GLOBAL TRENDS

- Explosion in the Number of Patents Related to Unmanned Aerial Systems

DANISH TECHNOLOGICAL INSTITUTE

Titel
Global Trends
– Explosion in the Number of Patents Related to Unmanned Aerial Systems

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Into the future with unmanned aerial systems

The number of unmanned aerial systems (UAS) has exploded since 2013. More than 85 percent of all patented UAS have been published in the last six years. Based on the development in the number of UAS lately, there is every indication that the expansion in the number of UAS will continue in the near future.

Operators of high-end technology are constantly finding more practical and innovative uses for UAS. The increasing number of patented UAS has increased the numbers of countries and companies on the market in connection with UAS technology. The future will probably bring even more global players that will contribute to the further expansion of UAS technologies as well as the diversity and sheer number of UAS platforms offered by manufacturers worldwide.

UAS have been referred to by many names, such as drones, Unmanned Aerial Vehicles (UAV), Remotely Piloted Aircraft Systems (RPAS), etc., but this report uses the UAS abbreviation.

In this report, Danish Technological Institute (DTI) dives into global databases with UAS patent data to gain a better understanding of the vast potential of the UAS technology. This kind of 'tech-mining' provides insight into identifying trends and patterns in the data. The purpose of the report is to use the data to gain strategic insight into technologies, actors, and markets.

Our strategy in the search for relevant patents is to identify a core set of patents that are highly relevant to the technology. Thus, we have identified 28,398 patent families of high relevance to the report.

By analysing the data location of each patent from 1990 to 2019, the main location for UAS patents is China, with Shanghai and Hong Kong leading the number of patent assignees. Shenzhen Daijang Innovation Tech takes out most patents and is known as a UAS manufacturer for aerial photography and videography and accounts for around 800 patents related to UAS. In the North East Asia region, South Korea also has a significant number of patent assignees. The US is a distant second in the number of patent assignees, and the patents are mostly concentrated near the coasts.

Furthermore, in relation to the technical specifications of the UAS, the tendency is that more types of energy sources have been introduced to the market in the last decade. The most used energy source over time and overall is battery-powered UAS. However, since the beginning of the 2010s, other energy sources have been introduced to the UAS market. Especially the number of UAS powered by solar and fuel cells has increased significantly and will likely continue to do so. The electric communication technique trends have also experienced changes over time. The number of patent publications has experienced a very steep increase in the past 2-3 years, with an accelerating innovation rate for both communication techniques relating to the control of the UAS (control of position, altitude, and traffic control) and other patents with more general techniques from using cameras on board the UAS platform - including television systems or radio transmission equipment. The innovation rate leads us to expect an increase in the market of platforms with extended capabilities for photography, transmission, processing and analysis of live images. The fields of application of the new technologies will be very broad.

The above UAS trends are just a few examples of the fast growth on UAS market. For more detailed results of the strategic insights into technology, actors and markets, please proceed to the next sections.

Findings of the data mining analysis

The first section presents the global hotspots. The subdivision of the global hotspots includes a short presentation of the most frequent keywords in the identified patents. Next, the section presents a heat map of patent assignees followed by the intensity of patent publications across time, by countries, across patenting companies, and finally related to different types of technologies.

The second section presents the number of patents for the top 10 players excluding China-only patents.

The third section presents a map of the number of European patents plus Norway, Switzerland, and Iceland as well as the top 10 European companies with UAS-related patents.

The fourth section deals with technological specifications, where the UAS-related patents are divided into different types concerning energy sources, propulsion types, and navigation systems. Finally, different communication techniques are presented.

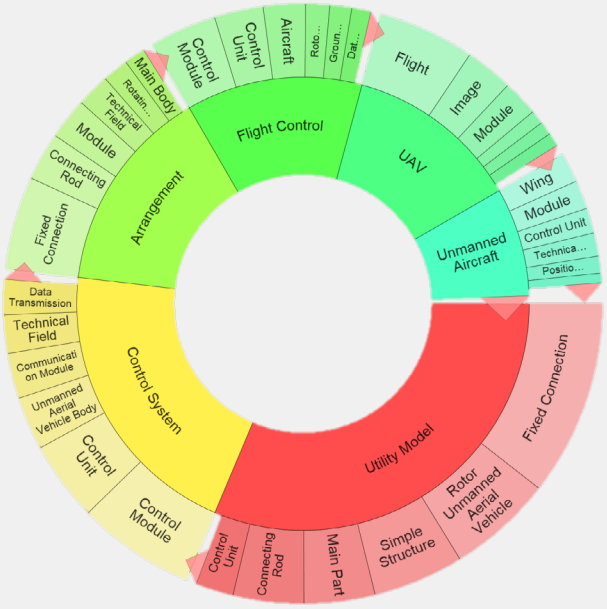
Global Hotspots

The current analysis is based on global patent databases via PatSnap where 28,398 UAS patent families were identified.

In Figure 2.1 the circle chart or 'wheel of innovation' categorizes the most frequent keywords in identified patents into a twotier hierarchy of the most recent 10,000 simple families in the technology field. The wheel of innovation thus represents an overview of keywords related to UAS patents and how they can be organised in groups.

The wheel of innovation can be used as an indication of the focus of technological development in an area. As Figure 2.1 shows 'utility model' and 'control system' are the two most frequent keywords when it comes to UAS patents, each with a number of keywords, including applications and specifications attached to them. 'Control unit' is the most frequently used keyword in the second tier of the wheel and is of key importance to the firsttier families.

FIGURE 2.1 WHEEL OF INNOVATION



The Circle Chart categorizes the most frequent keywords in identified patents into a 2-tier hierarchy of within the most recent 10,000 Simple Families in the technology field.

Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified. Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*"). Extract 7. dec. 2018.

China has been the market leader for years

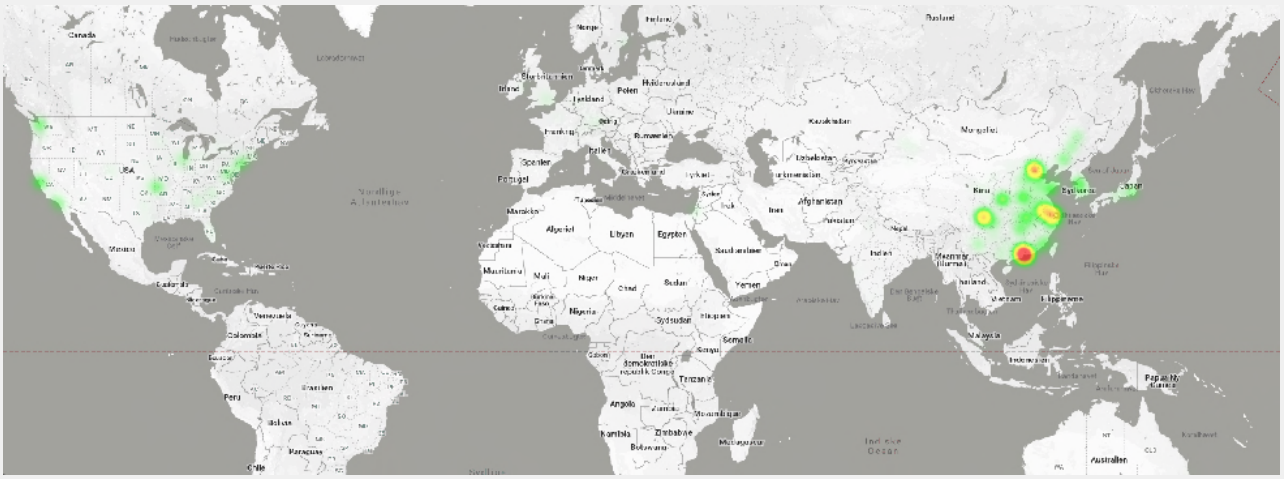
The heat map in Figure 2.2 shows that the main location for UAS patents is North East Asia, more specifically China, with Shanghai and Hong Kong taking the lead in the number of patent assignees. South Korea also has a significant number of patent assignees in the region.

The US is a distant second in the number of patent assignees. The patents are concentrated at the east coast and west coast as well as around Chicago and Arkansas. Both in the US and China, the UAS industry is traditionally based on military, industrial companies, but new actors such as Amazon or Walmart are also visible.

Very few UAS patent assignees are located in Europe where Germany takes the lead with its strong tradition for manufacturing and key role in Industry 4.0 development.

FIGURE 2.2 HEAT MAP OF PUBLICATIONS UP TO AND INCLUDING 2018 (CURRENT ASSIGNEE ADDRESS)

World of UAS innovation 2017-18 – number of patents



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified. Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*"). Extract 7. dec. 2018. Only patents from 2017-18 is included in the map. Map by batchgeo.com and based on assignee addresses.

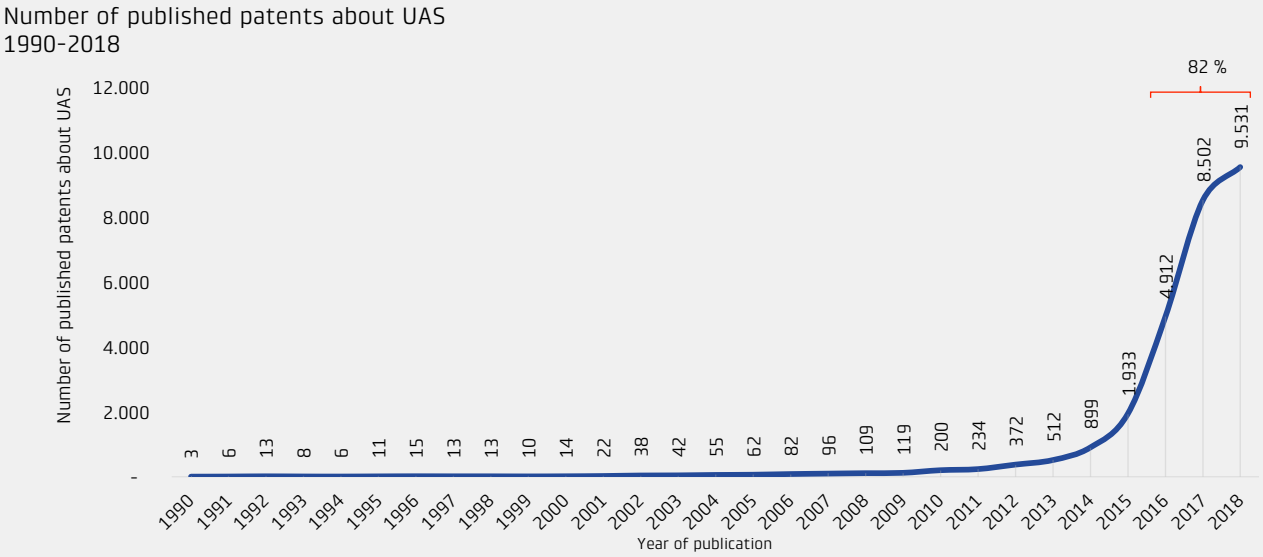
82 percent of all UAS patents have been published after 2016

Looking at the number of UAS patent publications, incremental growth characterised the development until 2014 when the number of patents took off and started doubling on an annual basis.

Figure 2.3 shows the relatively limited increase in the number of publications from 1990 and onwards and the rapid increase in numbers from 2014 - a development already indicated from 2011. From 2016 to 2018, the increase in UAS publications rose as much as 82 per cent, reaching almost 10,000 publications in 2018.

The application possibilities of UAS has broadened significantly over the past years with technological advances in materials, energy sources, and navigation systems as well as sensors and cameras, and the relative affordability has significantly increased the private demand, which in turn has supported further technological development. Consequently, it is reasonable to expect the number of patents to continue to increase in the years to come.

FIGURE 2.3 PUBLICATION TRENDS, 1990-2018



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified. Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*"). Extract 7. dec. 2018.

China is the most UAS patented country in the world

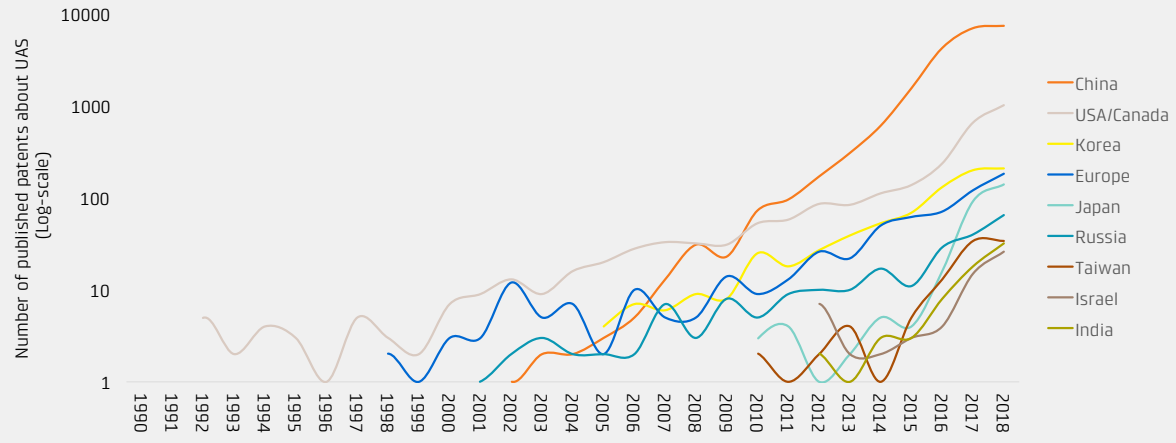
The US has been issuing UAS patent publications since 1992 and dominated the field until 2008 when it was surpassed by China. Today, China is the country that issues the most UAS patent publications. Many patents are issued in China only and if these patents are excluded from the analysis the number of patents in the analysis drops to 8,474 patents.

In 1998, Europe joined the top 10 and was followed by Russia and China in 2001 and 2002 respectively. In 2005, South Korea entered the top 10 at a relatively high level and currently ranks third on the top 10 list. As late as 2010, Japan and Taiwan joined the top 10 with Israel and India but in 2018 they are at the bottom of the list.

UAS technology is gaining ground in several areas including modern warfare. The countries on the UAS top 10 are not surprising as they represent countries with strong military and/or technological traditions.

FIGURE 2.4 PUBLICATION TREND BY COUNTRY, 1990-2018 (MOST PATENT BY TOP 10 COUNTRIES)

Number of published patents about UAS
1990-2018 – most patents by top-10 countries



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified.
Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*").
Extract 7. dec. 2018. Figures for Europe calculated separately.

3757 companies with UAS-related patents

Figure 2.5 shows that there were 3,757 companies related to UAS patents from 2016-2018, and this illustrates that the grouping of patenting companies appears to be located in relatively few countries. The most widespread activities of patenting companies take place in China. Approximately three out of four patenting companies are based in China. This implies that Chinese companies are considered to be market leaders concerning UAS-related patents.

The US has the second largest group of patenting companies. Approximately one in ten patenting companies are based in the US. The US patenting companies can be found on both coasts, but the largest share of companies is located in Texas.

The last country playing a leading role in patenting UAS is South Korea. There are 298 patenting companies in South Korea, just below the number in the US, which indicates that the two counties are the second-most patenting countries.

Beyond Chinese, American and South Korean patenting companies, very few companies have taken out UAS patents. The remaining companies are located in Europe, the Middle East, Australia and Southeast Asia.

FIGURE 2.5 UAS-RELATED PATENTS DISTRIBUTED BY PATENTING COMPANIES

World of UAS innovation 2016-18 – number of patenting companies – Total: 3757 companies

Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified.
Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*").
Extract 7. dec. 2018. Only patents from 2016-18 is included in the map. Map by batchgeo.com and based on assignee addresses.

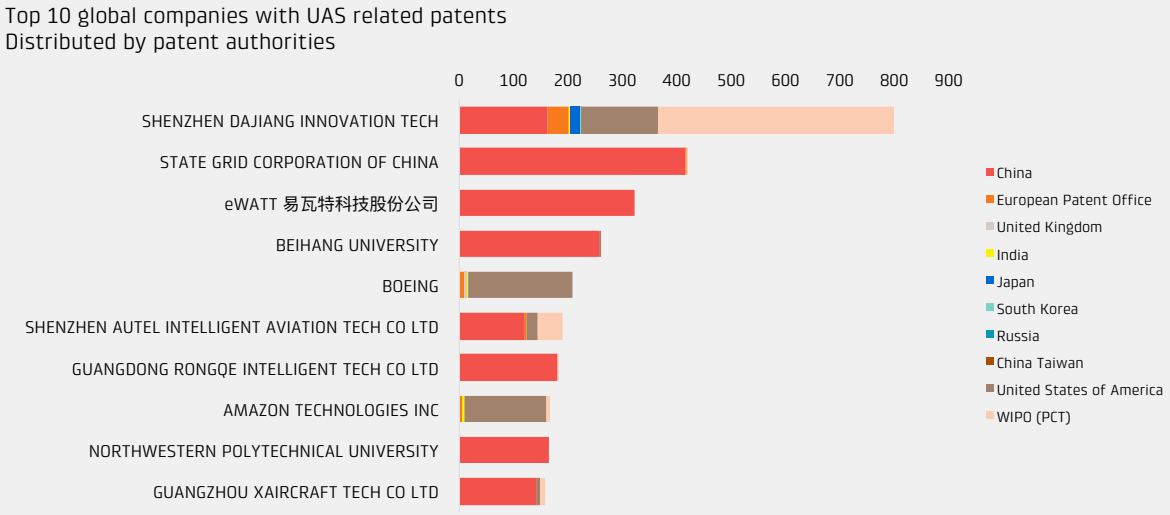
Top 10 global companies

Figure 2.6 presents the top 10 global companies across UAS-related publications. The figure illustrates that the most global patenting company is Shenzhen Daijang Innovation Tech. This is a Chinese technology company headquartered in Shenzhen with manufacturing facilities throughout the world. It is known as a manufacturer of UAS for aerial photography and videography. Shenzhen Daijang Innovation Tech is the world leader in both the commercial and civilian UAS industries, accounting for around 800 patents re-lated to UAS. Half of these patents are patented in WIPO (PCT) followed by 200 UAS-related patents in China and 100 in the US.

The second, third and fourth most UAS-related patenting companies are State Grid Corporation of China (UAS grid inspection system), eWatt (heavy duty UAS with focus on designing and implementing solutions for industrial and security applications) and Beihang University. They have all only taken out patents in China, ranging from approx. 300 to 400 patents.

A different picture is emerging for the fifth-ranking company, Boeing (UAS by sea, air and space), which mainly applied for its 200 patents in the US. The remaining companies in Figure 2.6 are distributed among patent authorities in China, the US and WIPO (PCT).

FIGURE 2.6 TOP 10 GLOBAL COMPANIES WITH UAS-RELATED PATENTS



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **2.873 patent families** identified.
Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*").
Extract 7. dec. 2018. Figures for top 10 companies calculated separately.

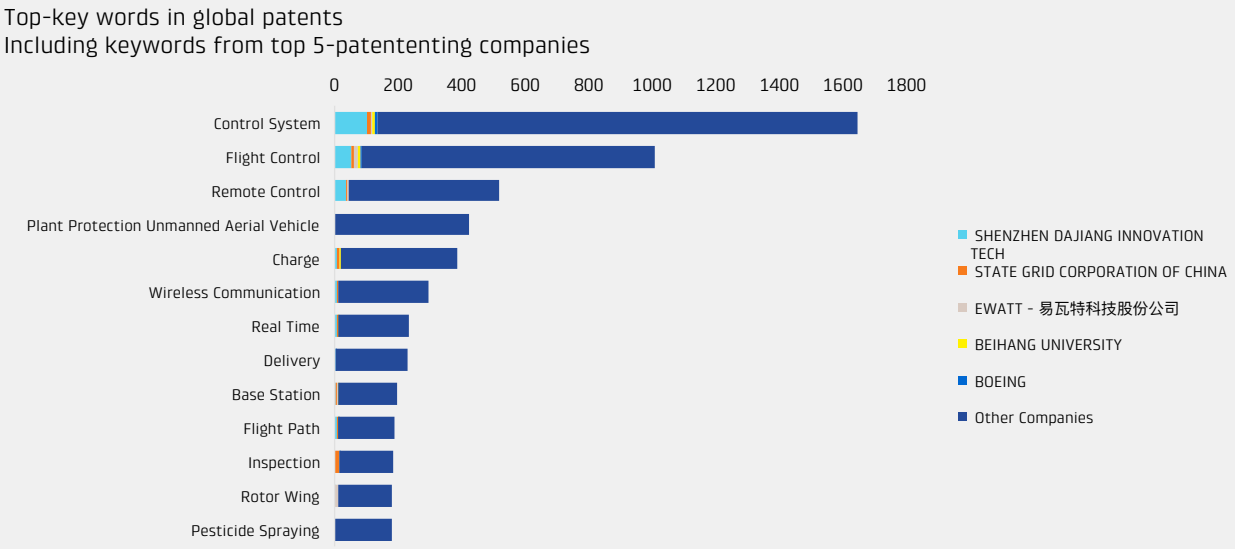
Top keywords in global patents

The most frequent keywords in the identified UAS patents are 'control system', 'flight control' and 'remote control'. Figure 2.7 lists the most common keywords found in UAS patents. Almost 10 per cent of the patents mention one or more of the three keywords in the title, abstract or claim section of the patents. Controlling the aircraft remotely is a key function for UAS development. Most of the top keywords are related to the UAS core technology, i.e., flying and communicating with the UAS, and include keywords such as 'charge', 'wireless communication' and 'base station'.

Four keywords are different, i.e., 'plant protection', 'delivery', 'inspection', 'pesticide spraying', and are more related to the utility or application of UAS. Precision agriculture, delivery of goods and inspection (of construction sites, construction, land use, inaccessible places and so forth) are areas that appear to be of commercial interest.

However, the UAS tech companies seem to be more focused on controlling and flying the aircraft than on the actual application of the aircraft. The UAS technology is also referred to as a technology platform. Like robots, UAS are platforms for technology such as cameras, sensors, carrying of goods or weapons, where it is the combination with other technologies that create value. Without combining with other technologies, flying platforms are of little commercial interest. The UAS industry is primarily concerned with the platform, while the combinations may be up to technology providers outside or connected to the UAS industry.

FIGURE 2.7 TOP KEYWORDS IN GLOBAL PATENTS



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified. Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*"). Extract 7. dec. 2018. A few general key words left out. Figures for top 5 patenting companies are calculated separately.

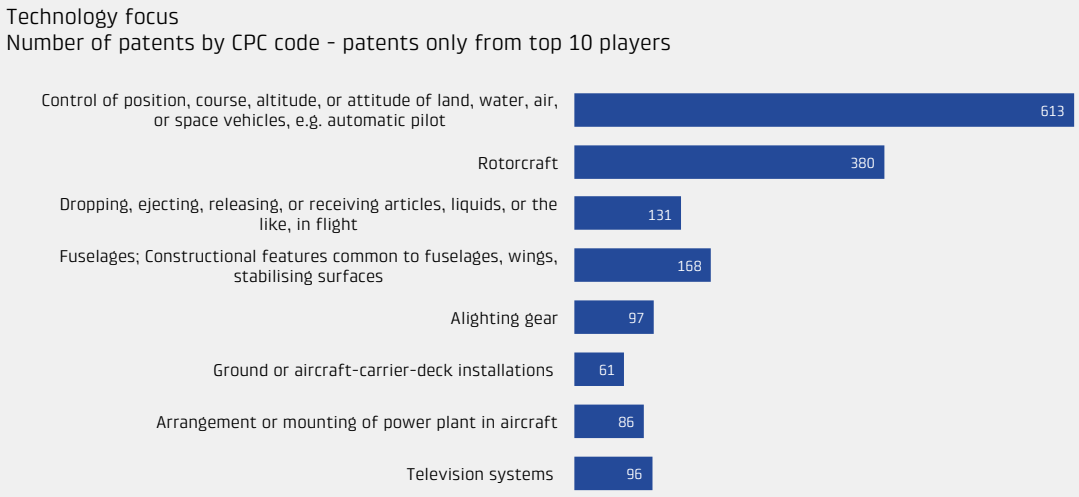
The pattern illustrated by the keywords is repeated when the technology classification from the top 10 players is listed. To make the technology codes more readable, the actual codes have been removed from Figure 2.8. Each patent is classified with several codes. The core of technological innovation for the top 10 players is still technologies related to 'how to fly a UAS', i.e., control, rotor system, fuselage, gears, etc. Although, 'Television systems' appear to be an important application technology as well.

The technology focus changes with different types of companies. We have made a rough division of the companies behind the patents – and we have excluded companies that have only applied for a patent in China.

The rough division places companies with more than 10-15 relevant patents in four groups:

1. UAS industry encompasses specialised companies focusing on UAS products, such as DJI, Prodone, Shenzhen and EWATT.
2. General electronics industry encompasses companies with a wider focus on electronics, software, and more general technology companies such as Samsung, IBM, Facebook, Google, AT&T, Qualcomm, Ericsson, Cisco, LG, General Electrics, as well as a few motor companies such as Subaro and Ford.
3. Aircraft and aerospace include general aviation companies such as Boeing, Lockheed, BAE, Northrop, Sikorsky, Bell, etc.
4. Retail companies encompass companies such as Amazon, Sony, Walmart, and insurance companies.

FIGURE 2.8 TOP TECHNOLOGY (CPC CODES), NUMBER OF PATENTS - PATENTS ONLY FROM TOP 10 PLAYERS



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified. Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*"). Results only calculated for top 10 players. Extract 7. dec. 2018.

In Figure 2.9 we have created an innovation landscape for UAS-related technologies using PatSnap. The 'landscape' is created by clustering keywords. A high density of patents within a cluster is illustrated with a hill or even a snow-covered mountain. Areas with only scattered keywords is illustrated with a lake. The hilltops are marked with related keywords and the type of companies behind the patents is illustrated with coloured markers in the map. The map is based on 8,474 patent families.

The interpretation of the map can only be made in broad terms: Along the 'west side' of the map the keyword 'control' seems to dominate, on the 'north side' the keyword 'monitoring' defines the landscape. The 'east side' relates to power and charging, and the 'south side' relates to image and communication.

The UAS companies can be seen all over the map, and especially in patents along the 'south' and 'east' rims of the map. Again, controlling, charging, batteries, propellers, power, and communication are important.

The general electric or engineering companies are visible especially regarding network communication and image generation. The aircraft and airspace companies are patenting in relation to network communication and air traffic. Finally, the retail companies seem to be deep into not only application of the technologies, but also developing their own platforms.

FIGURE 2.9 INNOVATION LANDSCAPE FOR UAS-RELATED TECHNOLOGIES

Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap Query:TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*") not (AUTHORITY:CN). Technologies exclusively patented in China not included. **8.474 patent families**.

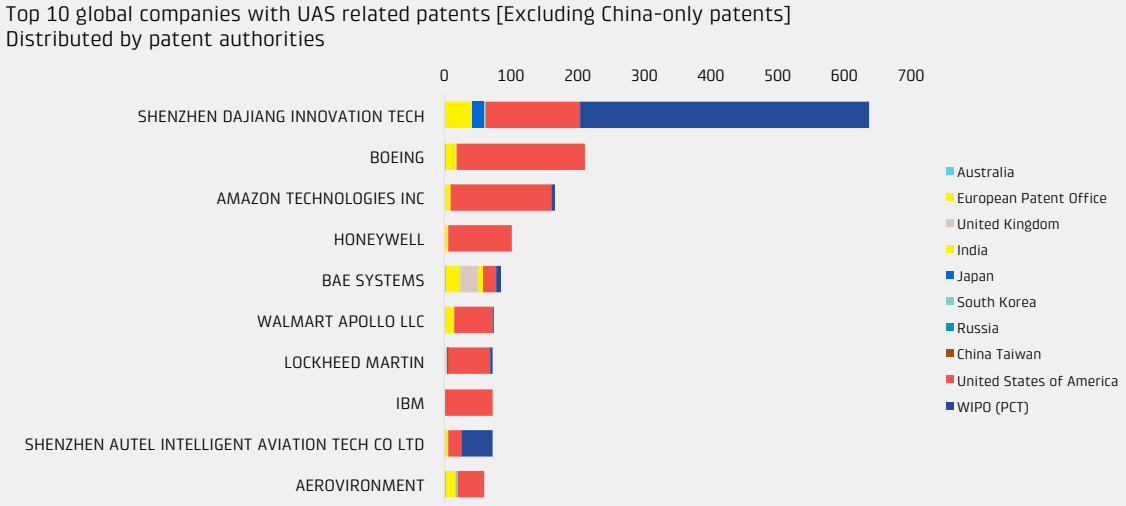
Top 10 global companies

Figure 2.10 illustrates the number of patents from the top 10 global players, excluding China only patents. Compared to Figure 2.6 the Chinese company Shenzhen Daijang In-novation Tech is still the market leader with one-third of the patents in WIPO (PCT). Moreover, the remaining number of Shenzhen Daijang Innovation Tech patents have been taken out in the US, Japan and the European Patent Office.

The second-ranking company is Boeing closely followed by Amazon Technologies Inc. with Honeywell as the fourth-ranking company. Honeywell, a UAS company, focuses on safety UAS inspection service, end-to-end drone-based inspections and data analytics for industrial companies all around the word.

The remaining companies hold around 100 patents among them - mainly in the US and only a few in WIPO (PCT), India, South Korea and the European Patent Office.

FIGURE 2.10 NUMBER OF PATENTS ONLY FROM TOP 10 PLAYERS (EXCLUDING CHINA-ONLY PATENTS)



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **7.689 patent families** identified. Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*")) not ((AUTHORITY:CN)). Extract 7. dec. 2018. All patents – except patents granted in China only.

Great Britain and Germany as the European market leaders

Figure 2.11 shows that the patents granted in Europe are spread widely across the continent. The map gives an overview of how many patents were published by European assignees in 2017 and 2018 and 130 patent families are accounted for in total. In Great Britain, south of London, we see the densest concentration of 33 patents from the same assignee.

A large number of patents have also been published in Germany, but they are distributed across the country. In Switzerland, one assignee has published 19 patents the past two years. In Ireland, near to Dublin, and in Sweden, around Stockholm, we also observe some UAS development activity.

Even though the above-mentioned countries have the highest number of UAS patents compared to the rest of Europe, most of the other countries have a fair number of the patents as well. UAS activities in Europe are quite widespread and concurrently with the growth of UAS markets, the number of patents could be expected to increase in the near future.

FIGURE 2.11 MAP OF EUROPEAN PATENTS

World of UAS innovation 2017-18 – Number of European patents

Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **28.398 patent families** identified. Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*"). Results only calculated for European patents.
Extract 7. dec. 2018. Only patents from 2017-18 is included in the map. Map by batchgeo.com and based on assignee addresses

Top 10 European companies with UAS-related patents

Figure 2.12 illustrates the top 10 European companies that have published UAS-related patents up until 2018. The company with the highest number of patents is BAE Systems, which is an international defence, aerospace, and security company. BAE develops technologies for maritime, land, and air purposes. For aerial systems they both manufacture, design, upgrade, and support trainer and combat aircraft. Thus, the patents related to UAS technologies from this company include military technologies.

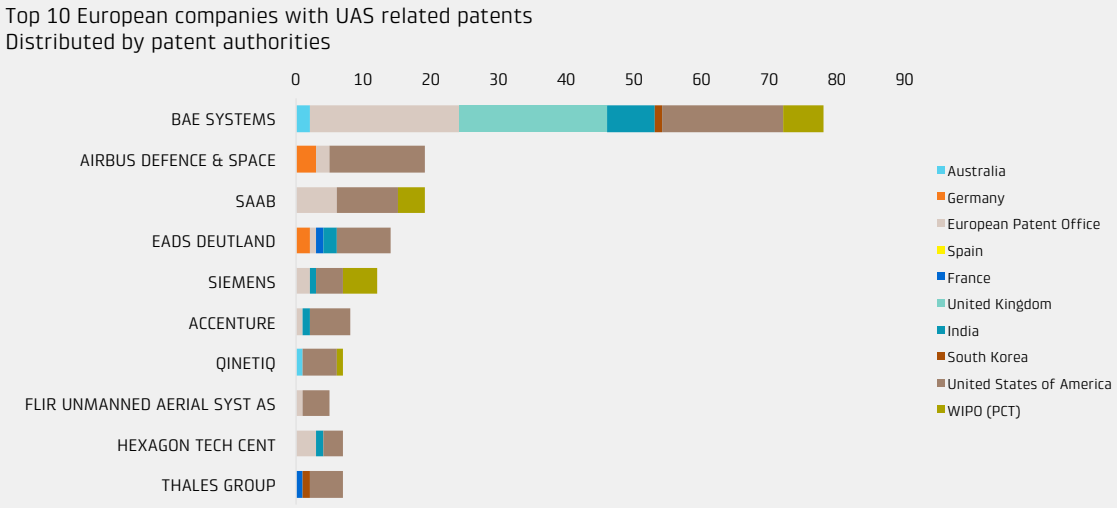
Airbus Defence & Space along with SAAB have 20 patent publications each. While SAAB is working to improve UAS endurance time, Airbus Defence & Space is primarily developing new electric technologies aimed at making UAS eco-friendlier.

A very recognisable company on the list is Siemens. In relation to UAS, Siemens is, for example, developing systematic inspection systems that use drones with 3D image analysis to monitor pipelines and large industrial facilities.

QinetiQ, which ranks as number 7 on the list, engages in experimentation and research to find solutions that meet all kinds of aeronautical challenges. Meanwhile, Hexagon Tech designs intelligent aerial surveying, and, in relation to this, Thales develops solutions for traffic management.

By looking into which UAS-related technologies these leading companies are developing we may gain an insight into the direction of how UAS will be used in the near future.

FIGURE 2.12 NUMBER OF PATENTS BY COMPANIES



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. **1.627 patent families** identified.
Syntax: TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*").
Extract 7. Dec. 2018. Only patents from European companies.

Technological specifications

This section presents the tendencies of the UAS technological specifications. Tech-mining is useful for identifying clusters across technological specifications, and the increase in the number of patents may indicate a strategic or market interest in a specific technology area.

In the following, we present the tendencies for various energy sources, followed by different propulsion types, and finally the patterns concerning different navigations systems.

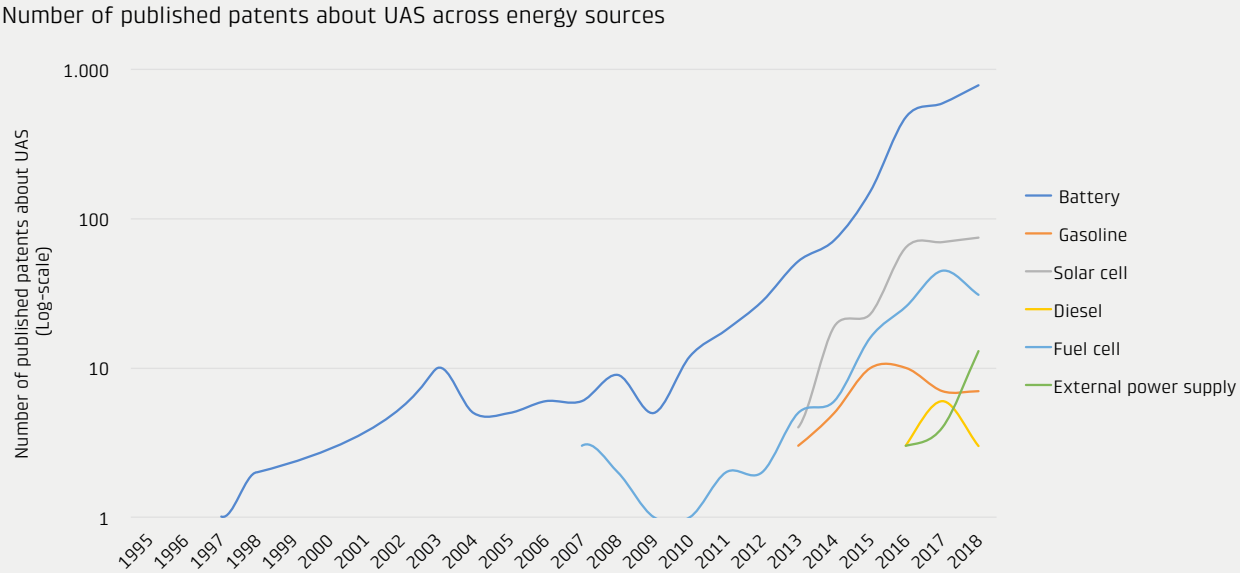
Battery as the commonly used energy source

Figure 2.13 illustrates the different types of energy sources mentioned in patent publications across UAS patenting. The figure presents most energy sources related to UAS patents, but aviation fuel, heavy fuel and kerosene are excluded due to the small number of patent families (<20).

Figure 2.13 illustrates that the most used energy source over time and overall is battery-powered UAS. Since the beginning of the 2010s, other energy sources have been introduced to the UAS market. Especially the number of UAS powered by solar cells and fuel cells has been increasing and it will likely continue to do so in the years to come. However, battery power for UAS is still the most preferred energy source.

Figure 2.13 shows that the least popular energy sources are diesel, external power supply, and gasoline. In comparison with the total number of UAS patents these three energy sources only represent a very small part of the UAS-related patents.

FIGURE 2.13 NUMBER OF PUBLISHED PATENTS ABOUT UAS ACROSS ENERGY SOURCES



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. Syntax e.g.: (TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*")) AND TAC: (battery).
Extract 7. dec. 2018. Figures for the six energy sources are calculated separately.

UAS with electric motors are the most frequently used propulsion system

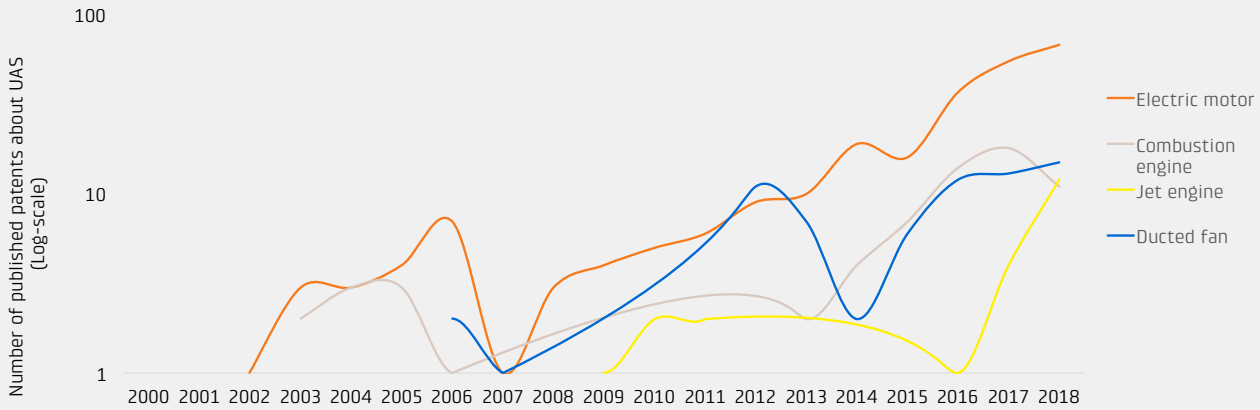
Figure 2.14 illustrates the number of published UAS patents that mentions propulsion system types. The figure presents the four most used propulsion systems. Electric pro-pulsion systems are by far the most common when it comes to UAS. They are much more sustainable than their combustion fuelled counterparts, and it is expe-cted that future developments will focus on the advancement of this technology. However, electric propulsion systems still lack the power and effi-ciency of combustion fuelled propulsion systems.

The other three propulsion types were introduced after the electric propulsion systems. The devel-opment of combustion, jet and ducted fan engines was increasing across the time period but with fluctuations the last few years.

Based on the overall number of patents related to UAS, it is assumed that there is a general tendency for vehicles to be powered by an electric propul-sion system when it fits the required mission capabilities. The efficiency of electric propulsion systems will continue to increase in the years to come.

FIGURE 2.14 NUMBER OF PUBLISHED PATENTS ABOUT UAS ACROSS TYPES OF PROPULSION SYSTEMS

Number of published patents about UAS across engine types



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. Syntax e.g.: (TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*")) AND TAC: ("electric motor"). Extract 7. dec. 2018. Figures for the four engine types are calculated separately.

GPS, radio control and autopilot is the most used navigation systems

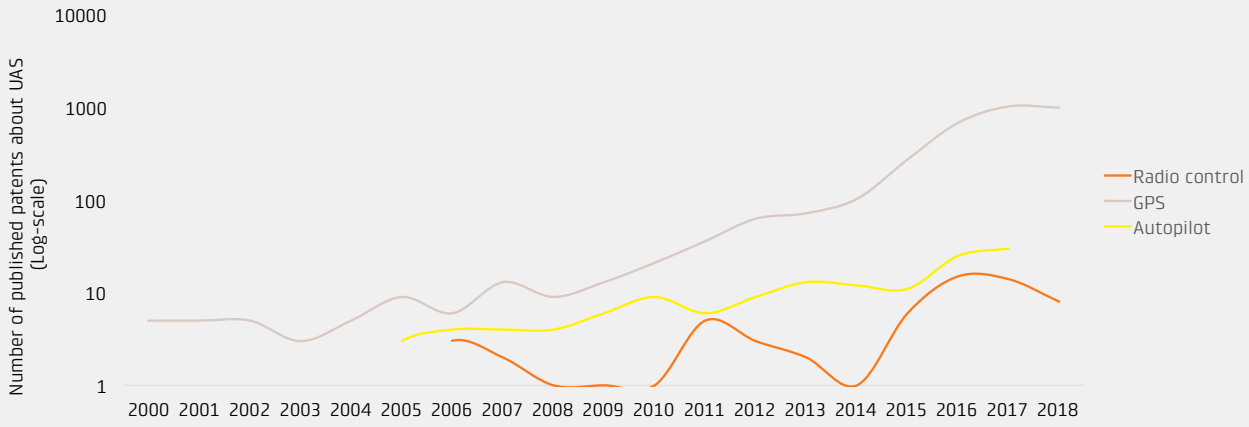
Radio-controlled UAS are operated wirelessly using radio waves sent by the pilot from a transmitter to a receiver in the platform. Often UAS remote controls are hand control units like joysticks, tablets or - for some purposes - ground control units. When on autopilot, the UAS can navigate without a pilot and the UAS often follow pre-programmed routes using waypoints from a GPS. A platform can be equipped with more than one navigation system allowing operators to choose between them according to the tasks at hand.

Figure 2.15 illustrates the number of patents that have been published since 2000 that mentions navigation systems. Patents for GPS systems have increased steadily and by far exceed the number of patents for autopilots and radio control systems. However, GPS is not an autonomous navigation system but is, as mentioned above, used with autopilot systems.

There have been huge fluctuations in the number of patents for radio control systems across the years, but each increase exceeds the previous year in numbers. Autopilot systems have seen a small but steady rise almost every year since 2005 when the first patents were published. Today, it is popular to develop UAS that can perform more autonomous operations – for example in agricultural circumstances. The increase in the number of patents for GPS and autopilot may reflect this tendency.

FIGURE 2.15 NUMBER OF PATENTS FOR NAVIGATION SYSTEMS

Number of published patents about UAS across navigation system



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. Syntax e.g.: (TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*")) AND TAC: ("radio control"). Extract 7. dec. 2018. Figures for the three navigation systems are calculated separately.

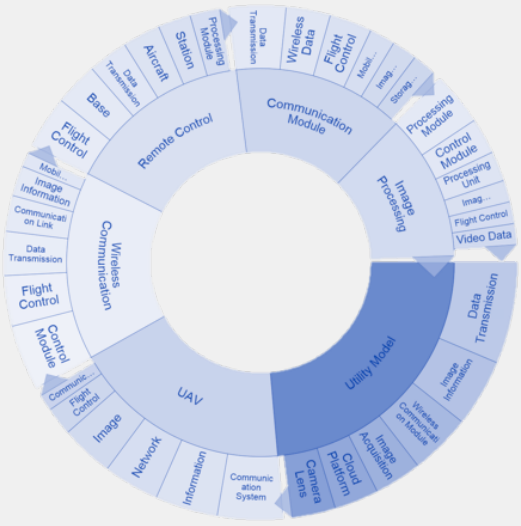
Communication techniques

Communication is crucial for UAS – both for control of the UAS and for gathering and analysing data from images and sensors. 11 percent of the identified UAS patents also mention 'electric communication techniques'. The wheel of innovation reveals the diversity of UAS patents that mentions electric communication techniques such as remote control, wireless data, image processing, cloud platform, data transmission and communication links.

Figure 2 17 illustrates the innovation over time of specific electric communication tech-niques. Note that the Y-axis is a log axis, meaning that there has been a very steep slope in the number of patent publications the last 2-3 years. The graph shows an accelerating innovation rate for both communication technologies relating to the control of the UAS (control of position, altitude – and traffic control) – and other patents with more general technologies from using cameras on board the UAS platform, such as television systems or radio transmission. The innovation rate leads us to expect an increase in the market of platforms with extended capabilities for photography, transmission, processing, and analysis of live images, and there will be many new fields of application for new technol-ogies.

FIGURE 2.16 11 PER CENT OF UAS PATENTS INCLUDE ELECTRIC COMMUNICATION TECHNIQUES

Wheel of innovation – UAS patents including electric communication techniques

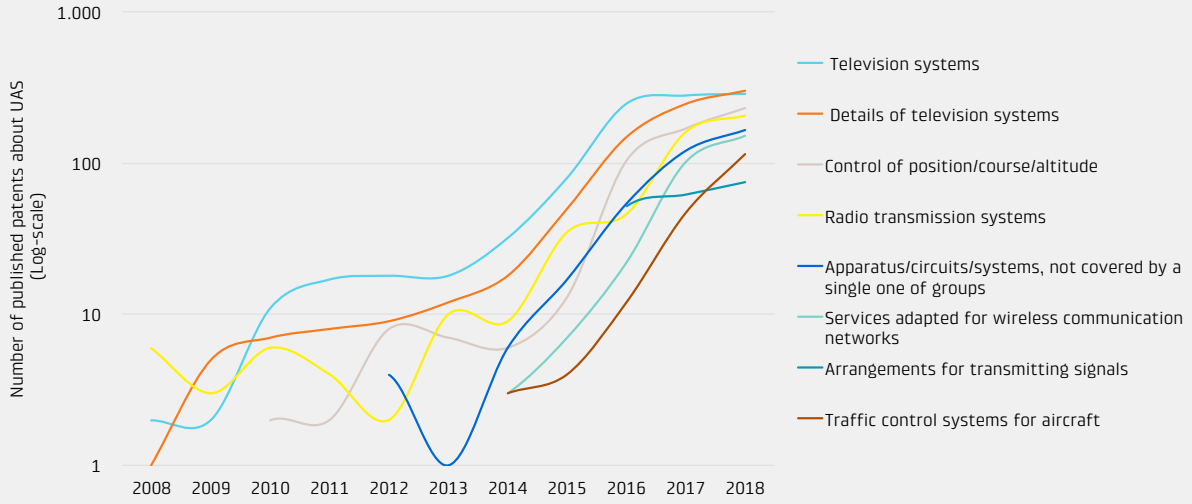


The Circle Chart categorizes the most frequent keywords in identified patents into a 2-tier hierarchy of within the most recent 10,000 Simple Families in the technology field.

Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. Syntax e.g.: (TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*")) AND ((IPC:"H04N")). Extract 17. dec. 2018. H04 is the IPC code for "ELECTRIC COMMUNICATION TECHNIQUES". **3.250 patent families** identified.

FIGURE 2.17 ELECTRIC COMMUNICATION TECHNIQUES IN UAS PATENTS

UAS patents including electric communication techniques



Source: Calculations by Danish Technological Institute based on a search in global patent databases via PatSnap. Syntax e.g.: (TAC:("Unman*" $w1 "Aircraft*") OR TAC:("remote*" $W1 "aircraft*") OR TAC:("Micro Air Vehicle*") or TAC:("Unman*" $w1 "Aerial*")) AND ((IPC:"H04N")). Extract 17. dec. 2018. H04 is the IPC code for "ELECTRIC COMMUNICATION TECHNIQUES". 3.250 patent families.

FIGURE 2.18 EXAMPLES OF UAS AND ELECTRIC COMMUNICATION SYSTEMS

Over the horizon communications network. A network and method are provided that utilize impulse radio technology to enable an impulse radio communication link between a ground control station and an unmanned ground vehicle. Moreover, the network can include one or more unmanned aerial vehicles that act as repeater platforms which can extend the range of the impulse radio communication link between the ground control station and the unmanned ground vehicle. Patent US20030164794A1

Apparatus for distributed airborne wireless communications. US8897770

Onboard **ultra-lightweight integrated high-definition video imaging** and high-bandwidth transmission device. CN104065860A

Method and System for Assets Management Using Integrated Unmanned Aerial Vehicle and **Radio Frequency Identification Reader.** US20160180126A1

Unmanned aerial vehicle supplies farmland **aerial image information to unmanned potato harvester.** CN205284151U

Source: Extracted by Danish Technological Institute. Syntax e.g.: (TAC:('Unman*' $w1 'Aircraft*') OR TAC:('remote*' $W1 'aircraft*') OR TAC:('Micro Air Vehicle*') or TAC:('Unman*' $w1 'Aerial*')) AND ((IPC:'H04N')). Extract 17 December 2018. H04 is the IPC code for 'ELECTRIC COMMUNICATION TECHNIQUES'. 3.250 patent families.

A brief introduction to tech-mining

Patent information is information about intellectual property rights. With a patent a sovereign state or intergovernmental organisation grants exclusive rights to the owner of an invention in the form of a specific solution, product or process for a limited period. In exchange for the patent, there is a detailed public disclosure of the invention.

What is tech-mining?

Patent information is stored in national and international databases. Each national authority stores information on the invention, the inventors, reference to other patents and technical classifications such as CPC [Cooperative Patent Classification] codes. The technical code systems are very detailed and the European Patent Office (EPO) and the US patent office (USPTO)[2] have cooperated on developing the codes.

A patent is valid within a geographical area. Inventors can apply for registration of an invention with patent authorities in several countries. In 2016, the number of new patent applications registered in a year passed three million patents according to WIPO.[3] In 2016, almost two out of three patents were filed in Asia – in 2006 about half of the patents in the world were filed in Asia. In 2016, almost 21 percent of the patents were filed in North America and 11 percent in Europe. When we count the number of patents, we usually refer to patent families where similar patents across several patent authorities count as one patent.

The authorities keep the patent information in publicly accessible databases, and inventors can use news searches to make sure that a 'new' invention is in fact new. The attraction of the patent databases from an analytical point of view is that the authorities constantly update the databases with detailed information on new technologies and their assignees.

Using big data techniques, data miners can analyse the wealth of patent data for strategic information on technological development over time and place. This type of analysis is referred to as tech-mining. The data source for tech-mining can be patent databases or it may be other data sources such as global databases of scientific literature or business-related databases. In some cases, the data-miner can cross reference databases to extract detailed strategic information. For the purposes of this report, we have mined technology-based data on unmanned aerial systems (UAS) in the patent databases.

Tech-mining is a relatively new analytical tool developed over the past 10-15 years. Patent information has always been publicly available, but tech-mining the big data in the databases is only possible thanks to the internet, powerful computers and analytical software. The analyses that we can do now in a matter of seconds were virtually impossible and almost unthinkable a decade ago.

The leader in tech-mining is Georgia Tech in the US, and over the years DTI has worked with Georgia Tech and their analytical software package 'Vantage Point' and Thomson Innovation to understand tech-mining. DTI applies the tech-mining tools in studies for the Danish government, for private companies as well as proposals and projects for the European Commission. Tech-mining is a fast-evolving discipline and new tools for tech-mining such as PatSnap are emerging with impressive visualisation of technological development. DTI is currently working with PatSnap.[4]

[2] http://www.cooperativepatentclassification.org/
[3] http://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2017-chapter2.pdf
[4] http://www.patsnap.com/

Insights from tech-mining

Tech-mining provides insights that can be found nowhere else, but tech-mining patent data is not an exact methodology. The advantage of tech-mining is to be able to identify trends and patterns in the data, but it is not enough for a full analysis or a complete understanding of technological developments and markets. The purpose of tech-mining is to extract strategic insights on technologies, actors, and markets from the data.

Tech-mining of patent data is useful for gaining insight into trends and how one technology develops and relates to other technologies. Tech-mining of patent data is also useful for identifying technological leaders and knowledge clusters, where an increase in the number of patents may indicate a strategic interest or a market interest in a specific technology area. Tech-mining also gives insight into where the actors (universities, research institutions, companies, inventors) are clustering.

Tech-mining in patents does not answer every relevant question, and there are several blind-spots in tech-mining of which to be aware:

- **First**, for several reasons not all technologies are patented because some companies want secrecy around their innovations; in some areas, technological innovation is moving so fast that technologies are obsolete before the patenting process is complete; or some companies think that patenting is too expensive.
- **Second**, national authorities and local offices are located all over the world and this leads to inconsistencies in the written information in the databases. For example, Danish Technological Institute is one of the leading patenting companies in Denmark, but the recorded name of the company may also be 'DTI', 'Technological Institute' and other variations. So poor data consistency means that data may be overlooked and misinterpreted. Smart software helps to alleviate this problem to some degree.
- **Third**, patenting cultures may differ from country to country. Thus, Chinese patents may be overrated since there are personal rewards involved in taking out patents, and in the US disagreements over technology rights that reach the judicial system could also inflate the number of patents compared to patents taken out in Europe.[5-6]
- **Fourth**, there is no market information connected to the patent data, there are no data on licensing and the value of patents. Moreover, often there are no links to business databases, and the data cannot be readily summed up into measures or indicators of strength. Tech-mining should not stand as the only source of an analysis, but it provides a useful supplement to any technology analysis with data and insights that are impossible to gain through other types of sources.

An overview of the insights and blind spots of tech-mining discussed above is provided in Table 3 1.

[5] Chinapower: 'Are patents indicative of Chinese innovation?' See https://chinapower.csis.org/patents/ and Markovich, 'U.S. Patents and Innovation', Council on foreign relations, 2012 see https://www.cfr.org/backgrounder/us-patents-and-innovation

[6] Europe has a 'loser pays costs' juridical system, where often in the US each party is responsible for paying their own attorney's fees. That has led to some inflation in the patent system in the US, where 'patent trolls' are companies with patents attempts to enforce patent rights against accused infringers far beyond the patent's actual value using hardball legal tactics. See Strowel & Utko,'The trends and current practices in the area of patentability of computer implemented inventions within the EU and the U.S.', EU Commission, 2016. https://ec.europa.eu/digital-single-market/en/news/report-trends-and-current-practices-area-patentability-computer-implemented-inventions-within

FIGURE 3.1 INSIGHTS AND BLIND-SPOTS IN TECH-MINING PATENTS

New insights from tech-mining

- Trend overview
- Insight into related technologies
- Patterns of converging technologies
- Identification of leaders
- Identification of knowledge clusters
- Identification of cooperations between companies
- Insight to new technologies
- Indication of market interest
- Indication of strategic interest
- Indication of national interest
- Geographic information
- Indication of market interest

Blind-spots

Not all technologies are patented
- To keep innovation secret
- Innovation is to fast
- Patenting to expensive

Poor data stringency / consistency
Different patent registrering cultures

Data to dream of:
- Data on licensing
- Monetary value of patents
- Links to business databases
- Strength point indicators / measures

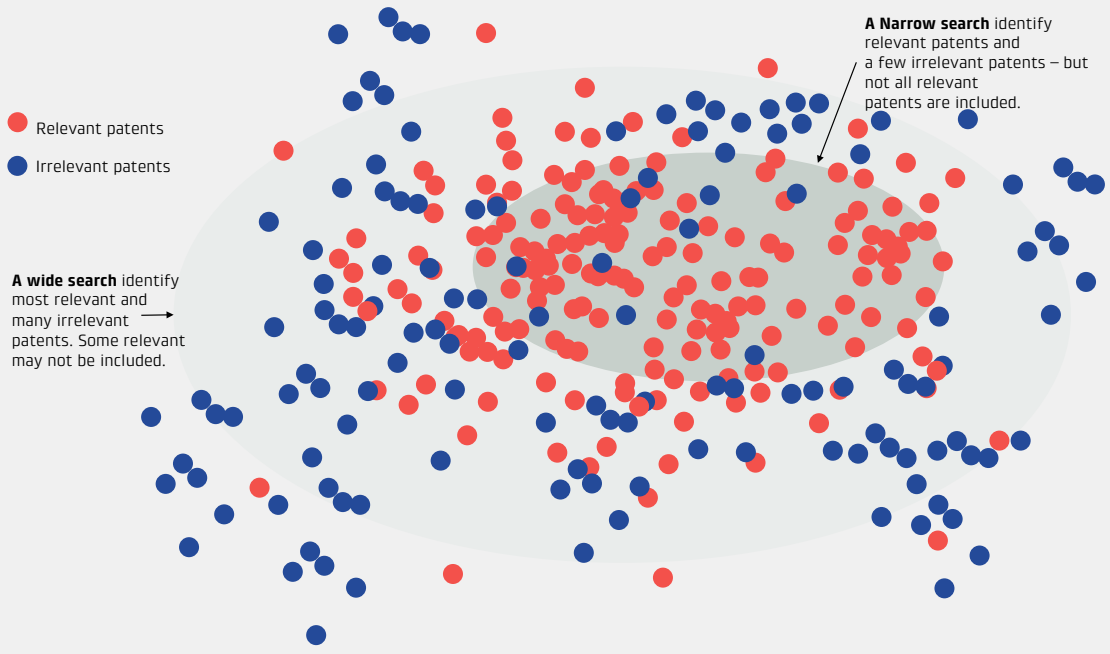
Source: Danish Technological Institute

Identifying a core-set of UAS technologies

Technology information in patents is stored in a semi-structured way and the information is described qualitatively. UAS technologies have different names such as Unmanned Aerial Systems, Drones, Remotely Piloted Systems, Micro Air Vehicles, and Unmanned Aircraft. There are no conventions to be followed, and some patents may be relevant to UAS but without mention of related words. Sometimes the patents just mention the acronyms UAS or RPAS, but searches for acronyms can falsely identify patents not related to UAS.

Moreover, the acronym UAS has a host of different meanings such as User Application Software, Urea-Ammonium Sulphate or Upper Atmosphere Sensor. The patent authorities attach technology codes to the patents. The technical classifications such as CPC [Cooperative Patent Classification] codes have more than 70,000 unique codes – but unfortunately none that uniquely identify UAS. This is a challenge for tech-miners who have to identify the relevant patents related to UAS with millions of patents all over the world. A search string can be something like 'TAC:('Unman*' $w2 'Aircraft*')' which in ordinary terms means 'Select patents where the text string beginning with 'Unman' are mentioned within a 2-word distance of text strings beginning with "Aircraft". The mention should be in the T: title, A: abstract or C: claims.' The text fields title, abstract or claims very often mention the most important terms of the patent.

FIGURE 3.1 TECH-MINING RELEVANT PATENTS



On the one hand, if the search definition is very broad, the search will identify the relevant patents but also many irrelevant patents. The share of irrelevant patents may be so high that analysis is meaningless. On the other hand, if the search is very narrow the patents found are mostly relevant it may also omit many relevant patents.

Some searches can generate more than 250,000 patents, so it is not possible to do a manual final sorting in a reasonable time, and even if we were able to sort the patents, we would run into grey zones of judging a specific patent as relevant or not. Therefore, the perfect identification of a technology is often impossible.

It is a trial and error process to formulate a search string with enough precision. In the trial and error process, we make use of 'the wheel of innovation' that weighs the most common keywords mentioned in the pool of patents we have identified (see Figure 2.1). If the related keywords are relevant to the technology we want to enclose we are on the right track, and if the keywords are irrelevant we need to redefine our search.

This is an important weakness of which to be aware when discussing the number of patents related to a specific technology. However, tech-mining does not require a high precision to identify trends, find the main companies or cooperation between companies, universities or governments.

Our strategy in the search for relevant patents is to identify a core set of patents with high relevance to the technology – knowing that we do not include all relevant patents in the world. The search string 'TAC:('Unman*' $w1 'Aircraft*') OR TAC:('remote*' $W1 'aircraft*') OR TAC:('Micro Air Vehicle*') or TAC:('Unman*' $w1 'Aerial*')' identified 28,398 patent families of high technological relevance to this study.

Danish Technological Institute

Danish Technological Institute (DTI) is a self-owned not-for-profit institute with six divisions and 35 specialist centres. DTI has more than 1,000 employees in Denmark, Sweden, Norway, Poland, and Spain. As part of DTI, we always have access to the best ex-perts in technology, business and competence development and innovation. This enables us to set a team that can solve our clients' technological problems

DTI develops, applies, and disseminates research- and technology-based knowledge to Danish trade and industry and the public sector and participates in development projects, which are of use to society in close collaboration with leading research and educational institutions both in Denmark and abroad. Thus, DTI is one of the leading and strongest technology and social science consultancy environments in Denmark. DTI was founded in 1906.

DTI is approved by the Danish Ministry of Higher Education and Science as an Advanced Technology Group Institute (GTS). Thus, DTI is one of the seven GTS Institutes in Denmark. As a GTS institute, DTI navigates independently of political and financial interests and any profits are invested back into new research and development and innovation.

DTI has a broad international client base in all industry sectors and public institutions and ministries, and we participate in global research and consultancy networks. This way we are always at the cutting edge of technological and societal changes to the benefit of our clients and partners.

Danish Technological Institute

During the past three years, Danish Technological Institute has developed new advances for UAS technologies to solve some of the challenges that might hinder the spreading of UAS technology more generally. For example:

DTI researches and develops fuel cell technologies powered by propane that have the potential to allow UAS to fly for more than 24 hours. The research includes research in new materials, energy technology and vision and sensor technologies.

For more information, please contact
Head of Section, Ph.D., Jan H. Hales,
jhhs@teknologisk.dk

DTI develops technology to improve the usefulness of UAS for building inspections. DTI's Concrete Centre specialists have worked to combine the UAS technology that gathers data with machine learning so that the processing of data does not necessarily have to be done manually.

For more information, please contact Consultant Morten H. Petersen,
mhop@teknologisk.dk

The potential for use of UAS in agriculture is expanding fast. Farmers could benefit highly from having their fields and crops surveyed automatically. With the right software, UAS can easily take on this task and autonomously fly to the assigned fields, whenever weather conditions allow, and gather information about crop sickness or pests. For this project UAS and agricultural specialists from DTI have collaborated to develop technology for this purpose.

For more information, please contact Senior Specialist Thomas Nitschke,
tnit@teknologisk.dk

Much of the value that UAS can provide for civil purposes depends on whether they can operate autonomously. DTI has developed software that will allow the UAS to do so.

For more information, please contact Consultant and leader of UAS Denmark Mathias Flindt,
mfl@teknologisk.dk.
Mathias Flindt is also Chairman of the DroneDanmark Association (https://www.dronedanmark.eu/).

Explosion in the Number of Patents Related to Unmanned Aerial Systems

The number of unmanned aerial systems (UAS) has exploded since 2013. More than 85 per cent of all patented UAS have been published in the last six years. Based on the development in the number of UAS lately, there is every indication that the expansion in the number of UAS will continue in the near future.

Operators of high-end technology are constantly finding more practical and innovative uses for UAS. The increasing number of patented UAS has increased the numbers of countries and companies on the market in connection with UAS technology. The future will probably bring even more global players that will contribute to the further expansion of UAS technologies as well as the diversity and sheer number of UAS platforms offered by manufacturers worldwide.

UAS have been referred to by many names, such as drones, Unmanned Aerial Vehicles (UAV), Remotely Piloted Aircraft Systems (RPAS), etc., but this report uses the UAS abbreviation.

In this report, Danish Technological Institute (DTI) dives into global databases with UAS patent data to gain a better understanding of the vast potential of the UAS technology. This kind of 'tech-mining' provides insight into identifying trends and patterns in the data. The purpose of the report is to use the data to gain strategic insight into technologies, actors, and markets.