Human Factors Integration: Fit for the Future

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Executive summary

For over quarter of a century, Human Factors Integration (HFI) processes, standards and technical guidance have been applied to help ensure that the needs of the personnel who operate and maintain Defence's systems are addressed within the Delivery of Defence Capability. The systematic integration of people, processes and technology is a key component of optimising system performance, managing risk, exercising duty of care, managing capital and through life costs and supporting the integration of Equipment, Personnel and Training Defence Lines of Development.

HFI has evolved over time adapting to changes in wider acquisition policy and technological development. Current Defence strategies suggest that the coming years will see significant changes to the operating environment and procurement processes, as well as the rapid development and adoption of new and potentially disruptive technologies. The cost-effective integration of People, Process and Technology has never been more important than it is today.

This paper has been produced jointly by the Defence Science Technology Laboratory (Dstl) and Defence Equipment and Support (DE&S) with the intention of stimulating discussion over how current HFI processes should be refined and adapted for the future in response to changing Defence priorities and strategies. It explores how changes in the wider organisational, strategic and technological context within which HFI is applied might drive future change.

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1 Introduction

The strategic, organisational, technological and operational context within which Human Factors Integration (HFI)[1] is applied is constantly changing, perhaps more so now than at any point in its history.

This Paper produced by Dstl and DE&S, explores what opportunities and challenges current Defence strategy, policy, and priorities together with advances in technology mean for HFI. The findings of this paper are based on an analysis of current Defence Strategies, insights from the MoD science and technology research portfolio, and views of those working on the application of HFI within Defence. The intent is to stimulate debate over how current HFI processes should be refined and adapted for the future. In particular, it explores the role that HFI should play within Front Line Commands (FLCs) and the early stages of the capability lifecycle, the technological developments, which will impact most significantly on HFI and how HFI will need to adapt to current Defence priorities and organisational change.

Based on an analysis of current Defence Strategies, priorities and technological trends this paper considers how HFI, as it stands today[2] might need to change to build upon the positive impact that it has done for in excess of quarter of a century.

1.1 Current HFI Policy

Current HFI policy is described in Joint Service Publication (JSP) 912 [1]. A more detailed description of HFI's goals, processes and products is contained within the Human Factors Integration Management System (HuFIMS) [2] and the standards by which HFI requirements and processes are contracted for are described in Defence Standard 00-251 [3]. Responsibility for the maintenance and update of these rests with Head DE&S Engineering Group. Other DE&S processes and policies also make reference to or call for input from HFI, most notably: Integrated Logistics Support (ILS) through Def Stan 00-600 [4]; Support Solution Envelope [5], and Guide to Engineering Activities and Review (GEAR) [6].

The importance of applying HFI effectively on a project is described in JSP 912 Human Factors Integration for Defence Systems. Part 2: Guidance [1]:

"Failure to consider the Human Component of Capability can have many adverse consequences: increased risk of accidents and incidents; higher training costs; reduced performance and mission effectiveness; breaches in duty of care; scarcity of appropriately skilled personnel; delays to the project schedule and substantial increases in design / redesign costs."

[1] For readers unfamiliar with the HFI process and the organisations involved in its application a short HFI Explainer is provided in Annex A to this paper.

[2] HFI is described in Joint Service Publication (JSP) 912 [1], Def Stan 00-251 [3] and associated process and technical guidance contained on the Human Factors Information Management System HuFIMS [2]

1.2 The Evolving Nature of HFI

The last 15 years have seen significant advances in both the development of HFI processes and more recently in the growth of the specialist support available within Defence Equipment and Support (DE&S) through the HFI Internal Technical Support (ITS) Team.

HFI exists within a wider context of changing strategic priorities and organisational processes. Recent policy and strategy papers highlight the significant changes that Defence will go through in the coming years to modernise and adapt to face the challenges of the future operating environment. The key sources that informed this paper include: the 2021 Integrated Review [7], Defence Command Paper [8] and 2023 updates to them [21][22]; DE&S Strategy [9] and Defence People Strategy [10]; 2023 Reserve Forces Review [23] and Haythornthwaite Review of Armed Forces Incentivisation (HRAFI) [24]

The most recent MOD Strategies have seen a particular focus on rapid technological modernisation, drawing on and rapidly exploiting emerging technologies such as Artificial Intelligence. These technologies will have a significant impact not only on how humans interact with technology but also on the numbers of personnel and the skills that they require.

To remain effective, HFI must adapt to these wider strategic priorities, process and organisational changes. Perhaps the most important of these for HFI is the drive identified within the Integrated Review and Defence Command Paper to modernise at pace through technological innovation and the use of more agile and rapid approaches to acquiring emerging technologies. HFI will need to adapt to a wider range of acquisition approaches, some of which will be faster and more flexible than those in place today. HFI will also need to acquire new specialist knowledge, methods and tools from both the human factors discipline and further afield, in order to develop new standards and guidance to inform the specification, design and acceptance of systems utilising new technologies.

1.3 The Need for this Paper

The application of HFI within Defence has enjoyed recent successes achieved through the establishment and recent expansion of the HFI Internal Technical Support (ITS) Team within DE&S. So why the need for this paper now?

HFI has undergone a number of changes since its inception, in response to technological change as well as maintaining currency with emerging Capability management and Acquisition approaches.

However, there are several reasons why a fresh look at the successes, opportunities and challenges facing HFI is needed now. These are as follows:

First, recent Defence strategies, notably the Integrated Review and associated Defence Command Paper and Defence AI Strategy, indicate that there will be significant changes occurring to the acquisition of capability in future. For HFI to remain effective in delivering its objectives it needs to prepare now for these changes.

Second, there are major technology changes, which will impact both on HFI as a process and on the HF methods, tools and guidance, which contribute to its execution. These technological changes are more significant for human interaction with systems than almost any other since the inception of HFI, with advances in areas such as Artificial Intelligence (AI), Robotics, Autonomy and Human Augmentation placing new demands on the skills and knowledge that HFI and HF practitioners provide. These technologies and the new capabilities that they enable will bring new challenges and opportunities for HFI, and will bring within them new development, test and assurance processes to which HFI processes may need to adapt, together with a need for new HF knowledge skills and tools to support the analysis, specification, development, acceptance, operation and disposal of such systems.

Third, as a consequence of the two points above there is a growing need to replicate the success that HFI has had in DE&S, informing equipment acquisition and capability delivery, in other parts of the Capability Lifecycle and Defence more widely.

1.4 Scope of this Paper

This paper together with the analysis that informed it were produced to highlight the opportunities and challenges presented by changes in wider Defence strategies and identify the technological priorities for Defence, which will most significantly impact on HFI.

The intention is to stimulate debate over how current HFI processes should be refined and adapted for the future and where new methods and technical guidance are needed. The goal is to ensure that HFI continues to make an impact within UK Defence, and that HFI expertise is best applied to make the greatest contribution to the delivery of effective, safe, affordable and sustainable Capabilities.

1.5 Intended Audience

There are three principal audiences for this paper:

- **Policy and Process Owners -** Those individuals and organisations who are responsible for implementing or have influence in promoting the uptake of HFI within their organisations, or own related standards and processes e.g. in safety, ILS, Capability Planning etc[3]. This group's understanding of the wider strategic context and ability to drive change is essential in influencing and delivering changes in HFI policy and practice that are practicable, sustainable and aligned with wider changes in Capability Development and Delivery.

- **Practitioners** - HFI practitioners who implement HFI policy and standards, and utilise the process and technical guidance currently available. As the principal users of the HFI process and guidance the views of this group are key to inform

[3] This includes: Chief of Defence People (CDP), MOD Finance & Military Capability (FinMilCap); DE&S Hd Engineering Group, HFI Policy Desk Officer and HFI Internal Technical Support (ITS) Practice Lead, Defence AI Centre (DAIC) and Defence Autonomy Unit (DAU), ILS, DOSG, FLC Capability Directorates/Owners, FLC Personnel Directorates, INM, RAF CAM, industry Human Factors and HFI Leads, MOD Defence Science and Technology (DST), Dstl Human Social Sciences Group Leader.

and support the development of any change required and to highlight any considerations omitted in this Paper. This includes HF and HFI specialists in DE&S HFI ITS Team, industry, Dstl and FLCs.

- **Related and Interested Bodies -** Organisations who have an interest in HFI or are influenced by its implementation. This includes: Systems Engineers, DLOD Owners, MOD Defence Academy, MOD Defence Innovation Directorate, Trials Development Units, international allies and professional bodies such as Chartered Institute of Ergonomics and Human Factors (CIEHF), British Standard Institution (BSI) and International Council of Systems Engineers (INCOSE), Health and Safety Executive (HSE) and others.

1.6 Key Drivers for Change (Focus Areas)

To maintain relevance and positive impact it is imperative that HFI adapts to the organisational, technological and operational context within which it is conducted and the opportunities and challenges that they present.

Based on a review of recently published Defence strategy and concepts documents[4] the following sections discuss how HFI might need to change to address the implications in four focus areas:

- **Focus Area 1** – HFI implications of the Strategic Defence Context and Future Operating Environment.
- **Focus Area 2** – HFI Across the Capability Lifecycle.
- **Focus Area 3** - Technological Change and its implications for HFI.
- **Focus Area 4** - Changes in the Defence Workforce and the future Personnel Strategy.

[4] Including: Integrated Review [7], Defence Command Paper [8], The Integrated Operating Concept, Mobilising, Modernising & Transforming Defence [15] and the Global Strategic Trends (Sixth Edition)..

2 FOCUS AREA 1 - CHANGES IN THE FUTURE OPERATING ENVIRONMENT AND DEFENCE'S STRATEGY FOR RESPONDING TO IT

The 2021 Integrated Review [7] and the Defence Command Paper [8] together with their 2023 updates [21][22] provide the strategic context within which HFI will operate over the coming years and indicate how it might need to adapt to remain an effective contributor across the capability lifecycle in the future. This Focus Area highlights the aspects of this strategic context that are of most relevance to HFI. Because of the strategic nature of this focus area it touches on aspects which will be addressed in more detail in later chapters.

2.1 Persistent Engagement, Global Campaigning and an Integrated Approach

The 2021 Integrated Review and associated Defence strategies highlighted that the UK will move from having a force primarily designed for the contingency of a major conflict and warfighting, to one that is also designed for permanent and persistent global engagement alongside our allies [8]. The implication of this being that more of our forces would be deployed overseas more often and for longer periods of time, both with NATO and alongside our wider network of allies and partners [7].

The 2023 Integrated Review refresh (IRR) identified that a transition into a multipolar, fragmented and contested world has happened more quickly and definitively than anticipated in 2021 and that commitment to persistent engagement should move into a global campaigning approach against the threats from state and non-state actors [22]. A campaigning approach brings together all the levers of Defence – not only military, but also informational, economic and Defence diplomatic – in conjunction with wider Government, elements of the private sector, and with our allies and partners, to address the most pressing security threats we face. It is representative of our integrated approach to deterrence and is the embodiment of multi-domain integration.

To campaign effectively, forward deployment and persistent presence remain important, helping us to understand the global security environment, sense emergent threats and opportunities, be poised to act, and learn lessons and adapt our approach. This

approach places demands in terms of flexibility, adaptability and interoperability not only of our systems, but also of our personnel. Defence needs to understand how this will affect our people in terms of the skills and training that they require, as well as what it means for their work/life balance, job satisfaction and impact on their families. While HFI might have a limited role to play in the latter of these, it should be called upon to support the design of systems to provide the degree of flexibility required without driving up personnel or training requirements to undeliverable or unaffordable levels.

The deployment of forces overseas more often and for longer will place increased demands on our military personnel particularly at a time when numbers are decreasing. These demands will have both short and long-term implications on the people component of capability. HFI should have a role to play not only in ensuring that the equipment provided to personnel is fit for purpose for the environments which they will deploy into, but also in ensuring that the habitability of living and working environments is suitable to sustain the effectiveness and morale of personnel over the expected deployment durations.

2.2 Flexible Force Operating alongside Our Allies and Partners

The events in Ukraine have underscored the centrality of NATO to the United Kingdom's national security and consequently NATO remains a strategic priority for UK Defence as do our relationships with our allies across the world [22]. As in integrator of people, process and technology HFI has a potentially powerful role to play in achieving effective interoperability not only across our own forces but also with our allies.

2.3 Rapid Pace of Technological Change and Adversarial Threat

Technology is set to change rapidly over the next decade and advances both in defence and dual-use commercial technologies will also present risks to UK security with adversaries having greater access to more capable systems. Some of our adversaries will have the ability to rapidly access and field these technologies, which will present new threats to our personnel, which we will have to provide protection against at speed. HFI as a practice must be in a position to support the rapid development and fielding of systems to counter emergent threats.

Insights from the war in Ukraine have highlighted the complex nature of modern warfare with a battlefield consisting of trench warfare reminiscent of the early twentieth century, overlaid by rapid innovation and adaptation of twenty-first century technologies. This juxtaposition of high and low technology warfare presents particular challenges for Defence in terms of the skill mix that personnel will require in future. Amidst the drive for technological change and modernisation the war in Ukraine is a timely reminder of the inherently human nature of warfare and that "traditional" skills, capabilities and methods and means of war will persist for some time to come and HFI will need to retain the expertise to support them.

Focus Area 3 explores in more detail the implications of technological change and what it means for HFI.

2.4 Integrated, Digitised and All Domain Warfare

The IRR [22] describes that the UK approach to warfare will be joint and all-domain, underpinned by data and information. It also emphasises the urgent requirement to continue to modernise the force in this area to keep pace with technological developments today, and to evolve to meet the threats of the future. It reinforces the need to understand and exploit the impact of digital capabilities, and invest in them now to enable greater precision, speed, lethality and mass. There is a requirement for sufficient mass and game-changing technology, combined with the skill of our personnel in employing them.

> ***Digitised**. We will seize the game-changing opportunities offered by the digital advances of recent years to maintain a decisive advantage against our adversaries. This will mean shifting our thinking to fully integrate both steel and software, iteratively developing – spiralling – our existing capabilities to achieve battle-winning advantage. This also requires us to invest in enhancing the skills of our people, and to take our Allies with us on the journey. [22]*

> ***Integrated**. To address the increasing range and complexity of threats globally, in space, and in cyberspace, we will foster a truly integrated approach to deterrence and defence. This means enhancing integration across all services and domains, across Government, and with allies and partners, and industry, as well as across regions, and the spectrum of conflict. [22]*

Fully exploiting the benefit of integrated, digital systems is dependent on getting the right information, to the right people, at the right time, in a format that supports the tasks that they are conducting. This needs to be done without overloading decision makers, increasing the risk of error, or driving up personnel numbers or skill requirements of operators and those responsible for setting up and supporting these systems to unacceptable levels. Human Factors practitioners will play a key role in optimising user interaction with these systems and the workflows that span multiple systems of systems, minimise risk and support the wider sociotechnical impacts that these systems have on Personnel, Training and Organisational DLODs.

2.5 Adaptability, Innovation, Experimentation and Exploitation of New Technologies and Adaptability

There is a clear desire articulated within Defence strategy to rapidly modernise our armed forces by becoming more innovative and agile in the acquisition of new technologies. The Defence Innovation Priorities, Defence Technology Framework (DTF) [14], Integrated Review [7] and Defence Command Paper [8] highlight key policies and motivations, which sit at the heart of efforts to mobilise and transform Defence through “technology-led modernisation”.

> ***Innovative.** Modernisation is the key to our fighting edge. We will accelerate the modernisation of our capabilities, through innovation and experimentation. We need to continue to prioritise research and development, and science and technology, working ever closer with industry to achieve faster pull-through of next-generation capabilities. Our strategic advantage is maintained when Government and industry are working in lockstep. A common endeavour will ensure clearer requirements, secure a robust*

industrial base and resilient supply chains, and enable faster development and fielding of new capabilities. [22]

With this desire for rapid fielding of new technologies the line between concept development, research, acquisition and in-service capabilities are likely to become increasingly blurred. HFI needs to become more involved in and relevant to Technology Demonstrator Programmes, Experimental and Prototype Warfare, Innovation Spearheads and Urgent Operational Requirements. It will be critical that Human Sciences are engaged in R&D and innovation activities from the earliest opportunity to ensure that the human component is considered from the outset. Thereby ensuring the knowledge of the opportunities, risks, requirements and impacts on the human component are understood so that they can be fed into Capability Planning and Acquisition activities.

There will be a need for increased awareness of HF and HFI within Trials units and innovation and experimentation based projects together with easily accessible guidance and best practice tailored to these groups. It is also critical that innovation should not be constrained solely to equipment and technology. Innovative non-technological means of achieving operational advantage should also be pursued as part of both the Human Sciences S&T and HFI agendas.

*The value of **adaptability at pace** – agility – on the battlefield has become clear. We have learned that staying ahead of the threat and gaining strategic advantage can be achieved through novel and creative means, exploiting technology and adapting weapons systems, such as Uncrewed Air Systems, during contact, rather than relying entirely on an existing force package. This underscores the requirement for a more agile acquisition process and an even stronger partnership between government and industry, both primes and small- and medium-sized enterprises. The battlespace is changing quickly, and so we must respond with a new partnership with industry and a focus on delivering rapidly upgradeable capability more quickly. [22]*

2.6 Focus on Defence People

The IRR places significant emphasis on Defence People *"… they are inescapably the foundation on which our strategic advantage is built. Regular, reservist or civil servant, they are the most important asset we have. As ever more autonomy and Artificial Intelligence come into the workplace, their importance does not diminish; instead, we would argue, they become ever more critical." [22]*

In the next decade we must transform our workforce to meet the ever-growing demand for technical skills in the modern battlespace but we must do this by upskilling our current service personnel and enhancing our training, education and apprenticeship offer to those who are joining anew. We are proud to recruit from every community in the United Kingdom – we will continue to do so. [22]

This interrelationship between people technology, innovation and modernisation is complex and is one that HFI has a potentially significant role in supporting – this is discussed in more detail in Focus Area 4.

Over the decades ahead, the ships, tanks and planes in our strike groups, armoured brigades and combat air squadrons will require ever fewer people but that will not necessarily mean our workforce will be smaller. We may have fewer people on the front line but a much larger community of specialists supporting them. As we learn more from Ukraine about the changing nature of modern battle and explore the opportunities in AI and automation, we will maintain our force levels broadly at the levels announced in DCP21. [22]

2.7 Implications for HFI

- To counter the emerging threats posed by our adversaries, the UK is seeking to modernise its armed forces by rapidly harnessing technological innovations. HFI has two fundamental roles to play in achieving this desire to modernise and innovate:

  - Firstly, supporting technology led innovation activities to understand user needs and applying Human Factors methods and guidance to inform design, thereby optimising human in the loop performance, and maintenance activities.

  - Secondly, supporting FLCs in understanding the inter-relationships between the people and technological components of capability and how to best integrate them.

  While this is not dissimilar to the role that HFI has today, it will need to be applied earlier and more rapidly within Capability Development and Delivery processes and non-traditional acquisition approaches and innovation activities. It will also require a closer relationship between Capability and Personnel Directorates to ensure the most cost-effective integration of the People and Technological components of capability.

- There is a need to take a more socio-technical approach to Capability development driven by the move toward an adaptable, digitised, integrated, all-domain force that is designed for permanent and persistent global engagement alongside our allies.

3 FOCUS AREA 2 – HFI ACROSS THE CAPABILITY LIFECYCLE

In order to outmatch the threats that the UK faces today and may face in the future the IRR [22] reaffirms the need highlighted in previous reviews [15][16][17][18] that Defence needs to radically reform its approach to acquisition. The IRR highlights the importance of driving greater pace and agility into how we acquire military capability to the front line, including by prioritising timely delivery over perfection and the use of iterative development as a means of adapting to changing need. The ambition set out in the IRR is to reduce radically the average time from the identification of a military need to contract placement and from contract placement to delivery to the front-line. Consequently, this focus area highlights some of the most significant implications for the future of HFI and how it contributes across the capability lifecycle.

3.1 Pace and Flexibility of Acquisition Processes and New Acquisition Pathways

Mobilising, Modernising & Transforming Defence [15] and the DE&S Innovation Strategy [16] state that in order for Defence to stay ahead of emerging threats it needs to transform and radically change the way it does business. These documents outline the need for Defence to become a more agile organisation, capable of continuous and timely adaptation, unencumbered by unwieldy process and structures. While changes in how the MOD is organised and operates is already occurring, the desire for further change is emphasised in the DE&S Strategy 2025 [17], Defence Command Paper [8][22], and Defence and Security Industrial Strategy (DSIS) [18]. These highlight the importance that a more agile approach to acquisition will play in staying ahead of our adversaries. It is likely that the desire for innovation and rapid adoption of technologies will lead to alternative means of acquiring capability, outside of the traditional CADMID based approach, which itself will change to become leaner and more responsive to customer demands.

To be relevant, effective and widely adopted, HFI processes must adapt to focus on innovation and agility. HFI will need to support incremental, evolutionary and disruptive changes in capability. It must maintain its focus on delivering usable, safe, high-performing and cost-effective systems, without slowing down innovation. This may

require new processes, methods and tools to deliver rigorous Human Factors analysis and Human Centred Design (HCD) input at pace.

HFI processes and guidance will need to ensure that they reflect the drive for agility and seek to reduce unnecessary and inefficient processes. Furthermore, processes and guidance will need to be updated to address very early capability lifecycle activities and how they will feed into subsequent activities, especially where innovation projects/activities might be rapidly pulled into acquisition or fielded almost immediately without the application of a “traditional” HFI approach.

3.2 HFI Processes and HF Activities in Agile Project Management Approaches

Agile approaches are becoming increasingly prevalent in both hardware and software development projects. For example, the Navy Executive Committee has directed that the RN embraces Agile through a bespoke approach blending Scrum; Lean Start-Up; Lean; Design Thinking; and Project, Programme and Portfolio Management (P3M) [19] methodologies. HFI practitioners will need to be prepared to work as part of Agile teams and product owners.

3.3 Technology Pull Through and Early Concept Development

DE&S will continue to play a proactive role in Defence innovation [9]. They will build on existing connections with military operators, industry, academia, the Defence Innovation Unit, Dstl, the Defence and Security Accelerator (DASA) and other Government departments and agencies to rapidly pull through new or emerging technologies into acquisition programmes. To achieve this the DE&S Strategy highlights the intent to establish centres of expertise for key capabilities.

Where Defence seeks to rapidly identify, acquire and exploit emerging technologies it will be essential to have equally responsive and Agile approaches to delivering the people component of capability. HFI should be intrinsic to this, providing an integrating bridge between the technological process and people elements of the system and wider capability.

Identifying and understanding the people related impacts of new technology types at the earliest possible opportunity will be critical. This should start with a Science and Technology (S&T) research programme, which identifies, explores and experiments with these technologies. Thereby learning early lessons not just about the technology itself, but also how it will be operated and maintained most effectively and what changes might be required to the people and training required. Having a human science component integrated within innovation activities, capability demonstrators and the core S&T projects will be critical to achieving this early understanding.

The knowledge generated about the human component and user needs during the research and experimentation programme will need to be passed onto the Capability Directorate to inform options analysis and requirements generation, the Personnel Directorate to inform personnel planning and strategy, and training organisations to support training development and planning.

3.4 Spiral development and Evergreen Capabilities

The IRR [22] highlights that Capability is “never done”, rather it must constantly adapt to the changing operational environment and adversary. Instead of defining the exact force structure or precise capabilities needed, Defence must build its ability to adapt rapidly to maintain strategic advantage. To achieve this Defence must rapidly incorporate feedback from end-users and exploit emerging technology effectively. We need to build on existing capability, incrementally increasing its effect. This will be achieved by reforming the acquisition paradigm from one focused on specifying exact requirements to one that supports and encourages iterative development and has greater agility for prioritising and allocating resources.

HFI will need to adapt to this change of approach with processes in place to engage with capabilities on an ongoing basis across their life to identify emerging user needs, support the design, test and assessment of incremental enhancements to capability and identify emergent implications for the workforce.

3.5 In-Service Updates and Modernisation

Systems, which are currently in service or in the current acquisition pipeline will persist into the time frames discussed in the Integrated Review and may need to be modernised or updated at pace to counter emerging threats. There will be increasing demand for HFI to support more regular In-Service upgrades or updates, particularly for digital systems in order to maintain an “evergreen” capability. There is currently no specific guidance for the application of HFI within in-service updates or modernisation of existing systems. Retrofitting and integrating new systems and technologies into existing platforms and systems, and incorporating them into current ways of working presents significant HF challenges. These include challenges related to physical integration within already constrained working environments, cognitive demands resulting from increased information availability and reliance on human ‘swivel-chair integration’ between new and old systems (reliance on the human to facilitate the integration of old and new systems). New systems will also increase training requirements and changes in the knowledge and skills requirements and numbers of maintenance and support personnel.

3.6 Increased Focus on Integration and Systems of Systems

The IRR [21][22] highlights that value is not derived solely from physical characteristics; rather it comes from the degree to which concepts and capabilities are integrated and how adaptable they are to change. The Integration Design Authority (IDA) has been established to champion this cause and drive Defence towards a software, not hardware-defined approach; and to valuing systems-of-systems above platforms. The principal role of the IDA will be to optimise UK Defence integration: it will do so by taking a Portfolio-level view of Defence on behalf of Head Office and beginning to offer Integration as a Service for Defence, providing the reference framework for Defence to make informed decisions regarding capability choices [22]. HFI should consider how it can support the IDA in ensuring that the HF risks and wider people implications resulting from Systems of Systems Integration are addressed. This may a require a shift away from HFI being a single project/single system focussed process to one that also supports the human centred development of capabilities made up of multiple systems.

In addition DE&S will use its position at the centre of Defence's acquisition network to seek greater alignment across Military Command requirements and programmes by placing an increased focus on integration across and between programmes. *"Future capabilities will need to be integrated across land, sea, air, space and cyber and interoperable with our allies."* [17].

The desire for DE&S to act increasingly as a capability integrator will require HFI practitioners to apply their knowledge outside of individual systems and support HFI at a System of Systems level. This is an area that should be an increasing focus for HFI due to the potential Human Factors issues that emerge at systems boundaries, as well as the opportunities that arise to optimise performance and enhance user experience through greater technological integration (which includes sub-optimal performance, increased risk of human error, increased training demands and safety risks). New processes and guidance may be required to support HFI practitioners working across acquisition projects and in-service support teams to achieve this.

The desire for integration and alignment across the requirements of the individual Commands and Programmes will raise both strategic and tactical challenges for HFI as well as opportunities. These include: understanding People Related Requirements across user groups and use cases, defining common user interface standards and style guides, common Target Audience Descriptions (TADs) and managing emergent HF risks at the system boundary. There will also be a role for Dstl and the S&T community to support the FLCs in considering Capability Integration and System of Systems from a Human Factors and socio-technical perspective from the outset of capability planning.

3.7 Accelerated Digital Solutions

DE&S recognise that digital technologies are central to the capabilities that they deliver and that while their traditional focus on large platforms remains critical, they will also embrace new ways of integrating systems and data across the battlespace. The DE&S Strategy [17] highlights a number of digitally focused areas of importance to HFI, including:

- **Capability Centres Of Expertise** - DE&S will *"bring together separate capability projects into centres of expertise which will act as "pools of knowledge" that draw upon the expertise of industry, academia, military operators, Defence Digital and Dstl."* [17]. HFI approaches and appropriate HF expertise should be embedded within these Capability Centres of Expertise.

- **Adopting Digital Lifecycles** – Recognising the importance digital technologies will play in accelerating delivery timescales and reducing project and support costs DE&S will *"bring digital solutions into our design, test, assurance and through-life support activities. This includes the use of digital twin technologies for trials, big data analysis to improve support, digital environmental tracking for equipment, and the digitisation of certification and assurance evidence."* [17]. HFI should consider whether it needs to adapt, in terms of the approaches, methods and tools which it draws on to support the use of digital lifecycles within acquisition. HFI practitioners may need to learn new skills to make greater use of digital twins and models within human centred design approaches and Human Factors analysis activities.

3.8 Maximising Productivity in Defence Procurement

DE&S is committed to becoming more efficient and effective. The DE&S Strategy highlights that *"To support the implementation of the MOD's Integrated Review, we must improve how we work and maximise productivity. We are targeting a reduction in workforce costs over the next four years through more efficient and effective processes, structures and ways of working." [17]*. In the desire for a leaner and more efficient DE&S organisation, there may be a drive to make HFI processes leaner and more efficient, potentially taking a more risk-based approach to its application. HFI may be challenged to justify its value and the size of the workforce supporting its application in future.

HFI will need to be in a position to articulate people related risks and the value that it adds to reducing project risk, maximising operational effectiveness and managing whole life costs through optimisation of people related costs, supporting safety and hazard reduction, and thereby delivering best possible value for the tax-payer. There may also be a need for the development of a rapid, low overhead, risk-based triage approach to HFI that can be applied to all projects regardless of the acquisition pathway to ensure that the people component is appropriately addressed.

3.9 Building a Stronger Relationship with Industry

Both the Integrated Review [7], Defence Command Paper [8] and their 2023 refresh [21][22] highlight that there will be significant changes in Defence's engagement and relationship with industry and the acquisition of capability in future. The Integrated Review [7] highlights the nature of this change: *"We will move away from the 2012 policy of 'competition by default' and prioritise UK industrial capability where required for national security and operational reasons. We will also reform and revitalise our approach to acquisition, exports and international collaboration, including greater use of government-to-government arrangements.".*

The Defence Command Paper [8] adds: "*The Defence settlement brings stability to the Defence programme and provides industry with the certainty they need to plan, invest and grow. Increased investment in R&D and close collaboration with industry will allow us to experiment and bring new and emerging capabilities more rapidly* into service, creating strategic advantage and economic opportunity.".

This is reinforced in the refreshed Defence Command Paper [22], which highlights that Defence will engage much earlier in strategic conversations with industry and move beyond the traditional customer-supplier relationship, developing long-term strategic alignment that not only delivers the capabilities required now, but "*binds the MOD and industry into a joint endeavour that can sustain the nation in times of conflict. This will require a collective effort that combines the expertise of the whole Defence enterprise: military, civilian, and industrial*" [22].

These industrial collaboration changes will impact on the manner by which HFI will be applied in some project types especially where there is closer partnership between DE&S and industry during project delivery. The current HFI process based around traditional customer/supplier, Capability Directorate/DE&S/industry delineations may need to be revised to support greater collaborative working. This may change the nature of the HF technical activities conducted by the Capability Directorate and DE&S.

The greater certainty provided by the DSIS [18] will deliver opportunities to build a resilient Suitably Qualified and Experienced Person (SQEP) HF and HFI capability within the industry supply base, however this may be targeted at certain capabilities of strategic importance to the suppliers and Defence. We must not be reliant solely on the trickledown effect, HFI must proactively exploit this investment opportunity; in order to grow industrial HFI capability to support future demand.

3.10 Expansion of the Supplier Base

There is a desire within current strategies to harness the innovation of small and medium sized enterprises within defence procurement and grow them to provide benefits for the wider economy as part of a wider export strategy. This desire to involve a greater number of Small and Medium Enterprises (SMEs) in procurement has a potentially significant impact on HFI as these organisations may not have an in-house Human Factors capability and may not be aware of HFI processes and best practice.

SMEs will need to be made aware of the need to conduct HFI management and HF activities through People requirements in Systems Requirements Documents (SRDs) and contractual deliverables. SMEs with no organic HFI capability will need to be able to access SQEP HF practitioners from independent consultancies or teams with larger defence primes who do have these capabilities.

3.11 International Collaboration, Multinational Procurement, UK Defence Industry Prosperity and Exports

Both the DE&S Strategy [17] and Defence Command Papers [8][22] highlight a desire for both increased collaboration with our allies and export success of UK defence industry. The application of HFI processes within these multinational projects may be more challenging and there is currently limited guidance on how this is best conducted, managing HF requirements and population characteristics from multiple nations.

The desire for the UK defence sector to prosper internationally may also have implications for HFI activities within FLCs, DE&S and industry. HFI practitioners will need to support the design of systems beyond the UK user population in order for systems to appeal to an international market. Where programmes are acquiring systems from UK suppliers, there may be a need to consider People related requirements from both a UK user and international user perspective. This may drive the inclusion of requirements beyond the immediate needs of the UK user group and use cases or allow the supplier to develop systems which appeal to an international market, even though they may impact the optimisation of system design for a purely UK market.

An additional, related consideration is that with increasing globalisation of the defence industry and the size of the US defence market, it is possible that Military Off the Shelf equipment will be designed around US Standards and the US user population. This might present challenges for existing HFI policy, where systems are not designed around UK standards and there will be an increasing need to understand what any design delta between UK and US HF standards and user characteristics means for the Personnel and Training LODs and potential HF implications arising from integration issues with other equipment and on operational performance.

3.12 Implications for HFI

- HFI processes and guidance must remain aligned with Defence's ongoing transformation within acquisition. In particular, HFI needs to reflect the drive for agility, efficiency and a wider variety of acquisition pathways. To reflect the desire for more rapid adoption of emerging technologies there is a near term need for revised guidance to support HFI activities conducted during the earliest stages of the capability lifecycle and within innovation projects that might be rapidly fielded without the application of a "traditional" HFI approach.

- The desire for DE&S to act increasingly as a capability integrator will require HFI practitioners to apply their knowledge outside of individual systems and support HFI at a System of Systems and Capability level engaging with organisations such as the IDA.

- HFI processes, guidance and expertise needs to be in a position to support the development of the digital technologies that are increasingly central to Defence capabilities. HFI approaches and appropriate HF expertise should be embedded within the Digital Capability Centres of Expertise, and ensure that they have the methods, tools and expertise to support digital lifecycles within acquisition. HFI practitioners may also need to learn new skills to utilise digital twins within human centred design approaches and Human Factors analysis activities.

- As a result of spiral development and evergreen capabilities there will be a need for HFI to support projects and capabilities on an ongoing basis throughout their lifecycle, identifying emerging user needs, supporting the design, test and assessment of incremental enhancements, and identifying emergent risks and implications for the workforce. A through life human centred design approach and organisational culture will be key to this.

- HFI will be applied to an increasing number of projects utilising Agile Project management approaches. Consideration should be given to developing process guidance and best practice for applying human factors within such projects. HF practitioners should consider undertaking training to familiarise themselves with Agile Project management approaches and how to work effectively within them.

- The current HFI process based around traditional customer/supplier and FLC, DE&S, industry delineations may need revision to support greater collaborative working. The increasing role for SMEs who may not have an organic HFI or HF capability will also need consideration. These changes may change the nature of the HF technical activities conducted by FLC and DE&S and their relationship with industry.

- There is a desire for both increased collaboration with our allies and export success of UK defence industry. The application of HFI processes within these multinational projects, may be more challenging as there is currently limited guidance on how HF requirements and population characteristics from multiple nations are most effectively managed.

4 FOCUS AREA 3 - TECHNOLOGICAL CHANGE: IMPLICATIONS FOR HFI

One of the four key trends identified in the Integrated Review, which is likely to have the most significant impact on HFI over the next ten years is that of “rapid technological change”.

Technological developments and digitisation will reshape our societies, economies and change relationships – both between states, and between the citizen, the private sector and the state. S&T will bring enormous benefits but will also be an arena of intensifying systemic competition [7].

This section considers the implications for HFI of a selection of technologies identified in the Integrated Review, Defence Command Paper, Defence Technology Framework and DE&S Strategy as being of greatest importance to Defence. This section looks beyond human machine interface and interaction technologies and takes a wider view of the technologies that are likely to have the greatest impact on the human component of capability and personnel more generally. A more detailed look at future human machine interaction technologies can be found in research commissioned by Dstl.[5]

4.1 Critical Technologies for Defence

The IRR [22] highlights five critical technologies for Defence: Engineering Biology, Future Telecommunications, Semiconductors, Quantum Technologies and of greatest impact for HFI, Artificial Intelligence. In addition Defence will enhance its capabilities in fields such as robotics, human augmentation, ChemBio, directed energy weapons and advanced materials, which will be critical to the delivery of military capability and national security tasks.

Artificial Intelligence - AI is a strategic priority for Defence, as set out in the Defence AI Strategy, one of whose key goals is the strengthening of the UK’s defence and security AI ecosystem. We will deliver innovative capabilities to support current operations (primarily in Command & Control and Intelligence) and tools for greater

[5] https://dstl.github.io/Human-Interface-Horizons/

organisational agility like supply chain management. We will increase investment in AI-enabled military capability options, prioritising them in Force Development and 'balance of investment' exercises, and identifying 'quick win' capability enhancements and new AI options in major programmes" [22].

4.2 Pace of Technological Change

Rapid technological change will present opportunities for the UK to field new defence capabilities. HFI must be in a position to support the development and acquisition of these emerging technologies, with the right knowledge, methods and tools and at a pace that matches the desire to rapidly exploit them. These advances both in defence and dual-use commercial technologies will also present risks to UK security where adversaries may have greater access to more capable systems. Some of our adversaries may have the ability to rapidly access and field technologies that present new threats to our personnel which we will have to provide protection against at speed. HFI as a practice needs to be in a position to support the rapid development and fielding of systems to counter emergent threats.

The rapid pace of change is likely to result in a growing gap between what technological advances make possible and the limits of existing global governance. This will make frontier spaces and the technologies, infrastructure and data underpinning their use subject to intense competition over the development of rules, norms and standards [7]. Due to HFI's focus on integrating people and technological components of capability it might be called upon to address, within acquisition, some of the moral and ethical aspects of potentially contentious technologies used in a defence context such as AI, ML and HA. Adversarial use of these emerging technologies outside of international law might present particular challenges from a HF point of view. For example, autonomous systems making decisions without a human-in-the-loop might increase tempo and place increased cognitive demands and time stress on decision makers. However, UK response to such threats using similar technology will need to be developed in line with international legal frameworks (See Section 4.10 for further discussion of these moral and ethical considerations).

Understanding how the technology landscape will change is important so that HFI Technical Guides and standards, new analysis methods and tools, and HFI processes are developed in advance of the need for them. The Defence Technology Framework [14] and Defence Innovation Priorities [16] highlight key areas of technological change, which HFI will need to prepare for.

4.3 A Joined up Approach to the Accelerated Adoption of Technology

The IRR [21][22] highlight that in order to exploit technology more rapidly there will be a more joined up approach within technology management.

"R&D, S&T and innovation structures will be reorganised to create a single joined-up system, reducing bureaucracy, increasing our ability to push S&T faster and more effectively into capability, and developing a new integrated science, innovation and technology strategy." [22].

"This will include a new system for technology management, including a more robust system integration capability to assure our ability to access, integrate and use cutting-edge technologies, and a stronger approach to generating and modelling options for the conversion of innovative ideas and technologies into capability. We will establish a technology feasibility and deliverability scrutiny function, to give greater assurance that we can deliver our most ambitious programmes." [22].

To support this joined up approach from a people perspective, an increasing number of S&T activities undertaking technology development or systems research will need to take a more human centred approach, considering user needs, human factors and wider people implications earlier and more comprehensively. As technologies mature HF practitioners working within the S&T programme will need to engage first with FLCs and then hand over to HFI practitioners working in acquisition, so a closer working relationship between DST, Dstl, FLCs and DE&S will be needed. This approach is needed to ensure that user needs are appropriately and comprehensively considered during this rapid development approach. Without this, there is a risk that capability is acquired quickly, but has suboptimal performance in the hands of users, poses a safety hazard or has not considered the Personnel and Training implications adequately with resultant risk to these DLODs.

Consideration should be given to the adoption of Human Readiness Levels (HRLs), such as those developed by HFES/ANSI [25], alongside Technology Readiness Levels (TRLs) to help ensure a balanced development of Human and Technological components of capability.

4.4 Data, Digitisation, Information Systems, Systems of Systems, and Multi Domain Integration

A theme running throughout recent Defence strategies is the importance of information systems, interconnectivity, interoperability, and integration between all domains as part of Multi-Domain Integration (MDI). Greater integration across Domains and interoperability between systems will lead to increased quantities of information potentially available to personnel across the battlespace. Increased information availability will only lead increased operational effectiveness if it is used and integrated effectively, otherwise it risks cognitive overload, confusion, error and delays in decision-making.

This increasing interconnectedness of systems across the battlespace and new Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR) systems supports a key strategic driver that "*Understanding and assessment will be increasingly important to effective decision-making and action. We will need to integrate physically, virtually and cognitively*." and that: "*Capability in the future will be less defined by numbers of people and platforms than by information-centric technologies, automation and a culture of innovation and experimentation.*" [8].

This is reinforced in [22] "*Data-driven capabilities such as analysis, automation and autonomy will deliver exponential gains in mass, speed and precision, with their compound benefits being increased lethality, mobility, and sustainability. They also promise significant productivity gains; generative AI tools alone will enable faster*

delivery of tasks from the most mundane, like drafting correspondence, to the mission critical production of code to update vital battlefield software.". [22]

Defence has a desire to achieve more effective decision-making enabled by greater integration and information availability across Domains. As systems and force elements become more integrated and interoperable there are risks of emergent Human Factors issues developing at system boundaries, these may result in sub-optimal performance, increased risk of human error, increased training demands and safety risks. HFI will need to look beyond supporting the development of individual systems to support the design and fielding of systems of systems.

The application of HF within concept and doctrine development, experimentation, acquisition and system development will be crucial to ensure that the right information is provided to the right people, at the right time, in the optimal format and personnel are provided with the ability to communicate and collaborate effectively with others across the battlespace. HF and HFI specialists should be a key part in the Development and Delivery of not only the systems, which deliver MDI, but also their integration and operational deployment as a systems of systems.

Greater levels of integration, interoperability, complexity, and functionality will present challenges around preparing the people component of capability from a job design, skills and training perspective as well as understanding the through life people costs of such complex integrated systems making options analysis and cost benefit analysis more complex. Assumptions regarding the use of automation and robotics to reduce the reliance on people may not come to fruition for a variety of reasons [12] and any assumptions made over personnel cost reductions may not be realised. Consequently, HF analysis will be needed to support decisions regarding the trade-off between the costs associated with increased levels of integration and the potential benefits in performance and reduced through life costs associated with training and support.

4.5 Emerging Importance of Cyber and Space Domains

The Cyber domain continues to increase in importance to Defence. An increasing number of HF specialists in this area will be needed and HF practitioners more broadly will need to be aware of the HF associated with the cyber domain and apply this to design to reduce vulnerabilities. HFI process and technical guidance specifically related to the Cyber domain needs to be developed and continually updated to keep pace with the rapid developments and threats faced in this field.

Similarly, Space will be a domain of increasing strategic importance to Defence, as the application of new technologies in space enables new possibilities and acts as a key enabler for other Capabilities. There is currently no domain specific HFI Technical Guidance to support the development and acquisition of space technologies and systems. It will be essential for HFI to be in a position to support this increasingly important domain. The United States Department of Defence (DOD) and NASA have been operating extensively in this field for many years and have established Human Systems Integration (HSI) and HF capabilities. Future UK collaboration with these organisations, as well as the growing domestic commercial space sector, should be considered to establish what already exists in terms of HF guidance for the design of

Space Systems as well as working together on the development of new guidance in areas of mutual interest.

4.6 Artificial Intelligence, Machine Learning and Autonomy

Artificial Intelligence (AI), Machine Learning (ML) and the autonomous systems that they enable are identified extensively within recent Defence strategy documents as being of particular interest to Defence; which have the potential to fundamentally change military capability and administrative functions alike. They have the potential to drive efficiency, effectiveness and distance personnel from hazardous and risky environments and make administrative tasks more efficient. They will also present new challenges and risks and will have potentially significant implications on the nature of the workforce in terms of numbers of personnel, their locations and the skills that they will require.

> *"The Defence AI Strategy [26] highlighted AI's enormous potential to enhance capability, increase the quality of decision-making and tempo of operations, and improve the speed and efficiency of business processes and support functions. Remarkable recent developments such as the rapid breakthrough of Large Language Models (LLM) reinforce the Strategy's key message: a radical upheaval is underway and AI-related strategic competition is intensifying; therefore, our response must be rapid, ambitious, and comprehensive."* [27]

In time, these technologies have the potential to radically impact on almost all aspects of the Defence Enterprise across physical and cognitive work and present new threats from our adversaries.

> ***"****Autonomous vehicles will increasingly perform a variety of functions, from last-mile resupply and logistics, to uncrewed wingmen flying as part of a system around our combat jets. Small cheap drones will increase our intelligence coverage and provide new options for delivering effects. Smart networks and sensors will feed sophisticated decision-support software, enabling faster decision-making. Software – not least in its power to make old technology new – will keep our capabilities at the cutting edge, giving us a decisive edge in the battlespace of the future." [22]*

4.7 Human Factors in the Delivery of Responsible AI

Sudden advances in AI have heightened concerns about AI-related risks. Defence is committed to being safe and responsible in its development and use of AI, and are establishing the frameworks and processes needed to assure responsible and ethical outcomes [22]. To achieve this Defence is using a broad 'systems' perspective to ensure AI-related issues are addressed systematically and effectively by focusing on outcomes, and delivering through clear frameworks & processes, of which consideration of the human impact of AI will form a crucial part.

A key aspect of MODs commitment to the responsible use of AI is the ethical framework [27], which will guide Defence's approach to adopting AI, in line with rigorous existing codes of conduct and regulations. These principles are applicable across the full spectrum of use cases for AI in Defence, from battlespace to back office, and across the entire lifecycle of these systems. Human Factors and consideration of the human

component are a fundamental component of these principles and the first three in particular. A summary of these ethical principles can be found in APPENDIX A.

4.8 Implications of AI for HFI

AI will have a significant impact on activities and roles across Defence from Combat through to back office administration. For Defence to realise the full benefit of its investment in AI it will not be enough to focus exclusively on the development of technology. It will be essential to understand how advances in AI can be best utilised within the wider socio-technical context, melding technology, people and process. It will be critical that Human Factors experts specialising in AI technologies are fully integrated and involved in AI development activities being undertaken in S&T, Capability Development, experimentation, acquisition and fielding as well as in initiatives such as the Defence Centre for Artificial Intelligence. This will place significant demands on HF and HFI practitioners to support their development, acceptance, fielding and maintenance and update across the capability lifecycle [12]:

- HF Practitioners will play a crucial role in delivering Defence's Responsible AI Approach.

- HFI practitioners will need an increased understanding of Robotic and Autonomous systems and the AI and ML technologies that underpin them. This increased understanding will need to be supported by evidence based technical guidance, best practice and a toolset to support specification, development and evaluation of Robotic and Autonomous systems and in the formation of Human Machine Teams (HMT).

- AI technologies will not just be fielded in operational contexts, but also in back office, administrative and support functions. HFI practitioners may be called upon to support the acquisition and fielding of these technologies within these applications. Human factors input will be increasingly required through the life of AI based systems as they are updated, upgraded and retrained with new datasets, to ensure that whole system performance and risks are appropriately considered and managed.

- Increased awareness of the People impacts of Robotic and Autonomous Systems (RAS) and the AI and ML technologies that underpin them will be required by desk officers within the FLCs involved in decisions regarding future Capability. Due to the complex nature of AI technologies and the impact that they can have across the DLODs, HFI specialists might be called upon earlier in the capability lifecycle to support FLCs in experimentation, requirements generation and understanding the risks and impacts on the People Component. It will be increasingly critical that the introduction into service of RAS equipment using AI technology is appropriately managed so that the potentially radical changes in people's roles, operating procedures and processes, organisational structures etc. are handled such that they are successfully adopted and utilised.

- In some areas AI, automation will have significant impacts on the tasks conducted by certain roles in future and the knowledge and skills that they require. HFI practitioners will have a significant role in shaping future roles and personnel

requirements through function allocation between human and machine and in user interface and work process design. The increased use by Defence of RAS and the AI and ML technologies that underpin them will put Defence into increasing competition with the civilian sector to recruit personnel at many levels with the knowledge, skills and attitudes required to operate, maintain and support these systems. HFI has a role to play in understanding and, through good design, managing the increasing demands for personnel with scarce skillsets.

4.9 Human Enhancement and Augmentation:

An area identified in the Defence Technology Framework (DTF) of particular relevance to HFI is the field of human enhancement and augmentation.

> *"Future conflict may expose UK Armed Forces to a technologically enhanced adversary where human enhancement is the norm. Armed Forces employing extensively enhanced human capability are likely to achieve a significant strategic and tactical advantage over those whose personnel are constrained to their innate abilities."* [14].

> *As technology becomes more sophisticated, we also need to think about our people; human augmentation technologies will help them overcome the environment and the adversary. All these capabilities will be delivered safely, ethically, and responsibly, in line with the values of the society we serve.* [22]

While HFI will have limited involvement in areas such as pharmacological and nutritional based enhancements it will have a significant role to play in the near to mid-term in the development and acquisition of:

- Systems, which adapt to the cognitive workload and/or physiological state of the user.
- Assisted wearable technologies and exoskeletons, which enable loads to be carried that exceed the unaided ability whilst reducing injury risk.
- Telepresence.
- Human-Machine Interfaces such as cognitive support tools to aid situational understanding and decisions; novel sensing capabilities (e.g. haptics) and visual display technologies, to augment the user's perception of the world.

In the longer term, depending on Defence's future policies on human augmentation and enhancement, HFI may have a critical role to play in the acquisition of more advanced and potentially invasive technologies such as brain computer interfaces and medical implants, which monitor the human body, and could also support cognition and spatial sensing. HFI needs to be in a position to work with medical regulators and a range of stakeholders outside of those traditionally engaged with to support the acquisition and support of enhancement and augmentation technologies.

4.10 Moral and Ethical Considerations of Emerging Technologies

Some emerging technologies will challenge current rules, norms and standards. HFI might be called upon to address some of the moral and ethical aspects of potentially contentious technologies used in a Defence context such as Artificial Intelligence (AI), Machine Learning (ML) and Human Augmentation (HA), where they impact on the human component of capability. Adversarial use of these emerging technologies outside of international law might present particular challenges from a HF point of view. For example, autonomous systems making decisions without a human in the loop might increase tempo and place increased cognitive demands and time stress on decision makers. However, UK response to such threats using similar technology will need to be developed in line with international legal frameworks.

There is a significant focus within Defence on the moral legal and ethical use of AI and autonomy within Defence systems. HFI and HF practitioners will play a key part in ensuring that meaningful human control is maintained within automated and autonomous system and will therefore play an important role in ensuring that systems together with their operating procedures meet the legal, moral and ethical standards to which the UK has signed up to. This will require HFI practitioners to understand and apply these standards and principles when developing HF requirements, informing function allocation, interface design and during user testing and acceptance activities.

4.11 Implications for HFI

- Over the next decade, technology is set to advance rapidly. We will see the emergence and adoption of new technologies, which will provide Defence with new capabilities and deliver new levels of performance. Some of these technologies will have significant implications for the people component of capability. It will be increasingly critical that the introduction into service of disruptive technologies is managed appropriately so that the potentially radical changes in people's roles, operating procedures and processes, organisational structures etc. are handled such that they are successfully adopted and utilised.

- With this desire for rapid fielding of new technologies the line between concept development, research, acquisition and in-service are likely to become increasingly blurred. HFI will need to become more involved in and relevant to Technology Demonstrator Programmes, Experimental and Prototype Warfare and Innovation Spearheads. The refinement of HFI tools and methods must continue, to remain agile and functional to the development and assessment of emerging technologies; and at a pace that matches the desire to rapidly exploit them. It will be critical that Human Sciences are engaged in R&D and innovation activities from the earliest opportunity to ensure that the human component is considered from the outset and knowledge of the opportunities, risks, requirements and impacts on the human component are understood so that they can be fed into Capability Planning and Acquisition activities.

- To support Defence's desire for accelerated technology adoption an increasing number of S&T activities undertaking technology development or systems research will need to take a more human centred approach, considering user needs, human factors and wider people implications earlier and more

comprehensively. As technologies mature HF practitioners working within the S&T programme will need to engage first with FLCs and then hand over to HFI practitioners working in acquisition, so a closer working relationship between DST, Dstl, FLCs and DE&S will be needed. This approach is needed to ensure that user needs are appropriately and comprehensively considered during this rapid development approach. Without this, there is a risk that capability is acquired quickly, but has suboptimal performance in the hands of users, poses a safety hazard or has not considered the Personnel and Training implications adequately with resultant risk to these DLODs.

- Consideration should be given to the adoption of Human Readiness Levels (HRLs), such as those developed by HFES/ANSI [25], alongside Technology Readiness Levels (TRLs) to help ensure a balanced development of Human and Technological components of capability.

- Defence will need evidence-based HF technical guidance, developed through research, analysis and experimentation available in advance of new technologies maturing to the point at which they could be fielded in military systems. A prioritised forward plan for future HFI Technical Guides is required. This should be produced and agreed by the MOD/Industry HFI Steering Group together with funding proposals for their development.

- Due to the position of HFI in integrating people and technological components HFI practitioners might be called upon to address the moral and ethical aspects of potentially contentious technologies within acquisition.

- There is a specific need for HF involvement in AI development to realise Defence's commitment to the responsible use of AI across the Defence Enterprise and in particular the ethical principles of *Human-centricity, Responsibility* and *Understanding*. HFI needs to consider what role it has to play within the delivery of AI enabled systems within Defence.

- The Cyber and Space domains continue to increase in importance to Defence. An increasing number of HF specialists in these areas will be required together with HF guidance pertinent to these areas.

5 FOCUS AREA 4 - CHANGES IN THE FUTURE WORKFORCE AND DEFENCE PEOPLE STRATEGY

5.1 People First and the Interrelationship between People and Technological Components of Capability

The Defence People Strategy [10] and the Defence Command Paper [8] highlight that the Defence workforce will continue to change and evolve. Defence's response to the 2023 IRR [22] places People at the forefront of its thinking as well as highlighting the intrinsic link between the technological and human components of capability and in particular the significant impact that AI and Autonomy could have on the workforce. HFI and HF practitioners are particularly well positioned to understand and communicate the implications of one on the other. However, this needs to be applied early in capability development and requires the support and closer integration of Capability and Personnel Directorates within FLCs (Figure 1).

"[people] are inescapably the foundation on which our strategic advantage is built. Regular, reservist or civil servant, they are the most important asset we have. As ever more autonomy and Artificial Intelligence come into the workplace, their importance does not diminish; instead, we would argue, they become ever more critical." [22]

"In the next decade we must transform our workforce to meet the ever-growing demand for technical skills in the modern battlespace but we must do this by upskilling our current service personnel and enhancing our training, education and apprenticeship offer to those who are joining anew. We are proud to recruit from every community in the United Kingdom – we will continue to do so." [22]

"Over the decades ahead, the ships, tanks and planes in our strike groups, armoured brigades and combat air squadrons will require ever fewer people but that will not necessarily mean our workforce will be smaller. We may have fewer people on the front line but a much larger community of specialists supporting them. As we learn more from Ukraine about the changing nature of modern battle and explore the

opportunities in AI and automation, we will maintain our force levels broadly at the levels announced in DCP21." [22]

In a digital-first world, we will make the most of the opportunities offered by automation and Artificial Intelligence. We will both grow an adaptable and sustainable workforce that can adjust quickly to evolving demands, and harness modern technologies to drive greater efficiency and effectiveness. As a top priority, we will look to digitalise and harness modern technologies to drive greater efficiency and effectiveness. [22]

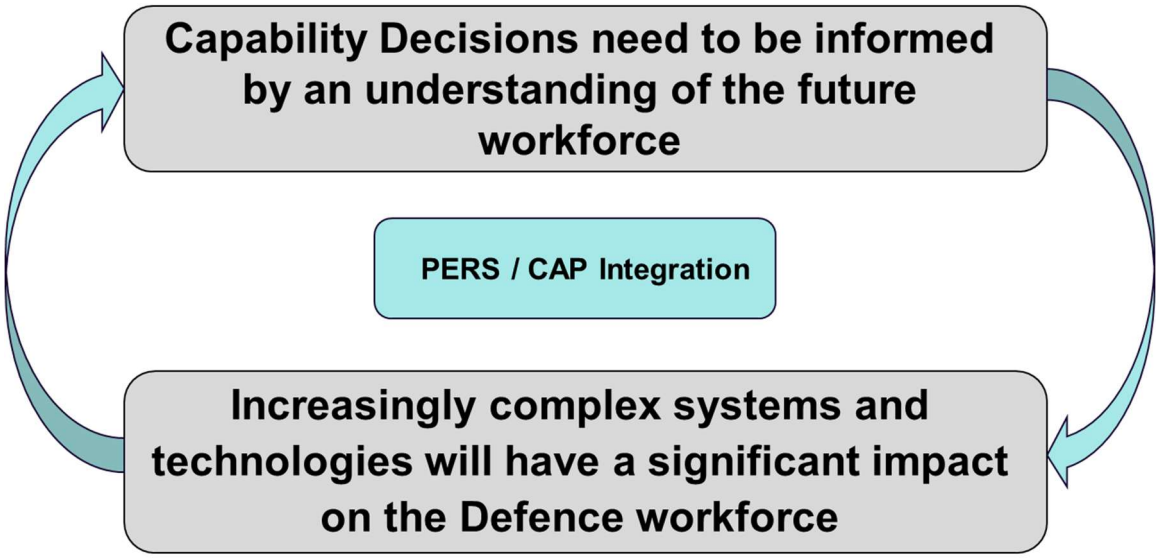

Figure 1 Capability development and workforce planning are intrinsically linked – HFI is well positioned to understand and communicate the implications of one on the other.

5.2 Decreases in Numbers, Increases in Specialisation

The Defence workforce is set to become smaller but more highly skilled and better reflect the nature of society from which it is recruited. It is likely that Defence personnel will become more specialist across Defence, with higher entrance requirements and more sophisticated technical skill demands. It will be essential to maintain up-to-date information regarding the physical, medical and cognitive characteristics of the whole workforce, both regular and reserve, perhaps through on-going and enduring capability rather than periodic surveys and assessment.

5.3 Greater Workforce Diversity

The proportion of females and personnel from ethnic minorities will increase across all roles and ranks and the importance of Reservists will continue to grow. The Integrated Operating Concept highlights the need to attract and retain a more diverse workforce, drawn across the Union and the Commonwealth, with skills and experience and diversity of thought aligned to the information age and contemporary conflict.

HFI will have a key role to play in ensuring that equipment, systems, clothing, Personal Protective Equipment (PPE) and platforms are designed for and usable by the full

diversity of the future workforce. HFI will also need to be cognisant of the risks of excluding or disadvantaging certain user groups through unconscious bias and/or lack of data leading to poor system design, this is particularly important for AI systems. There are multiple examples of this occurring inadvertently in the civilian sector, for example, pulse oximeters overestimating oxygen levels in people with darker skin[6] and gender and race bias in speech recognition systems[7].

Guidance on design for diversity might be required to ensure that system design takes into account the full range of users and is not subject to unconscious bias in both physical and software systems.

"We will continue to diversify our workforce, including through increased recruitment of women and ethnic minorities. We will explore how we can better recruit and support people with disabilities." [22]

5.4 An Increase in Reservists

With the increasing role that personnel across the Reinforcement, Operational and Strategic Reserve elements will play in the future force [23][24], HFI should consider providing guidance to take into account the needs of the Reserve Elements with systems design. This guidance should be developed with input from reservists to identify the particular challenges they encounter with the equipment that they use. Depending on the Reserve Element being considered a large proportion of reservists will have less opportunity and time to train with equipment than regular personnel. This places particular emphasis on the need for the development of systems that are quick to train, do not require specialist training infrastructure and are not subject to significant levels of skill fade. The application of good human centred design approaches, human factors best practice and the use of familiar interaction patterns and interface conventions will support these needs through the development of intuitive, low cognitive demand interfaces and systems designs. However, some Reserve Elements will be highly specialised and have professional skill sets that will also need to be considered within the design of the systems that they use.

Reservists may have different cognitive and physical characteristics from regular personnel and this should be considered within the development of the Target Audience Descriptions, systems design, testing and acceptance. This is particularly important where reservists might make up a large proportion of the user population e.g. in specialist roles.

"The War in Ukraine has reminded the world that Reserves are essential both on and off the battlefield. Making the Armed Forces more capable and resilient, the Reserves deliver both mass and access to battle-winning specialist civilian capabilities that

[6] Tatman R (2017). Gender and Dialect Bias in YouTube's Automatic Captions Proceedings of the First Workshop on Ethics in Natural Language Processing, pages 53–59, Valencia, Spain, April 4th, 2017. Association for Computational Linguistics ethicsinnlp.org/workshop/pdf/EthNLP06.pdf

[7] Pulse oximetry and racial bias: Recommendations for national healthcare, regulatory and research bodies (2021). NHS. Race & Health Observatory. https://www.nhsrho.org/wp-content/uploads/2021/03/Pulse-oximetry-racial-bias-report.pdf

Regular forces cannot readily generate or sustain. They are also a crucial part of Defence's engagement with the nation. Reservists must be recognised – at all levels in Defence – as a vital part of the Defence workforce and the introduction of the Spectrum of Service will further enable their utilisation and effectiveness." [22]

5.5 Application of Human Factors across Defence

Technologies such as AI, Automation and Robotics will be used across the Defence enterprise not just in operational and combat support capabilities. Applications might include administrative support, medical, HR, maintenance and staff work. Human Centred Design approaches have much to offer in this context to extract the greatest benefit from technology, understand and manage the people implications, optimise workflows and achieve productivity gains without second order effects on retention, health and well-being and achieving the sorts of change in the workforce attitude towards Defence careers that the Haythornthwaite Review of Armed Forces Incentivisation (HRAFI) [24] is seeking to achieve.

Defence should consider whether a wider human centred approach to the development of systems across the Defence enterprise and not confined to Acquisition is needed.

5.6 Implications for HFI

- Technologies such as AI, ML and Autonomy will have a significant impact on the Defence workforce in terms of the numbers of personnel required, their locations and the knowledge, skills and experience that they require. Understanding these implications early in the capability lifecycle will be increasingly critical, highlighting the importance of applying HFI within Capability Development and supporting closer integration between the Personnel and Capability directorates in the FLCs.

- The Defence workforce will continue to change and evolve. In order to ensure that platforms and equipment fully consider future diversity, it will be essential to maintain up to date data regarding physical, medical and cognitive characteristics of the whole workforce, perhaps through on-going and enduring capability rather than periodic surveys and assessment.

- HFI should consider providing guidance developed with input from reservists to identify the particular challenges that they have from an HF and usability point of view.

- Defence should consider whether a wider human centred approach to the development of systems across the Defence enterprise is needed and not just confined to Acquisition.

6 Conclusions

For over 30 years HFI has supported the delivery of safe, high performance and cost-effective systems through its approach to the integration of people, process and technology. However, HFI must continue to evolve and adapt to changes in the wider operational, strategic and technological landscape, providing the processes, tools, techniques and guidance to meet today's challenges and Defence's needs.

Based on an analysis of current Defence strategies, policies and priorities and technological trends this paper has provided insights into how HFI might need to adapt to the changing context in which it is employed. Across four focus areas, implications for HFI have been identified, which are intended to stimulate discussion within the HFI stakeholder community as to how HFI might need to adapt and continue to support Defence and the People of our Armed Forces. The following provide a non-definitive summary of the most pertinent findings for HFI:

Technological Change – Defence strategies highlight a commitment to modernisation through the adoption of cutting-edge technologies. HFI and HF practitioners working within Defence must stay up to date with the fast pace of technological development and the implications for their discipline. Existing HFI Technical Guidance needs to be updated and new guidance developed to support a best practice, evidence based approach to human factors associated with the emerging technologies of greatest interest to Defence.

Workforce Diversity – The Defence workforce is becoming more diverse and it is anticipated that it will be made up of a greater proportion of Reserves in the future. HFI should ensure that it has the data available to support the development of systems to accommodate this more diverse workforce.

Workforce Implications of Emerging Technologies – Some of the technologies of most interest to Defence will have significant impacts on the Workforce in terms of the numbers and locations of personnel and the skills that they require. HFI has a valuable role to play, especially during the early stages of capability development, in understanding the interrelationships between people, process and technology and

informing decisions that impact on them. As technology pervades all areas of the Defence enterprise, from combat systems to personnel management, there is potential for a wider human centric approach to technology adoption across Defence. Consideration should be given to how HFI might support this wider need for HF support across Defence.

Artificial Intelligence – It is anticipated that AI will have a radical and transformative effect on how people interact with technology, the jobs that they do and the skills that they require. HF and HFI will be called upon to support Defence's commitment to responsible and ethical use of AI and the development of Human Machine Teams that will be central to Defence's use of AI enabled capabilities.

Pace of Acquisition – A pervasive theme across focus areas is the desired pace of technological change and modernisation. HFI will have to work within a context of shorter acquisition timelines and more rapid transition of technologies from S&T and innovation projects to acquisition and into service. To support this desire the integration of the people and technological components of capability will need to be considered earlier within the capability lifecycle to allow the People and Training DLODs to develop as rapidly as the Equipment DLOD. This has implications for S&T programmes and Front Line Commands and the role that they play in the early stages of HFI. The desire for more rapid acquisition also has implications for the HFI processes and HF methods employed, which will need to match this increased pace without reducing the quality and rigour currently provided, especially in performance and safety critical systems. There may also be implications for the number of HFI practitioners required to deliver the increased level of input.

Acquisition and Development Approaches – Spiral acquisition and digital lifecycles will require greater through life application of HFI. A through life human centred design approach will be need to be taken to ensure that emergent user needs are identified and incremental updates to capabilities receive human factors input, test and acceptance. Agile project management approaches are becoming increasingly common, especially for software development. HFI and HF practitioners need to be able to work within Agile approaches, supported by training, and guidance material.

Systems of Systems – Increasingly, Capabilities will be made up of integrated systems of systems. HFI will need to support both system development, the integration of systems of systems and the HF implications within these constructs. HF impacts typically emerge at systems boundaries, impact on performance and safety and have wider personnel and training implications.

Relationship with Industry – There needs to be a closer, more strategic relationship between Defence and industry. Greater collaboration will impact on the manner by which HFI will be applied in some project types, especially where there is closer partnership between DE&S and industry during project delivery. The current HFI process based around traditional customer/supplier, Capability Directorate / DE&S / industry delineations may need to be revised to support greater collaborative working.

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List of abbreviations

ADL	Analysis Delivery Leads
AI	Artificial Intelligence
BAME	Black, Asian and Minority Ethnic
BOI	Balance of Investment
CADMID	Concept, Assessment, Demonstration, Manufacture, In-Service, Disposal
CAP	Capability (Directorate)
CDP	Chief of Defence People
CIEHF	Chartered Institute of Ergonomics and Human Factors
CIWG	Capability Integration Working Groups
CONEMP	Concept of Employment
CSA	Chief Scientific Advisor
DAU	Defence Autonomy Unit
DAIC	Defence AI Centre
DCP	Defence Command Paper
DE&S	Defence Equipment and Support
DLOD	Defence Lines of Development
DOD	Department of Defense
DT	Delivery Team
DTF	Defence Technology Framework
DSIS	Defence and Security Industrial Strategy
DST	Defence Science and Technology
Dstl	Defence Science and Technology Laboratory
EDP	Engineering Delivery Partnership
FinMilCap	MoD Finance & Military Capability
FLC	Front Line Commands
GEAR	Guide to Engineering Activities and Review
HA	Human Augmentation
HCoC	Human Component of Capability
HF	Human Factors
HFE	Human Factors Engineering
HFI	Human Factors Integration
HMT	Human Machine Teaming
HSI	Human Systems Integration
HuFIMS	Human Factors Integration Management System
IEA	International Ergonomics Association
INCOSE	International Council of Systems Engineers
INM	Institute of Naval Medicine
ILS	Integrated Logistics Support
IR	Integrated Review
IRR	Integrated Review Refresh
ISTAR	Intelligence, Surveillance, Target Acquisition, and Reconnaissance
ITS	Internal Technical Support
JSP	Joint Service Publication
KiD	Knowledge in Defence
MDI	Multi-Domain Integration
ML	Machine Learning
MOD	Ministry of Defence
MANPRINT	Manpower and Personnel Integration
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organisation
PERS	Personnel (Directorate)
P3M	Project, Programme and Portfolio Management
PPE	Personal Protective Equipment
PT	Project Team
RAF CAM	Royal Air Force Centre of Aviation Medicine

R&D	Research and Development
RAS	Robotic and Autonomous Systems
RN	Royal Navy
S&T	Science and Technology
SciAd	Scientific Advisor
SME	Small and Medium Enterprise
SQEP	Suitably Qualified and Experienced Personnel
SRD	System Requirements Document
SRO	Senior Responsible Owner
TAD	Target Audience Descriptions
TNA	Training Needs Analysis
TTCP	Technical Cooperation Program
URD	User Requirements Document

APPENDIX A AI Ethical Principles

The following describes three of the MOD's five AI ethical principles, which have particular relevance for HF and HFI practitioners

A.1 First principle: Human-Centricity

The impact of AI-enabled systems on humans must be assessed and considered, for a full range of effects both positive and negative across the entire system lifecycle.

Whether they are MOD personnel, civilians, or targets of military action, humans interacting with or affected by AI-enabled systems for Defence must be treated with respect. This means assessing and carefully considering the effects on humans of AI-enabled systems, taking full account of human diversity, and ensuring those effects are as positive as possible. These effects should prioritise human life and wellbeing, as well as wider concerns for human kind such as environmental impacts, while taking account of military necessity. This applies across all uses of AI-enabled systems, from the back office to the battlefield.

The choice to develop and deploy AI systems is an ethical one, which must be taken with human implications in mind. It may be unethical to use certain systems where negative human impacts outweigh the benefits. Conversely, there may be a strong ethical case for the development and use of an AI system where it would be demonstrably beneficial or result in a more ethical outcome."

A.2 Second principle: Responsibility

Human responsibility for AI-enabled systems must be clearly established, ensuring accountability for their outcomes, with clearly defined means by which human control is exercised throughout their lifecycles.

The increased speed, complexity and automation of AI-enabled systems may complicate our understanding of pre-existing concepts of human control, responsibility and accountability. This may occur through the sorting and filtering of information presented to decision-makers, the automation of previously human-led processes, or processes by which AI-enabled systems learn and evolve after their initial deployment. Nevertheless, as unique moral agents, humans must always be responsible for the ethical use of AI in Defence.

Human responsibility for the use of AI-enabled systems in Defence must be underpinned by a clear and consistent articulation of the means by which human control is exercised, and the nature and limitations of that control. While the level of human control will vary according to the context and capabilities of each AI-enabled system, the ability to exercise human judgement over their outcomes is essential.

Irrespective of the use case, Responsibility for each element of an AI-enabled system, and an articulation of risk ownership, must be clearly defined from development, through deployment – including redeployment in new contexts – to decommissioning. This includes cases where systems are complex amalgamations of AI and non-AI components, from multiple different suppliers. In this way, certain aspects of

responsibility may reach beyond the team deploying a particular system, to other functions within the MOD, or beyond, to the third parties which build or integrate AI-enabled systems for Defence.

Collectively, these articulations of human control, responsibility and risk ownership must enable clear accountability for the outcomes of any AI-enabled system in Defence. There must be no deployment or use without clear lines of responsibility and accountability, which should not be accepted by the designated duty holder unless they are satisfied that they can exercise control commensurate with the various risks.

A.3 Third principle: Understanding

AI-enabled systems, and their outputs, must be appropriately understood by relevant individuals, with mechanisms to enable this understanding made an explicit part of system design.

Effective and ethical decision-making in Defence, from the frontline of combat to back-office operations, is always underpinned by appropriate understanding of context by those making decisions. Defence personnel must have an appropriate, context-specific understanding of the AI-enabled systems they operate and work alongside.

This level of understanding will naturally differ depending on the knowledge required to act ethically in a given role and with a given system. It may include an understanding of the general characteristics, benefits and limitations of AI systems. It may require knowledge of a system's purposes and correct environment for use, including scenarios where a system should not be deployed or used. It may also demand an understanding of system performance and potential fail states. Our people must be suitably trained and competent to operate or understand these tools.

To enable this understanding, we must be able to verify that our AI-enabled systems work as intended. While the 'black box' nature of some machine learning systems means that they are difficult to fully explain, we must be able to audit either the systems or their outputs to a level that satisfies those who are duly and formally responsible and accountable. Mechanisms to interpret and understand our systems must be a crucial and explicit part of system design across the entire lifecycle.

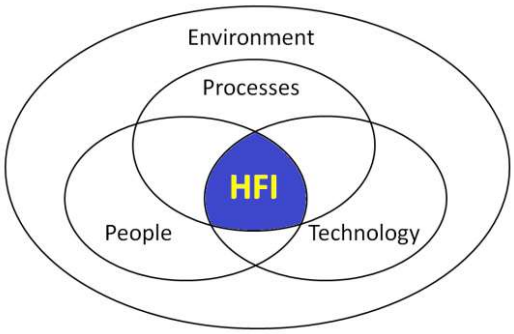
This requirement for context-specific understanding based on technically understandable systems must also reach beyond the MOD, to commercial suppliers, allied forces and civilians. Whilst absolute transparency as to the workings of each AI-enabled system is neither desirable nor practicable, public consent and collaboration depend on context-specific shared understanding. What our systems do, how we intend to use them, and our processes for ensuring beneficial outcomes result from their use should be as transparent as possible, within the necessary constraints of the national security context.

ANNEX A HUMAN FACTORS INTEGRATION EXPLAINER

A-1 WHAT IS HUMAN FACTORS INTEGRATION?

Human Factors Integration (HFI) is the UK MOD's process which supports the effective integration of people, process and technology within the context of the operational environment to deliver cost-effective capability.

It is a systematic process for identifying, tracking and satisfactorily addressing People-Related considerations, ensuring a balanced development of both technologies and human aspects of capability [1].



The HFI approach seeks to ensure that the right activities are undertaken at the right time within Capability development and delivery; activities which contribute to delivering the most cost effective solution and optimising the interactions between people and technological components[8] of the capability and taking into account the environment in which the Capability will be operated under all conditions of use.

A strength of HFI is that it draws on a broad range of specialist skills from both human science and engineering disciplines as well as contributing to analysis and engineering activities across a project. This positions it ideally to identify and resolve potential issues and optimise solutions across project stovepipes.

HFI has its roots in the US Army's Manpower and Personnel Integration (MANPRINT) initiative dating back to the 1980s. It has undergone a number of updates and revisions since its inception to reflect changes in acquisition approaches. Current HFI policy together with its goals, processes and products is described in Joint Service Publication

[8] The human component refers to the military personnel and civilian support staff who operate, manage, train, maintain and support the Capability, including the organisations within which they work. The technological component refers to all of the equipment, hardware, software, information and materiel necessary to deliver the required Capability. These two components are linked by organisational and management processes that include ways of working, operational tactics, techniques and procedures, and associated training.

(JSP) 912 [1]. The standards by which HFI requirements and processes are contracted for are described in Defence Standard 00-251 [3].

AN OVERVIEW OF THE DEVELOPMENT OF HFI IN DEFENCE

Since the 1990s, Human Factors Integration (HFI) has been the process used by the MOD to integrate the human and technological components of capability. It is a structured process designed to be applied across the whole Capability Lifecycle with the ultimate objective of supporting Defence in delivering high-performance, safe, sustainable and resilient military capabilities through the most cost-effective mix and integration of people, processes and technology.

HFI is not limited to the design of user interfaces, workspaces and interactions with equipment, nor is it intended to be only be applied within Capability Delivery/Acquisition. Rather, it seeks to address human factors considerations throughout the whole capability lifecycle and across all Defence Lines of Development (DLODs). The information that it provides should be used to: inform decision making during Capability Development, Delivery and Integration; understand the workforce and training implications of introducing new technologies; optimise human-systems interactions; and support MOD in meeting their health and safety obligations. HFI should also have a role through the In-Service Phase of the Systems life-cycle supporting introduction into service, in-service updates and upgrades and addressing emergent HF related issues.

A-2 BENEFITS OF HFI

HFI provides a flexible process to support the identification and mitigation of people-related risks and issues during Capability and equipment development. It delivers a wide range of benefits to Defence including [1]:

- HFI enables the effective integration of the human and technological components of capability, thereby optimising whole system performance and mission effectiveness.
- The application of HFI will support the development of the most cost effective human and technological solution to a capability gap.
- Risk Management – HFI will reduce the risk of accidents and incidents and help MOD meet its duty of care obligations; control training and personnel costs; manage risk between DLODs (e.g. understand future workforce demands and potential impacts of scarce skill sets on equipment solutions).
- Realise the benefits of emerging technologies, such as AI, Autonomy, Human Augmentation, etc.
- HFI can draw on resources that enable an efficient development process through early identification, avoidance and mitigation of HF problems and minimising delays to the project schedule and costs resulting from redesign costs associated with poor usability or failure to meet user needs.

To achieve these benefits HFI needs to be started early, be fully integrated within a project and be appropriately resourced.

A-3 HFI AND RELATED TERMS

There is often confusion over the similar sounding terms and acronyms used within HFI in particular around HFI, HSI, HF and HFE.

Human Factors Integration (HFI) is defined by JSP 912 as "A systematic process for identifying, tracking and resolving human-related issues to ensure a balanced development of both technological and human aspects of capability."

Human Systems Integration (HSI) is the name given by the US Department of Defense and a number of other Defence and industry bodies and is equivalent to the UK MOD's HFI process.

Human Factors (HF) is defined by the International Ergonomics Association (IEA) as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimise human well-being and overall system performance".

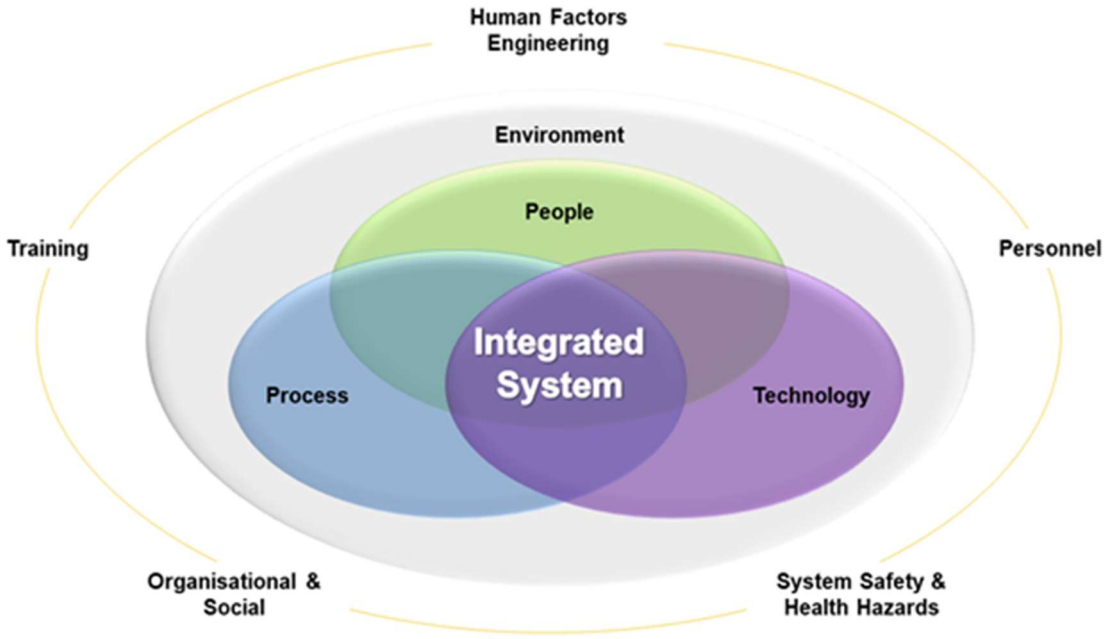
In some parts of the MOD the term Human Factors refers to the training required by those operating in safety critical roles to understand the Human Factors which contribute to accidents and impact on safe systems of work.

Human Factors Engineering (HFE) – Human Factors Engineering (HFE) is one of seven HFI domains. HFE is the scientific application of Human Factors data and methods to the design of equipment, tasks and working environments. (HuFIMS)[9].

[9] http://aof.uwh.diif.r.mil.uk/aofcontent/tactical/hfi/content/hufims_home_abouthfi.htm

A-4 HFI DOMAINS

HFI uses a framework of five[10] 'Domains' to allow for all aspects of human behaviour, capabilities and limitations to be addressed within the HFI approach.



The Defence Standard for HFI, DEF STAN 00-251, highlights that "*the five domains are not all of equal importance to or the specific responsibility of the HFI Focus within DE&S. The primary domain from an acquisition HFI perspective is HFE, which is effectively 'owned' by the HF community*."

The other HFI domains may be led by their respective discipline specialists and organisations and overlap significantly with wider DLOD or engineering activities. Hence a safety engineering specialist may have the lead on safety management for the system with input from a Human Factors practitioner, or the Training Authority will be the focus for the integration of HF activities with the Training DLOD.

However, as part of the holistic approach to HFI, work done in these areas must be reviewed to ensure that the human elements have been adequately considered across all DLODs, as decisions made in one domain can easily impact on another. For example, where the level of automation is increased there may be a change in required staffing levels and training requirements.

A-5 WHO ARE THE SIGNIFICANT CONTRIBUTORS TO HFI?

There are a number of key organisations across the MOD, industry and Academia identified in JSP 912 who should be involved in in the application of HFI. There are also

[10] The HFI framework was changed from seven to five Domains in 2022 consisting of: Workforce; Training; Human Factors Engineering; System Safety & Health Hazards; Social & Organisational.

organisations, such as MOD Head Office whose strategies and policies influence delivery of HFI.

This section outlines the roles that these organisations have in the application of HFI and supporting Human Factors activities as articulated in JSP 912 and associated process guidance provided on the KiD website[11]. This provides an idealistic perspective of the implementation of HFI. In practice this idealistic implementation of HFI and HF support varies from project to project, particularly outside of its application within the capability delivery/acquisition phase of the capability lifecycle. Some of the challenges in the application of HFI within these organisations are provided in the main body of this paper.

MOD HEAD OFFICE (CDP AND FINMILCAP)

MOD Head Office does not currently have a formal role in HFI policy or practice. However, the strategies which are set in Head Office, especially in FinMilCap and CDP have a significant downstream impact on HFI.

DEFENCE EQUIPMENT & SUPPORT

The Defence Authority for Technical & Quality Assurance within DE&S is the UK's Ministry of Defence (MOD) organisation that manages a vast range of complex projects to buy, support and supply vital equipment and services that the Royal Navy, British Army and Royal Air Force need to operate effectively.

DE&S is the current owner of HFI Policy, as set out in JSP 912 and the HFI Defence Standard 00-251. A single post within the Engineering Group is responsible for the maintenance and management of the policy and standard as well as the HFI technical and process guides contained in the Human Factors Integration Management System (HuFIMS). This post is also responsible for the assurance of projects' HFI activities as part of 1) the Integrated Logistics Support (ILS) Solutions Envelope and 2) reviews conducted as part of the DE&S Guide to Engineering Activities and Reviews (GEAR).

DE&S Engineering Group contains a team of HFI technical specialists within Internal Technical Support (ITS) who provide support to project teams within DE&S and to the HFI Policy Post.

FRONT LINE COMMANDS

Front Line Commands (FLCs), as Capability Sponsor, are responsible (as defined in JSP 912) for generating and contributing to a range of key HFI products and activities.

Responsibilities of the Capability Sponsor include ensuring that the User Requirements Document (URD) and Concept of Employment (CONEMP) include adequate coverage of the human component, and that the characteristics of users and maintainers are defined within a Target Audience Description. In reality, for many projects these products, which are key inputs for downstream HFI activity are generated collaboratively

[11] http://aof.uwh.diif.r.mil.uk/aofcontent/tactical/hfi/content/hufims_home_abouthfi.htm

between DE&S and the FLCs, sometimes with the support of other organisations such as industry or Dstl.

FLCs adopt a pan-DLOD approach to Capability Management. This means that FLCs should be drawing on Human Factors analyses to inform Capability Development activities. In particular they should ensure that the costs, risks and opportunities related to the integration of the human and technological components across all DLODs are understood and considered in options analysis, down-selection and balance of investment decisions.

In addition to the role of FLCs early in the capability lifecycle, they also have a key role throughout the acquisition process as User and customer for the equipment delivered by DE&S. In this position they have a powerful role to play in requirements management, design reviews, and system acceptance as well as influencing the focus of the DE&S project team. FLCs are also fundamental in making decisions regarding any trades/decisions that impact on the non-equipment DLODs.

DEFENCE SCIENCE AND TECHNOLOGY LABORATORY

The Defence Science and Technology Laboratory (Dstl) is part of the MOD and leads on the delivery of the MOD's science and technology programme, as well as supplying specialist science and technology services and providing expert advice, analysis and assurance within Capability Development and Acquisition. This position gives Dstl a good understanding of the emerging technologies which will be used in future generations of systems, as well as informing Capability Development and User Requirements generation.

The Human and Social Sciences capability within Dstl has a number of roles in relation to HFI. These include: leading engagement on HFI with international allies and standards organisations; delivering human sciences research to inform future HFI standards and technical guides (although it does not produce these guides itself), providing specialist HF support to platforms and systems, undertaking research that underpins future capabilities; providing HF and HFI support to DE&S Project Teams and delivering research to inform future workforce planning, personnel and training strategies.

INSTITUTE OF NAVAL MEDICINE (INM) AND RAF CENTRE OF AVIATION MEDICINE (RAFCAM)

While not typically applying HFI themselves INM and RAF CAM provide specialist HF analysis and support to projects applying it.

The Institute of Naval Medicine (INM) specialises in naval research, support, and training. A small Human Sciences team provides underpinning research to the Royal Navy, as well as independent technical advice and HF input on areas such as noise and vibration, safety, survival and habitability.

The RAF Centre for Aviation Medicine (RAF CAM) specialises in military aviation research and support. A team of aviation psychologists provide underpinning research to the RAF, as well as technical support to Military Air Accidents, and advice and

independent HF input on areas such as life support and ejection seat systems through a wider set of human sciences expertise drawn upon when required.

INDUSTRY

A combination of large organisations (usually prime contractors), smaller suppliers, and consultancies provide HF, HFE and HFI support across various stages of the procurement lifecycle. Typically, this involves working with industry based project managers to support project planning and risk management, and with the engineering team on requirements management, design, development, evaluation, and acceptance activities.

As commercial entities, the degree of HF, HFE and HFI activities undertaken by suppliers is typically driven by the requirements and contracted deliverables placed upon them. As such, it is essential that the Systems Requirements Documents and deliverables at project milestones, contracted through the Statement of Requirement, include appropriate consideration of HFI processes and Human Factors activities within them. Because of this, the level of involvement of HFI and HFE in projects can vary considerably from project to project.

ACADEMIA

Universities have supported Defence for many years, providing the highest levels of scientific expertise on a variety of complex human performance and wellbeing challenges. Universities have unique testing facilities and capabilities that permit specific studies (e.g. thermal habitability) or analysis that are beyond the expertise of industry to be conducted. This deep expertise can be called upon to support HF activities conducted as part of a wider HFI process. This may become more important in future as more complex technologies begin to be used in Defence systems. It is worth noting that some universities do not participate directly in Defence work, due to the ethical foundations that might underpin their institutions.

A-6 NATIONAL AND INTERNATIONAL STANDARDS

Defence seeks to adopt international and national standards wherever possible, only developing specific Defence Standards where absolutely necessary. While HFI has a specific Defence Standard [Def Stan 00-251], non-Defence Human Factors standards are often utilised alongside it for example within SRDs or test methods. The MOD has a seat on the British Standards Institute (BSI) and International Standards Organisation (ISO) committees related to physical ergonomics and interactive systems. This allows the MOD to contribute to and influence national and international standards so that they meet the needs of the Defence sector. The MOD is also a member of the INCOSE[12] Human Systems Integration Working Group which provides the opportunity to access world leading experts in the application of HF within systems engineering and influence internationally recognised best practice in this field.

[12] International Council on Systems Engineering (INCOSE)

A-7 HFI GOVERNANCE

HFI policy [JSP 912] is owned by the Defence Functional Authority (DFA) and is reviewed annually. The associated Defence Standard [Def Stan 00-251] is owned by DE&S Head Engineering Group and are reviewed and updated if needed on a 5 year cycle. The review process for Def Stan 00-251 is led by the HFI Policy Desk Officer and is managed within the Engineering Group's formal review processes. Updates to HFI Process and Technical Guidance provided through KiD is managed by the HFI Policy Desk Officer with support from the HFI ITS team.

The MOD/Industry HFI Steering Group and the associated Liaison Group provides a forum for representatives of MOD and industry to inform the development of HFI policy, processes, standards and technical guidance as well as liaising with other professional bodies and organisations.

A-8 INTERNATIONAL COLLABORATION

The UK has a close relationship with other nations who are working on the development of new HF methods, tools and conducting research into new human machine interaction technologies through The Technical Cooperation Program (TTCP), NATO and bi-lateral agreements. This provides access to a significant body of research and experience, but also allows the UK to access, influence and collaborate with allies to address gaps and potential obsolescence in our own standards.

There are fewer nations developing HFI-like processes and policies, the most notable of these is the US, who the UK engages with through these same multi-national and bilateral arrangements.

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For quarter of a century, Human Factors Integration (HFI) processes, standards and technical guidance have been applied to help ensure that the needs of the personnel who operate and maintain Defence's systems are addressed within the Delivery of Defence Capability. HFI has evolved over time adapting to changes in wider acquisition policy and technological development. Current Defence Strategies suggest that the coming years will see significant changes the operating environment, procurement processes as well as the rapid development and adoption of new and potentially disruptive technologies. Arguably the cost-effective integration of People, Process and Technology has never been more important than it is today.

This paper has been produced jointly by Dstl and DE&S with the intention of stimulating debate over how current HFI processes should be refined and adapted for the future in response to changing Defence priorities and strategies. It explores the challenges associated with the application of HFI today as well as how changes in the wider organisational and strategic context within which it is applied might drive future change.

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