[dstl] The Science Inside

Advanced Bridging

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Ministry of Defence

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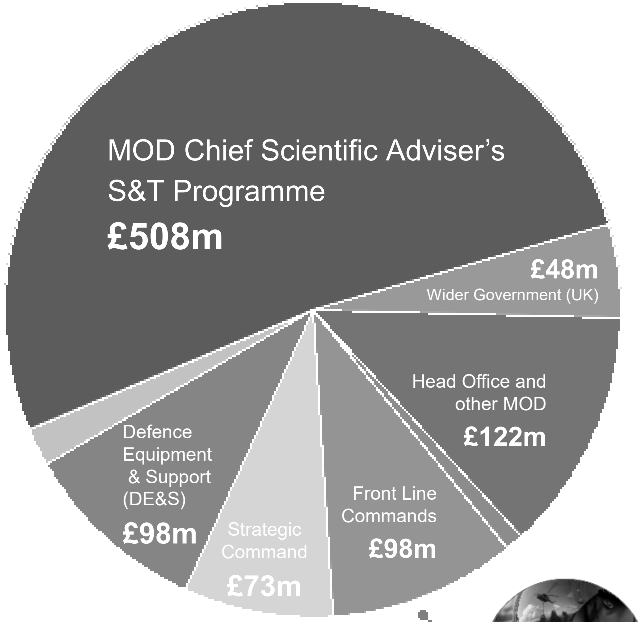
Dstl

- Defence Science & Technology Laboratory
  - An Executive Agency of the UK Ministry of Defence
  - Its purpose is "to maximise the impact of science and technology for the defence and security of the UK"
- ~ 4,900 people
- 2 main sites:
  - Porton Down, near Salisbury, Wiltshire
  - Portsdown West, near Portsmouth, Hampshire

Source (all): Dstl

Dstl, Customers & Capabilities



Defence Nuclear Organisation (DNO)
£21m

Other **£14m**

*Figures, April 2023

Dstl, 22 Strategic Capabilities

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- Above Water Systems
- Air Systems
- Homeland Security and CT Systems
- Information Systems
- Land Systems
- Underwater Systems
- Advanced Materials
- AI and Data Science
- CBR
- Communications and Networks
- Cyber
- Electromagnetic Activities
- Explosives and Energetics
- Human and Social Sciences
- Operational Research
- Robotics and Autonomous Systems
- S&T Futures and Incubator
- Sensing
- Space Systems
- Strategic Systems
- Survivability
- Weapons

The ‘Bridging’ Problem

- Increasing weight of AFVs = increased MLC rating
  - e.g. Challenger 2, mass grows through life
    - Bosnia (left) late 1990’s = ~ 62.5 tonnes (base vehicle)
    - Iraq (centre) 2003 = ~ 66.5 / 75 tonnes (Theatre Entry Standard)
- Usage of bridges relatively unknown (life remaining, repair)
- Host Nation Infrastructure


Source: MoD


Source: MoD

UK Current & Replacement Bridges

BR90 Close Support Bridge (CSB), General Support Bridge (GSB) and Logistic Support Bridge (LSB)


Source: Tank Museum


Source: BAE Systems


Source: Mabey

Project TYRO: CSB = WFEL / KMW Leguan
GSB = KNDS UK (KMW & Nexter) Dry Spt Bridge (DSB)

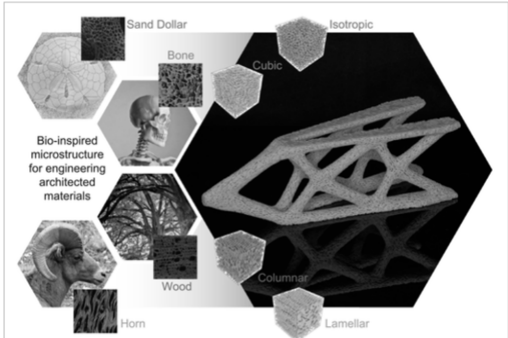

Source: KNDS


Source: KNDS

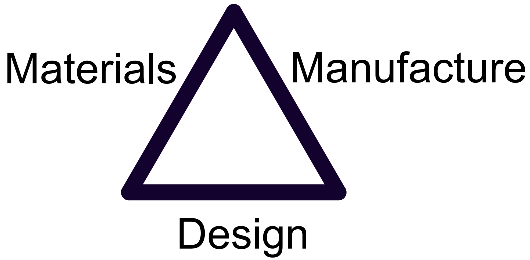
Interoperable with NATO partners' bridge systems

Research Objectives

- Advanced bridging solutions are required to compensate for vehicle weight growth and to enable a step change in gap crossing capability
  - i.e. MLC and span and/or reduce the bridge mass
- The CSB is primary interest, apply findings to other bridges (GSB and possibly LSB)
- Understanding will be used to advise Industry for ~2035 “generation after next” bridging solutions, i.e. beyond TYRO, “quick wins” could be applied to midlife upgrades for TYRO



Source: Senhora (Georgia Tech)



Source: SPS Technology

Research Phases

2018 | 2021 | 2024 | 2027 | 2030

Phase 0: Scoping study (Dstl)

Phase 1: 'Paper' Engineering studies (Industry/Academia)

Phase 2: Individual component and Scale prototype bridge testing

Phase 3: Full-scale prototype bridge construction and testing

Phase 0

- **Materials** developments, incl. Composites and Metals
- **Manufacturing** technology, incl. Additive Manufacture (AM)
- **Design** aspects, incl. joining materials, 'design out' problems
- ATiTUDE (Affordable Titanium for Defence), Army, Navy, Williams Advanced Engineering, Prodrive

Phase 1

- Light alloy (Al, Ti, Mg) or a Composite bridge solution?
- "Smart" design, utilise strengths / reduce weaknesses
- **Materials** & **Manufacture**, QinetiQ; all-metal bridges v and mostly-composite bridges
- **Design**, Enginuity; novel / art of the possible & Frazer Nash Consultancy (UK), HUMS

Phase 2

- Computer modelling and evaluation of designs as advised by the Phase 1
- Test individual components and scaled physical models of prototype bridges in laboratory conditions
- Down-select the bridge solutions, before full-scale

Phase 3

- Investigate a single optimum solution (or two at most)
- The testing would include a 'real world' environment.
- After testing and the optimum solution arrived at, suitable manufacturer(s) could be determined to produce the chosen bridges

Phase 0, Composite bridges, Previous Research

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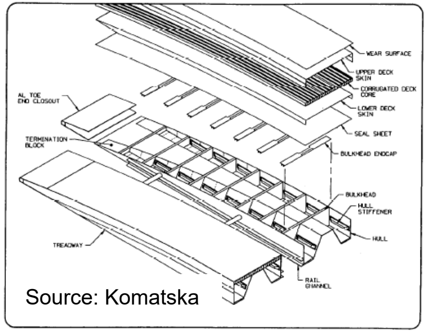
- Composite bridge design, manufacture & testing, investigated by UK MoD between 1990 and 1995
- Composite Army Bridge (CAB), University of California, DARPA, US Army, 1999 (& 2011):
  - **20-30% lighter than equivalent metallic (aluminium) bridge**
  - **MLC 100**, 14 m bridge, M1A1 Abrams, HET & M1A1, M88 towing M1A1
  - 72 instrumented crossings, 2000+ endurance crossings, static strains M1A1 at different locations
- Concern: Heavy vehicles moving quickly produce large dynamic responses (bouncing) and load factors, with potential damage to the carbon fibres, epoxy resin, bonded and bolted joints



Source: Komatska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Source: Komatska

Phase 1, Composite bridges, Directed Research

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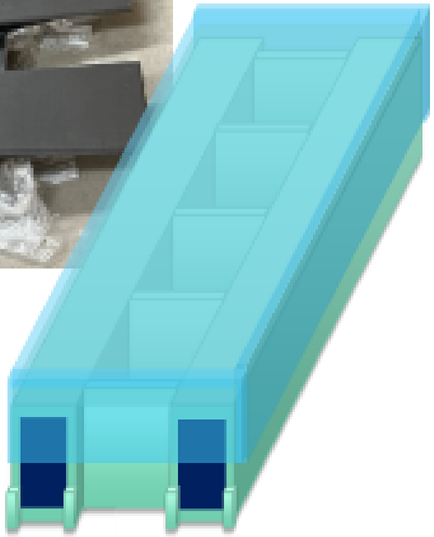
- **Dstl Advanced Materials Programme (AMP)**

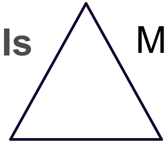
- Versarien plc, Graphene enhanced CFRP
  - Materials testing / characterisation
  - Bridge design / manufacture / testing
    - ¼ scale ~ No11 CSB
    - Mass < CFRP v Al
    - Mass < further G-CFRP v CFRP (& improved properties)
    - Optimised design and UD reinforcement reduce mass further
- National Composites Centre (NCC), 3D woven composites
  - Design and analysis of 3D woven beam sections and integration of connectors
    - Embedded / integrated metallic bushings / connectors / lugs
  - 3D weave improved mechanical properties, but increased mass v traditional 2D weave

Source: NCC



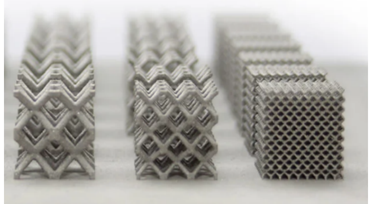
Conclusions / Future analysis

Materials

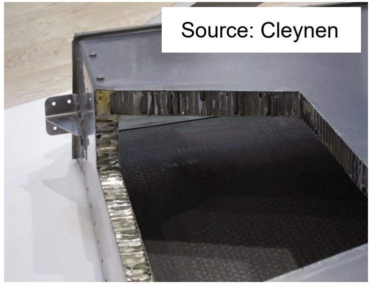


Manufacture

Design



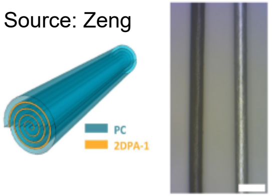
Source: Renishaw



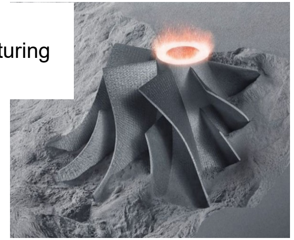
Source: Cleynen

- Composites
  - Carbon fibre for high strength / stiffness (metals for robustness / wear resistance)
  - Fillers can improve properties and reduce overall mass
  - Composite materials can be prone to damage, difficult to repair
- Metals
  - Aluminium-lithium increased durability (fatigue), lighter than current aluminium alloys
    - i.e. can withstand higher tensile / fatigue stresses
  - Titanium not suited to structural components (re TDTC) good for smaller components cost permitting
  - Watching brief on:
    - Aluminium-lithium alloys, Titanium and high strength steels

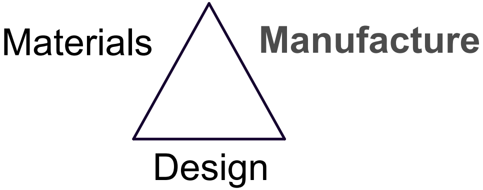
Source: Zeng



Conclusions / Future analysis

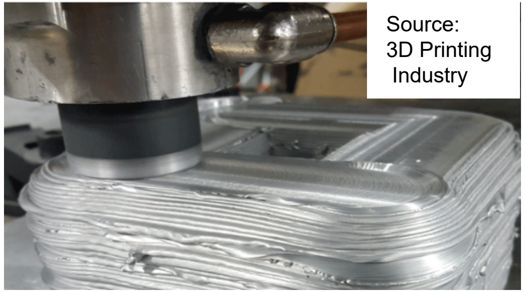


Source: Manufacturing Guide



Source: Additive Manufacturing

- Composites
  - Costly to implement regarding tooling, labour and design efforts
- Metals
  - AM laying down process of material (e.g. for an Aluminium alloy)
    - e.g. Wire Arc AM (WAAM) or MELD
    - may induce Anisotropy, a concern where fatigue is likely
  - Friction stir welding based AM techniques:
    - Repair of damaged sections and adding/repairing the nibs on trackways
    - Hard steel nibs added to an aluminium alloy deck, or coating the nibs with steel for greater wear resistance
- Composite & metallic components must be reliably incorporated
  - e.g. composite bolted joints re corrosion



Source: 3D Printing Industry

Conclusions / Future analysis

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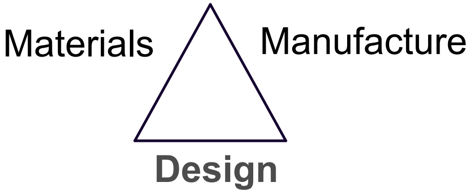
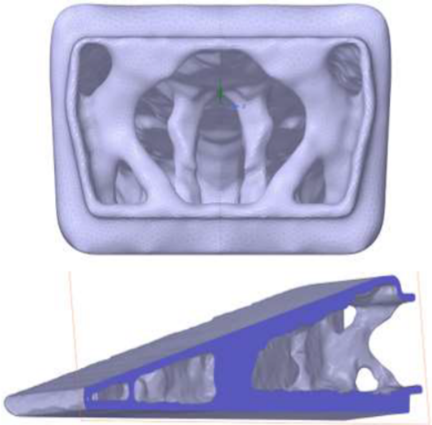
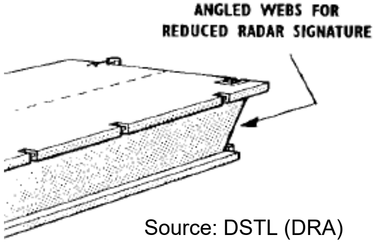


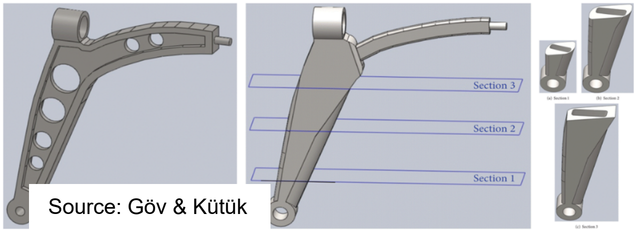


Source: Enginuity

- Optimise design through use of Finite Element Analysis (FEA) and Topographical analysis
- Internal pre-load system and cambering the span would improve performance and reliability
- Under-bridge reinforcement increases load-carrying without adding greatly to the bridge mass
- HUMS may be many simple sensors, with a few sophisticated sensors (e.g. ramps or joints)
  - As a cost effective solution for bridge management
- Signatures: Visual, Infra-Red (IR) and Radar, are not driving design factors
- Need to look at; weld strength of aluminium alloys, adhesives as a suitable alternative, plus effects of corrosion, etc



Source: DSTL (DRA)



Source: Göv & Kütük

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Thank you, Questions?

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Source: Author

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