UK Aerospace Technology Institute (ATI) Grant funding programme: Early Impact Evaluation

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Context

The UK civil aerospace industry is identified as an exemplar of leading-edge research and development (R&D), with high levels of productivity and innovation. It is one of the UK's world leading sectors. The UK's international competitors invest heavily to support their respective aerospace sectors, and so part of the strategic basis for supporting UK-based aerospace multinationals and their supply chains is to maintain a 'level playing field' against international competitors (e.g. Germany, France, Spain, USA). Within this context, the UK needs to fully exploit its economic value by undertaking collaborative R&D to further stimulate and accelerate business-led innovation in aerospace. Investment is required to: improve the UK's competitive position; address risks at early stages of research and technology (R&T) that make investments unacceptable on a purely commercial basis; enable more and stronger collaborations between companies and the research base; and encourage R&D that leads to 'stickiness' and production jobs being located in the UK.

Launched in 2013, the civil Aerospace Technology Institute (ATI) grant funding programme is a partnership between the civil aerospace industry and government aiming to sustain and achieve competitiveness and market share of the UK aerospace sector through targeted investments in industry-led R&D (higher-risk) projects. The programme provides grant funding for R&D projects with matched contributions from industry. The UK Government has committed £1.95bn up to 2026 to UK aerospace through the ATI R&D programme with the same amount committed by industry as matched-funding.

The ATI programme funds are delivered and managed by Innovate UK on behalf of the Department for Business, Energy and Industrial Strategy (BEIS). The Aerospace Technology Institute (ATI) is responsible for developing the long-term Aerospace Technology Strategy, and provides oversight and advice on the pipeline and portfolio of ATI projects.

SQW was commissioned by BEIS, in conjunction with the ATI and Innovate UK, to undertake an early impact evaluation of the ATI funding programme. The overall objective of the study was to establish the actual and expected effects of ATI funding on outputs and short-term outcomes. The evidence from the early evaluation will primarily be used to inform the policy and investment decisions in relation to future ATI funding. The remit of the study was to assess the ATI funding programme and not the institution, the ATI (i.e. focus was on evaluating the funding programme). Several different types of projects have been funded under ATI, but the scope of this early evaluation included only the Early ATI (i.e. launched between April 2013 and March 2016) and Capital infrastructure projects to build or upgrade testing facilities or equipment required for the development of new aerospace technologies.

The evaluation used a theory-based assessment – contribution analysis – to test the evidence on early outcomes, whilst considering other factors which may have contributed to these reported outcomes. The evidence was primarily based on 15 case studies of Early ATI and

Capital projects (involving project leads and partners), 22 stakeholder interviews and a workshop. To support the contribution analysis, data from the case studies informed a Qualitative Comparative Analysis (QCA) for specific outcomes of interest. The conclusions and lessons set out below indicate the influence of ATI funding within the 15 cases. They do not necessarily generalise for all the projects in the wider ATI portfolio.

Conclusions of this early stage evaluation

The availability of ATI funding has, to a large extent, led to or encouraged the initiation of projects on new or improved technologies that would not have happened in the absence of ATI funding – or would have done so later, or at a reduced scale or overseas. There has therefore been *additional* direct expenditure on R&T in the UK. The evidence points to medium-to-high levels of additionality for the 15 project cases that have been assessed: 11 out of 15 case study project leads indicated that projects would not have happened at all, or would have done so outside of the UK. For the other four projects, they would have happened at a reduced scale or later. It is likely that some activity may have happened in the absence of ATI, and it is notable that six similar projects that were not ATI-funded, that were discussed with project leads, had progressed in some form. An important observation from the evidence was the way in which UK operations were competing with their counterparts in other countries for R&T projects, which aligned with the strategic rationale for ATI in relation to maintaining a level playing field.

The 15 ATI-funded projects assessed have led to subsequent R&T or R&D projects, thereby leveraging further industry investment. In this context, ATI should be seen as one part of a complementary set of activities, i.e. ATI funding is making an important contribution to technological development, but it is doing so alongside other factors. Specifically:

- ATI-funded projects generated subsequent industry investments in R&T at TRLs 7-9 or R&T at slightly lower TRLs (14 out of 15 case study projects).
- ATI generally generated greater certainty for UK R&T/R&D investments in aerospace (14 out of 15 cases).
- The presence of other complementary R&T activities (that were non-ATI funded) was strongly related to subsequent industry investment in R&T at TRLs 7-9.

ATI has accelerated the development of new technologies through the 15 funded projects assessed. In all of the case studies (15), ATI helped projects to progress through TRLs (often at TRLs 4-6, but also at lower levels). Put together with the evidence on additionality, which included absolute, UK-level and speed additionality, it is clear that technological development has been facilitated or accelerated in most cases.

The Early ATI projects assessed were not found to have substantially influenced patterns of collaboration, although they have helped in two important respects, through: identifying new partners that were needed to provide specialist expertise; and strengthening existing collaborations.

- Project collaborations were mainly informed by the knowledge and expertise of collaborators, use of particular infrastructure (e.g. Catapult facilities), and the R&T priorities of companies.
- The collaborations were mainly developed through existing connections of the project leads, including with their supply chains and university/research organisations.
- There were some new collaborations as project leads identified partners with specific expertise. These new collaborations were facilitated by existing networks and the ATI itself through signposting and connecting.
- There was consensus amongst project leads and partners that their collaborative relationships were strong by the time of project completion, and that these had evolved over time as a result of ATI-funded projects.

ATI has, in part, influenced the plans of some aerospace companies to locate production in the UK – though the causal relationships are not clear. In 14 out of 15 projects cases the certainty provided by ATI funding had an influence on firms' plans to base production in the UK. Of these 14 project cases, six had an exploitation plan or equivalent for the project that specifically planned for UK-based production.

- ATI was perceived to generate greater certainty for UK R&D investments in aerospace, which would also, in theory, support production in the UK.
- There were mixed views on the strength of existing supply chains in the UK. Some supply chains were seen to be strong (e.g. composites, fuel pipes), whilst others were viewed as weak (e.g. tooling, dry fibre).
- There were mixed responses on the extent to which departure from the EU may have adverse consequences for locating production in the UK, albeit within an overall sense of uncertainty.

ATI has led to an improvement in infrastructure, which has been used by aerospace and other sectors. Stakeholders indicated that further infrastructure development was still required to catch up with international competitors. The evaluation found the main investments in UK technology infrastructure made through the ATI programme amounted to c. £150m across different types of facilities in industry, RTOs/Catapults and academia (all capital projects). The investments were spread geographically across the UK.

Spillovers were perceived to have occurred or were expected to happen across the case studies. It is difficult to track these through, and so this finding should be treated with caution. Spillovers were perceived by participants in 13 out of the 15 case study projects:

- Knowledge spillovers were identified for other businesses and universities, for example in relation to technologies such as large robotics.
- Market spillovers were identified in terms of reduced costs for customers (as new technologies/products become substantially cheaper) and environmental benefits (e.g. from reduced fuel consumption/CO_2 emissions).

- Spillovers were mainly perceived to occur in aerospace itself, and in: automotive, marine, energy, electronics, defence and construction.

Although the evidence on actual spillovers is unclear, there was stronger evidence that **the conditions to support spillovers have been supported by the ATI-funded projects assessed.** This has been through: development of multi/general purpose technologies; capacity and capability for R&T in the aerospace sector that could lead to more and better R&T; high levels of skills and transferability between firms and sectors; and people movements internally and externally.

The evaluation evidence identified the emerging technological developments since the ATI programme was created, including: electrification, additive manufacturing, composites, Industry 4.0, urban air mobility, and software and cyber security. **The cross-cutting nature of these technologies emphasises that projects need to be increasingly complementary with other activities.**

Within the UK, the development of industry-supporting policy was encouraging more collaboration, and providing complementarities between cross-cutting R&T under the Industrial Strategy Challenge Fund and the types of projects supported by ATI; these were seen to be complementary and so supporting the impact of ATI. In addition, the overall impact of the expected departure from the EU was unknown; **the uncertainty around the EU impact emphasised the rationale for ATI, which was seen as helping to support the competitiveness of the UK in the global aerospace market.**

Lessons

The overall lesson from the evaluation is that the strategic approach of the programme was seen to be working. This includes the long-term certainty of funding, the aerospace strategy's priority themes, and the encouragement of considering production plans early. These aspects were considered important in supporting UK competitiveness in a global market. The case study evidence also identified success factors at project level, including:

- the alignment with both the priorities of companies/research organisations and the fit with the wider direction of the industry
- having the right expertise for projects, both in terms of collaborators and subcontractor inputs, and effective project management by project leads
- the openness and flexibility from ATI to change project scope and timings during project delivery.

There were no consistent issues at project level on the areas that worked less well. However, a few case studies reported project-related issues on large collaborations, where there were challenges in maintaining cohesive relationships across all project partners. In addition, the evaluation identified suggestions for improvements, namely to:

- review how sharing of information could be maximised within collaborations (especially where there are IP issues)

- involve more SMEs within ATI projects, especially where supply chains are weaker (although this was recognised to be happening more)
- engage further “satellite” organisations that come to the UK to service equipment
- widen the definition of supply chains to include more than Tier 2 suppliers (e.g. to include materials suppliers within R&T projects).

1. Introduction

SQW was commissioned by the Department for Business, Energy and Industrial Strategy (BEIS), in conjunction with the Aerospace Technology Institute (ATI)[1] and Innovate UK, to undertake an early impact evaluation of the civil Aerospace Technology Institute (ATI) grant funding programme. The overall objective of the study was to establish the actual and expected effects of ATI funding on outputs and outcomes (focussing on short-term outcomes) – and so the extent to which the underlying theory of change is happening as intended.

The evidence from the early evaluation will be used to inform the policy and investment decisions in relation to the continuation of ATI funding, and also the longer-term evaluation.

What is the ATI programme?

The 2017 Industrial Strategy[2] sets out the UK's long-term plan to raise productivity and increase investment in skills and R&D (target of 2.4% of GDP by 2027). The civil aerospace industry is identified as an exemplar of leading-edge R&D, and high levels of productivity and innovation. Alongside pharma and automotive, it is one of the UK's world leading sectors. On productivity, UK aerospace is unrivalled in Europe, and second only to the US globally.[3] In total, through to 2026, the UK Government has committed £1.95bn to UK Aerospace via the ATI R&D programme (with a further £1.95bn committed by industry as matched-funding). This is now part of the Aerospace Sector Deal announced in December 2018.[4]

The ATI programme was launched in 2013 as part of the Coalition Government's Industrial Strategy. It is a partnership between the civil aerospace industry and government aiming to sustain and achieve competitiveness and market share of the UK aerospace sector, through targeted investments in industry-led R&D (higher-risk) projects. The programme provides grant funding for R&D projects with matched contributions from industry. By 2018, c. £1bn of government grants had been allocated to over 200 strategic and collaborative R&D projects (of which c. 100 have been completed to date). Programme funding equates to c. £150m p.a. (in nominal terms), which was considered a step change in funding for aerospace R&T (research and technology)[5] support from c. £50m p.a. prior to the programme.

The funds are delivered and managed by Innovate UK on behalf of BEIS. At the same time as the programme's creation, an independent body, the Aerospace Technology Institute (ATI),

[1] https://www.ati.org.uk/
[2] HM Government (2017) *Industrial Strategy: Building a Britain fit for the future* https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future.
[3] SQW based on ATI analysis of SBS (2014).
[4] https://www.gov.uk/government/publications/aerospace-sector-deal
[5] Throughout this report research and technology (R&T) is mainly used instead of research and development (R&D). R&D includes R&T.

was established. This is responsible for developing the long term UK Aerospace Technology Strategy for the sector, set out in the ‘Raising Ambition’[6] report (2015, updated in 2016).[7]

Several different types of projects have been funded under ATI, each with a different approval process which is evolving over time. These include Legacy (i.e. pre-ATI); Early ATI (i.e. before ATI’s Strategy was developed); ATI Collaborative R&D (smaller scale projects awarded through CR&D competitions); ATI Strategic Review Committee (SRC). Within each of these major approval schemes a few Capital only projects have been funded and these have been treated as a separate grouping. **The scope of this early evaluation includes only the Early ATI and Capital projects.** The Legacy projects pre-date any ATI influence and together with the smaller ATI CR&D projects are out of scope of this study which reflects the need for the evaluation to focus on key questions to inform policy on strategic investments in aerospace R&T. The ultimate outcomes from the R&T projects are often long-term (e.g. 10-15 years), and so the focus of this study is on outputs and early intermediate outcomes for projects that have closed, ideally for a few years. Hence the later SRC projects are also out of scope since they are either still live or too early in their delivery to be evaluated.

Evaluation questions and scope

Following the scoping phase of the study, it was agreed that the early evaluation was to address the seven evaluation questions identified in Table 1-1.[8]

Table 1-1: Evaluation questions for early impact assessment

#	Evaluation questions
EQ1	How far has ATI funding leveraged additional (direct) expenditure on new aircraft design and manufacturing technologies, both amongst beneficiaries of ATI funded R&D projects and their suppliers, and that otherwise would not have taken place at all/at a slower rate/at higher risk/outside the UK? Further sub-questions on additionality of projects and sources of investment/further investment: • How far has the availability of ATI funding led to – or encouraged - the initiation of new R&D projects in the new aircraft design and manufacturing technologies (i.e. projects that would not have come to fruition in the absence of ATI funding)? • Has ATI leveraged additional inward investment spend from supported businesses as a result of the funding, and influenced their decisions to invest in the UK in any way?

[6] Aerospace Technology Institute. Raising Ambition: Technology Strategy and Portfolio Update 2016.
[7] It is important to note that the remit of the early impact evaluation is to assess the ATI funding programme and not the ATI organisation. However, the early evaluation will need to draw on the Raising Ambition Strategy and the wider work of ATI.
[8] As set out in the SQW (2019) ATI Programme: Early Impact Evaluation Methodology Paper.

#	Evaluation questions
EQ2	How far has ATI accelerated the development of new aircraft design and manufacturing technologies funded through the projects (i.e. progress through Technology Readiness Levels (TRLs) as defined in Annex B of this report)?
EQ3	How far has ATI influenced patterns of collaboration (or introduced new ones), including increase the volume and strength of collaborative relationships both between firms in the aerospace supply chain, and with academic institutions?
EQ4	How far has ATI started to influence the plans of aerospace companies to locate production in the UK resulting in commitments for manufacturing jobs?
EQ5	How far has ATI led to an improvement in the infrastructure […] which is used to undertake R&D and helped to secure/create high wage employment in both R&D and the longer term manufacturing during production?
EQ6	How far is ATI expected to deliver spillover benefits in the UK based on evidence on nature and extent of collaborations/supply chain outputs and the potential for market spillovers such as in relation to greenhouse gas (ghg) emissions?
EQ7	What broader technological and policy developments have emerged since the ATI programme was created (incl. a preferred technological standard), and how are these likely to influence the impact of the scheme?

Source: SQW; Study Specification

It is important to highlight that the remit of the study was to assess the ATI programme and not the institution, the ATI. **The focus was on evaluating the funding programme, as opposed to any other activity carried out by ATI** (e.g. its role in strategic development for the sector). These other activities are important when providing an holistic view of the context in which the projects funded have been operating, but were not an explicit part of the scope of the evaluation.

Approach and research methods

Our overall approach to the early impact evaluation of the ATI programme involved a theory-based assessment.[9] This tested the extent to which outputs and early outcomes had occurred, and the extent to which they were a result of the programme – in line with the updated logic model and theory of change set out in section 2. The assessment involved using contribution analysis (CA) to test the evidence on early outcomes, whilst considering other factors which may have contributed to these reported outcomes. Our approach, therefore, drew on both qualitative and quantitative data. The work was undertaken across four phases of activity and used the main research methods detailed below. In summary these included: collation and analysis of project level monitoring data, top-down stakeholder perspectives and technology mapping, in-depth case study work, and an expert stakeholder workshop to calibrate and

[9] The approach was developed from requirements in the Invitation to Tender document, an earlier academic review of the ATI scoping methodology report and the methodology paper published with this report, which was developed and approved at the start of this project – see also section 5 of this report and Annex E

stress test the findings against the programme logic and theory.[10] The methods largely followed the recommendations of the scoping report for the evaluation.[11]

We used CA to test whether the logic had been followed as expected, consider what factors had been important in the causal chain, and assess the role of ATI relative to other factors. We drew on multiple perspectives to make this assessment – the project lead organisations and their partners, and the wider stakeholders. To help validate findings, we hosted a workshop with experts to test the evidence.

As part of the CA, we examined the additionality of the ATI funding primarily through the case studies. To support the CA, we used Qualitative Comparative Analysis[12] (QCA) – drawing on data from the case study interviews. It is important to note that given the limited application of QCA in innovation policy this was an experimental approach.[13] We applied a formal QCA for three specific outcomes where routes to impacts and other factors could be more readily articulated before the impacts have materialised:

- **Project progress through TRLs (4-6)**
- **Project generation of subsequent industry investment in R&T (at TRLs 7-9)**
- **Project influence of plans to base production in the UK.**

To clarify, CA was the overarching approach for the early impact evaluation, and the evidence provided by the QCA was used to inform the CA on the three specific evaluation outcomes above (further details on CA and QCA are presented in section 5 and Annexes E and F).

Consistent with the overall approach set out above, the work for the evaluation was undertaken across four phases of activity:

- **Phase 1: Set-up, research design, and monitoring review**
- **Phase 2: Stakeholder interviews, and technology mapping**
- **Phase 3: In-depth case study fieldwork**
- **Phase 4: Analysis of evidence, reporting, and dissemination.**

Further details of the research methods undertaken across the four phases of activity are set out in Annex E. The first phase of the study involved an inception meeting with the client group,

[10] Other research methods, such as surveys of beneficiaries, were excluded because the QCA approach required in-depth case studies. A large scale survey (or other similar methods) of beneficiaries would unlikely to have produced the same quality data to enable QCA. A survey alongside the case studies would also have had resource implications.
[11] SQW (2016) The Aerospace Technology Institute: Scoping study to establish baselines, monitoring systems and evaluation methodologies, *BIS Research Paper No. 271*
[12] QCA is a theory-driven approach that combines qualitative and quantitative methods to establish causation when comparing across a number of cases.
[13] The selection of case studies was informed by the need to ensure a balance of projects across a range of factors including e.g. project lead, number and type of partners, geography, amount of funding, types of technologies developed, stage and timing of projects, and other factors such as clusters/related projects. The case studies were not selected to maximise the effective use of QCA.

review of documentation and monitoring data[14], scoping discussions with key representatives from BEIS, ATI and Innovate UK, and finalising the methodology. Phases 2 and 3 involved primary fieldwork, summarised in Figure 1-1.

Figure 1-1: Primary research

Stakeholders

- 21 interviews completed (majority by phone)
- Government departments, LEP and devolved nations' development agencies, research base, sector representatives

Case studies

- 15 phone discussions completed with project leads
- 15 f-2-f interviews completed with project leads
- 33 partner interviews (across 9 case studies)
- Representatives at various levels from the lead project partner (e.g. directors, project managers, technical lead)

Workshop

- Validation workshop with 10 stakeholders to test emerging findings
- Representatives from BEIS, DIT, Innovate UK ATI, Catapult, sector representatives, aerospace firms

Source: SQW

It is important to highlight two aspects on the evidence gathered and the findings drawn from this. First, the evaluation evidence was primarily based on the 15 case studies, the unit of analysis for which was an ATI-funded project, and stakeholder interviews. The case studies involved collecting evidence from project leads and partners. The feedback and data provided was comprehensive. Project leads provided time and evidence, indicating strong interest and engagement with the programme and the evaluation. Second, the interpretation of key emerging findings should take into account that most of the case study projects had only recently closed or were near completion. This is pertinent given that the time-paths to commercialising R&T in the aerospace sector are long (typically 10 years or more), meaning that the ultimate effects of ATI were some way off. This matters for the early impact evaluation – with the effects likely to emerge over different time-periods across activity types.

Structure of this report

The remainder of this report is structured as follows:

- Section 2 provides further background to the ATI funding programme (including its strategic case and economic rationale, logic model and theory of change, and progress of the programme portfolio) and identifies the key implications for the evaluation.

[14] All monitoring data are available on a project basis, there is no full aggregation of the data. BEIS monitoring was voluntary, whereas Innovate UK monitoring was compulsory.

- Section 3 profiles the 15 case study projects, and presents the overall demand for funding from the ATI programme, and how projects were identified and developed.
- Section 4 presents the key outputs and outcomes achieved as a result of the ATI funding. This is based on evidence from the case studies, supported by stakeholder feedback and monitoring data.
- Section 5 presents the findings on the additionality of the ATI programme, i.e. what would have happened without the programme. The evidence from the different research strands was triangulated to understand the overall contribution of the programme. This includes the results of the QCA applied to three key outcomes (as described above).
- Section 6 sets out the emerging technological and policy developments, as identified through feedback from the case studies and stakeholders (including workshop participants). It also outlines how these developments were expected to affect the success of ATI.
- Section 7 summarises the key lessons in terms of what has worked well in the ATI-funded projects, and what has worked less well.
- Section 8 presents the emerging conclusions against the key evaluation questions, and identifies and makes recommendations for future development.

There are several supporting annexes:

- Annex A provides a list of stakeholder consultees
- Annex B provides definitions for ATI strategic themes, time and TRLs
- Annex C provides a list of the in-depth case studies interviewed
- Annex D presents a summary of ATI portfolio data (incl. investment in infrastructure)
- Annex E sets out our approach and research methods
- Annex F provides details on Qualitative Comparative Analysis
- Annex G outlines our approach to assessing R&D spillovers
- Annex H summarises government funding for aerospace R&D in selected key countries
- Annex I identifies issues to address for the future evaluation of ATI.

In addition, accompanying this report are separate documents with full write-ups of the 15 ATI programme case studies completed as part of the early impact evaluation together with the methodology report.

2. Background to the ATI programme

Strategic and economic rationale for the ATI funding programme

The UK aerospace sector is a high performing and productive sector with high value added and high wage jobs in aerospace multinationals and their supply chains. The sector needs to fully exploit its economic value by undertaking targeted collaborative R&D to further stimulate and accelerate business-led innovation in aerospace. The UK's international competitors invest heavily to support their respective aerospace sectors, and so part of the strategic basis for support is to maintain a 'level playing field' against international competitors such as Germany, France, Spain and USA, and new players such as Singapore and Poland.

Investment is required to: improve the UK's competitive position; provide greater 'certainty' for investment decisions; enable more and stronger collaborations between companies (B2B) and the research base (B2R); and encourage R&D that leads to 'stickiness'[15] and production jobs being located in the UK. Investment and collaboration across the business and research bases are therefore crucial for commercialisation of research and technologies, but particular market failures and barriers prevent this from occurring: information and coordination failures; high market and technical risk; and positive externalities (i.e. spillovers).

Programme inputs and key drivers

The ATI programme provides grant funding for R&D projects with matched contributions from industry. Programme funding equates to c. £150m p.a. (in nominal terms), with funds managed by Innovate UK. Innovate UK is responsible for the monitoring of the programme. The ATI is responsible for developing the long term Aerospace Technology Strategy, and providing oversight and advice on the R&T pipeline and portfolio.

The programme aims to deliver outcomes through the following key drivers: 'more' R&T funding and more certainty for investment decisions; prioritisation of technology areas to focus on the right projects; ATI projects lead to more/stronger collaborations; projects are successful in progressing through TRLs leading to further investment in R&T; R&T leads to 'stickiness' and the basing of production in the UK; infrastructure projects lead to the generation of new R&T capacity and R&T jobs in the UK; technologies and knowledge developed through ATI are relevant for other sectors, resulting in spillovers.

Progress of the ATI programme

Review of the ATI programme portfolio data found: 54 projects closed (45 Early ATI, 3 SRC and 6 Capital projects); 11 different lead partner organisations across the 45 Early

[15] In this context, 'stickiness' refers to R&D activities that are more 'anchored' in the UK i.e. not easily moved overseas.

ATI projects; Rolls-Royce and Airbus lead on projects accounting for nearly £269m of grants, or c. 80% of the total.

Most projects are in the ATI strategic themes: Propulsion of the Future and Aerostructures of the Future. In terms of timeframe for addressing market opportunities, most of the projects fall within the medium term (up to 2025).

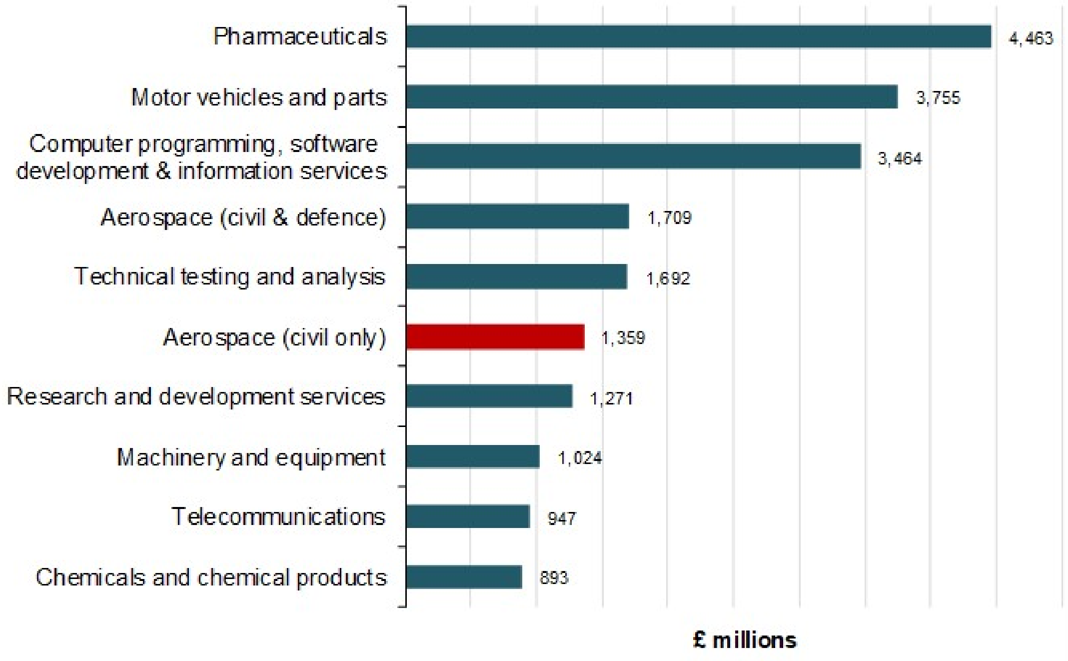
Strategic case and economic rationale for the ATI programme

The UK aerospace sector is a high performing and productive sector that is associated with high value added and high wage jobs in aerospace multinationals and their supply chains. Nevertheless, the sector needs to fully exploit its economic value by undertaking targeted collaborative R&D to further stimulate and accelerate business-led innovation in aerospace. This is particularly the case in the global context in which the aerospace sector operates: the UK's international competitors invest heavily to support their respective aerospace sectors, and so part of the strategic basis for support is to maintain a 'level playing field'.

Thus, investment is required to maintain or improve the UK's competitive position and grow market share. This is pertinent given the rapid pace of technological advances and the need for: greater 'certainty' for investment decisions because of the long timeframes associated with commercialising R&D in the aerospace sector; a focus on right projects to meet future industry demand aligned with sector priorities; more and stronger collaborations between companies (B2B) and the research base (B2R) – and how this enables economies of scale, spreads risk, and contributes to spillovers; and R&D that leads to 'stickiness' and production jobs being located in the UK. By way of context, Figure 2-1 depicts expenditure by UK businesses on R&D in 2018. The aerospace sector has consistently been a major spender on R&D in the UK, with spending of £1.7bn in 2018 and a ranking of fourth place by activity. However, this includes defence but civil dominates the total aerospace spend, and this was £1.4bn in 2018, with the sector ranking dropping only two places to a rank of sixth.[16]

[16] Office for National Statistics (2018) *Business enterprise research and development, UK.*

Figure 2-1: Expenditure by top 10 UK activities on R&D, 2018



Source: ONS (2018); The chart data measures all spending on aerospace R&D as a product irrespective of company industry.

Innovation is recognised increasingly as a collaborative process, requiring connections between those creating knowledge and those seeking to exploit it. Investment and collaboration across the business and research bases are therefore crucial for commercialisation of research and technologies, but market failures and barriers prevent this from occurring. These include the following, and we revisit how these are addressed in the next section:

- *Information and coordination failures*: individual firms are not aware of the expertise found in other firms and/or do not know where to go or how to access this expertise, especially lower down the supply chain. The barriers to truly collaborative R&T are exacerbated by sub-optimal inter-firm collaboration and a tendency for ‘top-down’ communication through the supply chain, making it difficult for SMEs to engage in R&T.
- *High market and technical risk*: the time-paths to commercialising R&D in the aerospace sector are long (from 5+ years for upgrades to components to 15-20 years for next generation aircraft), and this can result in uncertain “private” returns or perceived low returns depending on time preferences private actors. Therefore, the timescales for a return on investment and the associated risks are often too great for companies to bear on their own. In addition, the low or uncertain returns, and the timescales to achieving them, create barriers in securing external finance to fund R&T activities. Individual organisations are unwilling to engage in collaborative R&T, reinforced by the fear that benefits will be unevenly distributed.
- There are *positive externalities in the form of spillovers* of advancements within the aerospace sector and into other sectors (e.g. automotive, artificial intelligence, marine). In most cases, the social returns to R&D outweigh the direct economic benefit realised

by innovating firms. This means that firms do not undertake some projects that are socially desirable, leading to sub-optimal investment in R&T. Thus, government intervention is needed to maximise spillover benefits.

The Industrial Strategy recognises aerospace as a government priority given its role in driving leading-edge (high risk) innovation and R&T, and high levels of productivity. Given the rationale for the ATI programme, the overall purpose is to improve competitiveness and market share of the UK aerospace sector. This is to be achieved through targeted investments in industry-led (collaborative) R&T projects, which are intended to result in sustaining and creating high value-added jobs in the UK.

Inputs

The programme provides grant funding for R&D projects with matched contributions from industry. By 2018, c. £1bn of government grants had been allocated to over 200 strategic and collaborative R&D projects (of which c. 100 have been completed to date). Programme funding equates to c. £150m p.a. (in nominal terms), which was considered a step change in funding for aerospace R&T (research and technology) support from c. £50m p.a. prior to the programme.

The funds are delivered and managed by Innovate UK on behalf of BEIS. Innovate UK is responsible for the compulsory monitoring of the programme (BEIS also monitors the programme, though this is not comprehensive across all projects). The ATI[17] was established to provide strategic oversight and advice to support the programme. It is responsible for developing the long term UK Aerospace Technology Strategy for the sector, set out in 'Raising Ambition'[18] report (2015, updated in 2016).[19] It provides advice on the programme's investments and oversees the portfolio of projects.

Logic model and theory of change

The overall logic model and the key drivers and external factors influencing the logic model is set out in Figure 2-2. This was first established in 2015 and published in the methodology scoping report.[20] This has been reviewed and updated as part of the methodology study which was undertaken[21] at the start of this project. The updated logic model takes into account the recommendations of the academic review[22] (see also Annexes E and F).

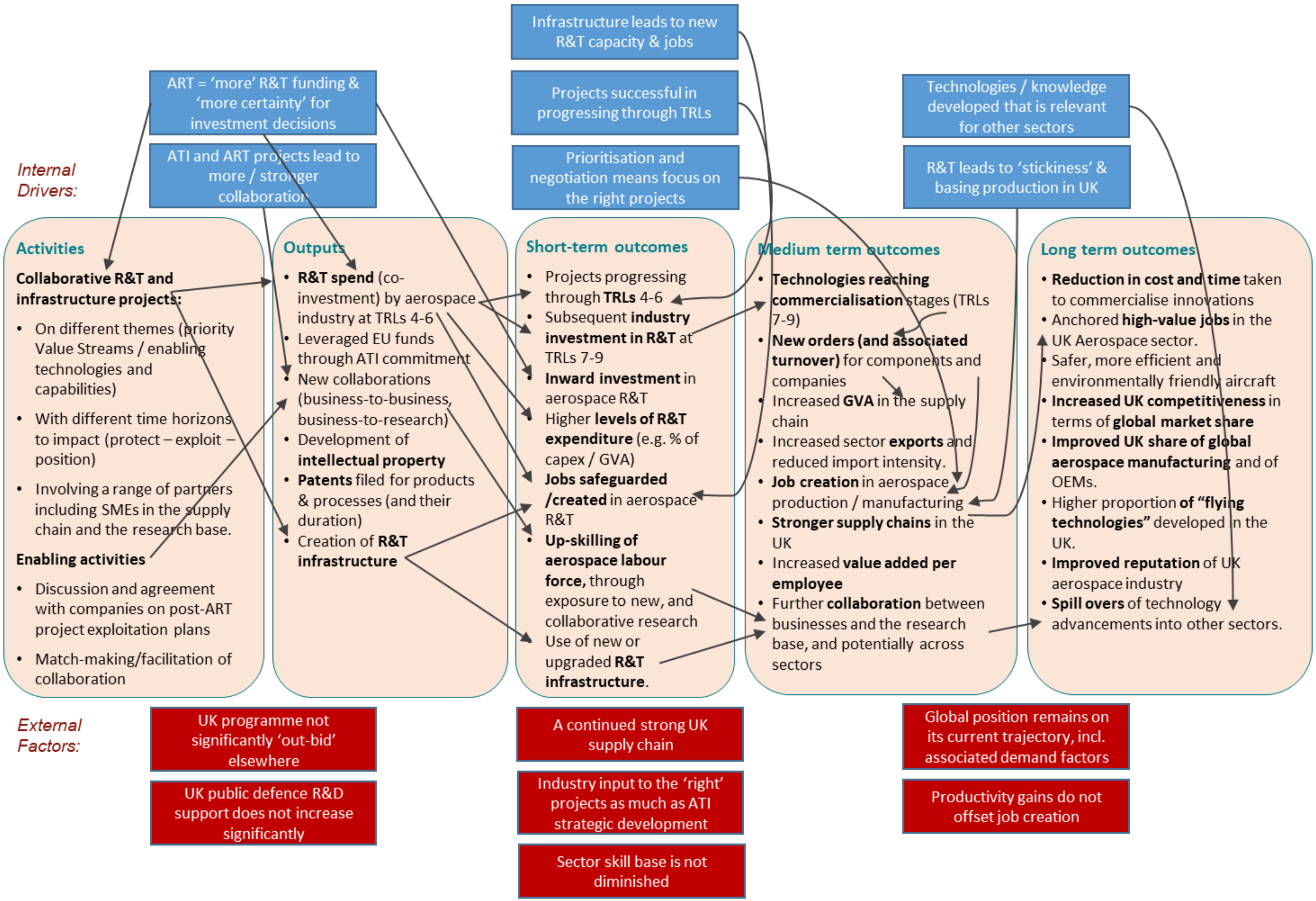
[17] The ATI is backed by a joint Government-industry commitment to invest £3.9 billion in R&T to 2026. It provides strategic oversight of the R&T pipeline and portfolio, and co-chairs the Strategic Review Committee with BEIS and advises on project investment.
[18] Aerospace Technology Institute. Raising Ambition: Technology Strategy and Portfolio Update 2016.
[19] It is important to note that the remit of the early impact evaluation is to assess the ATI programme and not ATI. However, the early evaluation will need to draw on the Raising Ambition Strategy and the wider work of ATI.
[20] See https://www.gov.uk/government/publications/aerospace-technology-institute-scoping-evaluation
[21] Methodology report – awaiting publication.
[22] Academic review – awaiting publication.

The logic model sets out the most important links between drivers and effects. In brief, the main drivers are as follows:

- ATI provides more funding and more certainty in relation to future funding, leading to greater confidence and helping to address barriers to R&T, resulting in more/ quicker investment in R&T in the UK.
- Prioritisation of technology areas informs projects coming forward and their selection, resulting in funding the ‘right’ projects – e.g. to aid UK aerospace competitiveness and to maximise the opportunities for future production jobs.
- Stakeholders involved and the ATI projects themselves generate more and stronger collaborations between companies in the supply chain due to introductions made, project requirements and technical and knowledge requirements.
- Technical success with projects progressing through TRLs – and leading to further investment in R&T.
- R&T that takes place in the UK leads to ‘stickiness’ and the basing of production in the UK. This results in production jobs being created/retained in the UK.
- Infrastructure projects, such as capital equipment, lead to the generation of new R&T capacity and R&T jobs in the UK.
- Technologies and knowledge developed through ATI is relevant for other sectors, resulting in spillovers. For example, infrastructure and knowledge developed on multi-purpose technologies can be applied in other sectors, facilitated by networks.

The logic model and drivers were drawn upon to develop a set of hypotheses, assumptions and alternative or complementary explanations as to how intended outputs and outcomes were expected to be brought about - the theory of change (see Annex E). These were developed to be tested in, and to frame, the early impact evaluation.

Figure 2-2: Logic model and key drivers



Source: SQW

Progress of the ATI programme

This sub-section summarises the ATI programme portfolio data that was provided by BEIS to inform the early impact evaluation. We present a review of the portfolio focussing on two categories of projects: Early ATI and Capital.

In total, there were 51 projects that were closed (or expected to end by December 2018). These projects fell into two categories: Early ATI (45 projects) and Capital (six projects):

- The Early ATI category refers to those projects where applications were reviewed in the early stages of the ATI (2013-15).
- Capital projects are for infrastructure/capital expenditure only.

The ‘headline’ statistics of the UK ATI Portfolio by category of project are presented in Annex D. We summarise and analyse the data for the two types of projects below.

Early ATI

All Early ATI projects, launched between April 2013 and March 2016[23], were commitments made before the Aerospace Technology Strategy was published in 2015. The applications were through direct approaches to BEIS, followed by independent assessment by Innovate UK. Early ATI projects were universally led by large companies, and have either closed or are due to close soon. Not all of these projects were 50-50 funded, particularly for capital funding. Note that a routine VfM assessment of all individual projects was not undertaken during this phase of the ATI programme. Until September 2016, only projects requesting grant funding over £10m were assessed and the few that were undertaken during the early-ATI phase tended to be bespoke as the capability and techniques were developed. No VfM assessments have been undertaken for any of the projects selected since they were all approved prior to September 2016.

Table 2-1 presents the key data for early ATI projects. We note the following:

- there were 45 Early ATI projects with 11 different lead partner companies
- Rolls-Royce and Airbus received the most grants (c. £269m, or 80% of total)
- projects involved between one and 16 organisations[24]
- GKN Aerospace acted as lead partner twice but led on a project with 15 other partners
- BAE Systems and Thales have been the lead partner once but were involved in projects with seven partners.

[23] UK ATI Programme Description by Type of Project.
[24] We understand this includes project leads.

Table 2-1: Early ATI projects, breakdown by lead partner

Lead Partner	Freq.	Average number of partners per lead	Total grant (£m)	Total cost (£m)	Total spend to date (£m)	Region of lead partner
Rolls-Royce PLC	17	2.5	116	232	114	East Midlands
Airbus	15	6.0	90	158	84	South West
GKN Aerospace Services Limited	2	11	26	44	25	South West
GE Aviation Systems Limited	2	4.5	10	17	8.4	South West
Thales UK Limited	1	7	6.4	12	6.4	South East
Bombardier Aerospace UK Limited	1	5	3.8	6.9	3.6	Northern Ireland
Collins Aerospace	2	2.5	3.6	5.9	3.5	West Midlands
Safran Group	2	3	3.3	5.4	3.1	South West
Spirit AeroSystems (Europe) Limited	1	3	2.4	3.5	2.4	Scotland
Leonardo Helicopters	1	1	2.1	4.3	2.1	South West
BAE Systems (Operations Limited)	1	7	0.6	1.3	0.6	South East
Total	45		264	489	253	

Source: 2018-09 ATI Portfolio Stats Excel

Table 2-2 provides a breakdown of Early ATI projects by value stream[25] and lead partner (see Annex B for definitions of value streams). 'Propulsion of the Future' and 'Aerostructures of the Future' value streams had the most projects, each accounting for around a third of the portfolio (38% and 31%, respectively).

Table 2-2: Early ATI projects, breakdown by 'value stream' and lead partner

Lead Partner	Propulsion of the future	Aircraft of the future	Smart, Connected and More Electric Aircraft	Aerostructures of the future
Rolls-Royce PLC	15	1	1	0
Airbus	0	1	3	11
GKN Aerospace Services Limited	0	0	0	2
GE Aviation Systems Limited	0	0	2	0
Thales UK Limited	0	0	1	0
Bombardier Aerospace UK Limited	1	0	0	0
Collins Aerospace	0	0	2	0
Safran Group	0	0	2	0
Spirit AeroSystems (Europe) Limited	0	0	0	1
Leonardo Helicopters	1	0	0	0
BAE Systems (Operations) Limited	0	1	0	0

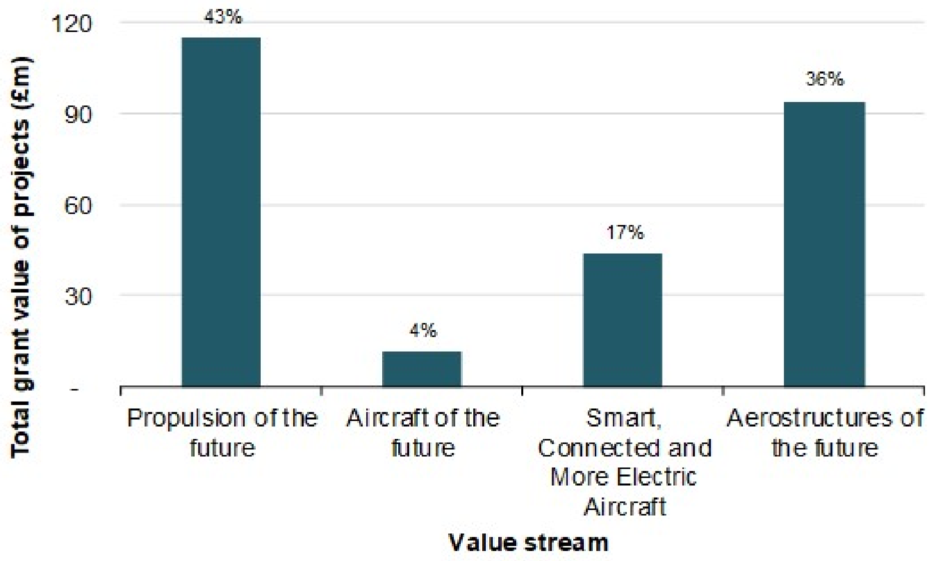
[25] ATI's R&T themes as set out in the Raising Ambition: Technology Strategy and Portfolio Update 2016. The ATI identifies four main strategic themes for the aerospace sector aligned with future market requirements: Propulsion of the future; Aircraft of the future; Smart, Connected and More Electric Aircraft; and Aerostructures of the future.

Lead Partner	Propulsion of the future	Aircraft of the future	Smart, Connected and More Electric Aircraft	Aerostructures of the future
Total projects	**17 (38%)**	**3 (7%)**	**11 (24%)**	**14 (31%)**

Source: 2018-09 ATI Portfolio Stats Excel

Figure 2-3 shows the grant value of Early ATI projects relating to each value stream: in line with the numbers of projects, 'Propulsion of the Future' and 'Aerostructures of the Future' received the largest amounts of Early ATI funding (43% and 36%, respectively).

Figure 2-3: Total grant value of Early ATI projects in each value stream



Source: 2018-09 ATI Portfolio Stats Excel

Table 2-3 provides a breakdown of Early ATI projects by the SEP (Secure, Exploit, Position) timeframe[26], and Figure 2-4 presents the value of grants according to the timeframe for projects. We note that most of the projects (just over 90%) are at 'Secure' and 'Exploit' stages, collectively accounting for 95% of the total value of grants allocated to Early ATI projects.

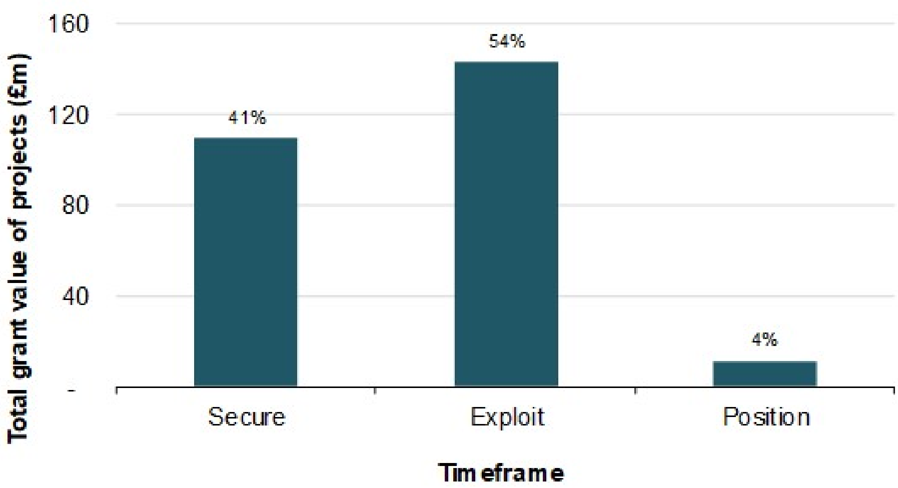
[26] The SEP model as outlined in the Raising Ambition: Technology Strategy and Portfolio Update 2016. Secure (0-5 years): Ensure vital UK technology capabilities are secured and developed, and manufacturing competitiveness is raised; Exploit (up to 2025): Accelerate UK technologies and capabilities to capture high-probability market opportunities; Position (beyond 2025): Prepare UK aerospace for long term success by pursuing game-changing technologies.

Table 2-3: Early ATI projects, SEP timeframe by lead partner

Lead Partner	Secure (0-5 years)	Exploit (5-10 years)	Position (10+ years)
Rolls-Royce PLC	6	11	0
Airbus	3	10	2
GKN Aerospace Services Limited	1	1	0
GE Aviation Systems Limited	1	1	0
Thales UK Limited	1	0	0
Bombardier Aerospace UK Limited	0	0	1
Collins Aerospace	0	2	0
Safran Group	2	0	0
Spirit AeroSystems (Europe) Limited	0	1	0
Leonardo Helicopters	0	1	0
BAE Systems (Operations) Limited	1	0	0
Total projects	15 (33%)	27 (60%)	3 (7%)

Source: 2018-09 ATI Portfolio Stats Excel

Figure 2-4: Total grant value of Early ATI projects by SEP timeframe



Source: 2018-09 ATI Portfolio Stats Excel

Capital projects

ATI funding is allocated to capital infrastructure projects to build or upgrade testing facilities or equipment required for the development of new aerospace technologies. This is in response to specific R&T needs of the aerospace industry. The built/upgraded infrastructure may then be used by subsequent R&T projects (ATI or non-ATI funded).

We note the following for the six Capital projects:

- there were five lead partners: Queen's University Belfast; Advanced Manufacturing Research centre; Aircraft Research Association; University of Nottingham; GKN Aerospace.
- four projects were in 'Aerostructures of the Future', and one each in 'Aircraft of the Future' and 'Propulsion of the Future.'
- three projects were in Secure, two in Exploit, and one in Position.
- grant offers were between £0.5m and c. £5m; all but one project had 100% grant funding.

Implications for evaluation

Drawing on the evidence and issues highlighted in this section, we identify the following key implications for the early impact evaluation:

- **First, the nature / scale of ATI, complexity in activity and routes to outcomes:** ATI is a complex intervention, supporting projects at different stages of R&T, with a range of intended outcomes (including spillovers) over varying timeframes. Supported beneficiaries range from SMEs to multinational primes, and include academic institutions, Research and Technology Organisations (RTOs) and Catapults. The small number of projects and complex routes to impact meant that, in using theory-based approaches, it was important to have a sound theory of change and a set of clear hypotheses and assumptions to test and assess. These are detailed above and in Annex E.
- **Second, time-paths to commercialising R&T in the aerospace sector are long:** the commercialisation time-paths in the sector are typically 10 years or more, meaning that the ultimate effects of ATI are some way off. Most of the 15 case study projects were closed from 2017 onwards (see Table C-1). This matters for the early impact evaluation – with the effects from these 15 cases likely to emerge over different time-periods across activity types. There may be some short-term outputs and outcomes, e.g. additional funding leveraged, projects progressing through TRLs and the establishment of new partnerships and relationships. However, the ultimate commercial benefits are likely to be long-term.
- **The selection of case studies had to consider a range of relevant factors, and not just the largest value projects:** given most organisations were involved in multiple

projects, it was important to explore a balance of projects, covering those led by the highest recipients of ATI funding (Rolls Royce and Airbus), including where they were leading clusters of related projects, and those led by others. Similarly, the value streams, Propulsion of the Future and Aerostructures of the Future, received the majority of the funding, but projects from the other two value streams also had to be considered. Finally, it was also important to consider cases of cross-over technologies between value streams.

3. Project profile, demand, and development

Project profile

The 15 ATI projects that were the subject of case studies were implemented between 2013 and 2018. The case study projects varied in terms of the ATI value streams, and the numbers of partners (from one to 16). They were almost all in either the ‘Secure’ or ‘Exploit’ timeframes (seven in each), with only one in the longer-term ‘Position’ stage. The total project costs ranged from £0.5m to £30m (with an average of £10m), and the total ATI grant size varied between £0.5m and £19m (with an average grant offer of £6m).

Project demand, origins, and development

Stakeholders reported healthy demand for the ATI funding, and that this largely stemmed from Tier 1 firms. Projects were identified and developed through: priorities of the company/research organisation; the role of strategic direction from industry (including ATI); and collaborator/supply chain inputs. Project collaborations were mainly informed by the knowledge and expertise of collaborators, use of particular infrastructure (e.g. Catapult facilities), and to reflect R&T priorities of companies. The collaborations were mainly developed through existing connections of the project lead companies, including with their supply chains. That said, there were also new collaborations through project leads identifying and approaching partners with the required expertise, and through referrals from existing connections. There was consensus amongst project leads and partners that their collaborative relationships were either “very strong” or “strong” by the end time of project completion.

The case for **why ATI funding was needed for projects** was fourfold: (1) the mostly large scale, high-risk, and long term nature of projects meant that private internal funds of companies were not available and discouraged other external private providers; (2) the UK was the preferred location for projects because of the strength of the existing knowledge and skills base in the project leads’ supply chain and also in the UK’s research base (including facilities through partners such as Catapult centres) – though ATI funding helped to secure some of the projects in the UK; (3) there was limited alternative UK and international sources of funding partly because of the particular nature of the projects; (4) ATI funding enabled collaborations and made it easier to leverage knowledge and skills of partners.

Project progress

Across the 15 ATI projects, the activities undertaken by project leads and partners covered the full R&T life cycle. Partner activities complemented the work done by project leads. Generally, project activities were delivered as expected. However, eight projects were granted extensions by ATI.

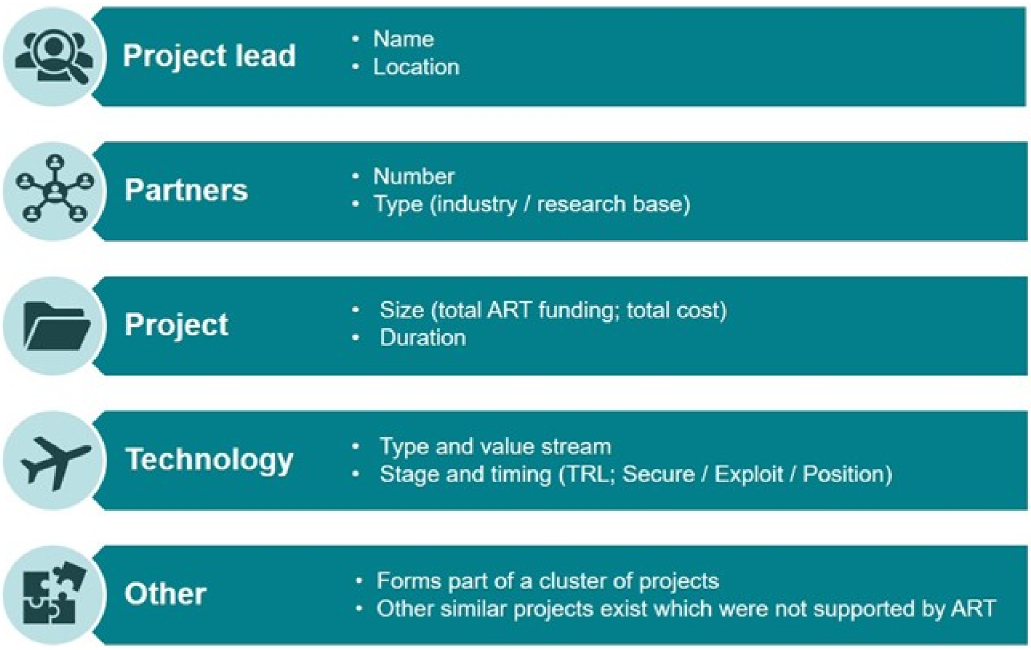
Five lead partners identified six similar R&T projects that were considered at the same as the ATI-funded project. Whilst all were taken forward through either internal funds or other public funding programmes half of these other non-ATI-funded projects had progressed more slowly. Three projects had progressed on a similar timescale to the ATI-funded project.

The evaluation evidence was primarily based on the 15 case studies, the unit of analysis for which was an ATI-funded project, and 20-plus stakeholder interviews. In this section, we briefly profile the 15 cases and how these were selected. We then explore the overall demand for funding from the ATI programme, how projects were identified and developed, why specifically ATI funding was needed for projects, and finally how projects progressed. The findings are based on evidence from case study consultations and the monitoring data provided by BEIS, Innovate UK and ATI.

Project profile

A longlist of possible case studies was developed and discussed with BEIS, Innovate UK and ATI. From this, we selected the final 15 cases. As discussed in Section 2, the selection was informed by the need to ensure a balance of projects across a range of factors including (as set out in Figure 3-1): project lead; number and type of partners; geography; funding (total project costs and grant value); types of technologies developed; value stream; stage and timing of projects (TRL, SEP timings); and other factors (e.g. clusters/related projects). The selection of case studies was not made to maximise the effectiveness of the QCA. Further details on the reasons for including each of the 15 projects are presented in Annex C.

Figure 3-1: Key selection criteria for case studies



Source: SQW

The final list of projects selected as case studies is shown in Table 3-1. Across the 15 cases, there were 11 different lead partners. Airbus and Rolls Royce were lead partners for three projects each. As explained in Section 2, the selection of multiple case studies for Airbus and Rolls-Royce was consistent with the fact that these two companies accounted for a significant proportion of the grants awarded (both in terms of numbers and value).

Table 3-1: Case study projects

Lead Partner	Project	Technology	Partners
EARLY ATI			
AIRBUS Airbus is an international aerospace design and manufacturing company	**1. FOAF (Factory of the Future for Aircraft Wing Manufacture and Assembly)**	Optimising aircraft manufacture through process improvement, focusing on the assembly of wing component technologies	Advanced Manufacturing Research Centre (AMRC), Manufacturing Technology Centre (MTC), Seco Tools, Cranfield University, Queen's University Belfast, BAE Systems, Short Brothers, Hexagon Metrology, Aertec Solutions, Eventmap Limited, Datum Tool Design, Airbus Group Limited[27].
	2. WDMA (Wing Design, Manufacture and Assembly)	Examining two different composite materials to determine which would be better suited for use in the wing box for the next Airbus single aisle aircraft	Spirit AeroSystems (Spirit) and the National Composites Centre (NCC)
	3. WIST (Wing Integrated Systems Technologies)	Twelve technologies for wing systems architectures, equipment and installation (including fuel systems, ice protection, and electrical and optical networks)	GE Aviation Systems, GKN Aerospace Systems, National Composites Centre, Tyco Electronics, Ultra Electronics Precision Air & Land Systems
ROLLS ROYCE	**4. Project 11 Core Demonstrator Concept**	New core engine demonstrator aimed at improving engine efficiency, fuel consumption and CO2 levels	No partners
	5. Advanced Repair Technologies	Blisk repair (requiring cost effective repair technologies following foreign object damage), on-wing repair	Universities of Birmingham, Nottingham and Swansea; and European Thermodynamics Ltd

[27] At the time of FOAF, Airbus Operations and Airbus Group were separate entities.

Lead Partner	Project	Technology	Partners
Rolls Royce is a British multinational engineering company producing technologies for civil aerospace and defence		(including robotic and CCTV applications), and composite repair (for new composite fan system)	
	6. Rolls Royce SILOET II Project 15 Advanced Turbine Technologies	New high-pressure turbine interface with combustion, also developing and proving shroudless blade technology	University of Cambridge (Whittle Laboratory)
GE Aviation GE Aviation, a subsidiary of General Electric, is a USA-owned provider of jet-engine components and integrated systems for civil and military aircrafts	**7. Future Flight Deck**	A next generation flight deck, built on human factors and human-machine interface principles, including the development and testing of several technologies (e.g. head-up, smart displays, high speed network switch, fault tolerant touch interfaces)	BAE Systems (Rochester), Coventry University, Southampton University
GKN AEROSPACE	**8. VIEWS (Phase 1)**	Multiple wing manufacturing technologies, including 86 technology strands across six themes: assembly,	Bombardier, GE Aviation Systems, Spirit AeroSystems, Advanced Forming Research Centre University of Strathclyde, Advanced Manufacturing Research Centre,

Lead Partner	Project	Technology	Partners
GKN Aerospace is a British multinational engineering group producing components for the aerospace industry		coatings, composites, design and methods, inspection, and metallics	Manufacturing Technology Centre, National Composites Centre, Warwick Manufacturing Group, University of Bristol, University of Exeter, University of Nottingham, Sheffield Hallam University
Leonardo Helicopters is an Italian-owned international civil and military aircraft and aerostructure manufacturer	**9. Extension to the Rotorcraft Technology Validation Programme (RTVP II)**	Helicopter active rotor technology including an active trailing edge embedded within a helicopter rotor blade and sensors within the rotor head to enable real time parameter monitoring	There were no partners within RTVP II, however academics from Liverpool University and Leicester University contributed to the initial phase of the programme, RTVP I
Safran Landing Systems is a French company involved in the design, development, manufacture and customer support	**10. LAGEMOSYS (Landing Gear Monitoring Systems)**	Improving health and usage monitoring for aircraft landing gears by developing a learning algorithm that could be matured to take a small amount of data to complete a very accurate assessment of the health of a landing gear Health and usage monitoring for aircraft landing gears	University of Cambridge and University of Sheffield

Lead Partner	Project	Technology	Partners
on aircraft landing gear, wheels and brakes			
THALES Thales is a French company that develops electrical systems and provides services for aerospace, defence, transportation and security sectors	**11. HARNet (Harmonised Antennas, Radios, and Networks)**	Integrated Modular Communications (ICM) as an approach to improve the efficiency, reliability and safety of the 'Connected Aircraft'	Cobham, University of Southampton, University of Bradford and Queen Mary University London
Collins Aerospace Collins Aerospace (formerly UTC) produces technological solutions for the global aerospace and defence industry	**12. LAMPS (Lightweight, Affordable Motors & Power-electronics Systems)**	Innovative system for motor and drives that reduces the size, weight and cost for future aircraft	Raytheon UK, TT Electronics (formerly Aero Stanrew) and ICW
CAPITAL PROJECTS			
QUEEN'S UNIVERSITY BELFAST	**13. SCENIC (Supply Chain ENablement for**	Establishing an open-access advanced manufacturing technology centre	No partners

Lead Partner	Project	Technology	Partners
Northern Ireland Technology Centre (NITC) is a technology and innovation centre affiliated with the School of Mechanical and Aerospace Engineering at Queen's University Belfast (QUB)	**Increased Competitiveness)**	equipped with state-of-the-art industrial machinery to support the computerisation of manufacturing	
Aircraft Research Association (ARA) is a Centre of Excellence in Aerodynamics located in Bedford	**14. ARCADE (Aerodynamic Research Testing Capability and Data Enhancement)**	Maintenance and development of ARA's transonic wind tunnel facility which allows industrial-scale testing at transonic speeds (the only such facility in the UK and one of only a handful worldwide) Maintenance and development of ARA's transonic wind tunnel facility	No partners
The Advanced Manufacturing Research Centre	**15. FRoMHAA (Flexible Robotic Machining in High Accuracy Applications)**	Developing a cell capable of flexible, high accuracy robotic machining to automate aerostructure manufacturing	No partners

Lead Partner	Project	Technology	Partners
(AMRC) is one of the UK's HVM Catapult Centres, and part of the University of Sheffield			

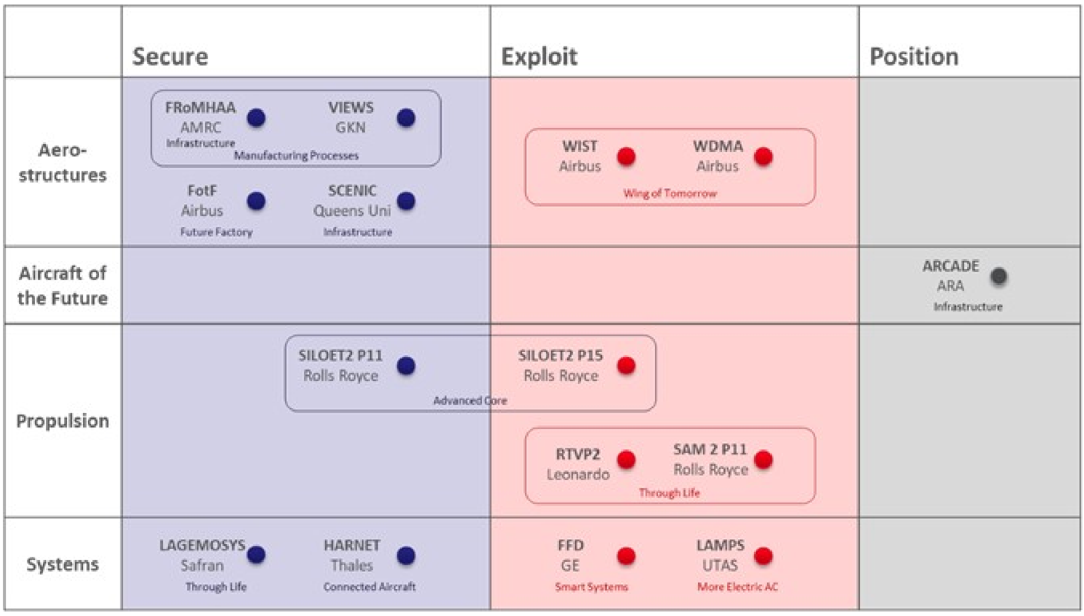
Source: SQW

An overview of the key details for each of the 15 case study projects is presented in Annex C. The following points can be noted about the profile of case study projects:

- The projects were undertaken between 2013 and 2018. At the time of undertaking the consultations, all projects had been completed and closed.
- The majority of case study projects fell within the ‘Secure’ and ‘Exploit’ timeframes (each represented by seven cases); one project was at the ‘Position’ stage.
- The cases were in the following ATI strategic value streams:
  - 6 in Aerostructures
  - 4 in Propulsion
  - 4 in Smart, Connected and more Electric Aircraft
  - 1 Aircraft of the Future.
- The number of partners involved in each project varied between one and sixteen; five case study projects (including all three Capital projects) included only the lead partner.
- The grant size varied between £0.5m and nearly £19m; the mean grant offer was £6m.
- The total cost of projects was between £0.5m and c. £30m, with the average project costing £10m.
- The geographic breakdown by lead partner was as follows:
  - 5 in the South West
  - 3 in the East Midlands
  - one each in: East of England, South East, North West, Northern Ireland, Wales, West Midlands, and Yorkshire and the Humber.

As part of our consultation with ATI technologists we explored the development of a project/technology map. Following our discussions, ATI technologists helped produce the map depicted in Figure 3-2. This illustrates how the case study projects included in the evaluation fit within the wider ATI portfolio in terms of their SEP timeframe and value stream.

Figure 3-2: Project/ technology map of how case study projects fit in the wider ATI portfolio.



Source: ATI; SQW

Project demand

The evaluation sought to understand the overall demand for funding from the ATI programme, and how the R&T priorities of the ATI programme were set and developed. The findings on these areas were drawn primarily from the stakeholder feedback and are set out below.

Overall demand for funding from the ATI programme

Overall, stakeholders reported there being healthy demand for the ATI funding. Some noted that demand had exceeded the supply of funds available. Several stakeholders (6 out of 11 that provided feedback on this topic) identified that funds were often required to de-risk large-scale research and development projects, particularly at early stages – which aligns with the evidence from the case studies on why specifically ATI funding was required (see later in this section). It was also noted that demand largely stemmed from larger, Tier 1 firms. It was understood that this was particularly the case at the programme's inception as larger companies were able to respond more quickly to the availability of funds. Stakeholders observed that there was demand from SMEs, though most funding had been provided to larger firms. Other funding competitions were seen as more appropriate for SMEs, such as NATEP[28] and the ATI's specific CR&D competition. Due to requirements around match funding, often SMEs would choose to take part in ATI-funded projects as subcontractors to Tier 1 firms, rather than applying for funds themselves. These sub-contracting arrangements have proved an effective way of engaging SMEs in the programme. From an industry perspective, one stakeholder observed that there was strong demand for such funding to enable the UK to continue to compete internationally. Governments in countries such as France and Singapore

[28] NATEP is now being funded from the ATI programme.

significantly support their aerospace industry. Therefore, ATI funding was seen to be required to ensure a level playing field for the UK.

How R&T priorities of the ATI programme were set and developed?

The ATI and its strategy, 'Raising Ambition', was widely recognised as the vehicle for setting the R&T priorities for the ATI programme. Many stakeholders (7 out of 10) indicated that the 'value streams' or priorities set within this strategy had been developed to reflect the relative strengths of the UK aerospace industries. Many (8 out of 10) also believed that priorities had been largely influenced by tier 1 firms, as well as the research base. One stakeholder, however, noted that the ATI played a key role in including the perspective of SMEs and supply chains within their horizon scanning and strategy development. Others viewed the strategy and R&T priorities as having been informed by general industry trends, for example towards lightweighting and alternative power sources.

The above points are relevant because they demonstrate three aspects. First, the fact that the main applicants to ATI were also key informers of the strategy helped to ensure that there was good alignment between ATI projects and the priorities. Second, it was not just the tier 1 firms influencing the priorities but also the research base, SMEs and supply chains (according to ATI, consultations were held with over 100 organisations) thus priorities and projects of the ATI programme also reflected the interests of these groups. Third, the priorities set within the strategy reflected the UK capabilities and competitive advantage, demand and market opportunities. This should help to increase the likelihood that production that flows from ATI projects is based in the UK.

Project origins and development

In this sub-section we draw on case study evidence to set out: how projects were identified and developed; how collaborations came about; funding options considered for projects; why specifically ATI funding was needed for projects; the objectives of projects; and project progress.

How project identified/developed?

Whilst there were various ways in which projects were identified and developed, a common and expected theme was that they related to the priorities of the company/research organisation in response to market opportunities. Not surprisingly, several of the ATI funded projects also had origins in previous projects – the ATI projects were the next iteration or stage of development. More widely, the role of strategic direction from industry (including ATI) was also highlighted, as were collaborator/supply chain inputs (albeit the latter was to a lesser degree). The main ways in which projects were identified and developed are presented in Table 3-2 below.

Table 3-2: How projects identified and developed?

How identified/ developed	**Description**
Company/research organisation priorities:	

Response to market demand, opportunities, and trends	• Respond to industry requirements for different types of specialist technologies and aerospace facilities
	• Market opportunities driven by internal circumstances/priorities of project lead companies e.g. fit with their company Technology Roadmaps
	• ATI-funded project provided the opportunity to refocus efforts
	• Projects also came about because of observed trends, for example:
	  - progression in commercial technologies that could be used to update flight decks but are difficult to implement (e.g. touch screens)
	  - changing requirements and targets within aerospace set by the EU (e.g. regarding airspace congestion and demands on pilots)
	  - observed demand (e.g. cockpits have not been updated for 20 years), and introducing new product lines (in line with company roadmaps)
	  - other countries starting their own civil aircraft programme (e.g. China), providing additional market opportunities

Achieve a more balanced portfolio of short and long term projects	• Company priorities to rebalance from long-term R&T on all-new aircraft towards exploiting R&T on serial programmes (aircraft currently in production) – earlier exploitation to see a return on R&T investment - creating a more balanced portfolio with some short term and long term projects.
Increase/ faster production, improve quality of technologies, and reduce costs	• Build aerospace components faster, increase production rates, and more cost effectively in the UK. However, in some cases this required the introduction of innovations in the manufacturing process and testing of technologies. • In addition, projects were identified for related reasons, for example: - reduce weight of aerospace components, improve accuracy of technologies, reduce emissions, achieve better fuel burn, and enable significant application in wider technological/industry developments (e.g. more electric aircraft)

How identified/ developed	Description
	- address technical issues in developing technologies (and processes), for example overcome bottlenecks in the manufacturing process (otherwise the work may shift to lower-cost locations such as Romania and China, or contracts would be lost)
Integration and testing of technologies, materials and processes	• Rather than individual components being developed in isolation and then combined at the end, projects adopted a codesign approach, explicitly thinking about integrating the systems from the beginning of the project – speeding up the cycle time through assembly. • Related to the integration is the testing of materials/technologies (e.g. composites) including the desire to bring about changes to the configuration of aerospace components (particularly as technologies could not be developed and tested in the normal production cycle).
Strategic direction from industry and collaborator inputs:	
Strategic direction and alignment with industry	• Projects were identified and developed because of strategic direction/setting by industry (these include both industry bodies and individual top-tier firms/OEMs). • In a minority of cases, projects were specifically aligned to ATI's strategies (e.g. Raising Ambition; Lifting Off and the Building Momentum for the UK Aerospace strategies). • More widely, the Aerospace Growth Partnership (AGP) strategy (and other strategies e.g. from Knowledge Transfer Partnership) influenced internal company strategies regarding investment in disruptive innovation in the UK.
Collaborator and supply chain inputs	• The knowledge and expertise of existing and new collaborators/ supply chain organisations (e.g. companies, universities and Catapult) helped to inform the design and development of projects. This is particularly the case where there was cross technology and sector applications. Consortiums helped identify and shape projects, enabling for more integrated solutions.

Source: Case studies; SQW

Stakeholders (9 out of 9) agreed that 'potential for UK production' was a key consideration within ATI project development and important to the programme. For example, this was a main focus of the development of the Boeing factory in Sheffield, enabled by ATI funding. However, it was noted that guarantees could not be provided, or conditions placed, on funding. In addition, multinational firms receiving support often required a degree of independence. One stakeholder observed that the potential for increased UK production resulting from ATI projects would depend on other factors, such as land/property and skills, as well as the ATI projects themselves. Another commented that the funding was more focussed on enabling UK production by allowing UK aerospace to remain generally internationally competitive, rather than through any specific project.

How project collaboration came about?

Project collaborations have mainly been informed (i.e. the incentive/reason to collaborate) by the specific knowledge and expertise of collaborators, use of particular infrastructure (e.g. Catapult facilities), and to reflect R&T priorities of companies.

The collaborations occurred mainly because of the existing connections of the project lead companies, including with their supply chains. The project leads had history of working with their supply chain (and other) organisations. This was partly driven by the need to draw on a mix of capabilities (e.g. design, prototyping, integration, modelling, simulation, manufacturing). Several project leads used their existing industry-academic connections. In a few cases these were not being maximised and ATI provided an opportunity to develop these. For example, in the view of one partner research organisation, *"we had a prior relationship with the project lead company but had never found traction in collaboration. This [ATI funded project] was the first opportunity to show what we could do for the project lead company".*

Whilst collaborations were mainly built on existing connections, there were also new collaborations formed (i.e. where there was no prior history of collaboration). These came about mainly through project leads identifying and approaching the required expertise to help develop the ATI-funded projects; and referrals from existing connections (e.g. from supply chain and university/research organisations). Interestingly, in one case a UK project partner had a long-established commercial relationship with the project lead in an EU country but not in the UK, but when the project partner opened a UK office, the project lead included the partner in various R&T projects (including ATI).

The role of ATI in signposting and connecting organisations to stimulate new collaborations (directly and indirectly) was identified in a small number of cases. For example, one project lead company reported that they worked closely with ATI and this had influenced their company strategy (including on collaborators); and another company reported ATI had made the introduction between the project lead and partner company.

The case study evidence was supported by the stakeholder feedback: collaborations were largely developed through existing connections, especially in the early stages of the programme. A minority of stakeholders (4 out of 10) mentioned that the industry was quite tightly knit, meaning often relationships were pre-existing, with few new entrants. That said, the ATI was described by three stakeholders as being good at brokering relationships. One stakeholder in particular noted that the ATI, as well as Technology Specialist Advisory Groups, enabled new entrants to be introduced into some collaborations. This is reinforced by the feedback from stakeholders participating in the validation workshop (held in July 2019). It was also noted that the ATI programme had increased collaborations within the industry over time, particularly at the tier one level and between competing organisations.

The main motivators for collaborations, other than longstanding relationships, were thought to be specific knowledge and expertise, ownership of required infrastructure and having aligned R&T priorities. One stakeholder also noted that firms often formed relationships to better position themselves for business opportunities.

Strength of the collaborative relationships at the end of the project

There was consensus amongst project leads and partners that their collaborative relationships were either "very strong" or "strong" by the end time of project completion. Generally, the same applied to the relationship between partners (i.e. not with project leads) – business to business (B2B) and business to research (B2R). It was also clear that relationships had "evolved" over time as a result of ATI-funded projects. In a few examples, the collaborations in the ATI funded project led to other collaborative projects (e.g. funded by CleanSky2) and "grew [a] completely new line of business". This suggests that in some cases the relationships have sustained beyond the life of the ATI-funded projects. The following are some examples of the feedback on the strength and progression of collaborations:

Strength of collaborative relationships – examples of feedback from case studies

"Very strong relationship with the University. The relationship evolved because of the project. It was difficult in the early stages to align industry and academia expectations. This was harder than our normal collaborations because there were multiple partners and it took time to get the tempo of the team right. We're now in a European follow up project with the University" (Project lead)

"Excellent relationship with partner on R&T, a good partner for 10 years. The partner became progressively more open during the project. The project reinforced the strength of the relationship and the partner is now on as a design and build partner (rather than R&T). To exploit technologies, it is more important to work cooperatively than competitively" (Project lead)

"Mixture of highs and lows…there was a lot of complexity with the number of partners in the collaboration, particularly in determining IP and deliverables. Decisions about IP gave it [project] a slow start, but once that was out of the way, the project was managed very well" (Partner)

"Stronger relationship with the project lead at the end of the project…gained more experience of working together" (Partner)

"It was initially tricky to work with other OEMs as they are all competitors, but the relationships became more open as the project progressed…by the end relationships were quite strong" (Partner)

"Good relations were built with the different HVMC centres, for example MTC, AFRC, AMRC" (Partner)".

Funding options considered for projects

There were a limited number of funding options considered by case study project leads. This was partly due to other UK public funding being of insufficient scale. For example, regionally available funds, such as from Local Economic Partnerships (LEPs), were deemed to be too small. In contrast, ATI funding was considered the only viable option given the scale of external funding needed and the high risk nature of the projects. In the view of one project lead, *"[the] ATI was the only game in town".*

The case studies identified other external public funding which is available from overseas including France, Germany and Spain (the Airbus nations in Europe), and USA. A summary of overseas government funding which is available in these and other key countries for aerospace R&D is given in Annex H. EU funding is also available for aerospace R&T (including the Clean Sky 2 programme)[29] but this was associated with being inflexible with many barriers to accessing these funds (e.g. too long a process). In the view of one project lead, USA-based public funds *"would have been difficult to tap into since the technology and expertise required for the project were based in the UK. In addition, NASA programmes typically only fund research that addresses specific areas that have been identified by them".*

Projects were progressed in the UK because of the project leads' existing R&T activities, access to their supply chains, and availability of their own facilities as well as wider infrastructure (e.g. Catapult centres). The ATI funding also provided a strong case for progressing projects in the UK, especially where UK operations had to make the case to overseas decision-makers, given the scale and type of projects to be funded. For example, for one project lead the ATI business case to their parent group was strong - the level of match funding was a large incentive, as was the flexibility and retention of IP following project completion. By comparison, the same project lead highlighted that US funding was less flexible, was primarily delivered through defence bodies, and the State retained full ownership of any resulting IP.

Why specifically was ATI funding needed for projects?

Figure 3-3 summarises the main reasons why ATI funding was needed for the projects. There was no single reason why UK companies would not fund projects themselves. It was a combination of location advantage, sound commercial case, and the long-term certainty that ATI funding provides. The feedback from project leads highlighted four main inter-related reasons:

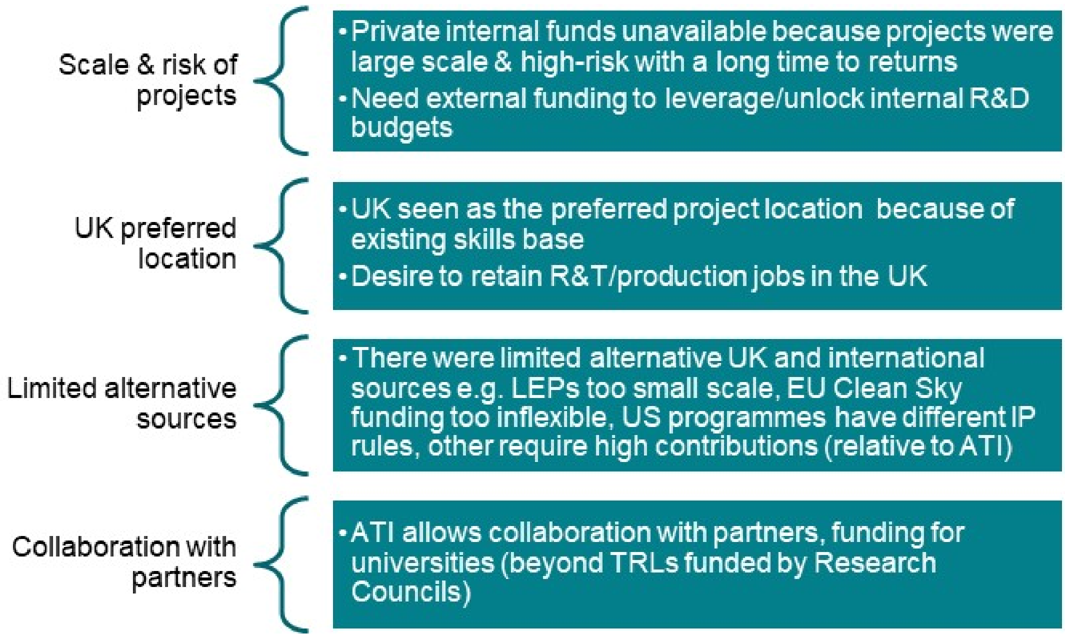
- First, the large scale, high-risk, and long term nature of projects (to achieve commercial returns) resulted in private internal funds of companies not being available (e.g. projects did not meet internal return on investment criteria) and that these types of projects discouraged other external private providers of funding (e.g. banks).
- Second, the UK was seen as the preferred location for projects because of the strength of the existing knowledge and skills base in the project leads' supply chain and also

[29] https://www.cleansky.eu/

more widely in the UK's research base. This was also related to the desire for project leads (and partners) to retain R&T and production jobs in the UK. Having ATI projects in the UK meant that project leads (and partners) would be in a stronger position to bid for the manufacture/assembly of technologies in the UK (against competition from overseas).

- Third, there were limited alternative funding sources, either UK or international (that could be used on UK-based projects), partly because of the first reason given above, i.e. particular nature of the projects, and because ATI was the source that offered the right kinds of terms such as on match funding. The availability of alternative funding was generally considered too small, inflexible, and unsuitable for ownership of IP of technologies developed (compared to what was being offered from ATI).
- Fourth, ATI funding enabled collaborations and made it easier to leverage knowledge and skills of partners. For example, there was one collaborative agreement rather than having multiple bilateral and trilateral agreements. Also, ATI enabled funding for universities beyond TRLs funded by Research Councils.

Figure 3-3: Why ATI funding was needed for projects



Source: Case studies

The evidence presented above suggests that ATI funding was needed to address one of the main market failures and barriers that prevent commercialisation of R&T, namely: high market and technical risk with the long time-paths to commercialising R&T in the aerospace resulting in low or uncertain "private" returns. Therefore, the timescales for a return on investment and the associated risks are often too great for companies to bear on their own. The risk also creates barriers in securing external finance to fund R&T activities. ATI funding essentially de-risks the process (market and technology).

Objectives of the projects

Whilst recognising that the specific objectives varied across projects, we classify these as relating to three main areas: product innovation, process innovation, and infrastructure (see Figure 3-4). In some cases, and particularly in larger projects, there was some overlap between the three. For instance, one capital project had dual objectives of improving the technical capabilities of its open-access testing facility whilst making internal processes more efficient (e.g. by reducing the changeover time for configurations in a stage of testing). Improvements in technologies and processes primarily related to an increase in efficiency and a reduction in cost, though improved safety and reliability were also cited in some cases.

Figure 3-4: Three key objectives of projects

Source: SQW

Project progress

Key activities undertaken

Across the 15 case studies, the activities undertaken by project leads and partners covered the full R&T life cycle. In most cases, the key areas of activity related to theoretical research (e.g. requirements specification and understanding the technology) or development (e.g. design and testing of software or hardware). In two of the Capital projects, new equipment was purchased and installed. Alongside the R&T activities, some consultees reported planning for commercialisation and exploitation of the new technologies, for instance working closely with the supply chain to understand applicability and demand. In several cases, project leads and partners engaged in dissemination activities following project completion, for instance through writing academic papers or presenting the findings (including through demonstrations).

The activities undertaken by partners complemented the work done by project lead, thus leveraging each other's expertise in particular areas: *"Each of the partners could address key areas from their perspective with an eye on how to pull the project together as an integrated whole." Generally, there was a high level of interaction between the lead and the partners – "never would a partner work in isolation."* Broadly, the connection between activities undertaken by the lead and the partners fell into two categories, namely:

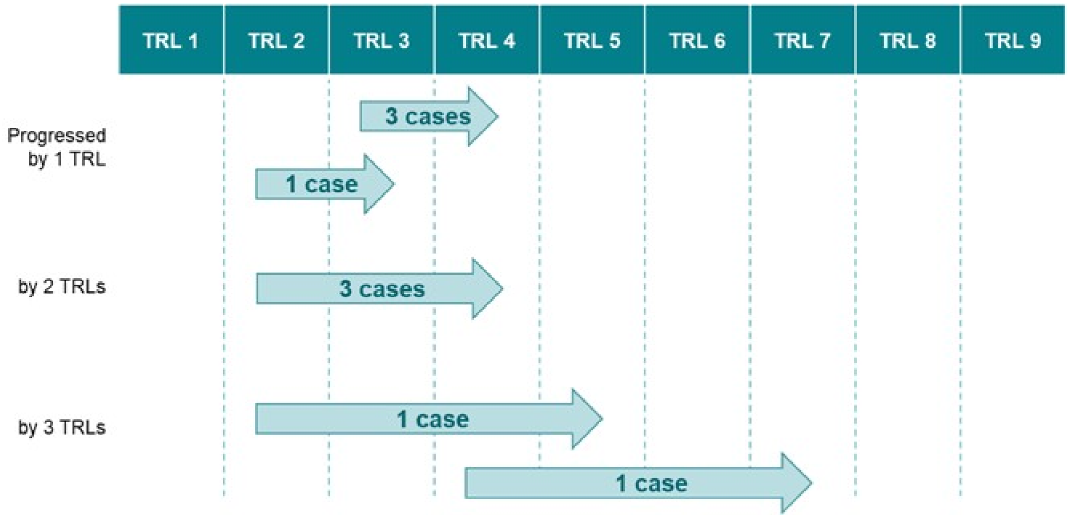
- partners building on the work done by project lead to *"validate and check that the fundamentals are correct"*

- partners working on activities that are separate but complementary to the work undertaken by project lead (e.g. lead working on functionality and partner looking at design features).

TRL progress

Figure 3-5 presents our analysis of the TRL progress[30] of case studies based on the monitoring data provided by BEIS (available for nine projects). This graphic shows how projects have progressed across the TRLs. For example, four projects had moved by one TRL level. Of these, three cases progressed from TRL 3 to 4, and in one case from TRL 2 to 3.

Figure 3-5: TRL progress of case study projects



Source: SQW based on ATI monitoring data

Alignment with expectations

Generally, project activities were delivered as expected. However, some delays were reported and, consequently, eight projects were granted extensions by ATI. There was a range of reasons for these slippages, including both internal and external factors. In some cases, the delays were not entirely unexpected, for instance technical difficulties are not surprising given the innovative nature of the work undertaken. The key reasons for delays were as follows:

- slow start to project – e.g. due to capacity constraints arising from commitments to other ongoing projects, or difficulties in coordinating the partners and helping the consortium to *"find its tempo"*
- technical difficulties associated with developing innovative technologies (e.g. design phase lasting longer than expected); in some cases this resulted in a change in focus and/or scope, for example some projects had:
  - increased the scope to develop additional technologies ("The Programme's flexibility allowed us to think bigger and get more value from the project")

[30] Where the project included multiple work packages, the average TRL progress has been recorded.

  - narrowed the scope to reflect what was technically feasible (“The scope of the project was far too broad to begin with… We were far too optimistic”)
  - modified work plan to integrate an existing, off-the-shelf technology and, in turn, reduce the scope
  - decided not to progress some technologies as a response to changing market conditions and demand
  - made improvements to reflect feedback received through dissemination activities
- other external factors – e.g. supplier-related contingencies.

Other similar projects that were not funded by ATI

In addition to the 15 ATI-funded projects considered as part of this evaluation, consultees identified some other projects that were considered at the same time and were similar in nature (see Table 3-3). All of these projects were taken forward through other means, either through internal funds or other public funding programmes (including EU funding). We do not have the data on whether or not these other similar projects initially sought ATI funding.

Compared with the ATI-funded projects, half of these other projects had progressed more slowly. This was considered to have been due to the additional time required to find alternative sources of funding, or the lack of pressure on meeting delivery targets when projects are funded internally. Three projects had progressed on a similar timescale to the ATI-funded project. No differences in quality were reported, though in one case the project was developed in response to a specific requirement from a client and was therefore less experimental than the ATI-funded project (with more *“customer pull”* throughout).

Table 3-3: Other R&T projects similar to ATI identified by case study project leads

Lead partner	Project	Description	Status: progress compared with ATI-funded project	Funding used
1	A*	Composites development	Progressed (slower)	
2	B	Manufacture of titanium using ‘fast’ technology	Progressed (slower)	Internal / Innovate UK grants / NATEP
	C	Reducing maintenance and optimising joint designs in landing gear	Progressed (slower)	Internal
3	D	Developing an active rotor blade for	Progressed (similar)	EU funding

Lead partner	Project	Description	Status: progress compared with ATI-funded project	Funding used
		performance improvement		
4	E	Not available	Progressed (similar)	EU funding
5	F	Developing a reconfigurable demonstrator for defence	Progressed (similar)	Catapult funding

*Source: SQW; *Project applied for ATI funding*

The above findings provide a ‘mixed’ picture of the additionality of ATI in terms of the reported speed and quality between other similar projects and the ATI-funded projects. The fact that none of the other projects progressed faster and three were slower compared to ATI-funded projects points to some speed additionality of ATI. However, three progressed at a similar rate compared to ATI-funded projects which potentially weakens the case for the additionality of ATI – albeit they had all received some other form of public or EU funding. These findings need to be interpreted in the context of the other evaluation evidence on additionality of ATI presented in section 5.

4. Assessment of early outputs and outcomes

Early outputs and outcomes

The evaluation found key outputs were achieved as a result of ATI funding to date: patents filed for products and services; IP developed; infrastructure created; R&T spend by aerospace industry (at TRLs 4-6); and development of new collaborations in terms of both business to business (B2B) and business to research collaborations (B2R). Furthermore, the activities and outputs of the ATI programme had led to short- and medium-term outcomes experienced by the case study project leads:

- 14 out of the 15 projects generated subsequent industry investments in R&T.
- All 15 projects progressed through, or part way through, TRLs 4-6 (in a minority of cases at lower levels).
- Influence of plans to base production in the UK (for 9 projects).
- Other outcomes such as upskilling, jobs in R&T and inward investment.

The above findings indicate that the key outputs and short-to medium term outcomes identified in the ATI programme logic model are being borne out in practice.

Development and use of R&T infrastructure

It was not possible to get a complete picture of the development and use of the R&T infrastructure of the ATI programme due to incomplete or unavailable data. Nevertheless, the case study evidence suggested that infrastructure has been improved and new infrastructure has been developed to assist with R&T. The stakeholder feedback suggested that this was typically within research facilities, building on existing capabilities and targeted at enabling the commercialisation of technologies (e.g. through HVM Catapult network). Usage was typically by businesses within aerospace and their supply chain, though there were also examples of use from other sectors such as offshore industries and automotive project leads.

Spillovers

The project leads identified that the most common types of spillovers (achieved and expected) were knowledge and market related. Knowledge spillovers related to creating value for other businesses and universities (e.g. in relation to technologies such as large robotics, and sectors e.g. naval and air traffic, defence). Market spillovers related to reduced costs (new technologies/products that are substantially cheaper for customers) and the environment (e.g. from reduced fuel consumption/ CO_2 emissions).

Spillovers occurred mainly amongst partners, suppliers, and customers, and to a lesser degree competitors; there were also spillovers to wider society especially environmental (e.g. reduced emissions). The spillovers mainly occurred or were expected to occur in: aerospace, automotive, marine, energy, electronics, defence, and space, construction, education. There was less evidence of knowledge spilling in to the aerospace sector; where this was the case it was from: nuclear (robotics technology); medical (endoscope technology) automotive and defence.

Outputs

The key outputs achieved by project leads as a result of ATI funding to date are presented in Table 4-1. The results indicate that most had filed patents for products and services; developed IP; created infrastructure; undertaken R&T spend (at TRLs 4-6); and developed new collaborations.

Table 4-1: Outputs achieved as a result of ATI funding

	Number of responses (project leads)
Patents filed for products and services	11
Development of intellectual property	11
Creation of R&T infrastructure	11
R&T spend (co-investment) by aerospace industry at TRLs 4-6	10
New collaborations (B2B and B2R)	9
Leveraged EU funds	0

Source: Case studies

The partner feedback is broadly consistent with the outputs identified by the project leads. Some examples are summarised below.

Examples of outputs (partners)

R&T Spend: *Second work package with company…and has follow on research application. Done three work packages with projects…this has led to further collaborations, some of which are through the ATI*

Patents filed: *Two patent applications, new collaborations (industry and research). All 100% attributable to the project, a great enabler"*

IP developed: *Using a suite of technologies [the Partner] identified c.15 patent ideas … it passed the patent opportunities onto project partners and sub-contractors. Six patents were registered*

New collaborations: *New business to research collaborations with the MTC, AMRC and Cranfield University*

Creation of R&T infrastructure: *Developed an industrial reconfigurable assembly demonstration. It is being used on other projects*

Research: *Published 4 or 5 research papers on the new technique developed in project – one has received national attention.*

We make two observations from the project lead and partner feedback: there were examples of organisations that shared IP opportunities with partners that could then progress these; and partners invested in R&T opportunities in collaboration with partners that they had worked with on the ATI project.

In addition to the feedback from consultations, we have reviewed the monitoring documentation provided by BEIS, Innovate UK and ATI[31]. We note that these data were incomplete and did not cover all 15 case studies.[32] This limited our ability to draw meaningful conclusions. Nevertheless, the outputs reported in the monitoring documentation were broadly consistent with the consultation evidence. For example, a key output reported in the monitoring data was R&T spend (co-investment) by industry: across the eight cases for which data is available, companies had collectively invested over £36m in match funding. There was also some evidence of development of intellectual property and creation of R&T infrastructure.

The main outputs stakeholders mentioned being aware of focussed around R&T spend or co-investment within the aerospace industry, new collaborations, the development of new R&T facilities and the development of intellectual property (IP). Stakeholders (6 out of 9 that commented on outputs) identified that the endorsement provided by the ATI investment enabled increased confidence in the value of projects, increasing investments in R&T at earlier TRL levels and the willingness to take risks.

Whilst there were outputs noted in relation to new business-to-business (B2B) and business-to-research collaborations (B2R), one stakeholder noted that the majority of collaborations were existing mature relationships. Another observed that infrastructure projects generated and strengthened collaborations between businesses and the research base. However, this was mainly for larger businesses as SMEs were perceived to be less willing to make use of academic facilities.

Overall, the evaluation evidence found that the ATI programme had done well in translating project activities into outputs as set out in the programme logic model and theory of change (see section 2). This was particularly the case for patents filed, IP developed, R&T spend (at TRLs 4-6), the creation of R&T infrastructure, and new collaborations.

We highlight one further point: there appears to be evidence of sharing of opportunities and exchange of knowledge and ideas between project partners suggesting the collaborative

[31] This covers close-out monitoring forms, project completion reports and exploitation plans.
[32] Economic monitoring has not been mandatory for existing projects until 2018.

relationships (B2B and B2R) formed and developed through ATI are starting to address some of the information and coordination failures associated with the commercialisation of R&T.

Outcomes

The evaluation focussed on the following three main outcomes achieved as a result of the ATI programme (these were also the subject of the QCA, see results in section 5). The evidence on each of these is set out in this sub-section. This is based on the feedback from case studies (project leads and partners), and supported by stakeholder interviews and the validation workshop.

- Has the project generated subsequent industry investment in R&T (at TRLs 7-9)?
- Has the project progressed through TRLs (4-6)?
- Has the project influenced plans to base production in the UK?

In addition, we present other short-medium term outcomes reported by project leads (aligned with the outcomes identified in the programme logic model in section 2).

It is important to highlight two points on the findings presented below: most of the case study projects were completed in December 2018 so there was a relatively short timeframe from when the projects ended to the time at which we were collecting evidence on outcomes (case studies were undertaken in the first half of 2019). Given the long time-paths to commercialising R&T in the aerospace sector (from 5+ years for upgrades to components to 15-20 years for next generation aircraft), the results should be treated as emerging. We would expect most of the outcomes and ultimately impacts to occur in the future. These will need to be evidenced in any future impact evaluation.

Subsequent industry investment in R&T

In almost all cases (14 out of 15), ATI-funded projects generated subsequent industry investments in R&T at TRLs 7-9 (two were at slightly lower TRLs). Importantly, all cases (15) reported that ATI "very much" generates greater certainty for UK R&D investments in aerospace. The majority (12) stated that there were other complementary (i.e. to the ATI-funded project) R&T activities taking place at the same time – emphasised in the role of other factors in contributing to outcomes (see section 5). All projects continued to be "very much" aligned with the priorities of their organisation, and all of the original projects were progressing technologically (as highlighted in section 3). In most cases, there was a "high" level of potential demand in the market for the technology relating to the project identified. (supported by project partner feedback).

In terms of how far the availability of ATI funding had led to – or encouraged – the initiation of new R&D projects, the objectives of the ATI-funded projects suggested that they were new and/or designed to improve technologies. The most common objectives were those identified in section 3 (see Figure 3-4) relating to: product innovation, process innovation, and infrastructure. Examples included: improving operational efficiency of an aircraft/manufacturing process (incl. size, weight, cost and speed of manufacture); developing and demonstrating a new technology; advancing a step change within a system/product/process.

Projects progressing through TRLs

In all cases (15), ATI progressed projects through TRLs (4-6, but also in a minority of cases at lower levels e.g. 1-3, 2-4, 3-6). In progressing technologies through TRLs, 6 of the projects faced "substantial" and a further 6 faced "some" technical impediments, including barriers to infrastructure (e.g. automation, "transition of materials", lack of technical experience of the firm). Only 2 projects faced "no" technical impediments. Interestingly, technical impediments were less of an issue for project partners.

Plans to base production in the UK

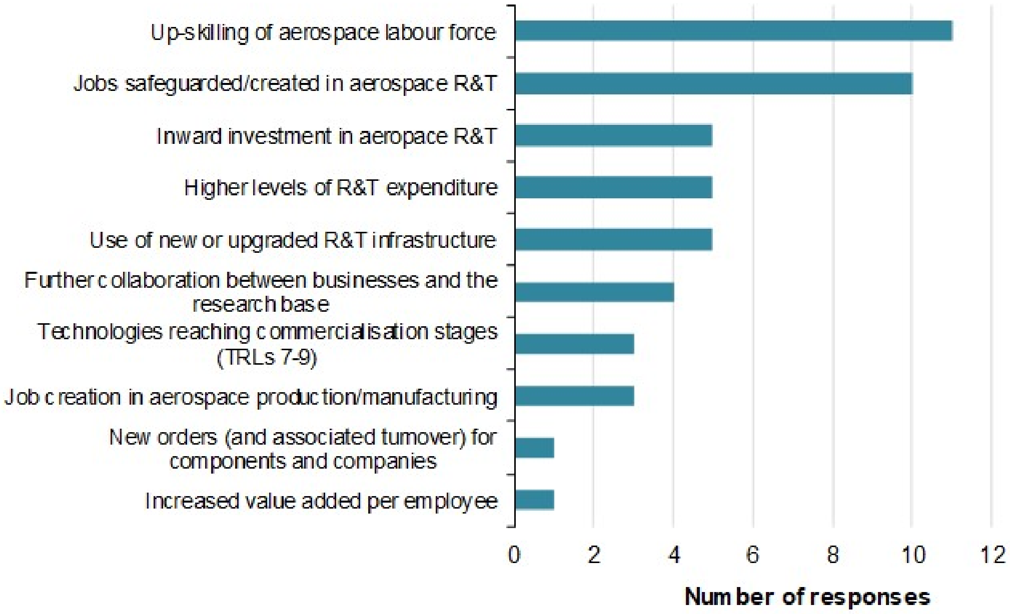
In most cases, the project or its outcomes influenced plans to base production in the UK. In 9 cases an exploitation plan or equivalent had been developed for the project that specifically planned for UK-based production (6 did not have a plan or equivalent for UK-based production). As indicated earlier, there was consensus that ATI was "very much" perceived to generate greater certainty for UK R&D investments in aerospace, which would also, in theory, support production in the UK.

In contrast, there were mixed views on the strength of the existing supply chains in the UK relevant to their product. Some project leads identified specific supply chains to be "quite strong" (e.g. in composites; fuel pipes), whilst others thought they were "quite weak" (e.g. in UK tooling; UK dry fibre). In contrast, partners were more positive about the strength of the supply chains, most considered suppliers to be "quite strong". It was also recognised that similar production did "not" already exist in the UK (10 cases; and two did not know). There were mixed responses on the extent to which an unfavourable Brexit may have adverse consequences for locating production in the UK – almost equal split between those reporting "large potential adverse consequences" and those stating "small" and "moderate" consequences.

Other outcomes

Figure 4-1 presents the other short to medium-term outcomes achieved by the case study project leads. The results suggest most of the outcomes related to (in order): upskilling of the labour force; jobs safeguarded/created in R&T; inward investment, higher levels of R&T spend; use of new upgraded R&T infrastructure; and further collaborations between businesses and the research base.

Figure 4-1: Outcomes achieved as a result of the ATI programme (project leads)



Source: Case studies

These outcomes are also supported by the partner feedback. Some examples are presented below.

Examples of outcomes (partners)

Project progressed through TRLs (4-6): *The project was at TRL4 originally. Partner did an assessment with the project lead at the end, it had reached TRL6, nearly 7. It is now fully deployed and in production.*

Project generated subsequent industry investments in R&T: *As a result of the learning developed through the project, Partner exported one technology (at demonstrator level) to a US customer for £12m.*

Project influenced plans to base production in the UK: *Project has helped to secure some work from operations in the Far East, particularly, retaining the inspection capability. This has led to job retention.*

Jobs safeguarded/ created: *Partner's R&D team has grown as a result of all the ATI funded projects, from c.12 to around 28.*

Our review of the BEIS economic monitoring data found that companies had achieved several key outcomes identified in consultation feedback. This included safeguarding or creating jobs in R&D (over 900 jobs safeguarded and 36 created across the eight cases where data were available), and training over 250 staff across all operations. There was also evidence of projects progressing through TRLs (in one case reaching commercialisation stages), job creation or safeguarding in aerospace production and manufacturing, increased value added per employee, and further collaboration between project leads and partners beyond project completion.

Many of the short- and medium-term outcomes targeted by the ATI programme were perceived by stakeholders to be expected or achieved. Specific outcomes commonly discussed included the progression of technology through TRLs 4-6, upskilled staff and safeguarded jobs. A few stakeholders (2 out of 9) noted that projects had led to the generation of new orders for firms, increased exports and GVA. Others (5 out of 9) focussed on how projects had helped to secure future capability within the UK through their investments in capability development and within the supply chain. In some cases, this had already begun to lead to the reshoring of jobs. However, it was widely recognised that outcomes were difficult to quantify, particularly in an early impact evaluation, due to industry timescales. Despite this, it was evident that the ATI had provided a clear voice of leadership for the entire sector.

Notwithstanding the uncertainties in the wider economic and political context, overall, stakeholders agreed that the ATI programme played, or had the potential to play, a significant role in influencing plans to base production in the UK. This was largely due to its ability to improve UK aerospace's overall position against its international competitors. One stakeholder discussed a prominent ATI-funded project that centred entirely around enabling increased UK production. The opening of the new Boeing factory in Sheffield in October 2018 and the development of a composite wing spoiler production line by Spirit were examples of such investments, which have led to increases in employment and skills.

The feedback from the workshop suggested the ATI programme had increased collaboration within the industry, particularly at the tier one level. Companies that were competitors had worked collaboratively for the first time through ATI funded projects and had continued to do so. This was thought to be linked to companies' increased ability to take risks within ATI projects. Many collaborations were between businesses as well as business and research centres. Furthermore, ATI's programmes had grown or retained the UK skills base.

Overall, the evaluation evidence found that the activities and outputs of the ATI programme (including the key drivers influencing the logic model set out in section 2) had led to short- and medium-term outcomes experienced by the case study project leads. These included: projects generating subsequent industry investments in R&T; projects progressing through TRLs 4-6 (in a minority of cases at lower levels); and projects or their outcomes influenced plans to base production in the UK (exploitation plan or equivalent had been developed for projects). In addition, other key outcomes were upskilling of the labour force; jobs safeguarded/created in R&T; and inward investment. The partner feedback generally supported the outcomes reported by project leads.

The above findings indicate that the key outputs and short-to medium term outcomes identified in the ATI programme logic model are being borne out in practice.

Development and use of R&T infrastructure

A key intended outcome of the ATI programme was the development and use of (new or upgraded) R&T infrastructure. Annex D (Table D-2) identifies the main investments in UK technology infrastructure made through the ATI programme. This amounts to investment of c. £150m across different types of facilities in industry, RTO/Catapult, and academia. The investments are spread across the UK.

It was not possible to get a comprehensive picture of the development and use of the R&T infrastructure of the ATI programme due to incomplete or unavailable data. We understand that currently Innovate UK does not collect information on usage as a regular reporting metric, and only ask for the accounts demonstrating economic and non-economic activity on the anniversary of the end date of the project for up to six years where Innovate UK have included this in the contract. This was only included for the newer projects. However, as part of evaluation of Industrial Strategy Challenge Fund (ISCF) programmes Innovate UK is collecting utilisation and other data as a standard.

Notwithstanding the above issues, the case study evidence indicated that infrastructure has been improved and new infrastructure was in the process of development in order to assist with the undertaking of R&T activities. This included, for example: Northern Ireland Technology Centre; Transonic wind tunnel; and Robot cell for use on production lines. It is difficult to determine whether the infrastructure is genuinely additional to the UK and the precise level of usage. However, the feedback from the Capital case study projects suggests high usage (e.g. Aircraft Research Association, transonic wind tunnel facility in Bedford) or expected high usage (e.g. Queen’s University Belfast, Supply Chain Manufacturing Centre).

The stakeholder feedback also suggested that significant infrastructure had been developed through the ATI programme. This was typically within research facilities, building on existing capabilities and targeted at enabling the commercialisation of technologies. Whilst some of the infrastructure developed was project specific or bespoke, there were examples with wider use and benefits. One stakeholder noted that infrastructure developed had simplified access to equipment, and in some cases was genuinely additional. Stakeholders highlighted examples of infrastructure developed, including: a design, manufacturing and engineering capability at Queens University Belfast, and several across the High Value Manufacturing Catapult centres. Usage was typically by businesses within aerospace and their supply chain, though there were also examples of use from other sectors such as offshore industries and automotive. A small minority (2 out of 11) of stakeholders commented that, in general, the scale of infrastructure investment required to enable the UK to compete with countries such as France, the USA and Germany had not yet been reached.

The validation workshop with stakeholders also gathered views on the infrastructure emerging from ATI funded projects. The workshop discussion highlighted the following:

- Much of the infrastructure emerging from these projects were driven by large programmes such as the Wing of Tomorrow/Ultrafan. Not investing in infrastructure to support other areas may represent a missed opportunity.

- There was appetite amongst firms to use ATI funding for capital projects. For example, through an ATI project, GKN set up a new manufacturing facility in Filton that comprised 30 engineers and 12 machines. This was a substantial investment for the firm.
- Many facilities funded through the ATI were used across sectors and most facilities funded through the ATI were perceived to be quite highly utilised (see above on Innovate UK data collection).
- Some gaps in infrastructure within the UK may become more evident in the future if the UK loses access to EU facilities.

Assessment of spillovers

A key rationale for the ATI programme is that it is expected to deliver spillover effects of technology advancements within the aerospace sector and into other sectors (e.g. manufacturing, automotive, artificial intelligence). The aerospace industry is highly R&T intensive and characterised by a high degree of interconnectedness between different actors (suppliers, collaborators, competitors). The premise is that innovative companies are likely to underinvest in high risk R&T because the private returns to the firm are generally much lower compared to the social return on investment[33] (social returns are typically two to three times the private return). ATI's own research (ATI, 2019)[34] on spillovers found that the social return to aerospace R&D investments was more than four times as large as the private return. A related issue is that spillovers are hard to identify, measure and quantify. This has implications for providing a complete and accurate picture on spillovers generated.

Taking account of the above, our approach to capturing the evidence on spillovers is detailed in Annex G and summarised below.

- Where spillovers were identified we collected evidence, to the extent possible, on a case-by-case basis on: the type of spillovers; how, where, and when they were expected to be realised; and any scale or quantification of the spillovers.
- We explored whether ATI projects contributed to developing conditions (sectoral and actor-based characteristics) that may have supported the generation of spillovers (i.e. influenced the likelihood of spillover effects occurring).
- We also identified whether there was any knowledge spilling into ATI-funded projects from other sectors, for example from automotive, manufacturing, defence.

The evidence on spillovers was gathered from the case studies, supported by the stakeholder interviews, the validation workshop, and our desk review. The findings are presented in the remainder of this sub-section. However, we first define the main types of spillovers commonly used in the literature: market, knowledge, and network (Table 4-2).[35] The table also provides examples of the mechanisms by which spillover occurs, illustrating the routes that spillover

[33] Research shows social return to investment is approximately two to three times the private return to R&D.
[34] ATI (2019) ATI INSIGHT: Economics of Aerospace: Technology Spillovers in Action.
[35] Jaffe, A.B. (1996) Economic Analysis of Research Spillovers Implications for the Advanced Technology Program, Brandeis University and National Bureau of Economic Research.

may take for aerospace R&T projects.[36] This has informed our analysis of the feedback on spillovers from the case studies.

Table 4-2: Spillovers – definition and mechanism

Type of spillover	Definition	Example mechanisms
Market	The workings of the market(s) for an innovative product or process create benefits for consumers and non-innovating firms. When a firm creates a new product, or reduces the cost of producing an existing product, market forces will tend to cause some of the benefits to be passed on to buyers.	Aerospace R&T can pass on benefits through cost reductions of technologies/products to customers, and generate benefits to society in terms of improved environment (reduction in carbon emissions).
Knowledge	Knowledge created by one firm that spills over into other firms, creating value for them and their customers (i.e. public good).	R&T projects are typically collaborative and may involve universities or research centre partners. These partners have incentives to disseminate the findings of research projects, e.g. publish academic papers or university education. Open-access facilities, such as Catapults, have members from a variety of industrial sectors, can create infrastructure or other know-how that can be used by other organisations, including in other sectors. R&T develops knowledge/skills which can be transferred through collaborative relationships, supply chains or simply through people moving on to new positions. This is particularly where there are non-competing applications of the technology.
Network	This occurs where there are interdependencies between certain technologies. The profitability of a set of interrelated and interdependent technologies may depend on achieving a critical mass of success.	Aerospace research makes available a kind of common "data" or "platform". Those not directly involved can access and utilise the data/platform for their own purposes, e.g. other

[36] Ibid 30.

Type of spillover	Definition	Example mechanisms
	As a result of these relationships, each firm pursuing one or more of these related technologies creates economic benefits for other firms and their customers.	businesses, researchers and government. Examples include open-access software and data analytics platforms.

Source: Jaffe et al (1996); ATI (2019); SQW

Types of spillovers…how, where, and when

The spillovers perceived by the case study project leads are summarised in Table G-2 (see Annex G). The table presents the types of spillovers perceived, how spillovers occurred (or were expected to occur), where they have been experienced (e.g. amongst partners, suppliers, competitors, customers, society), whether they have been achieved or expected to materialise in the future, and any evidence on scale or quantification of the spillovers.

It is important to highlight that case study evidence on spillovers was based on the bounded knowledge of our consultees. It may be that they are mistaken in their perceptions of spillovers or indeed are just not sighted on where spillovers have or are expected to occur. Notwithstanding this, we note the following from the case study responses:

- For 13 out of the 15 case study projects spillovers were perceived to have been achieved and/or were expected; in nearly all cases at least two examples of spillovers were identified.
- The most common types of spillovers by far were knowledge related (22 examples) followed by market (7 examples), with only a few examples of network effects.
- Similar numbers of projects reported spillovers had been achieved (14 examples) or expected (17 examples), or both (2 examples). This is as expected given the relatively short time that has elapsed since projects were completed.
- According to the recipients (project partners), knowledge spillovers have created value for other businesses and universities (e.g. in relation to technologies such as robotics, and sectors e.g. naval and air traffic, defence); recipient organisations expected to use the knowledge and apply this in different sectors.
- Market spillovers related to reduced costs (new technologies/products that are substantially cheaper for customers) and the environment (e.g. from reduced fuel consumption/ CO_2 emissions).
- Network spillovers were hardly identified perhaps because where there were interrelated and interdependent technologies (e.g. common data or platform) it was too early for those not directly involved to access and utilise these for their own purposes and report benefits.
- According to both project leads and partners, spillovers occurred mainly amongst partners, suppliers, and customers, and to a lesser degree competitors; there were also spillovers to wider society especially environmental (reduced emissions).

- Sectors where spillovers had occurred or were expected to occur included: aerospace, automotive, marine, rail, energy, electronics, defence, space, construction, education.
- Not surprisingly in nearly all cases consultees found it difficult to quantify the spillovers reported, although in a few cases an order of scale (mostly "small to medium").
- There was less evidence of knowledge spilling into projects; where this was the case it was from the following sectors and technologies: nuclear (robotics technology); medical (endoscope technology); automotive; defence; and manufacturing.

In addition, there was evidence of projects supporting conditions that may help to generate spillovers. The evidence of the effects on these conditions is, in some way, more reliable than the perceptions of spillovers reported above. Clearly here this does not necessarily mean that spillovers have occurred, but it does indicate that the change mechanisms have happened that could lead to spillovers. These supporting conditions were through:

- development or use of multi/general purpose technologies
- capacity and capability for R&T in the aerospace sector
- high levels of skills and transferability between firms and sectors
- people movements internally and externally, for example:
    - people moving to wind-turbine industry, and composites
    - high power electrical systems people move to automotive/ground vehicle systems
- there was one case where collaborations facilitated by the ATI lead to spillovers (between case study company and one of the Catapult centres).

Stakeholder feedback

Stakeholders noted that there were few tangible examples of spillovers at this point in the ATI programme. Nevertheless, consultees anticipated that the programme would help to develop knowledge and increase the scope for spillovers to occur. For example, many ATI-funded projects involved an element of knowledge sharing or skills development, leading to knowledge spillovers. Also, several projects developed infrastructure and capabilities that would be applicable in many businesses and sectors outside those participating in projects. In fact, it was noted that there were often crossovers between the technologies developed within the projects and other sectors. Enabling technologies, such as augmented reality, and technologies developed within the automotive sector particularly resulted in knowledge spill-ins.

Stakeholders agreed that the ATI programme had contributed to developing conditions that might support the generation of spillovers. These included: generating high levels of R&T; developing multi-purpose capabilities; kit and technology through infrastructure projects; people movements between industry and the research base; and geographical clustering, particularly around facilities or centres such as the Catapults. It was, however, noted that despite the closeness between aerospace and sectors such as automotive and energy, much of the technology developed within aerospace tended to be bespoke.

Finally, workshop feedback highlighted two points on spillover benefits. First, spillovers generated by companies from ATI-funded projects were generally not tracked. Second, corporate knowledge built up by ATI was thought to be a spillover benefit. This enabled the ATI to better support and guide companies and avoid duplicate investments by utilising knowledge built from previous programmes in to new ones.

5. Additionality and contribution

Additionality

We conclude medium-to-high outcome and project additionality for the ATI funding based on 15 projects. In 11 out of 15 projects, the outcomes and projects would not have occurred at all or would have done so outside the UK. For the other four projects, outcomes and projects would have occurred but at a slower rate and/or lower scale. Six other similar R&T projects that were considered at the same time as the ATI-funded project (and progressed through other funding) were discussed with project leads. Compared with the ATI-funded projects, half of these other projects had progressed more slowly, and the rest had progressed on a similar timescale to the ATI-funded project. This last observation tempers the overall view of additionality, suggesting that some activities may have happened anyway.

The feedback from partners and wider stakeholders generally supported the findings from the project leads. Most (16 out of 18) stakeholders agreed that without the ATI programme, the outputs and/or outcomes would either not have occurred at all, occurred outside the UK, or occurred at a slower rate and scale. The most common view held was speed and scale additionality, a slightly different perception compared to the case studies.

Contribution

The ATI programme has implemented activities as set out in the logic model and theory of change. These activities related to collaborative R&T and capital projects across different strategic themes and technologies (ATI value streams) with different time horizons (Secure, Exploit, Position), involving a range of partners including SMEs in the supply chain and the research base. The main drivers for the activities included: ATI providing ‘more’ R&T funding and ‘more certainty’ for investment decisions in the UK; and prioritisation of technology areas, resulting in the right projects being funded. The activities have translated into key outputs and outcomes as reported in section 4.

Whilst case study consultees identified other factors as contributing to the outcomes described (e.g. role of firm’s own commitment, other research projects, universities, innovation infrastructure), the role of ATI in achieving the outcomes relative to these other factors were described by project leads and partners as “important” and “critical”.

QCA

To support the above findings, the key results from our application of QCA to three key outcomes of interest were as follows:

- The absence of technical impediments was the factor most strongly related to progression through TRLs 4-6.

- The presence of complementary R&T activities along with the absence of alternative investment opportunities was associated with subsequent industry investment in R&T at TRLs 7-9.
- In 14 out of 15 cases, the certainty provided by ATI funding had an influence on firms' plans to base production in the UK.

Additionality

One of the key evaluation questions was to understand the additionality of the ATI programme: what would have happened to the outcomes and projects without ATI funding (i.e. what is the most likely 'counterfactual situation' without ATI). Table 5-1 presents the results on additionality for the 15 ATI-funded projects based on the feedback from project leads. **From this, we conclude medium-to-high outcome and project additionality for the ATI funding. In 11 out of 15 ATI-funded projects, the outcomes and projects would not have occurred at all or would but outside the UK (which also included some speed and/or scale additionality). For the other four projects, there was evidence of speed and scale additionality i.e. outcomes and projects would have occurred but a slower rate and lower scale.**

Table 5-1: What would have happened to outcomes and to the project without ATI funding?

	Outcomes (no. of responses)	Project (no. of responses)
Would not have occurred at all	7	5
Would have occurred but a slower rate	2	3
Would have occurred at a lower scale	1	1
Would have occurred but a slower rate + lower scale	1	0
Would have occurred but not the same quality	0	0
Would have occurred but outside of the UK (plus some scale and/or speed)	4	6
Would have occurred anyway	0	0

Source: SQW case studies; Note: responses are for project leads

In addition, there were six other similar (in size and/or TRL) R&T projects that were considered at the same time as the ATI-funded project (see Table 3-3). All of these projects were progressed through other means, using internal funds or other public funding programmes.

Compared with the ATI-funded projects, half of these other projects had progressed more slowly, and the rest had progressed on a similar timescale to the ATI-funded project.

It is also worth noting that the feedback from partners generally supported the above findings from the project leads, and stakeholders more widely.

Most (16 out of 18) stakeholders agreed that without the ATI programme, the outputs and/or outcomes would not have occurred at all, occurred outside the UK, or occurred at a slower rate and scale. Of these, the most common view held was the last of the three, i.e. speed and scale additionality (though the differences between the numbers of stakeholders holding each view was relatively small). This is different to the case study evidence where 11 out of 15 projects were stated as not happening at all or outside the UK versus four at a slower speed/scale – though the differences here are only slight.

One stakeholder mentioned that without the ATI programme, businesses would have been more risk averse and likely to wait for technology to develop before investing in it. Whereas it was perceived that many collaborations would likely to have occurred due to existing relationships within the industry, another noted that the development of infrastructure through the programmes motivated new relationships. Stakeholders who thought projects would have taken place outside the UK without the ATI programme pointed to similar incentives available in other countries.

Role of ATI and other factors in delivering outcomes

Whilst case study consultees identified other factors contributing to the outcomes described (e.g. role of firm's own commitment, other research projects, universities, wider innovation infrastructure), **the role of ATI in achieving the outcomes relative to these other factors were described by project leads and partners as "important" and "critical".**

Table 5-2: Other factors outside of ATI that have contributed to outcomes

Factors	Number of case studies
Firm's own commitment	11
Other research projects	7
Universities/ academics	6
Innovation infrastructure	5
Existing expertise	4
Supply chains	4
Other financial support	2

Source: SQW case studies

The stakeholder feedback also identified factors other than the ATI programme that were widely recognised as having contributed to achieving outputs and outcomes including:

- the availability of skills and labour, including technical capabilities
- alternative sources of funding support including from the EU
- existing supply chains; and relationships within the aerospace industry.

One stakeholder noted that industry drivers and trends had also contributed, reflecting that companies were responding to these in the technologies being taken forward. The capabilities of the High Value Manufacturing Catapult were mentioned as significant in enabling outcomes to be achieved. Relative to these factors, most stakeholders agreed that the ATI programme was an important contributory factor amongst others. Three stakeholders believed the ATI programme to be the critical contributory factor in achieving outputs and/or outcomes. Another believed the ATI programme was important alongside other factors in the short term but would show itself to be crucial in the medium-term. This is due to its role in 'future-proofing' the industry.

To support the contribution analysis, we present the key results from our application of QCA – drawing on data from the case study interviews – to three specific outcomes identified in section 2.

Qualitative Comparative Analysis (QCA)

QCA[37] is a theory-driven approach that combines qualitative and quantitative methods to establish causation when comparing across a number of cases. It is an iterative process which can add robustness to the analysis and create more coherent results in a similar way to sensitivity analysis and Monte Carlo modelling in economic impact assessments.

It is important to note that given the limited application of QCA in innovation policy its use in this evaluation was an experimental approach. QCA was considered potentially useful for the evaluation because:

- it provides a systematic way to assess the series of hypotheses, assumptions and alternative explanations as to how outcomes have been brought about
- it allows this even with small sample sizes (e.g. n values of 5-50; this evaluation uses QCA for 15 case studies)
- it allows for complex causation involving different combinations of causal conditions that generate the same outcome.[38]

QCA allows relationships between conditions and outcomes to be established, using logical statements of necessity and sufficiency:

- For a condition to be necessary, the outcome only ever occurs when the condition is present (but the condition can be present without the outcome).

[37] Ragin, C.C., (1987) *The comparative method: Moving beyond qualitative and quantitative strategies*. Los Angeles: University of California Press.
[38] Ragin, C.C., (2008) *What is Qualitative Comparative Analysis.* University of Arizona.

- For a condition to be sufficient, whenever the condition is present so too must be the outcome (but the outcome can occur without the condition).

A detailed methodology for the application of QCA to the 15 case studies is presented in Annex F.[39] The remainder of this sub-section discusses the results of the analysis for the three key outcomes of interest:

- Project progress through TRLs (4-6)
- Project generation of subsequent industry investment in R&T (at TRLs 7-9)
- Project influence of plans to base production in the UK.

It is important to re-iterate that the QCA results presented below are based on the 15 case studies, the unit of analysis. These results indicate the influence of ATI funding within these cases. The results do not generalise for all the projects in the wider ATI portfolio.

Projects progressing through TRLs

The absence of technical impediments was the factor most strongly related to progression through TRLs 4-6. Effectively, if there were no technical impediments, the project progressed through the TRLs. However, two factors – satisfaction with the consortium's expertise, and alignment with the organisation's priorities – had to be discarded from the analysis because of inappropriate data as explained below.

All lead partners were "very satisfied" with the expertise of the consortium, creating a 'limited diversity'[40] of responses. As there were no cases where lead partners were less than "very satisfied", there was no evidence to test the implications of an unsatisfactory consortium *within QCA,* although in reality consortium expertise may by (very) important. Put another way, consortium expertise may be relevant to progression through the TRLs, but QCA alone could not tell us this.

It is also noted that whilst QCA has confidently identified the condition that will lead to progression through the TRLs, this condition is only part of the story. In technical terms, **the solution is adequately sufficient but far from necessary.** In practical terms, not having technical impediments gives a good likelihood of progression through TRLs 4-6. But where there are technical impediments, other factors can compensate for this and allow the project to progress anyway.

[39] The methodology follows Kahwati, L.C. and Kane, H.L. (2019) *Qualitative Comparative Analysis in Mixed Methods Research and Evaluation.* Los Angeles: Sage Publications

[40] This refers to a description of condition that has little-to-no variation. This makes the condition hard to analyse because there are few observations of the differences associated with that condition. For example, using the variable of age when looking at undergraduate students could lead to limited diversity as most students are in the 18-25 bracket.

Table 5-3: Summary of results relating to each condition variable

Outcome variable	Condition variable	Result
Q1: Has the project progressed through TRLs (4-6)?	Q1a: Are there other complementary R&T activities taking place at the same time?	Presence correlates weakly with outcome
	Q1b: To what extent did the project face technical impediments, including barriers to infrastructure?	**Sufficient for the outcome**
	Q1c: How satisfied are you that the collaboration had the right expertise to take the project forward?	Limited diversity; assume a *trivial necessity*[41]
	Q1d: To what extent does the project continue to be aligned with the priorities of your organisation?	Limited diversity; assume a trivial necessity

Source: SQW analysis

Subsequent industry investment in R&T at TRLs 7-9

The presence of other complementary R&T activities (taking place at the same time) together with the absence of alternative investment opportunities not relating to the ATI-funded project was strongly related to subsequent industry investment in R&T at TRLs 7-9. Iterative analysis showed that the presence of complementary R&T is slightly more influential than the absence of alternatives. The implication here is that if the firm has a portfolio of research related to the technology, but few other avenues to take, then the original technology will be taken forward and invested in.

Again however, three factors had to be excluded from the analysis: the extent to which ATI generates greater certainty for UK R&T investments, technological progress of the original project, and market demand for the technology. Due to their limited diversity these factors were untested within QCA. Also similar to Q1, the findings of Q2 were adequately sufficient but they did not achieve necessity, meaning that whilst the main factor was complementary R&T, there were other factors which could influence the outcome.

[41] Within QCA, a trivial necessity refers to a condition which might be necessary for the outcome but is rarely/never not present so it unhelpful as an indicator, e.g. having a driving licence is a trivial necessity to become a Formula 1 driver.

Table 5-4: Summary of results relating to each condition variable

Outcome variable	Condition variable	Result
Q2: Has the project generated subsequent industry investments in R&T (at TRLs 7-9)?	Q2a: To what extent does ATI generate greater certainty for UK R&D investments in aerospace?	Limited diversity; no conclusions
	Q2b: Are there other complementary R&T activities taking place at the same time?	**Presence of this and absence of Q2f is sufficient for the outcome**
	Q2c: To what extent does the project continue to be aligned with the priorities of your organisation?	Presence correlates weakly with outcome
	Q2d: Did the original project progress technologically?	Limited diversity; assume a trivial necessity
	Q2e: What is the level of potential demand in the market for the technology relating to the project?	Limited diversity; no conclusions
	Q2f: To what extent are there alternative investment opportunities not relating to the project that your organisation has also considered?	**Absence of this and presence of Q2b is sufficient for the outcome**

Source: SQW analysis

R&T leads to plans to base production in the UK

For the third question, 14 out of 15 case study projects indicated that **the certainty provided by ATI funding had an influence on their plans to base production in the UK.** However, this limited diversity meant the contributory factors could not be analysed within QCA. Therefore, to allow further QCA analysis, Q3a (presence of an exploitation plan) was chosen as the outcome variable rather than Q3. The strongest relationship was with similar production in the UK – wherever there was similar production there was also an exploitation plan. However, as similar production was only found in one case there is a low level of certainty to this finding.

Table 5-5: Summary of results relating to each condition variable

Outcome variable	Condition variable	Result
Q3a: Has an exploitation plan or equivalent been developed for the project that specifically plans for UK-based production?	Q3b: To what extent is ATI perceived to generate greater certainty for UK R&D investments in aerospace?	Presence correlates weakly with outcome
	Q3c: To what extent are you confident that sales will be generated?	Presence correlates weakly with outcome
	Q3d: How would you describe the strength of existing supply chains in the UK relevant to the product?	Absence correlates weakly with outcome
	Q3e: Does similar production already exist in the UK?	Presence correlates strongly with outcome
	Q3f: To what extent may Brexit have adverse consequences for locating production in the UK?	Absence correlates weakly with outcome

Source: SQW analysis; the result is comprised of all five combined conditions in the table

Conclusions of QCA

A.1 For Q1, the absence of technical impediments was most strongly related to progression through TRLs 4-6. Effectively, if there were no technical impediments, the project progressed.

A.2 For Q2, the presence of complementary R&T activities along with the absence of alternative investment opportunities was associated with industry investment in R&T at TRLs 7-9.

A.3 For Q3, the firmest conclusion to draw is that certainty provided by ATI funding had an influence on firms' plans to base production in the UK (in 14 out of 15 cases).

Note on the use of QCA

The SQW Methodology Paper[42] noted that the study will allow us to see if QCA *"is appropriate (and meaningful) in addressing the evaluation objectives."* The application of QCA generated meaningful conclusions, although the method was not always applicable to some of the conditions in the analysis. The following points are noted on the use of QCA in the evaluation:

[42] SQW (2019) ATI Early Impact Evaluation – Methodology Paper. This paper was developed in the first phase of the study. Awaiting publication.

- QCA enabled a rigorous and systematic review for each question, increasing the firmness of the conclusions.
- For two of the three questions a clear solution was identified which met the *sufficiency* threshold. However, none of the solutions met the necessity threshold, i.e. there were cases of the outcome being present with a different configuration of conditions than that identified as sufficient through QCA.
- For the third question, QCA was inconclusive. Using a stricter outcome condition could have engendered greater diversity and led to more informative results.
- The systematic data-gathering demonstrated that many conditions had a lack of diversity. These conditions could not be analysed in-depth through QCA, so their relationship to the outcome remains untested.
  - A larger sample size could confirm if these conditions are trivial (always present/absent), which would mean they aren't helpful indicators of the outcome variable.
  - Alternatively, a different selection of case studies could have found greater diversity, thus allowing the conditions to be tested and conclusions to be drawn about their relevance.
- Finally, we have been able to look at the conditions supporting outcomes for ATI-funded projects – so it provides lessons within the portfolio of projects. It does not tell us about causality of ATI funding itself because of the absence of non-ATI projects in the dataset.

Assessment of contribution

This section assesses the contribution of the ATI programme by examining whether:[43]

- activities were implemented as set out in the logic model/theory of change
- there was evidence that the expected outputs and outcomes occurred
- the ATI programme, rather than other factors made the difference.

The assessment is based on the triangulation and analysis of the evidence from the case studies, stakeholder interviews, validation workshop, and our review of documentation and monitoring data. The findings of the contribution analysis are presented in the table below.

[43] Based on Mayne, J. (2008) Contribution Analysis: An Approach to Exploring Cause and Effect, ILAC Brief 16.

1: Is there a reasoned theory of change, and have activities been implemented as set out in the theory of change?
Overview of findings The underlying theory of change and logic model (including the seven key drivers and external factors influencing the logic model) for the ATI programme highlight the complexity in activities and the different routes to effects. This is reflective of the nature and scale of ATI. A reasoned theory of change is evident, and that the ATI programme has delivered activities as expected against this depiction (see section 2, and Annex E). **Key points of evidence** The case study and stakeholder evidence found that activities aligned with the strategic and economic rationale for the programme: to maintain a 'level' playing field' against the UK's international competitors; need for greater certainty for investment decisions; prioritisation and focus on the right projects to meet future industry demand; more/stronger collaborations – business to business (B2B) and business to collaborative research (B2R); and R&T that leads to 'stickiness' and production jobs being located in the UK. The activities were appropriate and relevant in addressing market failures and barriers preventing investment and collaboration across the business and research bases for commercialisation of R&T, in particular: information and coordination failures; and high market and technical risk. The case studies (and monitoring data) identified a fit between the activities delivered and those intended: collaborative R&T and capital projects were undertaken across different strategic themes and technologies (ATI value streams); they were also delivered with different time horizons in mind, in particular the short- and medium-term Secure and Exploit horizons; and they involved a range of partners including SMEs in the supply chain and the research base. In addition, 'enabling activities' were undertaken, for example: planning for commercialisation and exploitation of new technologies; dissemination activities following project completion; and facilitation of collaborations (mainly by project leads and partners). The strategic direction provided by the aerospace industry (which included ATI, and also the Tier 1s themselves that had fed into ATI strategic direction) had informed projects. In addition, the projects were developed following company/research organisation priorities and also as follow-on projects to previous R&T activities. The case studies found activities relating to match-making/facilitation undertaken by project leads and partners and less so from ATI. This may reflect that the case studies were earlier projects in the programme's life. The role of ATI in signposting and connecting organisations to stimulate new collaborations (directly and indirectly) was identified in a small number of cases, and stakeholders commented that the ATI's role had grown over time.
2: Is there evidence that the expected results have occurred?
Overview of findings The activities have translated into key outputs, and short- and medium-term outcomes. These include: subsequent industry investments in R&T; progression through TRLs; projects or their outcomes influencing plans to base production in the UK; safeguarding/creation of jobs in R&T; and the development/upgrading of infrastructure. There is also limited evidence of some long-term outcomes, specifically knowledge and market spillovers (and for projects contributing to developing

conditions that may support the generation of spillovers). This addresses a key rationale for the ATI programme.

Overall, the nature and strength of the project collaborations (including having the expertise to avoid or overcome technical impediments), and the role of ATI funding in providing the long-term certainty for investment have played key roles in achieving results.

The above findings are encouraging given the short time elapsed since projects were completed (most end of December 2018) and the long timescale associated with the time-paths to commercialising R&T in the aerospace sector.

Key points of evidence

The activities have translated into key outputs: patents filed for products and services; IP developed; infrastructure created; R&T spend by aerospace industry (at TRLs 4-6); and development of new collaborations business to business (B2B) and business to collaborative research (B2R). These activities and outputs have led to short- and medium-term outcomes: 14 out of the 15 projects generated subsequent industry investments in R&T; all projects progressed through technology readiness within the range of TRLs 4-6 (in a minority of cases at lower levels); and in most cases projects or their outcomes influenced plans to base production in the UK. Other key outcomes included upskilling of the labour force; jobs safeguarded/ created in R&T; and inward investment; development and use of new or upgraded infrastructure.

The case study evidence found consensus amongst project leads and partners that their collaborative relationships were either “very strong” or “strong” by the end time of project completion. Generally, the same applied to the relationship between partners (B2B and B2R). The expertise within collaborations has been important in leading to technological progress, which was also backed up by the QCA in relation to the importance of the absence of technical impediments.

There was incomplete or unavailable data on the development and use of the R&T infrastructure of the ATI programme. Nevertheless, the case study evidence suggested that infrastructure has been improved and new infrastructure developed to assist with R&T. The stakeholder feedback suggested that this was typically within research facilities, building on existing capabilities and targeted at enabling the commercialisation of technologies (e.g. through HVM Catapult network). Usage was typically by businesses within aerospace and their supply chain.

The case study consultees perceived long term spillovers (knowledge and market): 13 out of the 15 case study projects identified spillovers. These occurred mainly amongst partners, suppliers, and customers. There were also spillovers to wider society especially environmental (e.g. reduced emissions). The spillovers occurred or were expected to occur in: aerospace, automotive, marine, energy, electronics, defence, construction. There was less evidence of knowledge spilling in to the aerospace sector from non-aerospace sectors.

3: Was it the ATI-funding, rather than other influencing factors that made the difference, or the decisive difference?

Overview of findings

There is medium-to-high outcome and project additionality for the ATI funding. There are other factors contributing to the outcomes described (e.g. role of firm’s own commitment, other research projects, universities, wider innovation infrastructure). However, the evidence found that the role of ATI in achieving the outcomes relative to these other factors is “important” and “critical”. It does this by complementing other factors, rather than as the only decisive factor. The QCA also highlighted the role of ATI funding in providing certainty as being important in influencing plans for production in the UK.

Key points of evidence

In 11 out of 15 ATI-funded projects, the outcomes and projects would not have occurred at all or would but outside the UK (which also included some speed and/or scale additionality). For the other four projects, there was evidence of speed and scale additionality i.e. outcomes and projects would have occurred but at a slower rate and lower scale.

The feedback from partners generally supported the above findings from the project leads, and stakeholders more widely. Most (16 out of 18) stakeholders agreed that without the ATI programme, the outputs and/or outcomes would not have occurred at all, occurred outside the UK, or occurred at a slower rate and scale.

The case studies identified other factors outside of ATI that contributed to outcomes: firm's own commitment (11); other research projects (7); universities/ academics (6); innovation infrastructure (5); existing expertise (4); supply chains (4). Likewise, stakeholders identified other factors the availability of skills and labour, including technical capabilities; alternative sources of funding support including from the EU; and existing supply chains; and relationships within the aerospace industry.

The case study evidence found six other similar R&T projects that were considered at the same time as the ATI-funded project. Compared with the ATI-funded projects, half of these other projects had progressed more slowly, and the rest had progressed on a similar timescale to the ATI-funded project. The were no reported differences in the quality of projects between the ATI-funded projects and the other similar projects.

In summary, the QCA results are based on the 15 case studies and indicate the influence of ATI funding in these cases. The results do not generalise for all of the projects in the wider ATI portfolio. Also, the case studies are based on self-reported feedback, so there is perhaps some positive response bias. Notwithstanding these issues, the evaluation found the ATI programme has made a medium-to-high contribution to the actual and expected outputs and (short- and medium-term) outcomes. First, the nature and scale of the effects vary with most expected to be realised in the future, driven largely by the long time-paths to commercialisation in the aerospace sector. Second, ATI is one of a number of factors – internal to ATI and external – influencing the achievement (or expected) of outcomes. The underlying theory of change is happening as intended.

6. Emerging technological and policy developments

Technological and policy developments

The key technology and industry developments identified by stakeholders through the bilateral interviews and validation workshop were: electrification, additive manufacturing, composites, Industry 4.0, urban air mobility, and software and cyber security. These reflect key changes in demand within the aerospace market, or innovations within the materials and manufacturing processes used within the industry. Such developments highlight the requirement for longer-term funding to encourage forward-looking research programmes, potentially increasing the demand for the ATI programme. Key policy developments included the following:

- The increased alignment between the ATI and the Catapult network is expected to complement the ATI programme by increasing integration between firms and the Catapult centres.
- The ISCF and Aerospace Sector Deal are also expected to complement the ATI programme, supporting several cross-cutting R&T opportunities.
- Industry uncertainties within particular UK regions (e.g. Northern Ireland) and developments within overseas competitor countries highlight the increasing need for ATI to enable the UK to remain competitive.
- The role of the Department for International Trade (DIT) in supporting overseas opportunities had developed significantly, though it was recognised that more could be done.
- The overall impact of the expected departure from the EU was unknown, and this has generated significant uncertainty and risk. Views of stakeholders varied, though the scope for ATI funding and the ATI to have the potential to mitigate some of the risk was noted.

Likely implications for ATI

- The likely implications of these developments on ATI include the following:
- The ATI programme portfolio will need to continue to reflect technological and policy developments.
- The cross-cutting nature of the technological developments, rather than each development individually, is likely to impact the nature and direction of ATI projects.

Given the cross-cutting nature of the tech developments, future spillover effects may be more critical.

The evaluation sought to understand emerging technological and policy developments and how these were likely to affect the success of ATI. Informed by the stakeholder consultations (including attendees at the validation workshop), case studies, and our desk-based research, we discuss the main developments and their potential effects on ATI below.

Technological and wider sectoral developments

Stakeholders commented on the dynamic nature of the aerospace sector. Several industry and technology trends were highlighted, including the trends towards electrification, additive manufacturing, composites, Industry 4.0, urban air mobility, and software and cyber security. These developments, and their potential effect on ATI, are discussed in Table 6-1. For example, the increased prevalence of composites will change the materials and manufacturing processes used within the industry. The potential benefits of such changes, in terms of improvements to efficiency through e.g. lightweighting, are likely to inspire research programmes into how businesses within the market could harness them. Similarly, developments in Industry 4.0 are likely to overhaul manufacturing processes, creating significant opportunities for efficiency and productivity gains. The shifts towards electrification and urban air mobility reflect changes in demand within the market. The ATI programme portfolio will in future need to reflect these developments. Evidence from case studies suggests that this is already beginning to happen to some extent. One consultee cited their company's electrification agenda as a reason why their project was developed. Others also stated that business targets to make improvements to productivity and manufacturing processes through use of automation and composites motivated their research.

Overall, these developments are likely to increase the necessity for ATI support and its potential influence going forward. These developments identify the need for longer-term funding programmes to be able to support long-term changes within technology, such as urban air mobility. In fact, the ATI Insight paper (2017)[44] highlighted the long-term nature of the industry, noting that product development typically occurs in five to ten-year processes. The complementarity between technology developments, the role of the ATI and the Industrial Strategy Challenge Fund (ISCF) may also increase the impact of the programme.

Table 6-1: Technological trends within the aerospace landscape since 2013 and their implications for the ATI programme

Technology area	Developments and likely implications for ATI
Electrification –	• If the ATI continue to fund projects within this space, it could support the UK, which is already engaging with the transition to dual-core technologies faster than its competitors, in becoming a global leader and increase its market share. It is

[44] ATI (2017) Insight: The Economic Impact of UK Aerospace Industrial Strategy.

Technology area	Developments and likely implications for ATI
the shift towards a more electric aircraft, including hybrids. This includes developments in dual-core technology, electric propulsion and more electric systems and components.	clear from the ATI's 2016 strategy that electrification has been targeted by the ATI as a priority area for further research. It features within several of its integration initiatives and strategic technology themes, including propulsion of the future, smart, connected and more electric aircraft and future propulsion concepts. It also links to its stated focus on developing more environmentally advanced commercial aircrafts. • The shift towards developing more electric aircrafts has opened the sector to potential collaborations with new businesses and adjacent sectors through work conducted in electricity generation and battery power, potentially increasing spillover effects from funded projects. • Increased focus on electrification has reportedly increased competition for funding, resulting in an increase in the involvement of SMEs and spinouts, that are more specialised in electrification, in R&D programmes. • There may be complementarities with ISCF programmes relating to electrification, such as the Faraday battery challenge programme, which can inform some ATI projects.
Additive Manufacturing	• Stakeholders noted that there have been significant investments in additive technologies, which are relevant to the ATI funding programme. As these improve research supported by ATI, it will likely focus more on harnessing their benefits in terms of functional design of mechanical components, reductions in waste or for use in the repair of components, for example. Additive manufacturing has been identified as a 'cross-cutting' area of focus within the ATI's strategy.
Composites	• The use of components is likely to affect maintenance, repair and operations (MRO) within the aerospace industry. • Trends towards lightweighting within aerospace and adjacent sectors are likely to highlight requirements for use of composite materials within the industry. For example, the ATI predict that in the future business jets and rotorcraft will make greater use of lightweight materials such as composites. • The ATI strategy identified the development of a lightweight composite fan system as technology required to develop future large ultra-high bypass ratio (UHBR) turbofans; this is one of its major integration initiatives.

Technology area	Developments and likely implications for ATI
	• One of the ATI's aims is to strengthen the UK's position as a centre of large composite structures, as part of its 'aerostructures of the future' technology theme.
Urban air mobility – including developing air vehicles for short distances.	• This long-term industry trend is noted as being the future of transport in the second half of this century as populations and cities grow. • Development in this area will require research around developing aircrafts that emit lower levels of pollution (including noise pollution) and transport smaller numbers of passengers.
Industry 4.0 – the digitisation of industry, enabling increases in productivity. This includes the use of robots, automation and 'digital twins' within manufacturing processes.	• Industry 4.0 developments are driven by requirements to improve productivity and therefore UK competitiveness. Digitisation and automation has the capacity to reduce manufacturing costs and increase production rates for new aircrafts, leading to requirements for shifts in skills mixes as well. • The ATI predicts that digitally-enabled manufacturing technologies and supply chains will significantly change the requirements for manufacturing complex products. • Raising levels of automation in manufacturing and assembly was noted as a target within the ATI strategy's key strategic technology themes, implying that ATI projects will continue to focus on these themes. • Digital technologies are transforming maintenance, repair, overhaul and logistics (MROL) within the sector. In particular, using these technologies integrated vehicle health management is enabling a transition to service-based business models.
Software and cyber security	• The ATI identified secure digital systems as integral to the development of a smart, connected, more electric aircraft, one of its key strategic technology themes. This implies research within this area will be prioritised going forward. • Enabling the secure capture, management and analysis of big data will affect the industry's ability to generate value across product lifecycles.

Source: SQW; ATI Strategy (2016)

Stakeholders noted the absence of new aircraft programme launches as a relevant indicator for sector-level developments. For example, some key primes have not launched any all new large commercial aircraft programmes for some time, and instead have focused on developing variants of existing platforms.

During the validation workshop, stakeholders also commented on the current status of UK supply chains, noting their weaknesses in particular areas. Such weaknesses were believed to be largely related to the fast pace of technological advance within the industry. Stakeholders agreed that the ATI was a good platform through which to instigate an overall improvement in the UK's competitive supply chain. However, since supply chain organisations often work across sectors, it was acknowledged that support to such firms should not be provided by the ATI alone.

Policy and regulatory developments

The evaluation evidence also identified relevant policy and regulatory developments. The alignment between the ATI and the Catapult network was noted and was cited by case study consultees as having contributed to the success of their ATI projects. The ATI states within its strategy that it is extensively leveraging the HVM Catapult centres, for example, in order to support the development of technologies and capabilities that drive increases in productivity and reductions in manufacturing costs.[45] This is likely to complement the ATI programme, potentially enhancing its success through increased integration between firms and the Catapult centres. The Industrial Strategy Challenge Fund (ISCF)[46] and the Aerospace Sector Deal (2018)[47] were also expected to complement the ATI programme by supporting and funding several cross-cutting R&T opportunities, driving sector performance, a more stable business environment and business confidence.[48]

Overall, stakeholder feedback highlighted that, to ensure a level playing field for the UK compared to its overseas competitors, programmes such as ATI are required. This links to the rationale for the ATI programme as set out in Section 2 of this report. Political and economic developments overseas, for example in the USA, highlight the necessity and potential impact of ATI support further.

Furthermore, the aerospace sector, and the activities that are associated with it, are dependent on corporate decision-making that may be take place overseas, for example in the case of Bombardier in Northern Ireland, which has overseas ownership. The long-term certainty of ATI can seek to mitigate such risks. In this context, some stakeholders highlighted the importance of the regional impacts of firms, and so the need for national funding programmes such as ATI to support a place-based agenda.

The workshop stakeholders discussed how more could be done to engage satellite organisations from countries such as the USA, that come to the UK to service equipment present here, to establish themselves within the UK. The DIT are involved in supporting such firms and that its role in promoting trade and investment had significantly improved resulting in

[45] Ibid 6
[46] https://www.ukri.org/innovation/industrial-strategy-challenge-fund/
[47] https://www.gov.uk/government/publications/aerospace-sector-deal
[48] Ibid 40

increased overseas opportunities and closer co-ordination between trade and aerospace. However, it was suggested that it could work more with the ATI and Innovate UK in doing so.

Overall, the impact of the expected departure from the EU was largely unknown. The evidence highlighted, however, that it had caused greater uncertainty, for example around the future of funding sources, potential changes to partnerships within the industry including with primes based in the EU, and potential tariffs. This has impacted businesses by increasing the levels of risk around sales, production and scope for involvement in significant R&T programmes such as Clean Sky 2. Stakeholders noted that to date these impacts have been felt more severely at higher TRL levels of R&D funding, for example when developing manufacturing systems. More speculatively, stakeholders consulted believed that the departure from the EU was likely to reduce the labour supply, potentially creating recruitment or retainment issues within the industry, particularly for EU staff. Other potential impacts raised included reduced levels of FDI, UK-based production and R&D activity. The ATI programme, and the availability of the ATI's long-term strategy for investment, may help to alleviate such negative effects, though the overall net effect on the programme's impact is unknown and could still be negative.

7. Key lessons

What worked well?

The case study evidence identified key success factors for projects:

- **Company/research organisation priorities** – the ATI-funding provided structure and focus to organisations to execute their priorities in – providing a "stable and supportive framework" in which to undertake R&T.
- **Strategic direction and alignment with industry** – the strategic setting by industry influenced internal company strategies which in turn influenced the type of projects and technologies developed. The role of ATI was important.
- **Collaborator and supply chain inputs** – the inputs of partners from industry and the research base, and the supply chain were considered valuable. The knowledge and skills were important. High levels of interaction, open communication, knowledge sharing, problem-solving between most organisations.
- **Project management** – effective project management by project leads (e.g. quarterly project meetings, planning) led to successful projects.
- **Flexibility to change project scope and extend time** – the flexibility in allowing changes in project scope (e.g. broadening the scope to explore a range of applications) and for allowing time extensions.

The stakeholder workshop identified two key factors, namely: ATI's open and transparent processes, and its' long term strategy for the sector; the collaborative working within the industry, particularly at the tier one level. Some companies that were competitors had worked collaboratively for the first time through ATI funded projects.

What worked less well?

We found no common or consistent feedback from the case study projects on the areas that worked less well. This partly reflected the overall positive views on the ATI programme. However, in a minority of cases the following was highlighted: long timescales between applying and accessing funding; monitoring reporting; in large collaborations challenges of maintaining cohesive and consistent relationships across all project partners; competition and IP issues between industrial partners in a collaboration may limit the sharing of information (e.g. by academics in the collaboration).

Areas for improvement

According to case study consultees: consider how larger collaborations can ensure cohesion and consistency across all projects partners; review how sharing of information could be maximised. The stakeholder feedback (including from the workshop) suggested:

ATI projects could do more to involve more SMEs within projects; more work could be done to engage "satellite" organisations that come to the UK to service equipment; and to widen the definition of supply chains to include more than Tier 2 suppliers (e.g. to include materials suppliers within R&T projects).

What worked well…key 'success factors'

The project leads and partners provided feedback on what worked well in the ATI-funded projects. The key success factors identified were as follows:

- **Company/research organisation priorities** – the ATI-funding provided structure and focus to organisations to execute their priorities in responding to market opportunities, and integrating, testing of technologies and processes – providing a "stable and supportive framework" in which to undertake R&T.
- **Strategic direction and alignment with industry** – the strategic setting by industry (industry bodies, individual top-tier firms/OEMs and ATI, AGP) influenced internal company strategies which in turn influenced the type of projects and technologies developed. Generally, there was alignment between the aims of project leads and partners and that of the ATI funding. The role of ATI was considered important, in particular ATI's strategy development for the sector, support for developing UK's competitiveness in aerospace (industry and research), oversight of investments, consistency of ATI staff (helped in continuity of relationships with firms); and its' flexibility (see below).
- **Collaborator and supply chain inputs** –the inputs of partners from industry and the research base, and the supply chain were considered valuable. The knowledge and skills (especially technical) were thought to be important. Partners were fully engaged with the projects and there were high levels of interaction, open communication, knowledge sharing, and problem-solving between most organisations. Added to this was the ability to build relationships over time especially with those that would not usually work together
  - specifically, the collaboration between industry and the research base academia helped to apply research for the benefit of ATI-funded projects
  - ATI funding encouraged organisations to form new partnerships and work in different ways e.g. academic partners were not used to reporting on milestones and in some cases industry partners had not worked in collaboration with multiple universities
- **Project management:** the effective project management by project leads and where applicable partners (e.g. Innovate UK quarterly project meetings, planning) led to successful projects. In the view of one partner, the ATI-funding provided the "framework for how to plan, execute and manage a project" – this resulted in smoother project management and links to the next ATI project. In addition, the role of Innovate UK

monitoring officers was highlighted as a success because of their technical knowledge, flexibility, keeping the focus on projects through e.g. meeting quarterly with the project team to discuss progress and provide guidance – overall, good relationships between monitoring officers and companies.

- **Flexibility to change project scope and extend time** – the flexibility from Innovate UK and BEIS in allowing changes in project scope (e.g. broadening the scope to explore a range of applications) and for allowing time extensions (e.g. in one case a six-month extension) was deemed highly beneficial, for example in generating outputs and outcomes because the collaboration was able to incorporate feedback received from key stakeholders and potential clients within industry.

Overall, ATI was seen as adaptable to changes in project – this was considered important for the successful development of projects given the iterative and high-risk nature of the innovations.

Workshop feedback

The workshop stakeholders agreed that ATI had provided a focal point for the industry and for investments/projects in R&T. ATI had contributed to increasing the competitiveness of the UK. It had played a crucial role in enabling the UK to compete with Germany, France, Spain and other European countries. Many supply chain relationships and internal projects within international organisations would not have taken place in the UK without the funding provided. This was important because many European countries have multiple equivalent funding bodies (this aligns with strategic rationale for the programme to support a “level playing field” for the UK). Two key success factors highlighted by the workshop with stakeholders were as follows.

ATI’s open and transparent processes…long term strategy

ATI was considered to have an open and transparent process. The ATI were considered agile, quick to respond, and able to work with companies to develop their proposals, providing assurance that these were in line with a clear, long term strategy for UK aerospace that it had defined. This long term view encouraged companies to make investments in projects where returns may not be seen for 8-10 years. In contrast, US funding was highly fragmented, ad-hoc and short-term. Where long term investment was provided, with NASA, companies commented that these were often too complex and difficult to obtain.

Collaboration working

ATI projects had increased collaboration within the industry, particularly at the tier one level. Companies that were competitors had worked collaboratively for the first time through ATI funded projects and had continued to do so. This was thought to be partly linked to companies’ increased ability to take risks within ATI projects. Many collaborations were between businesses as well as business and research centres, and had grown or retained the UK skills base. It was also suggested that ATI had facilitated international collaborations through its links with similar organisations in other countries.

What worked less well?

The feedback from the projects did not identify any common or consistent views on the areas that worked less well. This partly reflected the overall positive views on the ATI programme. However, in a minority of cases, the feedback covered the following aspects:

- *Application/funding timescales* – the timescale between applying and accessing funding was considered too long – funding was not released quickly enough to help businesses be responsive to change in strategy.
- *Monitoring* – the monthly Innovate UK monitoring reporting was considered onerous and unnecessary.
- *Size of collaboration* – in large collaborations, it was hard to maintain cohesive and consistent relationships across all project partners, how could this be addressed going forward?
- *Focus on civil aerospace* – military focussed firms were considered more innovative in tech development, so should be engaged more?
- *Sharing of information* – academic partners found competition between industrial partners limiting as some academic work could not be shared freely with the wider collaboration because of IP ownership.

Areas for improvement

The suggestions for improvement made by case study consultees covered a mix of areas.

- It was proposed that more ATI funding should be focussed on developing collaborations, including through engagement with end users.
- Whilst recognising commercially sensitive nature of projects, there should be focus on finding ways for academics in the collaborations to publish research (because that is what they like to do) - collaborations need to more ambitious in this regard.
- In relation to monitoring, clearer guidance was requested on reporting on revenue for capital projects. Whilst recognising the important role of monitoring, it was noted that monitoring reporting of projects was very onerous.
- It was indicated that in response to long lead times for funding, there should be a review of how the process for release of ATI funding could be quicker in order to align with project lead and partner budgetary cycles. Note, however, that improvements have been made to speed up the approval process following recommendations in the process evaluation study.

More widely, the stakeholders also provided feedback on areas for improvement. Stakeholders suggested that ATI projects could do more to involve new, smaller companies within projects. Not doing so may lead to the perception that funding was only allocated to large organisations. This was partly due to companies preferring to work with firms they had existing relationships with (although this evaluation has found new connections were made). The challenges associated with involving new SMEs within publicly funded projects were identified: SMEs' resistance to bureaucratic processes, barriers to match funding requirements, issues with finding new, smaller suppliers, procurement processes and cultural differences amongst collaborators. It was also noted that projects that had started after those included within the scope of this evaluation, involved more SMEs and new suppliers.

In addition, workshop stakeholders made a broader suggestion on the role of supply chains as follows.

The strength of the UK supply chain was considered to be varied depending on the tech area/sub-sector (e.g. composites was considered strong but other areas such as systems needed improving). Where the ATI had grown capabilities in newer areas through its projects, funded companies often did not have access to supply chains within the UK. In more advanced areas, for example around building wings, requirements to innovate will mean UK supply chains will also have to develop. It was noted that a broader improvement in the UK's competitive supply chain overall was required. The ATI was thought to be a good platform through which to do this and also to encourage existing supply chain firms to remain in the UK. However, two suggestions were made going forward:

- More work could be done to engage "satellite" organisations that come to the UK to service equipment here.[49] The DIT was involved in supporting such firms and more work could be done with the ATI and Innovate UK on this.
- The definition of supply chains may need to be revised to include more than Tier 2 suppliers, to include materials suppliers within R&T projects. The systems and materials supply chains were viewed to be weaker.

[49] Validation workshop stakeholders noted examples where USA-based organisations (e.g. Electroimpact) had been supported in setting up UK bases to facilitate the ongoing servicing of equipment they had sold into UK organisations.

8. Emerging conclusions

The overall objective of the study was to establish the actual and expected effects of ATI funding on outputs and outcomes (focussing on short-term outcomes). The early evaluation addressed seven evaluation questions, the key conclusions on which are provided below. We used a theory-based assessment, with contribution analysis the overarching framework, to test the evidence on early outcomes, whilst considering other factors which may have contributed to these reported outcomes. Three points are highlighted with respect to the evidence used and analysis undertaken to answer these seven questions:

- The evaluation evidence was primarily based on 15 case studies of Early ATI and Capital projects, 22 stakeholder interviews and a workshop. Whilst the case studies were comprehensive assessments and stakeholders fed back on the broader programme, the conclusions largely reflect the findings from the 15 projects, and cannot be generalised to the wider portfolio. It is also important to highlight the potential bias in the self-reported evidence from case study project beneficiaries.
- Most of the case study projects had only recently closed or were near completion. This was pertinent given that the ultimate outcomes from the R&T projects are often long-term, and so the focus of this study was on outputs and early intermediate outcomes.
- To support the contribution analysis, data from the case studies informed a QCA for three specific outcomes. Given the limited application of QCA in innovation policy this should be seen as an experimental approach.

EQ1 How far has ATI funding leveraged additional (direct) expenditure on new aircraft design and manufacturing technologies? How far has ATI funding led to – or encouraged – the initiation of new R&D projects?

The availability of ATI funding has, to a large extent, led to or encouraged the initiation of projects on new or improved technologies that would not have happened anyway – or would have done so later, at a reduced scale or overseas. There has therefore been *additional* direct expenditure on R&T in the UK. The evidence points to medium-to-high levels of additionality with limited deadweight for the 15 projects assessed. The following evidence supports this judgement:

- Eleven of the 15 case study project leads indicated that projects would not have happened at all, or would have done so outside of the UK. For the other four projects, they would have happened at a reduced scale or later. This evidence of high additionality was tempered by the fact that six other similar R&T projects (as perceived by project leads) reviewed that were not ATI-funded had gone ahead in some form and/or later – three progressed slower and three at similar rate to ATI-funded projects. The projects that had progressed at a similar rate were funded through other public sources with not much of a difference in terms of the speed of progression between ATI and non-ATI-funded projects.

- The feedback from project partners and wider stakeholders generally supported the findings from the project leads, although with a greater leaning towards scale and speed additionality. Most (16 out of 18) stakeholders agreed that without the ATI programme, the outputs and/or outcomes would either not have occurred at all, occurred outside the UK, or occurred at a slower rate and scale.
- The evidence on project objectives supported the fact that the R&T activities were for new, or at least improved, technologies. These covered product and process innovation, as well as infrastructure, and included improving operational efficiency of an aircraft, developing and demonstrating a new technology, and contributing to a major step change such as in a new flight system.

In response to the second part of EQ1, **there is strong evidence that the 15 ATI-funded projects assessed have led to subsequent R&T or R&D projects, thereby leveraging further industry investment. In this context, ATI should be seen as one part of a complementary set of activities.** The key points of evidence supporting this conclusion were as follows:

- In almost all cases (14 out of 15 case study projects), ATI-funded projects generated subsequent industry investments in R&D at TRLs 7-9 or R&T at slightly lower TRLs.
- Importantly, all 15 case studies highlighted that ATI generally has generated greater certainty for UK R&T/R&D investments in aerospace. For example, in the view of a few case study consultees:
    - “ATI funding helps ensure there is a conveyor belt of technologies up to TRL 6 which gives greater certainty for internal investment decision”
    - “having ATI funding is crucial in decisions about where R&D investments will be made…there is a risk that R&D and production could go abroad without UK government support”.
- Outside of ATI directly, the majority of project leads (12) stated that there were other complementary R&T activities taking place at the same time, which linked to the observation that projects continued to be very aligned with the priorities of their organisation. The QCA found that the presence of other complementary R&T activities was strongly related to subsequent industry investment in R&T at TRLs 7-9. In other words, ATI funding generates certainty for UK R&T investment in aerospace, but for the ATI-funded project to lead to subsequent industry investment, a key factor is that the lead partner has complementary R&T activities taking place at TRLs 7-9. This implies that companies conducting multiple related projects are more likely to commercialise their R&T than companies conducting isolated R&T projects.
- It is also important to note that ATI-funded projects had origins in previous projects. In other words, ATI was one step in the process of development.

EQ2 How far has ATI accelerated the development of new aircraft design and manufacturing technologies funded through the projects (progress through TRLs)?

There is very strong evidence that ATI has accelerated the development of new technologies through the 15 funded projects assessed. In all of the case studies (15), ATI helped projects to progress through TRLs (often at TRLs 4-6, but also at lower levels e.g. 1-3, 2-4, 3-6). Put together with the evidence on additionality, which included absolute, UK-level and speed additionality, it is clear that technological development has been facilitated or accelerated in most cases – five projects would not have occurred at all and six would have occurred outside of the UK. This indicates that ATI funding has helped to develop technologies in the UK which would have been produced overseas or would not have been produced at all. In progressing technologies through TRLs, six of the projects faced "substantial" and a further six faced "some" technical impediments, including barriers to infrastructure (e.g. automation, "transition of materials", and lack of technical experience of the firm). Only two projects faced "no" technical impediments. Interestingly, technical impediments were less of an issue for project partners that were not leading the projects.

EQ3 How far has ATI influenced patterns of collaboration (or introduced new ones), including increase the volume and strength of collaborative relationships both between firms in the aerospace supply chain, and with academic institutions?

The Early ATI projects assessed were not found to have substantially influenced patterns of collaboration, although they have helped in two important respects, through: identifying new partners that were needed to provide specialist expertise; and strengthening existing collaborations.

Project collaborations were mainly informed by the knowledge and expertise of collaborators, use of particular infrastructure (e.g. Catapult facilities), and the R&T priorities of companies. The collaborations were mainly developed through existing connections of the project leads, including with their supply chains and university/research organisations. That said, there were some new collaborations as project leads identified partners with specific expertise. These new collaborations were facilitated by existing networks and the ATI itself through signposting and connecting. Of the 15 case studies, four of the project partners found collaborations as a result of engaging with the ATI and further four expected to achieve these in the future.

There was consensus amongst project leads and partners that their collaborative relationships were strong by the end time of project completion, and that these had evolved over time as a result of ATI-funded projects.

EQ4 How far has ATI started to influence the plans of aerospace companies to locate production in the UK resulting in commitments for manufacturing jobs?

The evidence suggests that ATI has, in part, influenced the plans of some aerospace companies to locate production in the UK – though the causal relationships are not clear. In 14 out of 15 case study projects the certainty provided by ATI funding had an influence on firms' plans to base production in the UK. Of these 14 cases, six had an exploitation plan or equivalent for the project that specifically planned for UK-based production. These findings suggest that greater perceived certainty for UK R&D investments in aerospace provided by ATI would, in theory, support production in the UK. The QCA found that exploitation plans (or equivalent) were influenced by the existence of similar production in the UK.

The influence of ATI funding on firms' plans to base production in the UK related to the fact that project lead organisations tended to favour in-UK R&T projects where there were complementarities for basing some production in the UK. In making the case within their organisations for R&T projects in the UK, the potential for subsequent production provided part of the context. In addition, project leads recognised the policy objective relating to having subsequent production jobs in the UK, and so were aligning to this. Three case studies highlighted job creation in aerospace production/manufacturing as an outcome as a result of ATI-funding (these three project cases reported high additionality). There was also some uncertainty over future production, and there were other factors that would ultimately inform this, with two particularly highlighted:

- There were mixed views on the strength of existing supply chains in the UK. Some supply chains were seen to be strong (e.g. composites, fuel pipes), whilst others were viewed as weak (e.g. tooling, dry fibre). In a few case study projects, ATI funding for technologies was expected to strengthen supply chains in UK. It was also recognised that similar production did not already exist in the UK in relation to some of the case study projects.
- There were mixed responses on the extent to which departure from the EU may have adverse consequences for locating production in the UK. Within an overall sense of uncertainty, there was an almost equal split between those reporting "large", "moderate" and "small" adverse consequences.

EQ5 How far has ATI led to an improvement in the infrastructure […] which is used to undertake R&D and helped to secure/create high wage employment in both R&D and the longer term manufacturing during production?

The evidence indicated that ATI has led to an improvement in infrastructure, with use by aerospace and other sectors. It was noted, by stakeholders, that there was still further infrastructure development required to catch up with international competitors. The evaluation found the main investments in UK technology infrastructure made through the ATI programme amounted to c. £150m across different types of facilities in industry, RTOs/Catapults and academia. The investments were spread across the UK.

It was not possible to get a complete picture of the development and use of the R&T infrastructure of the ATI programme due to incomplete or unavailable data. The case study evidence suggested that infrastructure has been improved and new infrastructure has been developed to assist with R&T. The stakeholder feedback suggested that this was typically within research facilities, building on existing capabilities and targeted at enabling the commercialisation of technologies (e.g. through HVM Catapult). Usage was typically by businesses within aerospace and their supply chain, and there were examples of use from sectors such as offshore industries and automotive.

EQ6 How far is ATI expected to deliver spillover benefits in the UK based on evidence on nature and extent of collaborations/supply chain outputs and the potential for market spillovers such as in relation to greenhouse gas emissions?

The evaluation found that spillovers were perceived across the case studies – though this evidence should be treated with caution. There was clearer evidence that the conditions to support spillovers have been supported by ATI-funded projects.

It is important to note that the evidence on spillovers was largely drawn on **perceptions** that these had occurred or would occur; it is difficult to track these through, and so the evidence here should be treated with caution. The evaluation found spillovers were perceived by participants in 13 out of the 15 case study projects. Knowledge spillovers were identified for other businesses and universities, for example in relation to technologies such as large robotics. Market spillovers were identified in terms of reduced costs for customers (as new technologies/products become substantially cheaper) and environmental benefits (e.g. from reduced fuel consumption/CO2 emissions). Spillovers were mainly perceived to occur in aerospace itself, and in: automotive, marine, energy, electronics, defence and construction.

There was clear evidence that projects have supported conditions that may help to generate spillovers. These supporting conditions were through: development of multi/general purpose technologies, i.e. that could be deployed elsewhere; capacity and capability for R&T in the aerospace sector that could lead to more and better R&T; high levels of skills and transferability between firms and sectors; and people movements internally and externally.

EQ7 What broader technological and policy developments have emerged since the ATI programme was created, and how are these likely to influence the impact of the scheme?

Developments in technology reflected on-going innovations in the aerospace sector that are cross-cutting, including: electrification, additive manufacturing, composites, Industry 4.0, urban air mobility, and software and cyber security. It was difficult to identify the direction and scale of influence on the impact of the ATI programme. Rather, **it was noted that the cross-cutting nature of these technologies will emphasise that projects need to be increasingly complementary with other activities.** The scope for spillovers was also highlighted given the wider potential for these technologies in aerospace and more widely.

There were two key observations in relation to policy developments. **Within the UK, the development of industry-supporting policy was supporting more collaboration, and providing complementarities** between cross-cutting R&T under the Industrial Strategy Challenge Fund and the types of projects supported by ATI. These were seen to be complementary and so supporting the impact of ATI.

The second issue was in relation to external competitiveness. The overall impact of the expected departure from the EU was unknown, and views varied. Related to this, it was highlighted that the role of the Department for International Trade was important, with more that could be done. In addition, **the uncertainty around the EU impact emphasised the rationale for ATI, which was seen as helping to support the competitiveness of the UK in**

the global aerospace market and providing a counterbalance through long-term certainty of funding.

Assessment of contribution against the logic model

The underlying theory of change and logic model (including the seven key drivers and external factors influencing the logic model) for the ATI programme highlight the complexity in activities and the different routes to effects. This is reflective of the nature and scale of ATI. A reasoned theory of change is evident, and the ATI programme has delivered activities as expected against this depiction (see section 2, and Annex E). The activities have translated into key outputs, and short- and medium-term outcomes identified below (as reported by project leads).

Table 8-1: Outputs and other outcomes achieved as a result of ATI programme (project leads)

Outputs (out of 15 responses)	Outcomes (out of 15 responses)
Patents filed for products and services (11)	Upskilling of aerospace labour force (11)
Development of intellectual property (11)	Jobs safeguarded/created in aerospace R&T (10)
Creation of R&T infrastructure (11)	Inward investment in aerospace R&T (5)
R&T spend (co-investment) by aerospace industry at TRLs 4-6 (10)	Higher levels of R&T expenditure (5)
New collaborations B2B and B2R (9)	Use of new or upgraded R&T infrastructure (5)
Leveraged EU funds (0)	Further collaboration between businesses and the research base (4)
	Technologies reaching commercialisation stages TRLs 7-9 (3)
	Job creation in aerospace production/ manufacturing (3)
	New orders (and associated turnover) for components and companies (1)
	Increased value added per employee (1).

Source: Case studies

In addition, there is also limited evidence of some long-term outcomes, specifically knowledge and market spillovers (and for projects contributing to developing conditions that may support the generation of spillovers).

Overall, the nature and strength of the project collaborations (including having the expertise to avoid or overcome technical impediments), and the role of ATI funding in providing the long-term certainty for investment have played key roles in achieving results. These findings are encouraging given the short time elapsed since projects were completed (most were completed at the end of December 2018) and the long timescale associated with the time-paths to commercialising R&T in the aerospace sector.

There were other factors contributing to the outcomes described (e.g. role of firm's own commitment, other research projects, universities, wider innovation infrastructure). However, the evidence found that the role of ATI in achieving the outcomes relative to these other factors was "important" and "critical". This was through complementing other factors, rather than as the only decisive factor.

In summary, the evaluation found the ATI programme has made a medium-to-high contribution to the actual and expected outputs and (short- and medium-term) outcomes. First, the nature and scale of the effects vary with most expected to be realised in the future, driven largely by the long time-paths to commercialisation in the aerospace sector. Second, ATI is one of a number of factors – internal or external – influencing the achievement (or expected) of outcomes. The underlying theory of change is happening as intended.

Lessons

An overall lesson at this early stage of the evaluation of ATI is that the strategic approach of the programme, including through the long-term certainty of funding, the priority themes and the encouragement of considering production plans early, was seen to be working. These aspects were seen as important in supporting UK competitiveness in a global market.

The case study evidence identified success factors at project level. The alignment with both the priorities of companies/research organisations and the fit with the wider direction of the industry were found to be important. In addition, having the right expertise for projects was key, both in terms of collaborators and subcontractor inputs, and effective project management by project leads. An important supporting programme factor was the openness and flexibility from ATI to change project scope and timings.

There were no consistent issues at project level on the areas that worked less well. This partly reflected the overall positive views on the ATI programme. Two programme-related factors were identified in some case studies, namely the long timescales between applying and accessing funding, and the burden of monitoring reporting. Project-related issues were identified on large collaborations, where there were challenges in maintaining cohesive relationships across all project partners.

In addition to these areas that had not worked as well, there were further suggestions for improvements made by case study and stakeholder consultees, as follows:

- Review how sharing of information could be maximised within collaborations (especially where there are IP issues).
- Involve more SMEs within ATI projects, especially where supply chains are weaker (although this was recognised to be happening more).
- Further engage "satellite" organisations that come to the UK to service equipment.

- Widen the definition of supply chains to include more than Tier 2 suppliers (e.g. to include materials suppliers within R&T projects).

Annex A: List of stakeholder consultees

Scoping interviews

Table A-1: List of scoping interviews

Name	Position	Organisation
Keith Brook	Sector Analysis	BEIS
Alex Parker	Economic Adviser	BEIS
Miles Gray	Policy Team	BEIS
Peter Willis	Senior Economist	ATI
James McMicking	Chief Strategy Officer	ATI
John Morlidge	Head of Aerospace	Innovate UK
Alfred Ng	Innovation Lead - Aerospace (Technology)	Innovate UK
Justin Davies-Trigg	Senior Programme Manager – Aerospace	Innovate UK
Justin Simmons	Programme Manager – Aerospace	Innovate UK
Lucy Weatherburn	Programme Manager – Aerospace	Innovate UK

Source: SQW

Stakeholder interviews

Table A-2: List of stakeholder interviews

Consultee	Position	Organisation
Richard Oldfield	Chief Executive Officer	National Composite Centre (NCC)
Jeegar Kakkad	Chief Economist, Director of Policy	ADS Group
Harriet Wollerton	Programme Director	National Aerospace Technology Exploitation Programme (NATEP)
Colin Smith	Chair, Aerospace Growth Partnership (AGP)	Aerospace Growth Partnership (AGP); formerly Rolls Royce

Consultee	Position	Organisation
Nik Hamilton	Investment Team Manager	Sheffield Local Economic Partnership, Creative Sheffield
Noel Brown	Technology Executive, R&D Advanced Manufacturing	Invest Northern Ireland
Pat Doyle	Innovative Procurement Executive, NATEP RAP Chair in Northern Ireland	Invest Northern Ireland
William McGuinness	Head of Aerospace and Development	Invest Northern Ireland
Roger Gardner	Aerospace Sector Adviser	University of Southampton
Keith Brook	Advanced Manufacturing and Services	BEIS
Alex Parker	Economic Advisor	BEIS
Miles Gray	Aerospace Policy lead for ATI	BEIS
Dickie Davis	Deputy Director for the Advanced Materials & Manufacturing Sector	Welsh Government
Brian Burridge	Chief Executive Officer	Royal Aeronautical Society
Colin Sirett	Chief Executive Officer	Advanced Manufacturing Research Centre (AMRC)
Gordon Venters	Head of Engineering, High Value Manufacturing Sector Team	Scottish Enterprise
Christopher McLean	Senior Executive, Aerospace and Defence Specialist	Scottish Enterprise
Sam Turner	Chief Technology Officer	High Value Manufacturing Catapult
Mark Scully	Head of Advanced Systems and Propulsion	Aerospace Technology Institute
Nour Eid	Technologist	Aerospace Technology Institute
Peter Willis	Senior Economist	Aerospace Technology Institute
Kedar Pandya	Associate Director, Business and User Engagement	Engineering & Physical Sciences Research Council (EPSRC)

Source: SQW

Workshop

Table A-3: List of workshop participants

Consultee	Position	Organisation
Jeegar Kakkad	Chief Economist, Director of Policy	ADS Group
Clive Lewis	Managing Partner	Achieving the Difference
Steve Murray	VP Strategy & Marketing UK	Thales
Alex Chahian	Formerly Grant Funding Manager UK	GKN
Faye Smith	Materials Specialist	Department for International Trade
Ian Collier	Director of Operations	High Value Manufacturing Catapult
Justin Davies Trigg	Senior Programme Manager, Aerospace	Innovate UK
Peter Willis	Formerly Senior Economist	ATI
Alex Parker	Economist	BEIS
Ricky Moroni	Aerospace Business Analyst	BEIS

Annex B: ATI strategic themes, timeframes, and TRLs

Value streams

The ATI Technology Strategy and Portfolio Update 2016 identifies four main strategic themes. These themes are aligned with future market requirements.

- **Aircraft of the future** - Strengthening the UK's whole-aircraft design and system integration capability, positioning it for future generations of civil aircraft
- **Propulsion of the future** - Advancing a new generation of more efficient propulsion technologies, particularly within large turbofan engines
- **Aerostructures of the future** - Ensuring the UK is a global leader in the development of large complex structures, particularly wings
- **Smart, connected and more electric aircraft** - Developing UK advanced systems technologies to capture high-value opportunities in current and future aircraft.

SEP timeframe

The ATI is supporting the sector to address priorities within the following timeframes expressed in terms of the 'SEP' Model i.e. Secure, Exploit and Position.[50]

- **Secure (0-5 years)** - Ensure vital UK technology capabilities are secured and developed, and manufacturing competitiveness is raised
- **Exploit (up to 2025)** - Accelerate UK technologies and capabilities to capture high-probability market opportunities
- **Position (beyond 2025)** - Prepare UK aerospace for long term success by pursuing game-changing technologies.

[50] Broadly described by market alignment in terms of addressing opportunities in the shorter, medium or longer term.

Technology Readiness Levels

Table B-1: TRL definitions for aerospace developments

TRL	Description
TR1	Basic principles observed and reported - transition from scientific to applied research
TR2	Technology concept and/or application formulated - Applied research - theory focused on specific applications
TR3	Analytical and experimental critical function and/or characteristic proof-of-concept through analytical and lab studies
TR4	Technology basic validation in a laboratory environment
TR5	Technology basic validation in a relevant environment
TR6	Technology model or prototype demonstration in a relevant environment
TR7	Technology prototype demonstration in an operational environment
TR8	Actual technology completed and qualified through test and demonstration
TR9	Actual technology qualified through successful operations.

Source: ATI Project Close-out Economic Monitoring Form

Annex C: List of case studies

Table C-1 presents the full list of case studies and summarises the key details about each project.

Table C-1: Final list of case studies

#	Lead Partner	Project Title	Value Stream	Time horizon	Grant offer (£m)	Total cost (£m)	No. of partners	Location	Project status	Duration
1.	Airbus	Factory of the Future for Aircraft Wing Manufacture and Assembly	Aerostructures of the future	Secure	8.8	13.5	13	Wales	Closed	04/2014 – 06/2017
2.	Airbus	Wing Design, Manufacture and Assembly (WDMA)	Aerostructures of the future	Exploit	8.7	13.1	3	South West	Closed	04/2014 – 09/2017
3.	Airbus	WIST - Wing Integrated Systems Technologies	Aerostructures of the future	Exploit	8.3	14.5	6	South West	Closed	04/2014 – 12/2017
4.	Rolls-Royce	Project 11 Core Demonstrator Concept	Propulsion of the future	Secure	8.0	15.9	1	East Midlands	Closed	10/2013 – 03/2015
5.	Rolls-Royce	Advanced Repair Technologies	Propulsion of the future	Exploit	4.5	9.1	5	East Midlands	Closed	01/2014 – 03/2017
6.	Rolls-Royce	Rolls Royce SILOET II Project 15	Propulsion of the future	Exploit	6.5	13.0	2	East Midlands	Closed	10/2013 – 12/2016

#	Lead Partner	Project Title	Value Stream	Time horizon	Grant offer (£m)	Total cost (£m)	No. of partners	Location	Project status	Duration
		Advanced Turbine Technologies								
7.	GE Aviation	Future Flight Deck	Smart, Connected and More Electric Aircraft	Exploit	5.9	10.9	4	South West	Closed	10/2013 – 12/2016
8.	GKN	VIEWS (Phase 1)	Aerostructures of the future	Secure	18.8	30.5	16	South West	Closed	04/2014 – 03/2017
9.	Leonardo Helicopters	Extension to the Rotorcraft Technology Validation Programme	Propulsion of the future	Exploit	2.1	4.3	1	South West	Closed	07/2013 – 11/2015
10.	Safran Group	LAGEMOSYS - Landing Gear Monitoring Systems	Smart, Connected and More Electric Aircraft	Secure	2.0	3.3	3	North West	Closed	07/2014 – 03/2018
11.	Thales	HARNet (Harmonised Antennas, Radios, and Networks)	Smart, Connected and More Electric Aircraft	Secure	6.4	11.6	7	South East	Closed	04/2014 – 12/2015
12.	Collins Aerospace (formerly UTC)	Lightweight, Affordable Motors & Power-electronics Systems (LAMPS)	Smart, Connected and More Electric Aircraft	Exploit	1.3	2.4	3	West Midlands	Closed	06/2014 – 08/2016

#	Lead Partner	Project Title	Value Stream	Time horizon	Grant offer (£m)	Total cost (£m)	No. of partners	Location	Project status	Duration
CAPITAL PROJECTS										
13.	Queen's University Belfast	SCENIC	Aerostructures of the future	Secure	5.0	5.0	1	Northern Ireland	Closed	10/2016 – 03/2018
14.	Aircraft Research Association Limited	ARCADE (Aerodynamic Research testing Capability and Data Enhancement)	Aerostructures of the future	Position	3.5	3.5	1	East of England	Closed	06/2016 – 02/2018
15.	Advanced Manufacturing Research Centre	Flexible Robotic Machining in High Accuracy Applications (FRoMHAA)	Aerostructures of the future	Secure	0.5	0.5	1	Yorkshire and Humber	Closed	06/2016 – 04/2017

Source: 2018-09 ATI Portfolio Stats Excel; SQW

Reasons for inclusion of case studies

Table C-2 provides a summary of the reasons for selecting the 15 case study projects.

Table C-2: Final case study list – Summary of reasons for inclusion

#	Lead Partner	Project title	Summary of reasons for inclusion
1	Airbus	Factory of the Future for Aircraft Wing Manufacture and Assembly	• Majority of ATI funding has been provided to Airbus primarily for Wing of Tomorrow - part of related/clusters of projects – wings (projects #1-3) • Large number of project partners • Provides regional breadth with lead partner located in Wales • Project with one of the higher total costs
2	Airbus	WDMA - Wing Design, Manufacture and Assembly	• Part of related/clusters of projects – wings (projects #1&3)
3	Airbus	WIST - Wing Integrated Systems Technologies	• Part of related/clusters of projects – wings (projects #1&2)
4	Rolls-Royce	Project 11 Core Demonstrator Concept	• Funded many projects on the advanced core and it would be good to review the technical progress and path to product exploitation
5	Rolls-Royce	Advanced Repair Technologies	• Project involving significant SME engagement • Example of a 'manufacturing' project, which should be represented in the sample • Potential to examine a similar project, ARTEFACT that was not supported by ATI
6	Rolls-Royce	Rolls Royce SILOET II Project 15 Advanced Turbine Technologies	• Provides an example of a 'turbine' project to ensure breadth of technologies are covered • Also an example of a technology that may be multi-purpose with potential applications outside of aerospace (e.g. in energy sector)

#	Lead Partner	Project title	Summary of reasons for inclusion
7	GE Aviation	Future Flight Deck	• Systems project with project partners: BAE Systems and universities
8	GKN	VIEWS Phase 1 (Validation and Integration of Manufacturing Enablers for Future Wing Structures)	• Project with one of the highest total cost and ATI grant offers • Diverse project progressing over many separate technology strands • Highest number of project partners • Key companies, Spirit AeroSystems and Bombardier, could also be interviewed as part of the project
9	Leonardo Helicopters	Extension to the Rotorcraft Technology Validation Programme	• Project relates to helicopter active rotor technology, so represents a different part of the sector • Covers 'Propulsion of the future' (along with the three Rolls-Royce cases above), so ensures some balance by value stream in the sample
10	Safran Group	LAGEMOSYS - Landing Gear Monitoring Systems	• Landing gear project • Project partners include Universities of Sheffield and Cambridge
11	Thales	HARNET (Harmonised Antennas, Radios, and Networks)	• Aircraft communication project • Provides regional breadth with lead partner in the South East
12	Collins Aerospace (formerly UTC)	LAMPS (Lightweight, Affordable Motors & Power-electronics Systems)	• Systems project that addresses an important part of the move to More-Electric Aircraft • Diverse SME project partners
CAPITAL PROJECTS			
13	Queen's University Belfast	SCENIC (Supply Chain Enablement for Increased Competitiveness)	• University lead partner • Provides regional breadth with lead based in Northern Ireland

#	Lead Partner	Project title	Summary of reasons for inclusion
14	Aircraft Research Association Limited	ARCADE (Aerodynamic Research testing Capability and Data Enhancement)	• Provides regional breadth with lead partner in East of England • Value stream – only Position project in sample
15	Advanced Manufacturing Research Centre	FRoMHAA (Flexible Robotic Machining in High Accuracy Applications)	• Provides regional breadth with lead partner in Yorkshire & Humber • Also involves High Value Manufacturing Catapult (a key organisation) as lead.

Source: SQW

Annex D: Summary of ATI portfolio data

Table D-1 presents the 'headline' statistics of the UK ATI Portfolio by category of project based on review of monitoring data.

Table D-1: Headline statistics of UK ATI Portfolio by category of project

Grouping	No. Projects	Average Partners	Average Grant per Project (£m)	Total Grant (£m)	Total Spent (£m)	Projects closed	Projects soon to close	Projects still very live	Projects closed (£m)	Projects soon to close (£m)	Projects still very live (£m)
Legacy	34	3.1	3.5	120	116	33	1	0	110	10	0
Aero Centre	11	4.4	3.1	34	32	11	0	0	34	0	0
ATI CRD	34	5.2	1.3	43	35	8	19	7	14	19	9
ATI-Early	52	4.5	5.7	298	277	26	19	7	171	93	34
ATI-SRC*	55	4.0	7.1	390	128	0	3	52	0	16	374
Capital	28	1.7	5.9	166	90	6	7	15	49	15	102
Total	214	3.9	4.9	1,050	679	84	49	81	378	154	519

Source: ATI Analysis of Innovate UK Public Data (September 2018) - not in scope for this evaluation*

R&T infrastructure

Table D-2 presents the ATI's programme's investments in UK technology infrastructure

Table D-2: Investment in UK technology infrastructure

	Infrastructure	Total cost (£m)	Location
INDUSTRY:			
AIRBUS	Airbus UK: Advanced Wing Integration Centre (AWIC)	37.0	Filton
GKN AEROSPACE	GKN Aerospace: Electronic Beam Melting Development Cell (Cell-EBM)	3.6	Filton
BOEING	Boeing UK: Gear & Actuation Manufacturing Facility	2.7	Sheffield
ROLLS ROYCE	Rolls-Royce: Proving Advanced Engine Concepts (PACE)	6.3	Derby
HEXCEL	Hexcel: Multi Axial Infusion Materials (MAXIM)	3.8	Duxford (near Cambridge)
RTO/CATAPULT:			

Infrastructure	Total cost (£m)	Location
Advanced Forming Research Centre (AFRC): High Temperature Hydraulic Forge (HIVES)	6.6	Glasgow
Advanced Manufacturing Research Centre (AMRC): Large Scale Titanium Casting Facility & Ceramic Shell Facility Advanced Fast Make Casting Facility (CastFast) Flexible Robotic Machining (FroMHAA)	20	Sheffield
Manufacturing Technology Centre (MTC): Aerospace Research Centre (ARC) National Centre for Net Shape and Additive Manufacturing Digital Reconfigurable Additive Manufacturing Facilities for Aerospace (DRAMA)	30.8	Coventry
Aircraft Research Association (ARA): Capital equipment Projects (Phases 1 and 2)	5.2	Bedford
TWI: Open Architecture Additive Manufacturing (OAAM)	6.5	Cambridge
National Composites Centre (NNC): Automated technologies for Manufacture of Composite Propulsion and Aerostructure	22	Bristol

	Infrastructure	Total cost (£m)	Location
	High-rate, High-volume technologies for Large Aerostructures (HISTRUCT) Novel technologies for Propeller and Aer-Structure manufacturing (NTPROSTRUCT)		
ACADEMIA:			
Queen's University Belfast	Queen's University Belfast: Supply Chain Manufacturing Centre (SCENIC)	5.0	Belfast
The University of Nottingham	University of Nottingham: Future Automated Aircraft Assembly Demonstrator (FA3D2) High Performance Transmission Systems Test Facility	6.4	Nottingham
University of Oxford	University of Oxford: Thermofluids Laboratory Upgrade (Osney)	6.1	Oxford
Imperial College London	Imperial College London: National Wind Tunnel Facility (NWTF)	2.6	London
Loughborough University	Loughborough University: National Centre for Combustion Aerodynamics	10.8	Loughborough

Source: ATI

Annex E: Approach and research methods

Overall approach

The early impact evaluation of the ATI programme involved a theory-based assessment. This tested the extent to which outputs and early outcomes have occurred, and the extent to which they are a result of the programme - in line with the updated logic model and theory of change set out in section 2 (and Table E-1, Table E-2). The assessment involved using contribution analysis (CA) to test the evidence on early outcomes, whilst considering other factors which may have contributed to these reported outcomes. The approach, therefore, draws on both qualitative and quantitative data. This includes collation and analysis of project level monitoring data, top-down stakeholder perspectives and technology mapping, in-depth case study work, and an expert stakeholder workshop to calibrate and stress test the findings against the programme logic and theory.

We used CA to test whether the logic had been followed as expected, considered what factors were important in the causal chain, and assessed the role of ATI relative to other factors. We will draw on multiple perspectives to make this assessment – the project lead organisations and their partners, and the wider stakeholders. To help validate findings, we hosted a workshop with experts to test the evidence.

As part of the CA, we examined the additionality of the ATI funding primarily through the case studies. This was relevant for all the evaluation questions.

We provide further detail on how CA was applied to the early impact evaluation of the ATI programme below. To support the CA, we used Qualitative Comparative Analysis (QCA) – drawing on data from the case studies and stakeholder interviews – as an experimental source of evidence on certain specific evaluation outcomes (discussed in more detail in Annex F).

ATI programme theory of change

Table E-1: Theory of change: drivers, hypotheses and assumptions

#	Driver	Assumptions/ hypotheses	Alternative explanations
1	**ATI = 'more' R&T funding & 'more certainty' for investment decisions**	Investments/ projects would not have happened at all, not in the UK, or not as quickly. The certainty provided by ATI has given confidence to invest in the UK. ATI funding has addressed barriers to investing, including excessive market or technical risks that	R&T activity would have happened in the UK anyway, e.g. due to the absence of any more favourable conditions offered elsewhere or because projects are key to companies' competitive positioning (and so important long-term investments within the risk profile

#	Driver	Assumptions/ hypotheses	Alternative explanations
		mean that companies or financiers are unwilling to invest in projects. This is particularly pertinent for projects that are furthest from market or have a high degree of uncertainty with respect to technical feasibility.	that companies or financiers can take). ATI funding has been used, alongside other funding initiatives, to supplement existing R&T budgets and plans.
2	**Prioritisation means focus on the right projects**	Reflecting the strategic rationale, ATI has identified where there are market opportunities and how UK strengths can be enhanced to take advantage of these. BEIS has worked with companies to identify where production jobs can be secured. These have influence projects coming forward and how they are implemented. Projects have potential to lead to longer-term benefits, and exploitation plans demonstrate these potential benefits.	Key industry players have identified R&D project priorities as part of their own strategic/competitive development. As part of this, companies have taken account of existing strong supply chains. SMEs have had less input to technology strategy development, with a risk that high potential projects have been overlooked.
3	**ATI & ATI projects lead to more / stronger collaboration**	ATI has identified where there are UK supply chains, new opportunities for networking, and other complementary industrial research initiatives. These have informed new collaborations that may not have occurred otherwise due to information and coordination failures, and resulted in additional collaborator investment.	Established supply chains and networks are the origins of collaborations. Investment has been stimulated through these existing routes to a greater extent than new networks through ATI. SRC processes favour larger firms, which has resulted in a focus on existing collaborations.
4	**Projects successful in progressing through TRLs**	Whilst noting the risks of R&T, some projects have been technically successful leading to progress/faster progress through TRLs and to subsequent investment in	Progress through TRLs would have happened through projects in any case given companies' commitment to them, and as a result of other non-ATI-funded R&T activities.

#	Driver	Assumptions/ hypotheses	Alternative explanations
		R&T at later stages. Initial ATI funding was required to de-risk later R&T, and/or to provide 'extra' kit, resource, links to make this happen. ATI projects happen inter-dependently with other R&T, and ATI-funded activities play a key role in the wider R&T plans of companies.	
5	**R&T leads to 'stickiness' & basing production in UK**	Companies have committed to, and so far retained, their plans on exploitation, leading to R&T and production jobs in the UK. The commitment to supporting technology and capability development in the long term through ATI has built business confidence to base production in the UK (countering other effects such as uncertainties around Brexit).	There are limited ways to ensure firms commit to follow-on investment in the UK, resulting in some benefits going overseas. Where there are well-established supply chains there is greater chance of UK-based production, though this has happened/may happen without ATI funding. Other factors have assisted in leading to production in the UK, including skills, facilities and access to markets.
6	**Infrastructure leads to new R&T capacity & jobs**	New infrastructure created by ATI investments that would not have been developed otherwise, because companies could not justify the cost individually or collectively. This leads to additional capacity to undertake new sorts of R&T and creates new R&T employment.	Companies would collectively invest in mutually beneficial infrastructure, e.g. through membership of Catapult centres or in partnership with universities. R&T activities that utilise the infrastructure could use alternative equipment.
7	**Technologies / knowledge developed that is relevant for other sectors**	Infrastructure developed is used for technology development in other sectors, leading to spillovers. ATI projects have developed cross-cutting or multi-purpose technologies that have the potential for adoption in	Infrastructure is used primarily by aerospace sector with the result that wider spillovers are not generated. There are barriers to diffusion of knowledge, such as protection of IP or limited cross-sector knowledge/ people movements.

#	Driver	Assumptions/ hypotheses	Alternative explanations
		adjacent sectors such as automotive, rail, marine, oil & gas. The networks and cooperation of ATI project partners (both private sector and research organisations) indicate a potential for spillovers. There are means for spillovers to occur, i.e. through supply chains, people movements, absorptive capacity.	Knowledge generated is not the result of ATI-funding per se, but from other/previous/ subsequent R&T and so spillovers cannot be attributed to ATI projects.

Table E-2: ATI programme outputs and outcomes (focus on short and medium term)

Outputs	Short-term outcomes	Medium-term outcomes	Long-term outcomes
R&T spend (co-investment) by aerospace industry at TRLs 4-6	Inward investment in aerospace R&T	Technologies reaching commercialisation stages (TRLs 7-9)	Reduction in cost and time taken to commercialise innovations
Leveraged EU funds through ATI commitment	Higher levels of R&T expenditure (e.g. % of capex / GVA)	New orders (and associated turnover) for components and companies	Anchored high-value jobs in the UK Aerospace sector
New collaborations (business-to-business, business-to-research)	Jobs safeguarded /created in aerospace R&T	Job creation in aerospace production / manufacturing	Safer, more efficient and environmentally friendly aircraft
Development of intellectual property	Up-skilling of aerospace labour force, through exposure to new, and collaborative research	Increased GVA in the supply chain	Increased UK competitiveness in terms of global market share
Patents filed for products & processes (and their duration)	Use of new or upgraded R&T infrastructure	Increased sector exports and reduced import intensity	Improved UK share of global aerospace manufacturing and of OEMs
Creation of R&T infrastructure (most relevant for capital projects)		Stronger supply chains in the UK	Higher proportion of “flying technologies” developed in the UK
		Increased value added per employee	Improved reputation of UK aerospace industry
		Further collaboration between businesses and the research base, and potentially across sectors.	Spillovers of technology advancements into other sectors.

Source: ATI logic model

Contribution analysis and its application

As mentioned above, CA is a theory-based evaluation approach that "aims to define the links between each element of a logic model, and test and refine these theoretical links between the programme and the expected impacts. It provides a framework for analysing not just whether the programme has had an impact, but how that impact materialised and whether any particular element of the programme or contextual factors were crucial to the impact".[51]

Theory-based approaches such as CA can increase confidence that the intervention has had an impact (Befani and Mayne, 2014).[52] Instead of examining *"what would have happened in the absence of the intervention?"* such approaches ask: *"is there strong evidence that the intervention – rather than other factors – was critical in causing the outcomes observed/reported?"* CA uses an iterative six step process (set out in Table E-3 below) of evidence gathering and analysis to compare an intervention's postulated theory of change to the evidence of what happened in practice. We will apply this to the ATI programme in articulating the problem to be addressed and through the proposed research methods to collate and analyse the evidence. Importantly, CA will enable us to test the logic model and theory of change especially the hypotheses, assumptions and competing/complementary factors described in section 3. Thereby, we can provide a plausible explanation based on the evidence as to how far the ATI programme has progressed in line with the logic model at this early stage.

Table E-3: Contribution analysis

Steps in contribution analysis	Comment
Step 1: Set out the expected attribution problem to be addressed	Has the ATI programme led to more R&T investment, more/stronger collaborations, technical progress, location of production jobs in the UK etc. (as per the logic model in section 2)?
Step 2: Develop a theory of change and risks to it	See above for the theory of change, the underlying assumptions and competing explanations. This provides the steps in the process of progressing R&T projects, and the associated intended effects
Step 3: Gather the existing evidence on the theory of change	Gather evidence: project monitoring and assessment data, stakeholder interviews, and case studies
Step 4: Assemble and assess the contribution story, and challenges to it	Assess and synthesise the evidence from the fieldwork

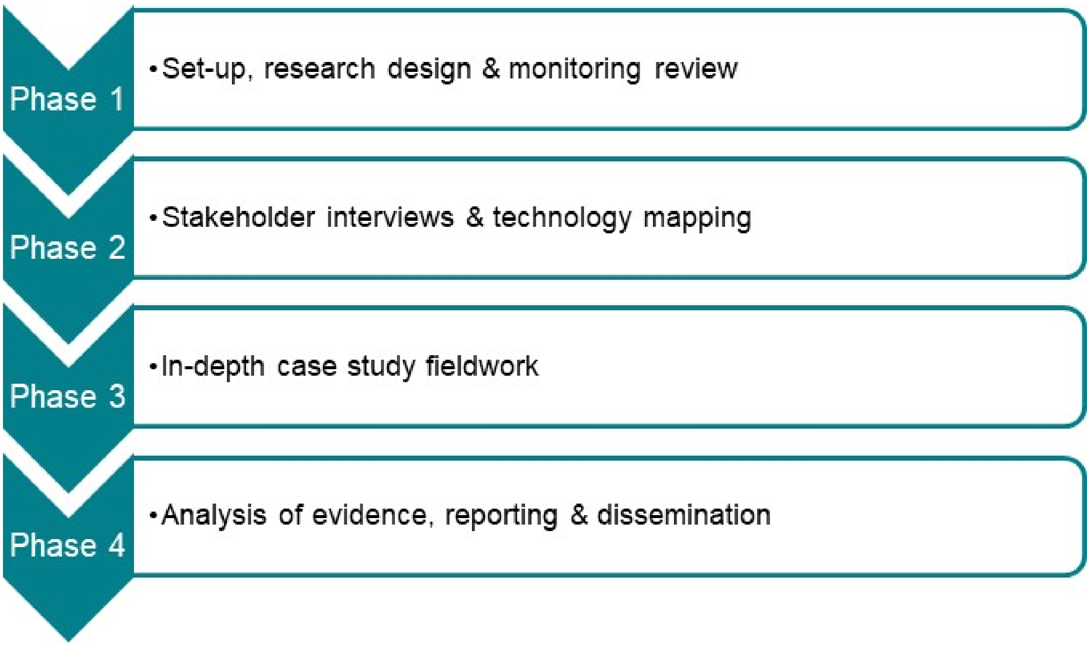
[51] Innovate UK (2018) *Evaluation Framework. How we assess our impact on business and the economy.*
[52] Befani, B. and Mayne, J. (2014) *Process Tracing and Contribution Analysis: A Combined Approach to Generative Causal inference for Impact Evaluation,* IDS Bulletin, Vol. 45 No. 6.

Steps in contribution analysis	Comment
Step 5: Seek out additional evidence	Principally, the expert workshop to stress test
Step 6: Revise and strengthen the contribution story	Arrive at a plausible explanation based on the evidence which can be qualitative and quantitative.

Source: Befani and Mayne (2014); SQW

Research methods

Our work plan involved four phases of activity (Figure E-1).



Source: SQW

Phase 1: Set-up and research design – This involved going back over the previous work completed to date, namely the scoping study, process evaluation, peer review and other documentation, as well as monitoring data, in order to refine the programme logic, and develop and agree the specific methodology for the early impact evaluation. This was supported by initial scoping discussions with key representatives from BEIS, ATI and Innovate UK. This phase was critical to refine and hone the evaluation questions, identify the specific evidence to be collected and analysed, and agree the detail of the methodology. The output of this phase was a methodology paper, including logic model, programme theory, key benefits to be assessed, and approach to data collection and analysis (including to assessing R&D spillovers).

Phase 2: Stakeholder interviews and technology mapping – This was one of two phases of data collection, involving interviews with stakeholder representatives from BEIS, ATI, Innovate UK, and other (see Annex A for list of stakeholders). The emphasis here was on understanding from an overarching perspective the early effects of the ATI, including within the wider sector and related sectors through technological developments, and the evolving landscape of innovation, research and technology (and how the landscape is affecting/will affect impacts). In addition, for the desk-based technology mapping exercise, ATI technologists helped produce a map to illustrate how the evaluation case study projects fitted in the wider ATI portfolio.

Phase 3: In-depth case study fieldwork – This phase was undertaken in parallel with phase 2, and involve15 case studies with projects, each involving up to 10 interviews. We agree sampling and selection with the client group before proceeding with engagement with the project lead organisations. Upon agreement with the case study process, we commenced the case study with each project. In effect each of these were mini-evaluations, requiring background research and preparation (informed by the data and document review in Phase 1), fieldwork interviews with project leads and project support organisations (from business, academia and research organisations), and analysis and write-up. The outputs of this phase were an initial set of consolidated findings from case studies completed, and then a final set of up to 15 case study write-ups to be used to inform Phase 4.

Phase 4: Analysis of evidence, reporting and dissemination – The final phase involved analysis and triangulation of the evidence, and an assessment of the evidence against the programme logic and theory of change. To support this, and to help draw together the top-down stakeholder perspectives, with the in-depth case study work, we held an expert stakeholder workshop (in June 2019). This helped to calibrate and stress test the findings against the programme logic and theory – thereby adding further rigour to the evidence. This was followed by the reporting process.

Annex F: Qualitative Comparative Analysis

Introduced by Charles Ragin (1987)[53], Qualitative Comparative Analysis (QCA) is a theory-driven approach that combines qualitative and quantitative methods to establish causation when comparing across a number of cases. The academic peer review of SQW's ATI scoping methodology report recommended using QCA when designing case studies (White and Matthews, 2018)[54]. The peer reviewers pointed out QCA as "useful for robust analysis of case studies where sample sizes are small". As part of the methodological stage, we considered how QCA could be applied to this evaluation. Following this, it was agreed with BEIS that **we would gather the evidence typically required in QCA through the case studies (which were important to inform the CA in any case) and would seek to apply a formal QCA for specific EQs** (where routes to impacts and other factors could be more readily articulated ex ante). Given the limited application of QCA in innovation policy this was seen as an experimental approach to complement the CA. One concern noted at the outset was that the dataset was small – with only 15 cases and relatively complicated pathways to outcomes – which could make it difficult to identify definitive conclusions.

We outline below what QCA is, and why it can be helpful to evaluations of programmes like ATI. The rest of the Annex then explains the process that was actually followed in the study.

What is QCA?

According to Ragin (2008)[55], QCA allows an assessment of causation that is complex, involving different combinations of causal conditions (or pathways) that can generate the same outcome. The aim is to identify the routes through which interventions have the impact that they do, rather than the "average" route (as typically the case through statistical analysis). It can be usefully applied to where there are small and intermediate-size "Ns" (e.g. 5-50). Importantly, QCA is an iterative process that facilitates a form of counterfactual analysis based on case-based, comparative research.

Through QCA, causal relationships can be established through explanatory factors and an outcome, which are expressed as logical statements of necessity and sufficiency (see definitions below), as opposed to qualitative comparisons or statistical correlations.

- **Necessary condition** is a condition that must be present for the outcome to occur, but its presence does not guarantee that occurrence.
- **Sufficient condition** is a condition that can produce the outcome by itself.

[53] Ragin, C.C., (1987) *The comparative method: Moving beyond qualitative and quantitative strategies.* Los Angeles: University of California Press.
[54] White, G. and Matthews, M., (2018) Review of Aerospace and Automotive Scoping Methodology Reports: Draft Final Report for BEIS.
[55] Ragin, C.C., (2008) *What is Qualitative Comparative Analysis.* University of Arizona.

In many instances, there are no purely sufficient conditions for outcomes to occur due to the complex nature of the environment in which these are expected to be realised. With QCA, it is possible to study these "INUS" conditions: *"Insufficient but Non-redundant parts of a condition which is itself Unnecessary but Sufficient for the occurrence of the effect".*[56] In our words this means that the condition is not causal, but without it the outcome may not happen, and in the context of ATI would mean that the ATI programme is not causal, but without the programme the outcome may not happen. According to Ragin (2008)[57], *"using QCA it is possible to assess causation that is very complex, involving different combinations of causal conditions capable of generating the same outcome".*

QCA is grounded in the analysis of "set" theory[58] (i.e. collections of cases of interest), not correlations as describe above. A central task involved in QCA is assigning cases to sets informed by several methods or data sources, alone or in combination. Set theory can help to understand causally complex patterns. In this regard, three concepts are important for understanding how and why the method differs from traditional quantitative and qualitative approaches:

- **Equifinality** - alternative factors can produce the same outcome
- **Conjunctural causation** - combinations of factors (of cases) produce an outcome[59]
- **Asymmetry** - if in one case x leads to y (i.e. x → y) then it is not assumed that in another case x will also lead to y (i.e. ~x → ~y).

While all types of QCA share this general set-theoretic framework, there are three main variants of QCA, which differ in terms of how this is implemented in practice. First, there is **"crisp set" QCA (csQCA),** which operates exclusively on sets where cases can either be full members or full non-members in the set (i.e., membership being scored dichotomously as either a "0" or a "1"). In contrast, **"fuzzy set" QCA (fsQCA)** extends crisp sets by allowing membership scores between "0" and "1". This permits the scaling of membership scores and thus allow partial membership. This perhaps better reflects reality as in many cases factors tend to vary by level or degree. Fuzzy membership scores address the varying degree to which different cases belong to a set, as follows:[60]

- A fuzzy membership score of 1 indicates full membership in a set; scores close to 1 (e.g. 0.8 or 0.9) indicate strong but not quite full membership in a set; scores less than 0.5 but greater than 0 (e.g. 0.2 and 0.3) indicate that objects are more "out" than "in" a set, but still weak members of the set; and finally a score of 0 indicates full non-membership in the set.
- Thus, fuzzy sets combine qualitative and quantitative assessment: 1 and 0 are qualitative assignments ("fully in" and "fully out" respectively); values between 0 and 1

[56] Mackie, J. L., (1965). *Causes and Conditions.* American Philosophical Quarterly, 12: 245–65.
[57] Ibid.
[58] Set theory is the branch of mathematical logic that studies sets, that is collections of cases of interest. In set theory, a "condition" is a "set". Sets combine in configurations (INUS) to produce outcomes.
[59] Note: factors or aspects of cases are referred to as 'conditions' in QCA.
[60] Ragin, C. C., (2008) *Qualitative Comparative Analysis Using Fuzzy Sets* (fsQCA).

indicate partial membership. A score of 0.5 indicates maximum ambiguity (fuzziness) in the assessment of whether a case is more "in" or "out" of a set.

A third QCA variant is **"multi-value"** QCA (mvQCA), which allows for multinomial categorical data to be used (e.g. not just 0 or 1 but 0, 1, 2, 3, 4). Multi-value QCA is identified in the evaluation literature as less used compared to the other two approaches.[61] In this paper, we focus on crisp and fuzzy set QCA because they are the two primary variants set-theory, and potentially relevant to answering our evaluation questions of interest.

Table F-1 illustrates fuzzy sets using three, four, and six-value fuzzy sets. The three-value set allows a third value, 0.5, i.e. neither fully in nor fully out of the set in question. The four-value scheme uses the numerical values 0, 0.33, 0.67 and 1.0 to indicate "fully out", "more out than in," "more in than out," and "fully in" respectively. This is useful where researchers have information about cases, but the evidence is not identical across cases. A more detailed fuzzy set uses six values, as shown in the fourth column.

Table F-1: Crisp versus fuzzy sets

Crisp set	Three-value fuzzy set	Four-value fuzzy set	Six-value fuzzy set	"Continuous" fuzzy set
1 = fully in 0 = fully out	1 = fully in 0.5 = neither fully in nor fully out 0 = fully out	1 = fully in 0.67 = more in than out 0.33 = more out than in 0 = fully out	1 = fully in 0.9 = mostly but not fully in 0.6 = more or less in 0.4 = more or less out 0.1 = mostly but not fully out 0 = full out	1= fully in Degree of membership is more "in" than "out": 0.5 < Xi < 1 0.5 = crossover: neither in nor out Degree of membership is more "out" than "in": 0 < Xi < 0.5 0 = fully out

Source: Ragin (2008)

[61] Vink, M. P. & Van Vliet, O. (2013). *Not quite crisp, not yet fuzzy? Assessing the potentials and pitfalls of multi-value QCA: Response to Them*. Field Methods, 25(2), 208-213.

How can QCA be useful for evaluating innovation programmes?

QCA is potentially useful for evaluations of programmes such as the ATI programme because it allows a robust analysis of evidence from case studies where sample sizes are small – e.g. 15 cases in this early impact evaluation of ATI. It combines qualitative and quantitative techniques to arrive at a more confident assessment of which factors alone or in combination contribute to the target outcomes, for example: increased R&T expenditure; jobs safeguarded/created in aerospace R&T; technologies reaching commercialisation stages (see logic model). This is pertinent given the various factors that can conceivably contribute to the intended (and intended) outcomes.

Further, QCA allows evaluators to test the relationships between key assumptions and external factors identified in a theory of change, and a given outcome or impact – across a set of cases. QCA can identify which of the factors tested are necessary or sufficient to obtain a successful outcome or impact. It can help to test and assess, in a more systematic way, the series of hypotheses, assumptions and alternative or complementary explanations as to how intended outputs and outcomes have been brought about (see logic model) - based on the refined logic model and drivers set out in section 3. In addition, we highlight the following for using QCA.

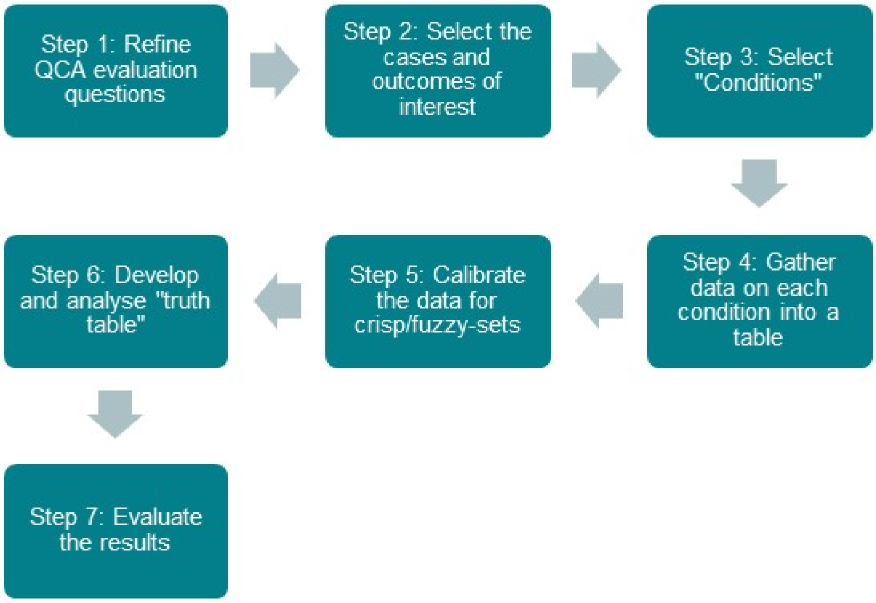
First, the QCA approach allows for *complex causation* involving different combinations of causal conditions (or pathways) that can generate the same outcome. The ATI programme can be considered both ‘complicated’ and ‘complex’. The ATI programme is ‘complicated’, because it has multiple components – supporting projects at different stages of R&D, with a range of intended outcomes over varying timeframes, and involving a wide range of partner beneficiaries (e.g. SMEs, multinational primes and academic institutions). It is ‘complex’, because there are potentially emergent and uncertain outcomes, in particular where spillovers may bring about unexpected benefits.

Second, QCA can establish alternative factors that can generate the same outcome (i.e. equifinality), and where combinations of factors (of cases) produce an outcome (i.e. conjunctural causation). For example, higher levels of funding from ATI, **and/or** focus on the right projects (through prioritisation), **and/or** increased/stronger collaboration between project partners could be viewed as factors contributing to technologies reaching commercialisation stage – progressing through TRLs.

How to apply QCA?

The evaluation literature identifies slight variations to how QCA is applied in practice. There is no exact or consistent approach. This partly reflects the nature of the intervention being assessed, availability of data, and this evolving area of evaluation practice. Nevertheless, we identify the ‘core’ steps typically used in QCA based on our review of the literature. These are shown Figure F-1.

Figure F-1: Steps in QCA



Source: Ragin (1987); SQW

QCA in practice

The rest of the Annex provides a comprehensive explanation of the QCA process as it was applied in the evaluation. The purpose here is both for transparency of the results given in the main body of the report, and also to document the application of QCA itself as the method was being trialled in this context. The structure is broken down into sections for methodology, results, discussion of findings in relation to three key questions, and conclusions. Terms given in italics can be referenced in the glossary.

Glossary

- *Calibration* – a process for quantifying data. This determines how information about each case is translated into variables to represent the *conditions*.
- *Case (or case study)* – an entity, person or organisation included in the sample of the research. In this research the cases are firms receiving ATI funding.
- *Conditions* – characteristics or properties of the cases. These are represented by variables that are based on the answers consultees gave in case study interviews.
- *Configurations* – a logical combination of one or more *conditions*. The combinations can include a mix of AND, OR and NOT operators. In a *truth table*, configurations do not use the OR operator.
- *Conservative (solution/approach)* – a strategy for deriving a solution. The conservative approach does not make assumptions about *logical remainders*. This approach leads to solutions that have more components.

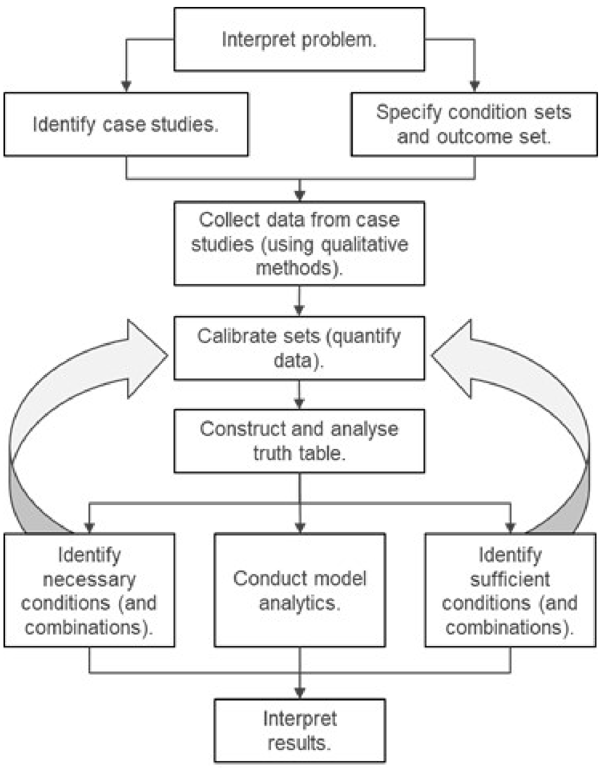
- *Consistency* – part of the results. This is a number between 0 and 1 representing the strength of a relationship. For a given *configuration*, this is the ratio of cases with and without the *outcome* variable. A high *consistency* implies that when observing that *configuration*, one would also expect to observe the *outcome*.
- *Contradictory truth table row* - a description of a *configuration* which contains cases both with and without the *outcome* variable. This leads to a mid-range *consistenc*y. One aim of repeated iterations to the analysis is to resolve these contradictions and produce coherent results.
- *Coverage* - part of the results. This is a number between 0 and 1 representing the relevance of a relationship. That is, the extent to which the *outcome* can be explained by a given relationship.
- *Data matrix* - a table with rows for each case, and columns for each *condition* (including the *outcome*). This is populated with interview data once that information is *calibrated.*
- *Limited diversity* - this is a description of *condition* that has little-to-no variation. A consequence is that the *truth table* will have unpopulated rows (see *logical remainders*). This makes the *condition* hard to analyse because there are few observations of the differences associated with that *condition*.
- *Logical minimisation* - an algorithmic process that compares *solutions* to identify any redundant variables. It reduces the *solution* to its core parts, using either the *conservative* or *parsimonious* approach.
- *Logical remainders* - a description of rows in the *truth table* that have not been assigned any *cases*. This means there are no observations of *cases* with the corresponding *configuration*. These can be processed with assumptions for the sake of simplicity (or *parsimony*), or without assumptions to retain a *conservative* solution.
- *Outcome* - an *outcome* is a particular kind of *condition*. The purpose of QCA is to identify how other *conditions* are related to the *outcome* in order to support an explanation for causality.
- *Outcome threshold* - a parameter used in the calculation of *solutions*. Effectively, this sets a cut-off point for how *consistent* a *configuration* must be if it is permitted to be part of a solution. A lower *outcome threshold* can capture more *configurations*, but a higher *threshold* captures only those with a stronger relationship.
- *Parsimonious (solution/approach)* - a strategy for deriving a *solution*. The *parsimonious* approach makes assumptions about *logical remainders*. This approach leads to solutions that have fewer components.
- *Row frequency* - a tally used in the *truth table*, representing the number of *cases* mapped to a given *configuration*. This is presented as a whole number, but when used in calculations it can take non-integer form when *cases* partially belong to more than one row.
- *Simplification* - a process to eliminate redundant variables from the analysis. This does not mean the *condition* is meaningless, rather, that it would not add any meaning to the conclusions.

- *Solution* - a label given to a *configuration* when it passes the *outcome threshold*. This represents the *conditions* QCA deems reasonable to cause the *outcome*. A *solution* can also be constructed from multiple *configurations* joined with OR operators.
- *Trivial necessity* - a *condition* can be given this label if it appears *necessary* (i.e. the *outcome* only appears with the *condition*), but the span of this *condition* is much broader than the *outcome*. Thus, it isn't a beneficial indicator.
- *Truth table* - a transformation of the *data matrix*; this table has one row for each possible *configuration* of the *conditions* (not including the *outcome*), and an additional column to list the cases that match those *configurations*. The table allows for calculation of the ratio of cases in each row with and without the *outcome* variable.

Overview

To give a summary of QCA's mechanisms: qualitative or quantitative data is collected. Qualitative data is converted into categories then quantified. The quantified data is used to map out each of the case studies so the difference between them can be compared systematically. One of the variables from the data is selected as an outcome – this becomes the focus of the analysis. Each of the other variables are tested to see how much influence they have on the outcome. The result is an indication of what variables are more, or less, associated with the outcome.

Figure F-2: Flowchart summary of QCA. The method is iterative.



Source: Adapted from Kahwati, L. C., Kane, H. (2018). Qualitative Comparative Analysis in Mixed Methods Research and Evaluation

The summary above can be expressed in the terminology of QCA as follows:

- data on pre-determined *conditions* is collected, quantified and stratified in a *data matrix*
- the conditions that characterise the system are explored fully in a *truth table* (including all *configurations* of conditions, i.e. all potential, hypothetical scenarios)
- the *data matrix* is mapped onto the *truth table*, populating each configuration with empirical evidence to suggest the causes of a given outcome
- algorithmic analysis produces indicators that describe the strength of these suggestions, explaining how conditions are linked to the outcome.

QCA is an iterative process. This enables the researcher freedom in reinterpretation of raw data, or adjustment of parameters. Doing so can add robustness to the analysis and create more coherent results (in a similar way to sensitivity analysis in impact modelling). The following section on methodology gives step-by-step commentary on how QCA was applied to one research question, as well as briefer commentary on how iterations of QCA were applied to a further two research questions.

Methodology

We applied QCA to outcomes where the expected causal pathways were relatively well articulated, and we can establish a relatively small set of clear factors (around 5) to test and assess. We then collected evidence against these factors and outcomes through the case studies so that an analytical framework could be populated and analysed using the steps of QCA identified above.[62] Taking all of this into account, we applied QCA to the following three outcomes:

- Projects progressing through TRLs
- Subsequent industry investment in R&T at TRLs 7-9
- R&T leads to plans to base production in the UK.

Table below sets out the three outcomes and the potential contributing conditions/factors to test and assess. These factors were informed by the logic model and theory of change, including the hypotheses and assumptions set out in section 3. We point out the following in relation to the table:

- we specify in the table how the outcomes will be measured
- we specify in the table how factors will be defined and measured, and these will be converted into binary crisp sets:
    - for those factors where responses are either “on” (yes) or “off” (no) this is straightforward

[62] The analysis is likely to involve appropriate software.

  - for those based on scales, where the data are “more in than out” it would be a ‘1’, and where they are “more out than in” it would be a ‘0’

- the evidence will be drawn from cases i.e. “projects”, including:
  - ATI-funded projects, and
  - other R&T projects that have been taken forward by companies that were unfunded by ATI (either unsuccessful project applications to ATI or other similar R&D projects that were taken forward through other means).

We discussed and agreed with the client the outcomes and factors identified in the table below.

Table F-2: Outcomes and factors

Outcome	Factors	Definition of factors
Project progressing through TRLs *As measured by the number of Levels progressed between start and finish*	ATI funding	Whether the project has received ATI funding or not
	Existence of other related R&T activities relating to the project	Whether or not there are other complementary R&T activities taking place at the same time
	Extent of technical impediments to project	Scale question on the perception of the extent to which the project faced technical impediments (incl. barriers to infrastructure)
	Satisfaction that the collaboration had the right expertise to take the project forward	Scale question based on perception of satisfaction with the collaboration and the expertise it brought
	Satisfaction that the collaboration had the right expertise to take the project forward	Scale question based on perception of satisfaction with the collaboration and the expertise it brought
	Extent to which the project continues to be aligned with the priorities of the lead partner	Scale question based on response on alignment (e.g. very, quite, etc.)
Subsequent industry investment in R&T *As measured by £ invested in, or sought for, R&T related to the project by all partners following project completion*	ATI funding	Whether the project has received ATI funding or not
	Extent to which ATI is perceived to generate greater certainty for UK R&D investment in aerospace	Scale based on a question on strength of perception (e.g. very, quite, etc.)

Outcome	Factors	Definition of factors
	Existence of other related R&T activities relating to the project	Whether or not there are other complementary R&T activities due to take place
	Extent to which the project continues to be aligned with the priorities of the lead partner	Scale based on response to a question on alignment (e.g. very, quite, etc.)
	Project progressed through TRLs	Whether or not the original project has progressed technologically
	Level of potential demand in the market for the technology relating to the project	Scale based on response to a question on level of potential demand (e.g. high, moderate, some, low)
	Alternative investment opportunities not relating to the project?	Scale based on perceptions of competing investment opportunities (e.g. no, limited, moderate, strong)
Plans to base production in the UK *As measured by extent to which lead partner is confident that production would be based in the UK upon commercialisation: percentage of production that is planned to be based in the UK*	Whether they have agreed an exploitation plan (or equivalent) with BEIS	Whether or not the lead has agreed an exploitation plan (or equivalent)
	Extent to which ATI is perceived to generate greater certainty for UK R&D in aerospace	Scale based on response to a question on strength of perception (e.g. very, quite, etc.)
	Extent to which lead partner is confident that sales will be generated	Scale based on response to a question on level of confidence (e.g. very, quite, etc.)
	Strength of existing supply chains in the UK relevant to this product	Scale based on response to a question on strength of supply chains (e.g. very strong, quite strong, etc.)
	Whether existing similar production based in the UK	Whether or not similar production already exists
	Extent to which Brexit may have adverse consequences for locating production in the UK	Scale based on extent of potential adverse consequences (e.g. none, small, moderate, large).

Source: SQW

Finally, it is worth clarifying that Contribution Analysis (CA) is the overarching approach for the early impact evaluation and the data required in QCA - through the case studies and stakeholder interviews - will be used to inform the CA on the three specific evaluation outcomes where routes to impacts and other factors are more clear ex-ante, as described in above.

Data collection

The purpose of QCA is to weigh the interaction of conditions, and to find the relative influence of various combinations of those conditions, in terms of coinciding with an outcome. Ideally, this leads to an explanation of the outcome.

This evaluation made three applications of QCA, seeking to understand the following outcomes:

- the progression of technology through Technology Readiness Levels (TRLs) 4-6 during the ATI-funded project
- the industry investment into R&T at TRLs 7-9 after the ATI-funded project
- the extent to which the project had an influence in basing production in the UK.

To explain these outcomes, data on four-to-six other variables were used as conditions (see Table F-3).

Table F-3: Case study questions incorporated into QCA

Outcome variable	Condition variable
Q1: Has the project progressed through TRLs (4-6)?	Q1a: Are there other complementary R&T activities taking place at the same time?
	Q1b: To what extent did the project face technical impediments, including barriers to infrastructure?
	Q1c: How satisfied are you that the collaboration had the right expertise to take the project forward?
	Q1d: To what extent does the project continue to be aligned with the priorities of your organisation?
Q2: Has the project generated subsequent industry investments in R&T (at TRLs 7-9)?	Q2a: To what extent does ATI generate greater certainty for UK R&D investments in aerospace?
	Q2b: Are there other complementary R&T activities taking place at the same time?

Outcome variable	**Condition variable**
	Q2c: To what extent does the project continue to be aligned with the priorities of your organisation?
	Q2d: Did the original project progress technologically?
	Q2e: What is the level of potential demand in the market for the technology relating to the project?
	Q2f: To what extent are there alternative investment opportunities not relating to the project that your organisation has also considered?
Q3: Has the project influenced plans to base relevant production in the UK?	Q3a: Has an exploitation plan or equivalent been developed for the project that specifically plans for UK-based production, e.g. a plan agreed with BEIS?
	Q3b: To what extent is ATI perceived to generate greater certainty for UK R&D investments in aerospace?
	Q3c: To what extent are you confident that sales will be generated?
	Q3d: How would you describe the strength of existing supply chains in the UK relevant to the product?
	Q3e: Does similar production already exist in the UK?
	Q3f: To what extent may Brexit have adverse consequences for locating production in the UK?

Source: SQW

All the above data were collected through qualitative consultations. The variables for the outcomes (the main part of the question) and condition (the sub-questions) was either binary or categorical, e.g. a binary yes/no, or along a scale, such as “very, quite, a little, not”.

A worked example of applying QCA to question one is provided below. Tables of results for questions two and three follow, before a discussion of these results.

Calibration

The first step in analysing the data is to prepare it in a form that can be used by the QCA algorithms. These algorithms require a complete set of numerical data.

Converting text to numbers

Qualitative responses were quantified through a process of *calibration*. For the first iteration of the QCA, the calibration of categorical data was done simply. Each of the categories (answers to the questions) belonged to a scale so they could be immediately converted to a decimal between 0 and 1 with equal spacing.

Table F-4: Example of different calibrations; i.e. translations of categorical into numeric data.

Question	Answer	First quantification	Alternative quantification
Q1	Yes	1	1
Q1	No	0	0
Q1a	Substantial	1	1
Q1a	Some	0.67	0.8
Q1a	Few	0.33	0.2
Q1a	None	0	0

This first, simple, quantification was revisited in later iterations of the analysis. Adjustments were made to skew the quantification in the 0-to-1 region. This can emphasise differences, which is useful in cases where the conclusions were less clear. Binary categories cannot be adjusted. The effects are noted in the discussion section.

Each of the questions in Table F-3 were calibrated in the manner of Table F-4, allowing the data from interviews to be quantified.

Dealing with missing data

The data gathered from interviews were incomplete. Two strategies were adopted for such instances. Either imputing a value to complete the dataset for a case, or to remove that case from the analysis if it had too many gaps.

In QCA, one can add or remove cases based on assessment of their viability. In seven instances, a case study could not provide adequate data related to either an outcome or the majority of its associated conditions. Those seven cases were removed from analysis. Leaving them in would have necessitated imputing more data than would be viable for robust results. This left 14 cases for question 1; 13 cases for question 2, and 11 for question 3.

Simplification

In addition to removing cases, conditions were also eliminated where it led to a simpler analysis. This was done in situations of *limited diversity*, where there was no variation in a given variable.

Limited diversity in condition variables

Limited diversity in the condition variables means that there exist potential configurations of conditions that are not evidenced by the data. It is impossible to draw conclusions about that condition. Whilst, the resolution taken here was to remove those conditions from the QCA process, it is important to remain mindful of them when drawing conclusions. Three examples are provided below.

In the analysis of the first question on progression through TRLs 4-6, the sub-question Q1c, on the expertise of the collaboration, only ever received answers of “very satisfied”. Zero cases were observed where a collaboration’s expertise was less than “very satisfying” – so, nothing could be deduced about the implications of an unsatisfactory collaboration. Effectively, there was no evidence from which to deduce anything, so the relevance of a collaboration’s expertise is unproven *within QCA*. This does not mean that the factor is irrelevant, only that using QCA cannot tell us whether the factor is irrelevant.[63]

Similarly, conditions were also removed from the second question (on the project influencing further industry investment in R&T at TRLs 7-9). Respondents all stated that ATI funding generated greater certainty in R&D investment into UK aerospace (Q2a), and that the original project had progressed technologically (Q2d). Respondents were also unanimous in saying there was “high” potential demand relating to the technology (Q2e).

Dealing with limited diversity in outcome variables

Limited diversity also affected the third question, although the problem here was with the outcome variable. Every case study gave a positive answer to the main part of the question: that ATI-funding has had an influence on the leads’ plans to base production in the UK. Without any observed cases in the negative, QCA could not suggest what was actually causing the outcome. However, to extract more meaning from the data, the outcome variable was redefined. The intersection of Q3 and Q3a was defined as the new outcome variable. That is, the influence on UK production *and* the development of an exploitation plan. The rationale supporting this change was that the new, stricter, outcome was similar in nature and implication to the original outcomes, whilst also presenting the diversity needed to use QCA.

Data matrices and truth tables

The tables below depict the data as it was harvested from interviews, its quantification, then the simplification steps (as described above).

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[63] In this example, it is intuitive that the collaboration’s expertise is relevant. Likely, good expertise is always present for projects that reach the funded status. Effectively, the point of using QCA here was to find out the extent to which the collaboration’s expertise was relevant, i.e. the sensitivity of the outcome to the condition of the expertise. Unfortunately, that sensitivity cannot be tested.

Table F-5: Data matrix for the 15 cases and their quantified answers the first QCA question (before simplification)

Outcome variable		**Condition variables**			
Case	**Q1: TRL progression through 4-6**	**Q1a: Complementary R&T**	**Q1b: Technical impediments**	**Q1c: Right expertise**	**Q1d: Still aligned?**
Airbus (FOAF)	1	0	0.67	1	1
Airbus (WDMA)	0	1	1	1	1
Airbus (WIST)	1	1	1	1	1
Rolls Royce (Advanced 3)	1	0	1	1	1
Rolls Royce (Advanced Repairs)	0	0	1	1	1
Rolls Royce (Advanced Turbine)	0	1	0.67	1	1
Collins	1	0	0	1	1
GE	1	1	0.67	1	1
GKN	1	1	0.67	1	1
Leonardo	1	0	1	1	1
Safran	0	0	1	1	1
Thales	1	0	0	1	0.67
AMRC	1	1	0.67	1	1
ARA	1	1	0.67	No data	1
Queen's University	No data	No data	No data	No data	No data

Source: SQW analysis of case study interviews

The data table above is taken after the initial quantification, using the original calibration. As expressed in the previous section, this table was simplified to account for limited diversity and missing data (removal of column Q1c and the row for Queens University).

Table F-6: Simplified data matrix for Q1

Case	Q1: TRL progression through 4-6	Q1a: Complementary R&T	Q1b: Technical impediments	Q1d: Still aligned?
Airbus (FOAF)	1	0	0.67	1
Airbus (WDMA)	0	1	1	1
Airbus (WIST)	1	1	1	1
Rolls Royce (Advanced 3)	1	0	1	1
Rolls Royce (Advanced Repairs)	0	0	1	1
Rolls Royce (Advanced Turbine)	0	1	0.67	1
Collins	1	0	0	1
GE	1	1	0.67	1
GKN	1	1	0.67	1
Leonardo	1	0	1	1
Safran	0	0	1	1
Thales	1	0	0	0.67
AMRC	1	1	0.67	1
ARA	1	1	0.67	1

Source: SQW analysis of case study interviews

The data matrix contains all the relevant information needed by the QCA algorithms. The initial step of the algorithm is to transform the matrix into a more suitable format: a truth table.

A truth table lists all possible configurations of the conditions, regardless of whether they were observed in practice. There is a row for every configuration with and without each of the three conditions. Each row of the data matrix is mapped onto the closest suitable row in the truth table. All the rows (cases) mapped to each configuration are collated. The number of cases in a row is called the *row frequency*. The number of cases in that row that possess the outcome variable is the *outcome frequency*. In the table below the bottom row is for the configuration Q1a=1 and Q1b=1 and Q1d=1. There are seven cases mapped to that configuration, and five of them have the outcome variable (progression through TRLs 4-5).

Table F-7: Truth table of the simplified, populated with cases from the data matrix, for the first QCA question

Q1a	Q1b	Q1d	Cases (outcome variable)	Outcome frequency	Row frequency
0	0	0	-	0	0
1	0	0	-	0	0
0	1	0	-	0	0
1	1	0	-	0	0
0	0	1	Collins (1), Thales (1)	2	2
1	0	1	-	0	0
0	1	1	Airbus FOAF (1), Rolls Royce Advanced 3 (1), Rolls Royce Advanced Repairs (0), Leonardo, Safran (0)	2	5
1	1	1	Airbus WDMA (0), Airbus WIST (1), Rolls Royce Advanced Turbine (0), GE (1), GKN (1), AMRC (1), ARA (1)	5	7

Source: SQW analysis of case study interviews

There are two issues present in the above truth table that may hinder satisfactory results. The aim of the iterative analysis is to produce clear, convincing explanations. But there are unpopulated rows, representing unknowns, as well as disagreement within rows, representing inconsistencies. Two kinds of adjustments can be made at this stage.

Refining the truth table

Of the truth table's eight combinations, it can be seen that only three are populated with cases. The rows without cases mapped to them are *logical remainders*. As before, this problem is driven by limited diversity.[64] However, the strategy for reconciliation here differs from that discussed above. Whereas before there was unanimity on expertise (Q1c) and that condition was removed from the analysis, now, the question on alignment (Q1d) is not generating sufficient variation with the current calibration. For Q1d all cases responded that the project continues to be "very" (=1) aligned with their organisation's priorities, except for Thales, who responded "quite" (=0.67). Consequently, the truth table has space for cases with little or no alignment, but all observations cluster away from that region. Instead of removing Q1d from the analysis, it is feasible to recalibrate the quantification, to pry apart the difference and foster greater diversity. Assigning a lower value to "quite" in Q1d (e.g. 0.2) resolves some of the limited diversity. Practically, this can be interpreted as emphasising the discrepancy; it would

[64] The challenge of limited diversity in this application of QCA can be attributed to the small sample size in conjunction with a relatively large number of conditions. Though that challenge necessitates adjustments to the method, such adjustments are explorative processes which are themselves informative.

move Thales to the first row of the table above. The effects of this recalibration are discussed in a later section.

The outcome variables for each case can also be adjusted at this stage (i.e. in later iterations). Adjusting the outcome has a consequent effect on the row consistency as the adjustment alters the ratio of cases with and without the outcome variable. Significantly, doing so can resolve *contradictory truth table rows*, i.e. disagreement in the truth table. Take the case, Airbus WDMA. In this example, it would be fair to reassess the borderline used for interpreting answers to Q1. The technology in this project progressed up to TRL 4, but not beyond. Though it surpassed proof of concept, the technology was not scaled up to larger-sized demonstrators. For that reason, in the original quantification, Airbus WDMA was given a zero for its outcome variable. However, the reason WDMA's progression was restrained was due to a decision made halfway through to use a different material. This setback hides the extent of progression made during the project. Arguably, WDMA's outcome variable for progression of technology could be set to one: enough TRL steps were passed (albeit some repeatedly), and the findings about the new material were notable. Such an alteration is dependent on what the research is trying to understand through the outcome variable. Again, the consequences are explored later.

Analysis

Consistency

In analysing a truth table, the next step is to calculate *consistencies*, that is to consider the proportion of the cases in each row which possess the outcome variable (the answer to Q1). If the calibration of every variable were binary, then the calculation of consistency would have been a straightforward ratio. But, as the calibration was categorical, the consistency calculation is more complex. This is because cases can have partial membership in more than one row of the truth table.[65] When cases from the data matrix are mapped onto the truth table, they are put in the most suitable row, but they may partially exist in more than one row.

Consistency can be conceptualised as a proportion; the actual calculation of the proportion for fuzzy set logic is not given here. Suffice to say, the row consistencies for Table F-7 were computed using the Excel plugin written by Lasse Cronqvist.[66] The row consistencies are given in Table F-8.

The next step involves the introduction of more parameters. In particular, an *outcome threshold* needs be implemented. This threshold determines the level of consistency necessary for a row of the truth table to be chosen for further analysis. A high threshold (0.9-1) reflects an exacting requirement; here, the relevant configurations in the truth table are nearly always associated with the outcome. Only where the row consistency is above the threshold is that configuration given an outcome of 1; this row is then included as part of the *solution*. The calculation of

[65] Binary calibrations are used in crisp QCA. Non-binary calibrations are used with *fuzzy* set logic. Further elaboration is given in the Methodology Paper.
[66] Cronqvist, Lasse. 2019. QCA Add-In [Version 1.1]. University of Trier. https://www.qca-addin.net

consistencies is made only on populated rows of the truth table. Logical remainders are not given consistencies. As such, only three rows from Table F-8 are presented below.

Table F-8: Truth table with row consistencies. The threshold is set to 0.9.

Case	Q1a: Complementary R&T	Q1b: Technical impediments	Q1d: Still aligned	Q1: TRL progression through 4-6	Row consistency
Collins, Thales	0	0	1	1	1
Airbus (FOAF), Rolls Royce (Advanced 3), Rolls Royce (Advanced Repairs), Leonardo, Safran	0	1	1	0	0.572
Airbus (WDMA), Airbus (WIST), Rolls Royce (Advanced Turbine), GE, GKN, AMRC, ARA	1	1	1	0	0.688

Source: SQW analysis, Lasse Cronqvist QCA add-in

In Table F-8 the outcome threshold is set to 0.9. Any rows with a consistency equal to or above 0.9 are given 1 for their outcome variable (the shaded column). Such rows are considered part of the solution. In the example above, this leaves only the top row as part of the solution. Here, the solution is the configuration of: no complementary R&T activities, no technical impediments and alignment with the organisation's current objectives (Q1a=0 and Q1b=0 and Q1d=1).

There are then two directions of study to analyse this solution: *conservative* (without using the logical remainders) or *parsimonious* (with using the logical remainders). Recall, the logical remainders in this example are the five rows that were excluded from Table F-8.

With either the conservative or parsimonious approach, the next step of QCA is to simplify the solution(s) through *logical minimisation*. This process filters out redundant conditions; i.e. if the outcome is present both with and without a given condition, then that condition can be removed to leave a system that is simpler. Inclusion of logical remainders at this minimisation stage invokes more assumptions but can yield simpler solutions.

The solution identified above, 'Q1a=0 and Q1b=0 and Q1d =1', cannot be simplified solely based on the information in Table F-8. However, logical minimisation is possible with an algorithm that makes assumptions on the outcomes of logical remainders. For instance, assume the configuration 'Q1a=0 and Q1b=0 and Q1d =0' has an outcome of 1. Combining this with the solution above, means that the condition Q1d can be removed – with or without that condition, the outcome is unaffected. Thus, the condition is redundant and can be removed. The following table gives the solutions at the end of the algorithm for logical minimisation.

Table F-9: Solutions to question one on TRL progression

Approach	Solution	Consistency	Coverage
Conservative	Q1a=0 and Q1b=0 and Q1d=1	1	0.2
Parsimonious	Q1b=0	0.917	0.365

Source: SQW analysis, Lasse Cronqvist QCA add-in

Sufficiency and necessity

After minimisation, solutions are paired with indicators that describe their sufficiency and necessity:

- Sufficiency – does the outcome occur with those conditions
- Necessity - does the outcome *only* occur with those conditions

The indicators for sufficiency and necessity are consistency and *coverage*, respectively. As above, consistency for a solution is the number cases with the outcome in that solution divided by the total number of cases in that solution. For coverage, the numerator is the same but that is instead divided by the total number of cases with the outcome in the whole system; i.e. how many of the outcomes are captured by that solution.

In Table F-9 there is only one conservative solution and one parsimonious solution. Both have high consistency but fairly low coverage. The interpretation is that QCA has confidently identified conditions that will lead to the desired outcome but that those conditions are only part of the story. Even the parsimonious approach only captures a minority of the outcomes. The solution is adequately sufficient but far from necessary. In practical terms, not having technical impediments (Q1b) gives a good likelihood of progression through TRLs 4-6. But where there are technical impediments, other factors can compensate.

Results

This section of the annex gives the data matrices and truth tables for the remaining two questions in the analysis.

Subsequent industry investment at TRL 7-9

Parts a, d and e were removed due to their limited diversity. Also, two case studies were eliminated as those interviews did not produce enough data for analysis. The resultant data matrix is given below.

Table F-10: Simplified data matrix for the second QCA question.

Outcome variable		**Condition variables**		
Case	**Q2: Subsequent industry investment at TRL 7-9**	**Q2b: Complementary R&T activities**	**Q2c: Align with organisation's current priorities**	**Q2f: Alternative investment opportunities**
Airbus FOAF	1	0	1	0.67
Airbus WDMA	1	1	1	0.33
Airbus WIST	1	1	1	0.33
Rolls Royce Advanced 3	0	1	1	1
Rolls Royce Advanced Repairs	1	1	1	1
Rolls Royce Advanced Turbine	1	1	1	0.33
Collins	0	0	1	0
GE	1	1	1	0
GKN	1	1	1	0.33
Leonardo	0	0	1	0.33
Thales	1	1	0.67	0.67
AMRC	0	1	1	0.33
Queen's university	1	1	0.67	0.33

As with question one, the alignment of priorities (Q2c) generates little variation. This limited diversity is telling of the nature of the ATI-funded projects, that they remain core to partners.

Table F-11: Truth table for question two

Case	Q2b: Complementary R&T activities	Q2c: Aligned with priorities	Q2f: Alternative investment opportunities	Q2: Outcome	Consistency
Collins, Leonardo	0	1	0	0	0.167
Airbus FOAF	0	1	1	0	0.667
Airbus WDMA, Airbus WIST, Rolls Royce Advanced Turbine, GE, GKN, AMRC, Queen's university	1	1	0	1	0.875
Rolls Royce Advanced 3, Rolls Royce Advanced Repairs, Thales	1	1	1	0	0.714

For this truth table the highest row consistency is 0.875, this lower than the consistencies from Q1. Maintaining a threshold of 0.9 would cut short the analysis as no row would be deemed part of a solution. Thus, the threshold is weakened to 0.8. This means that slightly weaker relationships are considered. However, 0.8 is the default suggestion for the outcome threshold as given in guidance.[67]

[67] Kahwati, L. C., Kane, H. (2018). Qualitative Comparative Analysis in Mixed Methods Research and Evaluation

Table F-12: Solutions to question two on industry investment

Approach	Solution	Consistency	Coverage
Conservative	Q2b=1 and Q2c=1 and Q2f=0	0.875	0.519
Parsimonious	Q2b=1 and Q2f=0	0.875	0.519

Source: SQW analysis, Lasse Cronqvist QCA add-in

The solutions here intimate that the presence of complementary R&T activities along with the absence of alternative investment, is a good indicator that the project will generate subsequent investment at TRLs 7-9. As before, the issue of alignment was pared out in the parsimonious solution.

Has the project influenced plans to base relevant production in the UK and has an exploitation plan been developed that specifically plans this?

For the third question, none of the sub-questions was eliminated. But, four of the cases were removed due to lack of usable data.

Table F-13: Data matrix for question three

Case	Q3&Q3a: Exploitation plan in UK	Q3b: Certainty in UK R&D	Q3c: Sales confidence	Q3d: Supply chains	Q3e: Similar production	Q3f: Brexit impacts
Airbus FOAF	1	1	1	0.33	0	1
Airbus WDMA	0	1	1	0.33	0	1
Airbus WIST	1	1	1	0.67	0	1
Rolls Royce Advanced 3	0	1	1	0.67	0	0.33
Rolls Royce Advanced Turbine	1	1	1	0.33	1	0.33
Collins	1	0.67	1	0.33	0	0.67
GE	0	1	0.67	0	0	0.33
GKN	1	1	1	0.67	0	1
Leonardo	0	1	1	0.33	0	0.7*

Case	Q3&Q3a: Exploitation plan in UK	Q3b: Certainty in UK R&D	Q3c: Sales confidence	Q3d: Supply chains	Q3e: Similar production	Q3f: Brexit impacts
Safran	0	1	1	0.4*	0.1*	0.67
AMRC	0	1	1	0.4*	0	1

**These data were missing, the imputed values represent an average of the column*

The outcome variable for this question suffered limited diversity. As outlined earlier, a new outcome was defined as the original outcome intersected with the company having an exploitation plan.

Table F-14: Truth table for question three

Case	Q3b: Certainty UK R&D	Q3c: Sales confidence	Q3d: Supply chains	Q3e: Similar production	Q3f: Brexit impacts	Q3&Q3a: Outcome	Consistency
GE	1	1	0	0	0	0	0.17
Airbus FOAF, Airbus WDMA, Collins, Leonardo, Safran, AMRC	1	1	0	0	1	0	0.38
Rolls Royce Advanced Turbine	1	1	0	1	0	1	0.87
Rolls Royce Advanced 3	1	1	1	0	0	0	0.20
Airbus WIST, GKN	1	1	1	0	1	0	0.53

Source: SQW analysis, Lasse Cronqvist QCA add-in

As with question two, the threshold for the outcomes here was chosen to be 0.8. In this case, there is only a single case in one configuration that meets this threshold: Rolls Royce Advanced Turbine.

Table F-15: Solutions to question three on basing production in the UK, with an exploitation plan

Approach	Solution	Consistency	Coverage
Conservative	Q3b=1 and Q3c=1 and Q3d=0 and Q3e=1 and Q3f=0	0.87	0.13
Parsimonious	Q3e=1	0.91	0.20

Source: SQW analysis, Lasse Cronqvist QCA add-in

Only one case included the presence of similar production. This case also generated the outcome of basing production in the UK. Thus, it creates a sufficiency condition with high consistency but low coverage. In question one, a similar type of result held implications for further analysis of the cases that did not present the sufficiency condition (i.e. how cases overcame technical impediments to progress through TRLs). However, here the implication is to recommend carrying out further analysis of the case with the sufficiency condition – this case is unique and merits investigation. The question here would be to ascertain if the uniqueness is of critical importance or is simply an anomaly.

The results presented above give the initial findings before iterations of manipulation and adjustment. Subsequent results are not presented here for reasons of brevity, but the effects are analysed and discussed below.

Discussion

Question 1: progression through TRLs 4-6

The initial result implies that not facing technical impediments is a strong and sufficient condition for TRL progression. However, that result had low coverage. Another iteration using different calibration resulted in higher coverage. Changing the quantification of responses to emphasise the difference in answers to Q1b so that “some” is given a value of 0.5 as opposed to 0.67 produces a very different truth table. With this calibration, six cases shift into a different configuration. That new distribution then increases the coverage of Q1b=0 (no technical impediments) up to 0.45 with a consistency of 0.9. This adds robustness to the argument that technical impediments are the driving factor. It is not possible to emphasise the differences in the other main variable, complementary R&T activities, because that format is binary.

Figure F-3: Visualisation of the recalibration of Q1b. An ‘x’ represents a case with the outcome variable and an ‘o’ represents a case without. Those highlighted in red are the cases that have shifted configuration.

	No technical impediments	Technical impediments	Frequency (outcome / total)
No complementary R&T	xx	oo xxx	5/7
Complementary R&T		oo xxxxx	5/7
Frequency (outcome / total)	2/2	8/12	10/14

	No technical impediments	Technical impediments	Frequency (outcome / total)
No complementary R&T	xxx	oo xx	5/7
Complementary R&T	o xxxx	o x	5/7
Frequency (outcome / total)	7/8	3/6	10/14

Source: SQW

The figure represents the distribution of cases with and without the outcome variable. The recalibration does not change the total number of cases with the outcome, but it does shift half of them to the left. The additional analysis shows that the QCA result is sensitive to the recalibration of Q1b (technical impediments), highlighting its importance.

In the top table, before recalibration, the majority of cases are classed as having faced technical impediments. The conjunction with complementary R&T only slightly improves the proportion with the outcome. In the bottom table, the distribution is more even. The presence/absence of complementary R&T has no effect on the proportions of cases with the outcome. Conversely, the condition of technical impediments has great influence.

It is worth considering the conclusions above with the other conditions Q1c and Q1d (satisfaction with the consortium’s expertise, and alignment with the organisations priorities). Whilst the issue of technical impediments is evidenced as being significant, this cannot be given precedence over the other, discarded conditions. There is insufficient data for comparison.

Question 2: investment in TRLs 7-9

In contrast to the previous question, here the presence of complementary R&T activities (Q2b) intersected with the absence of alternative investment opportunities (Q2f) is the most consistent factor driving the outcome variable. And, more so than the previous question, the coverage is higher. As before, the condition of alignment was eliminated in the parsimonious approach.

As with the previous question, there is only one condition to adjust with recalibration – Q2b is a yes/no question so cannot be recalibrated. Skewing the quantification for alternative investment opportunities, Q2f, can tease out another solution: the absence of complementary R&T and the presence of alternative investment. That is, as well as the original solution Q2b=1 & Q2f=0, there is another solution Q2b=0 & Q2f=1. This suggests that either one or the other, but not both, conditions have a likelihood to lead to the outcome.

Another adjustment for this question is to reassess cases for the outcome variable. In particular, the AMRC was coded with a 0 for the outcome, but only because it had not generated the subsequent investment at the time of interview. Then, the AMRC had secured investment up to TRL 6 – quite feasibly it could have since gone farther up the scale. Amending the AMRC's outcome to 1 has the effect of inducing full consistency in the Q2b=1 & Q2f=0 configuration.

Distinguishing the two variables Q2b and Q2f for precedence is difficult. Table F-11, the truth table for Q2, shows that there is more consistency to configurations with Q2b as opposed to without Q2f. This suggests that Q2b=1, the presence of complementary R&T, is more significant. However, this is a weak claim as there are only three cases where Q2b=0.

Another direction of analysis is to perform QCA on the complement of the outcome, i.e. what conditions lead to the outcome *not occurring*. The results here indicate that absence of both conditions is consistent with the complement of the outcome (consistency = 0.84, coverage = 0.42). This analysis highlights that there is a configuration with no alternative investment opportunities that consistently does not lead to the outcome. Thus, Q2f=0 can be devalued as a causal factor in the outcome Q2.

Considering all these means of study suggests that Q2b=1, the presence of complementary R&T, is the stronger causal factor in subsequent industry investment. Although, more data could be illuminative. As above, the other conditions which were eliminated from the QCA due to limited diversity aren't excluded from the conclusion. Q2a and Q2d (certainty about UK R&D and progression of technology in the original project), are likely *trivial necessary conditions*, that is, the Q2 outcome only ever appears with those conditions, but those conditions shouldn't be taken as an indicator of the outcome.

Condition Q2e, on the potential demand for the technology, was eliminated because too many respondents were unable to answer the question. However, if such refusals are coded rather than discarded it is possible to incorporate them in to QCA. Curiously, the result is that refusal to answer Q2e is associated with a positive outcome to Q2. i.e. those firms that wouldn't state the level of potential demand for the technology were more likely to be generating subsequent investment at TRLs 7-9.

Question 3: Influence on plans for UK-based production

The results from Q3 were hardest to analyse in depth. There was no diversity in the original outcome. This permits the strong claim that ATI-funding has a positive influence on firms' plans to base their production in the UK. Intuitively, this makes sense; and there is no observed evidence in contradiction. Further analysis was pursued with the condition Q3a, developing an exploitation plan, becoming the new outcome.

QCA results for the new outcome only identified one configuration with viable consistency (Q3e=1, similar production elsewhere in the UK). This one configuration was only populated by a single case (Rolls Royce Advanced Turbine) and consequently suffered low coverage. Immediately, this has an implication to recommend studying that issue in greater detail to understand the relationship between the new outcome, Q3a, and the relevant condition, Q3e.

Similarly, the case of Safran could be pursued for further study. For Safran, the interview gathered an indeterminate answer to the original outcome, Q3.[68] Further analysis here is relevant as this was the only instance of the outcome not definitively occurring.

For QCA on the new outcome, recalibrating the quantification fails to generate a substantially different result. Effectively, the distribution of those cases with the new outcome variable is evenly spread across the different configurations. It is plausible that the addition of more cases would improve consistency in some configurations. Equally, it is plausible that it would reduce the one and only area of consistency detailed above.

The QCA calculations were also taken on the complement of the outcome, that is, to understand what was influencing those cases which did not produce an exploitation plan. The parsimonious solution pointed towards the absence of similar production intersected with low estimation of Brexit impacts. This solution makes sense, in that without competition or concern for the instability of Brexit, firms did not face strong encouragement to develop an exploitation plan. However, the coverage for this solution was also relatively low, 0.32.

In summary, several variables have been identified which have some influence over the new outcome, although the evidence is not strong enough to form solid conclusions. Retrospectively, this issue of limited diversity in the original outcome variable could have been avoided if answers to the respective question were sought on a scale (e.g. very influential to not at all influential). It would then have been possible to calibrate the analysis to look for the conditions that generated more or less influence.

[68] Coding Safran's answer as a 0 and performing QCA with the original outcome yields the exploitation plan, Q3a, as the fully consistent solution. However, this QCA is not entirely viable, given that only one case would then be presenting the lack of the outcome variable.

Conclusions

The QCA method was successful in providing a platform for evidence-based assertions about questions 1 and 2.

For Q1, the absence of technical impediments, as opposed to the presence of complementary R&T, was more tightly related to progression through TRLs 4-6. Effectively, if there are no technical impediments, the project should progress. In general, this could be interpreted as the difficulty faced from a negative factor being more damaging than any constructive help coming from a positive factor.

For Q2, the presence of complementary R&T activities along with the absence of alternative investment was associated with investment in R&T at TRLs 7-9. The implication here is that if the firm has a portfolio of research related to the technology, but that there are few other avenues to take, then that original technology will be taken forward. Analysis also showed that the presence of complementary R&T is slightly more influential than the absence of alternatives.

For Q3, the only firm conclusion to draw is that ATI funding always has an influence on firms' plans to base production in the UK, at least under the conditions observed. But, this conclusion is caveated because there was not one observed case with low sales confidence nor a case where ATI funding was not perceived to generate greater certainty for UK R&D investments in aerospace.

For all three questions, limited diversity was a significant challenge. The clustering of data meant that the QCA algorithms could not test the significance of several variables which therefore had to be excluded from the analysis. The application of QCA is therefore of limited utility in this case. However, it was impossible to predict the responses from the 15 case studies beforehand so whilst this problem could be anticipated it could not be prevented. This problem is likely inherent in the nature of this kind of data gathering. Firms taking part in the research are all receiving substantial quantities of funding, and there may be a degree of bias in presenting a positive outlook for the programme. Accordingly, too much focus may have been given to outwardly positive areas, preventing any in-depth understanding of negative issues. Consequently, this hinders study into what could make ATI funding less successful.

Annex G: Approach to assessing R&D spillovers

R&D spillover effects are among the types of outcomes that are most challenging to assess. Nevertheless, they are an important part of the theory of change. The literature points out that the aerospace industry is associated with high R&D intensity and a high degree of interconnectedness between different actors (e.g. suppliers, collaborators, competitors) and sectors, resulting in substantial **market, knowledge and network spillovers** (see below). The aerospace industry is R&D intensive and relies heavily on innovation for growth. This innovation has the capacity to create substantial positive spillover effects for the rest of the economy.[69] However, since aerospace firms undertaking R&D activities are only able to appropriate a fraction of this full social benefit, (without support) they tend to underinvest in R&D relative to the socially optimal level. To ensure these positive externalities are not lost, there is a need for government intervention (e.g. in the form of investment).

Further, evaluations of public R&T interventions typically focus on the output of the firm that develops the innovation but there is good reason to expect that customers and other firms will often benefit significantly from innovations further along the supply chain or in adjacent markets. The research[70] indicates that these effects are likely to be large and positive and that excluding them risks significantly underestimating the return on the government's investment. There is no simple way to estimate the scale of spillover benefits, but more could be done to identify the types of spillovers and factor in how and where they occur.[71] Given this, it becomes more important to evidence the types of spillovers.

Jaffe et al (1996)[72] categorised spillover effects into three 'types':

- **Market (or rent)** - the workings of the market(s) for an innovative product or process create benefits for consumers and non-innovating firms. When a firm creates a new product, or reduces the cost of producing an existing product, market forces will tend to cause some of the benefits to be passed on to buyers
- **Knowledge** - knowledge created by one firm that spills over into other firms, creating value for them and their customers (i.e. public good)
- **Network (or product)** - this occurs where there are interdependencies between certain technologies. The profitability of a set of interrelated and interdependent technologies may depend on achieving a critical mass of success. As a result of these relationships, each firm pursuing one or more of these related technologies creates economic benefits for other firms and their customers.

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[69] Fathom Consulting (2015) *How Government can make a difference – assessing the potential impact on the UK economy of investing in UK Aerospace Technology, through ATI.*
[70] SQW for BEIS (2018) *Innovation, productivity and spillovers.*
[71] Ibid66.
[72] Jaffe, A.B. (1996) *Economic Analysis of Research Spillovers Implications for the Advanced Technology Program,* Brandeis University and National Bureau of Economic Research.

Table G-1 presents the three types of spillovers identified above and describes how they may occur in the aerospace sector and where they are likely to experienced: businesses in the supply chain, customers, competitors and collaborators.

Table G-1: Spillovers in the aerospace industry

	How?	**Where?**
Market (or rent)	Aerospace research often takes longer than most other sectors to commercialise and is may be brought to market in other industries before it is used on aircraft, leading to additional benefits for the consumers and supply chains. R&T projects require a degree of technical integration in an aircraft, for example engines and wing might be from different companies in the supply chain but need to be integrated. The workings of the market for this process may create benefits for suppliers and consumers.	• Suppliers • Customers
Knowledge	R&T projects create infrastructure that are situated in universities or research centres or other know-how that can be used by other organisations including in other sectors (e.g. ATI infrastructure projects). R&T projects result in knowledge and skills, which are transferred though collaborative relationships, supply chains or as people move from one company to another.	• Competitors • Collaborators
Network (or product)	Aerospace research makes available some kind of common "data" or "platform" that other products/services can be related to. Those not directly involved in the project can access and utilise the data/platform for their purposes e.g. researchers, government departments, and businesses.	• Collaborators • Customers • Competitors.

Source: SQW

Hall (2016)[73] points out that the key motivating factor for public intervention is the presence of spillovers to firms that are **adjacent in industry, technology, or geographically,** rather than businesses within the same field. This suggests programmes that support multi-disciplinary projects where the R&T has broad applications lead to greater social returns.

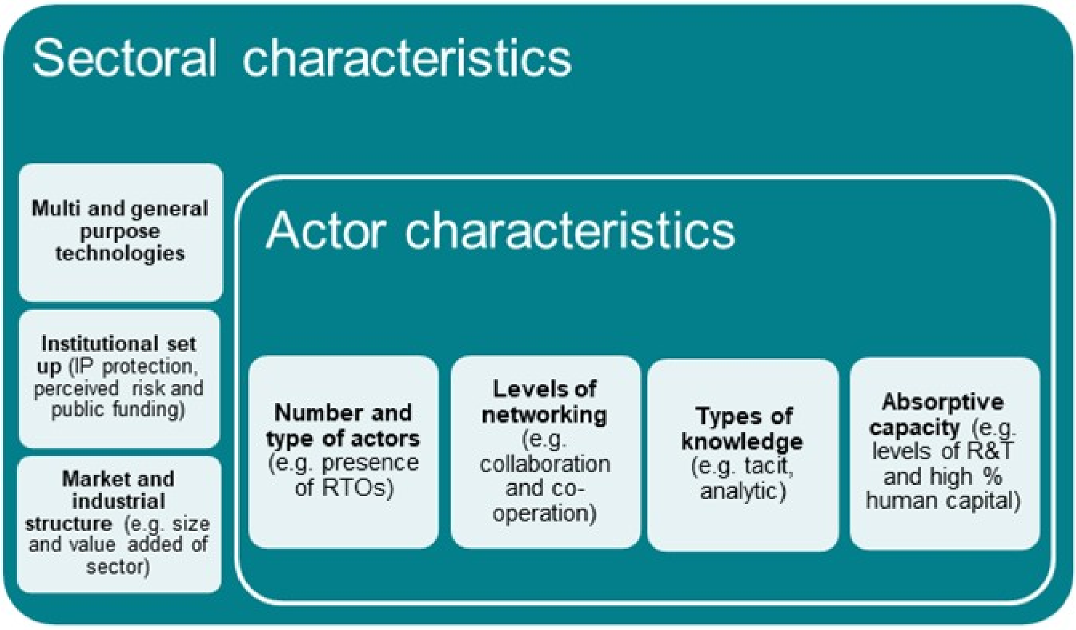
Another dimension to consider is that the **conditions in which firms innovate also bear significance for the likelihood of spillover effects occurring.** A set of sectoral and actor characteristics that lead to 'high' spillover effects is summarised in Figure G-1. This draws on

[73] Hall, B (2016) *Presentation on R&D, innovation and productivity.*

research for BIS (2014)[74] and our own research in innovation and spillovers (2018).[75] We propose these conditions are explored as part of the case study work.

Sectoral characteristics refer to the environment that innovating firms are operating within: sectors that produce technologies with multiple applications, have high levels of public funding and high GVA per worker are more likely to generate spillover benefits. Actor characteristics refer to the individual businesses operating within the sector. High presence of, and collaboration with, Research and Technology Organisations (RTOs) will also increase the propensity to produce spillovers. Presence of these two types of characteristics provide a useful proxy measure for the likelihood of spillover effects occurring.

Figure G-1: Conditions that influence the likelihood of spillovers occurring



Source: SQW

The aerospace sector displays some of the sectoral and actor characteristics that influence the likelihood of spillovers occurring shown in Figure G-1. Aerospace research often takes longer than most other sectors to commercialise, due to high development costs and high risks. The innovations are often **multi and general technologies with a broad range of applications**. Consequently, aerospace research may be brought to market in adjacent sectors before it is used on aircraft, leading to additional benefits for the consumer and supply chains (e.g. composites; electrification; automotive). These 'absorptive' adjacent sectors tend to also have **high levels of R&T and a skilled workforce** e.g. automotive, and other engineering sectors. Moreover, these sectors often form part of the **geographic clustering of aerospace** (and wider engineering-based) businesses.

[74] Medhurst, Marsden, Jugnauth, Peacock, Lonsdale (2014) *An Economic Analysis of Spillovers from Programmes of Technological Innovation Support.* ICF GHK report for BIS.
[75] Ibid 67.

Research for BIS (2014)[76] found quantification or valuation of spillovers "problematic" (i.e. difficult to quantify). Where spillovers have been quantified, the estimates vary widely: net social returns from spillovers are typically found in the range of 20-100% of R&D investment, with an average nearly 50% return.[77] Research on returns to public science and innovation investments suggests spillover returns are typically two to three times greater than private/direct returns.[78] It is also worth pointing out that it is difficult to predict when spillovers may occur.[79]

The ATI programme has potential to generate different types of spillover effects for customers, collaborators, competitors and businesses in the supply chain, as follows:

- **Knowledge** – the ATI programme funds a number of **infrastructure investment projects** which generate cutting-edge technology that is then placed in research institutions and universities. These act as 'public goods' and could provide the opportunity to exploit knowledge spillovers. How are these infrastructure projects used in practice? What is the additional value to researchers, competitors and collaborators?
- **Network** – ATI funded projects make available some data as a platform in the public domain. Those not directly involved in the project can access and utilise the data for their purposes e.g. researchers, government departments, and businesses. Do the new technologies create new platforms/infrastructure that is capitalised on by others (e.g. collaborators, competitors, customers). The **adjacency between sectors** involved in the R&T could provide insights into spillovers within networks. Have the cross-cutting projects led to benefits in other sectors?
- **Market** – aerospace R&T is commercialised for customers in aerospace and other sectors before it is deployed on aircraft. It would be useful to examine the **extent to which ATI-funded research has created value to users of new products/services in aerospace**. What are the benefits associated with the technology for these customers? Has there been 'added' value on the innovation? Is there consumer surplus?

Another issue that will also need to be considered relates to the presence and contribution of 'spill-ins' to the programme – ATI beneficiaries are likely to benefit from research spill-ins from other sectoral research, government R&T programmes (e.g. Catapults), for example from automotive, manufacturing transport, artificial intelligence (AI). These contributions should be factored in to the evaluation where possible and can be covered through stakeholder interviews and case studies.

Gathering evidence of these effects can be done directly with ATI funded companies, their supply chains and networks to test for presence, nature, and scale of spillovers. A 'co-

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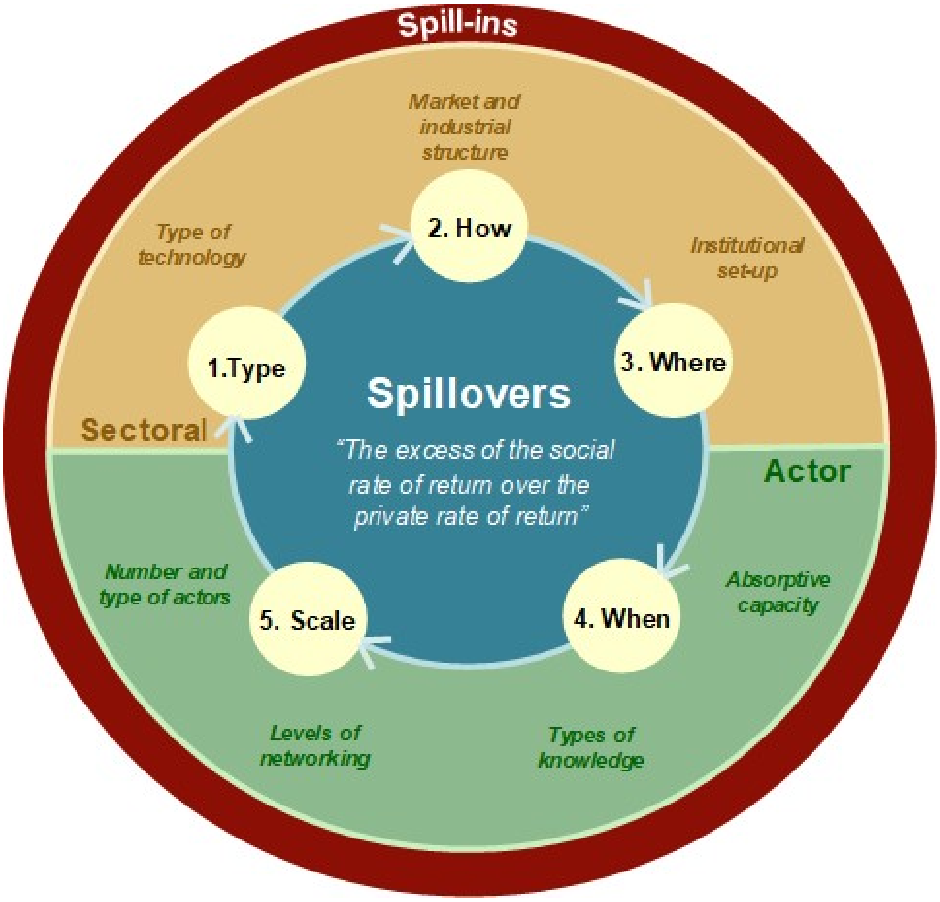
[76] Ibid 70.
[77] Ibid 70.
[78] London Economics (2015) *'Return from Public Space Investments – 'An initial analysis of evidence on the returns from public space investments'*. London Economics refer to research on returns to public science and innovation investments in this report.
[79] For example, market spillovers may occur earlier compared to knowledge spillovers where the timescales are more uncertain, as they depend on various transmission mechanisms. The timing of market spillovers likely to vary by sector.

nomination' approach can be used, where beneficiaries might be able to identify at least some of those where spillovers may have occurred. However, our experience has shown that such an approach is challenging and companies that are directly involved may find it difficult to provide information on spillovers, and those indirectly benefiting can be difficult to identify and engage. Even where indirect beneficiaries are engaged, it is difficult to determine quantitative values of spillovers. Therefore, where spillovers are identified we will evidence, to the extent possible: **the type of spillovers; how, where, and when they are expected to be realised; and where possible any scale or quantification of the spillovers on a case by case basis.**

In addition, a key part of the assessment of spillovers will be to explore the conditions (sectoral and actor-based) in which firms innovate as this influences the likelihood of spillover effects occurring (as identified in Figure G-1). This will provide evidence on: the extent to which ATI projects have developed cross-cutting or multi-purpose technologies that have the potential for adoption in adjacent sectors such as automotive, rail, marine, oil & gas; the extent of networks and cooperation of ATI project partners; and the existence of the means for spillovers to occur, e.g. through supply chains, people movements, and the role of infrastructure. The evidence will be gathered from case studies, supported by the stakeholder interviews, validation workshop, and monitoring review. Figure G-2 summarises the key aspects to be captured in the early impact evaluation. This we consider to be realistic given the nature of the intervention and from our initial review of the project monitoring and assessment data.

Figure G-2: Capturing spillovers (including spill-ins) in the ATI programme



Source: SQW

Spillovers from case study projects

Table G-2 summarises the spillovers reported by the case study project leads.

Table G-2: Spillovers from case study projects (project leads)

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
1.	Knowledge	Partner disseminated the knowledge it gained through the project to many businesses, including SMEs. One example is an SME which uses the adhesive deposition technology in construction.	Partners, third parties in non-aerospace sectors	Achieved	The AMRC has worked with c.500 SMEs since FOAF. Consultations provided two examples of dissemination related to FOAF, but the actual number is hard to quantify
	Knowledge	Partner university has a relationship with the project lead that is bolstered by projects. Students at the university can base their research on real problems faced in industry, thus developing a workforce that is well suited to aerospace.	University students	Expected	The university has an enrolment of c.4,000 postgraduate students.
	Knowledge	Through ongoing successor R&T programmes which are not led by the project lead, knowledge transferred to third parties	Competitors, third parties	Achieved	Difficult to quantify

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
2.	Not applicable	Potential multiplier effects to the supply chain were highlighted but no spillovers were reported to date	Not applicable	Not applicable	Not applicable
3.	Knowledge	Through ongoing successor R&T programmes which are not led by project lead, knowledge is being transferred to third parties. Project lead directly transferred knowledge to third parties, e.g. one University on novel ice protection proposals		Achieved	Unknown
	Market (environment)	The introduction of moulded thermoplastic fuel connectors can contribute to drag reduction and weight saving, thus making aircraft more fuel efficient. Once introduced, optical ice detection is also expected to reduce fuel consumption and thus CO2 emissions, leading to environmental benefits	Society	Expected	Unknown
4.	Knowledge	Suppliers gaining knowledge on new products and processes	Supplier	Achieved	Unknown
5.	Knowledge	Project lead recruited PhD qualified individuals from partner University - encouraged two-way movement between the company and the University	Partner	Achieved	Small

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
		Other partner universities involved in the project on additive structures and mechanical testing			
	Knowledge	Partner universities working with other companies e.g. in aerospace	Collaborators of project partners	Achieved	Small
	Knowledge	Robotic tool being used by project lead in standard operations	Project lead	Achieved	Medium
	Knowledge	Partner developing its own advanced solutions based on the project work undertaken and taking developments into the automotive and space sectors	Partner and their potential customers	Expected	Small
	Market	Air blending tool developed with University	Partner	Achieved	Small
6.	Knowledge	Enhancement and development of Whittle Lab test rig and other capabilities (e.g. 3D printing and blade manufacture).	Partner	Achieved	Medium
	Knowledge	Increased knowledge and learning at University of Cambridge, as well as potential use of infrastructure by other customers of the university (and thereby into other sectors, namely domestic, electronics and energy) Suppliers benefiting by developing new practices which can spread to other	Partners, suppliers, customers	Achieved/ Expected	

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
		customers/sectors e.g. on instrumentation and fast-make industrial 3D printing			
7.	Market (environment)	Reductions in weight and power within an aircraft lead to environmental benefits from	Society	Expected	Unknown
	Market	Technologies developed are applicable to current research within urban air mobility	Partners, suppliers, customers	Expected	Unknown
	Knowledge	Increased understanding of human factors within technology design through University participation and industry standard development	Project lead, partners, suppliers	Achieved	Unknown
	Knowledge	Tools developed are applicable to other production programmes for project lead	Project lead	Expected	
8.	Knowledge/ network	Through ongoing successor R&T programmes, which are not led by project partners, knowledge is being transferred to third parties – B2B and B2R	Customers	Achieved	Unknown
	Market	Technologies developed in project with broader applicability may support future spillovers, e.g. composites for the automotive and marine industries, and advances in automated inspection and metallics for the oil and gas industry	Partners, suppliers, competitors, customers	Expected	Unknown

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
9.	Market	The tool tested in project is currently being used on other projects, as well as within multiple other sectors including wind energy. The theoretical methods developed could be applied to any other flying machine.	Project lead, partners, customers,	Achieved/ expected	Unknown
	Knowledge	The ATI facilitated the dissemination of work conducted during the project through a series of activities and events such as presentations in semi-open fora. Partner university also ran a series of workshops focussed on the work conducted during phase one and how this affected subsequent work (completed project). Academic papers published.	Partners	Achieved	Unknown
10.	Knowledge	The partner university has built a demonstrator (TRL 7) of the learning algorithm model that it intends to take to tradeshows for other non-aerospace sectors (e.g. offshore).	Partner (research base)	Achieved	Unknown
	Knowledge	A university partner has improved its understanding of technology and made further innovations. The University expects to use the knowledge developed	Partner (research base), application in non-aerospace sectors e.g. construction (structural health of buildings)	Expected	Unknown

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
		to assess the structural health of buildings.			
11.	Not applicable	No evidence of spillovers. However, the project had contributed to developing conditions that may support the generation of spillovers, including: the development of multi-purpose technologies and high levels of skills and transferability between firms and sectors.	Not applicable	Not applicable	Not applicable
12.	Market	The technologies developed are expected to substantially reduce the cost of systems for customers	Customers	Expected	Reduction in price from $40k to $4k per system
	Knowledge	Project partners likely to apply learning from project into other sectors e.g. could use the new knowledge in defence, automotive, rail and other high-value powered electronics	Partners; non-aerospace sectors defence, automotive, rail and other high-value powered electronics	Expected	Unknown
13.	Knowledge	Knowledge from the project expected to transfer to students who, in turn, could take the new skills to industry through employment or Knowledge Transfer Partnerships (KTP).	University students and UK businesses/ suppliers	Expected	Unknown

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
	Knowledge	The capital equipment is not sector-specific - acting as a "focalpoint for industry", it is well placed to facilitate cross-industry learning and has already sparked an interest in automation from other industries e.g. set up a tailored facility for the food and drink sector.	Non-aerospace sector (e.g. food and drink)	Expected	Unknown
14.	Knowledge	The technologies developed have the potential to be used in other sectors where similar testing facilities can be used, e.g. defence.	Organisations in other sectors	Expected	Unknown
	Knowledge	Project lead has become involved in national and EU initiatives, creating opportunities to share its expertise with the wider research community.	Research community	Expected	Unknown
15.	Market	Once used within production, the technology has the capacity to reduce manufacturing costs to firms throughout the aerospace industry, including clients of large manufacturers.	Customers	Expected	Unknown
	Market (environment)	The cell may have applications in marine, automotive and nuclear industries. This could result in environmental benefits by	Society	Expected	Unknown

Case study project #	Type of spillover	How spillovers occurred	Where spillover occurred e.g. within project lead, partner, supplier, competitor, customer, other	Spillover achieved/ expected	Scale
		supporting the production of hybrid and electrical vehicles			
	Knowledge	The project developed the knowledge base around large robot dynamics, cutters, cutting strategies and one-way assembly which will be disseminated.			Unknown

Source: SQW Case studies

Annex H: Aerospace R&D funding in key countries

Table H-1: Aerospace R&D funding in key countries

Country	Organisation	Annual Budget	Objective / Description
UK	Aerospace Technology Institute (ATI): Civil aerospace	£150m Government grant and £150m company funding	Strategy includes maintaining the UK as a world leader in aerostructures, including design, integration, manufacture and assembly of the most efficient wings and other high-value structures. The development and manufacture of propulsion systems constitutes around half of the sector's direct economic activity in the UK, concentrated in large turbofan engines for widebody passenger aircraft. A diverse UK supply chain produces components and sub-systems for these engines.
France	The French National Aerospace Research Centre (ONERA)	£91m Government; £113m private sector contracts; £13m S1MA	Tasked to direct aeronautical research and support its industrial commercialisation, construct and operate research infrastructure, supply industry and government with high-level technical analyses and services, and train researchers and engineers.
Germany	Federal Aviation Research Program (LuFo)	€175m Government and €175m company funding	LuFo funds research into aeronautics technologies covering the entire innovation chain with a strong link to SMEs, covering basic research, technology development and technology demonstrators. Key projects include: passenger-friendly eco-efficient cabin; powerful, safe and energy efficient systems; quiet and efficient drives; innovative structures for fixed-wing and rotorcraft; flight physics.
Spain	Instituto Nacional de Técnica Aeroespacial (INTA)	£170m	Main areas of activity include research and development in propulsion, materials and remote sensing; and testing for the verification and certification of materials, components, equipment, systems and subsystems.
USA	National Aeronautics	£565m Aeronautics	An independent agency responsible for the United States civilian space programme, as

Country	Organisation	Annual Budget	Objective / Description
	and Space Administration (NASA)	budget (subject to annual review)	well as aeronautics and aerospace research. Includes themed research, such as the 2019 Urban Air Mobility Grand challenge.

Source: BEIS, ATI

Other notable research and/or development centres include:

- **France:** Technology Research Institute, Saint Exupéry[80] is located in Toulouse where Airbus is headquartered. This is a dedicated centre for R&T activities in Aeronautics, Space and Embedded Systems, combining resources from public and private partners. Many key aerospace companies are involved.
- **Germany:** The German Aerospace Center[81] (DLR) is the national research centre for aeronautics and space. The center is tasked with gaining a better understanding of the Earth and the solar system in order to protect the environment (including cleaner aerospace operations).
- **Japan:** Japan Aerospace Exploration Agency[82] (JAXA) is focussed in developing environmental improvements to turbine engines and wing aerodynamics/lightweight materials. The agency is also looking at next generation supersonic technology.
- **China:** As 25% of all Airbus' sales are to China, a capability to assemble Airbus wings has been developed through the COMAC/AVIC programmes, with opportunities to expand its remit.

80 http://www.irt-saintexupery.com/members-partners/industrials/
81 https://www.dlr.de/EN/Home/home_node.html
82 https://global.jaxa.jp/

Annex I: Summary of issues to address for the future evaluation of ATI

In undertaking this early evaluation, we have identified a number of issues that should be addressed for a future impact evaluation of ATI. Addressing these issues, which are identified below, will be important to strengthen the evidence base and enable a robust and fair assessment of the performance of ATI.

- **Ensure quality and greater use of monitoring data.** The monitoring documentation provided by BEIS, Innovate UK and ATI were incomplete and did not cover all 15 case studies. This limited our ability to draw meaningful conclusions and any broader observations about the programme as a whole. It will be important to ensure the monitoring (especially the quantitative data) is of better quality, complete and available in an easily understandable/ useable format. More will need to be made of the quantitative monitoring data to assess outcomes and impacts of ATI funding, thereby balancing any potential bias in the qualitative self-reported evidence.
- **Undertake value for money (VFM) assessment.** We propose that this should be on a project-by-project basis, which, when aggregated, could provide an overall VFM assessment of the ATI portfolio. A partial cost-benefit analysis would be feasible. This would compare the value of employment with the costs of projects (and the programme), and calculate a BCR accordingly. This should include both jobs created or safeguarded within the ATI project lead, project partners, and in supply chain firms that are directly associated with the ATI-funded project. A separate paper outlining an approach to VFM has been provided to BEIS.
- **Improve the QCA analysis.** It is important to re-iterate that, given the limited application of QCA (based on case studies) in innovation policy, this was an experimental approach used on three outcomes of interest. The case studies were not selected to maximise the effectiveness of QCA. In some cases, the QCA resulted in limited diversity (as discussed in Section 5 and Annex F). To some extent, this constrained the power of the analysis to discriminate between factors influencing outcomes. If QCA is to be adopted in a future evaluation, this could be made more robust by having more case studies and selecting these to offer a wider diversity in terms of outcomes and determining factors.

Finally, given the COVID-19 pandemic and the implications of this for longer-term effects for the aerospace sector, the next stage of the evaluation will need to consider how best to incorporate the issues relating to this into a future assessment of the ATI funding.

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