

**strategy&**

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# Assessment of the expected economic impact of the Tempest Programme (2021-2050)

## Final report

May 2021



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# 1. Executive summary

# The UK Combat Air Strategy sets out a bold vision for the development of the UK's future Combat Air capability

Launched in 2018, the **Combat Air Strategy** sets out the government's ambition for the UK's future Combat Air capability, **ensuring the UK remains a world leader in the sector**. UK Combat Air industry has delivered significant economic benefit to the UK, through the development of the most advanced technologies, employment of a highly skilled workforce and huge success in the export market.[1] **UK Combat Air sector delivers UK jobs, UK design, UK innovation and UK sovereign capability** by taking an innovative and international approach.[1]

**A strong national Combat Air sector gives the UK the military capability it needs to defend the country and its national interests, and choice in how it provides that capability without relying on others** – the very essence of sovereignty. Combat Air capabilities encompass all aircraft whose prime function is to conduct air to air and/or air to surface combat operations in a hostile and/or contested environment, whilst having the ability to concurrently conduct surveillance, reconnaissance, electronic warfare and command and control tasks.[1]

Underpinning this strategy the UK launched the Combat Air Acquisition Programme, which will be responsible for acquisition of the RAF's next generation combat air system, a system of systems which is likely to include a core manned and unmanned adjunct platforms. To respond to the challenges set out, **UK Government and UK Industry launched the Team Tempest partnership between the UK Royal Air Force (RAF) and four UK companies; BAE Systems, Leonardo, MBDA and Rolls-Royce**.

The goal of the partnership is to develop and bring into service Tempest, as part of the RAF's next generation combat air system. [2] **With an intensifying and evolving threat picture, the UK's ability to generate and employ Combat Air power remains critical to delivering the UK's national security.**[1] Therefore, the ability to design, develop, upgrade and certify capabilities to address evolving threats and meet operational requirements is key to retaining operating advantage (the ability to deliver Control of the air and Attack functions successfully) and freedom of action (the ability to act free from intervention by other states or entities).

**Retaining the ability to generate UK Intellectual Property, people, skills and facilities in the Combat Air sector is critical to sustaining UK operational advantage and freedom of action.**[1] When combined with a UK Government drive to being a world leader in embracing the fourth industrial revolution, the protection of and investment in key skills across, a collaborative and innovative UK ecosystem will underpin the UK's ability to respond to the challenges and opportunities of Industry 4.0 and digital skills.

**A key premise of the UK Combat Air Strategy is that effective international partnering in Combat Air is fundamental to the delivery of national goals and the management of cost.** In recent years more than 80% of defence exports has come from Combat Air.[3] Every major combat air program, where the UK has had a leading role, has returned significantly more revenue to the UK Government than originally invested, including the Eurofighter Typhoon and Hawk. For Eurofighter Typhoon, the export sales of Typhoon have already returned more than double the UK Government's £12bn investment.[4]



**The Tempest programme already makes up a key structural part of the UK Aerospace and Defence economic ecosystem and is integral to the evolution of Combat Air over the coming decades.**

**With Tempest, the UK plays a full and active role in the development of the next generation Combat Air capability, ensuring it has full access to the required Intellectual Property, skills and infrastructure and thus guaranteeing credible freedom of action for the decades to come.**

**Sources:** [1] Combat Air Strategy (MOD, 2018), [2] <https://www.raf.mod.uk/what-we-do/team-tempest/tempest/>, [3] <https://www.gov.uk/government/speeches/launch-of-the-combat-air-strategy-at-the-farnborough-air-show>, [4] <https://www.baesystems.com/en/article/typhoon-delivers-a-further-boost-to-the-uk-economy>

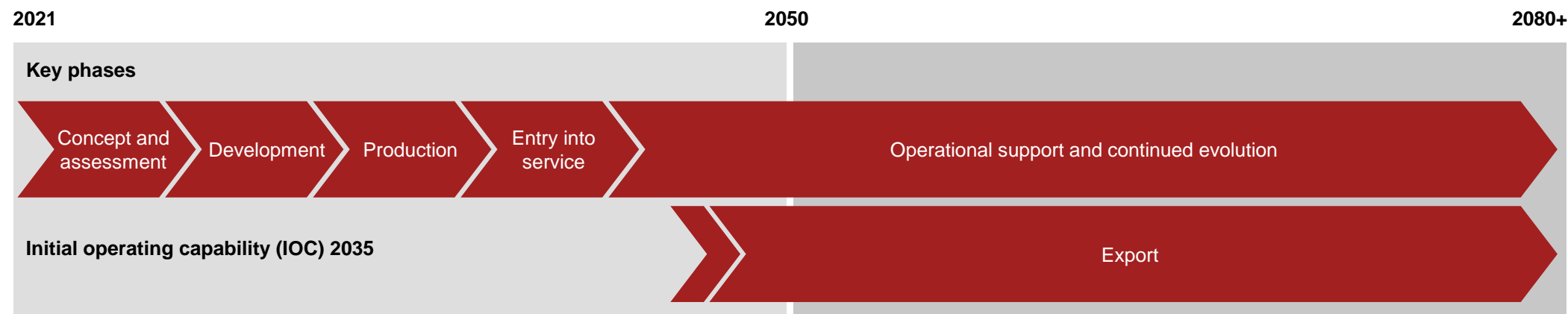
# This report assesses the expected economic impact of the Ministry of Defence's Tempest programme from 2021 to 2050 (1/2)

## Scope of the analysis and methodology

PwC was commissioned by BAE Systems on behalf of the four Team Tempest industry partners (BAE Systems, Leonardo, MBDA and Rolls-Royce) in September 2020 to analyse the expected economic impact of the Tempest programme in the UK from 2021 to 2050. This time period includes the Development, Production and Entry in to Service phases of the programme, as well as the early stages of operation. The MOD has indicated a target Initial Operating Capability (IOC) of 2035 for the programme.[1]

The analysis covers the period up to 2050, however **the programme will continue to deliver benefits that stretch for decades beyond this period.** In particular, the Tempest Combat Air System will remain operational within the UK's and its international partners' armed forces, thus requiring ongoing support and further R&D to be undertaken, with ensuing positive spillover effects on the industry and wider economy.

Along with this, the Tempest combat air system is expected to create significant Gross Value Added (GVA) and employment benefits to the UK through exports, particularly given that companies that export tend to be more productive, create more jobs, and pay higher wages.[2] Export-led growth will also provide opportunities to develop international relationships with partner nations. However, as the benefits of exports will only begin to be seen towards the end of the timeframe, and the large proportion of the export benefits will fall beyond the scope of this report, much of this benefit is not captured in the analysis. Because of this, **our estimates should be considered a conservative estimate of the overall benefits that the Tempest programme is likely to deliver for the UK economy.**



# This report assesses the expected economic impact of the Ministry of Defence's Tempest programme from 2021 to 2050 (2/2)

## Scope of the analysis and methodology

Our analysis consists of assessing 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.

Along with this, we have illustrated the additional, wider contributions of Tempest on the UK economy through a set of case studies, focusing on skills development, R&D spillover effects and regional development all of which are important to the broader governmental agenda.

### Our analysis includes:

The direct economic contribution, measured in terms of GVA and employment – i.e. impacts arising directly from Tempest partner activity

The indirect economic contribution (in GVA and employment) – i.e. impacts arising from the activities of Tempest suppliers and their supply chain

The induced economic contribution (in GVA and employment) – i.e. impacts arising from spending on goods and services by employees working on the Tempest programme and in the supply chain

### Our analysis excludes:

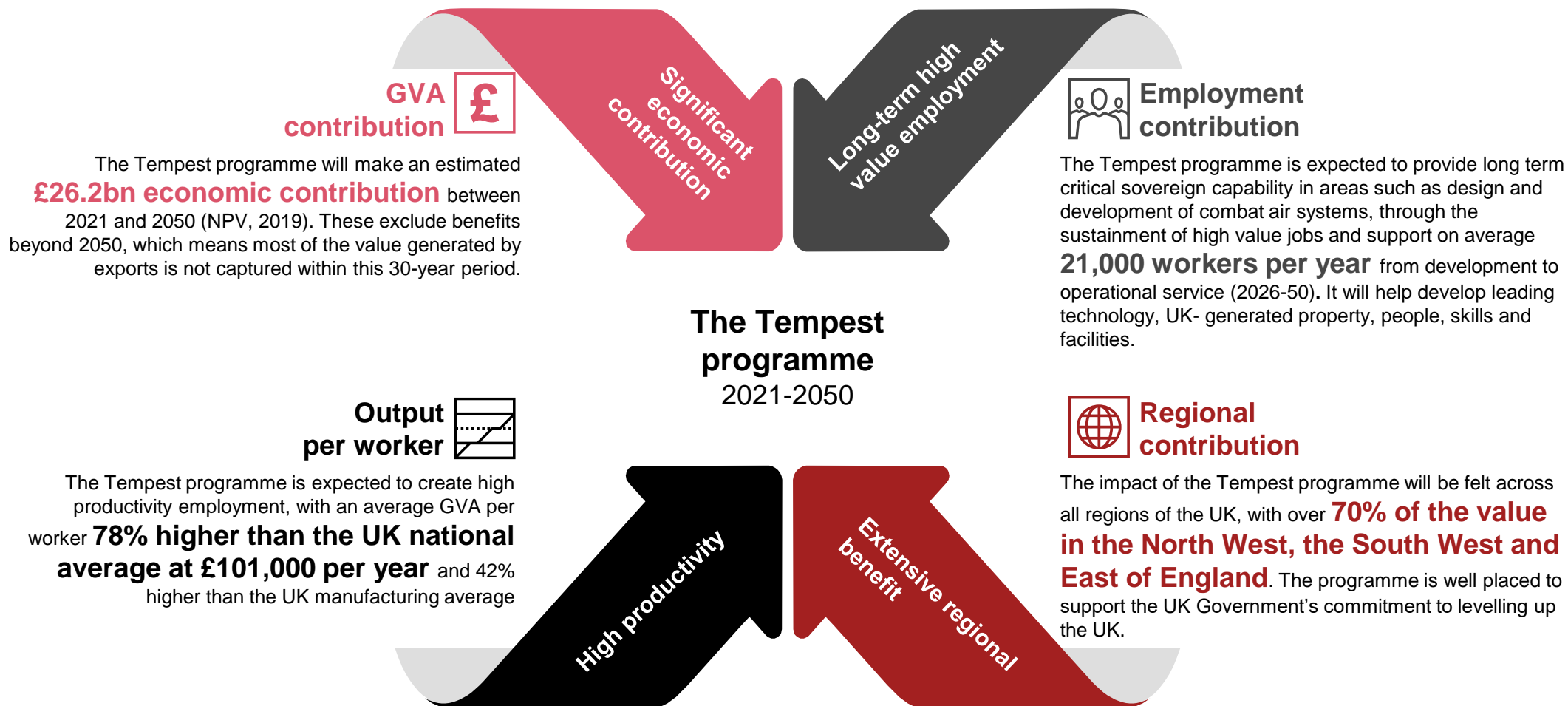
The impact of any spending in the UK by international partners involved in the Tempest programme or any Foreign Direct Investment (FDI)

Impacts that occur after 2050 – which includes the majority of the impact from exports

Economic benefits of spillover from R&D activity, and direct benefits from support and maintenance activity

# The expected GDP contribution of the Tempest programme from 2021 to 2050 is £26.2bn, supporting 21,000 jobs p.a. from development to operational service

## Tempest programme economic contribution



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

**Sources:** PwC analysis, Team Tempest industry partners data **Note:** Figures in text presented in NPV (net present value) terms in 2019 price basis. Gross Value Added (GVA): A measure of the value of goods and services produced in an area, industry or sector of an economy. Net present value (NPV): Used to compare estimates of costs and benefits occurring at different points in time, taking into account society’s time preference for incurring costs and benefits.

# The GDP contribution of Combat Air (2021-50), including Tempest, is £100.1bn supporting 62,000 jobs per year from development to operational service

## Economic contribution of four Tempest Partners' Combat Air activities

- 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.
- The Tempest programme, as a subcomponent of UK Combat Air, will contribute £26.2bn, or 26% of the total, and make up 34% of estimated employment contribution (21,000 workers per year).
- Other Combat Air activities include those required for the design, development, delivery, integration and support of other platforms, systems, products and services.
- Similarly to the Tempest programme, these impacts will be felt in every region of the UK, including all four nations.
- These figures **exclude benefits beyond 2050**, which means most of the value generated by exports is not captured.

### GVA and employment contribution of Combat Air activities (including Tempest) 2021-2050 and 2026-2050 respectively



**£100.1bn**

= Combat Air's total **economic contribution** between 2021 and 2050 (NPV, 2019)

- **Direct GVA contribution:** Combat Air activities, including Tempest, are estimated to directly generate value added of £39.6bn over the 30 year period (NPV, 2019 basis)
- **Indirect GVA contribution:** Combat Air activities are expected to stimulate additional value added of £33.9bn (NPV, 2019 basis) in the UK economy through purchases from suppliers
- **Induced GVA contribution:** spending by the Combat Air activities' direct employees and those supported in its supply chain is expected to generate additional value added of £26.5bn



**c. 62,000**

= Combat Air's **employment contribution** in the UK in terms of average number of workers supported per year between 2026 and 2050

- **Direct employment contribution:** the Tempest partners expect to directly employ c. 19,000 workers per year between 2026-2050 to support wider Combat Air activities
- **Indirect employment contribution:** through its purchases from UK suppliers, Combat Air activities could support a further 26,000 workers per year
- **Induced employment contribution:** the spending by the direct employees of UK Combat Air activities and those supported through the supply chain could lead to an additional 17,000 workers employed per year across the UK

**Sources:** PwC analysis, Team Tempest industry partners data **Note:** Figures in text presented in NPV (net present value) terms in 2019 price basis. Gross Value Added (GVA): A measure of the value of goods and services produced in an area, industry or sector of an economy. Net present value (NPV): Used to compare estimates of costs and benefits occurring at different points in time, taking into account society's time preference for incurring costs and benefits.

# Tempest is expected to drive significant wider contributions to the UK economy through promoting critical skills and R&D investment across the UK regions

## The wider contribution of the Tempest programme



### 1. Skills Spillovers

**The Tempest programme is promoting critical skills and capabilities so that the UK can continue to operate at the forefront of world-leading technology.** The programme is already acting as a magnet for encouraging the younger generation, across all regions, to pursue STEM careers. By developing the next generation of engineers and technologies, the Team Tempest partners are providing high-productivity jobs across the UK that trickles down through their supply chain and across other sectors as people switch jobs and sectors.

This contributes to meeting 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.



### 2. R&D Spillovers

**The Tempest partners are leading technology integrators and enablers in the UK, fostering a culture of innovation and capital expenditure** through their partnerships with catapults, academia and SMEs.

The programme is critical to funding the development of new technologies and contributes to the UK Government's ambition to be a scientific superpower.

By developing new skills and technologies and providing high-productivity jobs in areas most in need such as the North West, **the programme can support the UK Government's commitment to levelling up opportunity across the UK.**



### 3. Regional Development

**The Team Tempest partners are continuing to invest in R&D and skills across the UK regions.**

This is expected to increase economic productivity and prosperity by developing new products, services and jobs and also help to maintain the security of citizens.

For example, 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 averages.

**Without the Tempest programme, the level of investment in new technologies and development of the next generation of engineers and technologies in the combat air sector and beyond would be at risk**

# Skills spillovers: the Tempest programme is promoting critical skills so that the UK can continue to operate at the forefront of world-leading technology

Tempest will attract the younger generation to pursue STEM careers and provide upskilling opportunities across the UK



**The Team Tempest partners are investing in developing and applying new digital technologies.**

Its success depends on developing the next generation of engineers and technologists by shaping skills and training policies and standards, attracting the younger generation, increasing diversity and upskilling the existing workforce.

**The programme acts as a magnet for the younger generation** and, combined with the industry partners school outreach activities and award-winning apprenticeship opportunities, will stimulate the flow of STEM educated, diverse and experienced talent for the benefit of the wider economy.

By promoting STEM careers and attracting young people into the sector, **the Tempest partners are contributing to developing and sustaining high-productivity jobs (based on new digital skills) across the UK** to the benefit of not just the partners and the sectors but also the wider economy as trained talent switch jobs and sectors across the supply chain and across the UK regions.

This will contribute to meeting the UK Government's priority of tackling youth unemployment, increasing diversity and inclusivity in the workplace and improving productivity across the UK.

**Tempest is contributing to closing the high-tech skills shortage in the UK.**

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 programme already employs 1,000 graduates and apprentices by offering attractive employment opportunities in STEM subjects (e.g. industrial digitisation, AI, data analytics)** and is stimulating upskilling of the existing workforce to meet the skills requirements of the future to the benefit of the wider UK economy.

# R&D Spillovers: Delivery of Tempest stimulates R&D in new technologies and can contribute to the UK's ambition to be a scientific superpower

The investment in R&D for Tempest will generate benefits for the wider economy through applications of technologies in other sectors and collaboration with academia and SMEs

UK commitment to the Tempest programme provides partners with the confidence to invest, drive innovation and develop new world leading technologies

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 to ensure the UK has the military capability and agility to **safeguard national security** but also **maintain a highly skilled UK industrial base**.

At the same time, programme and commercial pressures exist, requiring new combat air systems to be developed more quickly and at lower cost

The milestones set for the Tempest programme represent a **challenge for industry to meet a significantly expedited timescale and cost aspiration**.

To help achieve this, the Tempest partners are collaborating across the UK's Catapult networks, enabling them to harness the best of UK science, engineering and innovation

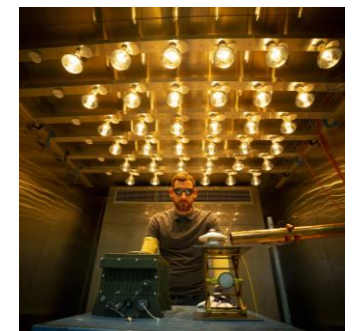
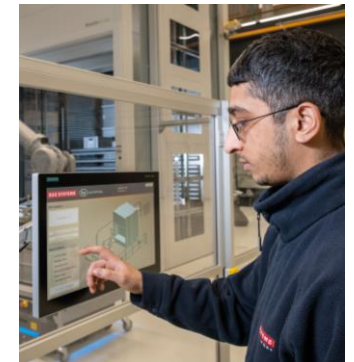
To achieve the programme's aims, the Tempest partners are drawing on their corporate reach across the UK's world-class universities and Catapult centres to support a coordinated approach to R&D investment, the national capabilities and skills needed to exploit new, disruptive technologies. This fosters a culture of innovation and capital expenditure and benefits the wider economy by building transferable skills and technologies that can be used in other sectors.

...by developing a collaborative and adaptive culture, so improving performance through agile working practices to help accelerate developing proof of concepts into commercially viable solutions

The Tempest programme is driving the partners to bring together **new and traditional businesses** (e.g. through working with Catapults) and develop new ways of doing business. It is also providing the opportunity to **combine digital engineering, agile development and open architecture** to speed up the development and innovation cycle – a real game changer.

...helping to generate a cycle of UK IP across industry, SMEs and academia, so strengthening UK competitiveness and delivering direct financial benefit to support UK prosperity and offering the opportunity to boost exports

The advanced technologies being developed for Tempest will have use outside the Combat Air sector (e.g. in civil sectors; the UK Maritime and Coastguard Agency operates Leonardo's E-scan radar technology to support missions; and Rolls-Royce high temperature technologies improving the efficiency of civil large engine programmes, reducing fuel burn and climate impact). **This technology leadership, in combination with building capability through cross-sector collaboration; will generate positive spill-over benefits for the UK economy.**



# Regional Development: The Tempest partners contribute to regional development by investing in R&D and skills across the UK to deliver Tempest

## The Tempest Programme can contribute to the Government's commitments to levelling up opportunity around the UK

The collective reach of the Tempest partners' business activities and those of their Tier 1 suppliers are located across all UK regions

The locations of the Tempest partners' business activities as well as those of their Tier 1 suppliers across the UK mean that **the economic contribution of the Tempest programme can generate benefits across all regions** with c. 70% of the direct and indirect (through Tier 1 suppliers) value generated in the North West, South West and East of England.

The Tempest programme will stimulate R&D in areas where there is less public investment and benefit a range of businesses through the supply chain and across sectors

The Tempest partners will invest in R&D across the UK regions. **It will also provide SMEs with access to facilities and expertise, enabling cross-sector collaboration.** This regional investment and collaboration can transform areas by driving innovations and making business more adaptable, therefore generating wider benefits outside the Tempest programme and Combat Air.

The partners are working collaboratively with Catapults, academia and specialist SMEs contributing to the improvement of their human capital and capabilities and helping to attract further investment

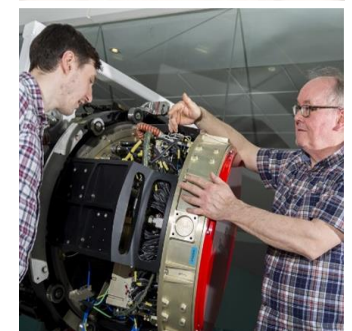
To make Tempest a success, the partners are working with Catapults that give them access to a UK ecosystem of leading research, specialist skills and technologies. This supports academia, SMEs, and the wider supply chain across the UK: it provides them access to commercial opportunities, grows their talent and reputation and improves their performance. **This helps them to attract and secure further research funding and investment further contributing to the development of the regional economies.**

The Tempest programme's economic contribution is expected to benefit UK regions which are most in need by creating and maintaining high-skilled jobs

By creating and maintaining highly skilled employment and training opportunities, based around new skills and technologies, across the partners and their supply chain distributed across the UK, **the Tempest programme is expected to benefit areas in most need, including the North West and South West.**

This means that wider economic benefits will be delivered through improved productivity and greater resilience

By developing new skills and technologies, **the Tempest programme is expected to provide high productivity jobs in areas that currently lag behind** such as in the North West and the South West. For example, regional GVA per worker for the Tempest programme is significantly higher than regional manufacturing averages. This can support recovery from Covid-19 and accelerate long-term economic growth and prosperity improving the regions' resilience.





## 2. Scope of report

# We used Input-Output modelling to estimate the GVA and employment contribution of the Tempest programme in three key stages

## Approach and structure of the report



### Key terminology

#### Gross Value Added (GVA):

- A measure of the value of goods and services produced in an area, industry or sector of an economy

#### Net present value (NPV):

- Used to compare estimates of costs and benefits occurring at different points in time, taking into account society's time preference for incurring costs and benefits

#### Input-Output (IO) modelling:

- A modelling technique that assesses how the Tempest partners and suppliers transform inputs into outputs which are sold to satisfy demand, using ONS data (Office for National Statistics)

We estimated the expected economic contribution to the UK of a Tempest programme in its own right and that of wider Combat Air activities, using Input-Output modelling to estimate the expected economic impact of the Tempest programme:

We have illustrated some additional, wider contributions of Tempest on the UK economy through a set of case studies, focusing on skills development, R&D spillover effects and regional development. An appendix provides more details on our methodology for each stage of our analysis.

### The rest of the report is structured as follows...

#### 3. Tempest and Combat Air economic contribution

Analyses economic contribution (in terms of GVA and employment) of the Tempest programme and wider Combat Air activities

#### 4. Conclusions

Focuses on wider contribution of the Tempest programme including, skills spillovers, R&D and its contribution to regional development.

#### Appendix 1: Wider contribution of the Tempest programme

Focuses on wider contribution of Tempest including, skills spillovers, R&D and its contribution to regional development

#### Appendix 2: Approach and Methodology

Provides more detailed information on our approach and methodology



### 3. Tempest and Combat Air economic contribution

# This section summarises the expected economic contribution of the Tempest programme in isolation along with wider Combat Air activities

## Summary of analysis

This section assesses the expected economic contribution of the Tempest programme in its own right, as well as that of the partners' UK Combat Air activities. The Tempest programme makes up an important subsection of the UK Combat Air industry and will be integral to the evolution of Combat Air over the coming decades.

### The rest of this section summarises:

- The estimated direct, indirect and induced GVA over the period (2021-50) and employment contribution from development to operational service (2026-50) associated with the Tempest
- How the productivity of Tempest programme employees (GVA per worker) compares with productivity in other sectors of the UK economy
- How the GVA and employment directly generated by the four Tempest partners and their Tier 1 suppliers breaks down across the regions of the UK over the same period
- The equivalent GVA and employment and regional analysis but for all Combat Air activities undertaken by Tempest partners
- How the total share of Combat Air activities made up by the Tempest programme changes over the time period



# For every £1 of direct GVA generated by the Tempest programme from 2021 to 2050, £2.20 is estimated to be created across the UK economy

## GVA and employment contribution of Tempest

### GVA contribution of the Tempest programme 2021-2050

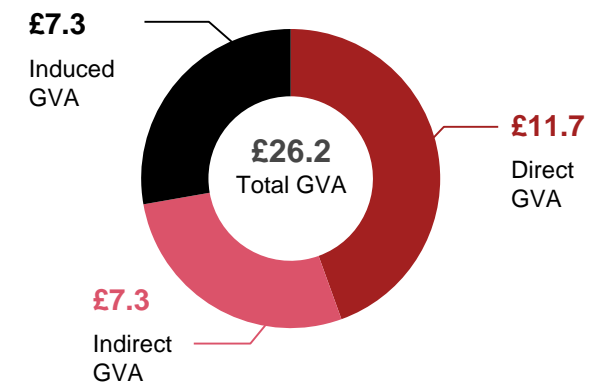


**£26.2bn**

= the Tempest programme's total economic contribution between 2021 and 2050 (NPV, 2019)

- **Direct GVA contribution:** the Tempest programme is estimated to directly generate value added of £11.7bn over the 30 year period (NPV, 2019 basis)
- **Indirect GVA contribution:** the Tempest programme is expected to stimulate additional value added of £7.3bn (NPV, 2019 basis) in the UK economy through purchases from UK suppliers
- **Induced GVA contribution:** spending by the Tempest programme's direct employees and those supported in its supply chain is expected to generate additional value added of £7.3bn
- The total GVA contribution of Tempest is over 2.2x the direct GVA contribution

### Tempest programme, GVA contribution in the UK (2021-2050, NPV 2019 prices, £bn)



### Employment contribution of the Tempest programme from development to operational service 2026-2050

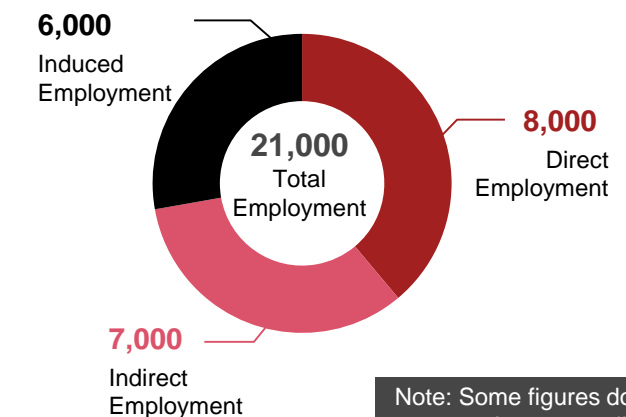


**c. 21,000**

= the Tempest programme's contribution in the UK in terms of average number of workers supported per year between 2026 and 2050

- **Direct employment contribution:** the Tempest programme partners expect to directly employ c. 8,000 workers per year between 2026-2050 to support the Tempest programme
- **Indirect employment contribution:** through their purchases from UK suppliers, the Tempest programme partners could support a further 7,000 workers per year over the 25 year period
- **Induced employment contribution:** the spending by the Tempest programme's direct employees and those supported through the supply chain could lead to an additional 6,000 workers employed per year across the UK
- The total employment contribution of Tempest is over 2.7x the direct employment contribution

### Tempest programme, Employment contribution in the UK (2026-2050, annual average workers)



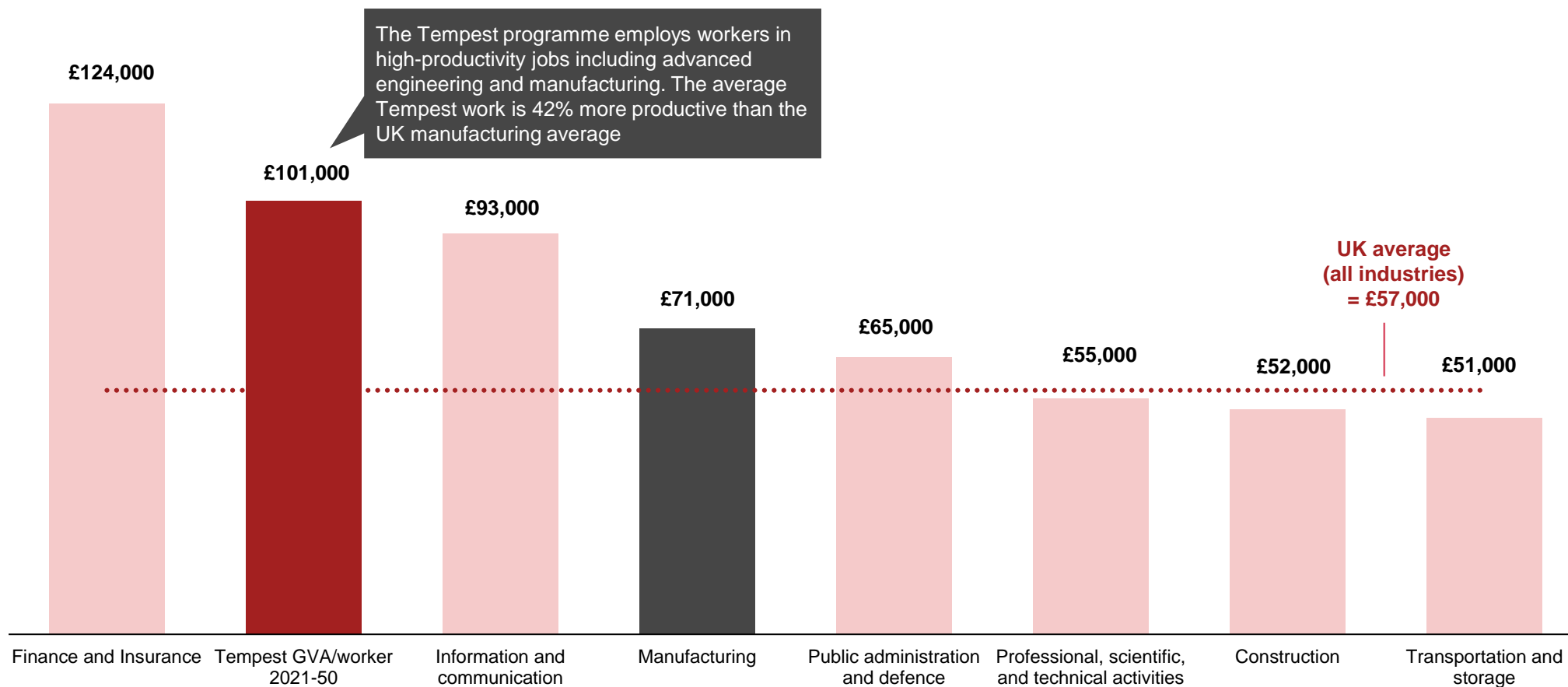
Note: Some figures do not sum due to rounding

**Sources:** PwC analysis, Team Tempest industry partners data **Note:** Figures in text presented in terms of average workers employed per year. Figures in chart presented in terms of average number of workers employed per year. Figure in headline refers to the Type II multiplier which is estimated by dividing the total contribution (direct, indirect, induced) by the direct contribution.

# The Tempest programme creates high productivity employment, with an average GVA per worker 78% higher than the UK national average

## 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



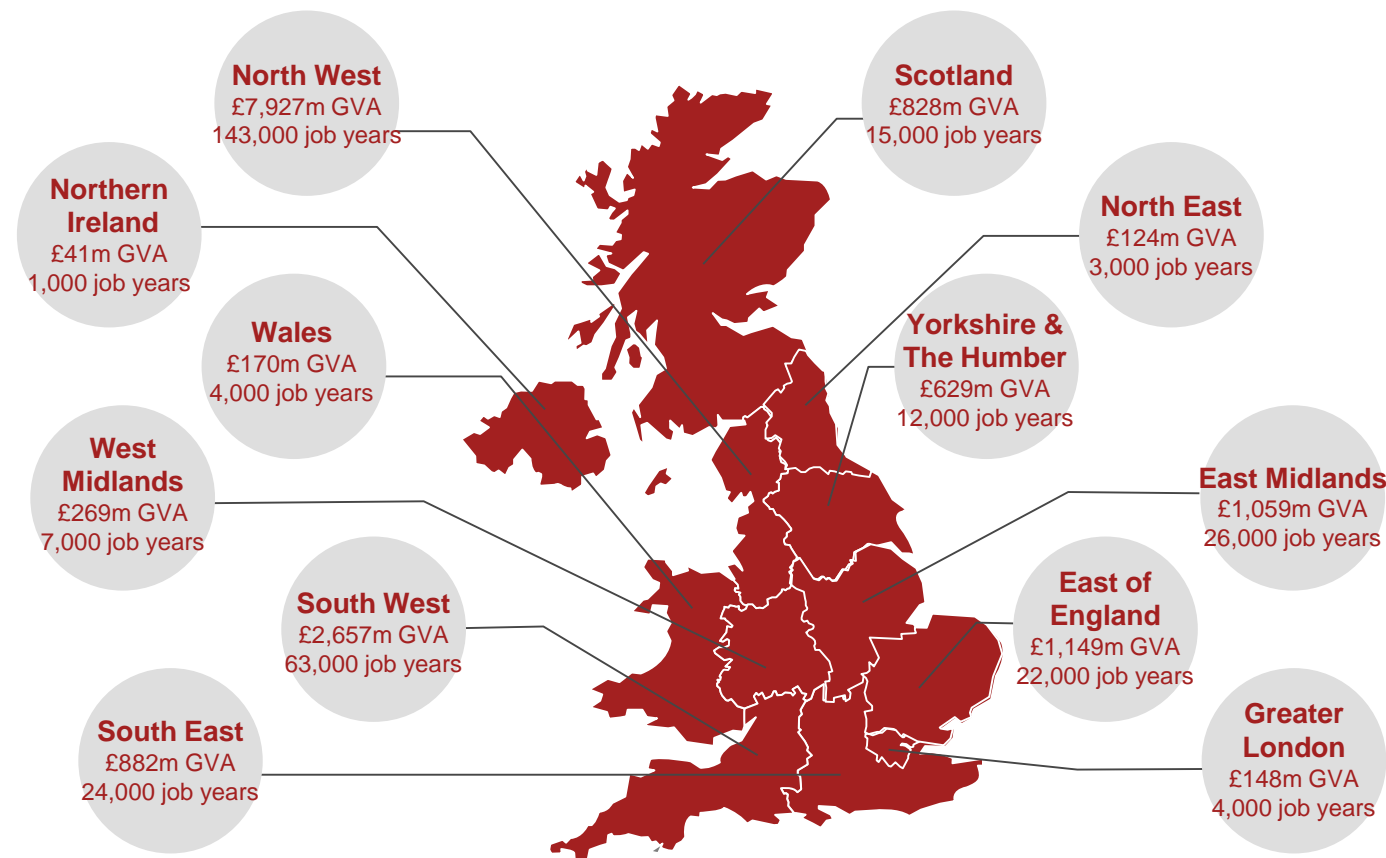
**Sources:** PwC analysis, Team Tempest industry partners data, ONS **Note:** Figures in text presented in terms of GVA per worker per year. GVA/worker calculated for industries by scaling up output per hour figures from ONS using national average of output/worker and mean hours worked per week for each industry (all 2018). Industries with most comparable outputs and supply chain selected. Tempest figures in chart presented in terms of constant prices (£) 2021-50 and estimated through dividing average direct GVA by direct employment over the period.

# The Tempest programme supports all UK regions providing economic and employment benefit across the country

## Assessment of partial GVA and employment contribution of the Tempest programme by region, based on direct and first-tier supplier spending only, 2021-2050

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

*This map shows the GVA and employment impact that can currently be attributed directly to regions. The remaining 39% of estimated impact cannot be directly linked to a specific region at this time.*




- Please note the data shown excludes the potentially significant impact from R&D spillover effects, as this impact was unable to be estimated at this time.
- Employment and GVA generated in the supply chain beyond tier 1 is real and significant but has not been calculated regionally. The figures shown also do not include induced effects.
- These figures show the total employment impact over the full duration of the programme (2021-50), although we believe the main employment impact will be felt from 2026 onwards, as presented elsewhere in the report.
- The location of the partners business activities and those of their Tier 1 suppliers mean that they have a role to play in levelling up opportunity across the UK. More detail of this impact and specific examples of partner's contribution to regional development are provided in Appendix 1.

**Sources:** PwC analysis, Team Tempest industry partners data **Note:** GVA figures presented in NPV (net present value) terms in 2019 price basis. Regional employment figures are presented in 'job years' to demonstrate the profile of the employment impact over the first 30 years of the programme. Job years are the 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 therefore estimating an average jobs per year on a regional basis may not present an accurate figure. Data shown are conservative estimates.

# Combat Air activities, including the Tempest programme, are expected to contribute £100.1bn of GVA to the UK economy over the next 30 years

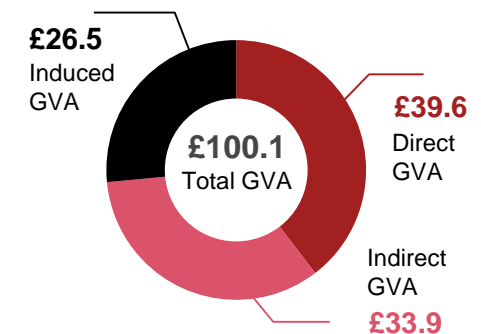
## GVA and employment contribution of Tempest partners' Combat Air activities

### GVA contribution of Combat Air activities (including the Tempest programme) 2021-2050

 **£100.1bn**  
= Combat Air's total economic contribution between 2021 and 2050 (NPV, 2019)

- **Direct GVA contribution:** Combat Air activities, including Tempest, are estimated to directly generate value added of £39.6bn over the 30 year period (NPV, 2019 basis)
- **Indirect GVA contribution:** Combat Air activities are expected to stimulate additional value added of £33.9bn (NPV, 2019 basis) in the UK economy through purchases from suppliers
- **Induced GVA contribution:** spending by the Combat Air activities' direct employees and those supported in its supply chain is expected to generate additional value added of £26.5bn
- The Tempest programme makes up 26% of estimated Combat Air GVA

### Tempest partner's Combat Air activities (including Tempest), GVA contribution in the UK (2021-2050, NPV 2019 prices, £bn)

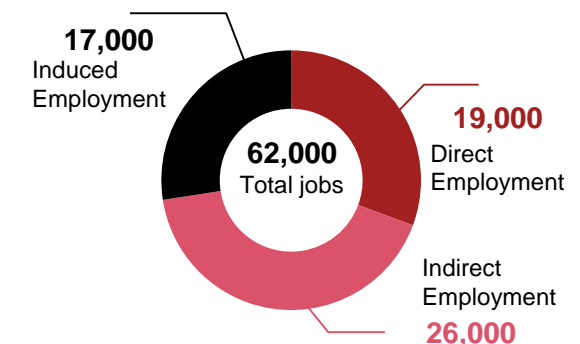


### Employment contribution of Combat Air activities (including the Tempest programme) 2026-2050

 **c. 62,000**  
= Combat Air's employment contribution in the UK in terms of average number of workers supported per year between 2026 and 2050

- **Direct employment contribution:** the Tempest partners expect to directly employ c. 19,000 workers per year between 2026-2050 to support wider Combat Air activities
- **Indirect employment contribution:** through its purchases from UK suppliers, Combat Air activities could support a further 26,000 workers per year
- **Induced employment contribution:** the spending by the direct employees of UK Combat Air activities and those supported through the supply chain could lead to an additional 17,000 workers employed per year across the UK
- The Tempest programme makes up 34% of estimated Combat Air employment

### Tempest partner's Combat Air activities (including Tempest), Employment contribution in the UK (2026-2050, annual average workers)

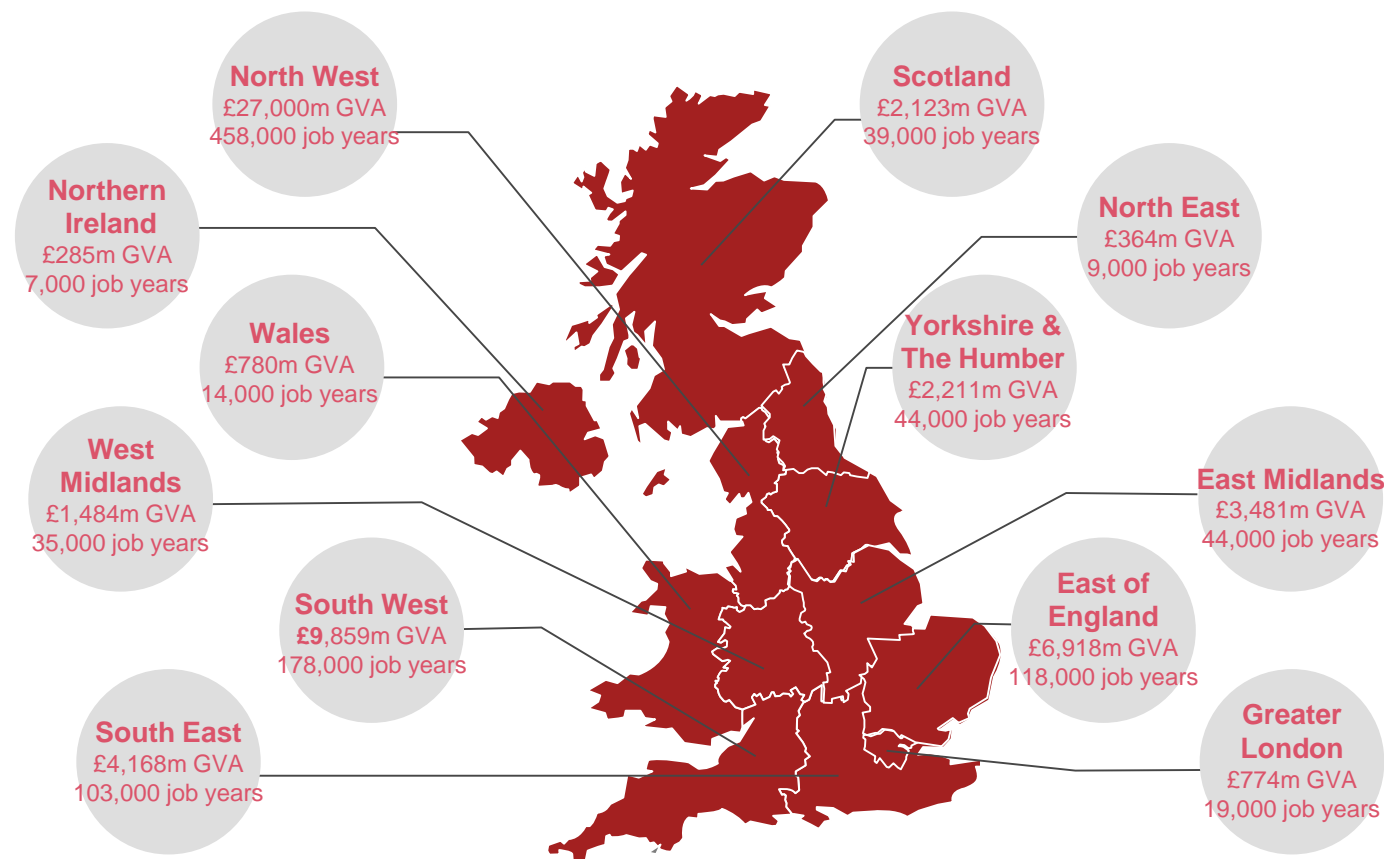


# As with the Tempest programme Combat Air activities benefit all UK regions

## Assessment of partial GVA and employment contribution of the Tempest partners' Combat Air activities by region, based on direct and first-tier supplier spending only, 2021-2050

**Combat Air activities (including Tempest), total direct and indirect (through first-tier supply chain only) GVA and employment by region (2021-2050, NPV 2019 basis and total person years of employment)**

*This map shows the GVA and employment impact that can currently be attributed directly to regions. The remaining 41% of estimated impact cannot be directly linked to a specific region at this time.*



- As with the Tempest programme results, please note the data shown excludes the potentially significant impact from R&D spillover effects, as this impact was unable to be estimated at this time.
- Employment and GVA generated in the supply chain beyond tier 1 is real and significant but has not been calculated regionally. The figures shown also do not include induced effects.
- These figures show the total employment impact across the Combat Air activities from 2021-2050. We believe the employment impact on the Tempest programme will be felt from 2026 onwards, as presented elsewhere in the report.

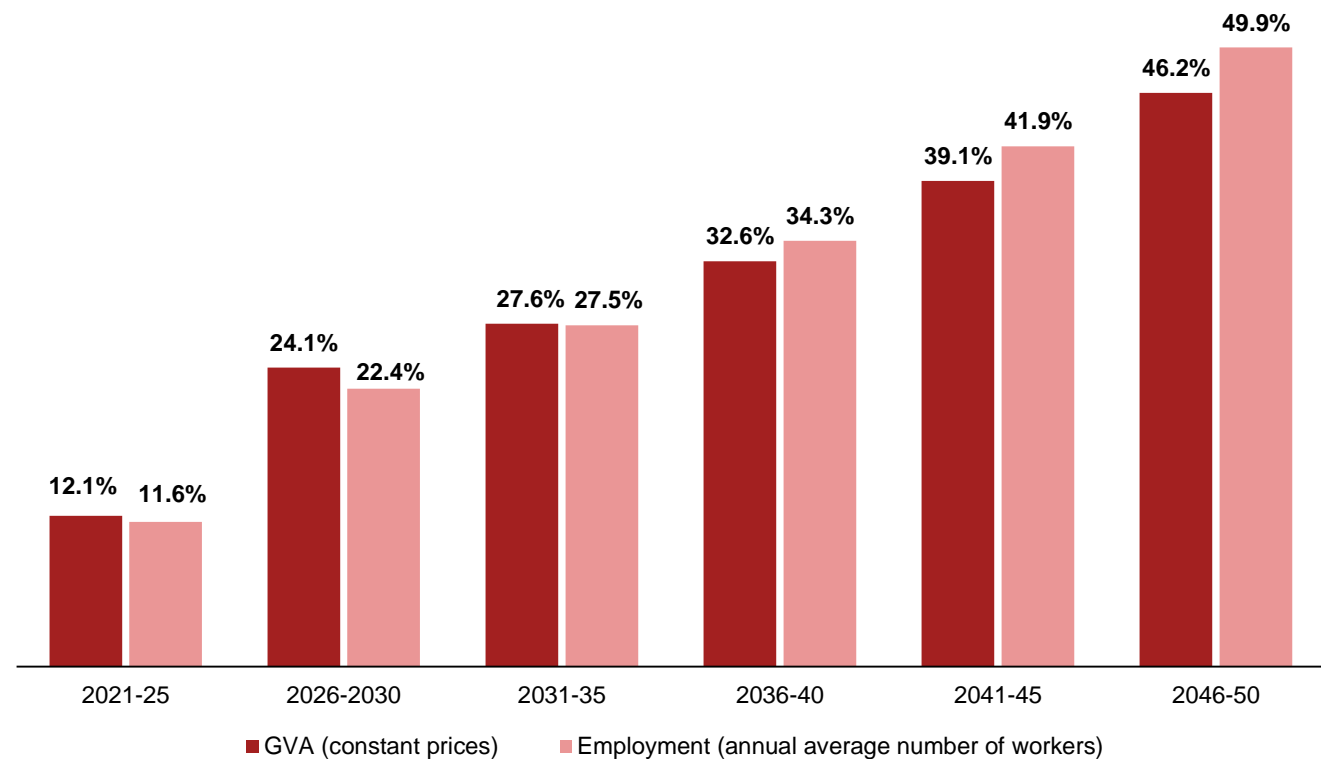
**Sources:** PwC analysis, Team Tempest industry partners data **Note:** GVA figures presented in NPV (net present value) terms in 2019 price basis. Regional employment figures are presented in 'job years' to demonstrate the profile of the employment impact over the first 30 years of the programme. Job years are the 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 therefore estimating an average jobs per year on a regional basis may not present an accurate figure. Data shown are conservative estimates.

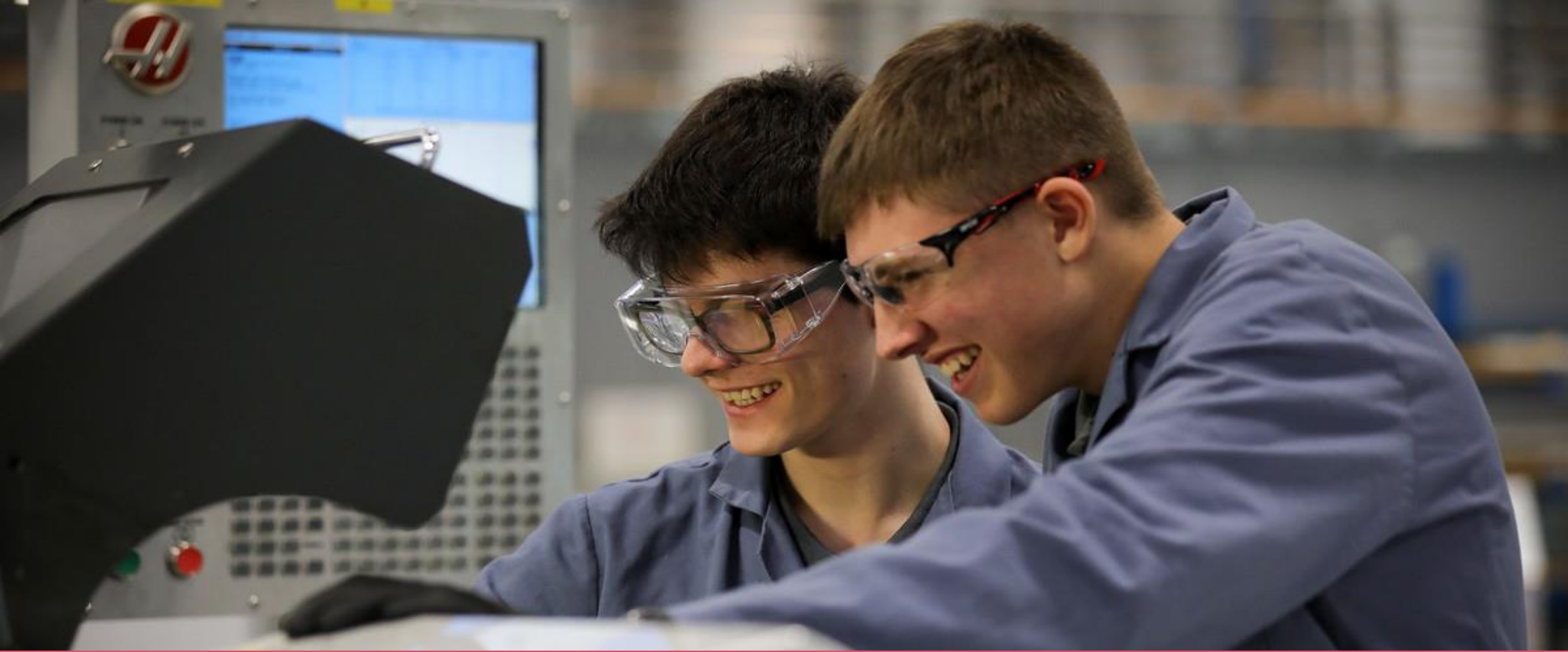
# Tempest makes up 26% of UK Combat Air from 2021-50, though this share increases over the period, reaching c. 50% of Combat Air by 2050

## Tempest programme share of UK Combat Air activities 2021-2050

- **Our estimates show a sustained growth in Tempest employment and GVA contributions over the period as the programme evolves** through the initial concept and assessment phases into development and out to operational service.
- The Tempest programme makes up an increasing share of total UK Combat Air activities, rising from around 12% to nearly 50% of its total economic contribution.
- This also excludes the substantial employment and GVA contributions expected beyond 2050 as export opportunities for Tempest develop, along with R&D spillover effects and benefits arising ongoing support of existing combat air systems.

Tempest programme share of UK Combat Air activities (2021-2050, % of total estimated UK Combat Air contribution)





## 4. Conclusion

# The Tempest programme has the potential to deliver benefits to the UK economy, including generating £26.2bn GVA and supporting 21,000 jobs p.a.

## GVA and employment contribution of Tempest and Combat Air

Over the next thirty years the GDP contribution of **Tempest programme is expected to deliver £26.2bn GVA benefit** (in NPV terms) and support an average of 21,000 jobs per year (from 2026-2050).



For every £1 of direct GVA generated by the Tempest programme, £2.20 is estimated to be created



For each worker employed directly by the Tempest programme, 2.7 are estimated to be employed

The impact of the Tempest programme will be **felt across all regions of the UK**. It is expected to 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**.

**With Tempest**, the expected **GDP contribution of the four Tempest Partners Combat Air activities** from 2021 to 2050 is **£100.1bn GVA supporting 62,000 jobs per year** (2026-50).

The figures **exclude benefits beyond 2050**. Most of the value generated by exports is not captured within this 30 year period.

Our **estimates should be considered a conservative estimate of the overall benefits** that the Tempest programme is likely to deliver for the UK economy.

Along with the economic contributions, the Tempest programme will support the UK 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**



**Develop world leading technology, UK-generated intellectual property, people, skills and facilities**, seen as critical to sustaining the UK's operational advantage, freedom of action and subsequent international influence



**Sustain and develop a capable UK industrial base** to allow the development of solutions to meet national requirements so enabling greater national control over cost and risk of delivering capability



**Continue to be at the heart of effective international partnering** so offering the UK the best opportunity to deliver affordable military capability and wider national objectives



Protecting and investing in the highly-skilled people working in the combat air sector and sustaining the critical sovereign capabilities is a driving force behind the Tempest vision. Through a commitment to the Tempest programme the UK will be in a position to retain these key skills and capabilities so enabling continued development of world leading technologies to deliver future generations of combat air systems. By doing so the UK is able to build upon its long and proud history of delivering world-class combat air systems and maximise the value derived from this critical sector.

Gross Value Added (GVA): A measure of the value of goods and services produced in an area, industry or sector of an economy. Net present value (NPV): Used to compare estimates of costs and benefits occurring at different points in time, taking into account society's time preference for incurring costs and benefits.

# Tempest is expected to drive significant wider contributions to the UK economy through promoting critical skills and R&D investment across the UK regions

## Wider economic impact of Tempest programme



### Tempest is promoting critical skills and capabilities so that the UK can continue to operate at the forefront of world-leading technology

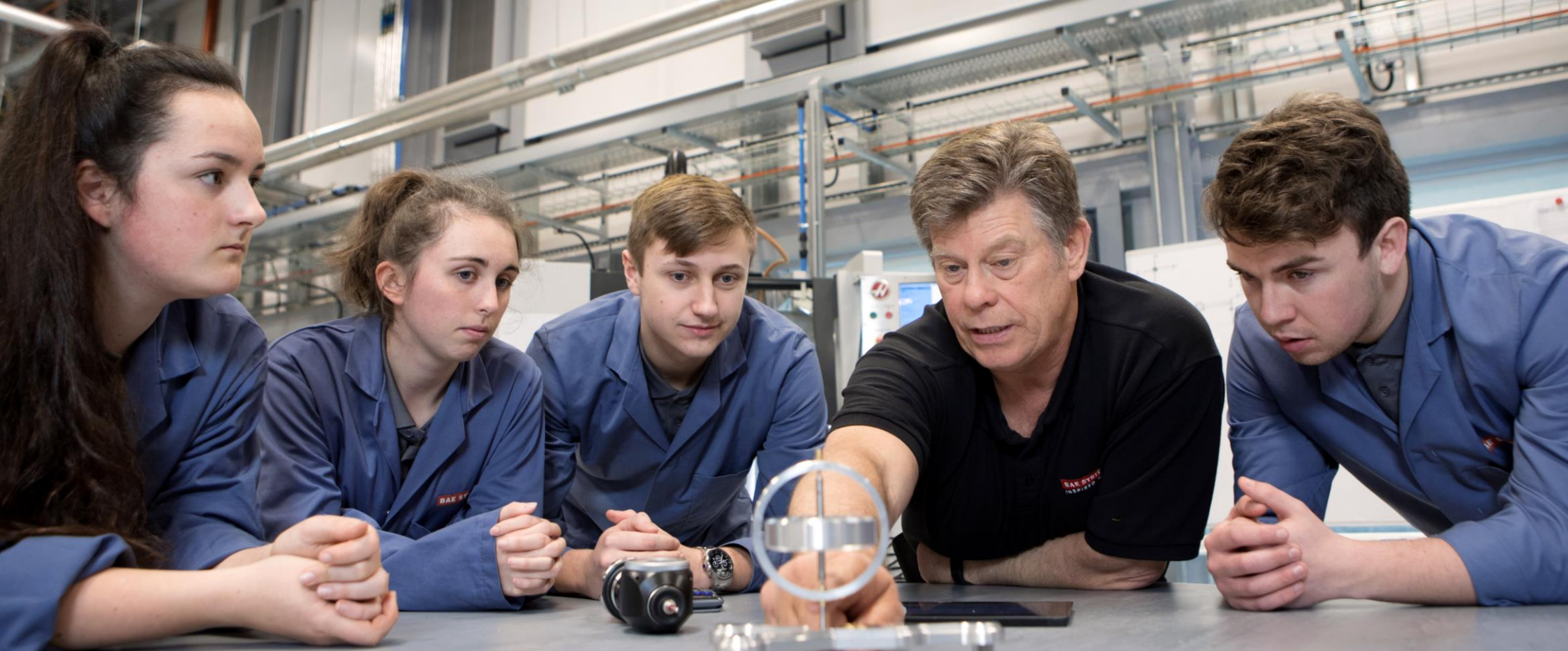
- The programme is already acting as a magnet for encouraging the younger generation, across all regions, to pursue STEM careers
- It also provides the Team Tempest partners with the confidence to continue investing in school outreach activities and offer award-winning apprenticeships
- The programmes' success depends on recruiting and upskilling people to develop the next generation of engineers and technologists capable of tackling complex problems
- The benefits are felt across the supply chain as people switch jobs (and sectors)
- This contributes to meeting the UK's Government priorities of improving productivity and tackling youth unemployment across the UK

### The Tempest programme is supporting high-skilled jobs and stimulating R&D across the UK regions

- The partners are using Catapult networks to gain access to the leading UK research, skills and technologies. This is also delivering benefits to academia and SMEs who, through these collaborations, can commercialise their technologies, improve their performance and attract further investment and funding
- The programme will **stimulate further investment in R&D and further support high-skilled jobs** across the UK helping to create high-value jobs and increase regional productivity
- By developing new skills and technologies and providing high-productivity jobs in areas most in need such as the North West, the programme can support the UK Government's commitment to **levelling up opportunity across the UK**

### The Tempest partners are leading technology integrators and enablers in the UK, fostering a culture of innovation and capital expenditure through their partnerships




- The Tempest programme requires the development of next generation combat air systems, platforms and technologies quicker and at lower cost
- To achieve this, partners are collaborating with Catapults, academia and SMEs and adapting new agile digital working practices
- The new technologies being developed for Tempest offer wider benefits through applications in other sectors in combination with building capabilities through collaborations
- The programme is critical to funding the development of new technologies and contributes to the UK Government's ambition to be a scientific superpower



# Appendix 1: Wider contribution of the Tempest programme

# This section illustrates the potential wider contributions of the Tempest Programme

Besides the economic contributions that flow directly from the activities of the four partners, the Tempest programme also has the potential to drive additional, wider economic contributions that are not captured by the analysis in Section 3. Specifically, the programme is expected to drive contributions in the three key areas summarised below, each of which is closely aligned to a key Government priority (as articulated in the context of the 2020 Spending Review). Each is considered in turn in the rest of this section.

	Wider contribution area	Relevant Government objective	Description
	<b>1. Skill spillovers</b> p28-37	<b>Strengthening</b> the UK's <b>economic recovery</b> from COVID-19 by prioritising jobs and skills	The Tempest programme is a national endeavour which is already acting as a magnet by attracting the younger generation to pursue STEM careers. Through the programme and through collaborations with academia and SMEs, the industry partners have the potential to shape the recruitment and development of the next generation of engineers and technologists. The programmes' success depends on recruiting and upskilling a talented workforce that is able to develop new technologies. These high productivity jobs will contribute to the UK's economy as trained talent moves jobs and sectors.
	<b>2. R&amp;D spillovers</b> p38-47	<b>Making the UK a scientific superpower</b>	Tempest's success depends on producing results faster and cheaper than previous combat air systems. To achieve this, the Team Tempest partners are working collaboratively with academia and specialist SMEs in the aerospace and defence sectors but also adjacent sectors and are adopting new agile working practices.  The fundamental nature and scale of the R&D activity envisaged as part of the Tempest will generate wider economic benefits as the technologies, insights and learnings are applied to other military or civilian applications and as academia and SMEs are able to attract further investments leveraging on the Tempest collaborations (i.e. generating spillover effects).
	<b>3. Regional development</b> p48-56	<b>Levelling up</b> economic opportunity	The scale of the Tempest programme and, in particular, the location of the four partners' business activities, those of their Tier 1 suppliers and those with whom they collaborate mean they have a significant role to play in levelling up the UK.

# 1

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Skills spillovers



# The Tempest programme will attract the younger generation to pursue STEM careers and provide upskilling opportunities across the UK

In doing this, it will support the development of sustainable, highly productive jobs in the UK

**The Tempest programme will accelerate the application of digital engineering by shaping the recruitment and development of next generation of engineers and technologists** – by doing this, it will support, on average, 21,000 highly-skilled roles per year between 2026 and 2050 across the Combat Air sector and **strengthen the UK's economic recovery from COVID-19 by prioritising jobs and skills.**

The COVID-19 pandemic has accelerated changes in how and where we work and has exposed the high-tech skills shortage in the UK and need to adapt, and quickly. Beyond the recovery from the pandemic, failure to prepare for the impact of technological disruption means risking the ability to benefit from the opportunities created by digital transformation and other waves of technological change.

The Tempest partners are committed to:

- Helping meet the UK Government's commitment to the UK being a world leader in embracing the fourth industrial revolution
- Providing a reservoir of STEM educated and experienced employees and in doing so contributing to the UK economy
- Increasing the diversity of their workforces by building diversity and inclusion into processes, practices, policies and systems

Tempest's success depends on **developing and applying new digital and other technologies** in innovative ways



This will require **large employment** – on average 21,000 workers per year between 2021 and 2050, of whom only 2,000 are currently engaged in the programme – **to be recruited and/or upskilled/retrained**



Many will need to develop **new skills** – in the context where these skills are (expected to be) in short supply nationally



To secure their workforce, the Tempest partners are committed to **building on their successful track record of managing talent (and skills development) over the lifecycle** – and, by doing this, they will bring wider value to the UK



**20-40%**

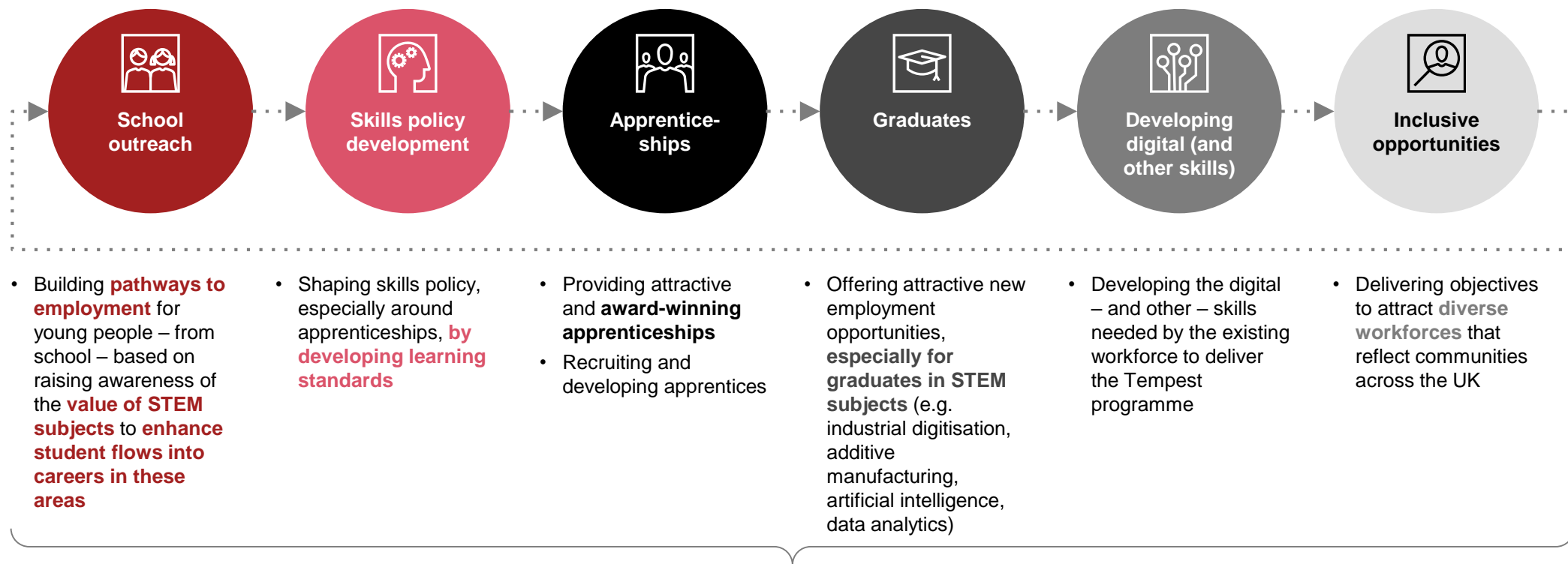
of the jobs currently held by 16-24 year olds **may be automated by the mid-2030s** (PwC)



**74%** of CEOs are concerned about the **availability of key skills** to grow their business (PwC's 23<sup>rd</sup> Annual Global CEO Survey)

# The Tempest partners will need to recruit, upskill and retrain a large number of people, many of whom will need to develop new skills

The Team Tempest partners are investing in building and managing their talent pool over the lifecycle of the programme



## Benefits to the wider UK economy

- The UK Combat Air Strategy provides the industry partners with the confidence to invest in attracting the younger generation and upskilling their workforce. This enables the UK to sustain high value jobs across the partners and their suppliers and across the regions
- These benefits go beyond the Tempest programme and wider Combat Air across the UK economy as trained talent switch jobs (and sectors) across the supply chain and across the UK regions
- It also helps the UK to bridge the gap between the skills people have and those needed for jobs in the digital world but also reducing the skills gap and increasing employment and productivity amongst disadvantaged groups

# The Tempest programme acts as a magnet in attracting young people into STEM careers

## The Tempest partners are working with schools, colleges and universities to promote STEM careers and build their workforce

- The Team Tempest partners are investing in the education and training of young people across the UK.
- The Tempest programme acts as a magnet for the younger generation in pursuing STEM careers and, in doing so, providing benefits to individuals and the wider economy through increased productivity in high value jobs and skills spillovers as people move across jobs (and sectors).
- Building clear and accessible pathways to employment for young people from school by raising awareness of the value of STEM subjects will enhance student flows into careers in this area.
- The Team Tempest partners provide substantial early careers programmes. To promote STEM subjects and careers to young people, they use forward-thinking UK engineering programmes such as the Tempest programme to excite and engage young people about careers achieved from the study of STEM. For example, the Tempest mock-up has been used at large STEM events (such as Big Bang, a combined Team Tempest event which attracts c. 70,000 young people each year). Other examples include:
  - BAE Systems' flagship education programme, a Schools Roadshow delivered in partnership with the Royal Air Force and Royal Navy, engages more than 100,000 school pupils each year
  - Each summer Leonardo hosts the 'Rampaging Chariots' tournament across its UK sites with more than 400 young people taking part each year
  - MBDA run engaging and inspirational activities like the 'Robot Rumble' to encourage a new generation into careers in engineering
  - Rolls-Royce's STEM education outreach programme aims to reach 25 million people by 2030, having already achieved 27% of that target with events such as its Annual Science Prize and Work Experience opportunities, all delivered by its 1,400 global STEM ambassadors
- **All these activities have a potential to increase flows into STEM careers for the benefit of the wider economy beyond the Team Tempest partners and defence sector.**



# The Tempest partners are shaping the defence sector's skills policy, including developing digital skills and identifying future skills needs

## Their involvement in the Defence Growth Partnership is an example of their work

- **The Tempest partners are helping shape skills policy, including developing a framework for digital skills.**
- This benefits many employers and employees, including apprentices, beyond those involved in the Tempest programme and Combat Air activities.
- **This includes working alongside government to shape and improve standards of training and apprenticeships** for the benefit of employers and apprentices alike, not just those involved in the Tempest programme.
- BAE Systems and Rolls-Royce are amongst a number of leading employers who, as part of the Aerospace Growth Partnership, are designing and developing the Aerospace and Airworthiness Apprenticeship Trailblazer standards.
- The new standards aim to shape the future of apprenticeships and meet the needs of large companies and SMEs by providing flexible pathways into careers in the defence sector for young people. The standards specify the knowledge, skills and behaviours needed for occupations that are crucial in the sector. They relate to technologies that companies in the defence sector use and also align to the engineering professional standards in the UK set by the Engineering Council.

- BAE Systems is also working in collaboration with others across the engineering and manufacturing sectors to ensure the UK has the skills to take advantage of Industry 4.0. This includes examining retraining/upskilling and technology investments to meet the skills required.

### The Tempest partners are shaping the development of new digital skills through their involvement in sector bodies

As members of the Defence Growth Partnership (DGP), the partners are working across the defence sector to address the shortfall in sector skills assisting in the development of a Defence Digital Skills Framework Portal that aims to upskill the workforces of the DGP members, and related SMEs and suppliers in the UK.

The Tempest partners, through the DGP, have been part of the working groups that have put together the Level 7 (Masters level) Systems Engineering Apprenticeship Standard, and the Defence Export eMBA at Cranfield University. MBDA technical experts also inform the University's Guided Weapons Masters of Science (MSc).

The Tempest programme is developing new digital technologies and a key feature of the work of the DGP's skills group has been to support skills development. It has identified future skills needs and created a new DGP skills portal.



# The apprenticeship opportunities created through the Tempest programme will develop highly valued skills

## The Tempest programme will offer attractive apprenticeships

- The Tempest programme will provide exciting, high quality apprenticeship opportunities for young people across the UK at a time when demand for apprentices has been hit hard by the effects of Covid-19 and concerns are being expressed about the future of apprenticeships post-pandemic.
- Only 58,160 new apprentices started in England between the start of the UK-wide lockdown on March 23 and July 31 in 2020 (46% less than in the same period in 2019). Furthermore, a recent study by the Sutton Trust found that the Government's £2,000 bonus for new apprentices is 'failing to stem the cull of on-the-job training programmes by employers' as more businesses are making apprentices redundant, threatening the Government's social mobility agenda.
- Despite this, **two years after the launch of the Tempest programme, 1,000 apprentices and graduates are already working on it across the four partners.** The opportunity to grow and develop talent will continue to increase in the coming years. For example, 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. At any one time the business has more than 2,000 apprentices training.
- **These apprenticeships will benefit the wider economy to the extent that trained apprentices switch jobs.** For example, across the partner companies, c. 15% of apprentices move on to other companies and sectors delivering wider benefits.

**1,000** apprentices and graduates working on the Tempest programme



**Skills development** through high-quality training programmes



**c. 15%** of trained apprentices will switch jobs to benefit the wider economy



### BAE Systems' early careers

BAE Systems is committed to developing best practice in apprenticeships and using this route to recruit its workforce. It does by sharing best practice in their skills training across their programmes. For example, BAE Systems colleagues from Australia visited the ASK and the Advanced Manufacturing Research Centre (AMRC) at Sheffield University to help with the digital shipyard construction for the Hunter Frigate.

### MBDA's award winning apprenticeships have been recognised nationally and inspire young people

The breadth of the awards shows that the work of their apprentices is not solely inward facing into the company, and can have a benefit for not just MBDA. The work that leads to winning national and regional awards for in STEM outreach and championing apprenticeships could lead to young people's career choice being at other companies, and not just in the defence industry. Other award winners use their success to help inspire others. Tatiana Peters won the Royal Navy Award for Advanced Apprentice of the Year at the National Apprenticeships Awards 2019. Having completed an apprenticeship scheme at MBDA and now being sponsored through a Bachelor's degree in engineering whilst in a permanent role, Tatianna continues to volunteer as a STEM and YAAN (Young Apprentice Ambassador Network) ambassador to be a relatable STEM role model and motivate the apprentices of tomorrow.

# Recruiting and developing graduates is also critical to building the Tempest workforce

## The Tempest partners are partnering with universities to attract students

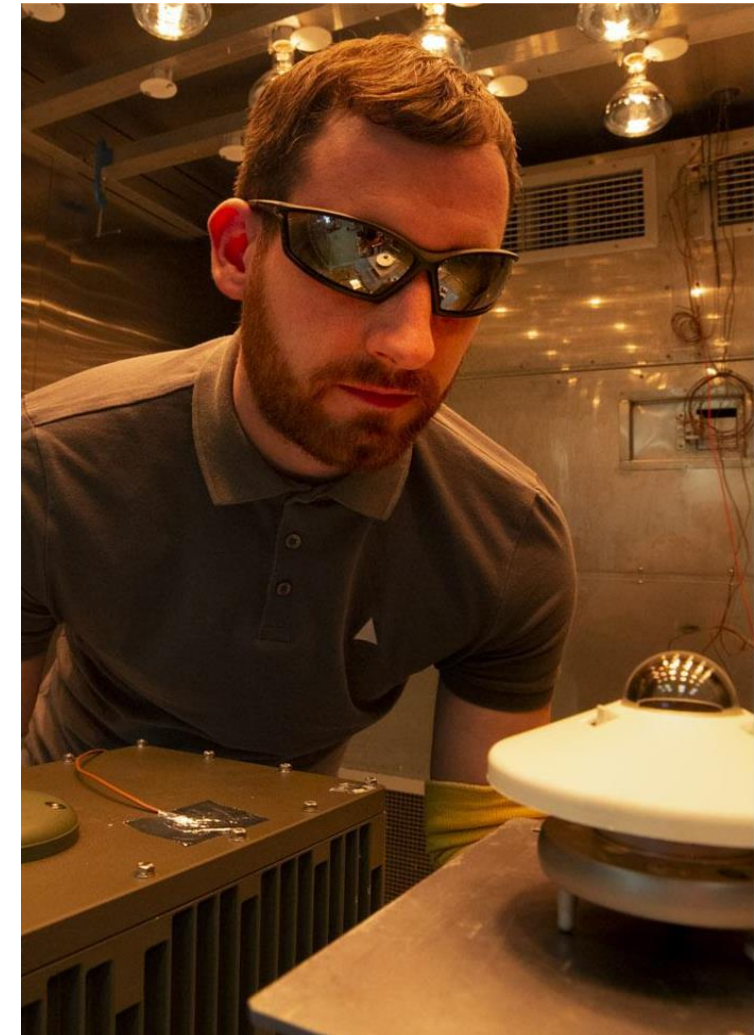
- The graduate schemes offered by the Tempest partners are high quality programmes. For example, Leonardo UK's graduate schemes are triple accredited by the IET, IMechE and IoP. These give young people around the country valuable opportunities to develop their skills in future-proof domains such as software engineering and cyber security.
- 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.

### Applications for Leonardo's early career opportunities are on the rise

Leonardo works in close partnerships with many universities across the UK to give students work experience opportunities that are designed to fast track their understanding of engineering careers and their effective application to cutting edge technology. Summer placements allow students to return to their studies with renewed insights into their engineering degrees, with exposure to the behaviours and mind-sets role modelled by engineering mentors. These are complemented by longer academically assessed placements, which are often Masters level industrial projects, which contribute to the students' degrees.

**These activities are very important because of the contribution of high-tech engineering to the economy of the UK and because of the nation's on-going engineering skills shortage.** In a recent survey of engineering professionals [1], 37 per cent identified the skills deficit as having the biggest impact on their sector, while an earlier report in 2017 by Engineering UK [2] showed that Engineering graduate supply falls short of demand by at least 20,000 annually.

**By recruiting and developing graduates, the Tempest partners are helping to close that gap by keeping students enthused about a career in high-tech engineering and then further developing their skills once they join the workforce.**



Sources: Team Tempest industry partners data, [1] [The Engineer UK](#) (March, 2020), [2] [Engineering UK](#) (2017)

# The Tempest partners are upskilling their existing workforce to enable more agile working practices

The partner activities are helping to bridge the discrepancy between the skills that people have and the skills that will be required in an increasingly digitised world

- The Tempest partners are transforming their **workplace cultures** – introducing agile working, increasing pace using digital engineering solutions, and exploiting emerging disruptive technologies. These new working practices create the need to **upskill the workforce**.
- The Tempest programme is helping transform the skills base by driving the adoption of digital technologies such as automation and analytics, to ensure the **skilled workforce will become more productive, efficient and agile**.
- Reskilling and upskilling initiatives, including some mentioned on the right hand side, will boost the **pool of available talent in the UK engineering sector**, supporting Tempest and enhancing the UK's skills base in the long term.
- The skills that employees develop will **benefit the extended supply chain** and **spill over** into other high value engineering sectors in the UK, making an important contribution to **economic prosperity and productivity and increasing international competitiveness**.



## MBDA's skills and learning strategy is based on lifelong learning

MBDA is inspiring, exciting and equipping its workforce with the skills that will help develop Tempest's future technologies not just for early careers candidates but also for its existing workforce. MBDA's skills strategy is based on a common approach to creating and maintaining a robust technical and behavioural skills foundation. This is used to inform recruitment, development and retention of employees. Accompanying this is a methodology for analysing skills requirements for the next five to ten years to identify how and when the skills need to be acquired or developed. Supporting this, MBDA has a holistic approach to learning that is supported by a transfer of knowledge from experienced staff to staff with less experience.



## Rolls-Royce Digital Academy promotes more agile ways of working by developing digital skills

The Academy has already trained 20,000 employees over the last two years who have developed the skills, awareness, networks and inspiration required to ensure that a 'Digital First' approach is applied across all projects and programmes. Working alongside their trusted partners and platforms the Digital Academy has strengthened learning around topics including data science, artificial intelligence, coding and digital culture, which will be key to the Tempest and those working across the programme.



## Leonardo's STEM Returners initiative will boost the pool of available engineering talent in the UK

Leonardo UK contributes to the long-term sustainability of the UK's skill base through various re-skilling initiatives. For example, through the STEM Returners programme, they allow experienced job applicants to restart their careers after a break by acknowledging and valuing transferable skills that they have gained.



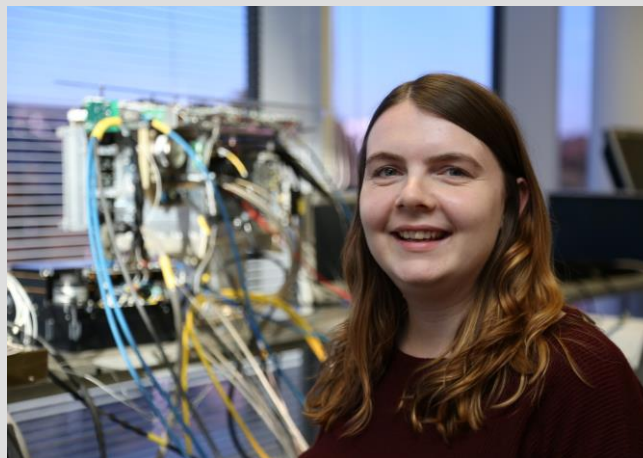
## BAE Systems' Academy for Skills & Knowledge (ASK) delivering critical skills for tomorrow

With £20m invested to date, the ASK facility in Lancashire is ensuring its workforce has the skills needed, such as digital skills, 3D adaptive layering critical to enabling specialist skills for programmes such as Tempest. Recognising skills development is an increasingly important component, be it locally or its support to overseas campaigns, the company is taking a collaborative approach to providing life-long learning and skills development to respond to the challenges and opportunities of Industry 4.0 and digital skills.

# Promoting greater workforce diversity and inclusion across the Tempest workforce will drive wider benefits

It will reduce the skills gap, increase employment and productivity and reduce occupational segregation

- The partner companies have individual programmes that actively strive to drive gender equality and provide inclusive working cultures through various schemes, initiatives and external partnerships to promote the skills and knowledge required for the defence industry in the future. **An environment in which a range of viewpoints and backgrounds are valued encourages creativity and problem solving which underpin high-tech engineering programmes such as Tempest and the vibrancy of the UK's engineering sector as a whole.**
- Leonardo UK, MBDA and Rolls-Royce are **members of the 5% Club**, which helps members increase the number, quality and range of 'earn and learn' opportunities across the UK. The opportunity to earn and learn makes a highly-skilled career in engineering more accessible to people from a wide range of backgrounds.
- All four companies actively reinforce an **inclusive work environment** embracing diverse talent and deliver inclusion and diversity programmes including cross-organisational network groups for LGBTQ+, gender balance, mental health, assistance for veterans and social mobility. Providing opportunities not only to progress skills talent but for all employees to thrive in the workplace regardless of their race, gender or background. For example, Leonardo's partnership with the Association For Black and Minority Ethnic Engineers (AFBE-UK) aims to **attract people from ethnic minorities to apply for engineering jobs.**



## Leonardo: providing an environment where female engineers can thrive – Fiona's story

Leonardo UK hosts a range of female-focused STEM outreach initiatives to increase its population of female engineers. This includes a range of activities with local schools to celebrate International Women in Engineering Day, as well as an annual summer placement programme for budding engineers. Dr Fiona Muirhead is an example of a gifted individual whose talent has thrived at Leonardo, through investment in her skills and professional development in an industrial setting.

Fiona was introduced to a professional engineering environment when she embarked on a summer placement at Leonardo. The innovative technology Fiona was able to work on and the stimulating teamwork she experienced proved to be the ideal setting for Fiona's ambitious career aspirations. In 2013, she secured sponsorship from Leonardo for a PhD in Radar Technology at Edinburgh University. Over the course of the following four years, she attended Leonardo Edinburgh site where her thesis was informed by seasoned engineers, who shared real life engineering projects and scenarios in which the thesis's theories could be applied.

Because of Fiona's exposure to the dual worlds of industry and academia, the work produced in her PhD was of such a quality that it caught the attention of the Royal Commission for the Exhibition of 1851. Leonardo supported her successful application for Royal Commission funding to further her developmental radar research, which continues to this day.

# In summary, the Tempest programme's success depends on developing the next generation of engineers and technologists

The UK's Commitment to Tempest will provide the partners with the confidence to invest in, and acts as a magnet for, the younger generation to pursue STEM careers and for upskilling their workforces

The Team Tempest partners are continuing to invest in developing and applying new digital technologies

The programme's success depends on **developing the next generation of engineers and technologies** by **shaping the skills and training policies and standards**, attracting the **younger generation** and **upskilling the existing workforce**. This will contribute to meeting the **UK Government's priority of improving productivity across the UK and helping to tackle youth unemployment**

The programme acts as a magnet in attracting young people into STEM careers

The Tempest partners are committed to providing **school outreach activities** and building **pathways to employment for young people**. They are working with schools, colleges and universities to promote STEM careers and build their workforce. This has the potential to **increase flows into STEM careers**

The Tempest partners offer attracting apprenticeships and new employment opportunities for graduates in STEM subjects

The apprenticeship and graduate opportunities arising from Tempest will develop **highly valued workforce skills which will benefit the wider economy**, as well as the Tempest programme and Combat Air, to the extent that the trained apprentices and graduates switch jobs (and sectors).

The partners are also **upskilling their existing workforce** developing the **digital and other new skills** required to deliver the Tempest programme

By training young people and **upskilling their existing workforce** to meet the needs of Tempest and their wider Combat Air activities, the Tempest partners will support the **development of new digital skills in key areas** (e.g. industrial digitisation, artificial intelligence, etc.) this will benefit the wider economy and **help the UK close the high-tech skills shortage**

The Tempest workforce will be based on **greater diversity and inclusion** across the industry partners

The Tempest partners are committed to a policy of **greater workforce inclusion**: for the economy as a whole, this will reduce the skills gap, increase employment and productivity amongst disadvantaged groups (e.g. women, ethnic minorities, disadvantaged communities) and reduce occupational segregation, as well as aligning with government's objectives in respect of equal opportunities

# 2

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R&D spillovers



# The UK Government aims to make the UK a scientific superpower; the Tempest Programme with support this objective

## R&D activity has the potential to generate wider economic benefits

The UK Government is committed to increasing investment in R&D to 2.4% of GDP by 2027 and to increase public funding for R&D to £22 billion per year by 2024 to 2025 as a major stride towards this goal. This is expected to increase economic productivity and prosperity by developing new products, services and jobs. It will also help to maintain the security of citizens.

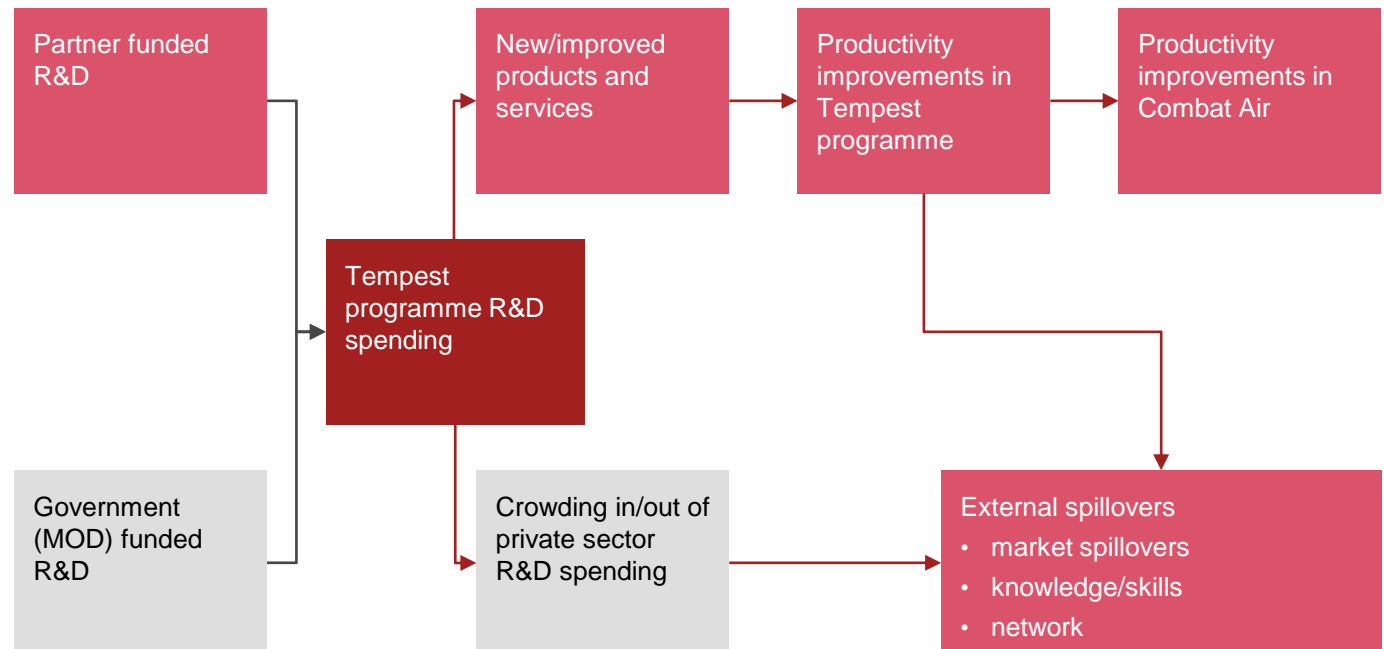
Successful R&D creates benefits both for the investor/funder as well as spillovers for those not directly involved in the initial R&D activities. These spillovers can occur through three key channels [1]:

- **Market spillovers**, if the price paid to the investor/funder is less than the full value of the new or improved product
- **Knowledge/skills spillovers** as the knowledge created is disseminated to other firms and organisations
- **Network spillovers** if the development of new products creates demand for complementary products

This section illustrates the potential contribution of R&D spillovers from the Tempest programme by summarising historic examples of the spillovers from the Tempest partners' earlier R&D.

The diagram on the below illustrates the mechanisms through which R&D investment on the Tempest programme can generate positive spillovers to the rest of the economy, beyond the Tempest programme and Combat Air activities.

- Both the UK Government (e.g. Ministry of Defence) and partners will fund R&D activity linked to the Tempest programme
- This spending will deliver benefits to the partners through new products developed and improved productivity
- In addition, public sector funded R&D stimulates wider private sector R&D
- This generates potential external spillovers to the wider economy



[1] Key spillover channels identified in: Lucking, Bloom, Van Reenen (2018), Hall, Mairesse and Mohnen (2009), BIS Research Paper 178 (2014), Aerospace Technology Institute (2019)

# The Government and the Tempest partners are investing in R&D to meet the demands of the Tempest programme

## The Tempest programme can generate wider benefits as R&D learnings are applied elsewhere

- The Tempest partners are leading technology integrators and enablers in the UK **fostering a culture of innovation and capital expenditure**. They manage **significant R&D partnerships with UK universities and SMEs** which focus on key areas of technology strategically important to the programme such as autonomy, propulsion, virtual reality and advanced manufacturing and machine learning. They leverage on their memberships in Catapult networks that gives them access to the UK's leading research, specialist skills and technologies.
- Considering the critical nature of Tempest programme in safeguarding the UK's future defence and security as well as maintaining a sovereign and highly skilled UK industrial base, **the Tempest industry partners have made significant investments in R&D to support the programme and future Combat Air capabilities**.
- Combat Air is an environment with some of the most demanding performance requirements. **It provides the stimulus for the creation and exploitation of cutting-edge technologies and techniques with significant spill-over benefits to the UK economy**.

- **The Tempest programme provides an opportunity for the partners to combine digital engineering, agile development and open architecture** to speed up the development and the innovation cycle – a real game changer.
- **The new technologies offer wider benefits, beyond the programme and Combat Air**. For example, new manufacturing techniques such as friction stir welding and large-scale additive layer manufacturing will be core to Tempest and the experience generated will have significant civil applications.



Changes in the threat environment require the development of next generation combat air systems, platforms and technologies

At the same time, commercial pressure exists to develop new platforms quicker and at lower cost

To achieve this, the Tempest partners are working **collaboratively with Catapults, academia and SMEs in the aerospace and defence sectors** but also **adjacent sectors** to leverage the best of the UK science, research and skillsets

To meet the commercial and technological challenges and deliver the programme successfully, the partners are adapting new **agile working practices based on digital approaches**

The new technologies offer **wider benefits**, beyond the Tempest programme and Combat Air through applications in other sectors (e.g. radar technologies used in civil applications)

# The changing face of the threat environment requires investment in new technologies to survive

## Tempest is acting as a stimulus for partners to leverage technologies from adjacent sectors

- The rapid development of technologies is changing the face of the threat environment, proliferating at pace that the future air environment will be increasingly complex and reliant on a connected and agile systems of systems military capability. **This requires the Tempest partners and their extensive supply chains to exploit new technologies** and stay ahead of the evolving threats to ensure the UK has the military capability and agility to safeguard national security.
- In addressing this challenge, the partners are **working collaboratively to harness emerging technologies** through an approach of sharing and collaboration in **partnerships with SMEs throughout the UK including those from adjacent sectors** such as the automotive industry, the health industry and the video gaming industry.
- BAE Systems' partnership with Formula 1's Williams Advanced Engineering, for example, is providing motorsport-inspired technology to enhance Tempest development work. Together with Rolls-Royce, the companies are jointly exploring how battery management and cooling technologies from the motorsport industry, particularly Formula-E, can be exploited to bring efficiency and performance gains in the design of a next generation Combat Air system.
- Crucial to the operation of Tempest will be the 'human operator' and the proliferation of technology and interface with the role of a pilot requires not only the adoption of augmented and virtual reality but careful assessment of psycho-physiology. **The partners are working with the digital health industry** on technologies which measure operator workload and mental stress in different circumstances whilst being able to use hand movement and eye-tracking with a sensation of touch in an AR/VR environment.



### The Tempest programme is driving MBDA's digital engineering innovations

Working with the MOD across Tempest and Complex Weapons, MBDA are studying how certification and clearance for weapons systems can happen at an enhanced pace, leveraging technology and stimulation, whilst still meeting the UK's world class standards in verification and safety.

For MBDA, Tempest is driving its **digital engineering and technical methodology** towards harnessing its decades of experience and data in physical weapons testing and integration, and **transferring it to the digital world.**

In synthetic environments, through **augmented and virtual reality (AR/VR)**, MBDA wants to leverage this data to provide the capability to trial and test multiple times, faster and quicker and at less cost than doing this in the real world. MBDA believe this will contribute to getting it 'right first time' findings from the virtual to the real world.

Working digitally in this way will enable MBDA to rapidly share its findings and results across all of its work. Not just in concepting and assessment, but in spiral development without the need for integration to start all over again, but also into training for end users across the spectrum of a systems lifecycle.

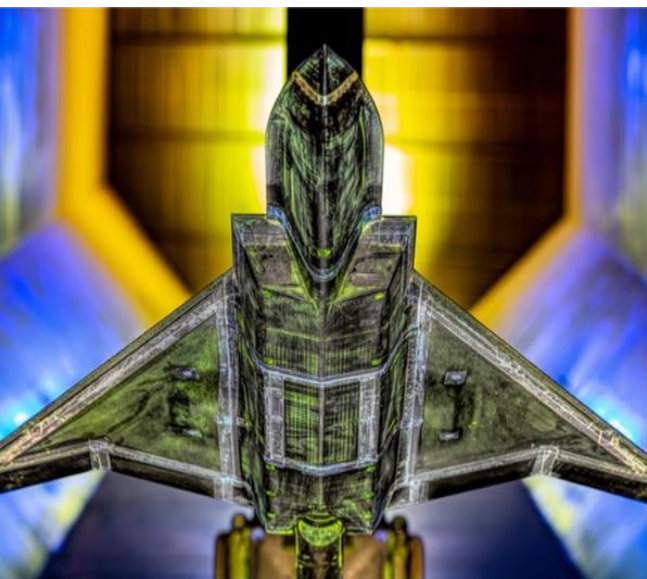
# The Tempest partners are developing new ways of working to drive affordability

## Commercial pressures are driving development of platforms quicker and at lower cost

The goal of the Tempest partnership is to develop the key technologies and capabilities which will allow a UK-led international collaborative Future Combat Air System to enter its Initial Operating Capability phase by 2035 and achieve Full Operating Capability by 2040. In the case of the UK, it is intended to replace Typhoon as it leaves service in the next 20 years.

These **milestones represent a challenge for industry to meet a significantly expedited timescale and cost aspiration** – and one which is both significantly faster and more cost effective than previous programmes.

To achieve this aim, the Tempest partners are blending the expertise and know how from the UK's well established aerospace and defence companies with academia and many high tech, specialist SMEs across the UK. At the same, **they are embracing new ways of working and investing in advancing technology to transform and drive pace and efficiency.** For example:



### MBDA's transformative ways of working to deliver capability, faster and at lower cost

With threats to UK Armed Forces evolving quicker and becoming increasingly complex, MBDA is working to deliver capability faster and at lower cost than ever before. The length and cost of weapons integration on platforms have been on an upward trend. Through Tempest, MBDA is **aiming for weapons integration** to take place in **half the time and at half the cost**. The company's vision for future weapons integration is for it to be as simple and as quick as plugging in a USB stick.

Tempest was established to change the way Combat Air suppliers collaborate. MBDA has embraced this to transform its ways of working. A key step is the move from linear processes to agile processes, similar to software design. There is also the change in the way it works with industrial partners. Weapons systems engineers are collaborating with their counterparts from the other industrial partners. With BAE Systems, MBDA engineers are shaping the carriage and release of effects in tandem with the design of payload bays. They are having input into the cockpit and the human machine interface (HMI) of how a pilot (whether in the cockpit or operating a platform remotely) can maximise their weapons effect whilst minimising the thinking time to achieve that. Working together with Leonardo UK there is the opportunity to explore how weapons systems can form part of an extended sensor network, maximising the data available in a battlefield to achieve an information advantage.

The collaborative work MBDA is carrying out as part of Tempest is laying the foundations for weapons integration to begin at the start of the programme, instead of at the end as it has been historically, contributing to a reduction in length and cost.

# The success of the programme depends on working collaboratively with many high-tech, specialist SMEs

## BAE Systems is working with the best capability across the supply chain to develop the new technologies required

**BAE Systems is working with DIEManalytics – a specialist disrupter – 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-Ratnam in 2002, DIEManalytics has a specialist understanding of data analysis and Artificial Intelligence (AI). The company develops visual models, simulations and decision aides to help make more effective defence decisions.

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. This means BAE Systems can get involved at a stage in the process in which there is already proof of concept, focussing on the development phase, rather than research and risk-taking.

**BAE Systems is working in collaboration with 3D printing technology experts, Renishaw, based in Gloucestershire**

BAE Systems are in the process of productionising a number of titanium components which make up the structure which surrounds the engines of Typhoon aircraft.

The aim is they will replace conventionally manufactured parts on the aircraft **making production 60% quicker and cheaper**, which will ultimately improve overall productivity and affordability. The parts are also lighter in weight compared to traditionally manufactured parts which helps improve the aircraft's efficiency and performance.

3D printing technology brings benefits in a number of ways, includes:

- Reduced cost through improved productivity/yield and increased automation
- Reduction in lead time (leading to further cost reductions due to a reduction in required support)
- Improvement in quality
- Reduction in mass

3D printing is being exploited in the **design stage for Tempest**. 3D printed scale concept models have undergone wind tunnel testing in Lancashire to help define and optimise the shape of a next generation combat air system. Using 3D printing in this way helps engineers quickly design, print and physically test ideas in a fast paced, iterative environment.



# The Tempest partners are leveraging relationships with leading universities and academic research centres to explore new technologies

These collaborations will contribute to improving the human capital and capabilities of academic institutes attract further investment into academia

**BAE Systems and Leonardo are collaborating with Strathclyde University** in areas such as hyperspectral imaging and the relationship on neuromorphic processing respectively and are funding PhD students and lectureships. These collaborations are a key part of gaining critical situational awareness from combat air system sensors.

**BAE Systems works with Cranfield University to develop autonomous systems for unmanned aerial vehicles and industrialisation of Additive Manufacturing.** In one trial involving BAE Systems and Cranfield, large-scale Additive Manufacture was used to produce a large engine mount frame for a Typhoon aircraft in record time. The process, which would normally have taken close to 2 years from design to being ready to fit on an aircraft, was achieved in 100 days.

**University of Sheffield is home to the Advanced Manufacturing Research Centre (AMRC), part of the HVM Catapult. BAE Systems** is a member of the High Value Manufacturing (HVM) Catapult and works with AMRC on a number of projects focused on machining and composites. This includes using the BAE Systems Factory of the Future as a 5G testbed to understand how best to use this technology and to drive productivity and efficiency across the supply chain, including SMEs.

**University of Edinburgh, Heriot-Watt University and Leonardo have a three way research partnership.** This has led to a long-term sponsored chair, joint leadership of the EPSRC/Dstl funded University Defence Research Collaboration (UDRC) and multiple PhD and EngD research programmes for students and Leonardo staff. The partnership also extends to the Centres for Doctoral Training (CDT) in Applied Photonics as well as Robotics and Autonomous Systems.

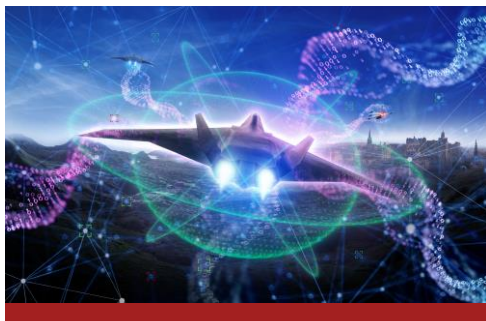
**University of Manchester and BAE Systems are collaborating on research in advanced materials.** BAE Systems is working with the university on development of next-generation aerospace materials, including graphene, and on flapless flight technologies. This kind of innovation paves the way for engineers to create better performing aircraft which are lighter, more reliable and cheaper to operate.

**University of Nottingham is working with BAE Systems in areas such as robotic assisted assembly.** Using off-the-shelf production robots, commonly used in the automotive sector, BAE Systems, the university and industry partners jointly developed the capability to monitor and control these robots through real time adjustments to achieve the demanding tolerance requirements needed to manufacture combat air system components.



# Technologies developed for Tempest have been applied and have the potential to be applied to other military or civilian applications

## Leonardo's E-scan radar technology and Rolls-Royce's integrated power management are good examples of wider civil applications beyond Tempest



### Leonardo's E-scan radar technology

At the heart of Tempest will be new radar technology capable of providing over 10,000 times more data than existing systems — equivalent to the internet traffic of a large city such as Edinburgh, every second.

The commitment needed to design such advanced radar technologies is substantial. It takes years of investment in skills, research and cutting-edge facilities. But the benefits are equally substantial. Leonardo has exported its E-scan radars from the UK to 30 countries, supporting hundreds of jobs in Scotland. In an example of the potential of this technology, Leonardo and BAE Systems are working to deliver the new ECRS Mk.2 radar for the Royal Air Force's Typhoon fleet.

This project will deliver the most capable radar system ever produced for a fighter jet and some of the advances the partners are making under this contract have a direct read-across into Tempest development work. **It's a good illustration of the way the partners are reducing risk in the Tempest programme overall.**

Meanwhile in the civil sphere, **the UK Maritime and Coastguard Agency operates Leonardo's E-scan radar technology** to support missions such as search and rescue and border protection. The Agency is soon to upgrade to the company's latest model, produced using some of the £970 million Leonardo invested in UK research and development during the six years to 2019. This new radar will help save even more lives using its patented 'small target detection' capability.



### 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 air vehicle electrical power. Finding a solution has the potential to be transformative, with important wider benefits.

Rolls-Royce believes it could reduce the number of energy exchanges and maximise the potential of gas turbines as the primary power source. Importantly, it also offers significant **potential spillover benefits into adjacent market sectors such as civil aerospace**, where the

drive towards a sustainable, environmentally sensitive future will lean heavily on more electric technologies.

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. The focus is on developing high-density power and propulsion systems that are future proof and can sit at the heart of Tempest's combat capability. This means being adaptable to future changes in requirement.

Much like their Team Tempest partners, Rolls-Royce is looking to draw on its network of world-class universities and catapult centres in the UK alongside its own employees.

# The Tempest programme is helping to drive forward technological adaptation and innovation

This will contribute to maintaining the UK's competitive position as a scientific powerhouse



**5G technology is an example of how the Tempest programme is encouraging collaborative innovation for the benefit of the wider UK economy beyond the programme products and platforms**

The UK Government is funding research and development projects aiming to put Britain at the forefront of 5G technology [1]. This funding boost, in combination with the new technologies required for the Tempest programme to be successful are encouraging the Tempest partners to work collaboratively with academia and SMEs to explore how 5G can be used to deliver the Tempest future fighter jet in half the time.

**BAE Systems** is working with the **AMRC, the Digital Catapult, Miralis Data, MTT, Three and IBM** leading a project in Preston that aims to develop integrated solutions to some of the key challenges to deploying 5G technologies in manufacturing, using 5G to test use cases such as robotic assembly, reconfigurable product assembly lines and distributed and shared VR/AR. The programme will establish a primary site at the **AMRC North West** and secondary sites in **BAE Systems Warton** and **AMRC Sheffield**.

Projects such as are an example of how the Tempest programme is stimulating the development of new technologies that can be applied beyond the Tempest products and platforms. By collaborating with SMEs and academia across the UK, the programme is benefiting the wider ecosystem and supply chain and **contributes to regional development and the UK's global manufacturing competitiveness.**

Andy Schofield, BAE Systems' Manufacturing and Materials Technology Director said:

“

5G technology is core to enabling the next generation of digital manufacturing processes and the acceleration of digital technology adoption across the manufacturing sector. The 5G FoF programme will drive forward holistic connectivity and unlock the potential of industrial digitisation. It will define a new paradigm for how future factories will operate enabling connectivity and business agility both across manufacturing operations and beyond into the supply chain. The transformative potential of 5G technology will be developed and demonstrated via a strong consortium, including the UK Catapult Network and the BAE Systems Factory of the Future which is applying game-changing digital technologies to advance manufacturing on the UK's next generation combat aircraft system, Tempest.

”

# Delivery of the Tempest programme contributes to the UK's ambition to be a scientific superpower

The investment in R&D for Tempest will generate benefits for the wider economy through applications of technologies in other sectors and collaboration with academia and SMEs

The UK Combat Air Strategy provides industry with the confidence to invest to develop the next generation of combat air systems, platforms and technologies

The changes to the threat environment require the partners and their extensive supply chains to exploit new technologies and stay ahead of the evolving threats **to ensure the UK has the military capability and agility to safeguard national security** but also maintain a **highly skilled UK industrial base**.

At the same time, commercial pressure exists to develop **new platforms quicker and at lower cost**

The milestones set for the Tempest programme represent **a challenge for industry to meet a significantly expedited timescale and cost aspiration**.

To achieve this, the Tempest partners are working **collaboratively** with **Catapults, academia and specialist SMEs** in the aerospace and defence sectors but also adjacent sectors...

To achieve the aim of the programme, the Tempest partners are looking to draw on their network of world-class universities and Catapult centres in the UK alongside their own employees. **This will foster a culture of innovation and capital expenditure and benefit the wider economy by building transferable skills and technologies** that can be used in other sectors.

...and adapt new **agile working practices** (e.g. adopting digital approaches) in delivering the programme to meet the commercial and technological challenges

The Tempest programme is providing partners **the opportunity to combine digital engineering, agile development and open architecture to speed up the development and innovation cycle** – a real game changer.

The new technologies **offer wider benefits** through **applications in other sectors** (e.g. civil applications)

The technologies being developed for Tempest have the potential **for use outside the Combat Air sector** the UK Maritime and Coastguard Agency operates Leonardo's E-scan radar technology to support missions); this, in combination with **building capabilities in the sector and adjacent sectors through collaborations, will generate positive spill-over benefits for the UK economy**.

# 3

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## Regional development



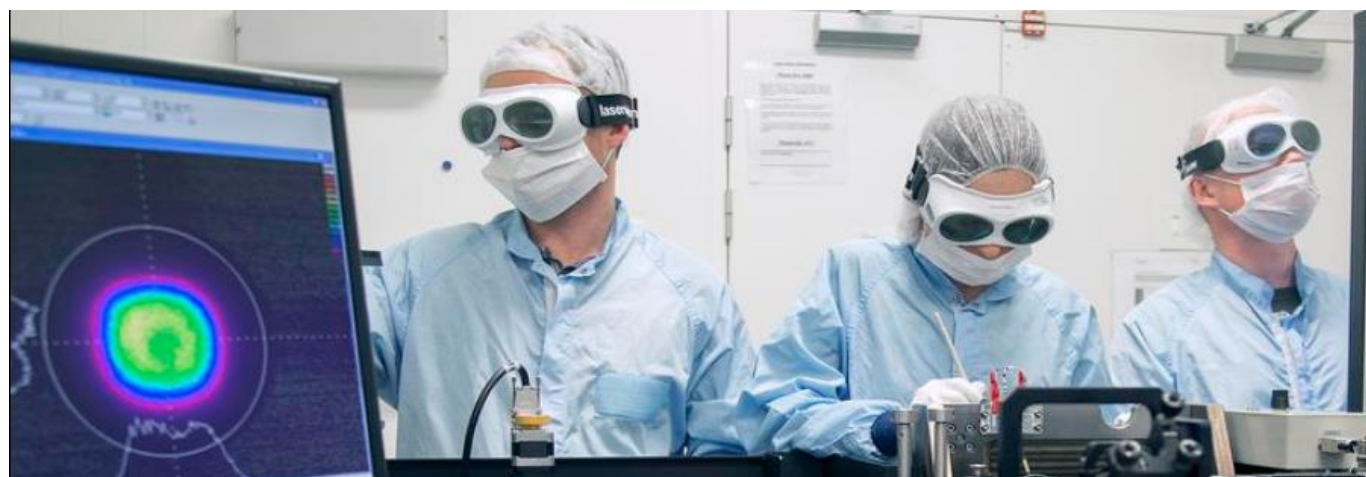
# The Tempest programme will contribute to the Government's commitment to levelling up opportunity across the UK

In doing this, the Tempest programme will bring wider benefits to the UK economy

One of the Government's priorities is to 'level up across Britain' by boosting economic performance, especially outside London and the South East. Although this is not the first time that addressing spatial disparities across the UK has been high on the policy agenda, the issue has become increasingly prominent. This is largely because the inequalities are:

- **Severe:** the UK has some of the widest economic disparities between regions of countries in the industrialised world
- **Deep rooted**, and show no sign of narrowing
- **Complex** and multifaceted
- **Exacerbated by the impact of COVID-19** which also has the potential to accelerate structural changes in the UK economy
- **Impacts of EU exit are still uncertain:** although the UK has now left the EU, the details of the future economic UK-EU relationship are still being negotiated with some options likely to have adverse impacts on some groups such as less-educated workers, many of whom are concentrated in traditionally 'left-behind' areas in the North of England, South Wales and the West Midlands.

The Tempest programme can contribute to 'levelling up' by **stimulating investment in R&D** and **supporting high-skilled jobs in regions of the country which are amongst the most in need**. For example, the Government's UK R&D Roadmap recognises that research and innovation activity and funding are highly concentrated in certain parts of the UK and that **investment in R&D can transform areas** by driving innovation and making businesses more adaptable so providing more opportunities for high-skill employment and training, directly **benefiting communities through improved productivity and greater resilience**. This can support recovery from COVID-19 and accelerate long-term economic growth and prosperity.



# The location of the Tempest partners business activities and their Tier 1 suppliers mean they have a role to play in regional development

## The Tempest programme's economic contribution will be spread across the UK regions

- The analysis in Section 3 estimates that the economic contribution of the Tempest programme in terms of direct and indirect (through spending with Tier 1 suppliers) will be spread across the UK regions with c. 70% of the value in the North West, the South West and East of England.

**BAE Systems Air business has significant presence in the North of England (North West and Yorkshire and the Humber)** with the hub for systems integration, advanced engineering and manufacturing across two main sites in **Warton and Samlesbury** employing approximately 10,000 people, with 700 people at **Brough** in East Yorkshire and a further 700 people focussing on information and cyber at sites such as **Christchurch** and **Yeovil** in the South West.

**The business works with a dynamic supply chain of approximately 3,000 companies across the UK.**

**MBDA has a major presence in the North West, East and South West of England.**

MBDA invested £50m in a cutting-edge manufacturing facility and integrated Logistics Centre in **Bolton**, which opened in 2018 creating more than 100 new jobs. It is now a base for nearly 700 staff, many being highly skilled employees in design, engineering and manufacturing. In the East of England, MBDA's site in **Stevenage** is its head office and base for a workforce of around 3,000, contributing to the town's vibrant and diverse business community. Many of the highly-skilled staffed there are involved in the company's UK R&D. MBDA's third site is in the South West at **Filton**, in Bristol where their Systems and Software departments are based. Across the UK, MBDA works with 1,300 companies in its Tier 1 supply chain.

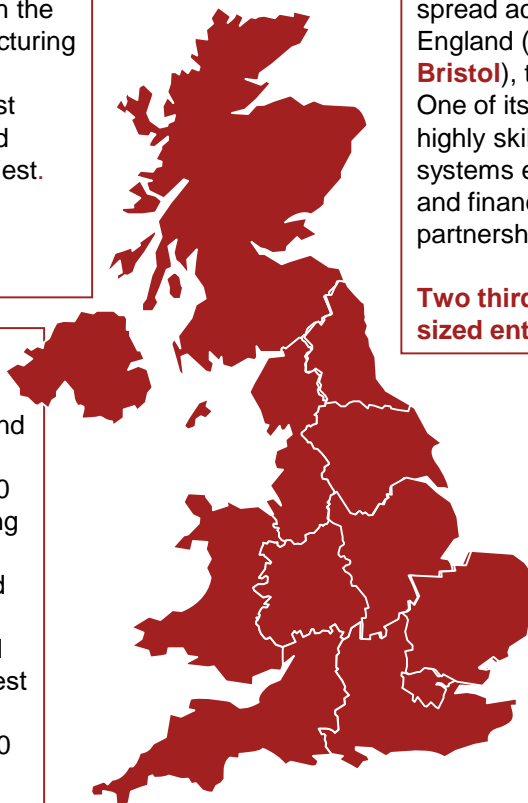
**Across the UK, MBDA works with 1,300 companies in its Tier 1 supply chain.**

**Leonardo** has a large presence in the UK with more than 7,500 workers spread across its **seven major sites** in Scotland (**Edinburgh**), the East of England (**Luton**), the East Midlands (**Lincoln**), the South West (**Yeovil, Bristol**), the East of England (**Basildon**) and South East (**Southampton**). One of its larger facilities in Edinburgh, Scotland employs 2,200 people in highly skilled professions such as software, hardware, electronics and systems engineering as well as key business functions such as commercial and finance. A further 600 people work at the site through business partnerships, mainly in outsourced service provision.

**Two thirds of Leonardo's 2,100 UK suppliers are small and medium-sized enterprises (SMEs).**

**Rolls-Royce's** primary UK base for their Defence business is in **Bristol, in the South West**, and employs around 3,000 people in highly skilled roles. Many of the workforce in Bristol work on the company's Defence business, responsible for the design, development, manufacture and support of military engine products for air and sea. The team is also responsible for the delivery of equipment and support services to 70 navies around the world and is the hub for composite technology development. Rolls-Royce continues to foster a dynamic supply chain alongside engaging SMEs across engineering, services and academia.

**In 2020 the Rolls Royce defence business contracted over 100 UK supply chain companies across its combat air programmes and works with over 1000 UK companies in total.**



# The Tempest programmes' economic contribution is expected to benefit UK regions which are most in need

## The contribution of Combat Air regional activities to the UK compared to the overall regional economy

### Regional impact of Tempest Partner Combat Air activities

The share of Combat Air activities (including Tempest) GVA generated in the North West is estimated to be **4.1x** more than the region's share of UK GVA; the share of jobs is over **3.9x** that of the region's share of national employment.

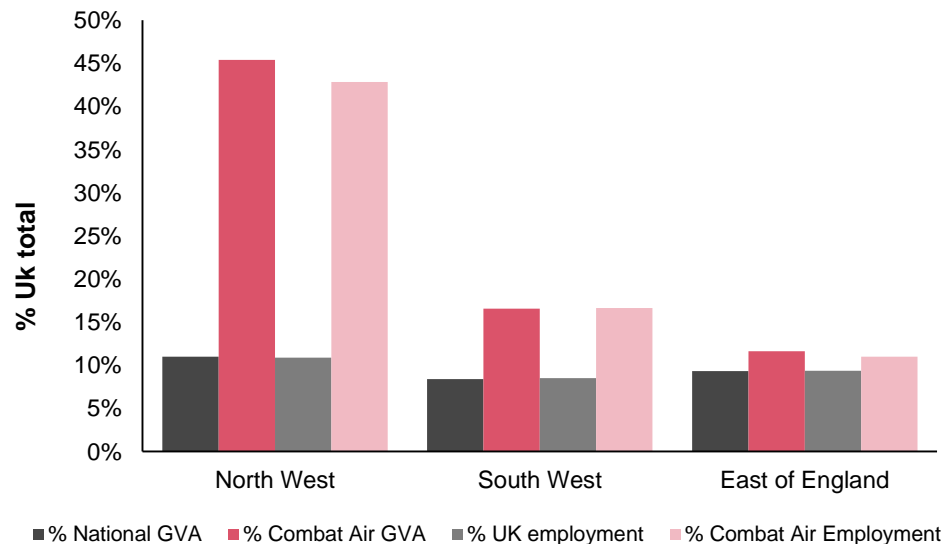
The South West and East of England will generate **around 2.0x** and **1.2x** more GVA and employment respectively than what would be expected if allocated on a proportional basis.

### Tempest programme regional productivity

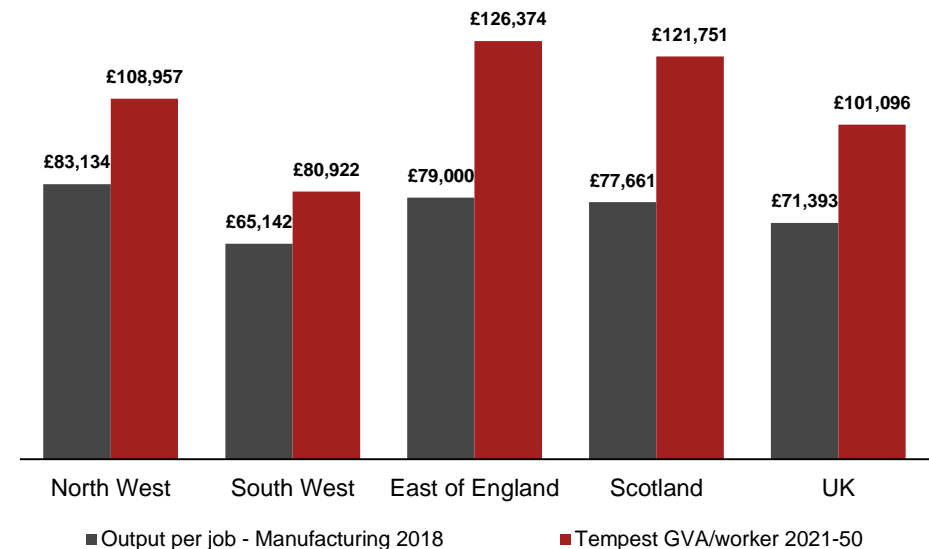
Regional GVA per worker for the Tempest programme is **31%** higher than the North West manufacturing average, **24%** higher than the South West manufacturing average and c. **60%** higher than the East of England and Scotland manufacturing average.

The average productivity of Tempest programme employees is estimated to be **42%** higher than the national manufacturing average.

Share of GVA/workers (Combat Air activities vs regional average)



Regional productivity (GVA/worker) – Tempest programme (2021-50) vs regional manufacturing average (2018)



Sources: PwC analysis, Team Tempest industry partners data and ONS data on regional labour force statistics and GVA

Notes: Figures for Combat Air refer to the total of direct and indirect (through first-tier supply chain spending excluding second-tier effects) GVA contribution of the Tempest programme between 2021 and 2050

# The Tempest programme will stimulate R&D in areas most in need and generate wider economic benefits for these regions

**BAE Systems' Factory of the Future is an example of how investment in R&D and partnerships with academia and SMEs is driving economic benefit in the North West and beyond**

- The Government's UK R&D Roadmap recognises that investment in R&D-focused activities can transform economic growth and societal benefit across the UK for decades to come and build the foundations for new industries.
- **The Tempest programme will stimulate further investment in R&D as well as further support high-skilled jobs which will deliver economic development to regions across the UK.**



## **BAE Systems' Factory of the Future in Warton, Lancashire: a connected intelligent factory for military aircraft technologies**

Designed and equipped with state-of-the-art technology, the Factory of the Future represents a unique, fully connected, digital space where revolutionary technologies meet an adaptable digitally minded engineering workforce to create solutions to research, test new technologies, build new capabilities and harness transformative solutions.

BAE Systems' multi-million pound investment in the Factory 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 as well as the business' current programme.

**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 metallic processing, smart materials and composites and product test and validation.

Through these partnerships with the wider supply, 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.

For example, off-the-shelf production robots, commonly used in the automotive sector, tend to work to within half a millimetre of accuracy. Yet the manufacturing of combat air systems demands tolerances to less than a third the width of a human hair on some programmes. Working in partnership with academia and industry, BAE Systems' Factory of the Future has developed the capability to monitor and control these robots through real time adjustments to achieve the demanding requirements. The use of robotic assisted assembly is increasing pace and productivity in the manufacturing process.

# The Tempest programme provides the impetus to invest in R&D activities through collaborations supporting high-skilled jobs for the future

## BAE Systems' Factory of the Future is also driving a number of skill-based initiatives

- The Team Tempest partners are continuing to invest in high-value technologies and recruit and upskill talent with the skills required for the future.
- The **partners investment in R&D and skills-based initiatives through partnerships with academia and catapults** has the potential to stimulate further investment in academia, i.e. industry investment and highly skilled talent attracts more investment and creates a 'ratcheting effect'.

### BAE Systems' Factory of the Future is supporting high-skilled jobs for the future across the UK

New roles are already being created as a result of the technologies within the Factory, such as 'Integration Engineer – Internet of Things' and Artificial Intelligence roles.

The Factory of the Future is also driving a number of **skills-based initiatives**, including:

- Working collaboratively with Cranfield University to create a new Master's degree in Applied Artificial Intelligence.
- Providing support to the IN4.0 TALENT Academy, proposed by the IN4.0 Group in partnership with The University of Central Lancashire (UCLan), Amazon Web Services, IET and the Tree of Knowledge. The Academy is focused on the development of future skills in the manufacturing and engineering sector, delivering a 12-week specialist digital skills training programme for North West-based science and engineering graduates.
- Supporting Prosperity through People alongside Rolls-Royce and Siemens. This is a 10 month leadership programme to help SMEs embrace modern working practices. As of December 2020, a fourth cohort was underway, featuring 75 delegates and 69 businesses.



# The Tempest partners membership in Catapult networks enables the Tempest programme to harness the best of UK science and engineering

The Tempest partners are collaborating with Catapults to develop new technologies and, in doing so, are driving efficiency and capability across the wider supply chain

Through collaborations with Catapults, new and traditional businesses are working together – at the regional and national level – to deliver cost efficiencies, accelerate the development of proof of concepts into viable commercial solutions, improving productivity and developing new business models. **Catapults can deliver benefits** to the Tempest partners, academia and SMEs and the wider UK economy.

- For the **Tempest partners**, they provide **access to a UK ecosystem** of leading research, specialist skillsets and technology to help the creation of collaborative R&D programmes through networking opportunities and direct engagement with SMEs.
- For **academia and SMEs**, they provide access to commercial opportunities and the facilities and expertise needed (e.g. Factory of the Future) to develop and test technologies, tools and processes and scale-up and commercialise them. Access to catapults also provides academia the opportunities to secure further research funding through IP generation and growth of their reputation.

The Tempest partners are engaging across a wide range of leading innovators from industry, SMEs and academia. Therefore ensuring the Tempest endeavour benefits from the technical design and consultancy expertise across areas such as airframe manufacturing and the automotive industry to ensure a collaborative systems of systems approach is taken to developing the UKs' next generation combat air system.

Below we set out some examples of **how regional investment and collaboration** can help **to unlock the potential of industrial digitalisation and improve the performance of manufacturers across the UK regions**. This can contribute to the UK's economic prosperity through increased **UK competitiveness, improved productivity** and potential commercial export opportunities.

## Working with the High Value Manufacturing Catapult (HVMC) Centres, the Tempest partners are helping to improve the capabilities of the wider supply chain across the UK regions

Rolls-Royce is actively involved across all seven of the HVMC Centres and BAE Systems has a role on the board of the Catapult Centres (NCC – National Composites Centre, AMRC – Advanced Manufacturing Research Centre and MTC – Manufacturing Technology Centre). Based on a report by WECD, for every £1 of public funding invested in the HVM, £15 of 'net' benefits are delivered to the UK economy.[1]

The AMRC North West, established in Samlesbury, will host a new 5G technology testbed in BAE Systems' Factory of the Future focusing on engaging with SMEs and the supply chain to make this technology available to the North West SME base and improve the performance of manufacturers across the North of England (see R&D case study). By being located on the Samlesbury Enterprise Zone, it enables ease of access and closeness with partners across multiple industries in Lancashire.

## Digital Catapult

BAE Systems are one of the seven industry partners supporting the Digital Catapult partner with the Made Smarter Technology Accelerator programme to set the digital challenges of the future.[2]

Fourteen challenges have been established ranging from increasing shelf life to sell through of products while reducing waste (Sainsburys) to scalable AI for visual inspection (BAE Systems). There are two specific challenges set to support the development of the Future Combat Air System

Across the FCAS/Tempest programme, customers' are demanding more complex and flexible products along with ever shortening timelines and challenging cost targets. Alignment of the Made Smarter Accelerator and Digital Catapult programmes supports the Tempest partners to achieving their goals and making Tempest a success.

# The Tempest partners are collaborating with leading universities and SMEs across the country to ensure the UK maintains its capabilities

Beyond the R&D benefits, these partnerships are contributing to national prosperity by supporting regional economies to develop and attract beyond the defence sector

## Northern Ireland

The Tempest partners are engaging across a wide range of leading innovators from industry, SMEs and academia. Therefore ensuring the Tempest endeavour benefits from the technical design and consultancy expertise across areas such as airframe manufacturing and the automotive industry to ensure a collaborative systems of systems approach is taken to developing the UKs' next generation combat air system.

## North of England

**Sheffield University:** the Advanced Manufacturing Research Centre (AMRC), located in Samlesbury, is to host a 5G testbed inside BAE Systems' Factory of the Future, to help understand how best to use this technology across its supply chain, including with SMEs.

**University of Central Lancashire:** BAE Systems is supporting the IN4.0 TALENT Academy proposed by Industry 4.0 training organisation IN4.0 Group, in partnership with the University of Central Lancashire, Amazon Web Services, the Institution of Engineering and Technology and the Tree of Knowledge, helping to develop future skills in the manufacturing and engineering sector.

**Made Smarter North West Pilot:** BAE Systems is supporting the pilot which is being delivered through North West growth hubs to increase adoption of industrial digital technologies by manufacturing SMEs.

## Wales

**Cardiff University:** Leonardo UK has a research partnership with Cardiff in the field of compound semiconductor electronics, an underpinning technology for Tempest and other Combat Air programmes.



## Scotland

**Edinburgh University and Heriot-Watt University:** Leonardo UK has a three-way research partnership with these universities which has led to a long-term sponsored chair, joint leadership with Edinburgh and Heriot-Watt of the EPSRC/Dstl funded University Defence Research Collaboration (UDRC) (with Strathclyde and Queens as partners) and multiple PhD and EngD research programmes for students and Leonardo UK staff.

The partnership also extends to the Centres for Doctoral Training (CDT) in Applied Photonics as well as Robotics and Autonomous Systems. Leonardo UK also funds the Engineering Chair in Signal Processing at Edinburgh University Strathclyde University – Leonardo UK has a similar research partnership with Strathclyde, with particular emphasis on research in the field of neuromorphic processing.

## Midlands

**Fairfield Control Systems,** based in the Midlands to deploy Intelligent Work Stations in the Factory of the Future. These collaborative work stations work with human operators to manufacture combat air system components and are producing evidence of a reduction in the learning curve for operators.

## East of England

**Cranfield University:** Work is underway to create a new Master's degree in Applied Artificial Intelligence, ensuring training and qualification paths exist for centennials.

# In summary, the Tempest programme contributes to regional development by supporting high-skilled jobs and stimulating R&D

This contributes to the Government's commitments to levelling up opportunity around the UK

The Tempest partners' business activities and those of their Tier 1 suppliers are **located across the UK regions**

The locations of the Tempest partners' business activities as well as those of their Tier 1 suppliers across the UK mean that the economic contribution of the Tempest programme can **generate benefits across regions** with c. 70% of the direct and indirect (through Tier 1 suppliers) value generated in the North West, South West and East of England.

The Tempest programme will **stimulate R&D** in areas where there is **less public investment** and benefit a range of businesses through the **supply chain and across sectors**

The Team Tempest partners **will invest in R&D across the UK regions** – driven by where their core sites and their suppliers are located – benefiting a range of businesses through the supply chain and across sectors. This regional investment can **transform areas by driving innovations and making business more adaptable** therefore generating wider benefits outside the Tempest programme and Combat Air.

The partners are working **collaboratively with Catapults, academia and specialist SMEs** contributing to the improvement of their **human capital** and **capabilities** and helping to attract further **investment**

To make Tempest a success, the partners are **working with Catapults that give them access to a UK ecosystem of leading research, specialist skills and technologies**. This supports academia, SMEs, and the wider supply chain across the UK: it provides them access to commercial opportunities, grows their talent and reputation and improves their performance. This helps them to **attract and secure further research funding and investment** further contributing to the **development of the regional economies**.

The Tempest programme's economic contribution is expected to **benefit UK regions** which are **most in need** by creating and maintaining **high-skilled jobs**

By creating and maintaining **highly skilled employment and training opportunities**, based around new skills and technologies, **across the partners and their supply chain** distributed across the UK, the Tempest programme is **expected to benefit areas in most need**, including the North West and South West.

This means that wider economic benefits will be delivered through **improved productivity** and **greater resilience**

By developing new skills and technologies, the Tempest programme is expected to provide **high productivity jobs in areas that currently lag behind** such as in the North West and the South West. For example, regional GVA per worker for the Tempest programme is c. 30% higher than the North West manufacturing average. This can support recovery from Covid-19 and accelerate long-term economic growth and prosperity improving the regions' resilience.



# Appendix 2: Approach and methodology

# Input-Output analysis is used to estimate the effect on GVA and employment through the supply chain

## The application of Input-Output modelling

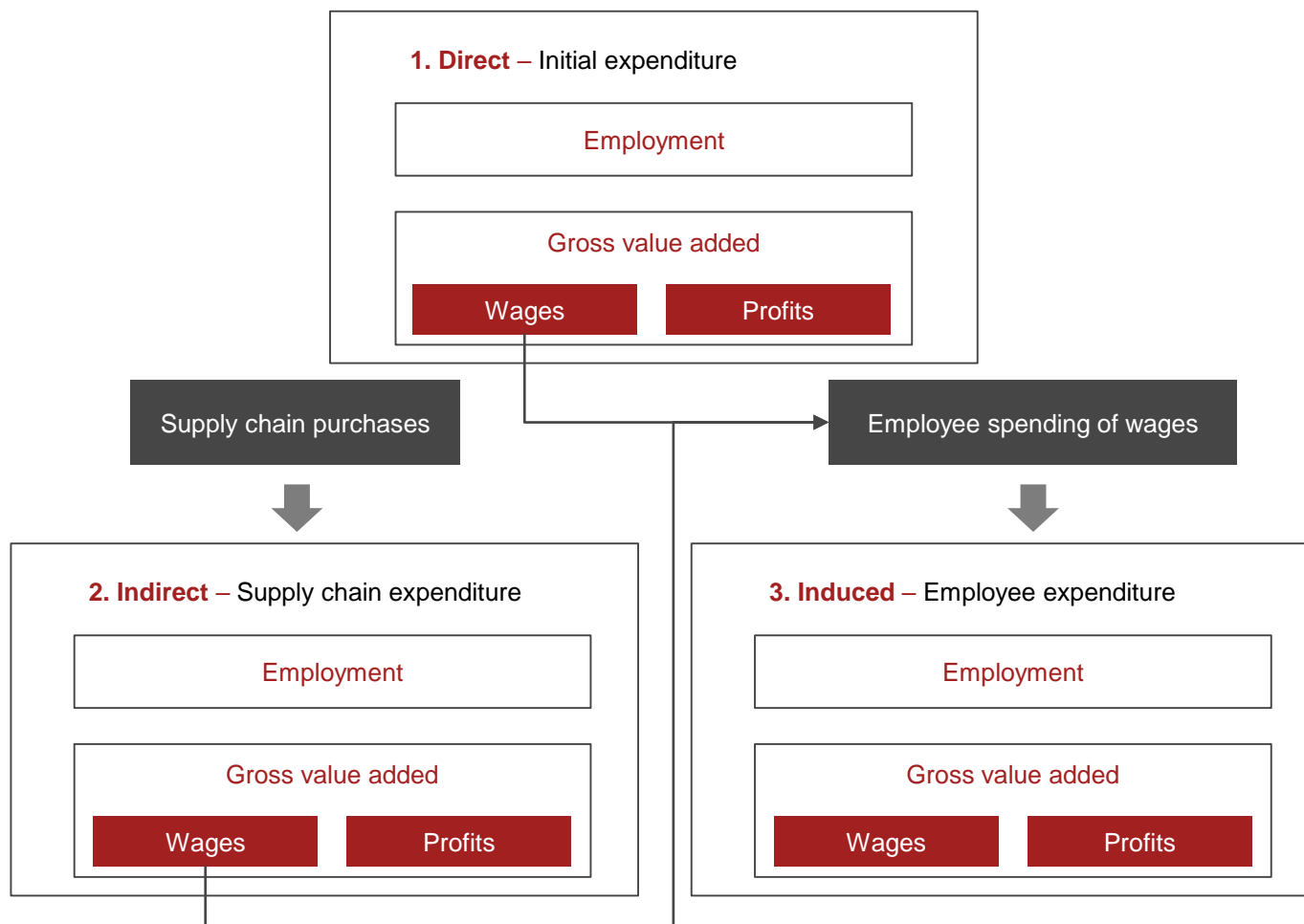
We assess the economic contribution of the Tempest programme and Combat Air activities to the supply chain in terms of GVA and employment using Input-Output (IO) analysis.

GVA is a measure in economics of the value of goods and services produced in an area, industry or sector of an economy. Both GVA and GDP measure economic output and their relationship is defined as:  $GVA + \text{taxes on products} - \text{subsidies on products} = \text{GDP}$ .

IO analysis assesses how the Tempest partners – and their suppliers – transform inputs (such as primary goods and machinery) into outputs which they sell to satisfy demand.

We use IO analysis, to estimate the direct, indirect (via the supply chain) and induced (due to the spending) GVA and employment contributions. IO tables are constructed by combining and transforming two important data sources – The Use Table and The Supply Table – these are produced for the UK economy by the ONS. The UK IO table contains data on the transactions between different sectors of the economy and is used to estimate the economic and employment multipliers for the indirect and induced contributions (i.e. an estimate of the extent to which a given purchase in one sector will generate demand for other sectors). Using projections on labour productivity, we use an updated UK IO table to account for the forward looking analysis in scope.

**Diagram of direct, indirect and induced contributions from a firm's expenditure**



# Input-Output tables describe the structure and relationships between sectors of the economy

## Input-Output modelling and methodology

The Input-Output table provides information on what the typical business in the supplier's sector requires for producing one unit of output. Equally, we can model the supplier's input requirements from other sectors to produce its own unit of output. In this way we can trace back the input requirements through the entire supply chain, and calculate the total value of production stimulated. This process of one sector stimulating economic activity in other sectors is referred to as the multiplier effect.

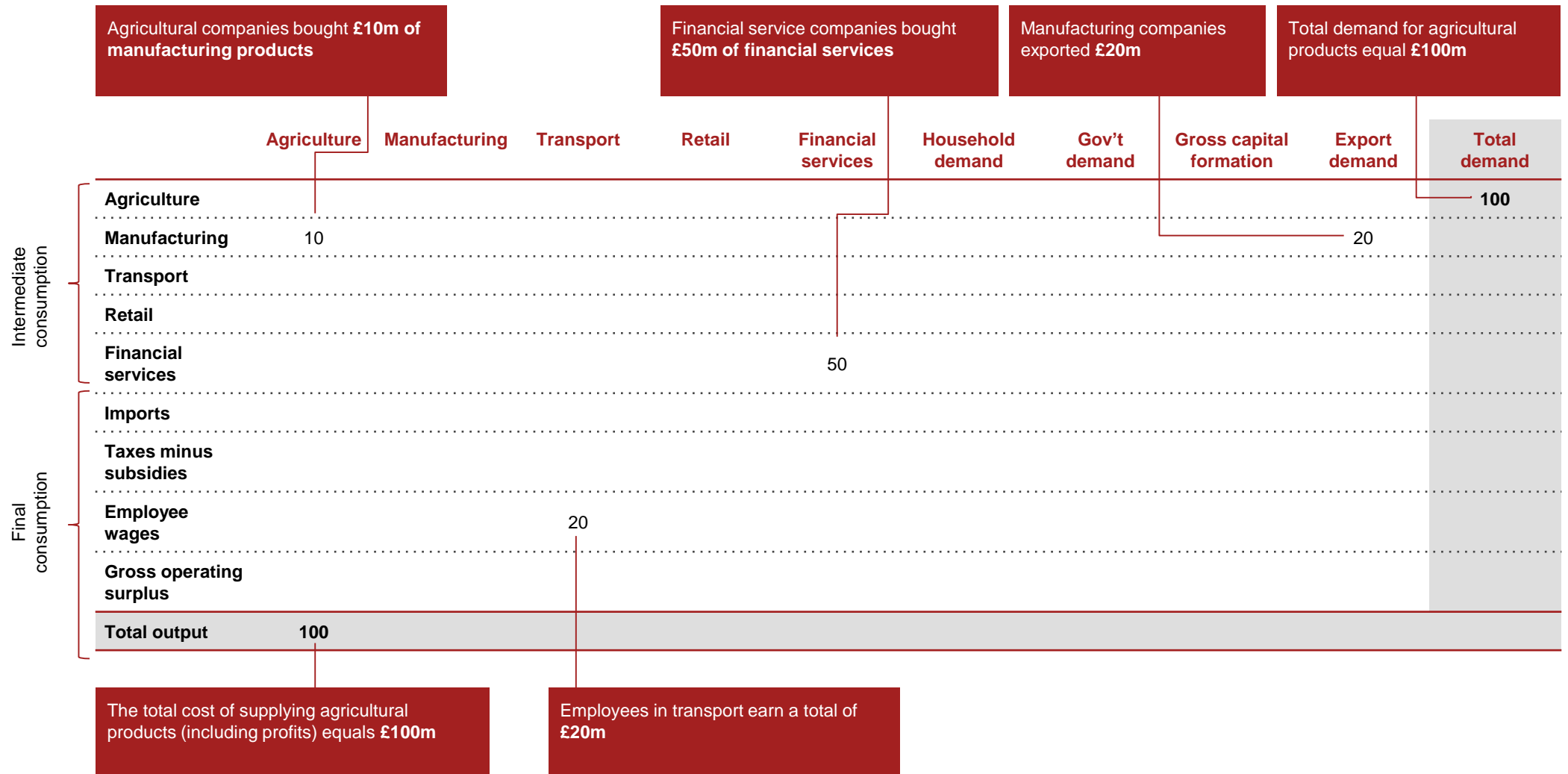
In addition to the above, an Input-Output table provides data on the share of revenue that constitutes profit and wages for each sector. We can apply this ratio to the total production value stimulated, and hence estimate the total GVA in the supply chain by sector associated to this. Additional statistics on employment provide information on the number of people that work in any particular sector. As we know the output stimulated in each sector, we can estimate the production value to job ratio. We can then apply this to the total production value stimulated in the supply chain. This allows us to estimate the number of jobs supported in the supply chain – the indirect employment.

These steps get repeated for calculating the induced contribution, but through using wage data to estimate how much production is stimulated in the supply chain that supports the products employees buy, e.g. accommodation, food and entertainment.



# An Input-Output table shows what the typical supplier in a certain sector requires for producing one unit of output

## Example Input-Output table



# We applied a number of key economic concepts to conduct our analysis and made several important assumptions about the Tempest programme

## Methodological notes and assumptions and data sources

### Methodological notes

- **Discounting:** We use discounting to aggregate and compare estimates of costs and benefits occurring at different points in time. Discounting enables us to take into account society's time preference for incurring costs and benefits. We discount the costs and economic benefits by the social time preference rate of 3.5%. This rate is recommended in HM Treasury Book to bring our figures to a net present value (NPV) to ensure we are comparing costs and benefits for a given time, and overall, even if these costs or benefits are experienced in earlier or later years.
- **Employment contribution:** We estimate the employment contribution (direct, indirect, induced) using data on the projected number of people that will be employed each year across the Tempest partners on the programme. This gives us the total workers across the time period of the analysis. We also present the average number of workers employed per year across the 30 year period.

### • Tempest programme – assumptions

- Analysis considers the Tempest programme activities by the four partners only and is based on activity and cost data provided by the four companies (BAE Systems, Leonardo, MBDA and Rolls-Royce).
- Analysis considers projected activities from 2021 to 2050.

### Data Sources

#### Input-output analysis:

- UK Input-Output Analytical Tables, 2014 (ONS)
- Annual employee and employment estimates, 2018 (ONS)
- Gross Disposable Household Income, 2016 (ONS)
- Inflation forecasts (OBR)
- Labour productivity forecasts (OBR)

PwC analysis of Team Tempest industry partners data

#### ONS

- GVA (by region)
- Working age population (by region)
- Gross median annual pay (2020)
- Unemployment rate, 16+ (July-Sept 2020)
- Share of high-skilled workers (NVQ4+ 2019)
- Mean hours worked per week by industry (2018)
- Productivity (GVA/employee aged 16-64, 2018) – PwC analysis using ONS data

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# Thank you

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