Training in the future, and how to get there.

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ABSTRACT

As we look to the future of training and education we can see a myriad of possible outcomes, with technology revolutionizing the way that it is delivered, undertaken, tailored and measured. To find some structure in these possibilities the UK Government's Defense Science and Technology Laboratory, with support from UK Industry, developed an evaluation approach that assessed what training and education might evolve into to uncover what technology and policies will need to be in place to deliver this shining future.

Through a process of examining current MOD strategies and industry technology roadmaps the team developed a broad set of future training scenarios, from "Just in time learning" to a "Holodeck on every Barracks". These scenarios were distilled into a final concise set of 7 by the broader community including UK Academia by applying critical analysis. This set of scenarios were decomposed into their constituent technologies or "bricks" which were analyzed across all of the scenarios to identify commonalities or "superbricks". Once identified these superbricks were built into roadmaps describing their path to maturation. The technologies were not looked at in isolation; their impact on people (from trainees to procurers) and the policies and processes that would enable their use were also investigated. Finally, through refinement the scenarios were distilled into 3 philosophies: People – where the focus is on the learner as the driver of change; Technology – where the focus is advances in technology; and Environment – where the focus is on where the training is delivered.

This paper describes this analysis approach, highlights some of the findings and outlines how they are being used to drive future research programs and policy updates.

ABOUT THE AUTHORS

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INTRODUCTION

Along with many other nations the UK is investigating and envisioning how its armed services will be trained in the future. The Developing Education Learning and Training Advances (DELTA) project by the Defense Science and Technology Laboratory (Dstl) aims to identify, develop, and test innovative approaches and technologies to accelerate and enhance learning, training, education, development and preparation of the Defense workforce, through-life. This paper describes the study undertaken by DELTA to explore and articulate potential Learning Futures, with the goal of providing the requisite information and evidence that would enable Defense to exploit next generation and Generation After Next (GAN) learning capabilities and technologies. The study sought to provide evidence-based analysis and recommendations to underpin an initial set of plausible Learning Futures scenarios.

Recent years have seen a significant uptick in the pace of development of technologies such as Artificial Intelligence (AI), Internet of Things, eXtended Reality (XR: umbrella term for Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) technologies). The application of AI and Machine Learning (ML) to Big Data and the use of increasingly sophisticated and ergonomic XR displays and peripheral devices and biometrics, are just a few of the current technologies that can open up opportunities for potentially accelerating and enhancing the future of learning, training, and education of the Defense workforce. Understanding future trends in the development of these and other technologies enables Defense organizations to devise strategies to exploit their disruption of learning ecosystem for themselves and thus, accelerate and maintain the readiness of Service Personnel (SP) more efficiently. The aim of this study was to develop a set of validated Learning Futures scenarios, supported by roadmaps and a “brick road” of individual technology and capability building blocks. This paper describes the study approach, its findings and their implications on Defense, its people and policies.

ANALYSIS APPROACH

Three core activities were conducted under this study; Learning Futures scenario development, roadmap development, and selection of preferred future scenarios.

Scenario generation was underpinned by a review of 25+ operationally and technologically relevant papers including the UK MOD’s 2021 Integrated Review (Cabinet Office, 2021), the Command Paper Defense in a Competitive Age (Ministry of Defence, 2021), NATO’s Science and Technology Trends 2020-2040 (NATO Science & Technology Organization, 2020), the Digital and Data Strategies for Defense (Ministry of Defence, 2021), (Ministry of Defence, 2021), Defense Artificial Intelligence Strategy (Ministry of Defence, 2022), the MOD Personal Information Charter (Ministry of Defence) and MOD’s AI Policy Paper (Ministry of Defence, 2022).

The purpose of the Learning Futures scenario development was to provide early insights into Generation After Next (GAN) Science & Technology (S&T), allowing Defense Learning to exert influence and invest early to maximize potential benefits before the S&T fully matures. Ideally, MOD would be able to accelerate identification and adoption of emerging S&T (evolutionary or revolutionary) that enable GAN Defense Learning.

Suggested GAN Learning Futures were encapsulated as distinct scenarios, reflecting known learner trends and predicted future technologies. The scenarios define a scope and purpose for each GAN Learning Future, and indicate how it could fit into future learning within the UK MOD (including learning for both Service Personnel and Civil Servants). Data supporting scenario development was gathered from a variety of open-source material and

Government Furnished material (GFX) including key UK MOD sources, trend analysis, interviews, and literature reviews.

The resultant scenarios provide a basis for identifying a possible "brick road" to the future consisting of relevant technologies and approaches. Analysis of the brick roads in turn allows identification of gaps in knowledge and thus recommendations for future UK MOD activities.

An initial set of 37 scenarios were identified. These were assessed by the team merging and removing scenarios until the target scenario count (approximately 20) was reached. The resultant 21 scenarios were then assessed by a broader UK MOD, industry and academia team which assessed their validity and priority. To support this each scenario was documented in a standardized format and scored by the assessment team using the Professional Head of Intelligence Assessment (PHIA) probability yardstick (UK Goverment, 2023), and considering the impact on Defense outputs. Through this assessment 7 scenarios were down selected.

The 7 scenarios were:

A. **Artificial Intelligence-empowered learning**. Provides the learner-centric data collection and analysis to tailor learning to the individual;
B. **Science fiction becomes science fact**. Provides increasingly rich virtual learning environments;
C. **Expertise, everywhere all at once**. Adds remote access and access to tutors anywhere;
D. **Learners in the spotlight**. Adds learner collaboration tools, gamification and career path tailoring;
E. **Interfacing with the future**. Add brains interfacing to further enrich the environment;
F. **The Live Digital Matrix**. Provides a multi-domain Live Virtual Constructive (LVC) kinetic learning environment;
G. **Learning for the military multiverse**. Adds non-kinetic domains and effects.

Each scenario was broken down into its key constituent parts ('bricks'). These bricks were developed, detailing how the technology needed to evolve to reach three successive stages of progression ('epochs') for the scenario. The epochs represented stages of maturity from piecemeal, through stove-piped to enterprise, charting the journey from present day to fulfilment of the scenario.

Bricks were derived from a QinetiQ-created taxonomy which mapped a total of 311 technologies and innovations, categorized into 22 areas ('superbricks'), listed below:

1. Computer Hardware, Software, Operating Systems, Applications and Web-based Computing
2. Communications and Networks
3. HMI Technologies
4. Information and Knowledge Management
5. Computer Systems Security – Cyber Security
6. Artificial Intelligence and associated fields
7. Process
8. Computer and Systems Architectures and Methodologies
9. Systems integration and interoperability
10. Enterprise Collaboration Technologies
11. Data Management
12. Consumer devices and electronics
13. People
14. Data and Information Storage
15. Position Navigation and Timing (PNT) – Geolocation
16. Sensor technologies
17. Bio-technology
18. Robotics
19. Quantum technologies
20. Nano-technology
21. Power sources, management and efficiency
22. Materials Science

Each of these 311 bricks were mapped against each scenario to identify if it was essential; beneficial but not essential; or not currently relevant. The results were then analyzed to identify which of the superbricks had the highest number of individual bricks that were essential to a particular scenario. This process led to the identification of several superbricks that were critical to all scenarios. These were amalgamated into the following combinations referred to as Universal Technology Foundations:

1. **Ubiquitous Computing Power** (consisting of superbricks: Computer Hardware, Software, Operating Systems, Applications & Web-based Computing, Computer Systems Security (Cyber Security), Computer/Systems Architecture & Methodologies, Quantum Technologies, and Power sources, management and efficiency);

2. **Data Management & Storage** (consisting of: Information & Knowledge Management, Data Management, and Data & Information Storage);
3. **Artificial Intelligence**;
4. **Secure High-Speed Communications** (consisting of Communications & Networks).

There were also other superbricks that were relevant to one or more but not all scenarios. These were also mapped against the relevant scenarios. People and Process factors were also identified and included as key superbricks which would significantly affect the success or failure of achieving the scenarios.

The maturity levels of the Universal Technology Foundations and scenario specific superbricks were assessed against the epochs for each scenario and were graded on a scale ranging from "UK MOD currently exploiting" to "will not reach maturity for deployment within 5 years". Superbricks that required future research also were identified and the role that the Dstl Learning Community should play in developing them was graded.

The information about each of the scenarios was further expanded to include use cases that provided a 'day in the life of a user' to bring to life the technologies. All of this information (scenario description, roadmap and use cases) was assessed again by personnel from the UK MOD, industry and academia to refine and validate the content. After this assessment the scenarios were finalized and short videos were created to stimulate engagement with senior stakeholders and policy makers.

The overall process is shown in Figure 1 starting from the Defense sources to generate the initial 21 scenarios that were refined to the final 7. These were assessed against the 307 technology bricks. The assessment identified the utility of each technology with the scenario and those with most utility these were consolidated into 22 superbricks. Each of these were analyzed for each scenario developing roadmaps for their maturation. Through final analysis the scenarios converged into 3 philosophies:

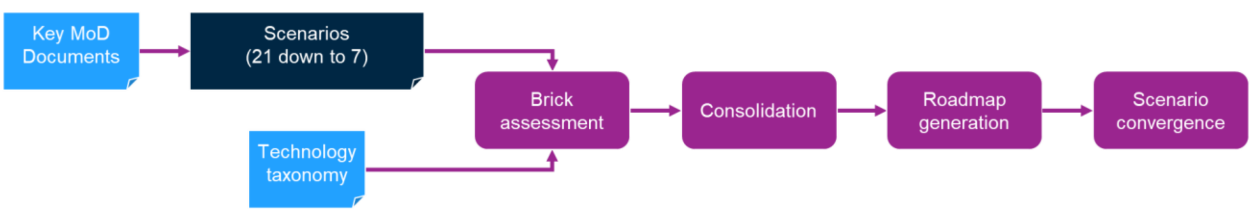

Figure 1. Scenario Development Process

FINDINGS

The seven scenarios resulting from the Scenario Development Process were:

Scenario A – Artificial Intelligence-empowered learning
The future described in this scenario revolves around the continuous collection of data and exploitation through AI. The wealth of data, ranging from biometric to performance, is used to update learners' Digital Twins and for feeding into intelligent AI tutors and data analytics. This enables evidence-based learning that is targeted to the strengths and weaknesses of learners, based on their career plans, as well as allowing the learning to be tailored ahead of a session and also in real-time using biometric data.

Further benefits of the breadth and depth of data and associated analytics include the ability to establish benchmarks for comparison, as well as to provide objective feedback on the effectiveness of the learning and its delivery. The Digital Twins also enable the detection of anomalies in learners' data, which could help identify risks to their wellbeing and allow the provision of pre-emptive care. Finally, the Digital Twins can be used to populate virtual training exercises, reducing the reliance on role-players and support staff.

Overall, the focus is on empowering new and existing personnel to take ownership of their career, providing them with the information and support to understand how the learning is contributing to their progression into a role that suits their skills and abilities.

Use cases per epoch:
Individual: A Sergeant in Edinburgh is attending a Platoon Sergeant's training course. Each day, the data from their physical training is captured, and used to update their Digital Twin. This tracks their progress, highlights areas for concern, and can even identify injuries.
Cohort: The data from the physical training is combined with equivalent data captured from classroom-based learning, which is monitored by their AI tutor. This contributes to the generation of a bespoke learning plan that considers rates of progress, a comparison with their cohort, learning preferences, and future ambitions.
Enterprise: Data from across the Armed Forces is analyzed to create bespoke learning plans for each individual, based on estimations of future need, projected attrition rates, and by comparing their development with that of similar personnel from past cohorts. This ensures the development of the right skills in the right place at the right time - for both the Sergeant and the Armed Forces as a whole.

Scenario B – Science fiction becomes science fact
Virtual training is more 'real' than ever. Learning across UK MOD is delivered via the military metaverse, a persistent ecosystem of virtual worlds that can be adapted to represent any context desired.

These virtual 'pockets' can be rapidly reconfigured, customized, or reused between training sessions. Personnel can train together from any location with an intranet connection and conduct learning at any level and for any situation. The technology is at a stage where the virtual is experienced as if you were 'there' - it provides sensory feedback to all modalities, you can hear, see, feel and smell.

The pinnacle of this is the ability to transform the space around the learner into a Holodeck; the physical space is scanned, and virtual elements are overlaid with true spatial awareness.

Use cases per epoch:
XR: A future instructor is delivering Joint Fires Integration training. Having booked the range time, and requisitioned the appropriate equipment, they use augmented reality technology to simulate the impact or air and artillery support, creating a semi-realistic experience at a fraction of the financial and administrative cost of live air and artillery.
Metaverse: The instructor can deliver a more sophisticated learning package in the metaverse - using VR to train simultaneously with both the personnel on base and those currently deployed on an exercise in Africa, as well as more advanced simulations of other force elements.
Holodeck: A highly advanced holodeck system, with Digital Twins of their colleagues and potential adversaries, innovative sensory feedback devices and nanobots constantly rearranging themselves to replicate the generated synthetic environment, makes simulated training feel just like the real thing.

Scenario C – Expertise, everywhere all at once
Learning is targeted and adapted to various delivery channels, having a larger reach than ever before. Learners can access a wide selection of learning from both AI and the best possible real tutors, at the point of need. Learning is conducted without being constrained by the need to commute to a physical training site or center thus improving the individual's harmony time and bolstering retention.

Although there is still a need for live training, the wealth of learner data enables learning organizations to identify the optimal delivery blend. Learning anywhere-anytime is a reality, with learners being able to access virtual learning from a range of devices, with content that is optimized for different device types.

Use cases per epoch:
Remote Tutors: A learner attends a leadership course at Sandhurst, taught by the best-in-class tutor - who delivers their lecture from their home base in Scotland. Immersive technology makes it feel - to an extent - like the lecturer is in the room.
Any Base: The learner attends the course from their home base, alongside officers from the Royal Navy and Royal Air Force (RAF) who are joining from all over the world. Course material creation is standardized at the highest level, making it much easier for tutors and experts to create world class learning materials.
Ubiquitous: World-class learning is available to Armed Forces learners wherever they are in the world - on base, on a training exercise, or on operations - and whenever they require it. This is delivered by a mixture of on-demand AI tutors and the best-qualified human instructors, learning and educating remotely through handheld video links, XR devices or even a Holodeck.

Scenario D – Learners in the spotlight

UK MOD is a learner-centric organization. Processes and systems are optimized to allow agility in supporting Learners' development through their career and attracting new recruits: the needs of all learning systems users are considered and supported (i.e. learners, trainers, course authors, Chain of Command).

Behaviorally targeted recruitment campaigns attract a larger number of recruits, who are then matched to the most suitable career options based on their skills and interests measured via standardized screening tests.

Continuous data is collected and performance and biometric metrics are analyzed which are then used to inform the optimal delivery blend, performance benchmarks, Digital Twins, and identifying a decline in performance amongst other things. The wealth of data collected and analyzed enables an evidence-based approach to learning delivery and design, and also the ability to tailor and deliver just-in-time remedial learning.
Learners have access to a wide range of content and delivery channels, delivered at the right time, aligned with their preferences, including innovative digital collaborative learning spaces, gamified courses and matchmaking with similar learners. Overall, this allows learning to be truly recruit-retain centric.

Use cases per epoch:
<u>Collaborative</u>: A potential recruit joins the Armed Forces, and enters a new form of basic training: one co-designed by instructors and those who have recently been through the experience as a learner. After basic training, they undergo cognitive tests and preference assessments to ascertain which roles and career paths will be most attractive to them.
<u>Gamified Learning</u>: Completing training (and strong performance) is rewarded by position on leader boards, allowing the recruit to compare their results with their past performance as well as with other learners. Game-like rewards (achievements, levelling up, etc.) are given out for completing bespoke challenges designed to enhance motivation and direct effort towards the areas where it will be most beneficial.
<u>Career-Spanning</u>: The potential recruit first engages with the Armed Forces through a VR recruitment portal - the biometric and cognitive data collected is the genesis of the Digital Twin that will stay with them throughout their career, developing as they do, helping map out their progression, evaluating where they will be of best use to the Armed Forces and how they can make the most of their talent. The Digital Twin is constantly updated and evolved with new data from their own performance and from others.

Scenario E – Interfacing with the future

User Interfaces are designed in such a way that there is commonality across platforms and systems providing similar functionality to reduce the overall need for learning. This means that there is a lot less familiarization required for learners to use a new platform or system.

Suppliers have access to a common set of standards for each type of platform and system, providing a basic interface that can be enriched with any added functionality.

Brain-computer interfaces are also used to enhance the abilities of learners and reduce the learning burden. Equally, they enable telexistence, wherein learners or trainers can control a system in a different location for the purposes of learning, without the need for commuting.

Use cases per epoch:
<u>Common Interface</u>: An experienced pilot takes a new role, flying a new aircraft type. The aircraft's control system has been designed to be extremely intuitive, with a common user interface provided across the fleet; i.e. every new aircraft has similar controls. This substantially reduces the learning required to get this pilot proficient with the new aircraft.
<u>Neuroenhance</u>: Alongside the controls being easier to master, the pilot has also received neuroenhancements (potentially both chemical and physical) to maximize their learning potential. This includes sensors able to detect much more subtle biometric data than is available conventionally.
<u>Brain-Computer Interface</u>: On receiving his orders, the pilot automatically has the technical specifications and testing data of the new aircraft downloaded onto his brain-computer interface - allowing them to become familiar with a new aircraft almost instantly. This information communication works both ways: the AI onboard the aircraft is instantly aware of physiological changes, and can adjust and prioritize what information is passed directly to the pilot through their Brain Computer Interface (BCI) based upon real-time feedback.

Scenario F – The Live Digital Matrix

Improvements in sensor technologies mean that it is possible to track platforms, systems and learners during a live exercise and present a Digital Twin of these in a virtual simulation. XR improvements allow virtual participants to be represented in the real-world and real-world locations to be augmented with features to suit the learning activity. Performance data is continuously collected and analyzed to inform the right level of fidelity and blend for larger scale, multi-level exercises.

Exercises can be run with learners in disparate locations, with some in the field and others represented virtually, reducing their need to travel and reducing live platform use. Feedback and performance is also given at multiple levels, as required by the exercise. Display technologies are used to overlay Digital Twins of autonomous and/or remote participants, whereas remote participants can see a Digital Twin of their peers located in the field.

All of this is enabled by a simulation infrastructure that allows seamless interfacing across platforms and systems, whilst being modular to enable rapid reconfiguration based on the exercise at hand. Opposing Forces also use realistic behavioral models that can be customized to reflect specific populations and their respective command structure.

Use cases per epoch:

Event-driven: A battlegroup commander is conducting a unit-level training event on Salisbury Plain. The event has been planned over several months, and all the units are there in person. The commanders are in their HQ building, monitoring the exercise remotely using data collected from a range of ground-mounted and wearable sensors and analyzed in real time by AI.

Integrated: The only units in the training area are the infantry, UGVs and UAS - armored elements, air support, and joint fires are all able to participate from their home bases in a synthetic replica of Salisbury Plan Training Area, and a USAF pilot in a simulator in the US is also involved. Synthetic munitions have realistic simulated effects - even for those in the field. This reduces travel time and the use of consumable resources.

Persistent: The commander is able to plan and deliver these training events much more efficiently, with other force elements either able to contribute remotely through simulators, entirely replicated by AI-powered simulations, or, in some cases, by autonomous vehicles and robots further reducing resource usage. The enemy are represented live by UAVs and in simulation; their behaviors and capabilities can be adjusted in real time to enhance the intensity of training.

Scenario G – Learning for the military multiverse

Learning culture sees a shift from focusing on depth of skills and knowledge to providing 'T‘-shaped education. Thus, learners become experts in their roles, and also gain an understanding of the other roles they are required to interact with in an operational environment.

As a result, they have a deeper understanding of how their roles contribute to delivering a greater combined effect, including outside of their 'home' domain. Individual learning ensures that learners understand how their role can impact effects across multiple operating domains (Air, Land, Maritime, Cyber and Electromagnetic Activities (CEMA) and Space). This understanding is further refined and tested through LVC simulation, with the domains and their effects being visualized.

Use cases per epoch:

Service-Focus: A land commander is conducting a training operation, launching a counterattack against a notional adversary who has occupied NATO sovereign territory and set up defensive positions. The commander is able to draw upon learning that covers what is expected of him from the other domains.

Integrated: Competencies are combined across the services; there is an enterprise level understanding of who needs to know what. Learning is conducted on a multi-domain basis; submarine crews sit alongside tank crews and relationships are formed across the domain at a more junior level than previously.

Persistent: Multi-domain learning becomes the norm; enhanced simulation and projection capabilities allow for more regular, cheaper multi-domain exercises. Data collection, analysis, and dissemination is enhanced by AI.

Universal Technology Foundations

As part of the creation of the roadmaps, and as mentioned above, four Universal Technology Foundations that are common to all the scenarios were identified:

1. Ubiquitous Computing Power;
2. Data Management & Storage;
3. Artificial Intelligence;
4. Secure High-Speed Communications.

These were viewed as critical enablers for almost all aspirational future visions of learning in UK MOD. It is recommended regular technology watches and research projects in these areas are conducted as a key priority for the learning community.

However, these foundations have broader applications than just the learning community; it is hard to think of any aspect of UK MOD (and government in general) that would not benefit from better application of more advanced digital technologies in at least one of these spaces. Close collaboration is therefore recommended across research communities, more broadly within Defense, other government departments, and industry.

People and Process

The scenarios have been constructed in support of the training and education of the Defense workforce. Through their construction some key considerations where highlighted:

- Suitably Qualified Experience Professional (SQEP) / skills
    - New roles: To enable and deliver the future learning scenarios new job roles will be required. This could include completely new disciplines within the Whole Force.
    - Through-life understanding: To allow users and decision-makers to safely use, procure, manage and maintain the systems that will deliver the future learning scenarios a level of understanding of the systems will be required.
    - Reversionary skills: To allow users to continue delivering their job functions when the future learning scenario delivery systems are unavailable some reversionary skills will be required. In addition, training will be needed to ensure that learners have the requisite skills to revert back to traditional methods and systems when the current ones are disrupted. For example, being able to still deliver training when there is no network connectivity or being able to perform jobs functions without AI support.
- Career Management
    - Attract and retain: The future learning scenarios may make joining part of the Whole Force more attractive. Once serving, to make career management easier, UK MOD should provide training and education more suited to trainees' needs and offer multiple career paths and opportunities to transition in and out of service. All of these should improve retention.
    - Transition out of service: The future learning scenarios offer skills that are readily transferable to roles outside of the Whole Force and can be used to deliver tailored training and education to aid the transition out of the service (e.g. during resettlement).
    - Whole Force management: Delivering integrated training and education across the Whole Force while balancing the needs of the trainee with those of the Force. Adaptive training programs enable trainees to progress through the training pipeline organically. The performance data generated can be used to monitor progression and provide in-depth people demand signals and support the management of continuity of expertise. Developing trainees with the skills to fulfil particular roles and offering flexible career paths to best employ the skills while matching their aspirations.
- Culture
    - Integration (not intra): Using the services and systems that the future learning scenarios provide to enable integration of individuals into the culture of the Armed Services no matter their background, the specific service in which they serve or if they are regular, reserve or seconded specialist.
    - Military ethos / team: The future learning scenarios provide a baseline coherent culture when joining the Whole Force as well as maintaining integration with the right balance of in-person, remote, human and AI interaction.
    - Safety and security culture: The future learning scenarios require a culture of responsibility where individuals understand their role in maintaining security and safety. This culture, driven from the top,

  with sufficient time to individuals to perform enables them to vigilantly challenge safety and security in all areas including the outputs from AI systems.
- Demographics
  - Baselining: Developing a set of tests to better understand trainees' skills on entry to the Whole Force to support identification of suitable roles and career paths and prior to use of any of the future learning scenarios so that they can be tailored to the needs of the trainee.
  - Diversity, Equity and Inclusion (DEI): Ensuring the future learning scenarios avoid bias and represent the population. Enabling opportunities within the Whole Force for non-traditional demographics and redesigning equipment and processes to increase accessibility.
- People Ethics
  - Scenario supported decision making / trust: Providing explainability and transparency in the future learning scenarios, especially when AI is employed. Where AI is used making sure it is trained using UK MOD data. Ensuring that human command decision and intuition maintain a role.
  - Prioritizing well-being: Ensuring that the future learning scenarios are delivered ethically and trainees are provided with support and care as they undertake them. Providing trainees with means to safely report incidents and the right to appeal.
  - Accountability / V&V: Ensuring that there is continued oversight and independent assurance, providing protection of privacy and regulatory compliance. That systems are robust and resilient for example preventing cheating and false data injection.

A number of implications on UK MOD process were identified. These covered the following areas:
- Implementation: Processes for the implementation of future learning technologies.
- Ethics: Processes to be put in place to ensure the ethical considerations of using these future learning technologies are examined appropriately and are subject to suitable scrutiny.
- Standards (technical or otherwise): Standard for the development and operation of future learning technologies as well as the data that they require and generate.
- Security: Processes for the securing of future learning technologies during development and operation and for the control of the data they require and generate.
- Privacy: Processes for the management of future learning technologies and the data they generate and process, including personal data and aggregated enterprise level data.

Scenario Convergence

A final analysis identified additional linkages between the scenarios, giving a path that converges into three distinct philosophies:
1. **People** – Scenarios that focus on the learner as the driver for change;
2. **Technology** – Scenarios that are primarily driven by advances in technology;
3. **Environment** – In these scenarios, the focus is on where and how learning is delivered.

EXPLOITATION AND INFLUENCE

In order to support stakeholders in exploiting and using the findings from the Learning Futures research, an html dashboard was developed. The dashboard presents the key findings in a series of interactive graphs which allow users to interrogate the data of most relevance to their role. The dashboard contains the following:
- **Introduction** – Providing an overview of the dashboard and the approach to develop it;
- **Scenarios** – A summary of each of the 7 Learning Futures scenarios included a video for each of them;
- **Enablers** – Qualitative assessments of the People and Process bricks;
- **S&T Bricks** – An interactive visualization showing the S&T capability bricks;
- **Scenario coverage** – Views showing how the S&T bricks map to the scenarios;
- **Research coverage** – Views showing where existing research is being undertaken on the S&T bricks, and where further research may be required.

The following figures provide examples of how the findings are presented in the dashboard.

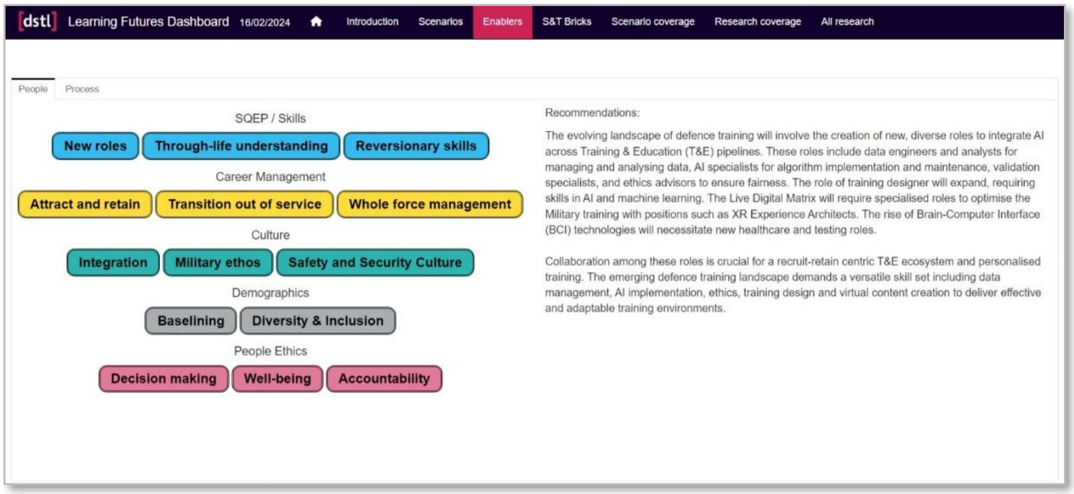

Figure 2. Enablers (People)

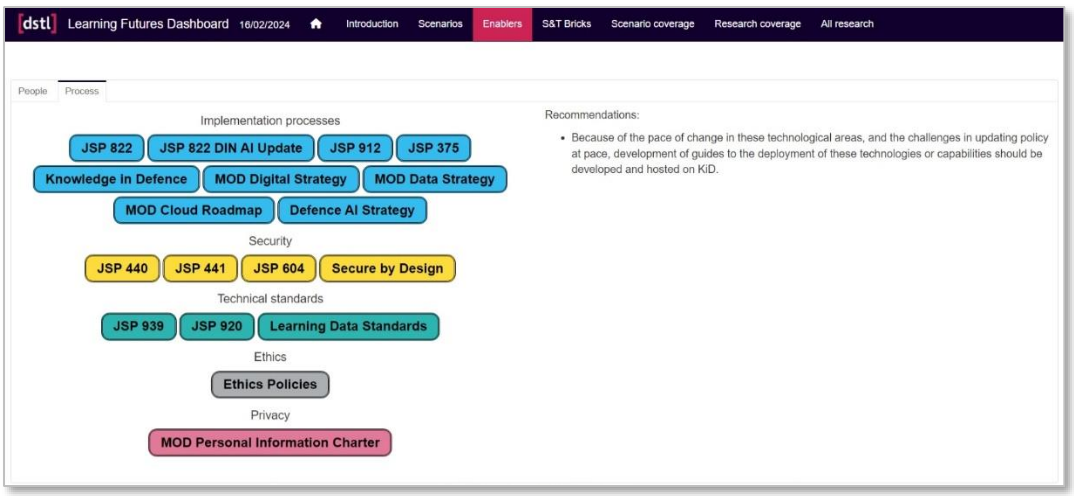

Figure 3. Enablers (Process)

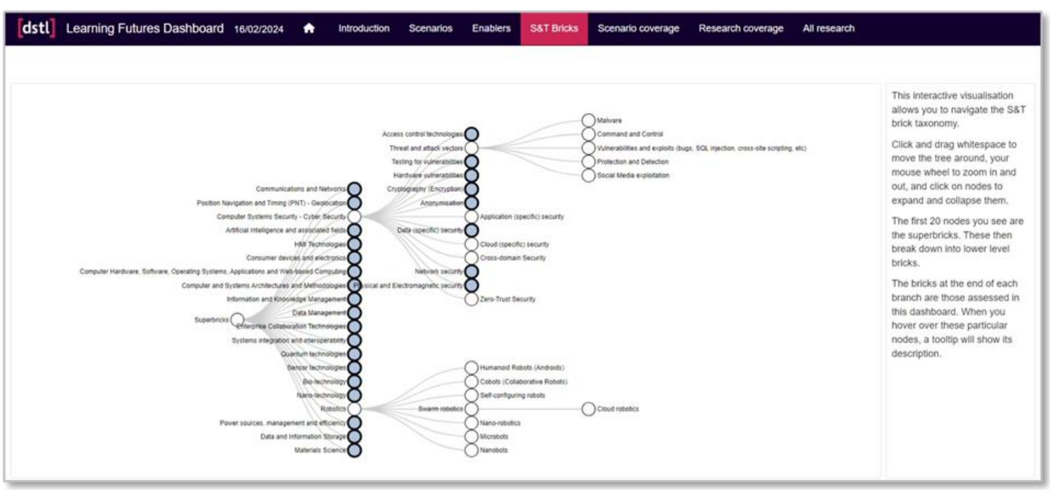

Figure 4. Science and Technology bricks

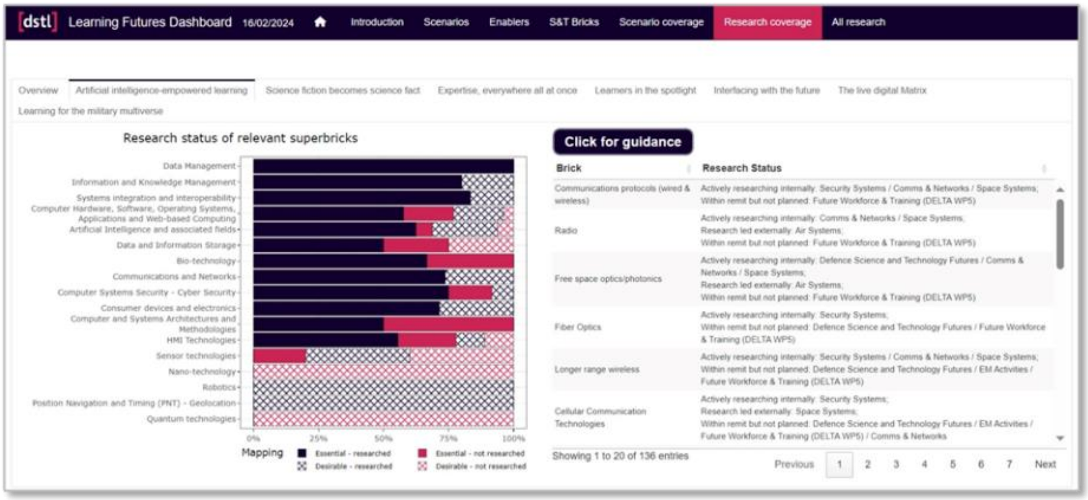

Figure 5. Scenario coverage

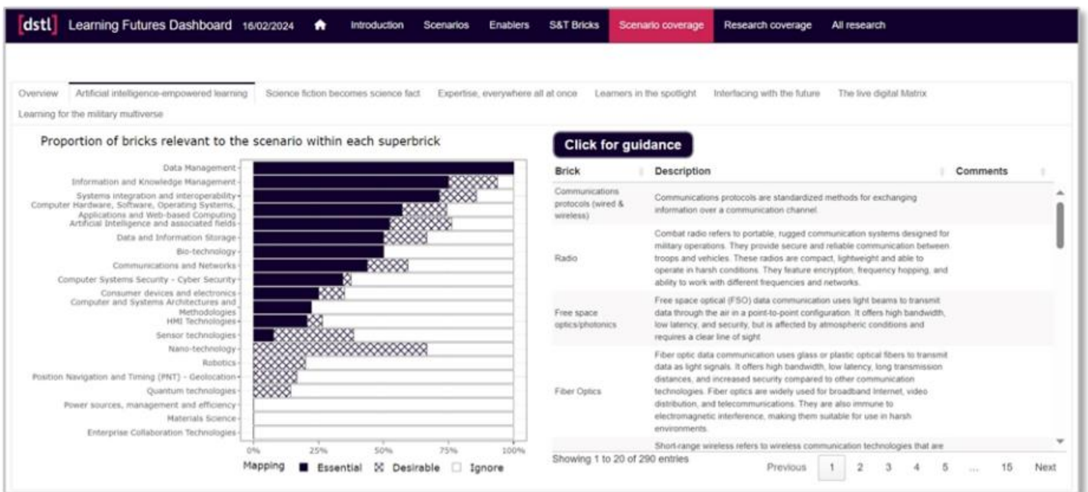

Figure 6. Research coverage

The analysis of the current and planned research has allowed Dstl to identify where additional effort could be directed to best advantage. Gap analysis has been used to recommend S&T areas for future research tasks and to identify opportunities in current programs for coordination and shared effort.

Policy considerations have been drawn out from the scenarios and are presented in the dashboard. These considerations from across the scenarios are consolidated into a series of recommendations for policy holders. In addition, gaps in the current policy landscape are highlighted, indicating where additional effort should be focused to ensure future technology developments are considered and covered by policy. In a similar way, people considerations have also been identified and consolidated. These offer insights into: how roles may need to change or be created in order for defense to exploit emerging technologies; what skills are likely to be required; and the ethical implications technologies such as AI pose.

The final report and dashboard have been supplied to stakeholders to allow them to interrogate the data and identify key trends in technology and learning approaches. It is anticipated that early identification of opportunities will allow UK MOD to position itself to invest in and accelerate critical technologies.

CONCLUSIONS

The delivery approach combined top-down (policy-driven scenario creation) and bottom-up (detailed taxonomy-driven identification of bricks) analysis, thus ensuring the depth and breadth of outputs and findings. Furthermore, the use of generic technology categories means that the findings are not tied to specific products, and are thus commercially independent and, to some extent, future-proofed and enduring. However, the rapid and accelerating pace of commercially driven technology change means that the taxonomies themselves must regularly be reviewed to ensure that promising new technologies aren't overlooked, especially when industry is iterating faster than UK MOD research programs.

The overall approach used on this task was collaborative, with foundational work by the delivery team enabling focused interventions (refinement and validation) by a diverse range of Subject Matter Experts (SMEs). This approach avoided swamping individual SMEs with a mass of detail outside of their respective areas of expertise and interest.

In terms of the research outputs generated, the use of videos to convey the vision of the future learning ecosystems depicted in each scenario appeared particularly powerful. Video creation adopted an engaging short-form approach, producing convenient bite-size chunks rather than a single monolithic 'lump' of narrative.

Overall, the recent rapid technological change is delivering capabilities that, if successfully integrated, offer UK MOD (and its peers and adversaries) step changes in Learning capabilities that are science-fictional in nature. Alongside the technological opportunities there will nonetheless, be challenges to overcome within the People and Process domains, for example SQEP, data, procurement, privacy and ethics.

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ABBREVIATIONS

AI	Artificial Intelligence
AR	Augmented Reality
CEMA	Cyber and Electromagnetic Activities
DEI	Diversity, Equity and Inclusion
DELTA	Developing Education Learning and Training Advances
DSTL	Defense Science and Technology Laboratory
GAN	Generation after After Next
GFX	Government Furnished material
LVC	Live, Virtual and Constructive
ML	Machine Learning
MR	Mixed Reality
NATO	North Atlantic Treaty Organization
PHIA	Professional Head of Intelligence Assessment
RAF	Royal Air Force
S&T	Science & Technology
SME	Subject Matter Expert
SP	Service Personnel
SQEP	Suitably Qualified Experience Professional
UK MOD	United Kingdom's Ministry Of Defense
V&V	Verification and Validation
VR	Virtual Reality
XR	eXtended Reality

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