Ministry of Defence

Future Combat Air System (FCAS)
Digital Engineering Strategy



Contents

Foreword 2
FCAS Digital Engineering Strategy on a Page 3
Context 4
- Why FCAS needs digital engineering 4
- FCAS and GCAP Scope 5

FCAS Digital Engineering Capability Model 6
FCAS Digital Engineering Vision 7
Strategic Ends .....
- Advanced Integrated Engineering Capability 9
- GCAP Integration and Interoperability 11
- Engineering Through Life 13
- Data and Information Architecture 15
- Collaborative Working Environments & Infrastructure 17
- Capability Innovation and Evolution 19
- People and Skills 21
- Wider Applications and Benefits 23

Glossary of Acronyms and Terms 24

Foreword



The Future Combat Air System (FCAS) will deliver world leading next generation combat air capabilities, created by world class talent and skills. Among these capabilities is a next-generation fighter jet that is being delivered by the Global Combat Air Programme (GCAP), a trilateral collaboration between the UK, Japan, and Italy.

FCAS is re-defining how the Combat Air industry deliver capability and transforming how the Royal Air Force (RAF) operates and supports combat air capabilities in the battlespace throughout their lifecycle. Advances in digital technologies and an increasingly software-defined and data-driven approach to digital engineering is how we are delivering capability faster than any previous Combat Air generation.

The digital transformation of the aerospace engineering and manufacturing sector are accelerating the way we concept, design, simulate, test and manufacture capability. This is an important military and strategic advantage, driving innovation demand into the industrial base, generating a sustainable, highly skilled workforce that stimulates economic growth and places the UK as a global leader for collaborative digital engineering of complex systems.

Richard Berthon, Director FCAS

As one of the world's most digitally advanced combat air enterprises, FCAS will be underpinned by cutting-edge digital capabilities, playing a critical role across FCAS, transforming how we integrate systems, automate processes, and exploit emerging technologies, maintaining information and operational advantage throughout its lifecycle. The approach to developing and building complex products and systems will be upgraded to a sixth-generation way of working through the integration of engineering disciplines using digital assets, and increasing use of AI-driven processes, high-performance compute and quantum technology.

The demand and investment that FCAS is driving into the industrial base will energise and digitally transform industry, enhancing efficiency and interoperability of engineering approaches. The journey to achieving a sixth-generation Combat Air digital engineering capability is a very important aspect of FCAS, with many spillover benefits and broader applications across wider Defence, industry and government. It will boost UK economic growth and productivity, creating new, highly specialised roles, upskilling the existing workforce and attracting the next generation of highly skilled engineers to transform the Combat Air sector into a forward-facing, continuously evolving, innovative workforce. Bringing together the entire systems engineering lifecycle – from defining requirements through to delivering and verifying software – in a secure, compliant, and fully traceable way, dramatically accelerates development cycles and reduces sustainment costs over the capability lifecycle. This digital engineering transformation will play a vital role in our military strategic capabilities for decades to come.

Air Commodore John Fortune, FCAS Chief Digital and Information Officer

FCAS Digital Strategy on a Page

Diagnosis: where Digital Engineering is today for Combat Air

The UK Combat Air enterprise operates with fragmented IT tools, data, connectivity and approaches, and requires rapid modernisation for future systems to realise benefits for military effectiveness and enterprise efficiency.

Vision: where Digital Engineering needs to be for FCAS

To establish a secure, integrated and fully traceable digital engineering enterprise across Defence and industry, enabling combat air capabilities to be developed, assured, delivered and upgraded at the speed of relevance. By combining software-defined systems, trusted data, artificial intelligence and high-performance computing, FCAS will accelerate development, reduce through-life cost and sustain operational and combat advantage through continuous capability evolution.

Strategic Ends: how to achieve the Digital Engineering Vision

Defence's approach to achieve the Digital Engineering Vision is focused on eight strategic ends.

Advanced Integrated Engineering Capability. State-of-the art sovereign digital engineering capabilities that significantly accelerate development cycles, upgrades and certification of combat air capabilities through-life, with integration across industry, the RAF and broader Defence.	**GCAP Integration and Interoperability.** Cutting-edge GCAP digital engineering capabilities that reflect UK ambition, are integrated across the GCAP enterprise and are interoperable with wider FCAS capabilities.	**Engineering Through Life.** Digitally transformed in-service engineering through advanced integrated technologies, enabling faster update cycles and more effective and efficient sustainment through-life.	**Data and Information Architecture.** Common engineering data and information architectures and models are implemented across the enterprise to enable sharing, exploitation and re-use to enhance military advantage and drive development, support and efficiency.
Collaborative Working Environments and Infrastructure. Transformed global collaborative working environments and infrastructure at multiple security classifications connect engineers across FCAS, GCAP, industry and MOD, enabling collaboration through-life.	**Capability Innovation and Evolution.** Constant evolution of engineering methods, tools and technologies to enable rapid development of products and services to maintain business and military advantage.	**People and Skills.** A highly skilled sixth-generation engineering workforce that is adaptable and able to proficiently operate digital engineering processes through-life.	**Wider Applications and Benefits.** Digital engineering capabilities are applied across wider Defence and invigorate the industrial base, enabling maximum efficiency and boosting UK economic growth.

Means and Ways: how the strategic ends will be achieved

This document outlines the strategy (the what and why). The FCAS Digital Plan will explain how the Strategic Ends will be achieved and will be released separately.

Context

The Combat Air enterprise has traditionally operated with fragmented IT tools, data, connectivity and approaches to disciplines, resulting in slow delivery processes and higher costs. To bring the Combat Air industry and military into a sixth-generation way of working, there must be a transformation of engineering processes.

Digital engineering is defined as:

> **Digital Engineering:** An integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal. Digital engineering updates traditional systems engineering practices to take advantage of computational technology, modelling, analytics, and data sciences.

Advances in digital technologies are enabling a more collaborative approach to engineering, with Artificial Intelligence (AI) driven generative design and digital manufacturing techniques that draw on common data and shared models to foster visibility and co-ordination that traditional siloed approaches cannot achieve. This digitally enhanced co-ordination across the capability lifecycle will dramatically accelerate development cycles and reduce sustainment costs over the capability lifecycle.

Why FCAS needs digital engineering

The Future Combat Air System (FCAS) is the UK's sixth-generation air combat capability, employing a system of systems (SoS) approach to provide a transformative combat air capability. The SoS approach consists of the Core Platform (aircraft), Autonomous Collaborative Platforms (ACPs), effectors (weapons) and a broader digital enterprise, all of which must interoperate with multiple assets across all UK battlespace domains and with partners and allies. The FCAS Digital Strategy outlines the strategic digital vision for FCAS and states digital engineering as an important strategic end. This strategy builds on that strategic end, to provide strategic direction for digital engineering for future combat air.

Digital engineering is vital to FCAS because:

- **Adversary systems and pace of adaptability is evolving, and FCAS must out-pace them to maintain military advantage.** To do this we need resilient, integrated and continuously evolving state-of-the art digital engineering capabilities, optimised by technologies such as AI and high performance compute.
- **FCAS must lead the UK Defence Integrated Force and integrate with our allies to maximise military capabilities.** Greater connectivity across the sixth-generation force must be supported by digitally enabled engineering approaches.
- **FCAS must deliver interoperable military capabilities.** Different air vehicle types and their support systems must interoperate within ambitious timeframes. Compatible digital engineering approaches will support collaboration across multiple suppliers and systems.
- **Digital engineering accelerates delivery timelines and reduces cost.** Reduced development cycles and improved quality and visibility across capability lifecycles will result in military and economic benefit.

Digital engineering is how FCAS will acquire, sustain, and adapt combat air capability at the speed required to maintain operational advantage.

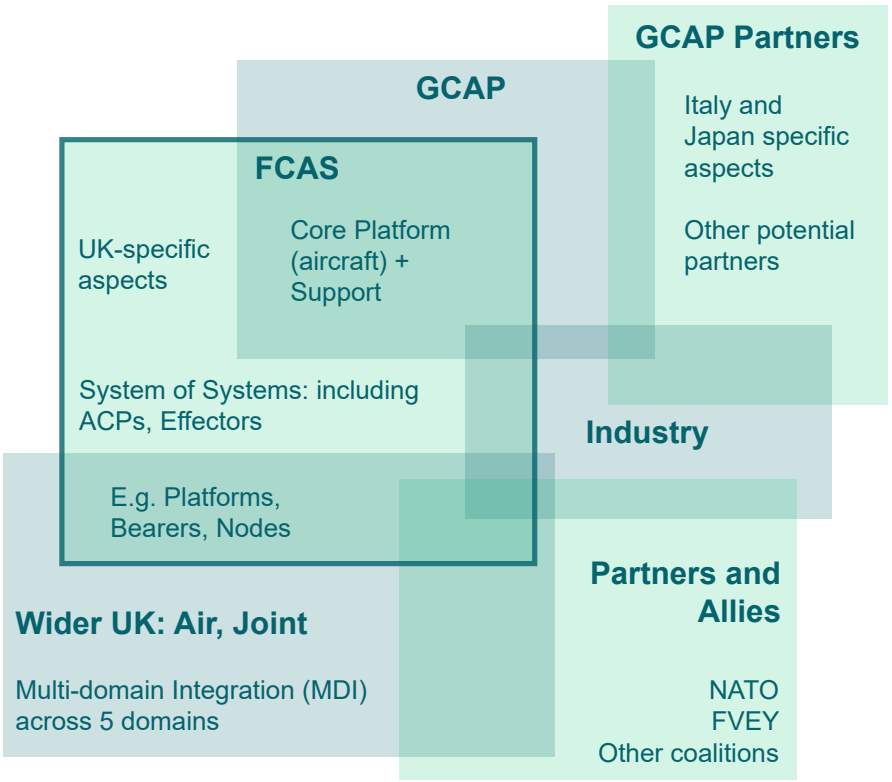
FCAS and GCAP Scope

The Global Combat Air Programme (GCAP) forms the heart of FCAS. In partnership with Japan and Italy, and other future potential partners, GCAP will deliver the Core Platform, Mission Enablement and support. GCAP will create an international enterprise with partner Ministry of Defence (MOD) organisations and global industrial collaboration to deliver, operate and sustain the capability through-life. In addition to GCAP, FCAS manage national scope covering:

- **System of systems integration** of the Core Platform (aircraft), support systems and other products and services into wider Air capabilities, UK Defence and with partners and allies.
- **Acquisition of assets not part of GCAP,** such as ACPs and effectors.
- **UK-specific capabilities and systems,** as part of common capabilities in the Air sector, for example relating to some aspects of training, support, Mission Enablement and Test and Evaluation capabilities, complementing those provided by GCAP.
- **Any UK-specific capabilities required for security or sovereignty reasons,** for example to manage aspects of through-life operation or adaptation of the Core Platform outside GCAP (which is the preferred delivery approach to maximise configuration control and minimise through-life cost).

The FCAS digital engineering approach must interoperate seamlessly across MOD and with GCAP and industry partners, linking data and tools to create a digital continuum across the design, build, test, support and update/upgrade record. Figure 1 below illustrates the scope of FCAS and GCAP.

Figure 1: FCAS enterprise context and scope



FCAS Digital Engineering Capability Model

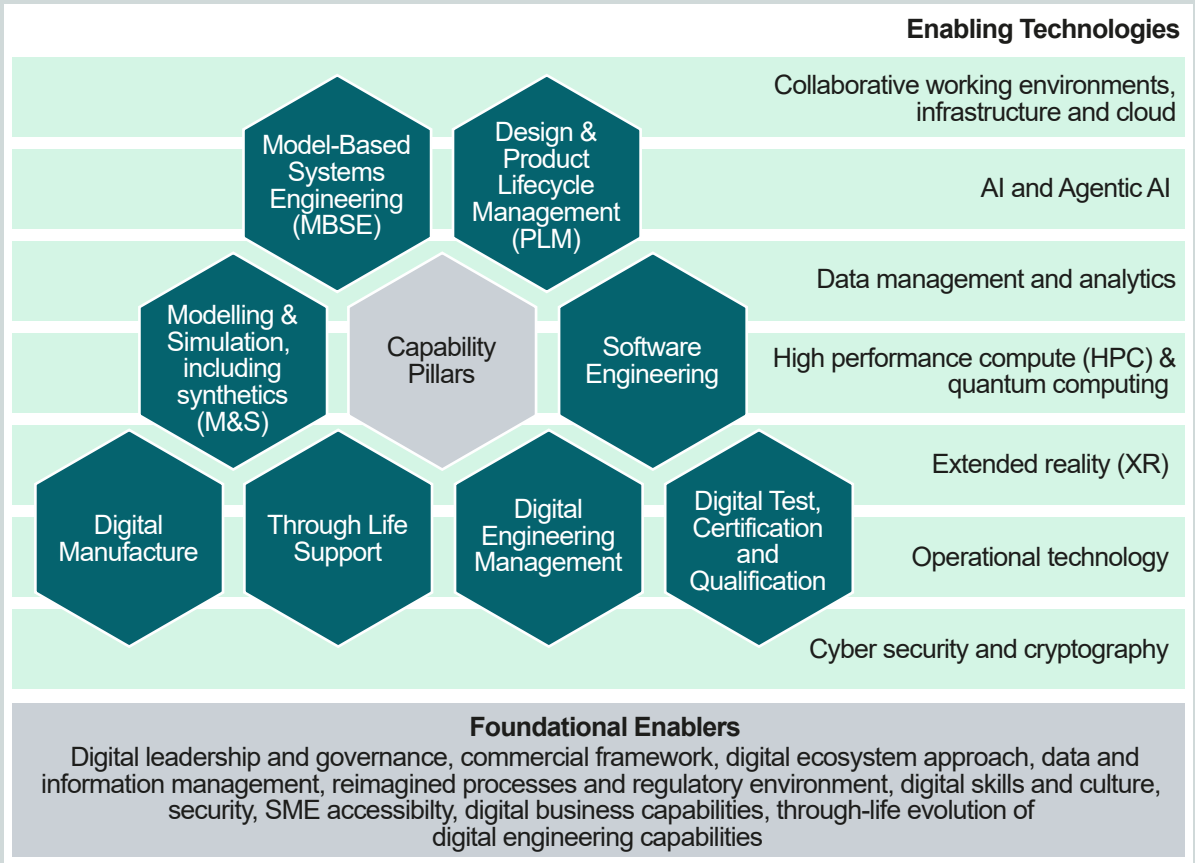
A coherent approach to digital engineering capability across FCAS is required to ensure through-life interoperability and military advantage. The FCAS Digital Engineering Capability Model (Figure 2) provides a high-level guide for digital engineering across the FCAS enterprise. This model is reflected in the GCAP digital engineering approach and should apply across all FCAS elements, including MOD and industrial suppliers outside of GCAP.

The model is a reference guide, noting that implementation will apply differently for each FCAS organisation according to need, circumstance and scale.

The model comprises **capability pillars,** supported by **foundational enablers** and crosscutting **enabling technologies** to improve, optimise and protect digital engineering capabilities through-life. These elements are intended to combine to form an integrated whole.

The terms in Figure 2 are included in the glossary.

Figure 2: FCAS Digital Engineering Capability Model



FCAS Digital Engineering Vision

To establish a secure, integrated and fully traceable digital engineering enterprise across Defence and industry, enabling combat air capabilities to be developed, assured, delivered and upgraded at the speed of relevance. By combining software-defined systems, trusted data, artificial intelligence and high-performance computing, FCAS will accelerate development, reduce through-life cost and sustain operational and combat advantage through continuous capability evolution.

An increasingly software-defined and data-driven approach to digital engineering capabilities will significantly accelerate development cycles, test, certification, qualification and acceptance through-life. These capabilities will enhance adaptability and underpin through-life support, enabling engineering and logistics efficiencies, adaptability and the sixth-generation combat air ambition. Engineering data and information will be accessible across GCAP, FCAS national elements, wider Defence, partners and allies across the capability lifecycle via a traceable and secure digital thread. This will align to the RAF future support concept covering engineering and logistics, as part of a more coherent 'Whole Force' approach aligned with evolving RAF core processes and trades.

Increased connectivity and data sharing must go hand in hand with robust cyber security and assurance measures. A greater attack surface increases potential attack vectors for adversaries. Cyber resilience across the FCAS enterprise is critical to protecting the combat air capability and maintaining operational advantage.

The principal challenge to transforming combat air engineering will not be the introduction of individual digital tools, but the integration of engineering activity across organisational, national, commercial and security boundaries.

There are many benefits from transforming digital engineering for Combat Air including:

- **Accelerated development and time and cost reduction.** A digitally enhanced co-ordination across the capability lifecycle through greater automation, reuse of digital artefacts and earlier testing will dramatically accelerate development cycles and reduce sustainment costs over the capability lifecycle.
- **Enhanced operational advantage.** Faster decision-making, improved interoperability and the ability to rapidly evolve software-defined capabilities will aid maintaining a competitive edge in an increasingly contested environment.
- **Highly skilled workforce.** Digital engineering will transform the workforce across the Combat Air industry, military and government into a forward-facing, continuously evolving, innovative workforce.
- **UK economic growth.** Developing digital engineering capabilities will boost industrial investment and growth across the UK Combat Air industry sector and with potential spillover benefits to other sectors.

This vision is characterised through eight Strategic Ends as described in the following pages.

[1] A sixth-generation combat air system is a rapidly adaptable and upgradable collection of crewed and uncrewed combat aircraft and supporting systems, which apply open mission systems and multi-spectral stealth to deliver Information Advantage, battlespace dominance, and disruptive and destructive effects as an integrated part of a multi-domain force.



Strategic Ends: Advanced Integrated Engineering Capability

State-of-the art sovereign digital engineering capabilities that significantly accelerate development cycles, upgrades and certification of combat air capabilities through-life, with integration across industry, the RAF and broader Defence.

FCAS will drive and develop seamless digital engineering capability across MOD and UK industry, supplementing GCAP digital engineering to meet wider FCAS needs and ensure appropriate sovereign control. National capabilities will be fully interoperable with GCAP through data and workflows, with the ability to integrate additional systems, such as ACPs from other nations and a range of suppliers. Digital engineering approaches should adhere to internationally recognised standards as much as possible to facilitate this.

The sixth-generation concept requires increased adaptability, ubiquitous and seamless data transfers globally and at multiple classifications, and a high degree of technical integration across governments and industry; all of which must be cyber resilient.

This will require increasingly autonomous and iterative design and development and advanced simulation development and testing environments, underpinned by AI and HPC with integrated capabilities to allow collaboration, resource sharing and economy of scale.

Key considerations are:

1. **Interoperability.** The digital engineering tools and approaches of systems acquired outside of GCAP, such as support elements, sovereign capabilities, effectors and ACPs, must be interoperable, including attendant digital engineering capabilities and data, requiring common standards and open architectures across FCAS and GCAP.

2. **Sovereignty.** The UK must have sufficient control of certain key aspects, notably the ability to assure the capability, the ability to operate it, the ability to sustain it, and the ability to modify at the operationally relevant speed. For example, sovereignty over software, including source code and build environments, to introduce rapid changes, which will require appropriate government and commercial agreements.

3. **Speed of through-life updates.** This will require iterative development and advanced simulation development and testing environments across the enterprise with lifecycle integration and continuous verification, qualification and certification.

4. **Transformed systems engineering, engineering management and manufacturing.** Model Based Systems Engineering (MBSE), modelling and simulation, advanced synthetics, Product Lifecycle Management (PLM) and transformed software engineering will form the core of the integrated future digital engineering environment.

5. **Software Approach.** The volume and reach of software will be far greater than previously, ranging across core aircraft and mission load software, ground training and synthetics, mission data exploit, logistics and through-life engineering. This will require a fully integrated software development capability for airborne programmable elements (software and hardware) and for enterprise-style software, for example for running simulations and data analytics.

6. **Agentic AI.** AI will be adopted where it demonstrably improves engineering speed, quality or insight, with human accountability, traceability and assurance. Agent Engineering offers the opportunity for goal-oriented, policy-compliant digital agents able to reason, plan and act across complex digital engineering workflows, interacting with digital engineering tools and humans to execute engineering processes and achieve assigned goals in a controlled, coordinated and assured fashion. Applications include MBSE, with requirements and architecture model development; design optimisation and quality assessment; software development; and simulations and testing. This offers huge efficiency opportunities through enhancing integration across disciplines, left-shifting development and freeing engineer time to high value-add tasks. Note that assurance of outputs, in particular relating to airworthiness, is a critical concern in the application of AI to engineering processes.

7. **Digitally Centric Test and Evaluation.** FCAS needs a digitally-centric approach to test and evaluation (T&E) to support qualification, certification and acceptance through-life. It lies at the heart of the sixth-generation concept to enable through-life adaptability. Regulation must evolve with the pace of new technology and methods with appropriate resource and skills.

8. **Commercial reform.** Meeting the desired rapid update cycles for software and exploiting the technology potential of AI-enabled engineering will require reform of commercial practices alongside the technology itself. Example areas are IP-aware collaboration patterns, requirements for common data labelling and agile change management.

GCAP Integration and Interoperability

Cutting-edge GCAP digital engineering capabilities that reflect UK ambition, are integrated across the GCAP enterprise and are interoperable with wider FCAS capabilities.

FCAS must influence the development of the GCAP digital engineering capability to meet the UK ambition for an advanced secure, compliant and fully traceable integrated capability.

The entire GCAP enterprise must integrate appropriate collaborative engineering capabilities spanning the GCAP Agency, Edgewing, national partner companies, the two consortia responsible respectively for propulsion and advanced electronics, national weapons partners and broader supply chains.

Interoperability between GCAP and UK MOD systems is key, for example through common data standards or other approaches, that allows portability of models and data and enables the digital thread concept for engineering information.

The UK will seek commonality where it generates value, interoperability where different solutions are justified, and sovereign control where freedom of action or modification demands it.

Key considerations are:

1. Influencing the GCAP approach. The UK must influence GCAP to adopt digital engineering approaches that best suit FCAS needs, for example regarding digital T&E capabilities.

2. GCAP global enterprise integration. GCAP engineering capabilities are hosted on an Advanced Collaborative Working Environment (ACWE) operating at multiple classifications which must interface with FCAS Collaborative Working Environments (CWEs) hosting the UK digital engineering capabilities required for FCAS national scope. This will allow transfers between classifications whilst maintaining appropriate separations and access controls.

3. Interoperability across systems. The ACWE must allow interoperation across established corporate in-house IT environments for partner companies, the wider supply chain and the MOD, for example via gateways, common standards, data models and exchange protocols, including tool-agnostic data formats.

4. Persistent through-life capabilities. The GCAP engineering capability, in conjunction with wider FCAS, Air and Defence processes and IT, will need to provide through-life Design Organisation support at the tempo of operational relevance (the rate required to adapt to the evolving threat environment).



Engineering Through Life

Digitally transformed in-service engineering through advanced integrated technologies, enabling faster update cycles and more effective and efficient sustainment through-life.

Digital engineering for through-life combat air capability sustainment and development is a strategic imperative for sustaining operational readiness, adaptability and management of support costs. This must include rapid and continuous upgrades in response to emerging requirements and opportunities. The digital engineering enterprise must endure from concept to disposal and support operational change throughout that period. The transformation of engineering processes is not simply faster development of the combat air capability, but the ability to continually sustain and modify a system of systems over decades.

Digital engineering can enable more rapid resolution to airworthiness issues, allow better informed safety risk management and unlock operational risk decisions, through providing granular detail and simple traceability from original design to the as-operated state. This will support the sixth-generation imperative of adaptability and rapid update/upgrade.

FCAS must both align to and drive the digital vision for the RAF and multi-domain approach, ensuring synergies across engineering, support, digital and people aspects.

Key considerations are:

1. The Whole Force balance. RAF future capability is predicated on a ‘Whole force’ approach, working seamlessly with industry partners, regular and reserve engineers and logisticians. Care must be taken to optimise RAF ‘horizontal’ synergies with other platforms and the development of RAF and wider Defence systems, capabilities and skills.

2. Freedom of Action and Modification. International collaboration is fundamental to FCAS through GCAP, but we need to remain flexible, ensuring partnerships do not unduly constrain us, or risk our supply chains in peace or war time.

3. Mission Enablement. There will be increasingly sophisticated mission enablement interactions with engineering support implications. AI and HPC will be required to enable this and in line with wider developments across Combat Air.

4. Real-time health monitoring. Key systems must be monitored in real-time to support scheduled and unplanned maintenance requirements.

5. Adaptation and rapid updates. Industry must be able to support and implement changes to systems for which they are the Design Organisation at the rate required to address a rapidly evolving threat environment - in hours and days, rather than weeks and months. Digital engineering will allow improved configuration control, synthetic T&E and facilitated through connected data pipelines across the enterprise. The ability to share models and data will be key.

6. Interoperability. Approaches developed for FCAS must work for other air platforms, either through adopting common systems or ensuring interoperability. The vision for future combat air is for a common suite of support user interfaces able to give a single view of platforms and equipment with regards to availability, logistics status and engineering information.

7. Deployed bases and austere conditions. The FCAS engineering and support concept must enable operation at deployed bases as part of the RAF Agile Concept of Employment (ACE) concept and with operational resilience in a denied or degraded environment.

8. Data-Led decision making. Delivering an effective Support Capability depends increasingly on continual access to comprehensive and reliable data. The aim is to converge support information systems, enhancing automated data sharing and minimising air-gapped solutions. FCAS must ensure the integrity and resilience of systems and information and develop improved ways of working, enabled by data-led decision making, freeing capacity in the future RAF workforce.

9. Authoritative version of the truth. The RAF seeks to generate a real time support picture to understand the capabilities, threats, risks and opportunities across the whole support capability. FCAS will contribute to this through an authoritative version of the truth per query and situation (e.g. tail number). There will be effective use of data with controlled but unfettered access, and ability to share, with a data architecture that allows portability across different systems and connection to industry systems as appropriate.

Data and Information Architecture

Common engineering data and information architectures and models are implemented across the enterprise to enable sharing, exploitation and re-use to enhance military advantage and drive development, support and efficiency.

Integrated data and information models will manage all system information across the lifecycle, with common data models and approaches across all organisations as required. GCAP data must be interoperable across FCAS and wider Defence to develop and sustain the overall FCAS capability through-life.

Digital engineering for sixth-generation Combat Air capabilities will require and generate orders of magnitude more data than historical approaches. Data will have varieties, volumes and velocities beyond those of any current combat air system, covering both Core Platform, mission data and engineering data with a need for increased integration between all these areas. A data-centric approach to digital engineering will be required with data treated as a strategic asset and managed through-life.

Automation and AI will streamline ingestion, including metadata capture, to standardise processes and deliver value through speed and accuracy of information management. This approach will join up the different and existing governance structures across government, industry and Defence, multi-nationally.

Engineering information must be accessible, trusted, traceable, secure and usable by authorised parties throughout the capability lifecycle, with the necessary commercial rights established from the outset.

Key considerations are:

1. **Data models, architecture, storage, access and movement.** How data for engineering is structured, tagged, stored, accessed and moved must be re-thought, architected and governed. This is critical to ensuring that MOD can access the required engineering data through-life across the enterprise, with required model access rights and means. Data management arrangements must also cater for the use of AI and Agentic AI/Engineering. Tool-agnostic repositories or knowledge graphs and contractual obligations on data format will be needed.

2. **Scalability.** The ability to store, process, and scale data, and manage specialist infrastructure such as large numbers of GPUs for AI model training at multiple classification levels is essential. Truly global access and sharing via secure, scalable platforms that evolve and grow will give enduring strategic military advantage.

3. Standards. MOD should influence GCAP to adopt internationally recognised standards for data, including product data, for example from ISO, aerospace and defence bodies and NATO. Tailoring and development of standards may be required to meet the cutting-edge nature of FCAS and GCAP. A standards profile and conformance policy should be established. Common language and semantic structures will be required.

4. Digital thread. Data will be linked and traceable across the enterprise and lifecycle by linking authoritative sources of truth. This will be critical for more efficient logistics provision and rapid updates/upgrades to support an adaptable capability. This must span global supply chains, linking across FCAS programmes and GCAP as required.

5. Cyber security. Information assurance approaches will conform to NATO Allied Joint Publication-6 and the NIST Cyber Security Framework. Cross-domain solutions will allow movement of information across classification and commercial boundaries vertically and horizontally across FCAS and GCAP, subject to redaction and appropriate user access controls. Data monitoring processes should ensure appropriate surveillance and control of data access.

6. Contracting for Information. Contracts across the supply chain must enable appropriate access to required information and models across the lifecycle, including rights to re-use for wider defence purposes. Revised contracting approaches are needed requiring collaboration between government and industry, for example ‘Contracting for Information’ policies (access, reuse, escrow, licensing, exportability) with tiered model access and Intellectual Property (IP) escrow triggers. IP-aware collaboration patterns proven in other regulated sectors should be adopted.

7. Governance. Robust governance will be required to drive common standards and approaches (processes, data, technology, infrastructure). This should include commercial agreements and policies on ownership and use of data, including the results of data manipulation, for example AI models trained on datasets from a different organisation. MOD should retain overall architectural control or oversight.

8. IP protection. Commercial and IP constraints across the FCAS enterprise must not constrain programme efficiency and effectiveness nor freedoms of action or modification. An example is the ability to share models which will be a vital feature to maintain through-life military advantage.

9. Access. Access must be possible by permitted users with due management of IP, security and export controls to ensure seamless access wherever required. The information must be trusted and interrogable to make decisions and understand the impact of change across a chain of information sets.

Collaborative Working Environments and Infrastructure

Transformed global collaborative working environments and infrastructure at multiple security classifications connect engineers across FCAS, GCAP, industry and MOD, enabling engineering collaboration through-life.

CWEs will form a digital foundation for FCAS, providing access to and integrating digital engineering capabilities, enabling communication, parallel working and collaboration across the FCAS enterprise, including RAF bases.

The GCAP ACWE will support the GCAP development phase enabling digital engineering, business and collaboration services across the globe for multiple organisations across a range of security classifications. It will endure through-life, linking to other environments, facilitating digital threads across the enterprise and connecting operations with industry, to sustain sixth-generation combat capability over decades. The GCAP ACWE must interoperate with national UK FCAS CWEs. The national CWEs will be required to meet additional UK engineering needs (covering ACPs, effectors, UK-specific systems, sovereign aspects and SoS integration). These must also interoperate with wider UK Defence environments. A set of policies, rules, common standards and an open architecture approach will enable this interoperability.

Key considerations are:

1. **A suite of evolving through-life CWEs.** The initial role of CWEs is to support engineering in the design and development phase but they must persist through-life to enable through-life support, including mission enablement. We will need to determine the optimal mix of through-life CWEs required and associated infrastructure.

2. **GCAP ACWE and FCAS CWE interoperability.** It is assumed that the GCAP ACWE will form a key enduring part of FCAS and persist through-life, alongside which will operate various FCAS and wider MOD CWEs.

3. **Digital identity and access management.** Access control will be critical to ensuring the security to CWEs and the data held on them. Individuals operating across CWEs must be assigned a single digital identity to access tools, workflows and data across FCAS, including GCAP and national systems. This approach will operate end-to-end and across the lifecycle and will call for zero trust approaches, attribute-based access control, encryption, continuous monitoring and vulnerability assessment, and recovery protocols at a variety of classifications.

4. **Tools and capabilities on the CWE.** FCAS needs the ability to add and change tools on the CWE in much faster timelines than we have on current Defence IT. The CWE tool suite needs to refresh with modern enterprise and engineering toolsets as these evolve over decades to come. An open data architecture and common standards will be needed to ensure interoperability and portability of data across tools.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FIBER OPTIC CONVERTER
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Capability Innovation and Evolution

Constant evolution of engineering methods, tools and technologies to enable rapid development of products and services to maintain business and military advantage.

The continuous development of technologies and processes will be key to maintain pace of adaptability advantage through-life. The FCAS digital innovation pipeline, aligning and collaborating across GCAP, industry, Dstl, SMEs, academia, and other Defence and civil innovation initiatives, will draw on innovative approaches and research to ensure the latest technologies are applied to digital engineering processes. Engaging with non-traditional defence suppliers and SMEs will offer significant benefit.

This will optimise processes and productivity, for example, AI applied to software development and systems engineering.

Key considerations are:

1. **Platform, tool and data separation.** Common open architecture that is platform, tool and data agnostic will be used with internationally recognised standards to maximise interoperability. A de-layered approach would allow tools to be updated or replaced independently from the underlying engineering data and platform, to embrace innovation and avoid vendor-lock, whilst preserving the digital thread through-life. Separation of ‘Front-office/Back-office’ approaches may be of benefit.

2. **Exploit AI and analytics.** We are already leveraging agentic AI to orchestrate processes and workflows, and to process (aggregate, clean, classify, analyse and visualise) data generated by the engineering processes. The wider engineering system should become instrumented and subject to ongoing analytics to enable continual improvement.

3. **HPC.** The availability of HPC will be an increasingly critical enabler through-life, particularly for product design, modelling, simulation and synthetics, software pipelines and AI.

4. **Exploit advances from other sectors.** Technology advancements in the digital sector such as hyperscale cloud and quantum computing will be exploited.

5. **Custom electronic hardware.** MOD will likely need to take a greater interest in the design and supply of complex electronic hardware, including chip design innovation (for example system-on-chip, system-in-package) and programmable elements due to the criticality for warfighting and potential acquisition difficulties.

6. **Alignment across Defence.** The innovation pipeline for digital engineering must cohere with the broader FCAS technology pipeline. Technology developed through this route must be available across Defence to maximise benefit from investment.

7. **Cross-functional agile approach.** We will embrace collaboration and innovation, using agile approaches, for example the ‘fail quick, learn fast’ philosophy, and avoid ‘development drag’ whereby development has been set and designed around a specific technological architecture which becomes outdated and is difficult to upgrade.

8. **Testing facilities.** It will be important to have reference architectures, and testing and sand-pit environments for digital engineering capability experimentation and innovation.

People and Skills

A highly skilled sixth-generation engineering workforce that is adaptable and able to proficiently operate engineering processes through-life.

FCAS will transform the engineering workforce into a future-facing, continuously evolving, innovative workforce. Sixth-generation Combat Air will need a more digitally skilled and adaptable engineering workforce across the enterprise, including industry engineering and support, regulators and the future RAF workforce, ranging from specialists to senior stakeholders and decision makers. Many traditional engineering roles will require new digital skills; for example, skills around the emerging concept of AI-human co-engineering ecosystems; and inspire the next generation of highly skilled engineers.

A key enabler to FCAS will be its diverse workforce consisting of military and civilian personnel working collaboratively with industry and GCAP partners to drive innovative new ways of working. The digital skills required for in-service team that will operate and support the capability through-life must be identified and planned for accordingly. RAF Operation and Support Personnel (Aircrew, Operators, Maintainers & Support staff) will be trained and upskilled as part of the digital transformation of engineering processes. The new skills required for FCAS will fuse disciplines, for example modelling and simulation, and test and evaluation.

FCAS will stimulate the Combat Air and wider defence industrial base and opportunities for collaborative approaches to training and development across the enterprise are encouraged.

Key considerations are:

1. **Shared enterprise approach through-life.** A collaborative approach is needed across MOD and industry in relation to attraction and retention approaches and sharing of training facilities. This will develop skills and experience, and aid workforce retention within the enterprise through new development opportunities.

2. **RAF skills and profession structure.** Required skillsets must be determined for roles across the future RAF workforce and wider Defence to support the sixth-generation combat air capability. Alignment between the Engineering and Cyberspace professions will be needed to ensure the RAF profession structure evolves to meet the needs of FCAS and wider changes in RAF capabilities.

3. Training and through-life upskilling. Digitally transforming engineering roles will require upskilling of the existing engineering workforce. A collaborative and sustained approach to training between the RAF and industry partners will ensure continual upskilling to maintain pace with technology advances.

4. Cultural transformation. The digital transformation of roles will need to be managed as a cultural transformation. The transition to digital ways of working and training for adoption of new tools and processes will be achieved through training and business change processes.

5. Decision makers and regulators. As well as training working-level engineers and specialists, senior decision makers, including regulators, who may be used to traditional methods must also be trained in new digital ways of working.

6. Diverse workforce. To recruit and retain the highly skilled workforce required, FCAS will seek to break down barriers to the recruitment of a diverse workforce and support the retention of highly skilled staff by making the working environment inclusive.



Wider Applications and Benefits

Digital engineering capabilities are applied across wider Defence and invigorate the industrial base, enabling maximum efficiency and boosting UK economic growth.

The transformation of digital engineering processes for Combat Air will have many benefits across Defence, UK industry and broader government. The UK's Combat Air industry is driving significant growth and productivity, supporting tens of thousands of high-skilled jobs, and is at the forefront of research and development. FCAS represents one of the UK's largest investments in defence innovation and will have impact beyond the programme itself, acting as a stimulus across Air, broader Defence and industry. It will set standards and processes and influence the development of digital engineering capabilities that will be important for future defence acquisition and operations.

FCAS will be a stimulus to UK economic growth by creating world-leading engineering capabilities across industry and developing 'state of the art' digital engineering, data and security solutions that can be applied across Defence and into other sectors. FCAS is pioneering data-driven decision-making, using advanced analytics and modelling and simulation to optimise performance and reduce cost. Real-time data integration will enable predictive maintenance, faster design cycles, and improved mission effectiveness that will have spillover benefits across Defence. For example, the Excalibur Flight Test Aircraft (FTA) project involves the overhaul of a Boeing 757 to enable the test and evaluation, in a real-world environment, of the next-generation integrated sensors, digital technology and integrated communications.

Key considerations are:

1. **Alignment and synergy.** FCAS investment priorities should align with other UK industry investment plans and ambitions, to exploit potential synergies and drive UK sovereign military and economic benefits.

2. **People and skills.** FCAS will build advanced knowledge, skills and competencies, creating high-quality jobs and boosting UK productivity. By upskilling the existing engineering workforce and inspiring the next generation of engineers, FCAS will drive the development of a digitally native highly skilled engineering workforce.

3. **Technology applications.** There will be spillover benefits of technologies into other advanced manufacturing sectors, through digital engineering tools, methods, skills and enablers (such as CWEs, data management and security approaches). The automation of workflows through the application of AI and quantum computing will optimise digital engineering processes.

4. **Export opportunity.** Digital engineering capability developed will be an exportable commodity. GCAP's tri-lateral partners recognise the importance of export possibilities for the success of GCAP, the sustainment of national defence industrial capability, and economic prosperity. Exporting digital engineering capabilities will strengthen the UK Defence industrial base and boost UK economic prosperity.

Glossary of Terms

Term	Description
Adaptability	The intrinsic ability of a system to be quickly and easily adapted to respond to emerging threats, in-service issues and to maximise Operational Effectiveness. It includes rapid software changes, resilience to change, and ease of substitution.
Advanced Collaborative Working Environment (ACWE)	A digital capability to enable GCAP military, business and engineering teams to collaborate across national boundaries to design, build, support, adapt and upgrade the next-generation future combat air system safeguarding information security at all program classification levels (GCAP RESTRICTED, GCAP SECRET and above).
Artificial Intelligence (AI) and Agentic AI	AI will drive quality, time and cost improvement through pattern and relationship spotting in vast datasets, enabling better prediction, classification, evaluation and optimisation. Agentic AI is a step further using goal-oriented, policy-compliant digital agents able to reason, plan and act across complex digital engineering workflows, interacting with digital engineering tools and humans to achieve assigned goals.
Autonomous Collaborative Platforms (ACPs)	A series of uncrewed vehicles which demonstrate autonomous behaviour and are able to operate in a collaborative manner with other assets. They constitute a portfolio of activity to deliver additive capability to the RAF.
Collaborative Working Environment (CWE)	A technical solution that enables all parties to access a single IT environment.
Collaborative Working Environments, Infrastructure and Cloud	Collaborative Working Environment, infrastructure, connectivity and cloud technologies will evolve and digital engineering capabilities will take advantage of this.
Commercial Framework	New commercial frameworks to enable true collaboration and to accelerate changes, including Intellectual Property protection (e.g. model sharing) arrangements.
Core Platform	The aircraft that sits at the centre of GCAP and FCAS.
Cyber Security and Cryptography	A holistic evolving approach to cyber resilience will be vital, applying the latest approaches from global cyber security techniques and cryptographic sovereign capability development.

Glossary of Terms

Term	Description
Data and Information Management	Understanding and integration of data is vital to the Digital Thread concept to enable seamless information transfers and traceability across federated authoritative sources of truth. Common data standards and open architectures enable tools and processes to generate and share the required data.
Data Management and Analytics	The gathering, analysing, and storing data that, due to the increasing volume, velocity and variety, is too large and complex for traditional data processing and data management applications.
Design & Product Lifecycle Management (PLM)	Mechanical, fluid, electrical and structural systems, air vehicle concept & configuration development, material management, environmental, electromagnetic engineering, digital product quality and configuration control. PLM and Data Management capabilities will provide an integrating function across the engineering lifecycle from concept to in-service.
Digital Business Capabilities	To maximise overall benefit, digital engineering must integrate with other reformed digital processes (including commercial, supply chain, procurement, manufacturing engineering and manufacturing).
Digital Ecosystem Approach	Interoperability maximised across digital engineering and FCAS products and services through agreed policies, open architectures and common standards.
Digital Engineering	An integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal. Digital engineering updates traditional systems engineering practices to take advantage of computational technology, modelling, analytics, and data sciences.
Digital Engineering Management	Including digital thread, data and workflow management, digital identity, authoritative source of truth, and the evolution of DE capabilities adopting innovation and emerging technologies. Process metrics will be captured and used to continually improve methods, particularly for software development.
Digital Leadership and Governance	An empowered design authority approach is required across engineering, data, models, CWEs and security to ensure strategy coherence and execution, which should align with the wider Defence approach to digital design authority. Digital engineering elements must be harmonised across the pillars shown to produce coherent capabilities used by engineers across the FCAS enterprise combining tools, data, information, processes/workflows, people, new skills and cultural transformation.

Glossary of Terms

Term	Description
Digital Manufacture	Including manufacturing engineering and digital manufacturing.
Digital Skills and Culture	Engineers trained in new skillsets and operating in a culture that can realise the benefits from new approaches.
Digital Test, Certification and Qualification	A digitally-centric capability to support test and evaluation, qualification, certification and acceptance through-life that integrates digital engineering processes, physical test and test through modelling, simulation and synthetics, at a pace to support required through-life adaptability.
Digital Thread	The collection of linked authoritative digital engineering information which will enable FCAS to implement a truly integrated digital engineering ecosystem using authoritative sources of truth as a continuum across disciplines.
Effector	Payload, which may include weapons or other non-kinetic payloads.
Extended Reality (XR)	Covers virtual reality (VR), augmented reality (AR), and mixed reality (MR). VR immerses users in a digital environment, AR overlays digital onto the real world, and MR allows digital and physical objects to coexist and interact in real-time. XR provides opportunity to improve user input to development and left-shift integration testing, verification and validation.
Freedom of Action	The ability to use, operate, sustain and deliver military capability at any time or any location.
Freedom of Modification	The ability to modify or adapt a capability without undue dependence on another nation.
Future Combat Air System (FCAS)	The UK's sixth-generation combat air system of systems.
GCAP Digital Ecosystem	The GCAP Digital Ecosystem is a set of interconnected digital components (applications, data, system software, interfaces, hardware, infrastructure, people and processes) that interact dynamically to provide information and data where and when required, whilst adapting to diverse conditions and emerging technologies.
Global Combat Air Programme (GCAP)	The tri-lateral programme between the UK, Italy and Japan to deliver the Core Platform.
GPU	Graphics Processing Unit, a measure of AI computing power.

Glossary of Terms

Term	Description
High-Performance Compute (HPC) & Quantum Computing	The availability of HPC will be an increasingly critical enabler through-life across many pillars, particularly product design, modelling, simulation and synthetics, software pipelines and in AI. Quantum computing will play a critical role in HPC.
Information Advantage	The credible advantage gained through the continuous, adaptive, decisive and resilient employment of information and information systems.
Mission Enablement	The capabilities to support and prepare the delivery of the mission, enhance live mission execution and conduct post-mission support.
Model Based Systems Engineering (MBSE)	Model based approach to all aspects of Systems Engineering from concept to in-service covering Systems of Systems, architecture, requirements engineering, safety, product security and human factors.
Modelling and Simulation, including Synthetics (M&S)	M&S will be critical across the engineering lifecycle, at many levels for multiple purposes. Examples include design, system integration, test and evaluation, operational analysis, training, tactics development (including M&S of threat systems for mission data), health management, logistics planning and fleet management, potentially through Digital Twins. Effective M&S will be a critical enabler for information advantage for FCAS operations.
Operational Technology	Devices and machines across the FCAS enterprise will be digitally connected allowing data-driven insights to improve performance and efficiency, for example from manufacturing and support facilities.
Reimagined Processes & Regulatory Environment	These capabilities must be combined to yield benefit with reimagined processes and workflows, for example to enable Multidisciplinary Design Analysis and Optimisation.
Security	Confidence across industry and government that their information will be protected to allow them to authorise federation and sharing of models and data. Cross-domain solutions to enable information moves across security and IP domains, likely with a data-centric security approach employing zero-trust architectures.

Glossary of Terms

Term	Description
Sixth-Generation Combat Air System	A sixth-generation combat air system is a rapidly adaptable and upgradable collection of crewed and uncrewed combat aircraft and supporting systems, which apply open mission systems and multi-spectral stealth to deliver Information Advantage, battlespace dominance, and disruptive and destructive effects as an integrated part of a multi-domain force.
SME Accessibility	The barriers to entry for Small and Medium Enterprises (SMEs) should be low, for example through a multi-level collaboration framework, with low infrastructure and licence costs.
Software Engineering	Including Application Lifecycle Management, DevSecOps, complex electronic hardware, software factory.
System of Systems	A configuration of systems in which component systems can be added/removed during use, which each providing useful services individually, but can be combined to create an effect greater than the sum of its parts.
T&E	Test and Evaluation.
Through-life evolution of digital engineering capabilities	Digital engineering capabilities that can evolve, for example by separating data from tools to allow substitution and maximising ease of interoperability across tools.
Through-Life Support (TLS)	Engineering capabilities required in relation to training, diagnostics/prognostics, logistics, Mission Enablement, through-life engineering, Design Organisation, configuration control, obsolescence management, reliability, maintainability & testability, support information system, support and test equip, tech docs/pubs, software support, disposal/termination.
Whole Force	Collaborative working between the military, government, Industry and international partners.