Part 1.1: Key message

“Understanding the possible failure mechanisms in an armour material is absolutely essential when designing improved armour materials and systems”

Part 1.2: An holistic approach to design

- Threat defined
- Initial design
  - Initial tests
  - Final design
  - Initial production
  - First Article Tests
- Full production
- Batch Tests
- In-service support

- Empirical data, design rules and analytical modelling

- Understanding of the Principles of Penetration Mechanics
  - Well designed experiments
  - Numerical Modelling

- Materials input data
  - Open and Closed Literature
  - New high strain rate data
Part 1.2: Armour design – another upgrade – even more decisions!!

Design decisions
- Grade of steel [*]
- Thickness of steel [*]
- Air gaps, $d_1$ [*] and $d_2$
- Grade of FRP [*]
- Thickness of FRP [*]
- Properties of FRP [*]
- Grade of ceramic
- Thickness of ceramic
- Grade of FRP support
- Thickness of FRP
- Obliquity of system
- Design velocity, $V_D$
- Armour engineering

Note: [*] FIXED

Part 1.2: Structural or appliqué?

Cast steel turrets, mantlets and hatch covers: $H_V \sim 300$

Appliqué armours: $H_V \sim 500-700$

Other disruptive armours: $H_V \sim 350-450$

Wear-resistant, high Mn, cast steel track pads: $H_V \sim 220$

Structural belly plates: $H_V \sim 280$

Weldable, structural, ballistic grades: $H_V \sim 280-350$

Part 1.2: Case Studies

Selected examples where new armour materials have been used and/or developed.....and made a significant difference to the outcome!
Part 1.2: Case Studies – Stillbrew up-armouring kit

- Image of the Stillbrew Crew Protection Package as fitted to the UK Chieftain MBT in the 1980s. The kit first saw service as part of the Chieftain Mk 10 (Bovington Tank Museum, 2014)
- Original, highly curved, turret castings in a WQ, Mo steel
- He and through-hardening recognised (even against FSPDS rounds!)
- New air-hardening grade of cast steel (now to UK DEF-STAN 95-26, 2011)

Part 1.2: Case Studies – UK ACAVP

- Converting splat liners into structural FRP armour materials
- RTM to Resin Infusion moulding
- E-glass NCF icw epoxy resin
- 10 year project!

Part 1.2: Case Studies – RAN Huon Class Minehunter

- Solutions restricted to non-magnetic materials
- Locally produced VBJI panels (E-glass NCF, VE resin)
- Spaced, composite armour solution
Part 1.2: Case Studies – Bushmaster up-armouring kit

- L1 to L2 through addition of FRP support panel
- FRP panels manufactured locally via PA-VBRI technique
- K900 aramid in VE resin matrix, with high Vf
- Bonded directly onto rear face of existing structural armour

Part 1.2: Case Studies – Correctional Look-out Towers

- Incident in 1990s; escape by helicopter; guards fired upon from above
- Full protection from 7.62mm ball rounds
- Weight INSENSITIVE application
- Steel/FRP hybrid principle, NewSentry armour, qualified to R2 AS2343
- Optimised steel properties to Hv ~450

Part 1.2: Case Studies – Hard Armour Plates

- Reaction Sintered Silicon Carbide
- VPP boron carbide
- ~20 designs; ~80,000 items
- ~$40m sales over seven years