

# INSIGHT

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## Introduction

To support the aim of securing the full economic potential of the UK civil aerospace sector, the ATI undertook an extensive and detailed review of international and UK aerospace patents.

Patents contain a wealth of technology data that is relatively standardised across industry, making them a strong candidate for meaningful analysis. Patents are associated with innovation and value, however, their potential for insight is far wider. This investigation of global aerospace patents aims to understand their economic value and subsequently use the data to assess international capabilities and developments that might be of strategic importance to the UK. Across national and corporate entities technology themes are analysed in the context of varying policy, culture and incentive. Policy, culture, commercial strategies and incentives can significantly influence patent statistics and these all play an important role in this study.



## **11** GLOBAL AEROSPACE PATENTS: *Technology, Innovation and Competitive Strategy*

## EXECUTIVE SUMMARY

Patents are important strategic and commercial instruments within aerospace. They can be used to block competitors, secure market freedoms and facilitate commercial and research partnerships. Inventors can secure their innovations for up to twenty years, creating a lasting competitive advantage.

Patents are used by some governments and analysts as indicators of innovation and success. This INSIGHT paper investigates patent activity in aerospace to understand innovation, capability and how R&D spend and policies are affecting the industry's patent landscape.

Policy and culture are important factors that make the correlation of patent activity and R&D relatively noisy. The cost and bureaucracy of filing, maintaining and defending patents can be a turn-off for smaller companies. Patents are also publicly accessible and companies must weigh up the benefits of the legal protection they offer over keeping inventions secret.

Historically, aerospace organisations tended to protect Intellectual Property (IP) through trade secrets, know-how and commercial agreements. This has shifted in the last decade as aerospace patents internationally have seen an increasing growth rate. National policy, corporate incentives, new technology and maturing markets all provide strong drivers for this change.

There are regional nuances too. Pivotal changes in US IP law (2009) shifted the IP ownership to "first to file", leading to marked increase in patent filing activity. China's patent quota system, employed since 1999, encouraged vast volumes of patent applications that seem largely superficial as few are converted to publications. This landscape is continuing to change, and the amendments made to Chinese IP law in 2013 are helping to address China's credibility problems. Western aerospace companies are increasing their patent activity in China, recognising the significance of the aviation market there but also the competitive threat posed by a rapidly maturing indigenous industry.

Technology maturity, as well as new markets and technology breakthroughs, are other key drivers for increased patent activity. New vertical take-off and landing (VTOL) aircraft concepts and electrification technologies are becoming more prevalent, signalling disruptive potential. The number of composite inventions rose over the past twenty years, perhaps partially explaining changes seen in the industrial landscape over that period. Growth of patent filings for mature conventional technologies demonstrates the increasing amount of invention required to increment performance and differentiate. Generally, technology patent trends align with in-country aerospace specialisms and capabilities.

Although the UK's presence in the patent data is relatively low, it is increasing. The UK government operates different incentives to other European neighbours. The quality of UK applications is thought to be high and less skewed by policies that drive unnecessary filings. However, the UK should take note of the differences with other countries and their trends. It should seek to boost creation of genuine world-leading IP through R&D support and other targeted mechanisms.

The ATI sees patents as a useful metric of research success and overall competitiveness. It is generally supportive of patent production as an output of funded research. However, the choice to patent relies on a mixture of company policies, competitive strategy, culture and government incentives that vary from region to region and company to company. Comparisons and judgements based on patents must therefore be approached with some caution as well as a good understanding of the underlying dynamics.

“ The UK air transport sector should seek to boost creation of genuine world-leading IP through R&D and well-considered patent incentive mechanisms to secure areas of long-term competitive advantage. ”

## PATENTS STRATEGIC CONTEXT

A patent is a type of IP used to give legal protection to novel products, processes or designs. They prevent competitors from exploiting an idea for a limited period, giving the owner a competitive advantage. Patents are also a useful indicator of innovation and can signpost technological and market trends. Furthermore, they are sometimes used by governments as a success metric for innovation policies or to exert geopolitical power.

Not all patents are created equal. For example, a collection (family) of patents may be required to protect a competitive manufacturing technology, a single patent can result in a multi-million-dollar pay-out and another patent may hold zero commercial or economic potential at all. In late 2011 a law suit came into play between Airbus and Aviation Partners Inc.<sup>1</sup> as a result of a patent filed in 1994. The patent detailed a “swooping” blended winglet, as seen on both the Boeing 737 and Airbus A320 (called a “Sharklet”). This resulted in a seven year legal battle and a “large payment”<sup>2</sup> to Aviation Partners in spring 2018. Conversely, some patents are filed systematically to superficially inflate statistics and represent no real value. Citations, as well as global publications, can be used as a proxy for patent value.

When it comes to patent commercialisation across industry, value can be extracted through licensing, monopolising technology and blocking competitors. Indeed, some businesses (sometimes referred to as “patent trolls”) exist with the sole aim of exploiting the litigious power of patents, buying up inventions to sue companies already in the market or demand royalties. Patents can also be used for commercial and national promotion, to make life difficult for competitors, and to facilitate contracts with commercial partners. In aerospace, value is rarely extracted through direct means such as licensing.

While the aerospace industry utilises trademarks, trade secrets, commercial agreements and other instruments to maximise return from technological developments, patents are considered important for leveraging aerospace IP<sup>3</sup>.

Smaller companies may struggle to find the resources to file and defend patents. There exists a view, within this community of small companies, that publishing patents risks leaking IP and signalling new markets at a time when a business is most vulnerable. Where this behaviour pervades, know-how and ideas are stored as trade secrets.

The opportunity to develop successful enterprises in the growing aerospace industry is not lost on small businesses and start-ups outside the sector. The ATI is engaging more and more with innovative companies on the periphery of the sector, looking to build relationships and transfer-in new technology. To avoid signalling to incumbents, these businesses may simply opt to move faster and under the radar until their technology is closer to market readiness and a formidable learning advantage has been gained. However, there are also many new entrants who lead with propriety technology as the basis of their new business venture.

For growing SMEs, mid-caps and large organisations, patents are becoming more important. As technology matures within a given paradigm, it becomes harder to improve performance and sustain advantage. Competition intensifies and companies tend to increase their use of patents to secure more incremental innovations and block competitors. Some experts see the aerospace industry as reaching the limits of the current technology paradigm, adding to the intense competition to secure the slimmest of margins.

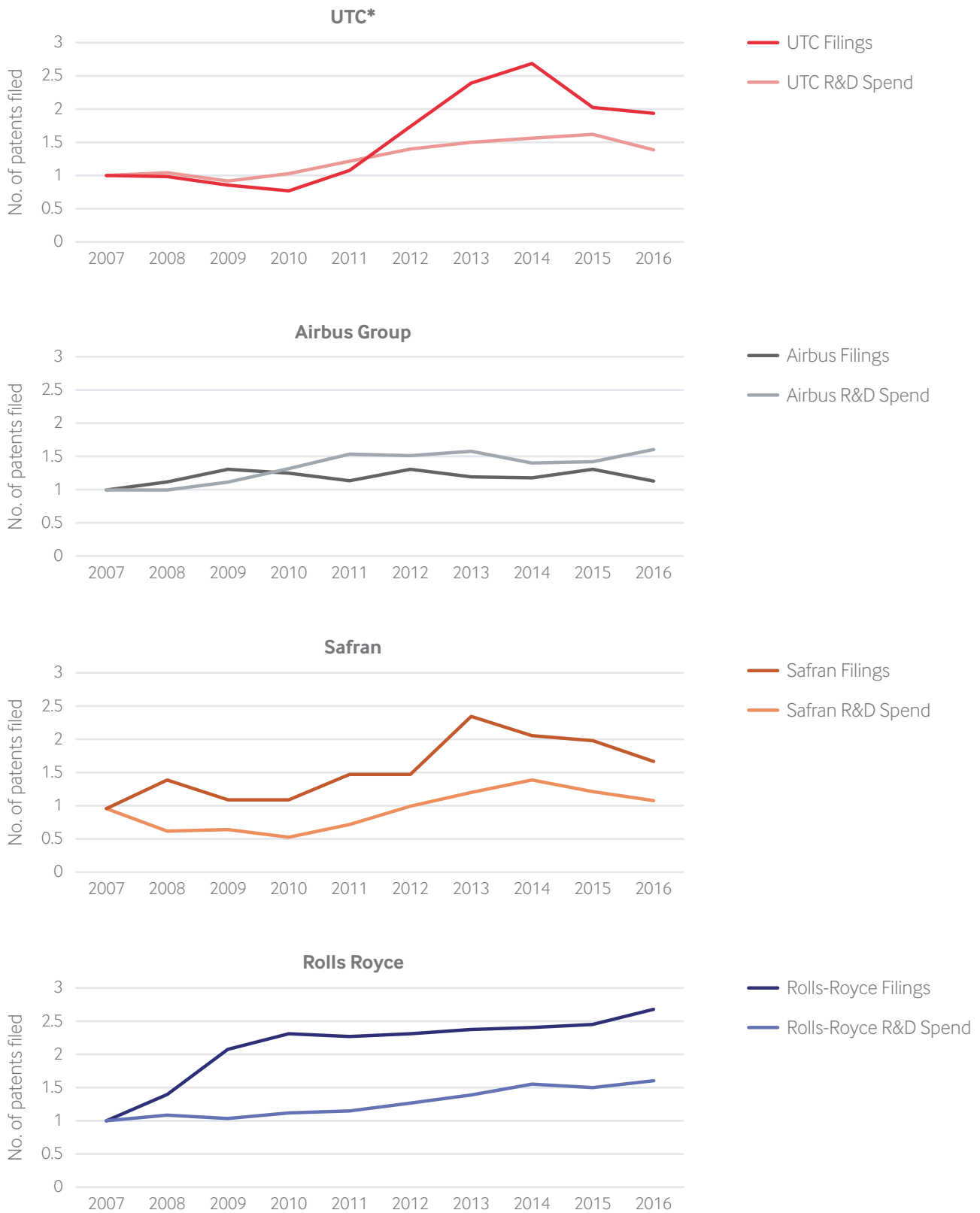
Industry interviews and academic literature supports correlation between R&D spend and IP generation. However, the data in Figure 1 shows this correlation to be quite weak. Other factors such as national policy, culture, corporate incentives and commercial manoeuvres likely mask this relationship. This is explored in more detail later in this INSIGHT.

<sup>1</sup>The Seattle Times - Seattle-based winglet manufacturer fights Airbus lawsuit

<sup>2</sup>Puget Sound Business Journal - “Airbus settles Sharklet fight with Seattle’s Aviation Partners, sources say”

<sup>3</sup>ATI industry interviews

Figure 1 – Aerospace organisation normalised R&amp;D and patent filings trends



Source: ATI Analysis of global aerospace patent data set, 2018

Patents are often published strategically, where there is perceived importance or competition in associated technology areas and are generally first filed in the country of invention. Patent filing location can therefore signpost technological activity, capability and innovation within territories. However, patents are not a direct proxy for innovation. While patents should describe something novel and useful, innovation relies on “the successful exploitation of new ideas”. In other words, commercialisation is necessary to qualify as innovative.

\*prior to merger with Rockwell Collins

## AIMS, METHODOLOGY AND ASSUMPTIONS

The aim of this INSIGHT is to understand global aerospace patent activity in order to shed light on the competitive landscape and market dynamics. This supports ATI's previous analysis of the social and private returns to aerospace R&D investment and informs continued development of ATI's strategy. It is also intended to provide UK industry and policymakers with further useful insight into global and regional technology and innovation trends.

The following objectives guided this investigation:

1. **What drives valuable patent activity?**
2. **What is the UK's presence within the global air transport patent landscape?**
3. **Do patent technology classification trends indicate future capability and workshare?**
4. **Are there strategic implications for the UK?**

The ATI partnered with IP Pragmatics in this study. A dataset of over 150,000 patents was created, utilising Derwent Innovations Clarivate Analytics<sup>4</sup> database and an explicit set of aerospace search terms. The patent data was analysed collectively as statistical datapoints of the following metrics:

- Inventor/organisation
- Country of first filing
- Countries of publication
- International Patent Classification (IPC) code
- Forward and backward citations

IPC codes inform the technology activity analysis. When plotted alongside organisation and country filing data, a map of country and organisation technology activity through IP ownership was established and interrogated.

In order to analyse the dataset, some assumptions were necessary, including that the country of first filing generally indicates the country of invention and that a published application is a good indication of commercially viable IP. Neither are always true and this paper tries to explain when this falls short. Assumptions have been discussed and verified through interviews with industry experts. The analysis also took into consideration the political, legal and competitive environment. The UK Intellectual Property Office (IPO) supported this study with legal and practical context, scope definition and reviewing of data. Qualitative analysis, including interviews with experts at Rolls-Royce, Airbus and GKN in addition to discussions with broader ATI stakeholders and workshops with our Markets and Economics Advisory Group, was used to draw deeper levels of insight and industry context.

For more details on patents including: definitions, global application processes, categorisation, prior art citation, filing and publications, please refer to ANNEX: Patents in a nutshell.

<sup>4</sup><https://clarivate.com/products/derwent-innovation/>

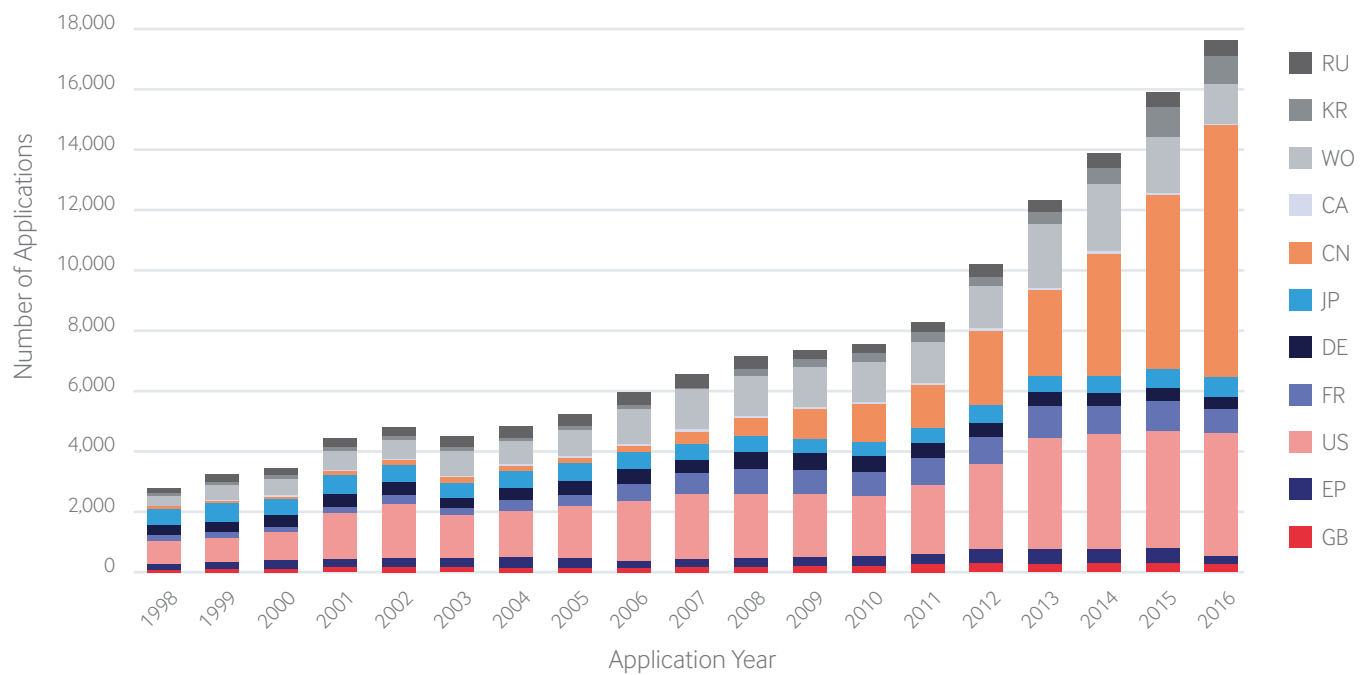
## NATIONAL AND INSTITUTIONAL AEROSPACE PATENT ACTIVITY

### Global

Globalisation and new entrants into the commercial airliner market, such as China, are impacting supply chain dynamics. The global aerospace industry is prioritising patent protection to differentiate and stake value in new and existing technology areas. This increased patent activity is also driven by the advancing maturity of conventional aerospace technology, and at the same time addresses technological shifts towards electrification and the emergence of new markets.

Differing patent laws and policies globally impact patent trends. Commercial manoeuvres from the global original equipment manufacturers (OEMs), as well as worldwide economics, also have a strong influence. Figure 2 plots aggregated patent filing data for aerospace worldwide, illustrating the rapid growth of aerospace patent activity, particularly since 2010.

Figure 2 - Global aerospace patent filing trends, by country of first filing

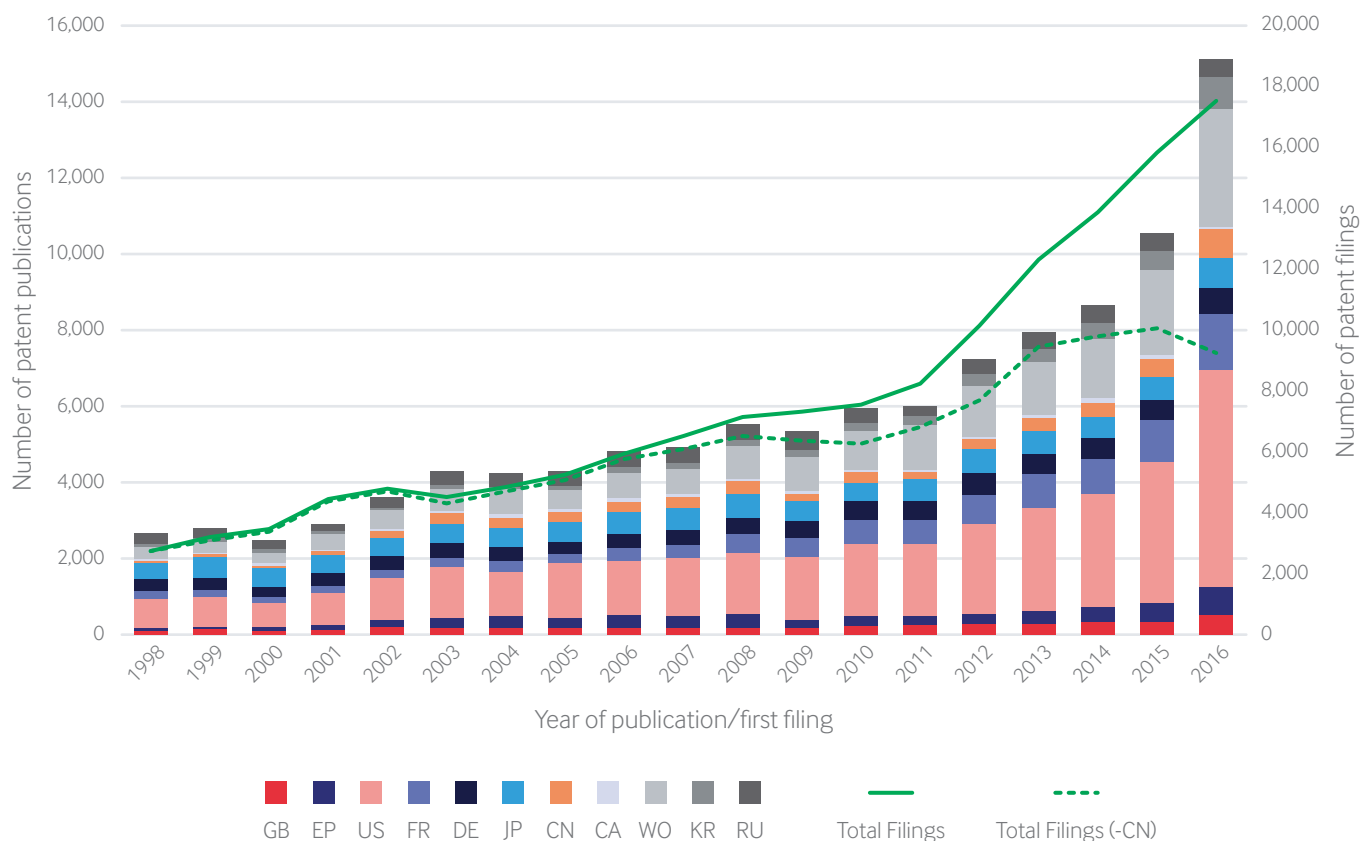


Source: ATI analysis of global aerospace patent applications

Figure 3 shows that the trend for worldwide publications has increased at a higher rate than individual inventions (first filings) for 2015 and significantly in 2016, if you discount first filing data from China (CN). This could suggest an increasingly global strategy is being implemented by aerospace organisations as inventions are published more broadly. Also, the growth in aerospace patent publications of 20.1% CAGR from 2011 to 2016, exceeds that of total worldwide across all sectors (5.2% CAGR).

The aerospace patent rate is underpinned by expanding technology research and intense competition. Trade secrets and commercial agreements still play a role in the protection of aerospace IP, but the data suggests the use of patents is becoming more prolific. Industry barriers such as high R&D costs and airworthiness regulations will not hold off competition indefinitely, with China close to releasing its first single-aisle airliner. The next sections of this paper dive deeper into the national and technological aspects of patents.

Figure 3 - Global aerospace patent publications by priority country (bars), including plots for total patent first filings and total filings with data on China removed (lines)

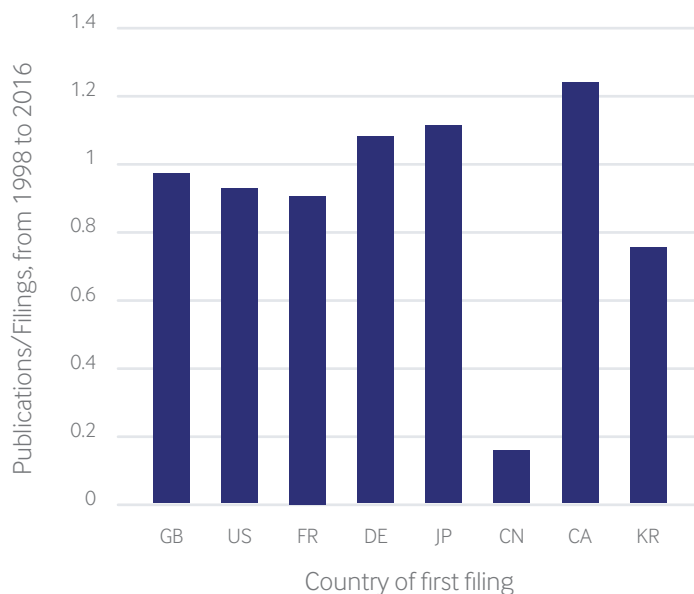


Source: ATI analysis of global aerospace patent applications

### China

The volume of patents filed in China is not indicative of relative presence but the trend should not be ignored. Although Figure 2 shows patent filing is heavily influenced by China after 2010, this does not necessarily imply growing technological or innovation leadership. The number of valuable patents, i.e. published and granted, are still relatively few. Notably, Chinese patent quota policies<sup>5</sup> implemented from 1999 seem to have driven dramatic yet superficial patent filings that are subsequently withdrawn. This is illustrated by Figure 4, which shows that significantly fewer Chinese patents are published (either at-all or globally) than in other leading aerospace nations. The fact that aerospace patent activity in China was low before 2010 indicates their relative infancy, as total patents filed in China across all sectors grew rapidly after the patent quota system was established in 1999.

Figure 4 – Global aerospace patent publications per first filing by priority country



Source: ATI analysis of global aerospace patent publications

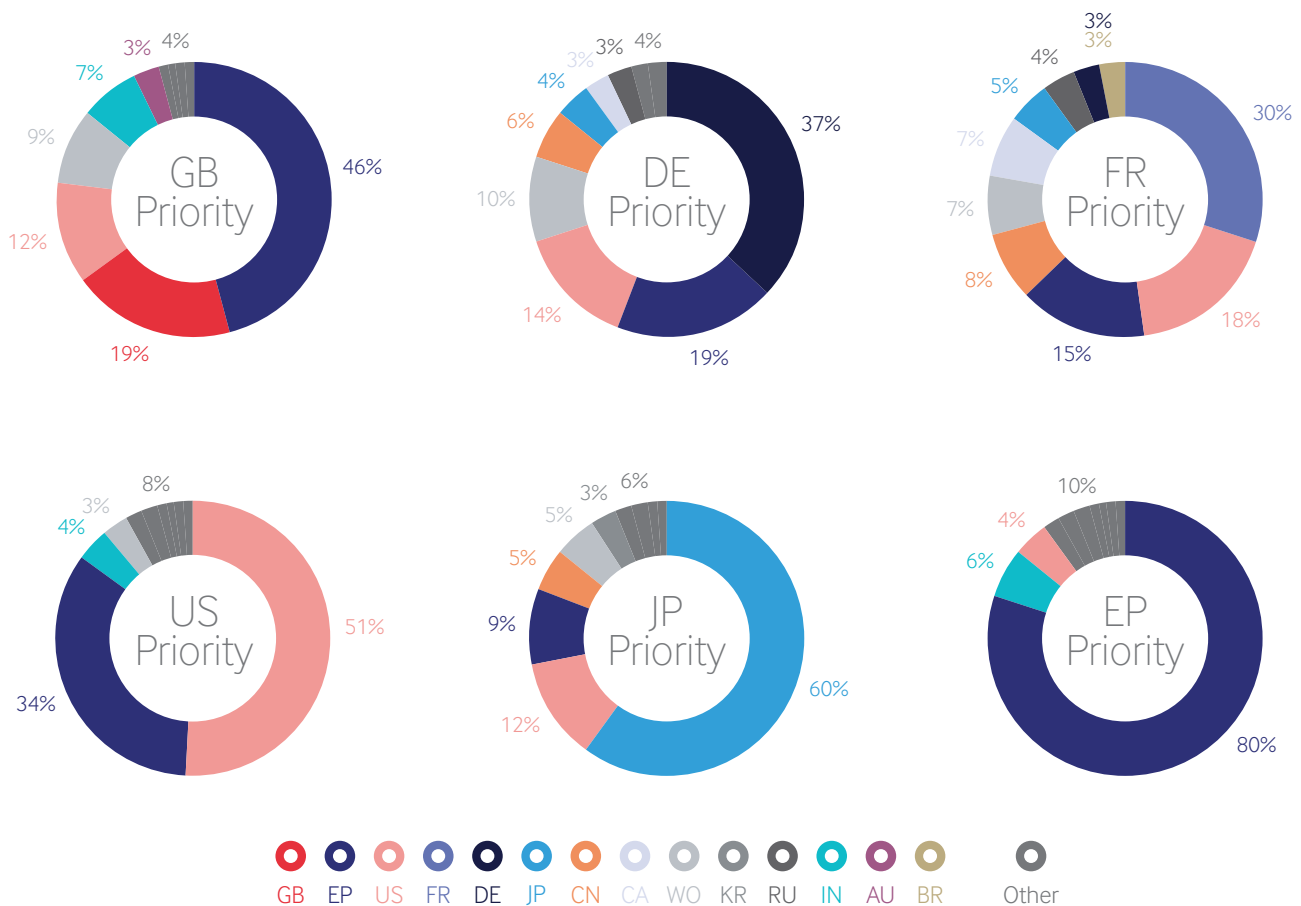
<sup>5</sup>Are Chinese Patent Applications Politically Driven? - <http://www.oecd.org/site/stipatents/Session%204.3.%20Wright.pdf>

Western aerospace companies are acutely aware of the risk of IP leakage in China. This is partly due to a track record of poor enforcement and the behaviours this has allowed to go unchecked. In 2009, Chinese patent law was amended<sup>6</sup>, bringing it more in line with the global litigious standards of other technologically advanced nations. Positive changes, such as an “absolute novelty requirement” and shifting the “burden of proof” from the claimant to the defendant (for certain important cases)<sup>7</sup>, make patent protection in China more favourable.

Western aerospace companies are increasing their presence in China, compelled by the rapidly growing market, access to new sources of innovation and potential funding. Joint ventures have been a necessary part of doing business in China for some time and patents are an important part of these deals. Companies are filing more patents and opening new research centres to plug into the R&D ecosystem. However, the world was reminded of the continued threat of industrial espionage in October 2018 when a Chinese operative was convicted of stealing jet-engine secrets from US firms<sup>8</sup>.

Curiously, UK and US companies have not sought as much protection in East Asia as other European nations, as illustrated in Figure 5.

Figure 5 - Global publications breakdown to other nations, after priority first filing



Source: ATI analysis of global aerospace patent publications, from 1998 to 2016

Despite the filing misnomer illustrated in Figure 4, ATI analysis suggests that patents resident in China are growing in perceived quality. Total home-grown patent grants overtook that of foreigners for the first time in 2009 and since 2014 aerospace patent publications in China have seen an upwards trend.

## US

The US is the global aerospace market leader, responsible for around 50% of civil aerospace revenues<sup>9</sup>. A recent law change in the US has led to a marked increase in patent activity in the US and the world-wide supply chain. In 2013, the US changed proprietary law from the “first-to-invent” (FTI) to “first-inventor-to-file” (FITF), creating an urgency to lock in patent rights.

The policy change has clearly affected the trajectory of US aerospace patent publications, increasing from 2,500 in 2013 to over 8,000 in 2017 (see Figure 3). Prior to 2013, US patent publications were growing steady at 8% CAGR. This could indicate a historical preference for trade secrets. However, as the new law disregards this prior art in the form of secrets, incumbents have rallied to protect their IP. This trend is well depicted in Figure 7, which shows the top 10 aerospace companies by patent filing. This is discussed later in this paper’s Corporate analysis section.

Overall, the US has a more active litigation environment, encouraging a culture of patent filing and legal enforcement. US law also stipulates that a patent application for an invention made in the US must first be filed with the US patent office. This behaviour raises the baseline filing activity above the industry average, although does not necessarily imply more high value IP, as previously discussed.

<sup>6</sup>[https://www.twobirds.com/~/\\_/media/pdfs/newsletters/2009/new-chinese-patent-law-march-2009.pdf](https://www.twobirds.com/~/_/media/pdfs/newsletters/2009/new-chinese-patent-law-march-2009.pdf)

<sup>7</sup>Allen & Overy - Chinese Supreme Court brings about sea of change for patent litigation in China

<sup>8</sup><https://www.justice.gov/opa/pr/chinese-intelligence-officers-and-their-recruited-hackers-and-insiders-conspired-steal>

<sup>9</sup>The Departments for Business Energy and Industrial Strategy (BEIS) & ATI civil aerospace and market analysis



## Europe

European organisations and countries have varying preferences to filing nationally or through the European Patent Office (EPO). French policy stipulates French inventors must first file in France. German law incentivises patent filing through The German Act on Employees' Inventions (AEI) and related Remuneration Guidelines<sup>10</sup>. This encourages the individual to file, by offering rewards as well as obliging the employer to file once an invention is declared by an employee.

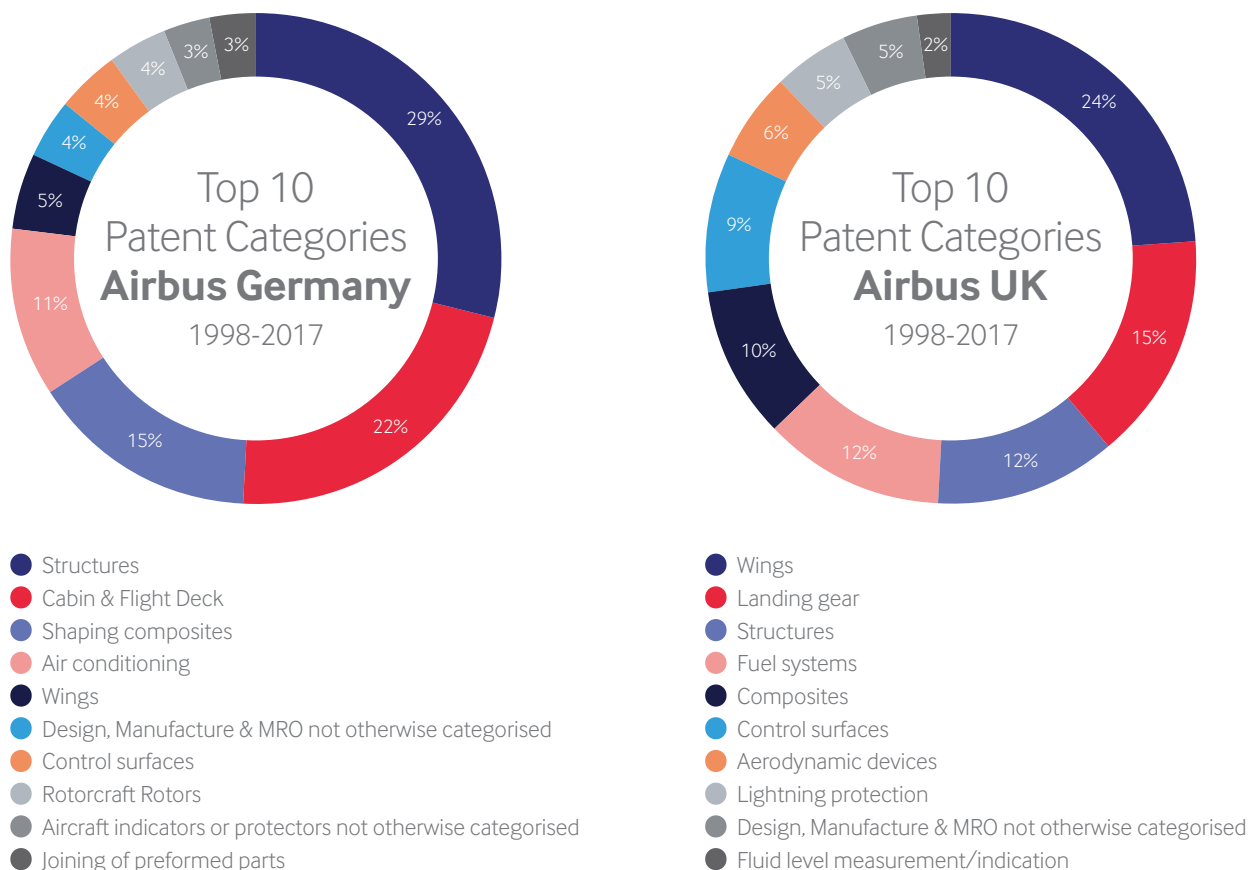
Tax incentives for patents also vary across European countries. The UK Patent Box<sup>11</sup> policy was first proposed in 2009 and offers a reduced corporation tax (10%) for profits earned from patented inventions, after implementation on the 1st April 2013. France has a similar scheme<sup>12</sup>. Germany does not have an equivalent tax relief scheme, but the AEI appears to be more effective in cultivating patents. Spain and Italy have policies like Patent Box, but still register relatively low numbers in the global patent dataset. For the UK, this suggests that either the Patent Box has limited impact on patent activity or that other factors are at play. This could be related to industry size, culture, corporate policies and incentives, or simply less R&D. UK R&D as a percentage of GDP (1.68% in 2016) is lower than many other developed economies such as Germany (2.93%), France (2.25%) and USA (2.74%) in 2016, and likely to be a contributing factor. The UK government has acknowledged this and recently set an ambition for public and private sector R&D investment to reach 2.4% of GDP by 2027<sup>13</sup>. This may lead to increases in UK aerospace patent activity.

Major UK aerospace companies file through either the IPO or EPO in relatively equal numbers. UK aerospace patent activity is growing faster than the UK total (across all sectors). This may stem from increased competition, changing technology, differing industry norms or generally higher innovation intensity compared with other sectors. However, UK aerospace patenting lags that of other European countries, most notably France and Germany. If patent volumes are a leading indicator of success, this could be a concern for the UK. The behaviour of pan-European organisations could be one-to-watch for a UK outside the European Union, as IP may be shuffled and repatriated if company IP strategies are revisited.

Airbus' European subsidiaries have differing patent themes. This is unsurprising given a degree of specialism that exists at each site. As an example, Figure 6 shows the top 10 patent categories originating from Airbus Germany and Airbus UK that highlights the capabilities of each subsidiary. Structures, cabin and flight deck patents are more prevalent in Germany, and trends in the last year showing composite inventions starting to take a lead. This aligns with the major components being manufactured in Germany, such as the A350 composite upper wing skin. After structures technology, Airbus France files most patents around navigation and air traffic control.

Airbus UK files almost a quarter of its patents using the IPC code relating to "Wings"; the majority were filed within the last few years. This points to IP generation through UK-led programmes such as Wing of Tomorrow (WoT)<sup>14</sup>. Landing gear, structures and fuel systems also correspond directly with Airbus UK capability. This data supports the use of patent classifications as an indication of geographic IP control and capability.

Figure 6 - Comparison of Airbus Germany and Airbus UK patent areas



Source: ATI analysis of global aerospace patent dataset, 2018

<sup>10</sup>German Law on Employees' Inventions, Hogan Lovells' LimeGreen IP - <https://bit.ly/2EWJ8YX>

<sup>11</sup><https://www.gov.uk/guidance/corporation-tax-the-patent-box>

<sup>12</sup>Global Research and Development Incentives Group April 2017 - PwC

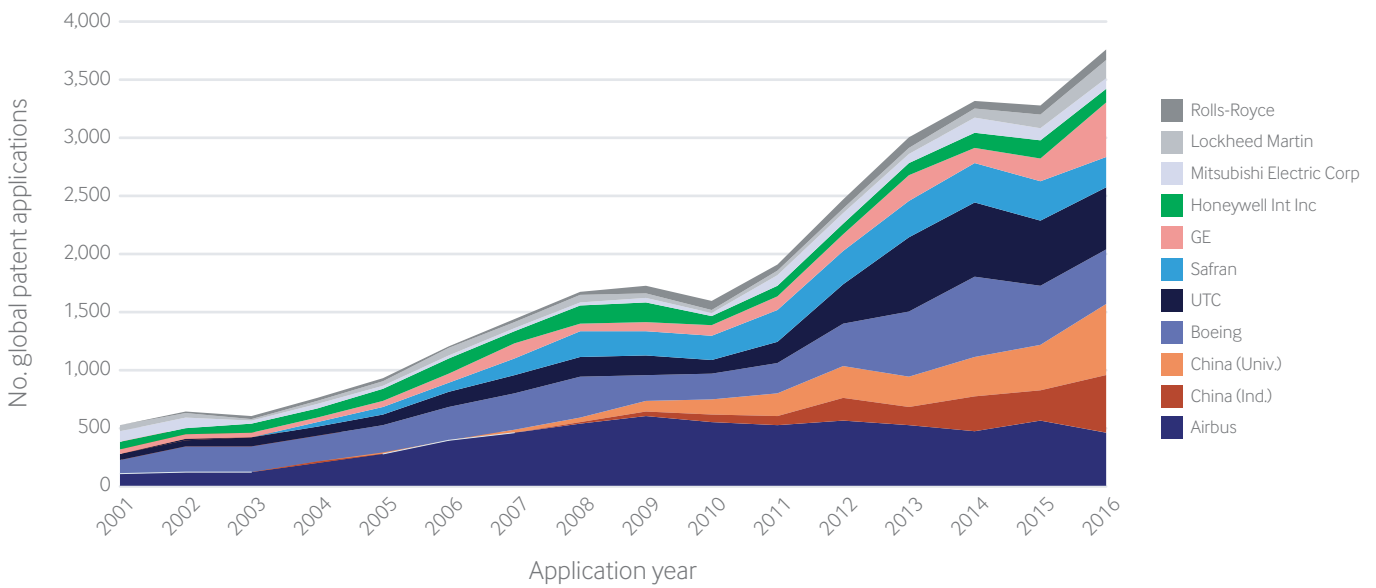
<sup>13</sup>[gov.uk/government/news/new-publication-showcases-record-investment-in-research-and-development-programmes](https://www.gov.uk/government/news/new-publication-showcases-record-investment-in-research-and-development-programmes)

<sup>14</sup><https://www.airbus.com/newsroom/news/en/2017/01/Wings-of-the-future.html>

Corporates

A closer look at corporate filing activity illustrates the impact of country policies discussed earlier and tells a story of past R&D investment.

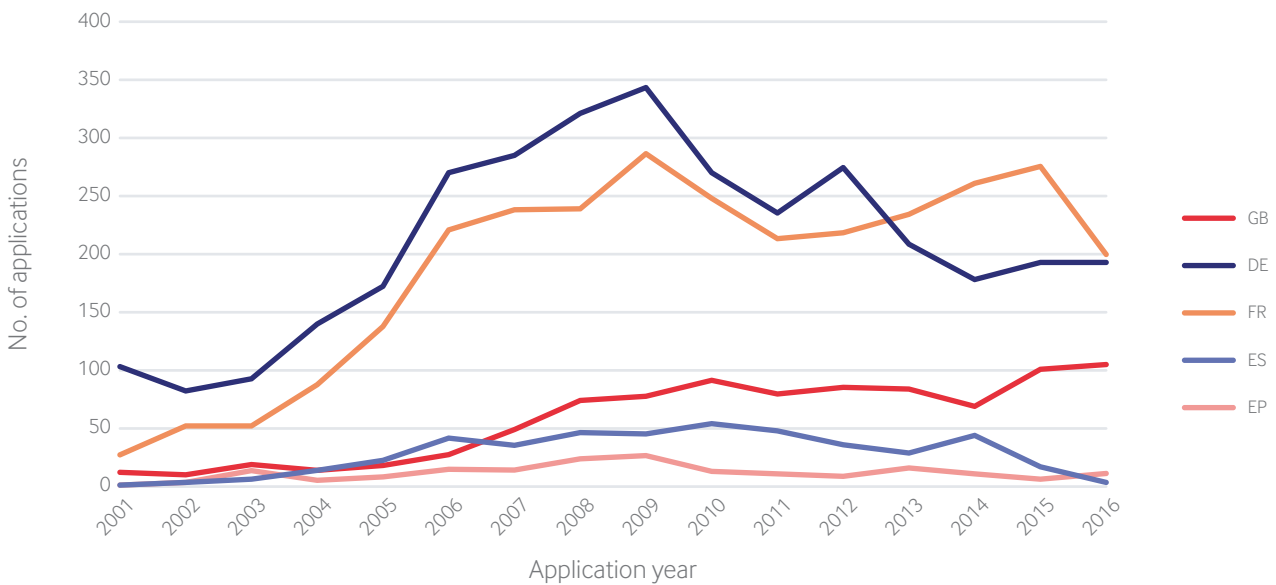
Figure 7 – Trends of the top 10 filing aerospace organisations



Source: ATI analysis of global aerospace patent dataset, 2018

The impact of the US “first to file” amendment on US firm patent activity is clearly shown in Figure 7. Boeing increased its patent activity between 2001 to 2008, likely driven by R&D on the 787 which incorporated significant innovations in composite technologies, electrification, smart systems and manufacturing processes. Boeing’s patent activity declined slightly in 2009 before escalating in accordance with the US law change in 2013. The global dip after the 2008 peak might be linked to the financial crisis. Chinese patent filing (from the top 10 assignees) is equally split between industry and universities, although the rationale for this is difficult to analyse due to the Chinese policies described earlier.

Figure 8 - Airbus patent filing by priority country



Source: ATI analysis of global aerospace patent dataset, 2018

As illustrated in Figure 8, Airbus filing peaked in 2008 due to a corporate level competitive filing strategy, which also tied in with major R&D projects. Airbus UK, as measured by GB (UK) first filings, is increasing. R&D on manufacturing and design programmes, such as Wing of Tomorrow, are important drivers. Airbus commented that approximately two thirds of the Wing of Tomorrow patent activity comes from UK inventions. Airbus UK patent activity is focused on wing, landing gear and composite technology, whereas filings in Airbus France and Germany are more broadly spread. Airbus’ Spanish filings are relatively low, but with clear targeting of composite materials and manufacturing.

## TECHNOLOGY THEMES IN AEROSPACE PATENTS

An analysis of patents by technology theme can provide a high-level indicator of investment priorities and the future competitive landscape.

### Overview

There are clear technology paradigms within the IP data, whether that be within nations, corporate entities or globally. By looking at these high-level trends, specific areas of interest are revealed for further analysis. Although patent filing numbers in isolation may not be conclusive, relative shifts and proportions between technology categories give a useful insight into technology strategies.

Historically, fewer patents were necessary to cover technology advancements. As the conventional aerospace technology matures, far more complexity and technology are required to make gains in performance. This drives higher rates of IP development as companies strive to differentiate. A great opportunity exists for new and disruptive organisations and/or technologies to seek, create and exploit IP in relatively uncontested markets and radically different technology spaces.

The increased technological maturity, competition and patent activity could suggest that aerospace IP is heading in the direction of the Data and Telecoms industry in which many patents were filed in pursuit of licencing and litigation. As aerospace technology matures within the current paradigm, patents are expected to play a more important role within the competitive environment.

There are clear IP technology trends emerging in aerospace, across incumbent aerospace nations and increasingly in developing aerospace nations like China. The “what” and “where” is crucial to understand in terms of new aerospace IP and future competition. Analysis of patent content highlights 3 big themes in the sector:

1. Vertical Take-Off and Landing (VTOL) Rotorcraft
2. Electrical Power Systems
3. Advanced Structures and Net-shape Manufacturing

Connectivity, communication and digitalisation are themes to watch, present in patent filings from 2015 onwards, but negligible before. The relative change in filings in the short time period suggest these may become areas of important competitive advantage in the future and are yet to fully exploited within civil aerospace.

Since 2014, China has led patent filings in each of these big themes, followed by the US then Europe. This does not necessarily indicate capability dominance (as discussed earlier), but that the US and Europe should take China’s expanding activity seriously. Indeed, incumbents are responding by strategically publishing patents in China<sup>15</sup>.

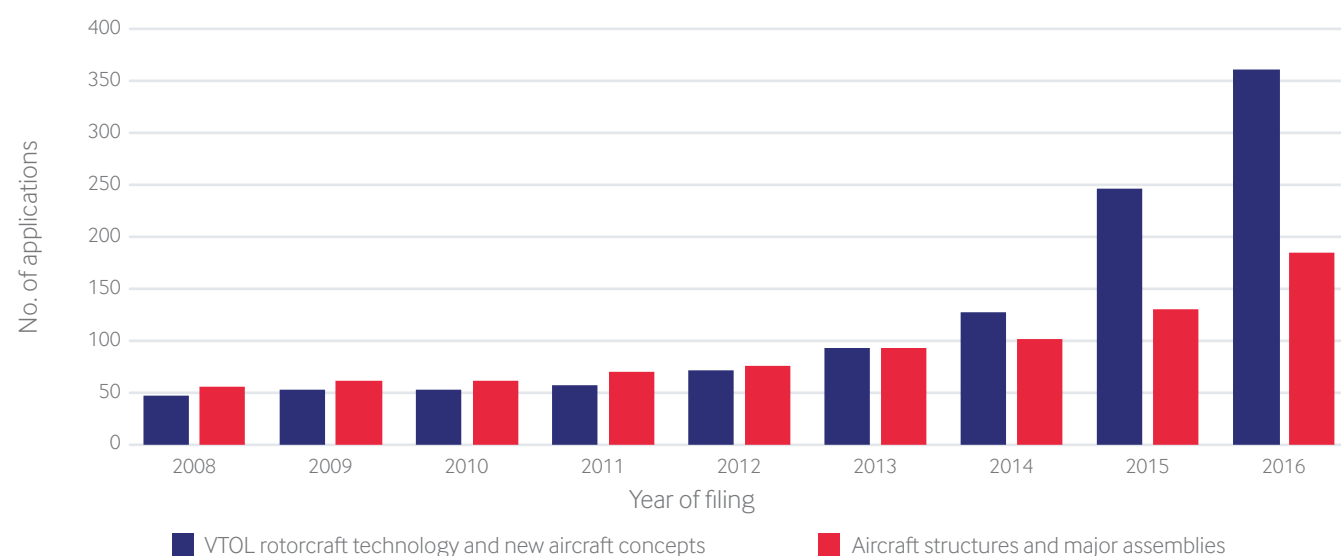
The UK is actively filing within the top technology themes. National strategies and investment initiatives, such as those of the ATI, aim to boost UK R&D and IP generation in these areas amongst others.

The major global aerospace incumbents have lost 15% of their share in patent filing over the last three years. Much of this is attributable to China, but not all. The data also suggests more new entrants are focusing on civil aerospace and the prospect of Urban Air Mobility (UAM).

### Vertical Take-Off and Landing (VTOL) Rotorcraft

Figure 9 provides a contrast between conventional commercial aircraft related patents and emerging aircraft concepts. VTOL rotorcraft may include commercial drones and new VTOL concepts for UAM (e.g. “air taxis”). Historically, this kind of IP upwards trend precedes a shift in the market and disruptive events<sup>16</sup>.

Figure 9 – Aggregated trend of VTOL and conventional tube-and-wing related inventions



Source: ATI analysis by aggregating the most common IPC categories

In addition to the shift in R&D focus, more new organisations are entering aerospace with capabilities, technologies and products with disruptive potential. Traditional aircraft structures have seen strong growth in patent filing which, in parallel to disruptive trends, signals intensifying global competition in mature markets.

<sup>15</sup>ATI analysis and industry interviews

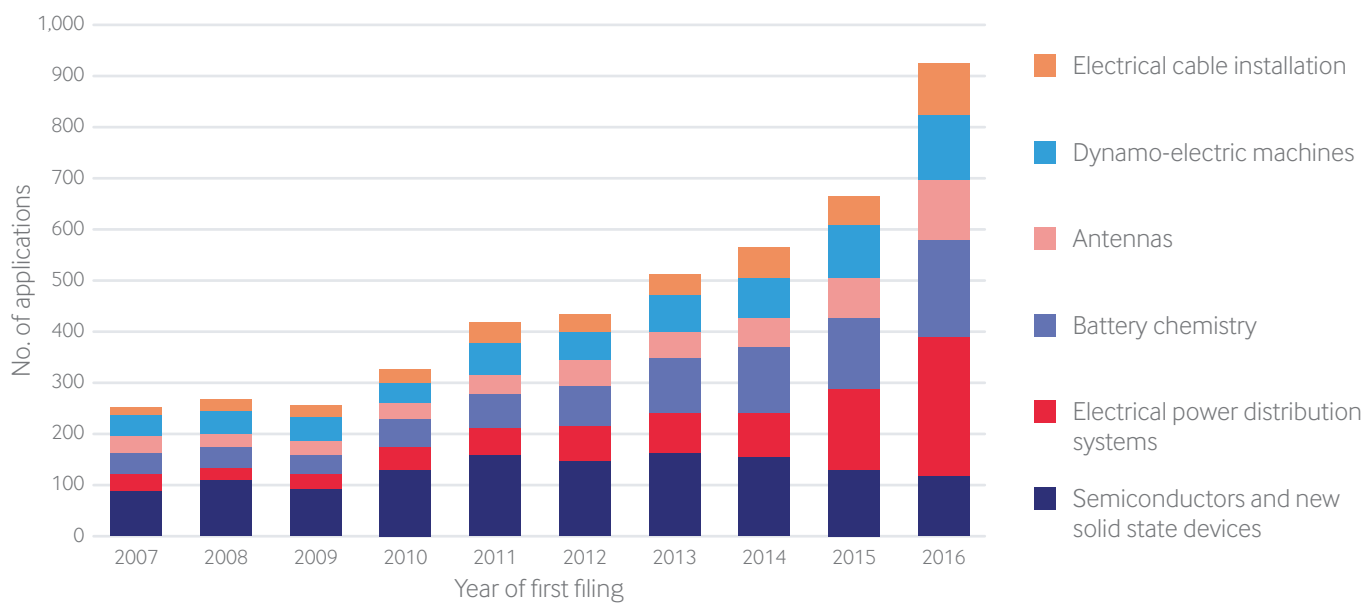
<sup>16</sup>ClearViewIP - Graphene Tech & IP

The surge in UAM IP started in 2014, after which organisations such as Zunum Aero, Lilium, Joby Aviation and XTI Aircraft emerged. These companies are inspired by a utopian vision of cityscapes awash with sky highways and futuristic personal flying machines. These will only be enabled by breakthroughs in electrical propulsion systems, autonomy and holistic operational change in the entire air transport system. ATI analysis and external publications<sup>17</sup> conclude that over 40% of patents filed for “air taxis” are propulsion systems and another 20% for associated control systems. These technological fields are not exclusive to UAM concepts but address complementary requirements in conventional jet aircraft advancement.

### Electrical Power Systems

The electrification of commercial jet aircraft is an area of great technological interest with potential to make aircraft more efficient and reduce costs<sup>18</sup>. Within both emerging and conventional aerospace markets, electrification is perhaps the most significant contributor to IP growth. Competition is fierce as the industry continues to exploit electrical systems to ever greater extent and firms seek opportunities to gain advantage and block their competitors.

Figure 10 – aerospace electrical patent trends by most filed IPC



Source: ATI analysis of global aerospace patent dataset IPC codes

Overall, patents relating to the generation, conversion and distribution of electrical power are underpinning aerospace electrical patent filing trends. Asia is leading the the recent filing growth, with activity in Europe and the US proving relatively flat since the delivery of the A350 and Boeing 787.

Figure 10 shows the fastest growing technology categories, which are also the most filed patent categories for electrical technologies in aerospace. The sharp jump between 2015 and 2016, primarily driven by energy storage and distribution, suggests a continued and more rapid rise can be expected in the future. A lot of this growth, especially for energy storage, is in China. Since 2014, China has also overtaken the US and Japan in semiconductor and solid-state system technology patents. Note, as stated previously in the case of China, this only indicates a level of activity, and certainly not technology dominance.

The Republic of Korea is a notable newcomer to this technology space, filing almost 300 electrical-related patents in aerospace since 2014 versus less than 200 in total prior (a similar rate to the UK). Since 2014, France, Germany and the UK filed 250, 104 and 85 respectively.

### Advanced Structures and Net-shape Manufacturing

Figure 11a and 11b show the patent application trends by the top filing nations of Composite and Additive Manufacture (AM) technology, respectively. Patents relating to composites technology have shown growth of 10.2% (CAGR) between the years 2000 and 2016, with over 650 globally published in 2016. The composite patent trends are being led by Boeing then Airbus, followed major Tier 1 suppliers such as Snecma (now Safran Aero Engines), UTC (now Collins Aerospace) and General Electric (GE). Germany and France lead in European patent filing in this theme, while activity in Spain demonstrates its specialism in this field. Spanish filings make up approximately 10% of the top 10 assignee filings in composite technology, yet overall Spanish filings are relatively low.

Composite capability was heavily deployed on the A350 structures, and trends in national composite patents support the distribution in associated workshare for the aircraft. As highlighted earlier in this paper, a rise in US composite patents preceded the Boeing 787 development. Composite technology is strategically important to the UK<sup>19</sup> for a multitude of potential markets including wings, engine components, actuation systems and nacelles to name a few.

<sup>17</sup>ClearviewIP - Air Taxis & IP - <http://www.clearviewip.com/wp-content/uploads/2018/01/AirTaxi.pdf>  
<sup>18</sup>ATI INSIGHT\_07 Electrical Power Systems, 2018  
<sup>19</sup>ATI INSIGHT\_09 Composite Material Applications in Aerospace, 2018

Figure 11b shows the relative boom in aerospace AM patents. Although, small in comparison with the electrification and composite patent trends, potentially since the majority of innovation is within processes which are notoriously hard to patent. However, aspects such as powder systems, apparatus, design software and specific products lend themselves to patent protection.

Looking internationally, just under 45% of AM patents since 2013 were first filed in the US, followed by China (20%) and France (15%). The UK has approximately 3% of the patents within this study's AM categorisation, although some may have been filed through the EPO (7%). In practice, these EPO filed patents are probably less likely to be from France and Germany due to national policy.

Although AM is being used to manufacture in-service aerospace components, its adoption remains limited. That said, the potential for radically altering how components are designed and made remains and the rising investment and patent activity in the field supports this. The UK supply chain includes a multitude of businesses for which AM may prove highly disruptive, but also those who are well-placed to take advantage<sup>20</sup>.

Figure 11a - Aerospace Composite technology patent trend, by priority country first filing

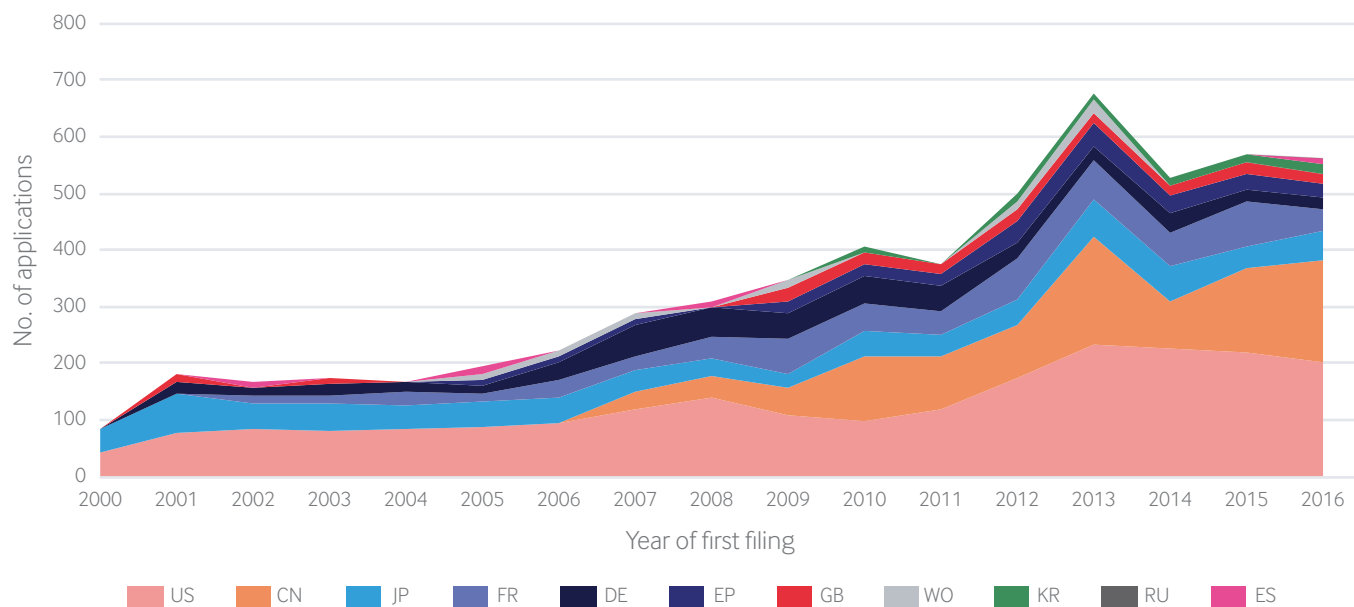
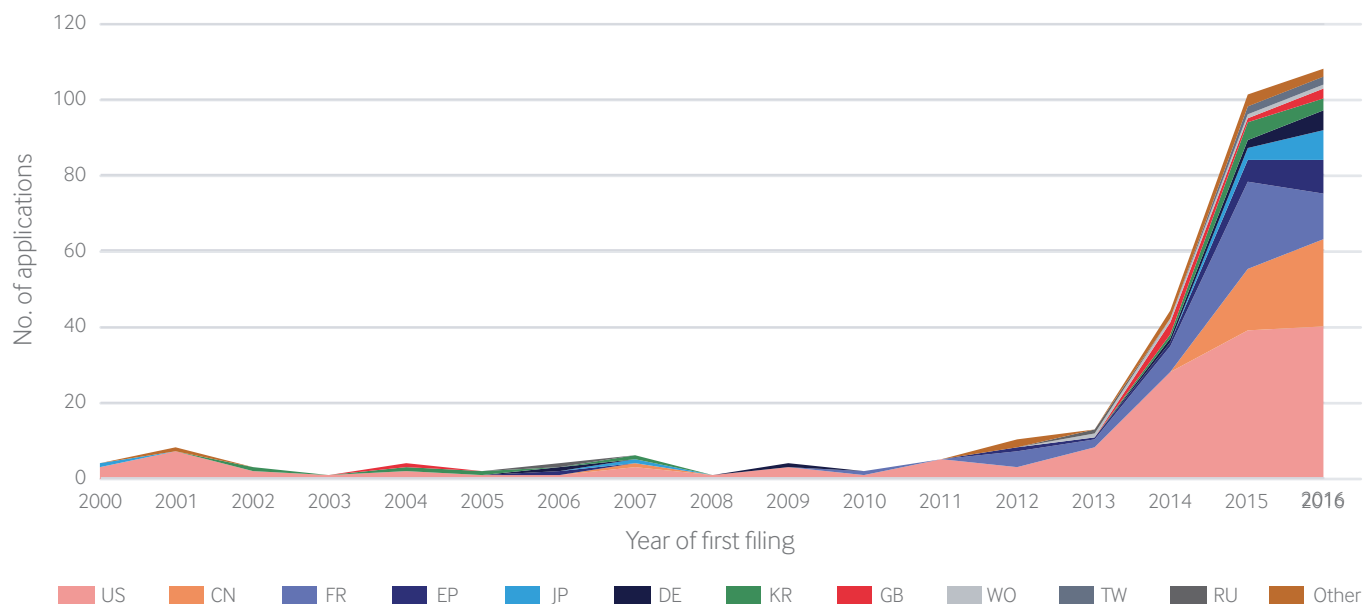


Figure 11b - Aerospace Additive Manufacturing patent trend, by priority country first filing



Source: ATI analysis of global aerospace patent data set IPC codes

<sup>20</sup> ATI INSIGHT\_08 Additive Manufacturing, 2018

## UK AEROSPACE IMPLICATIONS

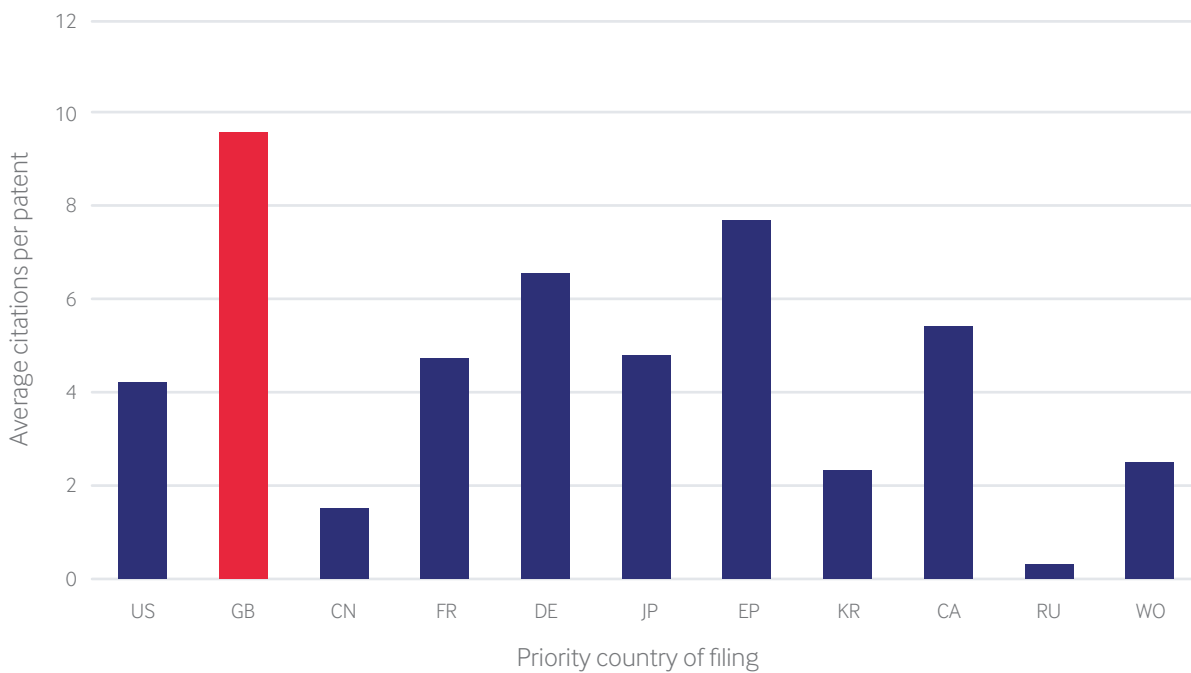
Patents can be pivotal in securing long term value to aerospace. For example, specific innovations in electrical machines by United Technologies Corporation (UTC) have secured them dominant positions in aircraft generators. Global patent activity is therefore of strategic importance to the UK aerospace industry. As developing nations such as China look to challenge incumbents, patents will play a key role in protecting IP and staking out the future competitive playing field.

Are UK organisations doing enough to protect IP in emerging markets? The data in Figure 5 suggests perhaps not. UK inventors are not acquiring as much IP protection in East Asia as other European nations, although global organisations present in the UK are.

The UK also file fewer patents (through the national patent office) than European partners, even when accounting for R&D spend and workshare. Policy differences aside, it appears that UK firms are not utilising patent protection as much as they could. However, Airbus is one of the greatest contributors to UK patent activity and being a European organisation, UK inventions may not necessarily be filed for protection through the UK patent office, even if the IP does ultimately reside in the UK.

Despite lower patent filings, the quality of individual patents in the UK is thought to be higher as they are free of policy incentives with the tendency to artificially inflate numbers. This is validated by the higher citation frequency, illustrated in Figure 12, and subsequent global publication numbers.

Figure 12 - Average number of citations for the top 100 patent assignees by country of priority filing

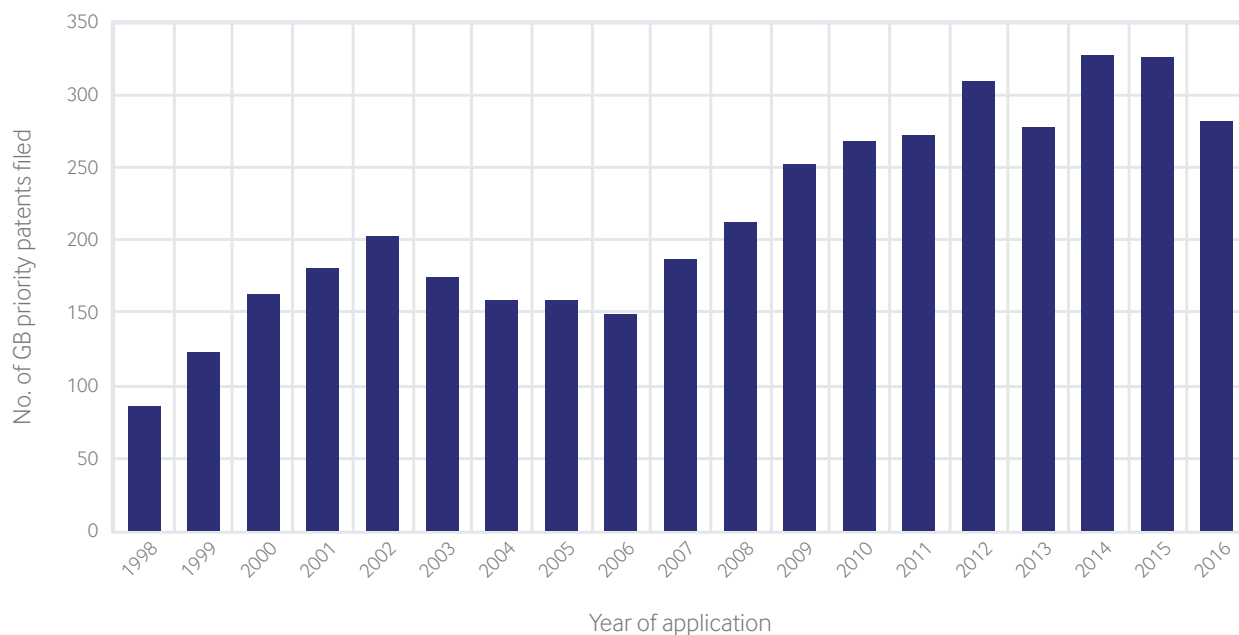


Source: ATI citation analysis of top 100 assignees by patent citations

Monetary incentives for patent filing do seem to increase the volume, as demonstrated by comparing activity across different UK organisations. Organisations that employ in-house patent attorneys and IP teams tend to generate more patents per capita than those who do not. After first being proposed in 2009, the Patent Box does not appear to have driven much change in UK aerospace patent trends, as shown in Figure 13. However, unlike the US and many other nations where patent rates dipped after 2008, the volume of UK patent applications maintained growth, albeit at a reduced rate. Furthermore, UK OEMs also tend to file patents through the EPO, which are not accounted for in Figure 13, and both Rolls-Royce and Airbus patent applications jump in 2009<sup>21</sup>.

<sup>21</sup> IPO and ATI analysis of Airbus and Rolls-Royce published patent applications

Figure 13 – GB priority aerospace patent filing trend



Source: ATI analysis of aerospace patent dataset

The aerospace industry is going through a period of technological disruption arguably equivalent to that seen following the introduction of the gas turbine engine. The patent trends presented in this paper highlight rapidly growing activity in batteries, electrical power, UAM and Unmanned Air Vehicles (UAVs). Companies are acquiring IP at an expanding rate, with much of this activity being led by China. Questions over quality aside, the UK's aerospace industry should take these trends seriously and seek to establish leading proprietary technology within these trending technology themes.

The ATI sees patents as a useful metric of research success and overall competitiveness. It is generally supportive of patent production as an output of funded research. However, the choice to patent relies on a mixture of company policies, competitive strategy, culture and government incentives that vary from region to region and company to company. Comparisons and judgements based on patents data must therefore be approached with some caution with a good understanding of the underlying dynamics.

## ACKNOWLEDGEMENTS

Our sincere thanks go to all the subject matter experts and business development managers from academia, research organisations and industry who were consulted during the course of this work. Notably, we would like to recognise The Intellectual Property Office, University College London, Rolls-Royce, Airbus and GKN. As with all our Economics and Strategy work, we'd like to thank the ATI's Market and Economic Advisory Group for providing independent critique and inputs to analysis and draft presentations of outputs and conclusions.

## GLOSSARY

**Patent application** – refers to a single invention filing

**Patent publication** – refers to a single publication of a patent through a single patent office. One invention/ patent filing can be published in multiple countries and are counted as multiple publications

**Patent priority country** – country where the patent is first filed, before being published in other jurisdictions

**Patent assignee** – the Company or Individual that submitted the patent

**Patent citation** – In citation analysis there are forward and backward citations however, this document refers only to forward citations i.e. number of references to the patent in question after patent publication.

**R&D** – Research and Development

**CAGR** – Cumulative Annual Growth Rate

**IPO** – UK Intellectual Property Office

**EPO** – European Patent Office

**WIPO** – World Intellectual Property Organisation

**PCT** - The Patent Cooperation Treaty, used by applicants who file through the WIPO to seek protection for an invention in a very large number of countries<sup>22</sup>

**IP** – Intellectual Property

**IPC** – International Patent Categorisation

**ALM** – Additive Layer Manufacture

**EPS** – Electrical Power Systems

**R&D** – Research and Development

**UAV** – Unmanned Air Vehicle

**BEIS** – The Departments for Business Energy and Industrial Strategy

*The WIPO standard two-letter acronyms for countries and other regional IP organisations:*

<b>CA</b>	Canada	<b>DE</b>	Germany
<b>ES</b>	Spain	<b>GB</b>	Great Britain (UK)
<b>KR</b>	Republic of Korea	<b>US</b>	United States of America
<b>CN</b>	China	<b>EP</b>	EPO
<b>FR</b>	France	<b>JP</b>	Japan
<b>RU</b>	Russia	<b>WO</b>	WIPO (PCT)
<b>TW</b>	Taiwan, Province of China	<b>AU</b>	Australia
<b>IN</b>	India	<b>SG</b>	Singapore

<sup>22</sup> <https://www.wipo.int/pct/en/>



## ANNEX

Intellectual property (IP) includes product names, branding, novel inventions, product design/aesthetics and anything written, created or produced by an individual or organisation. Copyright, patents, registered designs and trademarks are all types of IP legal protection.

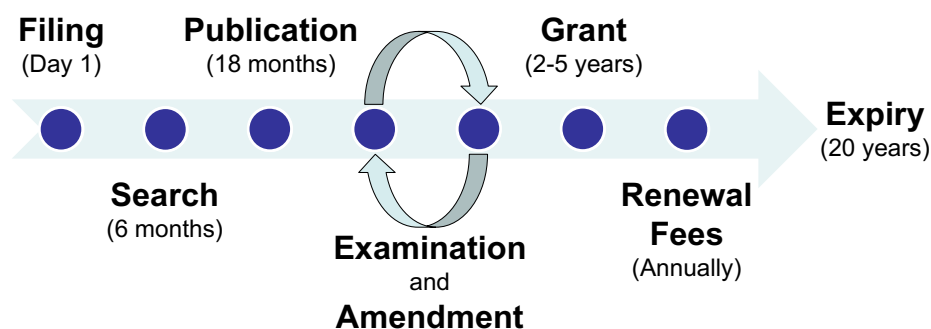
Patent types largely fall into two categories; utility or design. Registered designs or design patents are used to protect the “ornamental design” or shape of a product, and companies such as Apple Inc. use these extensively. Utility patents (simply referred to as “patents” in the UK), cover the creation of a useful, new or improved products, processes or machines. An invention is “useful” if it provides some identifiable benefit and is capable of use or being made. However, within civil aerospace, most patents fall under the “utility” definition. Reference to “patents” in this Insight Paper can therefore be assumed utility patents.

Patents are first filed through a patent office of choice. A “prior art” search is then completed to determine patent novelty. If successful, patents are published 18 months after initial filing, to allow for challenge and amendment. Patents can then be filed through other national patent offices for international protection. Patents are granted after 2-5 years and enforceable for 20 years thereafter.

Patent offices exist in 211 countries<sup>23</sup> through which patents are filed, published and granted. In addition, the World Intellectual Property Office (WIPO) is used extensively throughout the industry to obtain patent protection in multiple countries through the Patent Cooperation Treaty (PCT). Generally, and sometimes by law, patents are filed in the country of invention. However, this is not a rule of thumb and multi-national corporates may choose to file where the IP is most strategically important.

Figure 14 below illustrates the UK Intellectual Property Office (IPO) process. It is worth noting that the IPO prior art search is significantly faster and cheaper than the European Patent Office (EPO) or the WIPO application process. Therefore, patent offices are often selected tactically by businesses to reduce risk and minimise cost.

Figure 14 - IPO Patent Application Process



Source: UK Intellectual Property Office (IPO)

Patents are categorised by International Patent Classification (IPC)<sup>24</sup> alpha-numeric codes. The IPC is universal and managed through the WIPO. Each patent can have multiple IPC codes if it is cross-applicable. These codes start very broadly with eight categories (A to H), but quickly break down through a tree structure into industry specific technology areas. For example, “B64C” corresponds to aeroplanes or helicopters and “B46C0112” relates to aeroplane wing skins. IPC codes are an essential aspect for the usefulness of patent analysis.

Citations are another important aspect of patents. Backward citations, or prior art references, are declared on a patent to determine and document previous work done in the area and most importantly to establish patent novelty. Prior art is initially declared by the inventor and/or inventor’s patent attorney and used to narrow the field of applicability or prosecution e.g. to aerospace. This tactic can be used to strengthen the application in a specific industry and/or to reduce the chances of all prior art being found by the subsequent patent office search. The majority of prior art, however, is declared by the patent office, who ultimately determine the applicability and grant the patent. Forward citations are also recorded and commonly used in analysis to determine subsequent patents; potentially indicating the ongoing value of a patent and applicability across sectors.

<sup>23</sup> WIPO, Patent Office Directory - <http://www.wipo.int/directory/en/>

<sup>24</sup> WIPO, International Patent Classification - <http://www.wipo.int/classifications/ipc/en/>

## WHO WE ARE

The **Aerospace Technology Institute** (ATI) is an independent not-for-profit company at the heart of aerospace research and development in the UK. Our mission is to raise UK ambitions and lead technology in air transport to maximise the UK's full economic potential. We do this by providing objective technical and strategic insight, maintaining a UK aerospace technology strategy, and together with Industry and Government, direct match-funded research investments – set to total £3.9bn between 2013 and 2026.

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*All statements in this report (other than statements of historical facts) that address future market developments, government actions and events, may be deemed 'forward-looking statements'. Although the ATI believes that the outcomes expressed in such forward-looking statements are based on reasonable assumptions, such statements are not guarantees of future performance: actual results or developments may differ materially, e.g. due to the emergence of new technologies and applications, changes to regulations, and unforeseen general economic, market or business conditions.*