Tempest: Innovation for UK security and prosperity

Next-generation future combat air system
Introduction

In 2018, the UK launched its Combat Air Strategy which set out the government’s ambition for the nation’s future Combat Air capability; ensuring the UK developed the necessary technology, skill-sets and warfare capability to maintain operational advantage and safeguard UK air defence and security for the next generation.

The strategy recognised that expertise from within the UK’s defence and aerospace industry and its vast supply chain would be integral to its success and committed to continued investment in skills and new technologies, including those for the Royal Air Force Typhoon fleet.

The Combat Air Strategy set out a vision that would safeguard the UK’s world-leading position in combat air, through effective collaboration with UK industry and international partners as well as continued investment in technology and skills. It aims to maximise the overall national value that the UK derives from the Combat Air Sector; delivering military capability, international influence, economic and prosperity benefits.

Tempest is an exciting and ambitious multi-decade programme that is vital for our defence and national security, and to the preservation of critical skills in the UK which support our sovereign freedoms and capability. It will provide the Royal Air Force and their allies with a highly advanced military capability to counter an increasingly complex and data driven battlespace, but will also play an important role in helping the UK to be a leader in the development of digital technologies.

As an industry, we have a critical role to play in Tempest’s success. We must build on our strong heritage of delivering and supporting world-leading Combat Air capability but work in an increasingly agile way, with new partnerships and approaches that accelerate the use of new technologies and ensure we can produce results faster and more cost effectively than ever before.

From the moment Tempest was launched in 2018 it has attracted immense enthusiasm and a substantial interest from within and outside the sector, as companies and academic institutions look to play their part in this proud national endeavour. In the past few years, we have already engaged with well over 600 organisations across the UK, including small businesses, leading universities, as well as global partners and their industrial players. Collaboration is happening and we’re making great progress, testing the boundaries of conventional thinking, working in dynamic and inclusive ways to bring the UK’s vision to life.

On behalf of the Team Tempest partners, we asked PwC to conduct an independent assessment of the economic impact of the Tempest programme over the first 30 years of the programme.

Their research outlined the significant and wide-spread benefits of the programme, stimulated by the investment in the programme which will accelerate the development of new technologies and critical skills that will ensure the UK can continue to operate at the forefront of world-leading technology.

The programme is well placed to support the UK’s economic recovery and make a positive contribution to productivity and prosperity across the UK. This brochure is designed to present the broad impact of the programme.

It continues to be both a pleasure and responsibility to work on such an important programme that will contribute to our nation in so many ways and, along with our Team Tempest partners, we remain committed to delivering this vision for the next generation.

Michael Christie
Director, Combat Air Acquisition Programme, BAE Systems Air

£6bn

Defence aerospace has accounted for over 80% of the UK’s annual defence export orders over the past decade.
The UK’s Combat Air Strategy

Tempest will draw on groundbreaking technologies from the defence sector and beyond

Pioneering through partnerships

The Tempest programme was unveiled to the world in 2018 as the embodiment of the UK Combat Air Strategy. Its central aim is to deliver a UK-led international future Combat Air System programme that ensures the UK Royal Air Force retains Operational Advantage and Freedom of Action – doing so more rapidly and cost effectively than ever before.

The Tempest programme is underpinned by Team Tempest, a combined expertise of the UK Ministry of Defence, BAE Systems, Leonardo UK, MBDA and Rolls-Royce who, together with other industry partners, are defining a highly ambitious programme for the UK. Tempest is one option being considered as part of the UK’s Combat Air Acquisition Programme, which aims to secure the RAF’s next generation combat air system by the mid-2030s. Innovation sits at the heart of the Tempest programme, building on the UK’s strong heritage of world-class capabilities and advanced technology development programmes. Its success depends on producing results faster and more cost effectively than previous combat air systems.

To achieve this, the Team Tempest partners are working together to transform the sector, stimulating investment to drive the required pace and affordability. This approach sees the UK’s well established aerospace and defence industry blending their expertise and know-how with academics, catapult organisations and many high tech, specialist SMEs in adjacent sectors, whilst adopting new agile working practices. By creating and maintaining highly-skilled employment and training opportunities, the Tempest programme is expected to employ high-productive jobs including advanced engineering and manufacturing, helping to preserve important national skills whilst generating new capabilities in the Combat Air sector. This will positively benefit the wider defence sector, supporting the UK’s military, technological, industrial and economic goals.

International by design

The UK has a unique standing as an international partner of choice in the development of new systems thanks to long-term investment by UK Government and industry in Combat Air capabilities which have placed the UK at the leading edge of the development of current and next generation Combat Air technologies. Today, UK industry continues to apply its expertise on next generation combat air capability around the world, with the ongoing design and development support of the next generation fighter in Turkey, TF-X and in support of the UK Government’s discussions with Japan.

Forging collaborative, enduring and strategic industrial partnerships has been fundamental to the success of the UK’s Combat Air sector, where it boasts a rich heritage of international partnering built through programmes such as Tornado, Hawk, Eurofighter Typhoon, F-35 and their related missiles and missile systems.

The UK’s investment in air capability has seen partnerships established with industries and governments in Europe, Australia, the Middle East and the US, underpinning relations with these key allies for decades.

The Tempest programme is designed to offer effective international partnering, delivering the UK the best opportunity to deliver affordable military capability and wider national objectives. Each partner will bring a host of benefits and expertise to the table.

Sweden & Italy

Effective international partnering will play a fundamental role in defining and meeting the goals set out in the UK’s Combat Air Strategy and the delivery of an international future combat air programme.

In December 2020, the governments of UK, Sweden and Italy signed a trilateral memorandum of understanding to strengthen collaboration between the three nations, in a significant step towards the joint development of world-leading future combat air capability.

This agreement is underpinned by ongoing collaboration between UK, Swedish and Italian industry partners, announced in July 2020: comprising of leading defence companies from the UK (BAE Systems, Leonardo UK, Rolls-Royce and MBDA UK), Italy (Leonardo Italy, Elettronica, Avio Aero and MBDA Italia) and Sweden (Saab and GKN Aerospace Sweden).
Delivering a critical military requirement

The Tempest Programme - a military priority and a national endeavour

Along with meeting a major military requirement, the programme is expected to deliver significant benefits to the UK over its full lifetime. It will preserve sovereign capability whilst investing in highly-skilled jobs, with a specific focus on young people and developing technology and infrastructure - all of which supports economic growth and the long-term prosperity of the nation.

The partners are working collaboratively with wider industry to develop the technologies and experience required for the UK to lead the development of a next generation combat air system and retain its world-leading position in Combat Air.

Findings from PwC reveal that the Combat Air activities of the Team Tempest partners, including the Tempest programme, are expected to contribute £100.1bn of GVA to the UK economy over the next 30 years, supporting on average 62,000 jobs per year across the wider economy.

£100.1bn
Contribution from the Team Tempest partners Combat Air activities over next 30 years
Capability in the supply chain will be critical to the success of the Tempest programme

As work in the digital environment becomes more complex, changes are being embraced through the supply chain to deliver technologically-advanced capabilities and processes, which drive efficiency and increase productivity.

The four core partners have already engaged with more than 600 suppliers, SMEs and leading universities across the UK. This collaborative approach sees them blending their expertise and know-how with academia, catapult organisations and many high-tech, specialist SMEs across the UK and shifting the sector’s focus towards the use of agile approaches - such as digital automation, model-based systems engineering and digital twinning - to do things faster and more efficiently.

Sectors outside the defence industry are contributing to the early stages of the programme such as the gaming industry and Formula 1 motorsport. At the same time, the companies involved are embracing new ways of working and exploiting commercially available technology that will deliver benefit beyond the defence sector.

Sectors outside the defence industry are contributing to the early stages of the programme such as the gaming industry and Formula 1 motorsport. At the same time, the companies involved are embracing new ways of working and exploiting commercially available technology that will deliver benefit beyond the defence sector.

National Endeavour

Supply chain

The Combat Air sector in the UK represents a thriving industrial eco-system working in partnership with leading universities and an education system regarded as one of the best in the world. This combined technical and industrial expertise has put the UK at the heart of many of the world’s most sophisticated defence and aerospace programmes.

As leading technology integrators and enablers in the UK, the Team Tempest partners bring breadth and depth across the UK ecosystem, harnessing the best from across academia and industry; accelerating UK innovation; generating intellectual property with the application of digital engineering along with the investment in skills and life-long education.

As work in the digital environment becomes more complex, changes are being embraced through the supply chain to deliver technologically-advanced capabilities and processes, which drive efficiency and increase productivity.

The four core partners have already engaged with more than 600 suppliers, SMEs and leading universities across the UK. This collaborative approach sees them blending their expertise and know-how with academia, catapult organisations and many high-tech, specialist SMEs across the UK and shifting the sector’s focus towards the use of agile approaches - such as digital automation, model-based systems engineering and digital twinning - to do things faster and more efficiently.

Sectors outside the defence industry are contributing to the early stages of the programme such as the gaming industry and Formula 1 motorsport. At the same time, the companies involved are embracing new ways of working and exploiting commercially available technology that will deliver benefit beyond the defence sector.

---

Normal text continues here.

---

Normal text continues here.

---

Normal text continues here.

---

Normal text continues here.

---

Normal text continues here.
Supply chain in action

Electroimpact

Aircraft factories are traditionally custom-built to order, based on known technologies. But working with specialist supplier Electroimpact, Team Tempest partners are exploring a reconfigurable and agile concept to drastically reduce the time taken to build the next generation of combat aircraft.

The approach aims to do so by creating a reconfigurable build environment that can be switched from one product to the next in very short timescales. Successfully introducing a modular system enables BAE Systems and its Tempest partners to bring projects to production much quicker, helping break the increasing time cycle of combat air programmes.

Electroimpact, a Flintshire-based specialist in the design and build of airplane factories were tasked with taking the concept — a modular flooring system and modular robotic system for building Tempest — and turning it into reality inside the factory of the future. Traditionally, aircraft hangars have fixed jigs in place, where specific tasks are carried out. But, working with Electroimpact, the idea is for the use of space to be far more flexible.

Supply chain in action

Oxley group

Oxley is a world class provider of advanced solutions for defence, aerospace, rail and telecommunications applications and is a world-leading designer and manufacturer of LED lighting systems, based in Ulverston, Cumbria.

Oxley has been working on the initial stages of the Tempest programme, demonstrating technological capability and what is possible for the future platform.

University of Strathclyde

The University of Strathclyde is at the forefront of the UK Government’s High Value Manufacturing Catapult initiative which aims to act as the catalyst for the growth and success of advanced manufacturing. It is focused on turning ideas into commercial reality and bridging the gap between academia and industry.

The aim at Strathclyde, which is a partner to both BAE Systems and Leonardo, is to build full-size demonstrators of aircraft at the heart of a Tempest system, in the soon-to-be-built state-of-the-art digital factory in the new flagship NMR5 facility where the university will bring new innovative manufacturing processes to the factory floor.

That means as a transitional research facility Strathclyde wants to work with research bases, such as those at Nottingham University, to bring technologies together into an assembly demonstrator of a major component such as the fuselage. It would use its expertise in forging and forming; materials and materials testing and certification; machining and bulk additives; non-destructive testing; and the digital factory.

Supply chain in action

DIEManalytics

DIEManalytics is a specialist disrupter, involved in the programme to explore the potential of new and untested technologies and how they could influence the development of a future combat air system which stays ahead of its adversaries.

Founded by Dr Darrell Jaya-Rathnam in 2002, DIEManalytics has a specialist understanding of data analysis and Artificial Intelligence. The company develops visual models, simulations and decision aides to help make more effective defence decisions.

DIEManalytics is a specialist provider of advanced solutions for defence, aerospace, rail and telecommunications applications and is a world-leading designer and manufacturer of LED lighting systems, based in Ulverston, Cumbria.

DIEManalytics is working to explore options that might otherwise be viewed as too time consuming or risky for a larger organisation. For example, it has developed a programme which uses AI to predict how well Red might resist Blue’s planned course of action. The programme then suggests decisions Red might make by comparing the past to the present. BAE Systems is exploring with DIEManalytics how it can utilise diverse thinking such as this to rapidly and constantly develop and improve defence systems in order to stay ahead.

As a small SME, but one with a deep understanding of its field, DIEManalytics is working to explore options that might otherwise be viewed as too time consuming or risky for a larger organisation. For example, it has developed a programme which uses AI to predict how well Red might resist Blue’s planned course of action. The programme then suggests decisions Red might make by comparing the past to the present. BAE Systems is exploring with DIEManalytics how it can utilise diverse thinking such as this to rapidly and constantly develop and improve defence systems in order to stay ahead.
Supporting economic recovery and productivity

The Tempest programme is well placed to support economic growth and recovery, stimulating investment in R&D and supporting high skilled jobs in regions of the country which are amongst the most in need.

In 2020, the Team Tempest partners, BAE Systems, MBDA, Leonardo UK and Rolls-Royce commissioned PwC to analyse the expected economic impact of the Tempest programme in the UK from 2021 to 2050, the first thirty years reflecting the development, production and entry into service phases of the programme as well as the early stages of operation. The PwC report, Assessment of expected economic impact of the Tempest Programme (2021-2025), analyses the national and regional economic contribution measured in terms of GVA and employment of the Tempest programme in its own right, as well as wider Combat Air activities. The report findings provided a conservative assessment excluding the benefit beyond this point, including significant benefit from exports. The report also illustrates the additional, wider contributions of the Tempest programme on UK economy through a set of case studies, focusing on skills development, R&D skill over effects and regional development.

National benefit
- The Tempest programme is expected to deliver £26.2bn economic contribution between 2021 and 2050 (NPV, 2019). These exclude benefits beyond 2050, which means most of the value generated by exports is not captured within this 30-year period.
- The Tempest programme is expected to provide long-term critical sovereign capability in areas such as design and development of combat air systems, through the sustainment of high value jobs and support on average 21,000 workers per year from development to operational service (2026-50).
- The programme will create high productivity employment, with UK average GVA per worker 78% higher than the UK national average at £101,000 and 42% higher than the UK manufacturing average.

Regional Benefit
The Tempest programme can contribute to the UK Government’s commitment to levelling up:
- The impact of the Tempest programme will be felt across all regions of the UK including Scotland and Northern Ireland, with 70% of the value in the North West, the South West and East of England.
- Regional GVA per worker for the Tempest programme is 31% higher than the North West manufacturing average, 24% higher than the South West manufacturing average and c. 60% higher than the East of England and Scotland manufacturing average.

Economic data
The Tempest programme is expected to deliver significant benefits to the UK over the full lifetime of the programme, benefitting all regions of the UK, including Scotland and Northern Ireland.

- The Tempest programme is expected to deliver £26.2bn economic contribution between 2021 and 2050 (NPV, 2019). These exclude benefits beyond 2050, which means most of the value generated by exports is not captured within this 30-year period.
- The Tempest programme is expected to provide long-term critical sovereign capability in areas such as design and development of combat air systems, through the sustainment of high value jobs and support on average 21,000 workers per year from development to operational service (2026-50).
- The programme will create high productivity employment, with UK average GVA per worker 78% higher than the UK national average at £101,000 and 42% higher than the UK manufacturing average.
The Tempest programme supports all UK regions providing economic and employment benefit across the country.

Partial GVA and employment contribution of the Tempest programme by region 2021 – 2050

The Tempest programme, total direct and indirect (through first tier supply chain only) GVA and employment by region (2021 2050, NPV 2019 basis)

Productivity of Tempest programme workers compared to similar UK industry sectors
Annual productivity (GVA/worker) Tempest programme (2021 50) vs UK sectors (2018), constant prices

Tempest programme by region 2021 – 2050

Partial GVA and employment contribution of the Tempest programme by region.

All data shown is a partial assessment of the contribution of the Tempest programme by region. Employment and GVA generated in the supply chain beyond tier 1 is real and significant but has not been calculated separately. The figures shown also do not include indirect effects. Regional employment figures are presented in jobs years as aggregated figures of jobs in each region over the 30 year period. The employment profile of the programme will vary by year and by region.

Employment and GVA generated in the supply chain beyond tier 1 is real and significant but has not been calculated separately. The figures shown also do not include indirect effects. Regional employment figures are presented in jobs years as aggregated figures of jobs in each region over the 30 year period. The employment profile of the programme will vary by year and by region.

All data shown is a partial assessment of the contribution of the Tempest programme by region.
Social value

The Tempest programme will contribute to the UK Government’s priorities of improving productivity and tackling youth unemployment across the UK, as well as helping to address a national shortage of STEM skills.

Skills and education

Preserving UK capability and the critical skills is vital to ensure the UK retains its independent military freedom of action and national security, and at the same time makes a positive economic difference to the UK.

The UK’s Combat Air Strategy provides the Team Tempest partners with the confidence to continue investing in school outreach activities and offer award-winning apprenticeships. Together with wider industry, the sector takes an active role in promoting critical skills and capabilities so that the UK can continue to operate at the forefront of world-leading technology, developing skills in areas such as analysis and exploitation of big data along with use of the Internet of Things, skills that will be essential for the next generation. With a long history of nurturing talent, the partners deliver a range of high-quality work-based training that develops skills ahead of the demand of work.

Analysis by PwC estimates that 20% to 40% of jobs currently held by 16-24 year olds may be automated by the mid-2030s and 74% of CEOs are concerned about the availability of skills to grow their business. The Tempest programme is already acting as a magnet for encouraging the younger generation, promoting the importance of STEM subjects, creating enthusiasm for careers in high-tech engineering and supporting the partners’ commitment to increase the diversity of their workforces. Almost a third of BAE Systems’ Tempest workforce is under 35 and 19% are female.

More than 1,000 apprentices and graduates have been recruited across the Team Tempest partners since 2018.

By capitalising on the ambition of young people coupled with the technical innovation, education and leadership, the Tempest programme will help develop the next generation of engineers, manufacturers and technologists. It will also drive high-productivity jobs across the UK that, in turn, drive benefit through their supply chain and across other sectors.

BAE Systems’ UK based business intends to recruit a record of 1,250 new apprentices and graduate trainees in 2021, despite the economic challenges presented by the effects of Covid-19.

Science and Technology

The Government’s UK R&D Roadmap recognises that investment in R&D-focused activities can transform economic, growth and societal benefits across the UK for decades to come, and build the foundations for new industries.

The changes to the threat environment require the Tempest partners and their extensive supply chains to exploit new technologies and keep pace with evolving threats driven by the digital revolution. The advanced technologies being developed for Tempest will have application outside the Combat Air sector.

Through an innovative and collaborative approach, the Team Tempest partners have created technologies and undertaken development work in a matter of weeks that would previously have taken years, through transformative and agile processes.

The Defence sector has a strong track record of rapidly developing and integrating new technologies with civil applications. This experience is and will remain critical in helping the civil sector do the same.

The Tempest programme acts as a magnet for innovation which has the potential to stimulate further investment in R&D as well as further support high-skilled jobs which will deliver economic development to regions across the UK.

This has required a transformative approach by the partners and driving investment into truly game-changing technologies such as Electronic Warfare mission support solutions, augmented and virtual reality and Artificial Intelligence as well as new tools such as model-based engineering, increasing use of synthetic environments and adopting new ways of working.

Science and Technology

The Government’s UK R&D Roadmap recognises that investment in R&D-focused activities can transform economic, growth and societal benefits across the UK for decades to come, and build the foundations for new industries.

The changes to the threat environment require the Tempest partners and their extensive supply chains to exploit new technologies and keep pace with evolving threats driven by the digital revolution. The advanced technologies being developed for Tempest will have application outside the Combat Air sector.

Through an innovative and collaborative approach, the Team Tempest partners have created technologies and undertaken development work in a matter of weeks that would previously have taken years, through transformative and agile processes.

The defence sector has a strong track record of rapidly developing and integrating new technologies with civil applications. This experience is and will remain critical in helping the civil sector do the same.

The Tempest programme acts as a magnet for innovation which has the potential to stimulate further investment in R&D as well as further support high-skilled jobs which will deliver economic development to regions across the UK.

This has required a transformative approach by the partners and driving investment into truly game-changing technologies such as Electronic Warfare mission support solutions, augmented and virtual reality and Artificial Intelligence as well as new tools such as model-based engineering, increasing use of synthetic environments and adopting new ways of working.

The defence sector has a strong track record of rapidly developing and integrating new technologies with civil applications. This experience is and will remain critical in helping the civil sector do the same.

The Tempest programme acts as a magnet for innovation which has the potential to stimulate further investment in R&D as well as further support high-skilled jobs which will deliver economic development to regions across the UK.

This has required a transformative approach by the partners and driving investment into truly game-changing technologies such as Electronic Warfare mission support solutions, augmented and virtual reality and Artificial Intelligence as well as new tools such as model-based engineering, increasing use of synthetic environments and adopting new ways of working.

The defence sector has a strong track record of rapidly developing and integrating new technologies with civil applications. This experience is and will remain critical in helping the civil sector do the same.

1,000

More than 1,000 apprentices and graduates have been recruited across the Team Tempest partners since 2018.

39%

2020 saw a 39% increase in applications for Leonardo’s UK graduate and industrial placement roles and a 100% increase for its apprenticeship programmes in the UK.

£800m

Invested by the Team Tempest industry partners in the programme.
Sustainability is a vital component of the work Team Tempest does and of crucial importance to each of the partner companies.

The programme is continually striving to reduce its environmental impact, value and develop its people, make a positive social and economic contribution to communities and develop innovative technologies in collaboration with the supply chain. Examples of Tempest’s approach to sustainability are:

### Sustainability are:
- With the supply chain.
- Developing innovative technologies in collaboration and developing its people.
- Making a positive social impact.
- Reducing its environmental impact.
- Valuing the partner companies.

The programme is continually striving to:
- Be relevant and of crucial importance to each partner company.
- Be in line with the most sustainable means.
- Develop a digital enterprise.

### Building a digital enterprise

In order to succeed in delivering Tempest by the most sustainable means, the team are developing a ‘digital enterprise’ across multiple layers:
- A foundation layer, which defines how they communicate across multiple layers (e.g. the use of Agile methodology).
- An enabling layer, which embodies engineering, manufacturing and the supply chain (e.g. the Factory of the Future).
- A top layer, which allows for a tailored sovereign capability.

### Sustainable future

Specific to this industry, the key components of this digital enterprise are:
- Open standards – digitally-driven, flexible and easy to update.
- Modelling for speed and efficiency.
- Fewer energy exchanges.

The result is an enterprise that is ideally suited for what the industry needs to do.

### The ground-breaking ‘wearable cockpit’

BAE Systems’ software-driven, completely reconfigurable cockpit design is projected directly in front of the pilot/operator, revolutionising the training and combat cockpit environments of the future. This technology:
- Saves the need for creating and replacing physical hardware.
- Means upgrades and changes are easily managed without a massive equipment impact.
- Creates substantial affordability and flexibility.
- Helps meet the bespoke needs of customers.
- Will be usable in multiple aircraft – reducing development time, cost and training requirements.

### Rolls-Royce electric power generation

One of the key technological challenges for Tempest is how to combine increased electrical power generation capability with an intelligent power management system to meet growing demand for all-vehicle electrical power. Finding a solution has the potential to be transformative:
- Rolls-Royce believes it could reduce the number of energy exchanges and maximise the potential of gas turbines as the primary power source.
- Importantly, this would also offer significant wider-reach benefits into adjacent market sectors such as civil aerospace.

The Tempest programme has a clear ambition to revolutionise the way Combat Air systems are powered by:
- Making them more electric, more intelligent and more powerful.
- Focussing on developing high-density power and propulsion systems that are future-proof and can sit at the heart of Tempest’s combat capability.
- Being adaptable to future changes in requirement.
- Being able to make use of the network of world-class universities and catapult centres in the UK alongside its own employees.

### Testing aerodynamics

Wind tunnel testing is a critical element in any aircraft development programme. Using the latest digital twin technologies, conceptual shapes for the aircraft have been virtually designed and tested, with high-performance computers able to calculate the aerodynamic performance of different aircraft features and test pilots taking Tempest to the skies from a ground-based simulator. Once digitally tested, scale models have been 3D printed and tested at wind tunnel facilities in the North West. As a result of this digital approach, work which would have traditionally taken several months has been achieved in a matter of days, reducing energy consumption and driving efficiencies.

### BAE Systems’ multi-million pound investment

Its Factory of the Future in Warton, Lancashire is aimed at development of Industry 4.0 technologies such as AI, robotic assisted assembly, smart sensors and 5G, with the goal of driving additional productivity, pace and affordability into the manufacture of future combat air capabilities.

The intelligent connected factory is designed and equipped with state-of-the-art technologies in a digital space. Drawing on capability in the supply chain has been critical to the Factory’s development to date. BAE Systems is working with more than 60 blue chip and SME companies on the projects, including specialists in data, robotics, connectivity and additive manufacturing technology as well as academic institutions.

There is a focus on a number of underpinning digital technologies including digital manufacturing, autonomy and automation, competitive tooling, additive manufacturing, high-integrity metal processing, smart materials and composites and product test and validation.

Through these partnerships with the wider supply chain, BAE Systems is working to benchmark, adapt and digitally integrate existing technologies in order to create new capabilities applicable to the Combat Air sector and future products. Exploiting commercially available technology in this way is saving development time and cost, such as the use of robotic assisted assembly.

### Building a digital enterprise

In order to succeed in delivering Tempest by the most sustainable means, the team are developing a ‘digital enterprise’ across multiple layers:
- A foundation layer, which defines how they communicate across multiple layers (e.g. the use of Agile methodology).
- An enabling layer, which embodies engineering, manufacturing and the supply chain (e.g. the Factory of the Future).
- A top layer, which allows for a tailored sovereign capability.

Specific to this industry, the key components of this digital enterprise are:
- Open standards – digitally-driven, flexible and easy to update.
- Modelling for speed and efficiency.
- Fewer energy exchanges.

The result is an enterprise that is ideally suited for what the industry needs to do.

### The ground-breaking ‘wearable cockpit’

BAE Systems’ software-driven, completely reconfigurable cockpit design is projected directly in front of the pilot/operator, revolutionising the training and combat cockpit environments of the future. This technology:
- Saves the need for creating and replacing physical hardware.
- Means upgrades and changes are easily managed without a massive equipment impact.
- Creates substantial affordability and flexibility.
- Helps meet the bespoke needs of customers.
- Will be usable in multiple aircraft – reducing development time, cost and training requirements.

### Rolls-Royce electric power generation

One of the key technological challenges for Tempest is how to combine increased electrical power generation capability with an intelligent power management system to meet growing demand for all-vehicle electrical power. Finding a solution has the potential to be transformative:
- Rolls-Royce believes it could reduce the number of energy exchanges and maximise the potential of gas turbines as the primary power source.
- Importantly, this would also offer significant wider-reaching benefits into adjacent market sectors such as civil aerospace.

The Tempest programme has a clear ambition to revolutionise the way Combat Air systems are powered by:
- Making them more electric, more intelligent and more powerful.
- Focussing on developing high-density power and propulsion systems that are future-proof and can sit at the heart of Tempest’s combat capability.
- Being adaptable to future changes in requirement.
- Being able to make use of the network of world-class universities and catapult centres in the UK alongside its own employees.
Fast facts

Tempest is unconventional by design

The Tempest future combat air system will need to deliver a highly advanced military capability in an increasingly complex and congested environment. It will operate as part of a connected network of combat systems to provide seamless integration across land, sea, air and space domains.

Tempest reflects the requirement to embrace new information-centric technologies, with a digital thread running through it that allows a continuous flow of information to shape vital battlefield decisions and provide critical information superiority to military operators.

Tempest will need to be agile, upgradeable and supportable to maintain through-life relevance in an ever-changing world.

Team Tempest is made up of industry partners BAE Systems, Rolls Royce, Leonardo and MBDA, working with RAF’s Rapid Capabilities Office and the UK Ministry of Defence.

Employment

2,000

People working as part of Team Tempest

1,000

More than 1,000 apprentices and graduates have been recruited across the Team Tempest partners since 2018.

28%

of the BAE Systems’ Tempest workforce is under 35 and 19% of apprentices are female.

Economic Value

The Tempest programme is expected to deliver significant benefits to the UK over the full lifetime of the programme, benefiting all regions of the UK, including Scotland and Northern Ireland.

According to an economic impact assessment by PwC, commissioned by the Team Tempest partners:

- The Tempest programme is expected to deliver £26.2bn economic contribution between 2021 and 2050.
- The Tempest programme is expected to provide long term critical sovereign capability in areas such as design and development of combat air systems, through the sustainment of high value jobs and support on average 21,000 workers per year from development to operational service (2026-50).
- Tempest will create high productivity employment, with an average GVA per worker 78% higher than the UK national average and 42% higher than the UK manufacturing average.
- The work of the four partners and their supply chain in support of UK Combat Air activities as a whole is expected to contribute £100.1bn to the UK economy between 2021 and 2050, and support on average 62,000 workers per year between 2026 and 2050.
- The impact of the Tempest programme will be felt across all regions of the UK including Scotland and Northern Ireland, with 70% of the value in the North West, the South West and East of England.
- Regional GVA per worker for the Tempest programme is 31% higher than the North West manufacturing average, 24% higher than the South West manufacturing average and c. 60% higher than the East of England and Scotland manufacturing average.

Investment

The UK Government announced through the publication of a Defence Command Paper in March 2021 that it will make a strategic investment of more than £2bn over the next four years in Tempest.

To date the Team Tempest industry partners have invested more than £800m into the Tempest programme.

Partnering with UK expertise

The four core partners have already engaged with more than 600 suppliers, SMEs and academic institutions across the UK.