

The great aviation patent spike of 1910

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Abstract

This paper shows how aeronautics and aircraft patents in the 1880-1914 period reflect the technological and industrial environment. There was a long term steady increase in the numbers of patents in this area, comparable to growth in patents overall. When it became widely understood that controllable airplanes were a viable technology, there was a sharp increase from about 1906 to about 1910. An industry of airplane makers started up at that time. After 1911, the numbers of patents declined. This spike seems to have been driven both by growing numbers of individual patent filers and by inventors filing patents in more countries. It does not seem to have been driven by the research efforts of airplane manufacturers. Airplane firms took on more ownership of patents during World War I.

Keywords: patents; innovation; aeronautics; aviation; technology; startups

Introduction

In the late 19th century an increasing number of engineers, scientists, and hobbyists experimented with flying machines. Many were drawn to visions of how to fly as birds do, or in some other artificial way that would be more effectively controllable than a balloon. A technological and scientific field focusing on “aerial navigation” gradually developed, with its own terminology that became standardized across languages. These experimenters were in France, Britain, Germany, the U.S. and several other countries.

The aerial navigation experimenters used several fundamentally different technologies. Hot air balloons and hydrogen balloons were known to work, and some experimenters made more-steerable versions, called dirigibles. Others made models with mechanical flapping wings, called ornithopters. Others focused on gliders with fixed wings, or propulsion with propellers that would work for either balloons or gliders.

Increasing numbers of journals and societies were devoted to ballooning and to the heavier-than-air alternatives. In this paper we show some measures of activity in these areas of aerial navigation, which was later called aeronautics and practical aviation using counts of patents and publications. Journals, societies, patents, and publications grew steadily in number from the 1870s on.

Dramatic public demonstrations of airplanes around 1906 changed how many people thought about the field. The numbers of publications and patents increased sharply beginning in 1907. A wave of new airplane-making firms started up across the industrialized countries

¹ Preliminary and incomplete; please do not cite. Nothing here represents official BLS findings or policy. Views are the author's. I thank Leo Zimmermann and John R. Herbert for their extremely valuable research assistance. Comments would be welcome. Much of the data is available for use by others.

in 1908. In the next few years, dozens of exhibitions of airplanes were held and hundreds of new local aviation clubs appeared.

Patent flows show a sharp change too. Annual patent applications for aeronautics technologies more than quadrupled worldwide from 1907 to 1910. Since then, aeronautics has never represented as large a proportion of all patents. The absolute numbers of aeronautics patents declined in 1912 and fell sharply during World War I.

This paper will compare attributes of patents over time to identify aspects of this peak around 1910. The context was turbulent and confusing. Airplanes worked, on a small scale, and an exhibition of them could draw a crowd, but they were not generally useful or robust. A new industry was appearing, but it was not profitable. So far as we can tell, relatively few of the patent-filers actually worked in the new industry. And many patents were associated with technologies other than the newly dominant airplanes: balloons, dirigibles, helicopters, and ornithopters. The purpose of analysing the patents is to see what they illuminate about how the various inventors were thinking, both technologically and in terms of how they would relate to the new industry. Patent data, though peculiar, makes up a consistent and comparable stream of information across time and countries, even as the historical context changed drastically.

The data show that the numbers of aeronautics-related patents grew by about 5-7% a year from the 1870s to 1906, then jumped sharply upwards until 1909-1910, then declined in or after 1911 and continued to decline in World War I. These trends were similar across countries. The spike in patents included a temporary increase in balloon and other designs and topics, but is mainly associated with a shift to fixed-wing airplanes. That is, the shift to fixed-wing designs as a proportion of patents begins before this and continues in this period.

When inspecting what is different about the patents in the spike period from their predecessors, we have only partial answers. There is some increase in the numbers of foreign filings – that is, a patent that is substantively a duplicate of one in another country, by the same inventor. There is a slight increase in the number of patents explicitly associated with a company, but the overwhelming number still appear to be by individual inventors who have not yet sold the rights. Few patents appear to be funded by company research and development until World War I.

The next sections discuss what patents were in the period under study, some of the challenges in interpreting and comparing them across time and place, and some preliminary statistical results of these comparisons.

Patents of the time

For our purposes here, a patent is an indication of creative technological effort and an attempt to certify it. The concept of a patent and the system for administering a patent was evolving and becoming standardized. Formally, a patent is a legal claim to intellectual property which is novel, feasible, and useful. The inventor applies to a government for a patent, stating what the technology is, showing diagrams of it, and making legal claims of originality.² If the government grants the patent, the inventor has a right to a temporary

² The inventors did not have to demonstrate feasibility then as much as they do now.

monopoly to sell versions of the technology specified in the patent in that country. The governments numbered the patents and published the inventor's description. Patents different across countries somewhat, more than now, but by 1880 they generally met this description.

In many fields, such as railroad or mine engineering, a patented technology would be put to use commercially within a year. Commercial sales were a smaller factor for balloons and aerial navigation. The inventors were trying to make flying work, and less often trying to make or improve a product. We know of no patent infringement disputes in this area before the Wright brothers. So why did the inventors patent in a field like aerial navigation? It would be helpful if they had written their reasons for patenting in this area. We can make some inferences.

Many of them were engineers, and it was a professional pattern and a potentially prestigious professional accomplishment to record their work as a patent. If there were a future in aviation, the patentees could get some credit or make some claim to the proceeds. Then too, patenting was sometimes glorified in that era. Thomas Edison, Alexander Graham Bell, and Nikola Tesla had been recognized as founders of industries and held control of companies partly by patenting their inventions. The most important U.S. patenting agency, Munn & Company also published *Scientific American*, which emphasized patenting as useful, constructive, and a way to help create the future (Alexander, Miller, and Pierce, 2014). Cresee (1902), a Munn publication, told readers that most patents were profitable for the inventors. Furthermore in technical publications lists of patents were published regularly, giving visibility to those who patented their inventions.

For aerial navigation, some early experimenters thought it was best not to patent – not to make any claim of intellectual property – at least until the technology had been shown to work. Lawrence Hargrave and Alberto Santos-Dumont took this view, which we may call an “open-source” view. Once an expanding industry existed, it is clearer why the inventors patent. They could sell or license a patent's technology, much more easily than by manufacturing a product themselves. There is a complicated historical transition between the open-source phase and the industrial phase, which economists have not much modelled, and an understanding of the airplane case may help.

Figure 1 shows an example patent document from 1893. The invention shown is an important glider designed by Otto Lilienthal of Berlin, with wings in roughly the shape of those of a soaring bird. The patent filing illustrates certain elements most 19th century patents: a number in the national government's ordering scheme, a title, the patentee's name and location or citizenship, the date it was applied for (“filed”) and the date it was granted, and a diagram. This one is only two pages long, shorter than most patents of the time and much shorter than patent filings now. Its title is “Flugapparat,” meaning “flight apparatus.” Patent officials classified it by its technology, but the classification in this case is “Sport.” No more precise aeronautics category existed in the German system at that time.

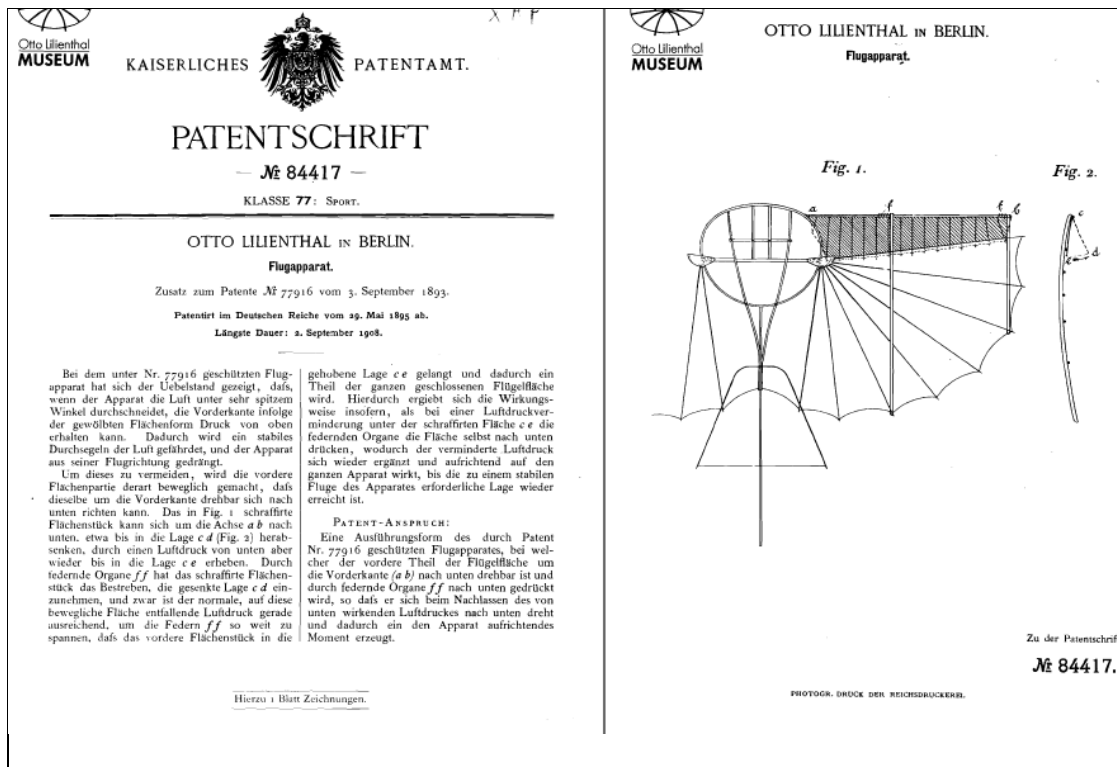


Figure 1 – Otto Lilienthal's 1893 patent

Four countries granted by far the most patents in this area: Britain, France, Germany, and the U.S. In each country patents grew exponentially for decades up to 1906, then the spike was distinct to aviation. Rules and fees differed somewhat by country, affecting levels of patenting.

Patent data sources and their challenges

Patent documents and data are published by national governments. Historical data from before the early airplane period is not always online, or not conveniently so. We have are able to get some data en masse from the European Patent Office via the UN's World Intellectual Property Organization, but much of it has been gathered eclectically by searching for key words, patent categories, or individuals in various online systems. Fewer than 1% of patents overall are relevant to aeronautics and aviation, and it required some choices to find and select them for the data set here. For details of the sources, see appendix A. Utility models, called Gebrauchsmuster in German, are like patents but they are not included in our data at this point.

Another set of ambiguities is associated with secondary patents. These are of two kinds, additions and foreign filings. An "addition" to an earlier patent, that is, a clarification or extended claim. These are patents themselves. A foreign filing is a patent application with the same design that has already been filed, but in a new country. Patent rights were strictly within a country at the time, though these practices are more internationalized since then. In the examples before the Paris Convention of 1883, one cannot usually tell just by looking whether a patent was a foreign filing; it makes no reference to its predecessor. After 1883, it would usually be clear that a patent is a foreign filing, but the information on the number of

the original patent is not always explicit. In uncertain cases, our working principle is that if the diagrams in two patents are the same, one is a foreign filing of the other, and if they are not the same, they are distinct originals.

The difference between first/original patents and supplementary/child patents is important for measuring innovation. Foreign filings may look like new patents in the data but generally do not represent the same inventive significance. A set of such closely related patents is called a patent family nowadays. This project finds and explicitly records many such links that were not clearly identified in sources.

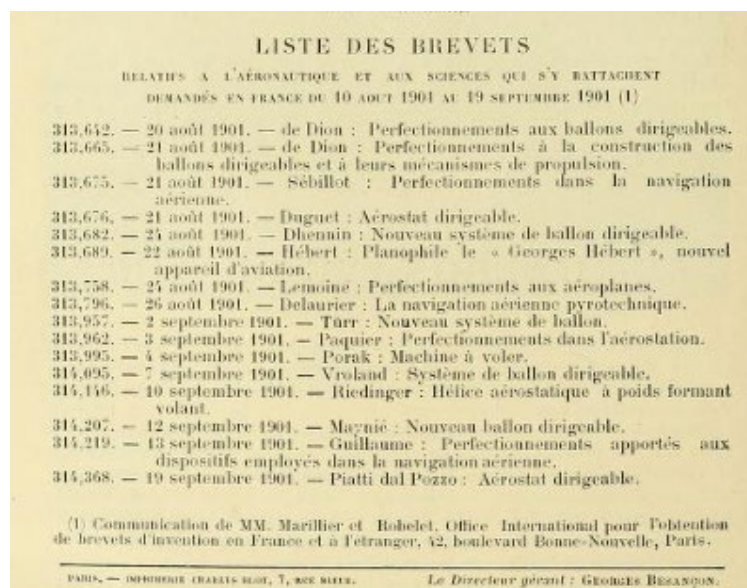
Which patents are relevant to aeronautics and aviation? Drawing that line is difficult for several reasons. First, it is not easy to get general lists of all patents especially before 1890. The U.S. is the easiest country for this as it has scanned all patents back to 1837 online.

Second, the technological classifications of the time do not identify aeronautics clearly. The classifications differed by country, and the official patent category systems of the time adapted differently to handle the new field of aeronautics. We apply keywords to each patent to standardize these, and for many historic patents the newer IPC and CPC technological classifications have been applied. In the case of Lilienthal's patent, the title includes the term for flight, which is one clue, and the patentee was famous for his accomplishments in this area so a museum and several books have listed this patent.

Third, there is the underlying uncertainty about which patents had implications for aeronautics at a time when it was not known that the soaring-bird model of an aircraft would be more successful than balloons, rockets, helicopters, or flapping-wing ("ornithopter") designs. Potential new technologies are associated with deep uncertainty.

Journals and reference works sometimes identified patents related to aeronautics according to contemporaries. Figure 2 shows an example. Like many such lists, it helps identify which patents were relevant, but does not give much detail about each patent.

Figure 2. List of aeronautics-related French patents from a 1901 issue of the journal *L'Aérophile*



Different national patent offices had different criteria for granting a patent at the time of early aviation. Several required each patent application to be evaluated carefully by a patent examiner for whether it met the main criteria of originality, feasibility, and usefulness. The

German patent office had the highest standards. The U.S. Patent Office also required each patent to be examined.

The British and French offices did not have an examination system, but instead a registration system, with lower criteria. Patents would be judged acceptable for registration without a careful technical evaluation, and a fee collected. The originality of the patent would be left for disputes in court. In a patent lawsuit, a potential user of the technology could show evidence that prior art already included the patented technology, and if successful such a lawsuit would limit or nullify a patent's claims.

Patents granted in the British and French systems therefore met a lower standard than those in the German system, and were more numerous than German ones. From reading the patents, it seems likely that there was more duplication among the British and French granted patents, and they are less likely to be clearly written and sharply defined. There may be some way to measure or demonstrate this. We are collecting information on the practices of other national patent offices.

The ever-improving data on patents are online at the Inventing Aviation web site at <http://econterms.net/aero>. Each patent has a wiki page. Related pages on inventors, authors, companies, publications, and airplane clubs and societies are linked to the patents. With this data it is possible to compare across countries, across time, across technologies, and with some knowledge of patent quality and institutions.

Each patent therefore has a variety of ambiguities and uncertainties. We use a wiki and have a page for each of our thousands of patents. This technique can be useful to other historians who wish to get summary statistics from data in which each object is complicated, ambiguous, and interrelated with others. *(Will show more about the wiki in the presentation.)*

Aero patent counts before the spike

The goal is to standardize the data enough to compare patents across countries and over time on several dimensions. Most of the relevant patents were filed in France, Britain, Germany, or the U.S. A challenge is that patents do not each stand alone as singular accomplishments. We show some preliminary comparisons, treating foreign filings and additions just like original patents for now. Patent counts in aeronautics grew by 5% a year or more in these countries up through 1906 as shown in Figure 3. This is similar to the rates of growth of patents overall, in all fields, in that period.

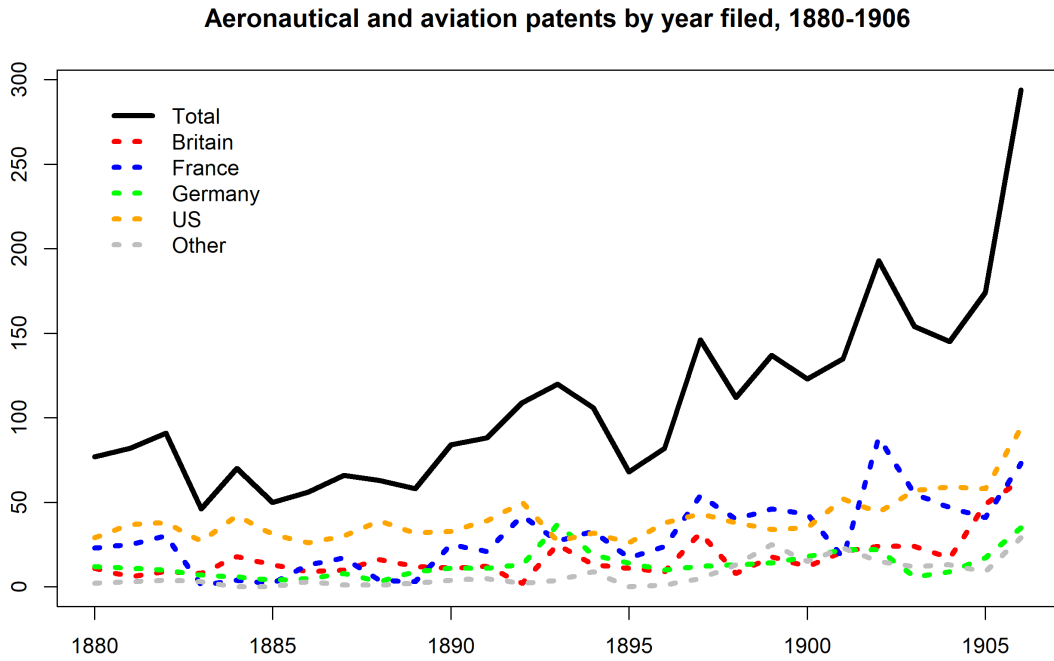


Figure 3 – Patents per year related to aeronautics and aviation before the airplane industry began, showing exponential growth then a sharp increase in 1906. When filing year is not available but grant year is available, (grant year minus one) is used as an estimate.

An estimate of publications excluding patents, in the field of aeronautics from Brockett’s 1910 *Bibliography of Aeronautics* grows at a similar exponential pace, shown in figure 4. These two charts give proxy measures of the growth of aeronautics as a field.

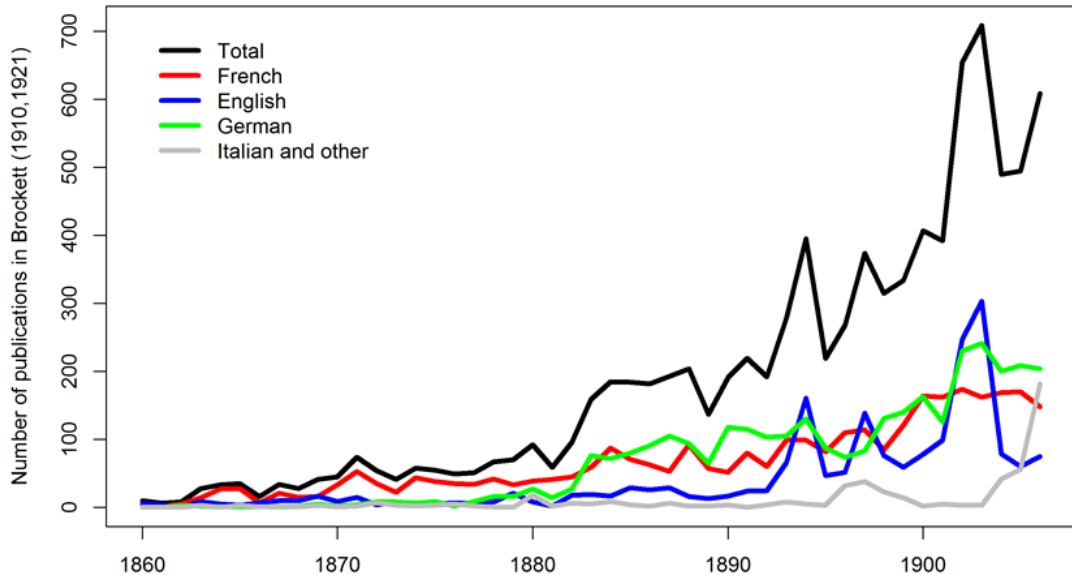


Figure 4 – Aeronautics and aviation publications per year drawn mainly from Brockett (1910), with minor improvements. The increase tracks with the patent flows.

Aero patents across countries and time in and after the spike period

Patent counts rise sharply after 1906, peaking in 1909. Figure 5 shows patent counts by filing year, that is, the year the inventor filed the patent application. A chart by the year granted is a bit more spread out. For some patents we have not yet filled in a proper grant year; in these cases we filled in the year of filing plus one; this is a plausible estimate in general. British patents peak ahead of other countries here, for which we have no explanation.

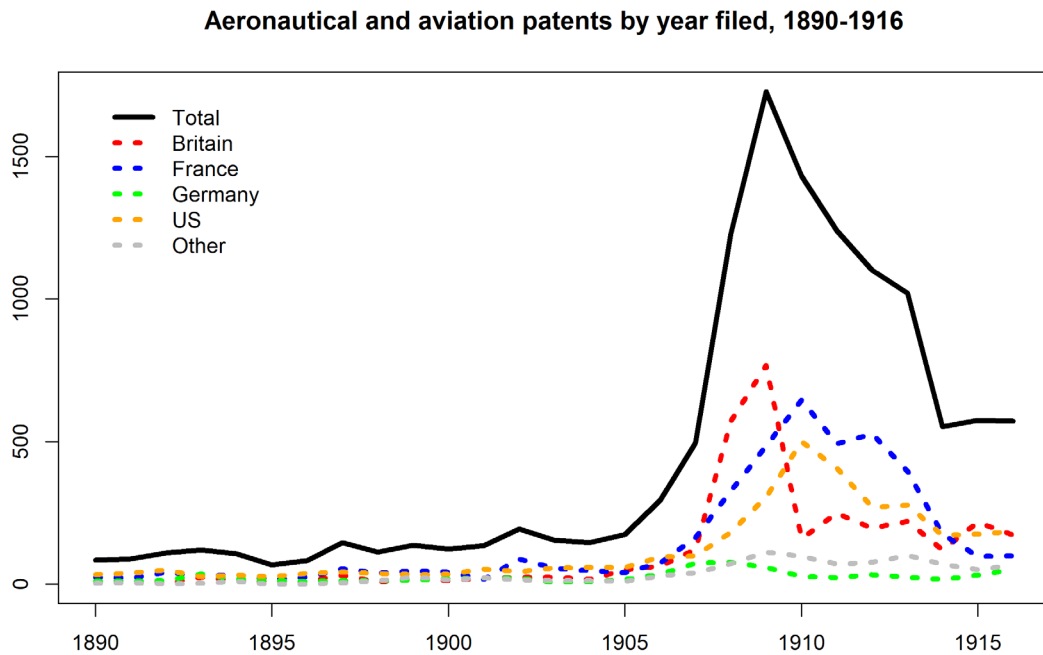


Figure 5 – Aeronautics-related patents per year for selected countries. Filing year is estimated by (grant year minus one) if it is not otherwise available.

Direct measures of patent documents

Looking at each patent individually we can gather basic information about the documents. For many of the aero patents of France, Britain, Germany, and the U.S. we have the numbers of text pages, of legal claims made, and of diagrams. Averaging for the sample of patents for which these are coded, German aeronautics patents had less text (about two pages) and fewer diagrams than aero patents in other countries, and they made fewer legal claims. U.S. patents were the longest, averaging 4 pages, and they more legal claims.

A hypothesis of Thomas Kuhn was that as a new scientific paradigm appeared, texts about it would be lengthy as the writer had to explain the concepts at length, and as the paradigm became established, the texts would encompass that into a standardized vocabulary. However, holding country differences constant, there does not seem to have been much change in the length of aeronautical patents over time.³

³ There will be more details in the workshop.

The text of the patents can be used in other ways eventually. Kelly, Papanikolaou, Seru, and Taddy (2020) have used the digitized text of all available U.S. patents to see which ones were influential in the sense that later patents used their terminology. It is a remarkable analysis. According to their measures, the 1906 Wright patent is one of the most influential of all time.

Roles of firms

From various sources our project has identified over 200 firms or organizations which made airplanes or were aeronautically significant suppliers or redistributors of airplanes in or before 1911. Many just appear briefly in the evidence then vanish, e.g. because they were assigned a patent or are referred to in a newspaper or advertisement but are not known to have earned revenues.

The industry did not have much revenue in this period, and it is difficult to measure. It appears that most revenues to the new industry came from exhibitions in this period, not yet from sales of aircraft. Exhibitions were sometimes huge; thousands of people came to the Reims 1909 exhibition, and the largest ever was in Los Angeles in early 1910 which had hundreds of thousands of attendees, paying on average perhaps a dollar in admission. Other revenues to these new firms came from contracts to sell airplanes to the national militaries, and an occasional experiment with air mail. Airplanes were first used in war in 1911-1912. Chadeau (1987) estimates production and exports of airplane and aero engines from France in this period. Revenues were growing but not sharply until World War I.

The early airplane makers spun off or branched in from other industries. Klepper (2009) defines spinoffs as those where a major figure in one firm came from another, and finds that by this definition spinoffs were common in the early U.S. automobile industry around the same time. The sources industries generally involved engineering and manufacturing, e.g. machine parts, engines, cars, boats, motorcycles, and rail cars.

Firms could had several potential roles in a patent filing:

- 1) An applicant for a patent may be a firm or other org, along perhaps with an inventor. Probably the firm paid for the R&D that produced the patent. No strong trend in firm-applicants during the spike, but an increase in World War I.
- 2) A firm might buy or license the intellectual property. The legal phrasing is that they would be “assigned,” the patent rights.
- 3) An inventor may have hired a patent agent – an individual or a company -- to help file the patent application to the patent office. In French and British patents the role of the agent was recorded on the patent document; in U.S. ones it can be inferred, with some difficulty. Firms may have used their own staff lawyers or other experts as patent agents, rather than hire one.

Figure 6 shows measures of the prevalence of these from a sample of our patents as a proportion of aero patents annually in each country.⁴ We see no strong change in this likelihood at the time of the patent spike. The procedures and the data on this varies by country, and given time we can compare in more detail.

⁴ Details of the data can be given in the presentation.

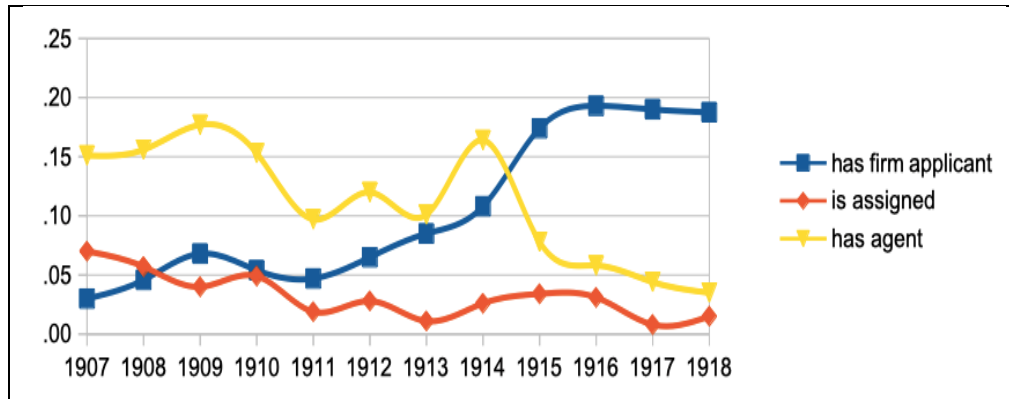


Figure 6 – Roles of firms in patents; shown as proportion of coded patents each year

Differences across countries

Four countries granted by far the most patents in aeronautics Britain, France, Germany, and the U.S. Basic trends in patent flows appear to be similar across these countries. The other industrial countries have similar trends, perhaps delayed a bit. Many inventors were aware of work in their field in other countries and inventions are almost as quickly cited in other countries as in the first country.

A few effects are country specific. Patents numbers decline more in Germany and France during in World War I than in other countries. A great spike in aero patents in 1909-1911 (see Figure 1) is especially high in Britain and may be associated with more startup companies there than in other countries.

In each country the number of patents overall, and in aviation, grew exponentially for decades up to 1906. The spike after 1906 was distinct to aviation. A complexity in counting is that many patents were secondary “foreign filings” of patent applications already filed in a home country. We find and record many such links that were not clearly identified in sources.

The Wright brothers filed major lawsuits in the United States in the period of the spike. They won in in the United but not in other countries. It is not clear from the data so far that this caused differences in aviation patenting patterns between the U.S. and other countries, either in terms of numbers or technological topics. The lawsuits were famous and influential, and there may yet be a detectable effect, but in principle the lawsuits could either have encouraged inventors to work on aeronautics and apply for patents, or driven them away.

Technology trends

Fixed-wing designs made up a larger fraction of these patents over time, as did patents related to control, stability, and safety. However, in the spike period there was an increasing in patenting of balloons and helicopters along with the recently-proven fixed-wing aircraft, suggesting that the patent boom was associated with a broad sense of opportunity and relevance, not tightly bound to the newly proven technology. Classification by technology required overcoming some challenges and adding to the original data, and it has been done for a large sample but not all the patents in Figure 3.

Figure 7 shows the proportion of patents associated with several issues and technologies. A patent may be associated with one or several technologies and we have not tried to adjust to scale to make each patent equally represented in the chart. We do not distinguish here between monoplanes and biplanes here because patents often could apply to either. Most of the early craft were biplanes, often made of wood. Monoplanes became more optimal when stronger metal materials and higher speeds are feasible. Some appropriate categories such as scientific instruments and navigation-and-control equipment are not yet included in the chart.

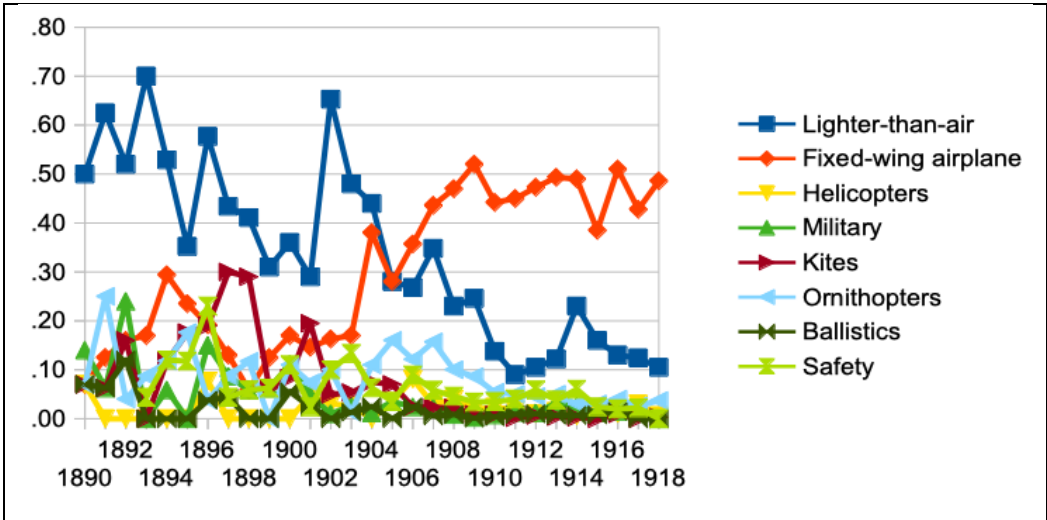


Figure 7 – Technology themes associated with aeronautic patents 1890-1918

From 1890 to 1918 the patents clearly associated with lighter than air craft decline as a fraction of aeronautical patents from around 50% to around 10%, and the patents associated with the new fixed-wing aircraft designs increased from about 10% to about 50%. We see the rise in fixed-wing aircraft starting in 1903, and it exceeds the balloons around 1909. Thus the fixed-wing aircraft was the new dominant design before it supported a strongly revenue-producing industry. Other technologies also seem to have a reduced proportion over time, and it may be possible to make a definitive finding about that at as the sample improves in the future.⁵

Based on comparing the frequency of categories of aeronautical patents to others (mainly in Belgian data for now), it appears that aeronautics fell a bit more in the 1914-1918 period than other categories did. Presumably that is because it was a technology usable in the war, and there was more reason for various actors to keep new invention secret.

What are the inventors doing to cause the spike?

The spike in patent numbers is stark. We know from context that it is associated with the new opportunities in aviation – technical and financial opportunities. If we could understand that better, it could give us a sense of which institutions help the invention and the industry

⁵ In the presentation I plan to make clear whether the absolute numbers for these categories went up during the spike period, and the keyword definitions used here.

appear. Here are some hypotheses about inventor behavior in the spike period to test in the patent data over time.

- *More people were drawn to aeronautics, and filed patents in an area that is new to them -- perhaps a Gold Rush – it was new and hot and apparently feasible*
- *Inventors are filing more additions to patents than they did before.*
- *Inventors filed in more countries than before (“foreign filings”)*
- *In some other way, inventors filed two patents for an invention where they would have filed just one, before*
- *Inventors put more time or resources into aeronautics than they did before, and coming up with more original ideas than before*
- *Inventors started or joined firms and built intellectual property in them*
- *Inventors sold more of their patent rights to firms than before*
- *Inventors filed patents for inventions they’d already made, or would have made anyway, but wouldn’t have patented*
- *Inventors filed more patents for inventions that overlapped or duplicated other patents*

These are data-scientific questions, that is, questions about what the patent data can tell us. Their answers do not fully address the larger motivating questions of how there came to be an airplane and an airplane industry, and what institutions and people helped that happen. Cultivating the data to answer these questions may help address the big questions however.

We have classified whether a patent is a foreign filing or addition in about 2/3 of the patent records. For all years and countries together, about 40% are in one these categories of “child patents” according to our estimates so far. This rises to about 46% in the 1909-1911 spike period. So that change is associated with some, but not much, of the increase. We have not yet tested whether additions (within the same country), or foreign filings, increased particularly. These are questions to be addressed further as the data fills out.

The decline after the spike and World War I

Why did aero patents decline after 1911? Here are three likely explanations, which overlap.

- The patenting frenzy simply went to unsustainable levels, and probably included more duplication among patents than before. Once patent examiners had mastered the new field, they didn’t accept as many duplicates.
- The patent boom represented a blossoming of alternative designs in this period of excitement, but then the basic airplane designs were increasingly standardized, and patenting further required more specialization, more equipment, more time, so fewer inventors could do it.
- The airplane business wasn’t booming. Military and postal contracts existed, but were not large enough. Passenger traffic was minimal. There were journalistic and scientific reasons to fly, but little revenue from it. Exhibition sales were the earliest source of big revenues, as huge numbers of people wanted to see an airplane fly, but by 1912 most of them had had their chance to see it. The numbers and sizes of exhibitions may be in decline by then, and presumably revenues too.

As World War I began, research and development expenditures on aircraft went way up but patenting did not. The underlying reason, presumably, was that aeronautics had military applications, and war technologies should not be openly published by people in country A, since they could be put to use by opposing country B. Patent rights from foreigners were sometimes seized – nationalized -- by the governments at war. Some patent applications were held up in the patent offices until the war was over. Others were granted but kept secret. Our database does not have enough cases of this to make empirical statistical statements yet, but in the long run we can measure the difference between filing date and grant date across countries and time periods, to see the effect of changes in the environment including the war.

Since airplane R&D went up while patenting did, not, patent numbers are a poor metric for rates of innovation during the war. Counts of aeronautics publications have the same problem – they seem also to have stayed low. Indeed, a number of aeronautics journals explicitly reduced their frequency of publication during the war.

Conclusions

The data shows that the numbers of aeronautics-related patents grew by on the order of 7% a year from the 1870s to 1906, then jump sharply upwards, then decline in or after 1911 and continue to decline in World War I. These trends are similar across countries. The spike in patents includes a temporary increase in in balloon and other designs and topics, but mainly is associated with a shift to fixed-wing airplanes. That is, the shift to fixed-wing designs as a proportion of patents begins before this and continued in this period. The patent-infringement lawsuits by the Wright brothers did not seem to affect the U.S. numbers compared to other countries

When inspecting what is different about the patents in the spike period from their predecessors, we have only partial answers. There is some increase in the numbers of foreign filings – that is, a patent that is substantively a duplicate of one in another country, by the same inventor. There is a slight increase in the number of patents explicitly associated with a company, but the overwhelming number still appear to be by individual inventors who have not yet sold the rights. Few patents appear to be funded by company research and development until World War I.

Appendix: Patent data sources

The European Patent office keeps a global database of patent documents with metadata. This is the most complete source. Julio Raffo and Intan Hamdan-Livramento of the UN's World Intellectual Property Organization made a data set from about 13,000 of these in the Patstat database available to Inventing Aviation and much of that data is now online in the wiki. These were based on searches in particular technical classifications.

To fill in all the desired fields requires looking at the original patent-grant documents, like the one in Figure 1. Most of these have been scanned by the national governments and are available from the public-facing EPO site <http://espacenet.com>. We search it frequently to fill in details from patents for which we have partial information, and to find others by the same inventors or with some other searchable characteristic. Google patents has many of these in a conveniently searchable way. Espacenet's coverage has been increased in recent years for the 1890-1910 period; we periodically discover historic patents there that seem not to have been there before. Espacenet does not include most patents filed before 1890.

Several national patent offices have digitized all their historic patents, or make a searchable database available. The US Patent and Trademark office has scanned all its patents back to 1836. National patent offices, especially the French INPI and the German DPMA, have some searchable information on the earlier patents. The Canadian, Australian, New Zealand, and Hungarian patent offices make some information about all their historic patents available online. Some of these systems require one to know a patent number to search for its information. We do not know how complete our coverage is but presumably we have most of the aeronautical patents worldwide before WWI by now.

During the period in question, many governments published regular gazettes listing newly approved patents. Several of these gazettes are scanned online and available on Hathitrust, the Internet Archive, google books, and other online sources. Published volumes from national patent offices and the U.S. Patent Office of the time listed foreign patents, and we have been through a number of at the US PTO's Scientific and Technical Information Center (STIC) library. There is more to do there but it is closed during the covid era.

We judge whether a patent is relevant to aeronautics and aviation either by its classification or by reading it. If it refers to aircraft, we include it. In ambiguous cases we include a patent record, but mark it as only marginally related to aircraft. Our data includes some patents which are not related to aircraft in our judgment if they have certain attributes that help us – e.g. that it was filed by a person who also filed aircraft patents, and helps fill out their history, or if any secondary source has indicated that it was relevant to aeronautics. In principle the wiki database should include some information about any patent that has been marked as relevant to aeronautics, although we do not cover engines yet.

The next table lists the countries with the most patents in our database, and the most significant sources. (The counts include some patents that are not related to aeronautics, or are out of our period of interest.) There will be many more from some of these countries. Google patents has information for most of these, generally those which are available on espacenet too. For the oldest patents we usually don't have complete information, e.g. not the author's full name. From several countries the search is challenging as the inventors names are not recorded, or not recorded in a standard way.

Table A1. Notes on patent data by country

Country (Abbreviation)	Patents in data	Notes on the country's early aero patent data
France (FR)	5036	Digitized and available on espacenet back to about 1900. There are a variety of earlier sources with summaries or lists: Online INPI.fr historic patent database, searchable from http://bases-brevets19e.inpi.fr/index.asp?page=rechercheAvancee . Patents were indexed in the <i>Catalogue des brevets d'invention</i> and <i>Bulletin Officiel de la Propriété Industrielle</i> in the 1880s; and in USPTO's <i>Subject-Matter Index of Patents for Invention, France</i> (1883); <i>L'Aérophile</i> issues 1898-1905 listed aero patents specifically; <i>Aéro-Manuel</i> , 1914, lists some aero patents
United States (US)	4790	All granted patents are digitized and available on USPTO site and on espacenet. Original technical classifications of patent are not easily available.
Great Britain (GB)	3724	Digitized and generally available on espacenet back to about 1905. Technical classifications used at the time are not easily available. Summaries of aero patents appeared in Brewer and Alexander's 1893 book, in Neilson (1910), and in many issues of <i>Aeronautical Journal</i> . <i>The Abridgements of Patent Specifications</i> listed others and some information about classification.
Germany (DE)	882	Patents began 1877; All German patents have data available at DMPA; most are digitized and online at espacenet, DPMA, or Otto-Lilienthal Museum. Regular lists of aero patents appeared in <i>Jahrbuch über die Fortschritte auf allen Gebieten der Luftschiffahrt</i> and <i>Deutsche Zeitschrift für Luftschiffahrt</i> . Alexander-Katz (1912) lists some. We exclude Gebrauchsmuster patents (quick patents) from this study for now.
Hungary (HU)	327	Hungary's patent office was distinct from Austria's. All historic patents are on the current Hungarian patent office web site, not espacenet.
Austria (AT)	153	Patent office distinct from Hungary's. Many patents are on espacenet; all are indexed by DPMA.
Belgium (BE)	148	Patents from the early aero period are not on espacenet; catalogs with summary information are in <i>Recueil des Brevets d'Invention</i> volumes, available in USPTO's STIC library; Originals available at archives in Brussels. Very antique and very raw indexed patent data may be found via the digitized material provided by the State Archives of Belgium.
Italy (IT)	90	We haven't found the patent documents online but summaries are listed in the regular government gazette <i>Bollettino della proprietà intellettuale</i>
Canada (CA)	78	Granted patents documents are digitized and available from CIPO & espacenet
Switzerland (CH)	70	All patents have some data at DPMA; documents are available at espacenet
Spain (ES)	66	Most are indexed at espacenet but documents are not often available.
Norway (NO)	49	Many patents from early aero era are not on espacenet ; Short descriptions available were library in Trondheim
New Zealand (NZ)	27	Patents from early aero era are available on IPONZ web site, not espacenet
Denmark (DK)	21	Patents start about 1864. They are on espacenet.
India (IN)	16	Had a patent office distinct from Great Britain's; Patents are on espacenet
Australia (AU)	16	Australia's early aero patents are all available from the Australian Patent Office web site; we think they are not generally on espacenet

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