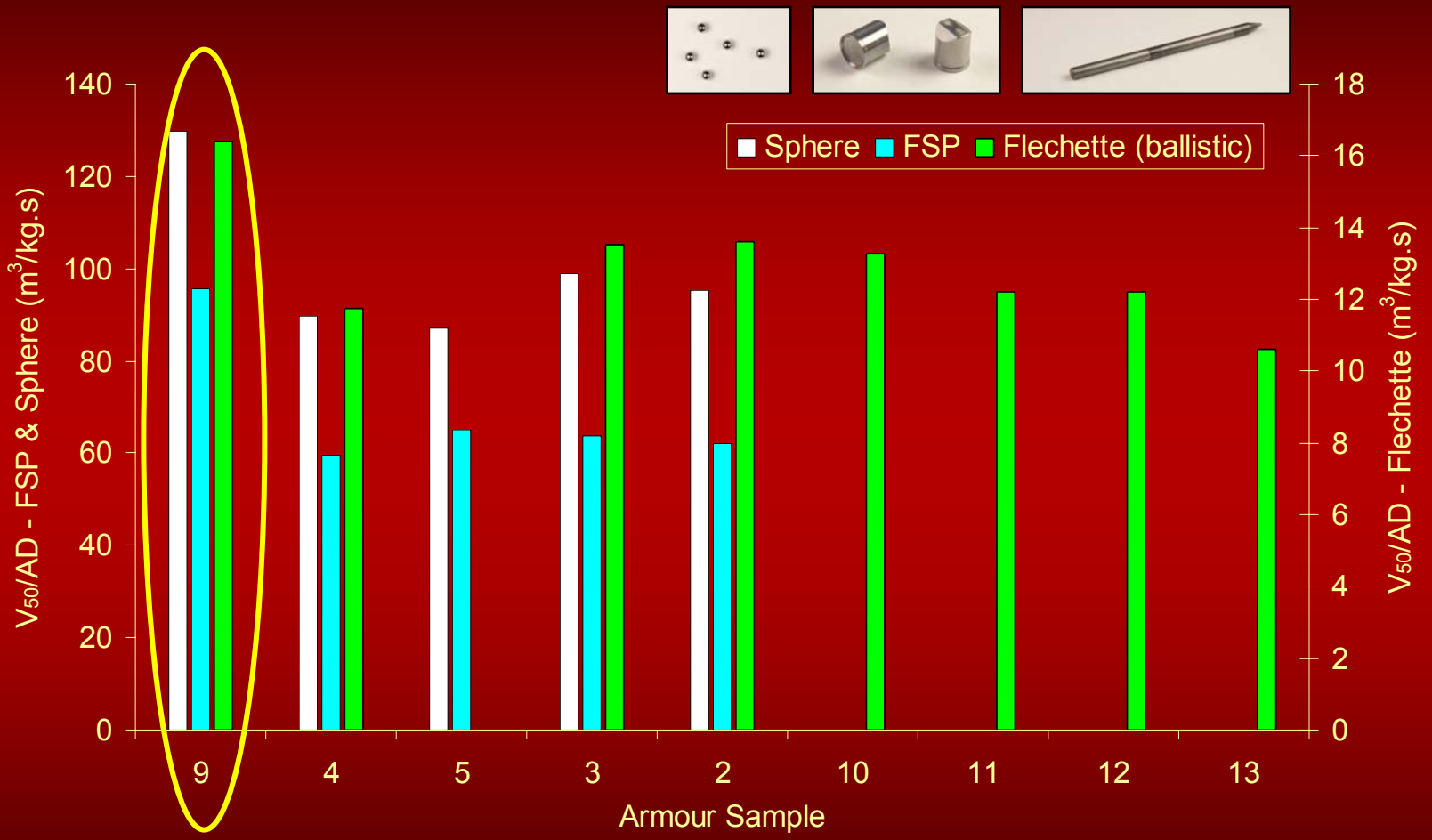
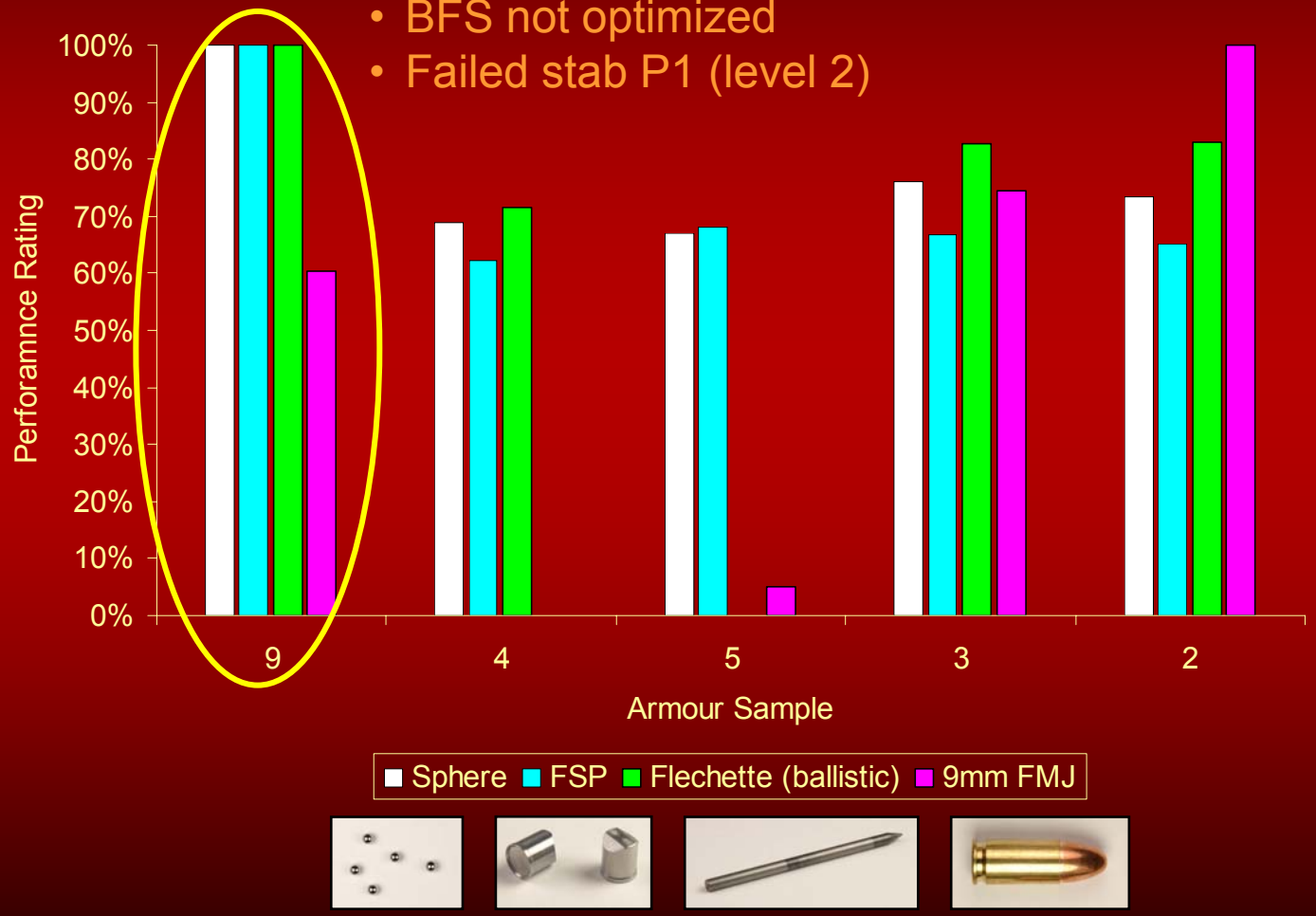


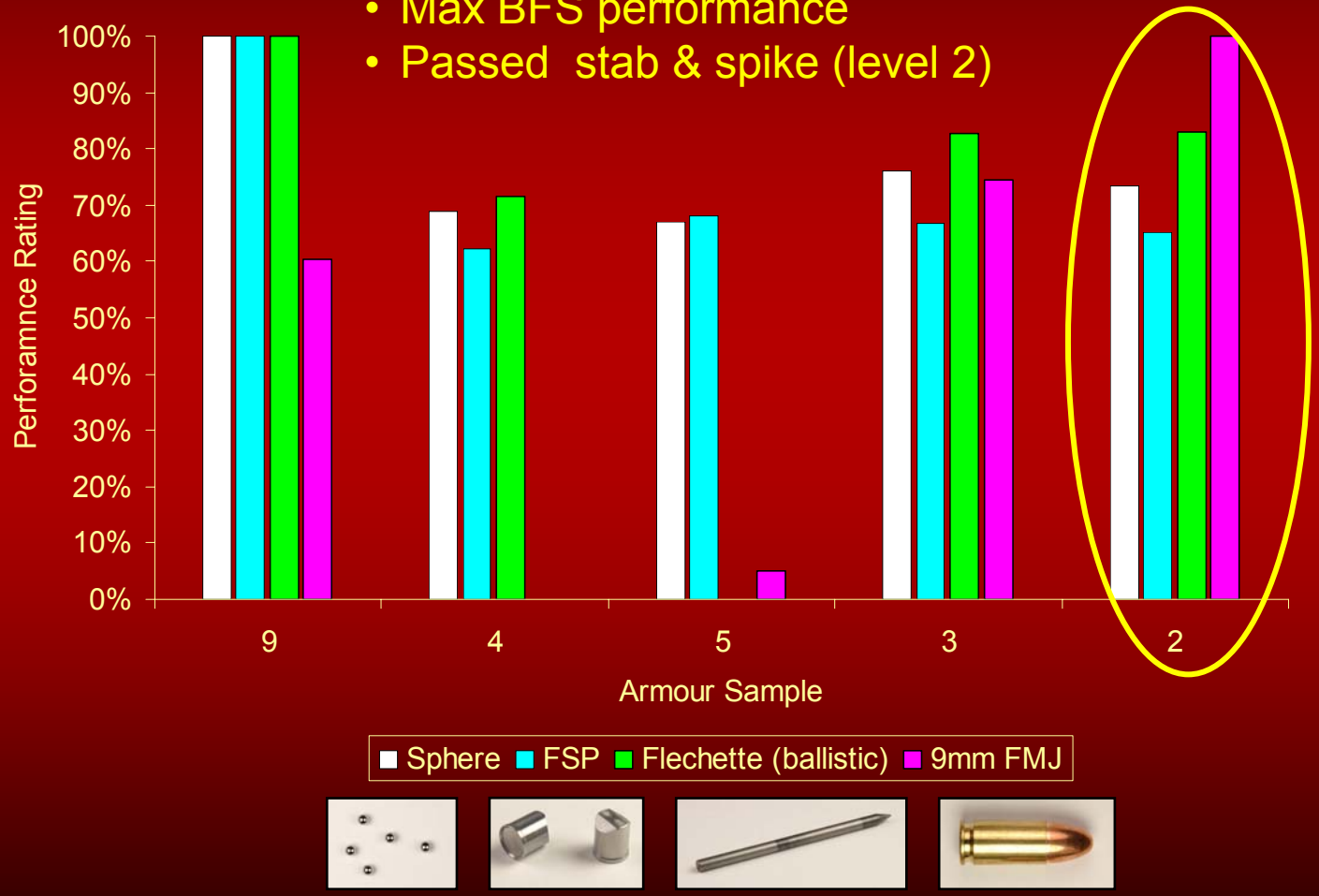
# Performance Rating - Ballistic

- Max performance ballistic penetration
- BFS not optimized
- Failed stab P1 (level 2)



# Performance Rating - Ballistic

- Good performance ballistic penetration
- Max BFS performance
- Passed  stab & spike (level 2)



# Conclusions

- Current technologies can provide minimum protection against stab, flechette, and ballistic threats.
- a.d. ≥ 9.9 kg/m$^2$ for 3 stab threats (level 2)
- Preliminary assessment of flechette resistance possible with drop mass method
- Performance optimization possible through # of layers, sequence, material combination
- Desired requirements can not be achieved for a.d. < 10 kg/m$^2$ (9mm HP Bofors and flechette)

# Way ahead

- Test all samples for stab Level 1
- Refine drop mass method: reduce weight to increase velocity, modify flechette simulator
- Complete ballistic test evaluation for samples No. 11 and 12
- Evaluate semi-rigid solutions (metallic or ceramic tiles) for high performance bullets
- Optimize performance with minimum aerial density
- Consider zones with different protection levels

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# Acknowledgment


- This work was supported by
  - *Defence R&D – Valcartier*
  - *Directorate of Land Requirements of DND Canada*


- Co-authors
  - *M. Keown (Biokinetics and Associates Ltd.)*
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Engineered Solutions for Impact Protection

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