midlands aerospace alliance

MIDLANDS ENGINE OBSERVATORY

Insights

Aerospace in the Midlands

The Midlands Engine and the Midlands Aerospace Alliance wanted to measure the economic contribution of the region's aerospace cluster and explore the distribution of R&D funding across its supply chains.

INSIGHTS

The need for better data to support policy makers

The Midlands is home to a substantial cluster of aerospace industry supply chains and R&D assets, one of the largest in the UK and Europe. Its extent and reach has, however, been difficult to define and quantify, leading to uncertainty about its real economic contribution.

Aerospace is a technology-rich industry driven by high investment in R&D, and UK aerospace benefits from considerable UK government R&D funding to maintain its competitive edge. Yet there is little data or knowledge about how this funding is distributed across the extensive supply chains of the Midlands aerospace cluster. Accordingly, it is difficult for policy makers to tell whether government R&D support is allocated optimally across the cluster in terms of boosting innovation, productivity, exports, sustainability and growth from a Midlands or UK economic perspective.

This Insights report highlights the findings from a project, "Aerospace in the Midlands", run by the Midlands Engine Observatory (MEO) and the Midlands Aerospace Alliance (MAA). It is the result of an extensive research programme carried out over the course of 2023, with the aim of deepening our understanding of the cluster:

- **Work package 1: Quantifying the size of the aerospace sector in the Midlands,** providing accurate information on the size of the industry through a bespoke bottom-up company-level database

- **Work package 2: Quantifying aerospace R&D funding support to the Midlands cluster,** gaining a comprehensive understanding of R&D funding to the industry, including its distribution across supply chains and locations in the region.

(Photo) Aerospace global reach
A Singapore Airlines Boeing 787-10, one of the world's most advanced passenger aircraft, retracts its landing gear on departure from Hong Kong. Midlands companies making key systems for the 787 include Rolls-Royce in Derby (engine) and Birmingham (engine controls), ITP Aero UK in Nottinghamshire (engine modules), Moog Aircraft Group in Wolverhampton (wing actuation control systems) and Collins Aerospace in Wolverhampton (engine thrust reverser systems).
A wide range of other "flying parts" manufacturers from across the region make Boeing 787 components. [Credit DltI2010]

INSIGHTS

Aerospace at a glance

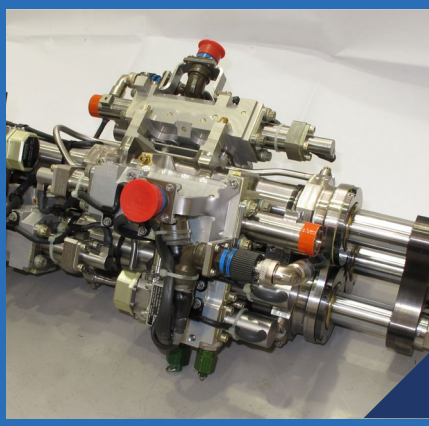
- Aerospace is a highly regulated, safety-critical, high-tech, advanced manufacturing sector, made up of businesses that design, develop, manufacture and maintain aircraft for civil and defence uses.
- It is a global, high-growth industry that in 2024 is still completing its recovery from the shock of COVID-19. The UK remains one of the world's leading aerospace nations, with turnover of circa £27bn and GVA of £10.9bn even during the downturn.[1]
- The sector is characterised by complex, technology-rich products with long product life cycles. There is high, upfront investment to develop new aircraft, often taking a decade or so, and the aircraft then require in-service maintenance, repair and overhaul for many decades more.
- The now-urgent need to dramatically reduce aircraft carbon emissions is creating a new, potentially revolutionary technology agenda for the aerospace industry. A range of possible technical solutions is being developed in the drive towards achieving a "Jet Zero" goal: e.g. sustainable aviation fuels, electric, hybrid and hydrogen-powered flights.

The Midlands aerospace cluster

Aerospace is one strand in a Midlands engineering supercluster that weaves together several industry sectors and supply chains. The region is at the heart of the UK's aerospace industry, specialising in the civil aerospace sector that makes passenger aircraft – and that is the focus of this report.[2]

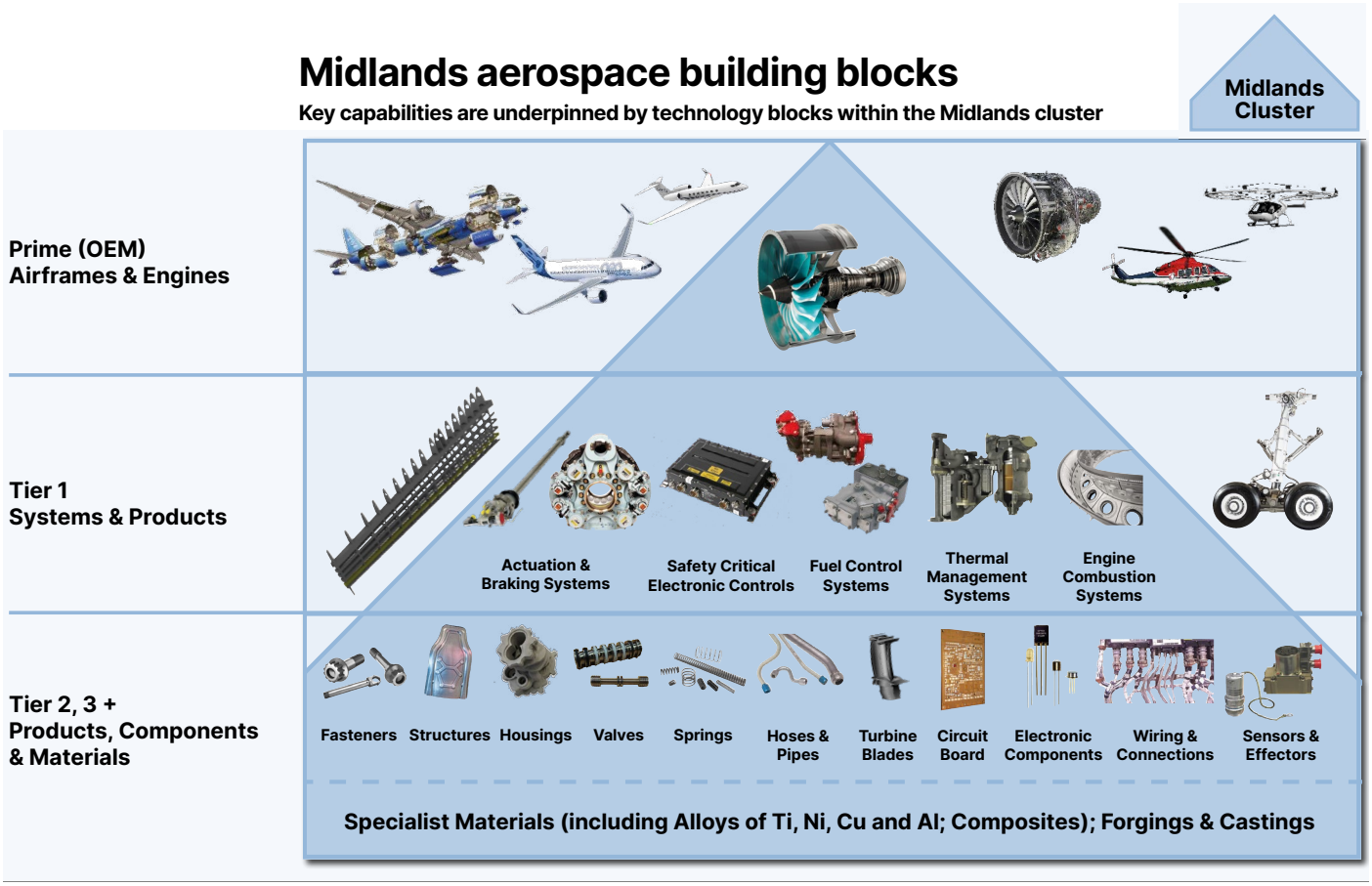
Midlands aerospace is characterised by:

- The design and manufacture of aero-engines, advanced aircraft systems and aero-structures.
- Important sites of a leading aerospace 'Prime' or Original Equipment Manufacturer (OEM - Rolls-Royce), and four global Tier 1 suppliers (Collins Aerospace, ITP Aero UK, Moog Aircraft Group and Parker-Meggitt) designing and making sophisticated aircraft systems (see picture).
- A deep, high-value design and manufacturing supply chain making aircraft parts for these companies, much of which also exports directly to overseas aerospace customers (initial estimates suggest 40+% by value). The breadth and depth of this Midlands' "Flying Parts" supply chain is depicted in the technology building blocks graphic opposite.
- Additional cross-sector businesses and 'indirect' suppliers of specialist services and equipment used in its factories and testing facilities that are part of a diverse and deep-rooted supply chain, also supplying into automotive, nuclear, marine, rail and other markets.
- A collaborative industry that supports its own regional aerospace cluster body, the Midlands Aerospace Alliance (MAA).



Moog Aircraft Group in Wolverhampton designed and manufactured the sophisticated actuation system that controls the main rotor blades of the world's first fly-by-wire commercial helicopter, the US company Bell's 525 Relentless. [Credit: Moog Aircraft Group].

1. ADS Industry Facts & Figures 2023; UK Aerospace Sector
2. The aviation industry – the region's airports, airlines and RAF bases – is outside the scope of this report.



Work package 1

Quantifying the size and contribution of aerospace in the region

Official data (based on Standard Industrial Classification (SIC) codes) that UK national and regional bodies traditionally rely on suggest the Midlands has about 20,000 aerospace jobs (1/5 of UK) in 180 companies (1/10 of UK) across 225 sites.

Aerospace is a difficult industry to quantify and SIC code data is widely recognised to be a poor foundation for policy making. Providing a more accurate assessment of the economic contribution of aerospace in the Midlands was therefore a key objective of the research.

Critical to achieving this was the development of a new, comprehensive and detailed dataset of all companies known to be part of - or serving - the aerospace industry in the region. We believe this dataset to be the first of its kind in the industry. It was collated through an extensive bottom-up methodology, which gives us the basis for an accurate understanding of the size and scale of aerospace in the Midlands in terms of businesses and jobs (see Methodology Annex).

Our dataset-driven method gives a more realistic foundation for assessing the aerospace contribution to the Midlands economy.

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What the dataset tells us

1. Applying a measure that focuses on core aerospace industry supply chains and allows for consistency across the UK, the Midlands is home to 326 company sites that are either internationally recognised AS9100-accredited 'Flying Parts' makers or AS9110- / AS9120-accredited 'Maintenance, repair & overhaul / parts distributors' (our company categories A, B and C3 - see Methodology Annex where we explain where this data comes from). These are effectively "gold standard" aerospace suppliers. Their sites are highlighted in Figure A.

   This is more than double the share of UK aerospace sites (21% vs 10%) reported in official statistics.

2. A somewhat broader definition adds specialist manufacturing companies that are not required to be accredited to the AS9100/10/20 standard, as well as other technically specialist, 'indirect' suppliers like those offering 'NADCAP' special services (the remainder of our Category C companies – see Methodology Annex for more on definitions). This gives a total of at least 524 firms at 595 business sites in the specialist Midlands aerospace supply chain. That is nearly three times the number quoted in official SIC code statistics (see figures B and C).

   Using a rigorous statistical methodology to adjust total job numbers at these companies downwards to account for the fact that many also supply other industries, the 500+ companies employ 36,500 people in the region undertaking work for aerospace markets. This compares with the 20,000 jobs officially reported.

   About half these jobs are at the Primes/ Tier 1s, one third at AS9100 "Flying Parts" makers, and one sixth at other specialist aerospace sites (see Figure B). Many jobs at these companies are highly skilled and well-paid.

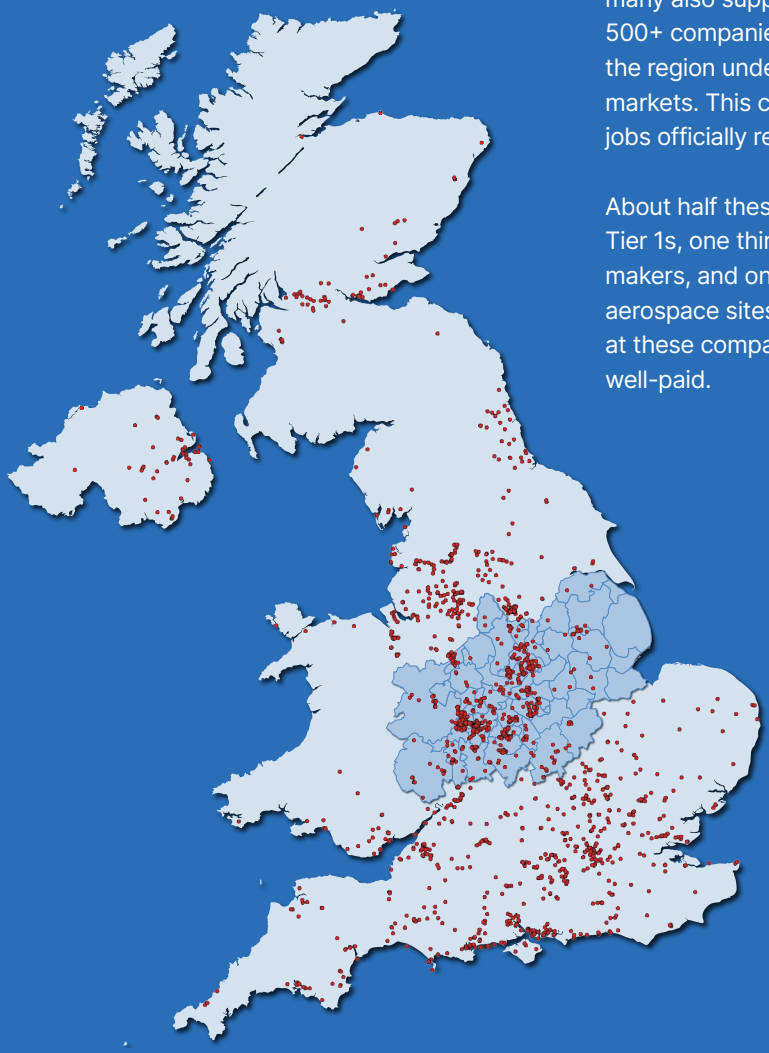


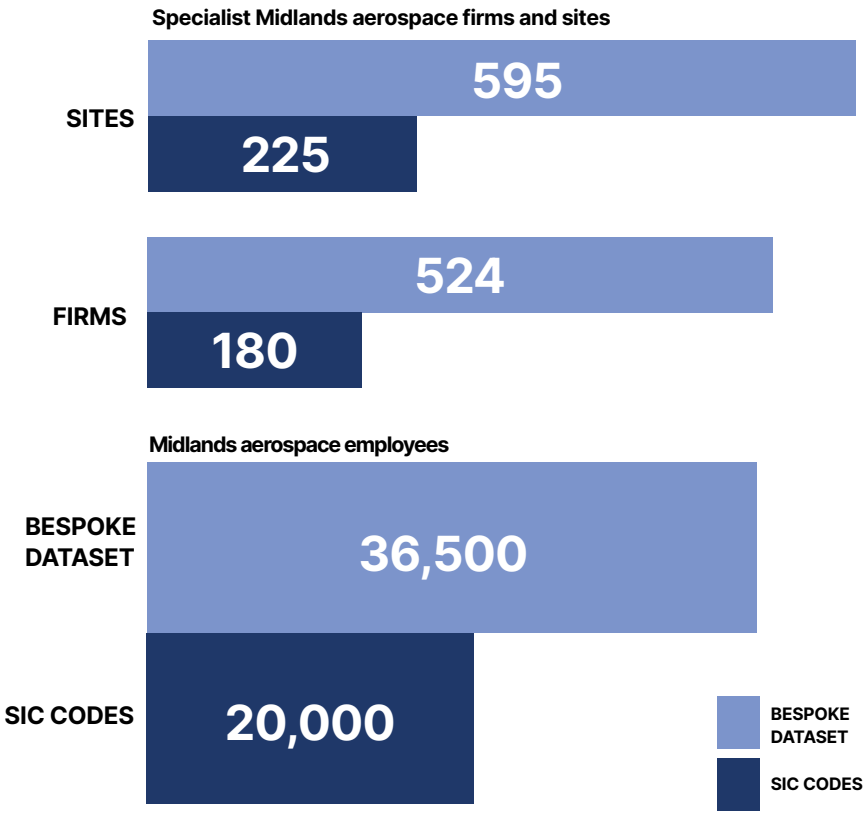
Figure A: The Midlands has 326 AS9100/ AS9110/ AS9120 accredited company sites, 21% of the UK total.

Company Category	Midlands jobs calculation	Individual Midlands companies
A OEMs and Tier 1s	17,753	8
B AS9100 accredited 'Flying Parts' makers	12,020	246
C Other technical specialist suppliers	6,767	290
Total	**36,540**	**524***

Figure B: Companies and jobs across different parts of the specialist supply chain

*A small number of individual companies overlap categories across sites; hence totals do not add up for the number of individual companies.

Figure C: Numbers of sites, companies and jobs: comparing SIC data and our dataset.



Technical specialist aerospace suppliers (Bespoke list, 524 firms)

36,500

+

Generic suppliers (+ 33,600)

70,200

+

Induced effect (+35,100)

105,300

Figure D: Regional economic multipliers reveal the aerospace cluster's overall impact on jobs. (For multipliers used to estimate generic and induced jobs see Methodology Annex).

Technically specialist Midlands aerospace people and companies generate over £3.5bn Gross Value Added (GVA) for the Midlands economy. When we include regional economic multiplier effects, over 100,000 Midlands jobs and £5.3bn GVA are created by the revenue brought into the region by Midlands business success in global aerospace markets (see Figure D). This means that aerospace is responsible for 2.0-2.3% of the regional economy.

The extensive company dataset this project has created will be a rich resource for use in the sector regionally in the years ahead, providing a basis for an even deeper understanding of the Midlands aerospace cluster and its varied technical capabilities and diverse range of supply chain companies.

Work package 1 conclusions

Key finding 1
The Midlands aerospace cluster has a significant role to play in the wider UK aerospace context, accounting for 21% of UK aerospace sites and 36,500 jobs.

Key finding 2
The success of Midlands aerospace companies and employees in global markets has a wider economic impact, generating more than 2% of the regional economy and sustaining over 100,000 jobs.

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Work package 2

Quantifying and analysing aerospace R&D funding support and its distribution across the Midlands

As we noted above, aerospace is a technology-rich industry in which governments around the world invest substantial R&D funding to retain their national competitive edge. The second strand of the research project involved analysing the R&D funding support the UK government gives to the aerospace industry in the Midlands. The goal was to evaluate the region's performance in a UK context and examine how R&D funding is awarded across the region's supply chains.

Our primary source of data on national R&D funding was the comprehensive R&D grant database that Innovate UK publishes on a regular basis. We focused on the 2013-2022 period, which contained all data relating to national Aerospace Technology Institute (ATI) funding (the main source of R&D grants to the industry) since its inception in 2013. We also drew on data sources covering European R&D programmes and local and regional R&D grants targeted at aerospace.

By meticulously linking this R&D grant data to our bespoke aerospace dataset, we were able to identify the level of engagement and success of Midlands aerospace companies in winning R&D grants from government sources. We also identified potential gaps where certain categories of companies have not received funding support.

Accordingly, we can compare the scale and economic contribution of different types of aerospace supply chain company with the amount of government R&D support awarded.

Analysis of this data reveals that:

- Companies and research bodies in the Midlands were awarded £763m in national, European and regional aerospace R&D grants between 2013/14 and 2021/22, receiving 39% of all awards to UK organisations.
- UK national funding has been by far the largest source of aerospace R&D support in the Midlands (87% of the total). Ninety-eight percent of this national funding to the Midlands has been via the ATI.
- ATI programmes awarded £640m to Midlands organisations in this time period - 41% of all ATI funding and significantly more than any other region (see Figure E). This compares with the region accounting for 21% of core UK aerospace sites (Work Package 1).

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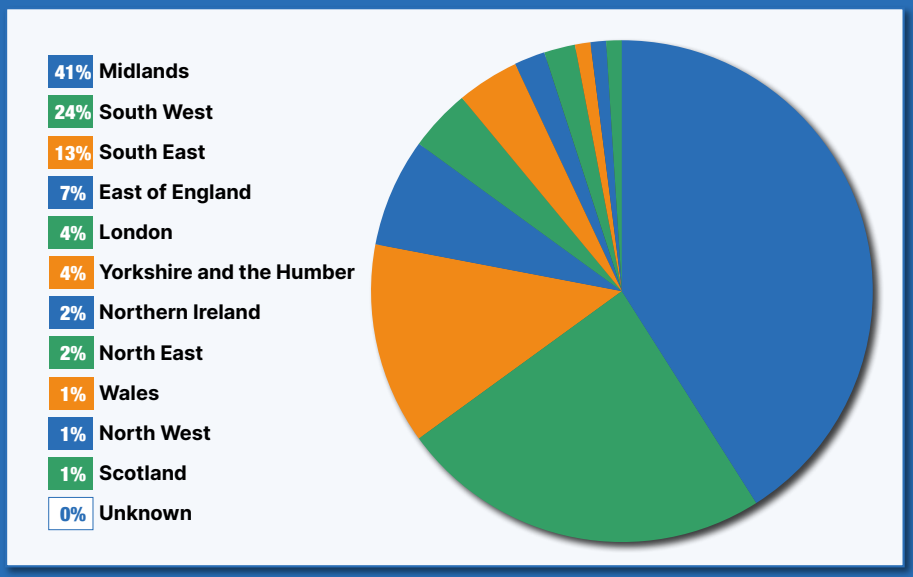

Figure E: Regional distribution of ATI funding, 2013-2022

- Analysis of the distribution of the R&D funding awarded to Midlands organisations reveals that it has been concentrated in a small number of firms and places:
  - According to traditional Innovate UK organisation categories, large companies have received the vast majority of national aerospace R&D funding to the Midlands, £520m (79%), more than £500m of which was been awarded to Rolls-Royce. The second category is universities and Catapults with £110m (16.5%). Small and medium-sized enterprises (SMEs) have received £30m (4.5%).
  - At least as relevant as this data, if not more so from both regional economic and technology capability perspectives, is how much funding is awarded to the specialist AS9100-accredited 'Flying Parts' companies to stimulate innovation. These technically sophisticated and experienced companies account for one third of the specialist aerospace industry's economic contribution to employment in the Midlands. Yet they have received less than 1% of national aerospace R&D grants. As shown in Figures F and G, 94% of all AS9100 companies in the Midlands have not been awarded any aerospace R&D grants directly from the ATI or other parts of the national aerospace R&D ecosystem.
- Initial analysis of European funding suggests a similar trend of funding concentration. By contrast, Midlands regional aerospace R&D programmes such as the MAA's NATEP 1 and the MAA/ University of Nottingham's Aerospace UP, albeit very small relatively (1% of total R&D grants, and with the closure of the ERDF programme now non-existent) have distributed their funding much more widely across supply chains.

Company category	Midlands jobs calculation	Individual companies	Total national aerospace innovation funding awards (2013/14 – 2021/22)	Companies with a national aerospace R&D funding award	Midlands companies awarded no national aerospace R&D funding (2013/14 - 2021/22)	
A: OEMs and Tier 1s	17,753	8	£518m (94.3%)	4	4**	50%
B: AS9100 accredited 'Flying Parts' Makers	12,020	246	£3.8m (0.7%)	14	232	94%
C: Other Technical Specialist Suppliers	6,767	290	£27.7m (5%)	55	235	81%
Total	**36,540**	**524***	**£550m**	**73**	**471**	**90%**

Figure F: Distribution of jobs, companies and R&D funding across the specialist aerospace supply chain in the Midlands

*A small number of individual companies overlap categories across sites; hence totals do not add up for the number of individual companies.
includes defence aerospace sites where activities are not eligible for national civil aerospace funding
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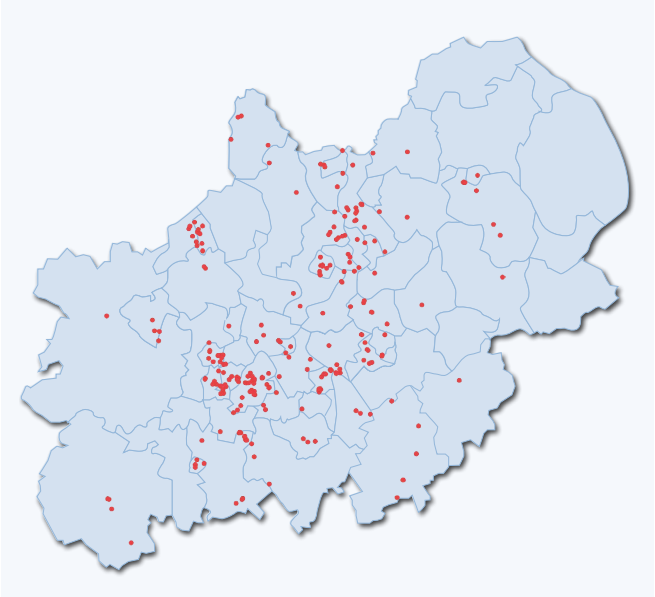
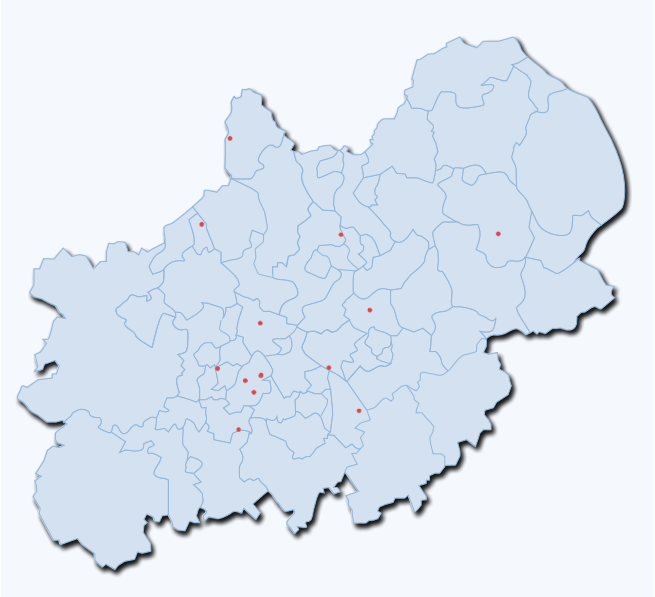


AS9100 accredited 'Flying Parts' makers in the Midlands



'Flying Parts' makers that have received ATI funding

Figure G: Comparing the geographical distribution of accredited aerospace suppliers with ATI aerospace R&D funding awarded to the same companies (2013-2022)

INSIGHTS

The importance of Rolls-Royce to the region

One company, Rolls-Royce, is the main Midlands recipient of UK government aerospace R&D grants, receiving 91% of grants awarded to industry, and 75% of all national grants to the region. This is a key reason why the Midlands appears disproportionately successful at winning grants.

This is unsurprising given the company's national champion status in developing new technologies – especially in whole aero engine integration - and its need to maintain long-term competitiveness vis-a-vis global rivals strongly supported by their own governments. Vital to the Midlands economy, Rolls-Royce's ability as a major strategic firm to attract government R&D funding is important to the region.

Through direct engagement with Rolls-Royce, we are aware that the company spends a considerable part of its R&D budget subcontracting R&D project work to the aerospace supply chain. Rolls-Royce data suggests that the company's subcontract R&D spend at UK suppliers over the period of our research was £448m, equivalent to 88% of ATI grants the company received.

This report certainly should not be taken to suggest any reductions in funding to any particular organisation. More "equitable" distribution of subsidies is not the issue here: indeed the focus on how many grants are awarded to SMEs that seems to interest many policy makers may be a distraction. Our report instead raises broader questions related to companies in the wider technically specialist aerospace supply chain.

These firms make a significantly larger contribution to the Midlands economy than previously recognised, yet receive virtually no government support. The obvious question is whether they – and perhaps half of them are not SMEs at all – should also be supported by government bodies to invest in R&D that helps make aerospace more sustainable.

Could these companies then both contribute more expertise to UK aerospace Primes and Tier 1s and also – like these – compete even better globally through their direct exports on the basis of their own innovative technologies and capabilities?

Rolls-Royce's UltraFan™ was part-funded by considerable ATI R&D grants. The engine, first fully tested in 2023 and capable of running on sustainable aviation fuel (SAF), is the world's largest aero engine technology demonstrator, providing both a new engine design and a suite of technologies that can support more sustainable air travel for decades to come. [Credit: Rolls-Royce]

Work package 2 conclusions

Key finding 3
Midlands aerospace benefits from a high level of UK aerospace R&D grants: receiving 40% of awards, twice the region's share of UK aerospace sites.

Key finding 4
R&D grants are highly concentrated, with 94% of specialist "Flying Parts" maker aerospace companies in the Midlands receiving no grants at all from the national aerospace R&D ecosystem. This may suggest a level of untapped innovation, productivity and export potential and a lost opportunity for the regional aerospace cluster to contribute to sustainable aviation.

Conclusions and recommendations

A number of implications for policy follow from the report's four key findings:

1. **Significant in wider aerospace context**
   Midlands policymakers should stay abreast of the economic and technology dynamics of the UK and global aerospace industry. They should work with the regional cluster to exploit future opportunities and to support continued growth across supply chains.

2. **A sizeable contribution**
   Midlands policymakers should take full account of aerospace for its contribution to the regional economy and dedicate appropriate resources to support the cluster.

3. **Benefits from significant aerospace R&D grants**
   All stakeholders should acknowledge that aerospace is a high-R&D-investment sector that governments subsidise to retain their countries' competitive edge and high-value manufacturing jobs and to accelerate the advent of more sustainable aerospace and aviation.

4. **R&D grants are highly concentrated**
   The vast majority of specialist aerospace companies receive no grants directly from the national aerospace R&D ecosystem. Midlands and national policymakers now need to understand why this is the case, whether it is optimal from a regional economic perspective, whether investing in R&D grants for aerospace supply chain companies might increase the cluster's regional impact and contribution to global sustainability, and, if so, how to implement any policy change.

Our fourth recommendation can be broken down into a number of questions:

a. Why do the vast majority of Midlands aerospace companies not access national R&D funding?

b. Is there demand in the supply chain for the R&D subsidies from government that some large companies and research bodies receive?

c. Are UK R&D grant subsidy schemes in fact designed to encourage specialist aerospace supply chain companies to innovate? (This is not the same as "SME funding".)

d. Can aerospace cluster partners contribute to making national R&D funding more accessible?

e. What lessons can be drawn from regionally-designed and delivered aerospace R&D programmes projects such as the MAA's NATEP 1 and Aerospace UP?

f. Would the region benefit from coming together behind a "Midlands Aerospace Technology Strategy" (MATS), which took regionally important considerations such as innovation in advanced manufacturing supply chains into account, to complement national aerospace strategies?

More generally, Midlands policymakers should encourage engagement around this study's findings with national and regional industry and policy leaders, and consider follow-on actions, perhaps building on the initial partnership agreement between the MAA and ATI signed in 2023.

INSIGHTS

Future research

This project's findings, albeit detailed and substantial, only take us so far. A number of additional potential research activities also flow from the study's conclusions and recommendations:

- Research into subsequent R&D project spend (flow-down) by initial grant beneficiaries such as Rolls-Royce's subcontract spend, and the potential benefits to the wider supply chain.
- An assessment of demand in the supply chain for R&D funding, what kinds of R&D supply chain companies would wish to undertake (see A&M EDM case study), and its potential contribution to jobs and GVA.
- Deeper dive research into regional aerospace technology capabilities and related SWOT analysis.
- A survey of the extent and relevance of non-national aerospace-specific R&D grants for Midlands aerospace companies (e.g. any R&D grants for manufacturing, regionally-led programmes). Given the 2023 HORIZON funding agreement between the EU and UK, a deeper dive into European funding to Midlands aerospace could also be fruitful.
- Research into how many, and which, Midlands aerospace companies access and use the knowledge and capabilities of relevant publicly-funded R&D assets (e.g. universities, Catapults like the Manufacturing Technology Centre) that have also received substantial aerospace R&D grants from government.

There is substantial evidence that supply chain companies can also conduct R&D into new technologies and capabilities. A&M EDM is a specialist AS9100- and NADCAP-qualified business manufacturing bespoke, high value, low-volume components for aerospace. With support from regional aerospace R&D programmes, the company has also developed an in-house 'design-make' capability in rotary engines to power small, unmanned aerial vehicles.
[Credit: A&M EDM Limited]

The MAA and MEO are now using the comprehensive data and findings from this project as a foundation for wider research and projects.

The project complements and extends **other recent work** carried out by The Midlands Engine and The Data City on aerospace within the parallel "Investment Potential in Clusters" project.

Annex: Summary of methodologies

Work package 1 methodology

Our new dataset was developed at site and company level, "bottom-up," drawing on multiple sources. The core source was data on AS9100, AS9110, and AS9120 certified companies via the International Aerospace Quality Group's OASIS database (for more information on IAQG: https://iaqg.org/). AS9100 is a specialised aerospace version of the more familiar ISO9000 standard, and can be considered a "gold standard" for identifying technically specialised aerospace companies in a way that is comparable across places.

This was supplemented by data relating to NADCAP certification (another global industry technical standard – the National Aerospace and Defense Contractors Accreditation Program), MAA member companies and other firms that have received some aerospace innovation funding in the past 10 years – drawn from the databases of R&D funding programmes.

This dataset was systematically cleaned and companies allocated to the following categories for further analysis, harnessing the MAA's industry expertise.

A. Primes and Tier 1: Original Equipment Manufacturers (OEM) and major Tier 1 suppliers

B. AS9100 accredited 'Flying Parts' Makers

C. Other Technical Specialist Suppliers, sub-categorised into C1 (NADCAP-accredited special processes), C2 (Other flying parts manufacturers), C3 (MRO companies accredited to AS9110 & Distributors accredited to AS9120), and C4 (other specialist "indirect" manufacture and support of tooling for manufacturing, testing equipment and the like).

D. Suppliers of Generic Goods and Services: multi-sector business services that support the aerospace industry (professional services, logistics, other support services etc).

Categories A, B and C were the focus of our database development and analysis, with Categories A, B and C3 providing data comparable with other regions. Other Category C data was added to incorporate all known technically specialised companies in the Midlands.

Data on Category D companies was utilised in part to determine a supply chain economic multiplier (see below).

See Figure H for the categories used and the number of sites and companies identified within each.

Universities, Research Technology Organisations (RTO) and other non-aerospace (such as aviation) companies were also captured but excluded from the analysis presented here. An additional detailed "specific technical capability" layer was added to the Category A, B and C companies for future work.

Linking our aerospace dataset with broader company datasets (Bureau Van Dijk FAME and The Data City) allowed analysis of jobs per company, with additional adjustments applied to ensure any necessary estimates were based on Midlands sites only.

Analysis of data from a parallel MAA company survey (sample size 200) of reported business dependency on aerospace market sales (means for Categories B and C aerospace dependency = 62%; 54% respectively) permitted downward adjustments of gross employment data to capture only jobs due to aerospace markets.

We drew on detailed data from a series of previous UK aerospace OEM economic impact reports by Oxford Economics[3] to estimate employment in the generic business supply chain (Category D, for which our company data is weak). Based on close analysis of Oxford Economics data of UK spend by aerospace OEMs, we applied a multiplier of 1.79 for generic goods and services employment to Category B and C companies (not to Category A companies, to avoid double counting). A typical induced-jobs multiplier (spend in the local economy by employees) of 0.5 was applied to all Category A-D employment.

Because our jobs data is from 2021 and 2022, in the depths of the aerospace industry's serious COVID-19 downturn, a conservative additional 10% of jobs was added to the totals to recognise the post-COVID-19 employment recovery that was under way in 2023.

3 Oxford Economics economic impact reports used and data multipliers averaged were: Airbus, Leonardo, Thales, BAE Systems

Company category		Midlands sites	Individual Midlands companies	Calculated Midlands jobs
A	**Primes (OEMs) and Tier 1s**	**20**	**8**	**17,753**
A1	Design-manufacture-test sites	15		
A2	Support services	5		
B	**AS9100 accredited 'Flying Parts' Makers**	**269**	**246**	**12,020**
C	**Other technical specialist suppliers**	**306**	**290**	**6,767**
C1	NADCAP accredited special processes not already included in A and B	15		
C2	Other flying parts manufacturers	114		
C2.1	Other flying parts	82		
C2.2	New entrants flying Parts	28		
C2.3	New entrants SAF Fuel tech	4		
C.3	MRO accredited to AS9110 and distributors accredited to AS9120	38		
C4	Specialist 'indirect' manufacture and support, inc. tooling, test equipment and facilities, engineering and factory services	139		
Total		**595**	**524***	**36,540**

Figure H: Breakdown of Midlands specialist aerospace company categories by sites, companies and jobs
*A small number of individual companies overlap categories across sites; hence totals do not add up for the number of individual companies.

Work Package 2 methodology

Covering the financial years from 2013-14 to 2021-2022, data on UK government aerospace R&D funding was compiled from several sources, our core source being Innovate UK's grant awards database, containing all information relating to Aerospace Technology Institute (ATI) funding since its inception in 2013, as well as a number of additional aerospace R&D programmes and grants. To ensure all ATI funding was captured, programme titles were cross-checked with ATI directly.

This data was supplemented by a) European funding data via EU data sources and b) regionally-led funding data via MAA programme databases, including the original NATEP 1 (National Aerospace Technology Exploitation Programme, 2013-17) and Aerospace UP (Aerospace Unlocking Potential, 2020-23). European funding data was converted from euros into pounds sterling using annual average exchange rates.

R&D grant awards were systematically and carefully allocated to companies in our aerospace company dataset (Work Package 1) to allow for further analysis at the firm level and category level.

Across all sources, data was collected using aerospace-specific programme and project titles (via keywords and industry knowledge). In a small number of cases data was edited to reflect reality – for example related to company size and location of company activity, in some cases incorrectly coded in the Innovate UK database. Every effort was taken to capture all relevant data, but it is possible that some projects and funding sources are missing from the analysis.

We are grateful to colleagues at Rolls-Royce and the Aerospace Technology Institute for confirming and, in some cases, correcting our data.

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