Drones

Mapping Potential Collaborators in the American Drone Research Environment

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Dansk resumé

Den danske regering arbejder for at styrke internationaliseringen af dansk droneforskning. Samarbejder med verdens førende forskere skal give dansk droneforskning mere luft under vingerne og bidrage til at udvikle teknologi og skabe nye private arbejdspladser i Danmark.

USA står bag den største andel den globale forskning på droneområdet og er derfor en vigtig partner for danske forskere og virksomheder. Amerikanske forskere udtrykker også stor interesse i samarbejde med Danmark på både forsknings- og uddannelsessiden. For at skubbe gang i frugtbare samarbejder præsenterer ICDK Silicon Valley i denne Outlook rapport potentielle partnere fra nogle af USA's førende forskningsinstitutioner. Rapporten er et supplement til den kortlægning af syv af internationale dronemiljøer, som Uddannelses- og forskningsministeriet udgav december 2016. I denne rapport går vi et spadestik dybere og fokuserer særskilt på USA.

Rapporten består af tre dele. Først præsenteres de overordnede rammer for det amerikanske miljø, der viser den store volumen af droneaktiviteter inden for forskning, entreprenørskab og erhverv. Dernæst uddybes den amerikanske lovgivning på droneområdet, der viser at amerikanske delstater ligesom Danmark i vidt omfang har adgang til avancerede testfaciliteter og fleksible juridiske rammer. Afslutningsvist identificeres universiteter og forskere, som overfor ICDK har tilkendegivet interesse for konkrete samarbejder.

God læselyst!

Abstract

The field of drones is rapidly expanding as drones are evolving beyond their military origin to become a potentially very useful tool in a number of different sectors such as construction, agriculture, and journalism.

The Danish Government's Drone Strategy from 2016 has set a framework for the technological and commercial development for the use of drones. The strategy includes an ambition to promote the internationalization of Danish drone research and industry. To help realize this goal, the government mapped seven global hot spots for research collaboration in 2017. In this report, we take a deep dive into one central hotspot: USA. Innovation Centre Denmark, Silicon Valley has mapped potential collaborators at some of the leading universities in the United States within drone research and drone education. This ICDK Outlook outlines these potential collaborators after a brief introduction to the status of the field of drones and a resume of the current American drone legislation.

Photo: Emilia Flockhart

1. Introduction

In October 2016, the Danish Government launched the Danish Drone Strategy[1] focusing on the civilian use of drones. In this strategy the Danish Government presented six ambitions to enhance the development and use of drone technology. One of the central ambitions is to **promote the internationalization of Danish drone research and industry**. This ICDK Outlook taps into the aspirations to internationalize Danish drone research by mapping potential collaborators for Danish universities to provide basis for establishing research collaboration and student exchanges between leading Danish and American universities within the growing field of drones.

First an introduction to the status of the fields of drones is provided, which outlines the developments in drone investments and research – with a special focus on the United States. Second an introduction to the regulatory conditions including the current state of drone legislation in the United States is provided. On this basis a map of potential collaborators and partners in the United States for the Danish drone research environment is outlined.

BOX 1: Drone = Unmanned aerial system
An unmanned aircraft system (UAS), sometimes called a drone, is an aircraft without a human pilot onboard – instead, the UAS is controlled from an operator on the ground. The terms Drones, Unmanned Aerial Vehicle (UAV), and Unmanned Aircraft Systems (UAS) are often used interchangeably.

Innovation Center Denmark, Silicon Valley has identified the potential collaborators through a preliminary analysis, which was conducted through interviews with a number of researchers at American universities, and attendance at the biggest drone event in the world, AUVSI XPONENTIAL in May 2017 in Dallas. A list of people interviewed is available at the end of the paper including contact information for the potential collaborators that we have been in contact with.

[1]The Danish Drone Strategy

2. Status of the field of drones

The field of civilian drones is undergoing rapid development and is spreading to a number of different sectors. The combination of increasing price competition and new technologies makes drones accessible to many more people – also those without specialized skills. Previously, drones have had a military connotation but now drones are actively used in civilian sectors such as agriculture, construction, and broadcasting. With eased airspace regulations, increasing venture capital investments, and major technology companies' engagement in drones, the development of civilian drones is expected to have great economical and societal potential.

Throughout the world, the ecosystem of drone software and hardware vendors is growing. Small private companies and startups constitute a large share of the drone vendors[2], and drone startups have seen significant investment the last couple of years. The global venture funding to startup investment boomed in 2015 by 214 %[3].

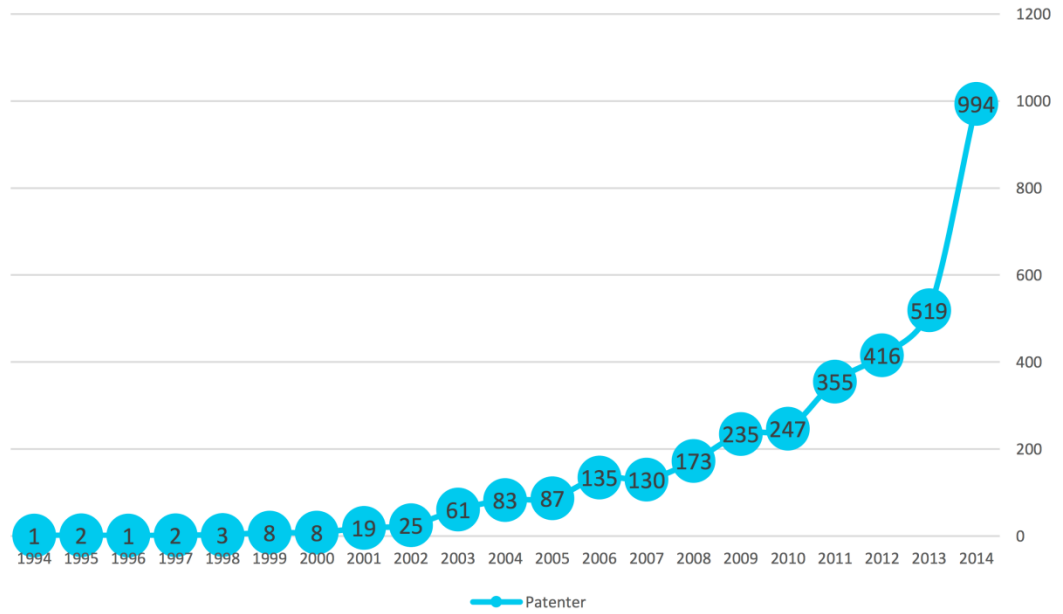
There has also been a significant growth in corporate investments in drone startups. In 2012 there was one drone startup deal involving corporates – in 2015 there were 17[4]. The most active corporates in drones during the period from 2012 through 2016 were Qualcomm Ventures, Commercial Drone Fund, Google Ventures, Intel Capital, and Verizon Ventures– in that order[5].

Teal Group's 2016 World Civil UAS Market Profile and Forecast[6] projects that non-military UAS production will increase from $2.6 billion worldwide in 2016 to $10.9 billion in 2025 – this equals a 15.4% compound annual growth rate in constant dollars. The Teal Group estimates that the market will total $65 billion over the next decade.

The growing global interest in drone technology is also shown in the number of drone technology patents taken out over the years. In the period 1994-2016 4313 patents were taken out within drone technology, and the development has been accelerating. In 2014 the number of patents was twice the number in 2013, which was twice the number in 2009[7].

[2] Business Insider
[3] CB Insights
[4] CB Insights
[5] CB Insights
[6] Teal Group's 2016 World Civil UAS Market Profile and Forecast
[7] Danish Technological Institute

Figure 1: Growing interest in drone technology



Source: Danish Technological Institute, 2016. Calculations based on data from Derwent Patent Index. The numbers from 2015 and 2016 are not included as they are incomplete.

2.1 The United States: A Drone Front-runner

The United States is a front-runner when it comes to drone technology patents. One third (32%) of the patents within drone technology are taken out in the United States. Only China has taken out more patents than the U.S.[8]. American companies like Boeing and Honeywell have taken out most patents in the period from 2001-2014. For example, Boeing market "Phantom Eye", which is a liquid hydrogen-fueled, high-altitude and long-endurance unmanned aircraft system for persistent intelligence, surveillance and reconnaissance, and communications missions. The Phantom Eye is capable of maintaining its altitude for up to four days while carrying a 450-pound payload.

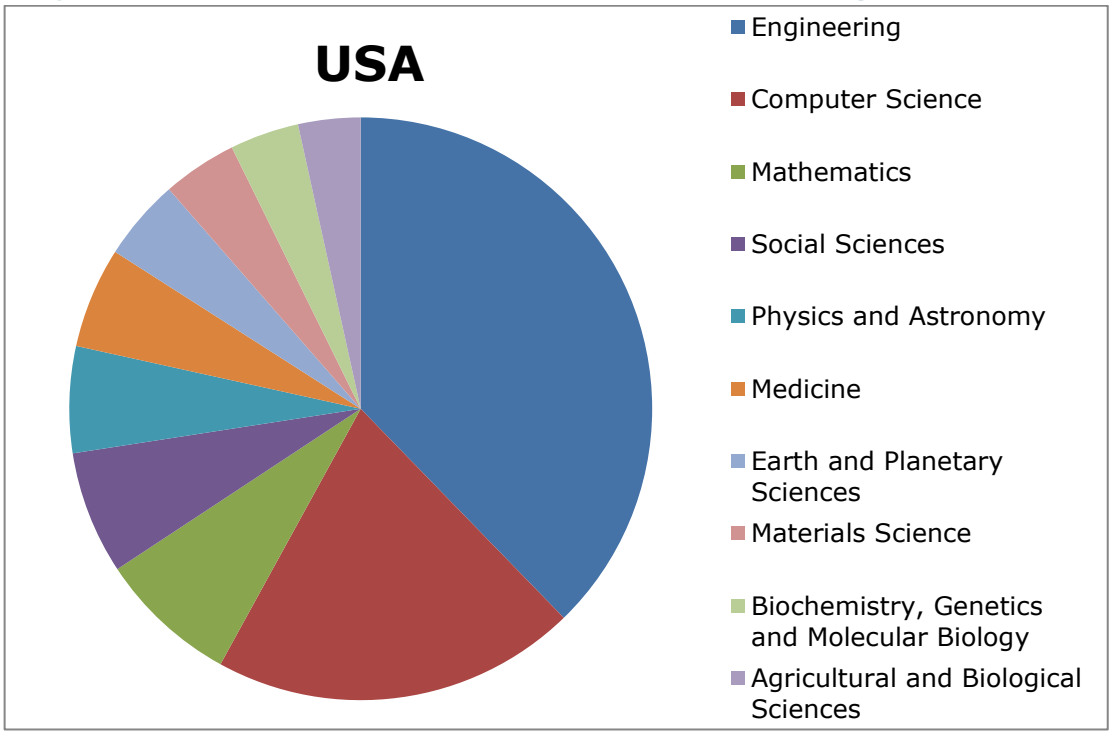
The United States is also one of the leading nations within drone research. It is the country that has most academic publications within drone research in the period from 2013 to 2016, and there are American co-writers on one fourth of the publications in front of China, which has co-writers on one fifth of the publications[9]. When one looks at the fields within the American drone research, Engineering is the largest field (2619 publications in the period) but Computer Science also constitutes a sizeable share (1406 publications).

The publication diagram below shows the overall distribution among the top 10 fields in drone research in the United States.

[8] Danish Technological Institute

[9] Scopus-data, data downloaded April 4 2017.

Diagram 1: Publications within American drone research, top 10 fields.



Source: Scival, Elsevier B. V. (2017). Scival is based on Scopus-data. Data downloaded April 4 2017.

The United States' position as a frontrunner in the drone industry and research is also reflected by an increasing educational attention on drones already from high school level – both focusing on educating drone operators and developers and broader research within development of drone software and hardware. An increasing number of universities in the United States offer degrees in drone technology, have drone research labs, and increasingly prioritize resources on drone research.

There are several drivers and challenges for the development of the drone industry and the practical implementation of the technological breakthroughs; both of which are crucial to drone legislation. Some of the main drivers are affordability, flexibility, and utility; the costs of drone software and hardware are being driven down, and drones can perform various types of data collection more efficiently than competing solutions – sometimes also with less risk to human life. On the other hand, the use of drones still faces decisive challenges regarding to safety, including issues such as endurance, drone tracking systems, and elimination of single point of failures, and these uncertainties have a great impact on the drone regulation legislation – for example limiting flights beyond visual line of sight and operations over people. As legislation is one of the absolute most determining conditions shaping the future of drones, the following section describes the state of the drone legislations in the United States.

3. Current American Drone Legislation

In the United States, the federal department responsible for legislation regulating civilian use of drones is The United States Department of Transportation (USDOT). The Federal Aviation Administration (FAA) has authority over the American airspace from the ground up, and is responsible for the advancement, safety and regulation of civil aviation, as well as overseeing the development of the air traffic management. The mission of the FAA is to provide the safest, most efficient aerospace system in the world.

In addition to federal drone regulation, several states also have passed laws regulating the use of drones.

Photo: Andrew Turner

3.1 National Law on Civilian use of Drones

In the United States, 'The Small Unmanned Aircraft Rule (Part 107)' from August 2016 constitutes the national rules for operating unmanned aircrafts weighing less than 55 lbs. at takeoff.

The rules for operating an unmanned aircraft depend on why you want to fly. Table 1 shows the rules applying if you want to fly for fun or for work respectively.

Table 1: Summary of the Small UAS Rule

	Fly for Fun	Fly for Work
Pilot Requirements	No pilot requirements	- Must have Remote Pilot - Airman Certificate - Must be 16 years old - Must pass TSA vetting
Aircraft requirements	Must be registered if over 0,55 lbs.	- Must be less than 55 lbs. - Must be registered if over 0,55 lbs. (online) - Must undergo pre-flight check to ensure UAS is in condition for safe operation
Location Requirements	5 miles from airports without prior notification to airport and air traffic control	Class G airspace *
Operating Rules	- Must always yield right of way to manned aircraft. - Must keep the aircraft in sight (visual line-of-sight). - UAS must be under 55 lbs. - Must follow community-based safety guidelines - Must notify airport and air traffic control tower before flying within 5 miles of an airport	- Must keep the aircraft in sight (visual line-of-sight)* - Must fly under 400 feet* - Must fly during the day* - Must fly at or below 100 mph* - Must yield right of way to manned aircraft* - Must NOT fly over people* - Must NOT fly from a moving vehicle*
Example Applications	Educational or recreational flying only	Flying for commercial use (e.g. providing aerial surveying or photography services) Flying incidental to a business (e.g. doing roof inspections or real estate photography)
Legal Regulatory basis	Public Law 112-95, Section 336 – *Special Rule for Model Aircraft* FAA Interpretation of the Special Rule for Model Aircraft	Title 14 of the Code of Federal Regulation (14 CFR) Part 107

*These rules are subject to waiver.

In summary, with these rules companies do not have to go through the waiver process to request special permission from the federal government for any commercial drone endeavor. Previously, commercial drone operation required businesses to go through a lengthy waiver process, with strict requirements including a manned aircraft license requirement. People no longer need a pilot's license to fly a commercial drone – instead passing an aeronautical knowledge test at an FAA-approved facility and passing a background check is sufficient to qualify for an airman certificate. The rules allow drones to carry loads but the visual line-of-sight rule and weight restrictions (maximum 55 lbs.) still keep companies from making drone deliveries for example.

3.2 The legislation is ongoing

FAA is continuingly working on the drone legislation to provide more optimal conditions also for the commercial use of drones. For example they are working on a series of projects at FAA's Center of Excellence looking at rules for operations over people and developing tests that manufactures can use to certify their aircraft for flight over people. Another safety issue that FAA pays a lot of attention to is aircraft collision. FAA has together with partners completed a number of field evaluations of possible drone detection systems while in the process of developing minimum performance standards for any unmanned aircraft detection technology that might be deployed around airports in the United States[10].

BOX 2: Part 107 in numbers

- More than 820,000 operators have registered their aircraft
- More than 745,000 of those are hobbyist
- Approximately 60,000 are commercial operators of unmanned aircraft
- FAA has issued more than 43,000 Remote Pilot Certificates under Part 107, since it became effective in 2016

Source: FAA

To help unmanned aircraft operators determine whether they can fly in specific areas, the FAA has developed a safety app, B4UFLY, which provides real-time information about airspace restrictions and other flying requirements based on one's GPS location. FAA continues to make updates to BFUFLY, and the app has been downloaded some 220,000 times.

3.3 State legislation

Although regulation of the airspace falls within the jurisdiction of the FAA, 35 states have enacted laws addressing UAS issues within their borders[i]. States across the country have especially passed UAS legislation related to privacy implications because they do not find such issues sufficiently covered by FAA. Association for Unmanned Vehicle Systems International (AUVSI) has made a 2017 State Legislation Map, that provides an overview of state specific UAS legislation.

[10] Recent court rulings have created uncertainty about the authority of the FAA. Since 2015 hobbyist have been required to register drones and display a registration sticker on the drone that includes registration number to legally fly them. In May 2017, the US Circuit Court of Appeals for the District of Columbia struck down this regulation, as they found that FAA does not have the authority to regulate this area. The decision does not affect requirements to commercial drone operators.

4. Mapping potential collaborators

Through Innovation Center Denmark, Silicon Valley's preliminary analyses a sizable interest in potential collaboration with the Danish drone research environment has been encountered from universities throughout the United States. In this section, an overview of potential collaborators within drone research and education is provided. Contact information on the potential collaborators is available in Appendix A.

4.1 Exchange of researchers and students in Silicon Valley and Denmark

At University of California, nearly every campus has a 'Drone Lab' and there are several options for establishing researcher and student exchange programs. It is an option to establish such collaboration through The Center for Information Technology Research in the Interest of Society (CITRIS). Innovation Centre Denmark, Silicon Valley already has a partnership with CITRIS and can facilitate the contact in the case of Danish interest. The potential collaborations can be designed in several ways, varying from shorter visits during a summer to full Master's exchange with students from the Master of Science in Engineering study program specializing in Drone Technology at University of Southern Denmark.

UC Berkeley: Research in failure mitigation

At UC Berkeley, researchers focus on research within fault tolerance and failure mitigation through automatic fault detection such as systems that allow quadrocopters to maintain stable despite the complete loss of a propeller. Mark Mueller has earlier collaborated with the Danish company SkyWatch and express interest in student exchange.

UC Merced: Cognitive drones and Aviation Safety Management

At UC Merced there is an increased interest in environmental, agricultural, archeological, and ecological research groups work on drones on a very broad spectrum He is very interested in educational collaboration and offers to host students 3-6 months or PhD students for a year.

UC Merced is the UC campus responsible for aviation safety management for the whole UC-system. They take care of safety policies, safety risk management, and safety assurance and for this purpose they have developed a single UC UAS Fleet Management System portal for all UAS activity in the UC-system. UC Merced house the chief policy writer for Unmanned Aircrafts for the UC system and campuses and architect for UC UAS training programs and fleet management. UC Merced is very open to sharing knowledge and experience with aviation safety management at universities.

4.2 Collaboration with research environment outside of California

The interest in potential collaboration with the Danish research environment is not

only limited to California. The Innovation Center Denmark, Silicon Valley has established a network of potential collaborators at universities throughout the United States, and in this section an overview is provided of contacts outside of California.

Embry-Riddle Aeronautical University: Online drone education and corporate partnerships

Embry-Riddle – a pioneering institution in the field of unmanned and robotics education – has residential campuses located in Florida and Arizona. They launched the first Unmanned and Autonomous Systems Engineering program in the United States, and they have a very recognized online worldwide program that offers a diverse selection of degrees – including both a Bachelor of Science and a Master of Science in Unmanned Systems.

At Embry-Riddle they have experience with facing the challenges of online programs, and they experiment with new methods to achieve practical application of knowledge, skills, and abilities in the development and conduct of unmanned systems. Embry-Riddle is very open to share experience and potentially establish future collaboration with Danish drone researchers.

Besides innovative educational models, Embry-Riddle Aeronautical University has well established corporate and government partnerships, that could provide inspiration for the Danish drone research environment. They partner with the largest aerospace, security and defense companies leading the industry, organization like NASA and the FAA, which helps the students secure relevant internships and co-ops and assist in developing solutions to current aeronautical and aerospace problems.

University of Maryland: Test Site, Wind Tunnel and drone tech course

University of Maryland has established a drone Test Site for research purposes. The test site works directly with FAA and NASA to advance UAS research and demonstrate operational capabilities. The test site supports the application of UAS in a wide range of fields –ranging from forestry & agriculture, health & safety, and counter UAS to data & airworthiness validation.

University of Maryland also houses a Wind Tunnel where research, development, and education activities with application spanning many areas including unmanned systems.

The Engineering program of the University of Maryland Earstern Shore (UMES) offers a drone technology course Design of Autonomous Aerial Systems, and UMES also operates an agricultural research drone over one of two farms it owns.

University of Maryland is very interested in international collaboration regarding drone research and potentially establishing exchange programs.

Old Dominion University: Unmanned & Autonomous Vehicle Laboratory

The Unmanned & Autonomous Vehicle Lab, created in 2015, supports student projects to build fixed wing UAV's. They help the undergraduates build an entry for the SAE Aero Design East Competition every year, and are also active in flight dynamics experiments using small UAV's under automated control. Currently their research focus is on modifying commercially available autopilots/flight controllers to allow inflight system identification. For example the aircraft is put through a maneuver that commands elevator motion and allows identification of the short period longitudinal mode. Director of the lab, Dr. Drew Landman and Assistant Professor Onur Bilgen are very interested in establishing an international student exchange program.

Kansas State Polytechnic: Bachelor's degree in unmanned aircraft systems

Kansas State Polytechnic was one of the first universities in the United States to offer a bachelor's degree in unmanned aircraft systems. The UAS program is the principle initiative of the university's Applied Aviation Research Center (AARC). AARC is involved in a number of professional research partnerships with federal agencies, private sponsors and internal university groups, and are open to more international collaborations. The AARC completes approximately 100 missions each year, which help perpetuate the continuous influx of new UAS technology into the program and connect the students to the industry.

University of North Dakota: Major in Unmanned Aircraft Systems and NASA Partnership.

University of North Dakota's John D. Odegard School of Aerospace Sciences also offers a Bachelor of Science in Aeronautics with Major in Unmanned Aircraft System Operations, and is another potential collaborator for Danish Universities.

Last year The North Dakota Department of Commerce announced a five-year contract to support NASA unmanned aircraft systems research. The initial award of $197,950 supports a diverse group of local partners, where University of North Dakota is one of the central players. North Dakota has invested more than $34 million to establish a national UAS test site, to establish the Grand Sky UAS Business Park and to advance North Dakota's position as a hub for the nation's growing UAS industry.

University of Colorado Boulder: Collaborative environment and Atmospheric Science

At The Research and Engineering Center for Unmanned Vehicle (RECUV), which is a university, government, and industry partnership dedicated to the development and application of unmanned vehicle systems, they also have lots of experience with international collaboration. They have partnerships and collaborations with players on 5 different continent including Europe.

They are specialized in using unmanned aircraft to study atmospheric and weather science. For example they study the nature of phenomena such as tornados to improve forecasting of severe storms.

RECUV is very recognized in the United States and conducts cutting-edge applied drone research. It is founded on a very collaborative culture and some of the leading professors at the center are very keen on potential collaboration with Danish researchers.

Georgia Tech: Flight control and auto pilot

The Georgia Tech institute of Technology, better known as Georgia Tech, is a leading research technological university with a comprehensive interdisciplinary focus.

Eric N. Johnson is the Lockheed Martin Associate Professor of Avionics Integration in the School of Aerospace Engineering at Georgia Tech, and Director of the UAV Research Facility. His research focuses on fault tolerant estimation and control theory; and digital avionics system design and integration. Some of his research programs have included the Active-Vision Control Systems MURI and the Software Enabled Control program, as well as the development of several research Unmanned Aerial Vehicle (UAV) Systems. A majority of this research is conducted in the Unmanned Aerial Vehicle Research Facility at Georgia Tech, where he is also responsible for the education of Master's and PhD's with specialties within flight control and auto pilot.

Eric has some experience with international university collaboration and is in discussion with a potential industrial sponsor in Japan. He is very open to potential collaboration with Danish universities and is already working together with Danish operators in Colorado.

Rutgers University: AE degree and broad focused research

The Mechanical and Aerospace Engineering (MAE) Department at Rutgers University in New Jersey, USA, has more than 30 full-time faculty with more than 800 undergraduate students and 200 graduate students. The Aerospace Engineering (AE) program offers the only AE degree among New Jersey's public universities, and a core focus of the program is unmanned aerial systems. Rutgers University is also involved in the Mid-Atlantic Aviation Partnership (MAAP), a university consortium conducting research for FAA to integrate unmanned aircraft into the US airspace. Among the aerospace engineering industries nearby that hire Rutgers graduates are Lockheed Martin in South Jersey, Boeing in Philadelphia and Sikorsky in Connecticut.

The department recently hired several new faculties who are experts in this field, and has additional hires planned to expand and complement expertise in the area. For example, Dr. Xiaoli Bai focuses on: optimization-based path planning for UAVs, nonlinear programming, optimal flight control, and GPS-denied navigation. Dr. Javier Diez focuses on unmanned hybrid air/underwater vehicles, sense and avoid using stereoscopic cameras, UAV Slam, and optimization of multirotor propulsion systems. Dr. Onur Bilgen focusses on design, modeling and testing of unmanned fixed- and rotary-wing aircraft, multifunctional (morphing) structures, control surfaces and propulsion for UAVs, and design and modeling of piezocomposite flapping-wing ornithopters.

In case of interest in collaboration Department Chair, Dr. Alberto Cuitino has shown great interest.

5. Discussion

Wrapping up, the field of drones is growing and developing very rapidly, and revenues from drones are projected to top $12 billion in 2012 compared to $8 billion in 2015[11]. However there are still technological barriers regarding safety issues such as elimination of single points of failure and sense and avoid which cause restrictive drone legislation. And the legislation is certainly an important aspect shaping the future of drones as it is still limiting the commercial use of drone for package delivery with requirements that one person must always remain in line of sight of the drone. Another aspect of the legislation sharpening the future of drones concerns the lack of international standards, which is also crucial for the future deployment of drones commercially. This means that there are both technological and legislative obstacles to overcome for the commercial drone market to actually opening and giving companies the chance to deploy drone commercially for delivery or the like.

Photo: Catherine Mosiniak-Paillier

The United States in one of the absolute frontrunners in the field, and a great potential has been identified for research collaboration between Danish and American universities. Some of the leading universities within drone research in the United States have shown great interest in collaboration with Danish universities and see potential in establishing student and researcher exchange programs.

From the Danish perspective, it is an ambition to attract international drone researchers and companies to use the test facilities around the H.C. Andersen Airport in Odense and the idea is that these facilities can provide foundation for international collaboration. However, the attractiveness of the facilities in itself from an American perspective is not clear-cut. From speaking to several actors in the field, it appears that for test facilities to be attractive it is important that permissions are easily given both to flights beyond visual line of sight and to flights over populated areas. There are several test facilities within the borders of the United States so the test facilities in itself will not be enough to become a leading drone nation. It is an advantage of the Danish test facilities that fast in-house approvals are given at SDU and the possibility to do "live" testing outside the test center. Still, Denmark must play on the flexible legislative conditions and keep enhancing the collaboration between the industry, the universities, and the governmental actors to consolidate its position as

[11] BusinessInsider

a leading drone nation.

6. Appendix A: Contact Information on Potential Collaborators

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About ICDK Outlook

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The Innovation Attachés are a part of Innovation Centre Denmark which is a partnership between Denmark's Ministry of Foreign Affairs and the Ministry of Higher Education and Science. Together the two ministries manage seven centres in Brazil, China, India, Israel, Korea, Germany and the USA. ICDK Outlook is a concept where the attachés provide new knowledge and inspiration about opportunities or trends within a given topic with relevance for stakeholders within higher education, research and innovation. Find out more about Innovation Centre Denmark on www.icdk.um.dk, where you also can find all ICDK Outlooks.

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