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Master thesis

Comparison of Selected UAS Test Areas in Europe and America regarding Practical Aspects for Developers

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Affidavit

I hereby affirm in lieu of an oath that the present Master's thesis entitled

"Comparison of selected UAS test areas in Europe and America regarding practical aspects for developers"

has been written by myself without the use of any resources other than those indicated, quoted and referenced.

Graz, 13 September 2017

Alexander Lappi, BSc

Preface

The six months which I spent at the Austrian Aeronautics Industries Group (AAI) from March to August 2017 did not only result in this thesis, but also in an uncountable amount of experiences and memories, which I would hardly have made elsewhere. My employment at this company offered me to get the chance to have a unique, close and practical view on the Austrian Aeronautics Industries, especially within the interviews as a part of the study UAST, which were conducted with numerous companies from different niches and gave me as a student an outstanding possibility for planning my future career.

I would like to thank Secretary General KR Ing. Franz Hrachowitz for giving me the opportunity to work for the AAI, Mrs. Schmöllerl for her sunny personality which eased numerous intensive office days, and especially Raoul Fortner, MSc, who hired me to work for the AAI and was furthermore constantly zealous to maximize the value I could gain from this employment – Not only by fully incorporating me into the project UAST and taking me to numerous events and memorable business trips, but also by unhesitatingly and intensively supporting me during the creation of this thesis as my company supervisor

Thanks to Ing. Andreas Hinze, who supported me as my academic supervisor and gave me the necessary freedom to create this thesis in conformity with my tight schedule.

At last, I dearly thank my entire family, especially my mother Andrea, my sister Julia, my grandmother "Omi" Maria and "Hans-Peterl", who constantly support me in what I am and what I do. Due to your support I was able to reach what I have reached, wherefore I would like to dedicate this thesis solely to all of you.

Alexander Lappi

Leibnitz, September 2017

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Abstract

Unmanned Aircraft Systems (UAS) are increasingly used not only in the defense area but also in the civil sector for manifold purposes, including geosciences and agricultural optimization, film production, various rescue operations, or surveillance tasks, such as power line inspections. Due to their increasing complexity and functionality, detailed tests of UAS are necessary before bringing them into operation. New challenges are the current developments in the area of BVLOS-UAS, (Beyond Visual Line of Sight) and (partial) autonomy (including certified sense-and-avoid systems).

Therefore, not only multiple countries in Europe (e.g., Germany, Netherlands, France, Spain, Belgium, Denmark, or Norway) but also the USA, Canada, Australia, and others have established UAS test sites for the various needs of developers. For this thesis, a study was performed, and certain conditions and features of selected test facilities (e.g., size, services, costs, or the regulation of the designated airspace) are summarized and analyzed in this paper.

A key result of this thesis (performed at the Austrian Aeronautics Industries Group – AAI – during the study of UAS test areas (UAST) is a consolidated overview of 42 international UAS test areas worldwide, including sites in Europe, USA, Canada, Australia, Africa, and Asia. Consequently, the researched test areas are ranked according to not only specific Austrian test requirements but also to their total suitability for Austrian UAS tests, resulting in a Top 10 ranking of UAS test areas worldwide according to Austrian UAS developers' needs. In particular, U.S. test areas are capable of fulfilling Austrian testing needs best – but are quite far away – while numerous civil European test areas do not have the necessary airspace or BVLOS capabilities available yet.

A further outcome of this thesis is the finding that even the testing of civil UAS is often connected to military infrastructure or airspaces, which is shown by the fact that a significant amount of existent test areas evolved from (former) military facilities or (still) cooperate with military institutions. But this thesis also illustrates that civil UAS testing has become an increasingly important topic during the last decade. Therefore, it can be concluded that Austrian UAS developers will try to intensify their domestic UAS testing, as foreign UAS test areas that fulfill important criteria are also quite far away, and using Austrian military airspace (or installations) can often be the quicker and easier solution. Further possible perspectives are examined in this thesis and its conclusions.

Kurzfassung

Unbemannte Luftfahrt-Systeme (UAS) werden im militärischen und im zivilen Bereich für diverse Zwecke (Geowissenschaften, Optimierungen im Agrarbereich, Filmproduktionen, Rettungseinsätze, Infrastruktur-Inspektion etc.) eingesetzt. Ihre steigende Komplexität und Funktionalität erfordert umfassende Tests vor der Inbetriebnahme. Neue Herausforderungen sind BVLOS (Beyond Visual Line of Sight) und (Teil-)Autonomie (inkl. sense-and-avoid).

Daher haben nicht nur zahlreiche Länder in Europa (z.B. Deutschland, Niederlande, Frankreich, Spanien, Belgien, Dänemark oder Norwegen) sondern auch die USA, Kanada, Australien und weitere Länder UAS-Testgebiete für die Bedürfnisse von Entwicklern eingerichtet. Im Rahmen dieser Arbeit wurde eine Studie durchgeführt, welche spezielle Aspekte und Eigenschaften der einzelnen Testgebiete (z.B. Größe, Services, Kosten sowie die Organisation des Luftraums) zusammenfasst und analysiert.

Ein Hauptergebnis dieser Arbeit ist eine Übersicht über 42 internationale UAS-Testgebiete weltweit (ínkl. Europa, USA, Kanada, Australien, Afrika und Asien). Zudem werden die Testgebiete sowohl entsprechend der einzelnen Testanforderungen österreichischer Entwickler, als auch der Gesamttauglichkeit für österreichische Tests gereiht, was in einer Top-10-Rangliste von Testgebieten weltweit und auch speziell in Europa gemäß den Bedürfnissen österreichischer Entwickler resultiert. Insbesondere U.S.-Amerikanische Testgebiete sind dabei in der Lage, diese Bedürfnisse am besten zu erfüllen (befinden sich jedoch weit entfernt), während zahlreiche europäische Testgebiete derzeit weder über eine ausreichende Ausdehnung des Luftraums, noch über die Möglichkeit für BVLOS-Flüge verfügen.

Ein weiteres Ergebnis dieser Arbeit ist die Feststellung dass auch zivile UAS-Tests oft in Verbindung mit militärischer Infrastruktur und/oder mit militärischen Lufträumen stehen. Dies wird durch die Tatsache veranschaulicht dass sich ein signifikanter Anteil der Testgebiete aus (ehemaligen) Militäreinrichtungen entwickelte oder (nach wie vor) mit solchen kooperiert. Diese Arbeit zeigt auch auf, dass das zivile Tests im letzten Jahrzehnt ein immer wichtigeres Thema wurden. Daher ergibt sich die Schlussfolgerung, dass österreichische Entwickler vermehrt UAS-Tests in Österreich selbst anstreben werden, da ausländische Testgebiete, welche wichtige Testanforderungen erfüllen, einerseits weit entfernt sind und andererseits das Nützen österreichischer Militäreinrichtungen (bzw. des militärischen Luftraums) oft schneller und einfacher erfolgen kann. Weitere mögliche Perspektiven werden im Rahmen dieser Arbeit und in ihren Schlussfolgerungen untersucht.

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1. Introduction

1.1. Subject and Purpose of the Thesis

The Unmanned Aircraft Systems (UAS) field (both worldwide and in Austria) and especially the practical applications of UAS (see 2.1) for various tasks (not only in the commercial but also in the private sector) have been rapidly increasing within the last decade and show strong trends for even stronger growth in the future. Many consider UAS as promising technology with numerous advantages (including time and cost savings as well as the mitigation of risks for humans within dangerous environments) in different areas, such as infrastructure inspection, photogrammetry, search and rescue, geosciences, and applications for public safety. The development of new technologies (e.g., sense and avoid, autonomy, etc.), which are constantly improving and getting more complex, nevertheless happens faster than the development of the necessary regulatory framework, which also leads to constraints for the related testing of new technological developments. Due to the fact that the testing of new, uncertified technologies (not only within the sector of manned but also unmanned aviation) always entails the hazard of accidents and therefore also the injury of both humans and property, special test areas are absolutely necessary in order to mitigate such threats and to execute tests in a safe manner.

While, internationally, significant progress has already been made and numerous test areas dedicated also to UAS testing (UAST) have been established (e.g., in Germany, France, Spain, United Kingdom, Scandinavia but also in the USA, Canada, Asia, Africa, and Australia), there is no possibility for Austrian UAS stakeholders to test their developments domestically due to the fact that there is currently no such civil test area in Austria. Thus, the purpose of this master's thesis is to detect currently existent UAS test areas worldwide and to provide research on the respective aspects especially relevant for Austrian UAS developers (e.g., data concerning the airspace dimension and organization, population density within the test area, topography, possible test scenarios, operator models, accessibility, etc.). Furthermore, these aspects are then compared to the known exact requirements of Austrian UAS developers in order to create a ranking of the researched test areas according to their suitability for Austrian testing purposes. The entire thesis and especially the test area ranking should then provide the Austrian UAS community with an overview of existent possibilities for adequate UAS testing despite the lack of a domestic civil test area in Austria.

1.2. Background and Motivation

The Joanneum University of Applied Sciences, with its bachelor's and master's degree course in aviation, provides a broad, aviation-related academic training program in economic as well as technical disciplines, also drawing attention to the current developments within the UAS field. This includes not only new or upcoming UAS technologies but also the emerging need for counter-UAS systems. Considered altogether, members of the worldwide UAS community can be considered as "pioneers" who are introducing the concept of unmanned aviation – and all the possibilities that it enables – into civil utilization, which will make it a commonplace technology soon. Nevertheless, the UAS branch is still in its infancy and needs to be formed by not only technological progress but also by an adequate regulatory framework.

"At the moment the UAS branch is like the former Wild West,
where everybody needs to find their place first. Some will survive, but others will not."
- Raoul Fortner (Navigation Get-Together, TU Graz, 2017)

In particular, the fact, that one can actively influence the establishment of UAS technologies and developments by participating in the UAS field and by devoting oneself to UAS-related topics makes it exciting to work within this field and to write an interesting master thesis about a quickly developing segment in this sector: UAS test areas (UAST).

The Austrian Aeronautics Industries Group (AAI), which also actively participates in shaping the Austrian UAS field, not only offered to create the present master's thesis during Project UAST (see 1.3) but also offered the possibility to take part in this process during an interesting and also intensive master's degree internship. All this, combined with the formal requirement of a master's thesis to obtain a Master of Science (MSc) degree, generated the following thesis.

1.3. Supervising Company (AAI) and Project UAST

As mentioned in 1.2, the supervising company behind this master's thesis, AAI, is a non-profit association founded in 1999. The main task of this association – which is mostly financed by membership fees – is to represent the interests of its members, which are Austrian enterprises and research institutions active in the aviation/supply/industry, and to act as a link between the national and the international aeronautics industry as well as the respective authorities (see Figure 1).

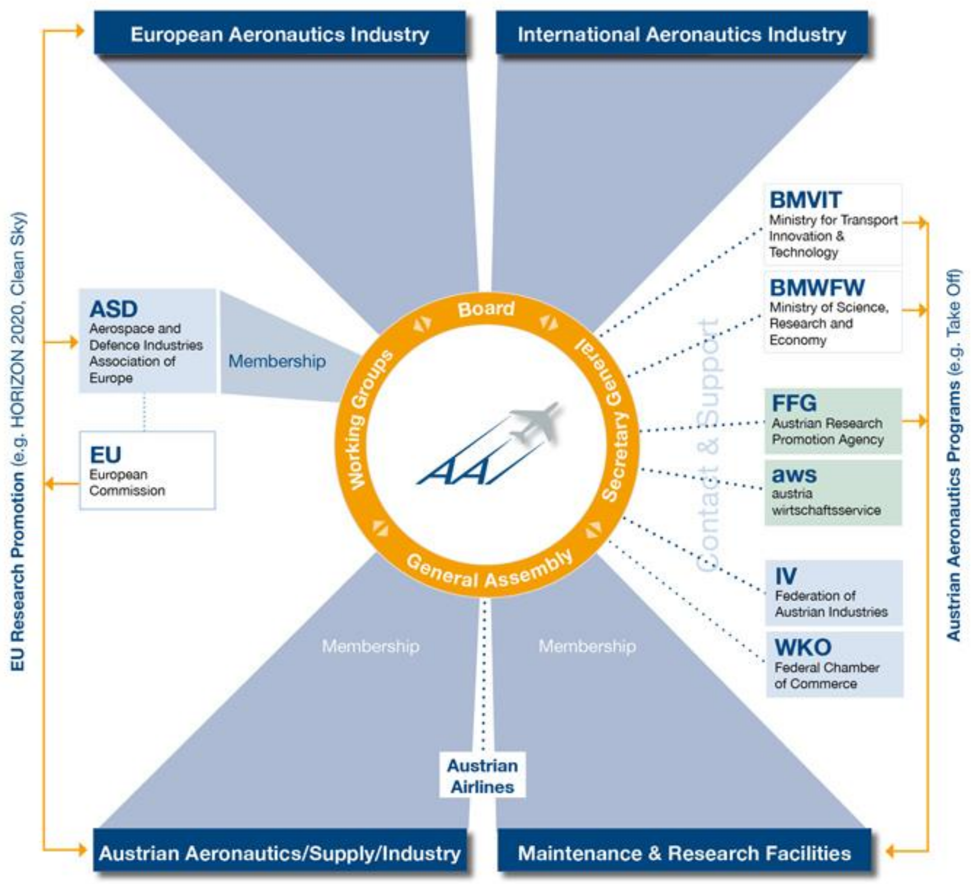

Figure 1: The AAI as a linking element between national and international industries as well as authorities
(AAI, "Vision & Mission," https://www.aaig.at/aboutaai/vision-and-mission)

As AAI states in its self-description: "*AAI represents—on national and international matters—the common interests of its about 35 members: Austrian companies and (research) organisations with proven business activities in the Aeronautics/Supply/Industry and Service sector. Key values of these companies are productivity, quality, flexibility and reliability … AAI and its members cover more than 85% of the annual aeronautics industry turnover in Austria, and are also members of ASD (Aerospace & Defence Industries Association of Europe), engaged in many committees of ASD and therefore fully integrated into respective European information and decision processes*" (WKO, Fresh View Aviation 2017, p. 14f).

Key competencies of AAI members include (ranked by percentage of annual turnover): composites and plastics (43%), metal and metal processing (18%), service and maintenance (16%), small aircraft, engines and UAS (7%), communication, electronics and information systems (7%), manufacturing technology, test and ground equipment (5%), interiors, equipment and other components (3%), and engineering, consulting, and research (1%).

Aside of hosting events (such as the annual Bodensee Aerospace Meeting, the S1000D User Forum, various workshops, etc.) and offering training courses in numerous disciplines (e.g., Production/Design/Maintenance Organization Approval, Quality Management Systems, Simplified Technical English etc.), AAI has also installed three notable working groups, including

1) The AAI-Quality Committee (AAI-QC), which coordinates all activities related to quality management, such as the Austrian implementation of the AS/EN 9100 (global industry standard for quality management in aerospace).
2) The ILS Working Group Austria (AAI-ILS-WG), which brings together all civil and military stakeholders for integrated logistics support (ILS) for implementing industry standards from the ASD suite of ILS specifications, such as S1000D.
3) The UAS Working Group (AAI-UAS-WG) see details below.

In 2012, AAI founded the "AAI UAS Working Group" (AAI-UAS-WG) and deliberately opened it also to non-members of AAI. Therefore, this working group brings together all interested developers and researchers from the entire Austrian UAS community, and it consists of about 40 members. (see Fortner in RPAS Yearbook 2016, p. 98)

- "A third of them full AAI-members, also working in the AAI-UAS-WG, including internationally well known companies like Schiebel and research institutions like the Austrian Institute of Technology (AIT), TU Wien and the University of Applied Sciences in Graz (FH Joanneum).
- Aside of BRP-Rotax, the others are mostly small enterprises (developers) or research institutions, working on the UAS itself or developing related applications for specific missions (e.g. geosciences, film industry).
- National partners within the AAI-UAS-WG are the Austrian Aero-Club (ÖAeC) with its section for model aircraft, as well as Film and Music Austria (FAMA) in the federal chamber of commerce (WKO) and the MOD."

Due to its longstanding experience in the development of the Austrian UAS sector, in early 2017, the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) mandated AAI to conduct an official study of the current needs of the Austrian UAS developers for testing and the current status of international UAS test sites. This study, called Project UAST (UAS Test Areas) was therefore the focus of the underlying master's internship and the nucleus of this master thesis, especially the elaborate research done by Alexander Lappi and Raoul Fortner for the overview of 42 international test areas (chapter 3).

2. Basics of Unmanned Aircraft Systems (UAS)

The following subsections explain the technological and regulatory basics of Unmanned Aerial vehicles (UAV) and Unmanned Aircraft Systems (UAS).

2.1. Technological Principles of UAS

The term UAV describes an aircraft that is operated by a pilot who is not physically present on board. As defined in ICAO Circular 328 AN/190 (ICAO, 2011, p.3), the aircraft is either remotely operated by a pilot who is located apart from the aircraft or it is able to fly autonomously, which means that it follows a given trajectory on its own without requiring external control inputs.

2.1.1. Taxonomy of UAS

Barnhart et al. (2012) state that the combination of a UAV with further components, such as different kinds of payloads, control elements, data link communication architecture and a ground control station or catapults for starting as well as the human element results in a so-called Unmanned Aircraft System (UAS). As visible in Figure 2, Fortner et al. (2014) provides an even more detailed breakdown of UAS components mostly according to Air Transport Association (ATA) chapters. They provide five different categories of components, including

1. Components that belong to the actual aircraft (blue), such as the aircraft structure and frame, the power plant (rotor or propulsion engine), electronic systems (communications, navigation, avionics, autonomy systems, etc.), and electrical systems (e.g., power supply). Those components also occur in manned aviation, wherefore the ATA chapters are applied
2. Components located apart from the aircraft (e.g., on the ground), which include not only the control station or infrastructure for takeoff and landing but also the operating pilot with all related human factors (green).
3. Components for mission control and payload-mission systems (sensors, freight, interfaces as well as the related up-/downlink etc., colored in gray)
4. Hydraulics and wiring (orange)
5. Safety- and redundant systems (red)

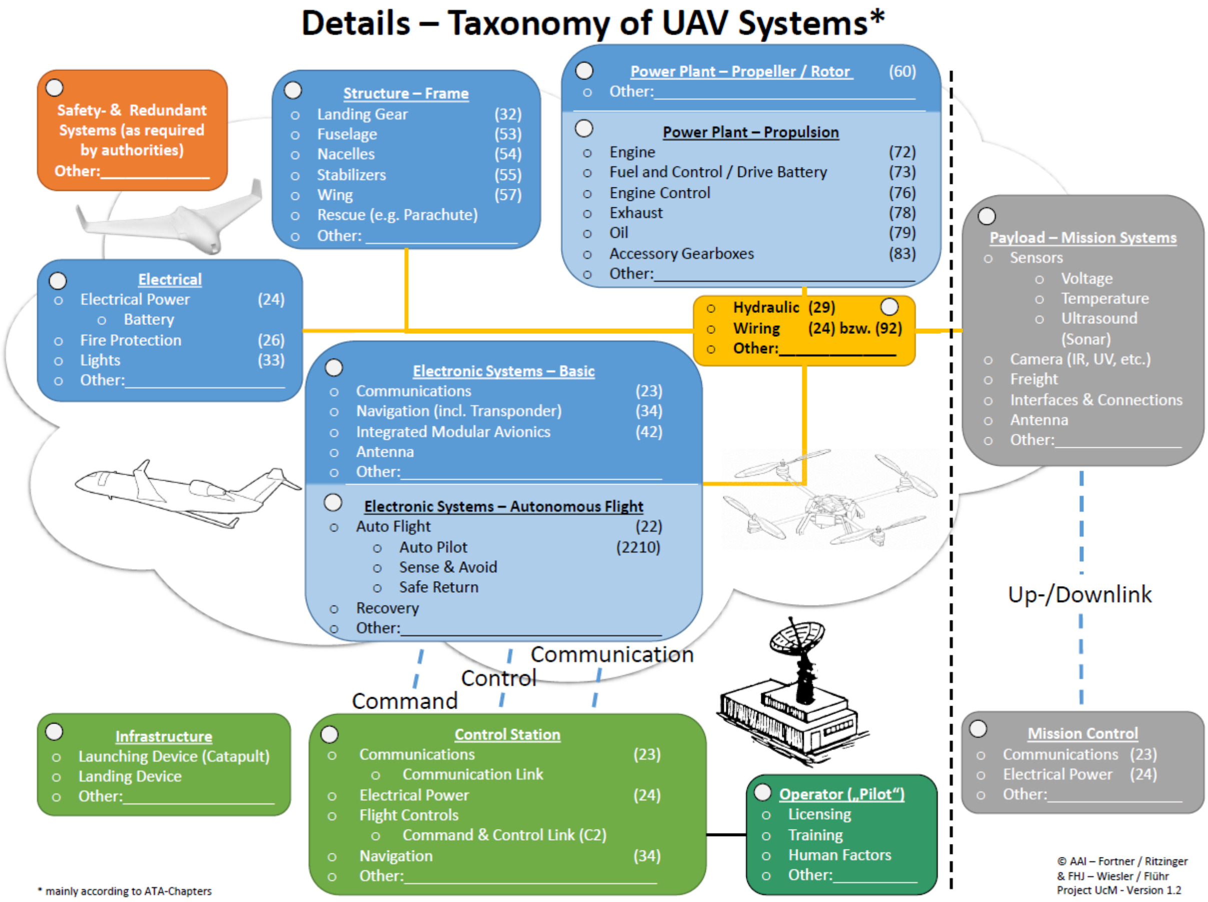

Figure 2: Taxonomy of UAV Systems including the different kinds of components (Fortner, 2014, slide 9)

Like conventional manned aircraft, UAS can also be divided into different design types (especially fixed-wing, rotary-wing, and hybrid). Nevertheless, there are also other possibilities for grouping UAS (e.g., according to their mass, mission, or propulsion), as visible in the RPAS Yearbook 2016. Every type of aircraft, though, needs some sort of surfaces (e.g., airfoils and control surfaces) not only to generate the necessary lift but also to control the aircraft's direction. To achieve the necessary air flow for lift generation, the air foil can either be fixed (fixed-wing aircraft) or rotating (rotorcraft). Furthermore, there are also hybrid solutions to combine certain advantages of both types.

2.1.2. Fixed-wing UAS

The functional principle of fixed-wing UAS is equal to that of conventional (manned) airplanes. The airfoil is fixed and therefore does not have any velocity in relation to the aircraft itself. While air must stream around the airfoil in order to generate lift, the necessary thrust is externally generated by some sort of propeller or engine. As Kroes (2013) visualized, certain control surfaces are also needed in order to move the aircraft toward desired directions (see Figure 3).

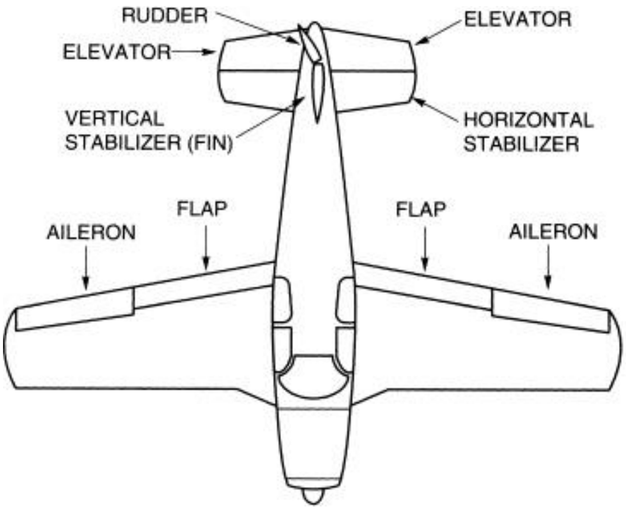

Figure 3: Control surfaces on fixed-wing aircraft according to Kroes (2013), Chapter 5

- ***Horizontal stabilizers:*** For longitudinal pitch stability, these create counterforce to the pitching moment created by the wing.
- ***Vertical stabilizers (fins):*** For yaw stability, these are necessary for single engines when the airstream caused by the propeller hits the rudder, which therefore causes a yaw moment.
- ***Ailerons:*** Moveable, these are used for controlling the roll movement.
- ***Rudder:*** Moveable, this is used for controlling the yaw movement. For a clear direction change, the rudder needs to be used in combination with the ailerons, as solely engaging the rudder would just change the orientation of the aircraft without an actual direction change (Newton's law of inertia).
- ***Elevators:*** Elevators control the movement around the lateral axis (pitch). Wind forces on the elevators cause the tail of the aircraft to rotate downward or upward, changing the wings' angle of attack and therefore making the aircraft climb or descend.

As QuestUAV states, the advantages of fixed-wing aircraft are that the simpler structure (compared to a rotorcraft) leads to a lower necessity of maintenance, less complicated repair, and lower costs. More important for fixed-wing UAS are their higher speeds and a higher endurance (which also leads to a greater maximal range and to larger areas which can be monitored) that can be achieved due to the more efficient aerodynamics. Additionally, heavier payloads can be transported. Nevertheless, a fixed-wing aircraft is not capable of taking off vertically. Therefore, a runway is required to start. In addition to that, the aircraft must be in motion constantly in order to generate lift, which leads to a reduced suitability of fixed-wing aircraft for inspection flights where hovering is a big advantage.

2.1.3. Rotorcraft UAS including Multicopters

As Kroes (2013) mentions, rotary aircraft belong to the most versatile and useful type of aircraft. The difference of fixed-wing aircraft is the source of lift: While fixed-wing aircraft generate lift with an airfoil that moves with the aircraft itself, the airfoil of a rotary-wing aircraft performs its own motion and therefore creates lift without the necessity of the aircraft moving. The airfoil of a rotary-wing aircraft is nevertheless similar to that of a fixed-wing aircraft, as the same laws of aerodynamics apply. As mentioned by QuestUAV, the missing control surfaces that are part of a fixed-wing aircraft are substituted by varying the thrust of the individual propellers. State-of-the-art multicopters have either one (helicopter), three (tricopter), four (quadrocopter), six (hexacopter), or eight (octocopter) propellers.

Kroes (2013) also states the advantages of rotorcraft, which are – among others – the capability of moving in any spatial direction (upward, downward, forward, and backward), as well as being able to hover in one certain position (which is important for many rotorcraft UAS missions). Due not only to the mentioned advantages but also to the fact that rotorcraft can be launched from almost anywhere without needing much space, Kroes (2013) suggests that they are useful for tasks such as transport, surveillance, inspection of infrastructure, construction, agricultural work, and others.

In contrast to fixed-wing aircraft, rotorcrafts make use of lift generation in a different way by also using a part of the lift for generating thrust (as shown in Figure 4).

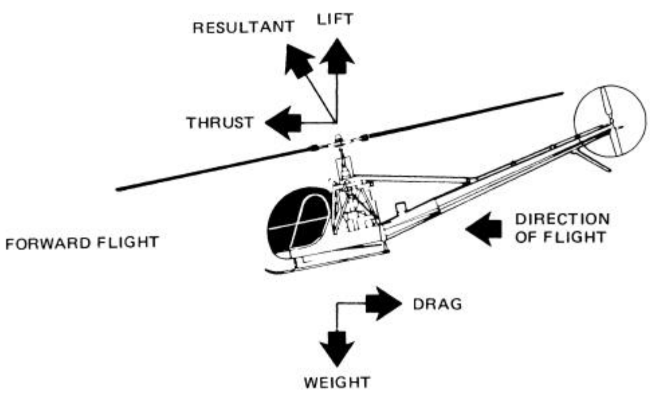

Figure 4: Principle of lift and thrust generation by rotorcrafts
Kroes (2013), chapter 5

According to QuestUAV, rotorcrafts nevertheless show certain disadvantages, such as a not only higher technical and electronics complexity but also minor velocity and range compared to fixed-wing aircraft. In particular, UAS with electric propulsion show a weak ratio of mass (heavy batteries) to endurance.

2.1.4. Hybrid and other UAS

The conventional classification of UAS (as introduced in chapter 2.1.2 and chapter 2.1.3), including fixed-wing and rotorcraft UAS, can be extended by a third type: As Lemmens (2015) states, hybrid UAS, which are a mixture between fixed-wing and rotorcraft UAS (comparable to manned aviation), combine the advantages of both aircraft types. This is due to the fact that, by using hybrid technology, fixed-wing UAS can be equipped with vertical takeoff and landing (VTOL) as well as hovering capabilities, which simultaneously eliminates the significant disadvantage that a conventional fixed-wing UAS is required to stay in motion constantly in order to generate lift. This can be realized by enabling its rotor blades to rotate from a vertical pose into a horizontal pose, as Lemmens (2015) describes (see Figure 5). Moreover, the hybrid concept eliminates the necessity of a runway for starting or landing a fixed-wing UAS, which. according to Lemmens (2015), reduces the risk of damage to onboard equipment.

Figure 5:Hybrid-UAS with rotor blades in the horizontal pose
(GIM International, "Hybrid UAS/UAV: Fixed Wing and Chopper in one Aircraft," https://www.gim-international.com/content/article/hybrid-uas)

Using the hybrid concept also makes it possible to create UAS that are not only able to hover, but also to travel at high speeds, cover much larger distances, and carry heavier payloads (in contrast to conventional multirotor UAS). Nevertheless, a hovering hybrid consumes a similar high amount of energy than a conventional rotorcraft, which reduces the airtime, as suggested by Matheson (2017). He further states that, with the help of this technology, not only new applications for UAS can be realized, but also existing applications can be improved. Hybrid UAS do not require a runway, but they are able to carry heavy payloads for large distances and could therefore be used to realize UAS-based package delivery. They could – especially by means of their hovering capability combined with high possible speeds and high endurance – also improve existent UAS applications such as surveillance, search and rescue, and the inspection of infrastructure.

2.2. *Regulatory Framework for UAS*

The world-wide creation of the regulatory framework for the operation of UAS in Austria is currently happening on three levels, as shown in Figure 6.

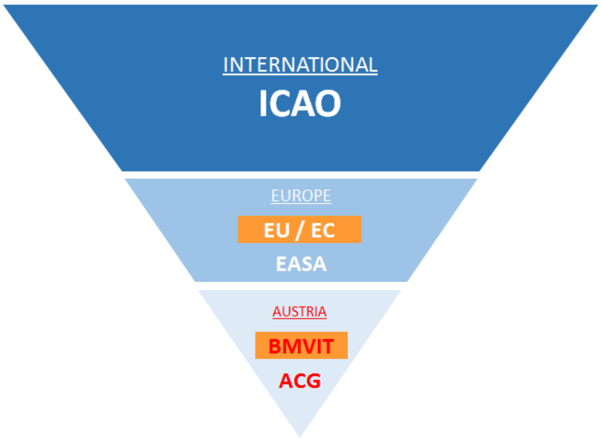

Figure 6: Legislative organizations on the international, European, and Austrian levels

While the International Civil Aviation Organization (ICAO) and the European Aviation Safety Agency (EASA), together with the Joint Authorities of Rulemaking on Unmanned Systems (JARUS), pursue a worldwide (and, respectively, European) approach to set up this framework, every country has its own legislative duties and responsibilities. This leads to the case that the regulatory framework set up by the EASA is currently only applicable for UAS with a maximum takeoff mass (MTOM) above 150 kg, while decisions on regulations for UAS with a MTOM below 150 kg are still made by the individual countries themselves. This may change in the EU within the coming years, though.

2.2.1. International Level (ICAO)

The highest authority active worldwide within the aviation sector is the ICAO, which was founded in 1944 with the task of administering and monitoring the compliance of its member states with the regulations defined in the Convention on International Civil Aviation (Chicago Convention). As the ICAO (now part of the United Nations, or UN) states, this convention is currently signed by 191 UN-member states, which enables the global standardization of regulations within the aviation sector to make it "*safe, efficient, secure, economically sustainable, and environmentally responsible*." In order to achieve this goal, the ICAO uses the instruments of standards and recommended practices (SARPs) as well as procedures for air navigation (PANs) and the so-called "Annexes" of the Chicago Convention.

With Circular 328 AN/190, the ICAO (2011) defined and regulated UAS for the first time in 2011. Pilotless aircraft may only be operated with the authorization of the competent authority in the respective member state, as stated in article 8:

> *"No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization."*

Furthermore, the same article defines a pilotless aircraft as not to be operated by a pilot on board but remotely piloted from a different place or being capable of flying fully autonomously. While the ICAO does not expect the integration of fully autonomous unmanned aircraft into non-segregated airspace within the near future, this should nevertheless be possible for remotely piloted unmanned aircraft. Therefore, minimum safety requirements will have to be fulfilled. Fully autonomous flight should, however, be possible in segregated airspace with respective authorizations, but the underlying regulations will require a significant amount of time.

Therefore, as stated in circular 328 AN/190, the ICAO considers the development of a suitable regulatory framework for unmanned aviation to be an "evolutionary process" that will last for several years. This means that an exact, fully-developed regulatory framework made by the ICAO is not existent yet but substituted by the regular issuance of so-called "guidance material" and SARPs based on new findings and decisions.

As previously mentioned, the ICAO expects the currently growing civil UAS market to stagnate if a regulatory framework is not established in time. Nevertheless, the ICAO considers unmanned aircraft as an active participator in air traffic, and, regarding the development of regulations, parallels are drawn to manned aviation by adapting existent articles. Not only aircraft certification (certificate of airworthiness, type certificate, etc.) but also the licensing of pilots, crew members, and Air Traffic Controllers (ATC) are intended to be similar to those used for manned aviation.

2.2.2. European UAS Rulemaking

As also visible in Figure 6, the rulemaking for aviation on the European level is performed by the European Union (EU), which therefore installed the European Aviation Safety Agency (EASA) in 2002. As the European Commission (which is a formal body of the EU) states, the definition of safety rules and regulations for the operation of UAS in Europe is currently enabled by a proposal for the revision of EASA basic regulation 216/2008. Within this proposed regulation, the requirements for "*the design, production, maintenance and operation of unmanned aircraft and their engines, propellers, parts, non-installed equipment and equipment to control them remotely*" are defined. It furthermore states that – comparable to the approach of the ICAO – the design, production, maintenance, and operation of UAS must be certified similar to the way it is in manned aviation.

Not only in the Technical Opinion paper on the introduction of a regulatory framework for the operation of unmanned aircraft published by the EASA (2015) but also in the Prototype Commission Regulation on Unmanned Aircraft Operations (2016), the EASA has developed a first approach to define a regulatory framework. Within the Technical Opinion paper, the EASA (2015) put forth 27 proposals to define a roadmap for prospective regulations. In both papers, the EASA furthermore defined three different categories of UAS application (as shown in Figure 7) as well as their respective requirements.

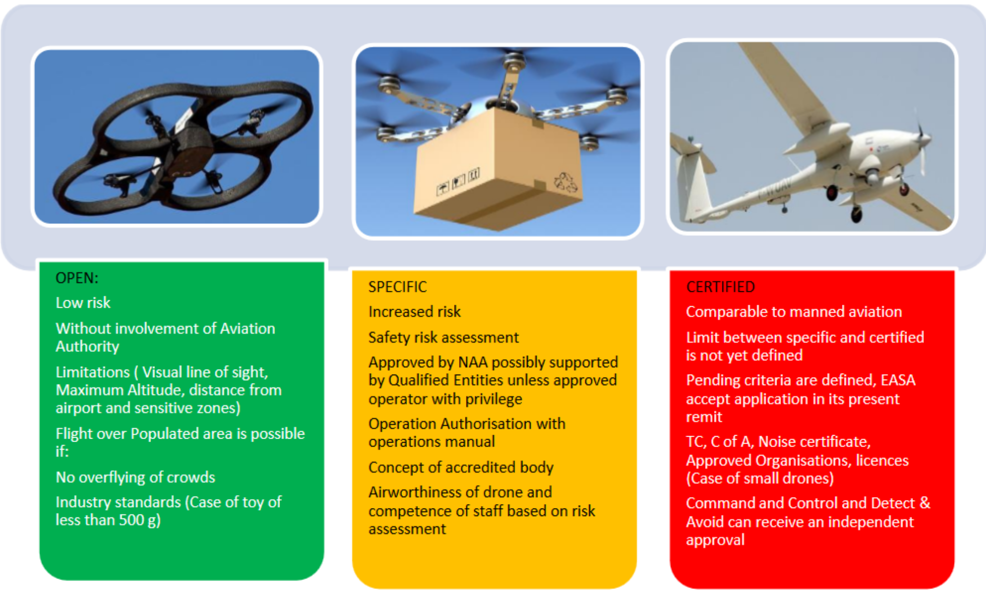

Figure 7: Different categories of UAS according to the EASA proposal (EASA, 2015, p.18)

1. ***Open:*** This category will be used for UAS applications that show a small risk for third parties in the air or on the ground. Within this category, an approval for the operation of a UAS is not required. Nevertheless, a minimum horizontal distance of 50 m to crowds as well as a maximum altitude of 150 m must be kept. Furthermore, only flights within the visual line of sight (VLOS) will be allowed. The potential for accidents within this category should though not be underestimated, as even small UAS can reach considerable heights and cause serious hazards for other participants in the air traffic. The EASA (2015) also suggests further subcategories within the open category in order to address "harmless" UAS, which should solely be sold with do's and don'ts of UAS operation on leaflets:
    - A0: (MTOM < 1 kg)
    - A1: (MTOM < 4 kg)
    - A2: (MTOM < 25 kg)

2. ***Specific:*** The specific category will be used for UAS applications that exceed the barriers of the open category. Therefore, a safety risk assessment has to be fulfilled (e.g., by the operator), where the planned area of operation, population density, weather, airspace category, effects on air traffic management (ATM), competency of the pilot, and effects on the environment are taken into account. Furthermore, the exact planned operation must be stated. In contrast to the open category, an authorization for executing the flight must be obtained prior to the flight. However, as flight scenarios are authorized individually, this category does not show specific limits regarding weight, altitude, or the UAV's MTOM. The EASA (2015) nevertheless offers certain standard scenarios (e.g., photogrammetry, inspection of infrastructure, precision farming, etc.) that enable a simplification of the authorization process similar to current Austrian UAS risk assessment (see 2.2.3).

3. ***Certified:*** If the risks during UAS operation are similar to those in the manned aviation and special scenarios (e.g., detect and avoid) are also planned, the certified category is applied. Within this category, the fulfillment of requirements of not only unmanned but also manned aviation is necessary. Compared to the specific category, a broader range of UAS applications is covered while simultaneously accepting a higher risk level (e.g., cargo transport with large UAS and high MTOM or transport of persons and other applications where the risk assessment of the specific category is

not sufficient anymore). Furthermore, not only the licensing of the UAS operator (remote operator certificate) and all pilots, but also the approval of organizations which are involved into the design, production, and maintenance of the UAS and training of its crew, is obligatory. In addition to that, it is required to prove the airworthiness of the UAS according to the standards in manned aviation.

2.2.3. Austrian UAS Rulemaking and Risk Assessment

According to the Austrian ministry for transport, innovation and technology (Bundesministerium für Verkehr, Innovation und Technologie, BMVIT), the operation of UAS is liable to Austrian aviation law (Luftfahrtgesetz, LFG) as of 1st January 2014. Both the size and MOTM of the UAV and its purpose define the respective category that is applicable.

While aircraft that are operated for the purpose of the flight itself only are defined as model aircraft (§24e LFG), the Austrian law defines two different UAS categories (class 1 and class 2) for deviating purposes. An operational authorization is required for UAS that are categorized as model aircraft but heavier than 25 kg as well as for UAS that are categorized within class 1 or class 2.

As the Austro Control Group (ACG), which is a sub-authority of the BMVIT (see Figure 6) has confirmed, a UAS is either categorized in class 1 or class 2 once the purpose of its operation is not "the flight itself" but other (commercial) purposes or missions (e.g., photogrammetry). In order to operate such a UAS, an authorization by the ACG is required. Furthermore, the law defines the two different UAS categories as follows:

- ***<u>Class 1</u>*** (§24f LFG)**:** Operated within VLOS (direct visual contact without technical aids), with a maximum altitude of 150 m of distance.
- ***<u>Class 2</u>*** (§24g LFG)**:** Operated beyond VLOS (BVLOS); authorization correspondent to the European model according to manned aviation, but only scheduled for trial at the moment.

As the law furthermore states, UAS do not need an authorization if they show a maximum kinetic energy of 79 Joules (which equals a weight of 250 g) and are operated below 30 m (§24d LFG). Also, indoor operations are not covered by Austrian aviation law.

For UAS in class 1, ACG conceptually created a categorization according to a risk assessment, which is contained in the airworthiness and operational capability notice 67 (Lufttüchtigkeits- und Beriebstüchtigkeitshinweis Nr. 67, LBTH 67) issued by the ACG. This paper contains a two-dimensional matrix (shown in Figure 8), which categorizes UAS class 1 (VLOS) in different categories (A, B, C, or D) according the risk of their operation ,which results from a combination of the area of application and the MTOM of the UAS (< 5 kg, 5-25kg, 25-150kg).

	UAS Class 1 (VLOS) – Area of Operation			
	I undeveloped (no buildings)	II unpopulated	III populated	IV densely populated (except crowds)
MTOW up to and including 5 kg	A	A	B	C
MTOW up to and including 25 kg	A	B	C	D
MTOW above 25 kg and up to and including 150 kg	B	C	D	D

Figure 8: Categorization of class 1 UAS (VLOS) according to LBTH67 of ACG (Ritzinger et al., 2014, p.1)

The four different kinds of application areas are defined as

I. ***Undeveloped:***

No buildings, no present persons who are not involved into the flight (pilot, crew, etc.)

II. ***Unpopulated:***

Not more than secondary buildings (warehouses, silos, etc.) or buildings without utilizable rooms. Only occasional, temporary appearance of people (e.g., hikers)

III. ***Populated:***

Primary buildings (residential houses, schools, stores, offices, etc.)

IV. ***Densely populated:***

Spatially closed, populated area (e.g., city center)

As the ACG additionally states in LBTH 67, the operation of UAS over crowds (sporting events, concerts, demonstrations, etc.) is subject to further investigations and therefore only individually permitted by special authorization. For each of the categories according to LBTH 67, the ACG states certain requirements.

General requirements:

Beneath the certain requirements applicable for each different category, every class 1 UAS must fulfill basic requirements, such as insurance, according to §164 LFG. Additionally, noise limits according to attachment N to the LBTH 67 must be complied with. The operating limits of the UAS must be defined and complied with as well. The pilot has to be at the age of at least 16 years.

Category A:

In addition to the general requirements, the UAS needs to have non-complex, manual steering at least. Furthermore, the pilot needs to have the proficiency to operate the UAS. Moreover, all used components must be state of the art.

Category B:

In addition to the general requirements, the UAS needs to fulfill the airworthiness requirements according to attachment B to the LBTH 67 tailored certification specification, which must be ensured and confirmed by the operator. Additionally, the UAS needs to have non-complex steering with stabilization. Furthermore, an operational safety assessment according to attachment F to the LBTH 67 needs to be performed. Pilots of a UAS within category B must bring a written declaration of not only their proficiency to operate the UAS but also of their physical fitness.

Category C:

In addition to the general requirements, the UAS needs to fulfill the airworthiness requirements according to attachment B to the LBTH 67 tailored certification specification, which must be ensured and confirmed by the operator. Additionally, the UAS needs to have complex steering with stabilization and navigation. Furthermore, an operational safety assessment according to attachment F to the LBTH 67 needs to be performed (single point of failure analysis). Also, a check list containing all maintenance work to be performed to ensure the airworthiness of the UAS, as well as a pre-flight checklist, must be created. Pilots must either be in possession of an aviation license (except for parachutes, hang gliders, or paragliders) or prove their legal knowledge within an examination at ACG. In addition to that, the pilot must either show an aviation medical fitness certificate or a driving license fitness certificate not older than 5 years.

Category D:

In addition to the general requirements, the airworthiness requirements are defined individually by the authority according to the type and configuration of the UAS (based on the airworthiness requirements in attachment C to the LBTH 67 tailored ES-LUAS/LURS by JARUS). Additionally, the UAS needs to have complex steering with stabilization, navigation, and automatization. Furthermore, an operational safety assessment according to attachment F to the LBTH 67 needs to be performed (single point of failure analysis). Also, a check list containing all maintenance work to be performed to ensure the airworthiness of the UAS, as well as a pre-flight checklist, must be created. Pilots must either be in possession of an aviation license (except for parachutes, hang gliders, or paragliders) or prove their legal knowledge within an examination at ACG. In addition to that, the pilot must either show an aviation medical fitness certificate or a driving license fitness certificate not older than 5 years.

Note: A reduction of the necessary category certification is possible by mitigating the risks in a specific area of operation (e.g., by blocking access to the area for unauthorized people).

2.2.4. Further Legal Issues

In addition to the constraints and requirements, which have be considered from the aviation law point of view, it is also necessary to comply with other fields of law not directly related to aviation, such as privacy, data security, and also telecommunication regulations.

(1) Data security and privacy

In particular, data security issues have a high potential to appear once a UAS is equipped with a camera. As Lachmayer (2016) states, data security considerations reach a serious level if a person can be identified on the pictures taken by the UAS. Additionally, flying over public places, especially foreign properties, with an equipped camera can cause problems in terms of data security. Also, privacy rights might get violated if a UAS operates on foreign property. Moreover, Lachmayer (2016) mention that personal data – if it has been obtained without the respective person's approval – has to be deleted once it is detected, as also stated in §27 of the Austrian data privacy act. Proissl (2016) added that taking pictures from the air is regulated by the same law as taking pictures from the ground. The right to privacy must not be infringed. Especially when such material is made public without authorization, the respective victims can seek damages. This is also supported by §1 and §33 of the Austrian data privacy act, which state that every person has the right on nondisclosure of private data and that persons who unlawfully collect such data have to pay damages. When a UAS operates on foreign property, a lawsuit due to civil nuisance could also be the result. Proissl (2016) therefore recommended obtaining the approval of the relevant persons before taking pictures or making them unrecognizable.

Cavoukian (2012) made numerous recommendations in order to avoid data security or privacy law issues. At first – if a UAS is used to take pictures – consultation of relevant stakeholders is recommended in order to find out if any measures against the infringement of privacy or data security need to be taken. Second, privacy impact assessments (PIA) should be conducted before operating the UAS to detect the possible impact of the planned activities on the privacy and data security of third parties and how to mitigate possible infringements. Furthermore, privacy protection policies should be incorporated in training programs and the certification of UAS operators. Cavoukian (2012) also suggests that especially companies that use UAS should face certain restrictions that prevent them from collecting data that is not related to their actual work. The most highlighted and, according to Cavouakin (2012), the most effective measure is the concept of privacy by design (PbD), which says that UAS manufacturers should implement concepts for privacy and data security from the very early development phase of their products. As a result, the UAS should itself limit privacy intrusion to the lowest possible extent, which is "necessary to achieve required, lawful goals."

Certainly, the proper solution of all relevant privacy issues (also for private users) will be a key factor for the acceptance (or rejection) of UAS by the civil society according to Fortner in DerStandard (2015).

*(2) **Telecommunication***

Another component of UAS operation that might lead to law infringement if not considered properly is telecommunication. As Cziczatka (2016) states, every radio unit needs an authorization, which is normally issued with a governmental decree to exactly define the authorized frequency, transmitting power, area of use, and other issues. Furthermore, he states that a radio unit that is operated in Austria must comply the directive 2014/53/EU ("RED").

As included in the Austrian frequency assignment plan issued by the BMVIT (2016) attached to the frequency use directive, every available and legal frequency range in Austria is assigned to certain purposes. However, there is no existent frequency that could exclusively be used by UAS. Nevertheless, the International Communication Union (ITU, 2015) states that the World Radio Conference (WRC) 2015 "*opened the way for the development by ICAO for worldwide standards for Unmanned Aircraft Systems (UAS)*." Until international frequencies for UAS are finally established, though, manufacturers like DJI assign their systems to reserved frequencies (e.g., for short range devices, 2.4/5.8 GHz). Furthermore, Cziczatka (2016) mentions that the operation of radio units is liable for costs. Nevertheless, there are generally authorized devices (e.g., remote controls, wireless headphones, and WLAN) that do not require an authorization and are free of charge. However, the use of non-authorized frequencies as well as the modification or illegal installation of the UAS radio unit might lead to a breach of law.

As Cziczatka (2016) states, further respective regulations can be found in the following Austrian telecommunication regulations (original titles in German): Telekommunikationsgesetz (TKG 2003), Bundesgesetz über Funkanlagen und Telekommunikationsendeinrichtungen (FTEG), Amateurfunkgesetz (AFG 1998), Funker-Zeugnisgesetz (FZG 1998), and Rundfunkgesetz.

2.3. History and Modern Applications

2.3.1. History of UAS Development

The history of unmanned aviation simultaneously began with the history of aviation itself. From the very beginning, it was military purposes, in particular, that lead to progress and new developments within the unmanned aviation section. Starting from Chinese generals using differently colored, unmanned paper balloons to distract their enemies around the time of 200 A.D. (Barnhart et al., 2000), to the so-called “Austrian Balloons” in 1849 – which were bomb-carrying, unmanned balloons used by the Austrian military to attack Venice (Saad, 2015) – to current applications in modern warfare, the military industry has always acted as an innovation driver in manned and unmanned aviation.

As described by Barnhart et al. (2012), the major advantage of early unmanned aviation was the reduced risk for humans in the event of accidents. This was also the reason why Otto von Lilienthal used unmanned gliders to test new wing designs in 1890. At the same time, Nikola Tesla started his experiments on unmanned aviation, which resulted in multiple accidents but – as the aircraft were unmanned – no human damage. The early problem of UAVs was (just as for manned aviation) the missing concept of flight control, which was nevertheless solved by the Wright brothers for both disciplines at the beginning of the 20^{th} century.

According to Barnhart et al. (2012) and Valavanis et al. (2015), a further step toward unmanned aviation was made by Elmer Sperry. He was able to transfer his work on gyroscopic devices for the stabilization of torpedoes to the stabilization of unmanned aircraft, resulting in the demonstration of the so-called “Hewitt-Sperry Automatic Airplane” in 1916, which is considered as the first modern unmanned aircraft.

Between World War I and World War II, military developments did not focus on armed UAVs but on anti-aircraft weaponry instead, as stated by Barnhart et al. (2012). Therefore, big efforts were made in order to develop target drones for weapons testing, and withdrawn aircraft were often modified to make them fly unmanned. The passive role of UAVs changed to an active one after 1945 during the Cold War, when people recognized the advantages of unmanned aviation in reconnaissance missions (see Figure 9).

EVOLUTION OF US DRONE WARFARE	Phase 1 **The Target Drone**	Phase 2 **The Flying Bomb Drone**	Phase 3 **The Surveillance Drone**	Phase 4 **The Hunter-Killer Drone**	Phase 5 **The Police Drone**
Time period	Early twentieth century	Interwar period	Cold War, particularly after the Cuban Missile Crisis	Post-September 11, 2001	Post-September 11, 2001
Institutions	U.S. Army	U.S. Air Force	U.S. Air Force and Strategic Command	U.S. Air Force, CIA and JSOC	Police forces, Customs and Border Patrol
Military logic	Drones were used as practice dummies	Drones were used to deliver ordinance across enemy lines	Drones were used to photograph denied or dangerous areas	Drones were used in a military "manhunt" during the war on terror	Drones are being used by police forces in the U.S and Europe
Key Geographies	Developed in UK and US military shooting ranges	Trialed across English Channel	Drones were used across North Vietnam, Cuba, China	Afghanistan (AF), Pakistan, Yemen and Somalia (CIA and JSOC)	Cities in the global North, used by hobbyists and criminals
Spatial Logic	-	Cross the Battlefield, Bomb the Nation State	Surveil the Battlespace, Capture photos	Hunt the Battlespace for dangerous individuals	Swarm the Street, protect VIP buildings
Iconic drones	Hewitt-Sperry Automatic Airplane, Kettering Torpedo	Glide Bomb, Modified B-17 bomber (Aphrodite)	Various Firebee drones, also known as Lightning Bugs	Predator, and later Reaper drone, also the hand-held Raven	Various quadcopter drones

Figure 9: The evolution of UAS application areas within U.S. warfare
(Understanding Empire, https://understandingempire.wordpress.com/2-0-a-brief-history-of-u-s-drones/)

This resulted in the development of not only the so-called "Lightning Bug" (shown in Figure 10), which is considered to be the first UAV according to modern standards but also the first rotary-wing UAV built by the U.S. Navy in 1960. As Valavanis et al. (2012) states, the Soviet Union also made efforts toward unmanned aviation for reconnaissance purposes by creating its own UAV, which was, however, not capable of being used multiple times. Since then, unmanned aircraft have frequently been used on various battlefields all over the world. Guillot (2016) mentions a further milestone in the (military) use of UAS in the 1990s.

> *"Despite the U.S. military's sporadic use of unmanned aerial vehicles, Whittle says it remained a niche technology until the mid-1990s, when engineer Abraham Karem designed what eventually would be known as the Gnat 750. It was able to stay in the air for up to 12 hours and provide users with a 60-mile panorama. The Gnat 750 became the basis for what would become the Predator drone."*

Figure 10: The Ryan Model 147, also called "Lightning Bug" in the US Airforce Armament Museum
(UAS Vision, "Ryan Firebee on Show at Airforce Armament Museum," http://www.uasvision.com/2012/09/28/ryan-firebee-on-show-at-air-force-armament-museum/)

The development of unmanned aviation intermediately stagnated after the terror attacks on 11th September, 2001, as Barnhart et al. (2012) describes. These events and also the fact that pilots, in particular, feared losing their jobs due to the growing unmanned aircraft technologies led to a negative public opinion, especially about UAS, which nevertheless could be overcome. While the U.S. Army operated 30 UAS in 2001, the amount raised to 2000 UAS by the year 2010. Also, the public appreciation of UAS increased due to the fact that the arguments for cost reductions and fewer hazards for pilots gained the upper hand. As Valavanis et al. (2015) describes, the demand for not only long-endurance UAVs but also small UAVs for civil(!) purposes has increased rapidly within the past decade, as they offer a wide range of suitable applications (see Figure 12).

2.3.2. Modern Civil UAS Applications

The rapid technological progress that has been achieved within the UAS area, especially within the last decade, did not only improve the trust of reliability and safety of UAS but also enabled numerous possible applications in various fields as well as the resulting advantages. Nowadays, UAS are not only used for military purposes, but they are also used in the areas of natural sciences and research (e.g., geosciences), environmental monitoring, public safety, disaster management, and photogrammetric surveying, as well as in the film and photo industries.

A vital application of UAS in the civil area was shown by Kim (2015), who assessed the applicability of UAS for disaster management. Within his work, he describes UAS as useful for reacting to ecological disasters. With the pictures provided by UAVs, rescue forces cannot only get an initial overview of the situation but also gain essential initial information for the search of injured people. In addition to that, the pictures can help to weigh the possible risks that could occur during an operation as the photos could also help find adequate strategies, assess the accessibility of the affected area, and coordinate different teams. If UAVs are engaged with adequate equipment (e.g., infrared cameras), they can be used to search for injured buried or lost people. Additionally, they could be used for the quick transport and airdrop of medical kits and medicine. Finally, Kim (2015) suggests the application of UAVs within contaminated areas (which already happened after the nuclear disaster in Fukushima 2011 in order to monitor the radiation level and to view destroyed cities and villages) as well as for the inspection of critical infrastructure after an ecological disaster in order to prevent further damage (executed method employed after hurricane Sandy in 2012 and an earthquake in China in 2013). Kim (2015) also clearly mentions the advantages of using UAS for such applications by stating that UAVs not only deliver high-resolution pictures because of their ability to fly in very low altitudes, but they can also be deployed quickly on demand because of their portability.

A similar suggestion was made after an experiment by Silvagni et al. (2016), where a UAS was used for the simulation of search and rescue missions with a focus on avalanches. Therefore, a conventional UAV with the capability of operating under challenging conditions (high altitudes, low temperatures, and strong winds) was attached with the relevant equipment, such as an avalanche beacon receiver, various (infrared) cameras, and an emergency kit.

Due to the fact that the survival probability in the event of an avalanche sinks to under 80% after only 10 minutes, it was also necessary to optimize all processes (flight planning, deployment, and flying the trajectory) to a minimum of time. The UAV then autonomously executed its mission with the aid of an automatic mission update and integrated terrain-following capability. The results showed that executing search and rescue missions with UAS is faster than conventional on-foot methods, which even intensifies when large areas need to be searched. Silvagni et al. (2016) additionally mention the advantage that, with this method, the hazards for rescue forces are reduced drastically, as they do not have to enter the affected area until victims are found. At the end, the study's author recommended including searches with UAS into the standard procedures and to carry a UAS standardly in such events (e.g., in skiing regions).

Another possibility for using UAS in the civil area was shown by Schober et al. (2017). In their study, the suitability of UAS for the inspection of infrastructure (e.g., highways, railways, and power lines) and protective structures against natural hazards (e.g., avalanche dams) was examined. The importance of being capable of properly inspecting such types of infrastructure is underlined by the fact that its failure would have catastrophic consequences for human safety. For the execution of the study, a conventional DJI Phantom equipped with a high-resolution camera was used for test flights at the Austrian Pass Lueg, which has a high density of critical infrastructure. As the results show, the orthophotos made with the help of UAS (see Figure 11) by far surpassed the ones made with conventional, manned high-altitude flights. They showed a high resolution as well as an excellent picture of the surface and the inspected infrastructure, which made it – in combination with 3D models – possible to detect rock-fall release areas in the designated territory. In addition to that, the inspection results were also validated by conventional inspection methods, which is another argument for the suitability of UAS. Schober et al. (2017) concluded their study by confirming that UAS are highly suitable for executing various inspection tasks and obtaining photogrammetric data, especially within inaccessible terrain.

Figure 11: High-resolution orthophoto based on UAS photogrammetry
(Schober et al., 2017, p. 4)

Stokkeland et al. (2015) made an approach on an even higher technical level by executing the inspection of wind turbines with a UAS in combination with an integrated optical tracking system following the wind blades. The results showed that the UAS was able to make a closer approach to the different components of the wind turbine. Thus, this method produced images of higher quality and with a higher degree of accuracy than conventionally obtained images. In addition, the inspection with UAS appeared to be more cost effective, a further argument for Stokkeland et al. (2015) to confirm their method's suitability at the end of their study.

Hunt et al. (2017) describes the application of a UAS for detecting and monitoring the propagation and damage on potato plants caused by the Colorado potato beetle at the Oregon State University. Within this study, a DJI S800 hexacopter was used in combination with a high-resolution camera to scan designated potato plantations from different altitudes in order to monitor the process of the potato beetle infestation and the resulting consequences for the plants. Finally, Hunt et al. (2017) suggests that aerial remote sensing proved to be a valuable and effective method – no matter if manned or unmanned. Nevertheless, the use of UAVs was shown to be advantageous due to the fact that they are not only able to produce high-resolution pictures from a lower altitude than manned aircraft, but they are also more cost and time effective, enabling the finding of beetle infestations already in the early stages. Further UAS applications in natural science and resource management are mentioned by Johnson et al. (2015). They state that UAS are also suitable for animal monitoring, habit assessment, polar monitoring, vegetation assessments, surface water quality monitoring, and weather monitoring. In addition, they also confirmed previously mentioned applications, such as the creation of terrain models, better responses to emergency situations (e.g., wildfire response), and infrastructure monitoring.

Ham et al. (2016) further describes UAS as useful platforms for the inspection of infrastructure and construction sites, as “these platforms can frequently survey construction sites, monitor work-in-progress, create documents for safety, and inspect existing structures, particularly for hard-to-reach areas.” According to Ham et al. (2016), UAS show various advantages in this field, including lower costs, faster execution of the inspections compared to conventional (manned) methods, as well as increased data visualization and post-processing.

As stated by Kleine Zeitung (2013), the suitability of UAS not only for tasks within the area of geosciences but also for infrastructure inspection, agricultural applications (e.g., winegrowing), as well as for search and rescue (e.g., in the event of the descent of an avalanche) is also suggested by the late Bruno Wiesler (former godfather of UAS programs at the department of Aviation at the Joanneum University of Applied Sciences) who furthermore states that UAS are especially suitable for applications in difficult terrain where (manned) helicopters are either too expensive or unsuitable.

Skryzipietz (2012) showed a structured summary of a variety of civil applications for UAS provided in Figure 12 (although there are numerous further applications).

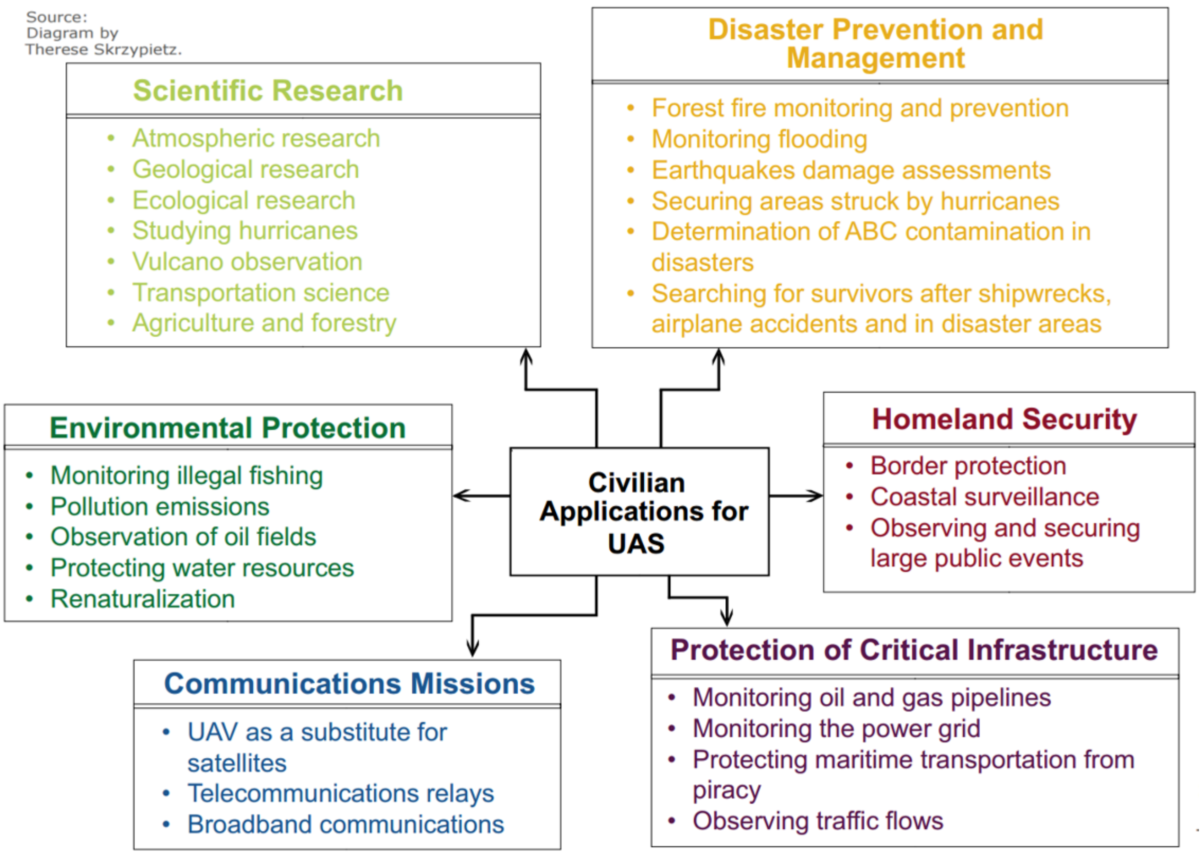

Figure 12: Different areas and actual examples for civil UAS application
(Skrzypietz, 2012, p.12)

3. Current Status of UAS Test Areas Worldwide

The following subchapters show the background and necessity of UAS testing, the approach to detect currently existing UAS test areas worldwide, as well as the most important test aspects for Austrian developers. At the end, a consolidated summary of 42 researched test areas in Europe, USA, Canada, Australia, Africa, and Asia is illustrated.

3.1. Background about UAS Testing

With the evolution of UAS the necessity of testing also emerged – a logical consequence, as new developments have to be tested before being put in service. Analogous to the history of UAS (see 2.3), the history of the respective testing also has a strong military origin.

- ***Military UAS testing for decades***

Due to the fact that the development and use of UAS for civil purposes began decades after military UAS programs, the respective tests were also executed (secretly) solely by military organizations as well as secret services for decades. Even if there is no public evidence, it can be assumed that test sites similar to present facilities (e.g., the New Mexico test site WSMR in the USA, the Denel Overberg Test Range in South Africa, or the Woomera Test Range in Australia as well as the famous Area 51) were already used and showed respective analogies. Similar test areas might also exist (among others) in Russia and China, although there is no valid public information about that.

As Garcia (2015) states, the first UAS tests took place during World War I, where "radio-controlled" UAS were developed and tested. As the war ended in 1918, before the completion of the respective development processes, these UAS could never be realized for actual use. As Garcia (2015) further mentions, the "technology rush" during World War II also led to further testing of UAS, where they were needed as aerial targets for the training of anti-aircraft crews (as also stated in 2.3). This thesis assumes that the invention of rockets by Wernher von Braun at the end of WWII is a separate issue, not directly connected to UAS.

The military testing and use of UAS also continued during the Vietnam War, after the United States launched the so-called "Red Wagon" program to develop and test modern UAS.

According to Garcia (2015), the military purpose and mission of UAS changed within the 1980s and 1990s from “target drones” to (ammunition-carrying) platforms for combat missions and/or reconnaissance, which led to different testing requirements and to new UAS programs, such the development of the Gnat 750 (later called Predator) in the mid-1990s (see 2.3.1), as well as the “Eagle Program” executed by the CIA in 2002. It also inspired feasibility studies for the use of UAS as unmanned combat air vehicles (UCAV) announced by France and the United Kingdom in 2014. Finally, Garcia (2015) suggests that, nowadays, at least 50 countries use UAS for military purposes, where many of them also have their own development and testing programs. As the research in the Project UAST (Fortner et al., 2017) showed, even civil UAS tests are often somehow connected to military organizations (e.g., due to the usage of military facilities and airspace or due test area operators that cooperate with the military).

- ***Beginnings of civil UAS testing at the end of the 1990s***

Civil UAS tests have grown enormously during the last decade (simultaneously with their actual civil use), as global companies such as Google, Amazon, and UPS invest a lot in their respective developments. But, comparable to the earlier military programs, these large companies today also operate with a significant amount of secrecy during their UAS tests, although they are definitely quite professional. Nevertheless, civil UAS developments and the respective testing originated from the development of model aircraft, as stated by Guillot (2016): “*Hobbyists have been strapping cameras to remote-controlled planes and helicopters since the 1980s, but [later] advances in processors and operating systems have made the flying machines less expensive and easier to operate [nowadays].”*

At the end of the 1990s, UAS tests slowly slid from the military domain via dual-use into the civil domain, a process preluded by events such as the first transatlantic flight by a Californian enterprise in 1998 with a UAS covering a distance of 3,200 km, as stated by Flight Global (1998). The flight, officially the first Atlantic crossing by an unmanned aircraft, was executed with a fixed-wing UAS (Aerosonde Mark I, see Figure 13) to *“test and demonstrate the viability of low-cost autonomous aircraft for long range, overwater weather reconnaissance.”* The fact that only one out of the three launched UAS reached its target furthermore supports the argument that UAS testing is not only absolutely necessary regarding safety, but it should also be executed within a safe environment.

Figure 13: The Aerosonde Mark I "Laima" used for the first Atlantic crossing with a UAS
(Flight Global, "First Atlantic crossing by an Unmanned Aircraft,"
http://www.barnardmicrosystems.com/UAV/milestones/atlantic_crossing_1.html)

Michel (2015) mentions that, in the same year, NASA (in cooperation with AeroVironment) also performed the first mostly civil UAS tests with the development of the "Pathfinder," which is a long-endurance, high-altitude UAS for research tasks and data collection in high areas of the atmosphere.

At the beginning of the second millennium, the first pure civil UAS tests were also conducted (e.g., by 3D Robotics), as stated by Guillot (2016). However, as there were no test areas available solely dedicated to civil purposes at that time, those tests were more than likely performed at military facilities, as mentioned in the last section.

Comparable to military programs, the secret testing of civil UAS (applications) is also a common practice, as shown by Shead (2016a), who reported that Amazon has been protecting its test area with a wall and security guards since the leak of its position. Many other civil UAS tests by other global companies are also known to be secret. Investigative media outlets have also looked into this issue, with some stating that the "email chain shows that Amazon has been testing drones in the UK for longer than initially thought" (Shead, 2016b).

- ***Dedicated civil UAS test areas***

Simultaneous to the establishment of first purely civil UAS test areas in the last decade, the mass production of UAS such as the "DJI Phantom" also became a reality, as Guillot (2016) further mentions. The high number of civil test areas available today further enables the (faster) development of pioneering technologies, such as the delivery of packages by UAS, as tested by Amazon in the United Kingdom (Shead, 2016).

All this is the result of the fact that, during the last decade, the subject of civil UAS development and testing has grown enormously, as did the civil UAS test sites, some of them even developing from purely military-oriented areas to mostly civil UAS test sites.

- Beyond some further US-American test areas (mostly connected to the military), in 2013, the Federal Aviation Administration (FAA) of the United States approved seven UAS test areas all over the USA.
- Also, numerous test areas have been established in Canada, Europe, Asia, and the rest of the world, including members of the International Consortium of Aeronautical Test Sites (ICATS), which is an association of seven test areas in the USA, Canada, France, Wales, and Spain (founded in 2014).
- Although most civil UAS testing is executed in civil areas, some of the presently existing test areas also use military facilities.
- As stated by the executive director of the ICATS, Marc Moffat (2015), the execution of UAS tests requires a safe environment, the eventual assistance of experienced UAS developers and operators, as well as close cooperation with the competent authorities. He further suggests that test areas should establish ideal test conditions and be geared to the development of new technologies.

The further history of civil UAS test areas is so heavily contemporary that it is already well documented in the overview of the 42 international UAS test areas presented in section 3.4 together with links to all necessary background information (especially regarding their founding years, which were all within the last decade, most of them within the last 5 years).

3.2. Worldwide Survey of existing UAS Test Areas

In order to gain information about currently existing UAS test areas and further detailed information about them (operator, airspace, infrastructure, etc.) extensive Internet research was performed during Project UAST, also supported by manifold contacts of AAI. The research process was split into two parts: After initial research in March 2017, which was foreseen to solely gather an overview about currently existent UAS test areas, a second stage of research necessary to get in-depth information about the test areas regarding certain selected aspects was performed later and updated in August 2017. The basic research included UAS test areas all over the world, but the most detailed results were achieved for test areas in Europe (22 test areas), followed by the USA (11 test areas) and Canada (two test areas). Nevertheless, test areas in Australia (two test areas), Africa (two test areas), and Asia (three test areas) were also found.

The in-depth research focused on gathering more details within three key focus areas (including desired individual aspects relevant for developers).

(1) Operator-related information

Within this area, the test areas' structure of operators and owners was researched. Seven different categories were found, where each test area could fit into multiple categories (governmental/regional involvement, university, other research facilities, manufacturers, association/cluster, solely test area operator, among others). Additionally, eventual military involvement as well as the use of (former) military airfields or airports was also examined.

(2) Airspace information

The spatial extension (lateral and vertical), the eventual separation of the test area into multiple subareas, the population density underneath the airspace, as well as vegetation and topography were examined. Furthermore, the important possibility of performing BVLOS tests inside the test area and the formal documentation of the airspace in the Aeronautical Information Publication (AIP) were assessed.

(3) Information about infrastructure and services

The accessibility of the test area (connection to roads, motorways, and airports), the infrastructure provided (offices, workshops, hangars, test-related infrastructure, communication, and others), and services by staff on site were researched. The terms of usage, the costs for the usage of the test area, and its infrastructure (if detectable) were also examined.

Finally, a thorough verification of the results followed. The examination of the UAS test areas found with AIP information from Google Maps made it possible to determine the exact location of the test areas and the resulting connection to roads, motorways, and airports. As a consequence, it was also possible to determine the population density in the vicinity of the test areas' launch area and airspace, as well as the topography and vegetation. Additionally, this method also made it possible to estimate if BVLOS test flights could really be performed within each test area if not stated decidedly. Also, a rough estimation of the present infrastructure on site (buildings, hangars, and runways) following the satellite images delivered by Google Maps could be made. This re-check confirmed the initial assumption that some test sites promise more features on their websites than they can deliver in reality.

3.3. Selected Aspects of existing UAS Test Areas

A short description of the relevant aspects of UAS test areas is given in the following subchapters. In addition to the work of Ureche (2016), who made a very mathematical approach by determining for the first time a suitable test area for the Schiebel CAMCOPTER® S-100 according to its possible technical performance (under supervision of Dipl.-Ing. Gerhard Lippitsch from Austro Control), this thesis also has a much broader perspective on the practical needs of the Austrian UAS stakeholders (researched during Project UAST by Fortner et al., 2017), as introduced in this chapter.

3.3.1. Airspace Extension and Population Density

In order to make the decision to perform UAS flight tests in a certain test area, the requirements for the airspace might be one of the most important aspects for developers, especially for testing large UAS. The driving attribute of the available airspace is its spatial extension. The more space available, the greater the number of different UAS applications that can be tested becomes. While a large horizontal extension (lateral) of the airspace is important for testing large UAS with a relatively long range and for having performing multiple tests in the same test area simultaneously, a large vertical extension (altitude) is important for testing specific applications, such as high altitude tests, surveys, specific cameras, laser scanning, or photogrammetry. The fact that the majority of Austrian UAS stakeholders are active within those competencies makes the requirement of a large spatial extension even more important.

Another important attribute of the airspace is its formal categorization. Due to the fact that the testing of UAS prototypes entails an increased risk of accidents, it is recommendable to establish the test area within segregated airspace, which would prevent regular air traffic from interfering with test flights and therefore also avoid unnecessary risks. A large number of researched test areas, moreover, arranged their airspace to be officially marked in the AIP charts, which is considered to be a further measure to mitigate the risk of accidents by making the test area as public as possible. The temporary reservation of airspace via notice to airmen (NOTAM) without being displayed in the AIP charts might lead to the intrusion of air traffic participants who failed to observe the respective NOTAMs prior to their flight, while a permanent entry of the airspace into the AIP charts might contribute to a general recognition of the segregated area and therefore to a reduced risk of unintentional intrusion.

Additionally, the population density in the area underneath the used airspace should be as low as possible in order to minimize possible restrictions. The testing of UAS should not lead to an increased potential of accidents for residents. Nevertheless, the test flights might lead to accidents, wherefore a low population density (or an even unpopulated area) is essential in order to not only eliminate the risks for humans but also to have as much freedom within the airspace as possible. Furthermore, data-security and privacy concerns might increase if the application of photogrammetry equipment is tested within a populated area. As already mentioned, the fact that the majority of Austrian UAS stakeholders are active within this area is a further argument why a sparsely populated or even unpopulated test area is recommendable in order to enable restriction-free testing.

3.3.2. Surface and Topography

Especially for UAS testing within the area of geosciences, the surface and topography of the test area ground is essential. The test area should therefore optimally contain diverse vegetation (woods and grasslands) and topography (both flat and hilly) in order to satisfy the needs of geoscientific UAS applications. In addition to that, agricultural fields are also useful for tests in the area of precision farming. Furthermore, also the possibility of tests above water could be an asset, which nevertheless runs the risk of losing a UAS in the event of a crash. As it can be expected that a UAS is already capable of basic flying before being tested in a test area, the focus of developers might go toward testing under rough meteorological and/or topographical conditions. Therefore, testing within mountainous or even alpine terrain might be an adequate solution.

3.3.3. Segmentation and Diversity of Subsites

The segmentation of the UAS test area into multiple subareas entails the important advantage that, with this method, many more different attributes regarding airspace, vegetation, topography, meteorological conditions (wind, etc.), population density, and others can be combined within one single administration, which furthermore reduces the necessary organizational effort for multiple tests. By locating the different subareas in a way that they enable as many different test scenarios as possible, a wide range of different requirements set by developers can be met. While multiple subareas naturally enable multiple simultaneous tests of different UAS, the separation in small and large test areas can additionally ease the access of developers of small UAS to the test area, as they can use the small test area and the necessary space without unnecessarily blocking large, unused airspace.

At last, the separation into multiple subareas also enables organizations to make individual offers to different UAS developers, as the costs for small subareas could be significantly lower than those for big subareas, which makes testing of small UAS more attractive without excluding large UAS. In total, this method allows the customization of tests according to the customers' technical or economic needs.

3.3.4. Accessibility and Geographical Position

For the operation of a UAS test area, it is essential to have low-threshold access for developers regarding the geographical accessibility. On the one hand, developers articulate the requirement of very diverse test areas (regarding vegetation and topography) with low population density, but, on the other hand, such areas are mostly located remotely from more highly populated areas and connection points, such as airports and railways. Additionally, the proximity of a motorway would also be preferable in order to enable easy access to the test area. Nevertheless, this would also lead to conflicts of UAS testing and the presence of humans as well as sensitive infrastructure, which could result in restrictions for tests.

Thus, a reasonable compromise between the proximity to connection points and an adequate distance to populated areas in order to safely execute tests must be found. An ideal solution seems to be a test area that is located, at most, a two-hour drive from an international airport (or a similar connection point) while not near an area with high population density but an adequate vegetation and topography. Additionally, an adequate size of available airspace must also be possible and therefore incorporated into this compromise.

3.3.5. Costs of Usage and Services

Naturally, the costs for performing UAS tests are also essential criteria for developers regarding the selection of a test area. As this research showed, there are different approaches of pricing UAS tests. While some UAS test areas solely charge for the actual testing (with fees per hour, half a day, or a full day), a minority of areas require a membership (and the resulting annual membership fee) in an association in order to be allowed to perform tests in the respective area (and may charge additional daily fees).

3.3.6. Civil and/or Military Infrastructure Background

As this research showed, a significant amount of currently existing UAS test areas developed from either (former) regional airports or with a military background, such as (former) military airports, military airspace, or weapons test ranges. This method, though, not only enables the renewal of inactive or poorly utilized facilities by making them available for UAS tests, but it also introduces a way to increase their economic performance. Furthermore, the utilization of such facilities shows several further advantages: As they have been already used for aviation before their utilization as UAS test areas, the necessary infrastructure in order to execute the flights and also the post-processing (runways, buildings for meetings, offices, hangars, workshops, etc.) is already present and most-likely shown to be functioning (and legally well established). Furthermore, the airspace most likely has the necessary attributes in order to safely perform UAS tests, as it is often already segregated from conventional air traffic (including some formal AIP entry).

Although there might still be other air traffic at regional airports if they are still active, military facilities have the further advantage that the airspace is exclusively reserved for military operations, which might occur less frequently and therefore offer more time for UAS tests. Additionally, most military airfields or similar facilities are located remotely from populated areas in order to achieve a certain level of secrecy. This furthermore enables not only the testing within sparsely populated or unpopulated areas but also an increased level of freedom for tests.

Nevertheless, the usage of both civil and military airfields also has potential disadvantages when they are still in use: While conventional air traffic might still occur at regional airports and therefore limit the availability for UAS tests, the same issue might be found at military airfields when they are used for the military’s own tests.

3.3.7. Capability and Permission for BVLOS Tests

The execution of BVLOS flights (and therefore also tests) will be the crucial driving aspect for UAS tests within the near future, which has also been confirmed by Austrian UAS stakeholders, who performed intensive research on this topic. Such flights nevertheless face the issue that BVLOS flights are currently not allowed by authorities neither in Austria nor in certain other countries, as this technology is still under review.

Therefore, BVLOS test flights need to be executed within segregated airspace, which should be possible in a UAS test area. This requirement also influences the necessary spatial extension as well as the categorization of the airspace, as the airspace on the one hand must either be large enough in order to lose visual contact or include mountainous terrain. That can also lead to loss of satellite links or BRLOS: Beyond Radio Line of Sight. On the other hand, the airspace needs to be categorized as segregated airspace in order to gain the authorization for BVLOS flight tests.

3.4. Consolidated Summary of 42 UAS Test Areas worldwide

The widespread research that was performed in order to detect the international test areas presented in this chapter was conducted as a part of the study of UAST at AAI (Fortner et al., 2017, see also 1.3). As a result, 42 international test areas as well as respective data valuable for developers are presented in this section. While some of the test areas provided a broad spectrum of relevant information, others only provided an insufficient amount of useful data (e.g., on their websites), which is nevertheless also attributable to the intentions of the respective test areas (either open for outer developers or focusing on internal research/tests).

The following (main) data sources were used to research the test areas and to obtain the data presented in the following table(s)

- The websites of the respective test sites
- A variety of Internet resources (background reports, news, official sources like FAA) for an intensive in-depth investigation about the background of every (!) test site
- Information from Austrian UAS Stakeholders (especially within the AAI-UAS-WG)
- AIP (especially section ENR 5 and 6) as well as ICAO charts
- Google Maps
- Experience reports by Austrian UAS stakeholders that already used that test site

Further details about the research and clustering of these 42 international UAS test sites are also presented in section 3.2, but the key information for "reading" the overview is as follows.

- European test sites (22) are marked in BLUE (four of them mainly military).
- US-test sites (11) are marked in RED (seven of them marked as FAA-approved and also including the specially marked "Pan-Pacific Test Range Cluster" with four sites).
- Canadian test sites (2) are marked in ORANGE (both civil).
- Australian test sites (2) are marked in GREEN (both military).
- African test sites (2) are marked in DARK YELLOW (one military).
- Asian test sites (3) are marked in YELLOW.

The key information about each test area is clustered in three groups:

(1) OPERATOR (background about founders and operators of the area)

(2) AIRSPACE (including lateral dimensions, altitude, BVLOS and AIP entry)

(3) INFRASTRUCTURE and SERVICES

Test area - ID TEST	01	02	03
Test area - COUNTRY (IOC) Test area - REGION	BEL (Belgium) Sint Truiden, Limburg	DEN (Denmark) Odense (Peninsula Funen west of Kopenhagen)	ESP (Spain) Catalonia (Barcelona)
Name (full) **Name (short)** **WEB (formal & background)**	**Droneport NV** **Droneport** www.droneport.eu/en/testsite https://en.wikipedia.org/wiki/Sint-Truiden_Air_Base	**UAS Test Center Denmark** www.uastestcenter.com/airspace/approved-airspace/technical-specifications https://de.wikipedia.org/wiki/Flughafen_Odense	**BCN Drone Test Center** www.barcelonadronecenter.com http://www.catuav.com
Year of establishment	2013	2015	2012
Operator	DronePort (City / Airport Sint Truiden)	UAS Test Center Denmark	CATUAV (private company by Jordi Santacana, earth observation with UAS)
Governmental / regional involvement	X (LRA - Limburg Regional Airport)	X (Hans Christian Anderson Airport, City of Odense)	
University		X (University of Southern Denmark)	
Research organization			
Manufacturer			X (CAT UAV)
Association / cluster / NPO		X (SDU UAS Center, UAS Test Center Denmark)	
Solely test area operator			X
Other:			
(Former) military facility (green) / or (former) civil airfield (blue) or hybrid/cooperation (green-blue)	Former military airfield of St. Truiden (until 1996)	Hans Christian Andersen Airport (EKOD)	
Airspace - LATERAL: Max. extension (in km²)	84 km² (largest subsite)	867 km² (3 subsites)	25 km²
Airspace - Segmentation into subsites?	5 subsites (some in development)	3 subsites (all capable of BVLOS)	1 site
Airspace - VERTICAL: Max. altitude / airspace category	150m (Area 2) / 2.000ft (Area 4)	1.066 m MSL	4.000ft (1219,2m) ASL (supposedly expendable)
Airspace - Population density on ground	Some villages, also reaches to St. Truiden	Numerous villages, partially over Odense, 50% over sea	Few villages, apart from that unpopulated pre-alpine upland
Airspace - Topography and vegetation on ground	Indoor / flat / agricultural test areas (agricultural fields)	Flat, urban and rural, sea	Hills, mountains, farmland, forests
Airspace - Over land / sea / both	Land	Land and sea	Land
Airspace - BVLOS possible? (if known)	BVLOS	BVLOS (over sea)	BVLOS
Airspace - Entry into AIP / other arrangements	**EB-R53 (Bevingen), R 61,62,63,64 (Sint-Truiden 1-4)**	**CTR Odense EKOD - EK-R OD 1,2,3**	**LE-TSA 31 (CTC-MOIÁ)**
Test area - Accessibility	1 hour by car from Brussels	17 minutes by car from Odense, 2 hours by car from Kopenhagen	1 h 15 min by car from Barcelona
Test area - Infrastructure / services	Area 1: Indoor test range, 3 offices, workshops, seminar room for 20 people, internet, WIFI, 4G, seperated zones optionally Area 2: Small outdoor, 4G, permanent contact with control tower, in AIP (350m x 130m) Area 3: Medium outdoor (under development!) Area 4: Large outdoor (12kmx7km) Area 5: Agriculture test area (under development!)	RWY: 2000x45m asphalt, airspace category G, data cloud for verification, 30 ground control points for precision verification, offices and conference facilities, hangar, repair facilities	RWY: Unpaved grass runway, helipad , outdoor surface for modifications, geodetic markers and ground control points, offices, UAV mechanics on site available, electronics workshop, remote sensing laboratory, conference room (60 people), UAV ground control center, hangar, meeting room, warehouse, UAV and payload rental, TCAS for UAV, spezialized library, kitchen, accommodation, consultancy, tracking, weather service, training
Test area - Terms of use		UAS below 25kg (Larger on application: < 150kg)	Availability: Day pass tickets Mo-Fr, 09:00 - 18:00 24 / 7 on request
Application fields	Research, product development, UAV pilot training, UAV applications for agriculture, sensor testing & calibration, hardware testing, non-certified equipment testing, indoor inspections & applications	BVLOS tests possible. Simple test flights, advanced testing of equipment, precision verification and calibration, UAS flight training	UAS testing, UAS training, UAS certification, consultancy, events

04	05	06	07
ESP (Spain) Villacarrillo, south of Spain	**FIN (Finland)** Southern Finnland	**FIN (Finland)** Northern Finland (Lapland)	**FRA (France)** Southwest of France (Region around Bordeaux)
Atlas Center **ATLAS** http://atlascenter.aero/en http://www.catec.aero/en/management/fada.htm https://www.youtube.com/watch?v=fYUMEKX15UI	**Finland UAS Centre** http://uasfinland.eu/eng/services.html https://www.facebook.com/UAS-Centre-Finland-1375580122457713/ https://en.wikipedia.org/wiki/Mikkeli_Airport http://kiikalasaatio.com/	**Robonic Arctic Test UAV Flight Center (Military)** **RATUFC** http://www.robonic.fi/ratufc-introduction/ https://en.wikipedia.org/wiki/Kemij%C3%A4rvi_Airfield	**Cesa Drones** **CESA** cesadrones.com/en/editos/6-cesa-drones/
2014	2016	2006	2010 / 2011
FADA (Andalusian Foundation for Aerospace Development)	Operated by Future Sky Oy	Robonic (Manufacturer of UAS launch systems, SAFRAN-Subsidiary)	Cesa Drones (independent test centre)
X (IDEA - Andalusian Innovation and Development Agency)			X (Cluster Bordeaux Technowest)
X (INTA - National Institute of Aerospace Technoloy)			
X (CATEC, Airbus, etc.)		X (ROBONIC)	X (Aeronefs Services)
X (AICA - Andalusian Association of Research and Industrial Cooperation)			
	X		
	Mikkeli City Airport (EFMI) Salo-Kiikala Airfield (EFIK) - Information solely in Finnisch!	Airfield Kemikärvi (EFKM) Actually military airspace (shooting range)	Military base Souge (main site) - 28 km² Airfield Biscarosse / LFBS Airfield Montalivet / LFIV - 50km coastal strip (Atlantic) Dax Heliport Sainte-Helene - 0,15km²
1.000 km²	Temporary reservable	Up to 11.000 km²	> 28km²
1 site		No	5 subsites
5.000ft	Temporary reservable	G (FL95, <3.000m), C	Depending on the respective site (150m, 1.000ft, 2.000ft, 3.000ft)
Very low population, close to desert	Very low in western direction	0	No population within the main test area
Farmland, mountains, desert	Flat, forests, lakes	Flat, forests, farmland	Flat, farmland, grassland, coastal strip
Land	Land	Land	Land and sea
BVLOS?			BVLOS
LE-TSA 30 (ATLAS)	**CTR EF-MI (Mikkeli)**	**EF-R 92 A,B,C,D,E (ROVAJÄRVI)**	**LF-R 247 A,B (Camp de Souge)**
2 hours by car from Grenada / Cordoba, 4 hours by car from Madrid	2,5 hours by car from Helsinki	1 hour by car from Kuusamo Airport	At to Bordeaux Airport (administration), others 0,5-2 hours by car
RWY: 600x18m asphalt, 400x10m grass, offices, meeting rooms, security and surveillance systems, 2 hangars of 300m² each, maintenance and repair garages, techn. & logistics support. Electrical installations and network connectivity in the hangars. UAVs for testing available. Aeronautical radio, met station, staff for maintenance on site, security, coordination of flight ops.	Services: Airspace reservation (at Mikkeli City Airport: EFMI, Salo-Kiikala Airfield: EFIK, other areas upon request), consulting, staff providing expertise, assistance in flight planning, risk assessment, operational audit, technical evaluation, CAA manuals and documentation, drone log books, UAV for equipment testing on site	RWY: Catapult and asphalt (1400x23m). Planning of permits and reservations. Ground facilities will be arranged temporarily according to customer, logistics support (accomodation, vehicle)	RWY: 800m paved. Certification support, creation of map file, indoor and outdoor test zones, adobtable environment: Creation of thematic test zones (mountains, marine, search and rescue..), meeting room, weather station, air to ground radio, GPS, real-time vector monitoring, range-finding and camera, surveillance during flight, 3D Plot of Path
			Trainings on fixed dates / Details depending on subsite (Access to military sites restricted)
Light and tactical UAV operations, validation of navigation techniques, testing, certifications, qualification of pilots, operators and MRO mechanics, simulations, implementation of UAS in management of natural disasters, fires, environmental accidents, surveillance, meteorology, agriculture, forestry, photography, security and defense.	Instrument testing, remote sensing, training, UAS courses	UAS development, testing and evaluation, operational training (especially for fixed-wing UAS with catapult start)	Flight testing, qualification, training, certification

08	09	10	11
FRA (France) Bretigny (30km south of Paris, Departement Essonne)	**FRA (France)** Pourrières (Provence, east of Marseille)	**FRA (France)** Southwest from Toulouse	**FRA (France)** Esperce (South from Toulouse)
Drones-Center www.drones-center.com/infos-pratiques/plan-dacces/ http://www.coeuressonne.fr/grands-projets/la-base.html https://fr.wikipedia.org/wiki/Base_a%C3%A9rienne_217_Br%C3%A9tigny-sur-Orge	**Centre d'Etudes et d'Essais pour Modèles Autonomes** **CEEMA** http://s434494529.siteweb-initial.fr/ https://fr-fr.facebook.com/drone.ceema.fr/ http://www.ceema.fr http://www.filieredrone.com/strategies/article/ceema	**Toulouse Francazal** https://dronesintoulouse.com/ https://www.robotics-place.com http://www.airborne-concept.com/ https://de.wikipedia.org/wiki/Flughafen_Toulouse-Francazal	**Terrain d'essai en vol de drones de l'ONERA** Esperce, 31190 AUTERIVE GPS: 43.315333, 1.404445
2014 / 2016	2008	Under development	
Cluster Drones Paris Région (Association *2016)	Technopôle CEEMA (Private initiative Mustafa Kasbari) (also manufacture drones themselves)		Research facility ONERA (Office National d'Etudes et Recherches Aérospatiales)
X (Association "Coeur d'Essonne Agglomération")		X	
		X (University network "Micro Drones" - MAV Research Center)	
			X (ONERA)
	X (ATECHSYS *2007, partially informal, see http://atechsys.fr)	X (Airborne Concept)	
X (Cluster Drones Paris)		X (Cluster Robotics Place)	
Former (military) Base Arienne 217 (until 2012)		Former (military) Base Arienne 101 (until 2009, especially for flight tests of DGA)	
3 km²	0,85 km²		3,14km² - 1km radius (Center: 43°18'58"N,001°24'13"E on RWY)
1 site	1 site		1 site (altitude expendable)
150m (Airspace theoretically up to 1.500ft)	2.500ft		500ft / additionally 1.000 ft via NOTAM
Sparsely populated (former military Airspace) but diverse plans for fitout on ground https://www.youtube.com/watch?v=X1JXUkf9-fU	Barely populated, solely test center/companies		sparsely populated, 1 small village
Farmland, grassland	Forest, partially farmland		Forest, farmland, some farms
Land	Land (with 4.000m^2 basin)	Land	Land
LF-R 113 A, B, C (Bretigny)	**LF-R 1250 (Pourrieres) - SouthWest part of LF-D 155**		**LF-R 62 (ESPERCE) A (500ft), B (1.000ft)**
0,5 - 1 hour by car from Paris / connection to RER-C	45 by car from Marseille Airport	15 minutes by car from Toulouse-Blagnac International Airport	40 minutes by car from Toulouse-Blagnac International Airport
Currently 200 m² office space, education facilities and instructors, lobby, working space, workshops, data evaluation after flight, offered courses, 500m² closed hangar, also suitable for indoor flights (8m² ceiling height, volume of 4000m³) for pilot training indoor, structural testing. New buildings starting 2018. 2 different airspaces up to 150m AGL (with DGAC). Testing cameras & UAS for education rentable. Consulting with technical /operational expertise	RWY (300m x 20m - including 200m asphalt), workshops, restaurant and 22 beds http://www.filieredrone.com/IMG/pdf/plaquetteceema_bd.pdf furthermore 4.000m^2 basin for underwater drones All around visual cover due to forest	Probably use of existent military infrastructure (hangars etc.) and existent concrete RWY (1.800m)	Hangar and grass RWY
Supposedly also open for externals			Airspace: MO-FR 0700 - 1900
Education according to DGAC, trainings, especially for Scenario 2 (BVLOS in the vicinity of 1000m unpopulated) as well as Scenario 3 (populated in the vicinity of 100m) and Scenario 4 (unpopulated in the vicinity of more than 1000m). Specialization on photogrammetry, photography, videography, thermography, inspection flights, UTM, counter-UAS	UAS-Tests below150kg (short and also long tests), events (also international), conferences, demonstrations, trainings, according to the first impression rather for small drones and model builders ("Modèles Autonomes")	Currently especially trainings and demonstrations offered publicly, rest in development. Planned prospectively: Research- and test center for "intelligent transport technology" with robotics and drones	General test area of ONERA for manned- and unmanned research tests

12	13	14	15
GBR (Great Britain) Wales	GER (Germany) Bavaria (Oberpfaffenhofen)	GER (Germany) Lower Saxony (Wesendorf, north of Braunschweig)	GER (Germany) Wümme (Bremen)
Wales UAS Environment **WUASE** www.wuase.com www.flyuav.co.uk www.nationalaeronauticalcentre.co.uk https://en.wikipedia.org/wiki/ParcAberporth	**Deutsches Erprobungsgelände UAS** **DEU** www.bavairia.net/themenbereiche/luftfahrt/deu-uas/ http://www.edmo-airport.de/de/informationen-fur-die-nachbarn http://edmo-airport.de/sites/default/files/1-851-16.pdf	**UAS Testzentrum Nord** http://copting.de/flugschulungen-und-seminare/fluggelaende-schulungszentren-und-testareale/flug-schulungs-und-testgelaende/ http://uas-testzentrum.de/	**Bundesverband für unbemannte Systeme** **BUVUS** http://buvus.de/verbandsarbeit/forschungsstuetzpunkte/ https://de.wikipedia.org/wiki/Flugplatz_Rotenburg_(Wümme)
2013	2015	2015 (in development)	2016 (in development)
Qinetic www.qinetic.com	bavAIRia Grob Aircraft (until 2017) Special Airport Oberpfaffenhofen (from 2017): EDMO GmbH	Copting GmbH (Braunschweig)	BUVUS (Bundesverband für unbemannte Systeme)
			X (Regional airport and City of Rotenburg)
			X (Northern Business School, Hamburg)
X	X (Grob in Mattsies)	X (Copting GmbH)	
	X (BavAIRia)		X (BUVUS)
	X (Airfield EDMO, before Airbus, now privately owned)		
Former military airbase Park Aberporth Now Aberporth Airport / West Wales Airport (EG-FA)	Special Airport Oberpfaffenhofen (ED-MO) https://de.wikipedia.org/wiki/Flugplatz_Oberpfaffenhofen (earlier Special Airfield Mattsies of Grob, ED-MN) https://de.wikipedia.org/wiki/Flugplatz_Mindelheim-Mattsies	Former military test area (Hammerstein casern) until 2006	Airfield Rotenburg a.d. Wümme (ED-XQ) (former military airfield)
8.600 km² (1.500 over land, 7.100 over sea)	Currently approximately 400m x 300m on the airport area , approximately 2km x 300m planned prospectively		Permanent approval currently in negotiation, individual until today
6 connected airspaces			
Over land: FL 125 / FL 225 (6.858 m) Over sea: Unlimited	officially max. 50m theoretically (AIP, individual clearance) max. 3.500ft (600m) MSL		
Low population density, some villages	low to partially medium population, motorway adjacent	Federal highway adjacent, but former-military test area, no population	Sparsely populated in northern direction, but motorway 8km northwestern City of Rotenburg southeastern
Flat, farmland, grassland, sea	Flat, grassland, farmland, forests	Flat, grassland, forests, industry park (Hammerstein park)	Farmland, grassland, forests
Land and sea	Land	Land	Land
EG-D 201E, 202, 202A/B/C (Land) - 201,201A/B/C/D/F	**CTR Airfield Oberpfaffenhofen (ED-MO)**	**Flight over closed ground (former TÜPL)**	**Airfield Rotenburg a.d. Wümme (ED-XQ)**
2 hours by car from Cardiff	30 minutes by car from Munich	1 hour by car from Hannover	45 minutes by car from Bremen
RWY: Multiple tarmac and grass runways (longest: 2286m), hangar, operating rooms, ATC management system, conference and office facilities, 24/7 CCTV, refuelling capabilities, fibre optic network. Technical support, pilots and maintenance staff available, data link testing facilities, tracking instruments for performance tests.	For now small meadow beneath RWY (for starting / landing), fitout planned for the future and possible, otherwise entire infrastructure of a small airport (hangars, facilities, services, workshops etc.)	Meeting rooms, closed storage rooms, electric supply, security, offices, catering. Execution of tests by test area if desired, and / or subject-specific expertise für technics, rapairs, tests	RWY: Asphalt (800m), grass (1.200m)
	Mo-Fr, 07:00-19:00, Exceptions to be negotiated with tower Radiotelephony briefing required		
BVLOS tests possible, UAS research and development, test and evaluation of small and large UAVs, trainings	Tests of new concepts concerning aircraft, sensor technology, integral system incl. GCS (VLOS only, max. 25kg MTOM)	Tests, training, demonstrations	Civil research

16	17	18	19
ITA (Italy) Apulia (Airport Tarent-Grottaglie), South Italy	**NED (Netherlands)** NRTC: Marknesse (Flevoland) Space53: Enschede Airport Twente	**NOR (Norway)** Tromsø, Målselv/Bardu und Ny-Ålesund, Spitzbergen	**NOR (Norway)** Island of Andoya (northern Norway)
Grottaglie Airport Test Bed https://www.flightglobal.com/news/articles/uav-test-range-established-at-taranto-grottaglie-airport-412846/ http://www.takeoff-grottaglie.it/indexENG.html https://de.wikipedia.org/wiki/Flughafen_Tarent-Grottaglie	**Netherlands RPAS Test Centre** **NRTC** www.nlr.org/capabilities/netherlands-rpas-test-centre/ http://www.space53.eu/ http://www.nlr.nl/dronecentre/ http://twentedronetest.com/	**Arctic Centre for Unmanned Aircraft** **ASUF** www.unmannedsystemstechnology.com/2015/04/norway-opens-arctic-centre-unmanned-aircraft/ www.asuf.no/english	**Andoya Test Center (Military)** http://testcenter.no/
2015	Under development since 2010, supposedly more test areas planned	2015	1962
Airport Tarent-Grottaglie (LIBG) - Aeroporti di Puglia (AdP)	Netherlands Aerospace Center (NLR)	ASUF (Partnership between the Northern Research Institute, the Arctic University of Norway and Lufttransport)	Norwegian Space Center Ministry of Trade Kongsberg Defence Systems
X (Regional airport)			X (Ministry of Trade)
		X (UiT - Arctic University of Norway)	
	X (NLR)	X (Norut - Northern Research Institute)	
X (Leonardo?)	X (Space53)		X (Kongsberg Defence Systems)
X (DTA - Distretto Tecnologico Aerospaziale)			
		X (Lufttransport)	
Former military airfield, until today naval airbase Since 1954 simultaneous civil usage meanwhile also airport for delivery of Leonardo commercial operation apparently weak	Currently tests at Enschede Airport Twente (EHTW, former military) Earlier tests at Den Helder Airport (De Kooy Airfield) - partially military		Military Airbase Andoya (EN-AN)
370km² - 70 / 100 (transfer corridor) / 200 (over sea, 6x35km)			
3 sites (the third one solely over sea), additional sites planned over sea		3 sites	
5.000ft AGL/ASL			partially unlimited
Sparsely populated over land (except for small villages and industrial parks) No population over sea		Almost no population, in Svalbard purely arctic	Sparsely populated, remotely located at the coast of Andoya, north of the Arctic Circle
Farmland, sea			
Land und sea		Land and sea	Land and sea
BVLOS supposedly over sea			
CTR LIBG, LI-R315 (land), R316 (corrid.), R317 (sea)	**ATZ TWENTE, supposedly temp. Restrictions near Marknesse**		**EN-D472...474, a dozen further D-areas around EN-AN**
40 minutes by car from Brindisi International Airport	1 - 2 hours by car from Amsterdam		
RWY: 3200x45m asphalt. Hangars, offices, fuelling, weather forecast, indoor areas for production activities	Maintenance and modification support, as well as support for design and certification process, datalink equipment. Intruder aircraft for sense-and-avoid testing Twente: Airport-Infrastructure (Runway etc.), also Indoor-Testing Marknesse: More Training / Education, no own airspace in AIP	Education and training services, operational services, operation in arctic conditions	Telemetry systems Radar and optical tracking systems Flight termination systems Trials Control System Marine surveillance Secure voice communication systems Instrumentation mobile for flexibility and coverage
			Around the clock daylight-operation Airspace activation 30 minutes notice via NOTAM
Mixed operatoin (military-civil, manned-unmanned), also for the local aviation industry (earlier Alenia, now Leonardo) Big plans for extension (to 100.000 km² airspace over sea) Few valid internet information, but already SESAR-projects	Test flights, sensor and application testing and / or evaluation, flight examinations, pilot training, certification tests Not much Web-information in English, seems to develop between Marknesse and Twente www.nlr.org/news/nlr-tests-large-drone-at-twente-airport	Targets: unmanned aircraft for emergency preparedness, environmental monitoring, technology development in the arctic. Tests of materials for use in cold and extreme climates. Education, training	Aircraft system testing and drop tests Tests of missile systems from ship and more Tests of boosters and rocket motors Test of missile seekers UAV/RPAS testing and operational training GBAD test and operational training

20	21	22	23
SUI (Switzerland) Thun	**SWE (Sweden)** 900km north of Stockholm	**SWE (Sweden)** Karlskoga (Central Sweden)	**USA** Grand Forks (North Dakota, ND)
Test area of the Swiss Army (Military) **Thun** http://www.birdviewpicture.ch/im-einsatz-fuer-das-schweizerische-militaer/ http://www.vtg.admin.ch/de/die-schweizer-armee/waffen-schiessplaetze/wplthun.html	**Vidsel Test Range (Military)** http://www.fmv.se/Global/Dokument/Verksamhet/Test%20och%20Evaluering/facts_about_vidsel.pdf viseltestrange.com https://en.wikipedia.org/wiki/Vidsel_Test_Range	**BOFORS Test Center (Military)** www.testcenter.se/services/testing/uas-testing/	**Northern Plains Unmanned Aircraft Systems Test Site** **NPUASTS** http://www.npuasts.com/
	1958	1999	2014
Swiss Army - Military Training Area Thun	Swedish Defense Material Administration	BOFORS (private company, once owned by Alfred Nobel) now attached with BAE Systems AB & Saab AB	Northern Plains Unmanned Systems Authority (University of Dakota, ND Aeronautics commission, ND Dept. of commerce, ND aviation council, State office of the adjutant general, ND State University
X (Swiss Army)	X (Schwedish Armed Forces)		X (ND Department of Commerce, ND Aeronautics Commission)
			X (University of North Dakota, North Dakota State University)
		X (https://en.wikipedia.org/wiki/Bofors)	
			FAA: www.faa.gov/uas/research/test_sites
Military Training Area Thun (located at Airfield Thun: LS-ZW)	Vidsel Air Base (ES-PE) https://en.wikipedia.org/wiki/Vidsel_Air_Base	Aside of Villingsberg (Swedish Armed Forces P4 shooting range)	"Low-use airports" like https://en.wikipedia.org/wiki/Hillsboro_Airport https://en.wikipedia.org/wiki/Carrington_Municipal_Airport https://www.airnav.com/airport/5L0
	24.000 km² or 7.200 km² according to homepage	200 km²	
	Numerous beneath R02?		Several UAS test ranges via COAs with NOTAMs
Theoretically up to 5.000ft AMSL (1.500m)	Unlimited	32.000 ft (10km) AMSL	200, 400, 1.200, 3.000, 10.000 ft
Sparsely populated, but military use is established	Entirely unpopulated	City of Karlskoga in the west, otherwise unpopulated	
		Forests, lakes	Mostly rural, urban
Land	Land	Land, small lakes	
			BVLOS
LS-D18 (THUN)	**ES-R02 (VIDSEL) in the core, partially more (ES-R01 etc.)**	**ES-R18 (BOFORS, VILLINGSBERG)**	**COA (Certificate of Waiver or Authorization)**
20 minutes by car from Bern		30 minutes by car from Örebro	
Grass RWY, military facilities (buildings etc.)	RWY: 2km (asphalt), hangars, buildings for technical purposes.	Workshops, jet wind tunnel, test laboratory, optical tracking system, telemetry, helicopter service for surveillance, tracking and transport, accommodation. Aside Karlskoga Airport (ES-KK) Support with permits & approvals "2.000km^3 of aerial freedom for your UAS"	Hard surface RWYs, variety of UAS available, mobile operations trailers, 2D radar & support vehicle, cooperative airspace ground sensor networks, business & lab facilities, airspace visualization tools, manned & unmanned simulators, staff on site. Services: Support with airworthiness certification
			Day / Night operations 24 hour NOTAM equirement Safety review, flight readiness review, pre-flight check before testing
According to AIP further (military) UAS tests in Switzerland at: - BIERE (AIP: LS-R19): www.vtg.admin.ch/de/die-schweizer-armee/waffen-schiessplaetze/waffenplatz-biere.html - EMMEN OST (AIP: LS-R31, military airfield LSME, also RUAG)	In the UAS branch: EW environment Sensor tests Training Weaponization	Small and medium UAS. Demonstrations, tests and trainings for both qualified and unqualified systems. Core business: Testing of weapons and ammunition	UAS research, airworthiness certification http://www.kfyrtv.com/content/news/FAA-authorizes-Northern-Plains-UAS-Test-Site-to-oversee-unmanned-aircraft-408528275.html

24	25	26	27
USA Fairbanks (Alaska, AK)	**USA** Tillamook (Oregon, OR) Northwest-USA directly at the Pacific coast	**USA** Warm Springs (Oregon, OR) Northwest-USA	**USA** Pendleton (Oregon, OR) Northwest-USA
Pan-Pacific UAS Test Range Complex (PPUTRC) - Lead by the University of Alaska - Still growing with further partners like Hawaii, Mississippi, see: http://acuasi.alaska.edu/pputrc			
Alaska Center for Unmanned Aircraft Systems Integration **ACUASI** http://www.acuasi.alaska.edu/	**Tillamook Test Range** http://uastestranges.soaroregon.com https://www.facebook.com/SOAROregon http://tillamookuas.com	**Warm Springs Test Range** **WSUAS** http://uastestranges.soaroregon.com https://www.facebook.com/SOAROregon http://wsuas.com https://www.facebook.com/wsuas/	**Pendleton Test Range** **PUR** http://uastestranges.soaroregon.com https://www.facebook.com/SOAROregon www.pendletonuas.com https://www.facebook.com/PendletonUASRange/
2012	2013	2013	2013
University of Alaska Fairbanks (UAF)	SOAR Oregon (non-profit organization) Johnson Near Space Center (NSC) (provider of flight services)	SOAR Oregon (non-profit organisation) http://www.procopio.com/posts/view/building-a-tribal-economy-from-thin-air-space	SOAR Oregon (non-profit organization)
X (University of Alaska)			
	X (SOAR)	X (SOAR)	X (SOAR)
FAA: www.faa.gov/uas/research/test_sites		X (Indian tribes with sovereign territory)	
	Tillamook airport / Former naval air base (KTMK) https://en.wikipedia.org/wiki/Tillamook_Airport	Madras Municipal Airport https://en.wikipedia.org/wiki/Madras_Municipal_Airport Prineville Airport https://en.wikipedia.org/wiki/Prineville_Airport	Pendleton Airport (KPDT) - Simultaneously base of the national guard https://en.wikipedia.org/wiki/Eastern_Oregon_Regional_Airport https://oregonencyclopedia.org/articles/pendleton_field/
	83.000 km²	2.600 km²	36.000 km²
		4	
	A, D, E, G, up to 130.000 ft MSL	E, G, up to 17.999 ft MSL	D
	Sparsely populated, mostly unpopulated (Northern US Pacific coast)	Sparsely populated, mostly unpopulated (mostly Native American reservation)	Sparsely populated out of Portland
	Maritime, coastal, forests, mountains, urban, rural	1.000 ft - 10.500 ft MSL Forest, high desert, mountains (> 3.000m), canyon	Farmland, forest, large riverways
	Land and sea	Land	Land
	BVLOS	BVLOS?	BVLOS?
COA (Certificate of Waiver or Authorization)	**CTR KTMK, airspace W570 (ocean), high altitude COA**		**CTR KPDT, NOTAMS, R-5701 ? (BOARDMAN)**
	2 hours by car western of Portland, Oregon	2 hours by car southeastern of Portland, Oregon	3 hours by car eastern of Portland, Oregon
	2 asphalt RWYs (one 1.500m with GPS approach) supporting night operations, hangar supporting payload integration, assembly and preflight preparation, avionics laboratory, UAS control tower, fiber internet, test benches, altitude chamber, storage rooms, classrooms, conference centers. Support for mission planning, safety-/flight readiness reviews, expert staff on site, Range communication, video feeds, radar, sodar, ADS-B, tracking, weather service	2 RWYs with night use, hangars, maintenance facilities, work stations available, power lines, mobile command center, high speed WiFi, secured storage facilities, office, training center with training rooms and class rooms, catering service, conference center, accommodations, full-time staff on site, weather service	3 RWYs, 1 RWY exclusively dedicated to UAS. Storage facilities, control tower, UAS workspaces, mobile operation center, electric supply, water, darkwire hardline access. Training classrooms, conference center, personnel on site. Chase aircraft available, repair stations, accommodations.
		Year-round flying: "The tribe was awarded the right by the Federal Aviation Administration to certify drone operators" https://en.wikipedia.org/wiki/Warm_Springs_Indian_Reservation	
Research, development, testing, integration of payloads, pathfinder missions, special emphasis on the arctic regions	High altitude testing, humid, wet conditions, BVLOS tests, disaster preparedness, training, search & rescue, technology development, infrastructure inspection, law enforcement	Controlled air and land testing. Target applications: Transmission line and linear infrastructure inspection, natural resource conservation, wildland firefighting https://wsuas.com/2017/06/warm-springs-test-range-expands-operations/	Certification, sensor testing, see and avoid. Procedures development, engineering, integration, modeling, simulation. Infrastructure Testing

28	29	30	31
USA Community of California (Maryland, MD) US eastern coast near Washington D.C. / Chesapeake Bay	**USA** Las Vegas or Reno (Nevada, NV)	**USA** Las Cruces (New Mexiko, NM) Southern USA at the Mexican border	**USA** Griffiss Int. Airport, Rome (State of New York, NY) Northeast-USA
University of Maryland UAS Test Site **UMD UAS Test Site** http://www.uas-test.umd.edu/ http://es.vccs.edu/wp-content/uploads/2014/10/ESCC-UAS-Tech-Interchange-UMD-02oct14.pdf http://www.uasmagazine.com/articles/863/university-of-maryland-uas-test-site-receives-first-coa	**Nevada Institute for Autonomous Systems** **NIAS** http://nias-uas.com/about/ https://www.nasa.gov/feature/ames/nasa-plans-first-beyond-visual-line-of-sight-drone-demonstration-in-nevada	**New Mexico State University UAS Test Site** **NMSU UAS Test Site** https://uastestsite.psl.nmsu.edu/ psl.nmsu.edu/The%20UAS%20Flight%20Test%20Center	**New York UAS Test Site** **NUAIR** http://nuairalliance.org/capabilities/ https://www.facebook.com/NUAIRAlliance http://www.govtech.com/dc/articles/New-Yorks-Griffiss-International-Airport-to-Serve-as-New-Drone-Testing-Corridor.html
2013	2013	2007	
University of Maryland (UMD)	State of Nevada (Office of Economic Development)	New Mexico State University (NMSU) Physical Science Laboratory (PSL) - Flight Test Center (FTC)	NUAIR Alliance Northeast UAS Airspace Integration Research Alliance (non profit organization/cooperation with 50-150 partners)
	X (State of Nevada)		X (Massachusetts DOT, Griffiss Airport, CenterState CEO, ...)
X (UMD)		X (NMSU)	X (Univ. from Massachusetts, Syracuse, Clarkson, Northeastern,...)
			X (RIT, MIT, ...)
			X (Raytheon, Lockheed Martin, Saab, ...)
			X (NUAIR)
X (Cooperation with U.S. Navy - Special Use Airspace, SUA)	NASA & FAA: www.faa.gov/uas/research/test_sites	DoD & FAA: www.faa.gov/uas/research/test_sites	NASA & FAA: www.faa.gov/uas/research/test_sites
St. Mary's County Regional Airport / near Naval Air Station (KNHK) Crisfield-Somerset Airport Webster Field Wallops Island Field	Henderson Unmanned Vehicle Range / Mesquite UAS Test Range Desert Rock Airport (part of Nevada Test Site), Mercury https://en.wikipedia.org/wiki/Desert_Rock_Airport Reno Stead Airport (NASA Tests) https://en.wikipedia.org/wiki/Reno_Stead_Airport	Las Cruces International Airport (KLRU) and further https://en.wikipedia.org/wiki/Las_Cruces_International_Airport Partner: Holloman Air Force Base (KHMN), White Sands (WSMR) https://en.wikipedia.org/wiki/Holloman_Air_Force_Base https://en.wikipedia.org/wiki/White_Sands_Missile_Range	New York Griffiss International Airport (KRME) (former Air Force Base) https://en.wikipedia.org/wiki/Griffiss_International_Airport
http://www.globalsecurity.org/military/facility/moa-pax.htm		15.000 Square Miles / ~ 39.000 km²	7.000 square miles (18.000 km²)
Yes			Test ranges in New York (state), Michigan and Massachusetts
FL 200, < 250	1.200 ft AGL (Airspace Class G according to COA)	18.000 ft AMSL	FL 250 (FL 750 upon request)
Sparsely populated, some villages in the southeast		Sparsely populated, partially closed area (WSMR) owned by US government including former nuclear test area (Trinity)	Very sparsely populated in the north und in the east, cities in the west and southeast
Forests, grassland			Forests (especially in the north) and grassland, farmland, lakes
Land and sea			
	BVLOS	BVLOS (eventually with manned control plane to fly alongside UAS)	
R-4002, 4005, 4006, 4007, 6609 (partially military), COA	**COA (Class G), "corridor" in development (with FAA)**	**COA, tw. R-5103, R-5107 (certain segmentation, MOA)**	**CTR, COA (next: corridor), near MOAs (Fort Drum)**
1,5 hours by car from Washington D.C.			Located at the Griffis Airport, 45 minutes by car from Syracus Int. Airport
Services: Education opportunities, expertise concerning airspace integration, airworthiness, command and control, propulsion, control stations, sensors etc.	Services: Teaching and mentoring on executions of UAS techniques, methods and risk-management processes. Assistance in FAA aircraft registration and crew certification, mission planning, consultation, training, airspace management, traffic management systems	3 RWYs @ Las Cruces International Airport (1,8 - 2,2km). Trained staff (aircrew, engineers and technicians) on site. Hangar available, office facilities, technical support. Also: UAS propulsion test facility.	1 RWY (3,6km). Various facilities and technologies, staff on site. Ground-based sense-and-avoid system. Hangar available
"An airworthiness evaluation is required for all operations conducted by UAS Test Site pilots."		"The time from initial inquiry to first flight can be a matter of weeks." "operate any UAV with 48 hours notice"	
Airspace integration, counter UAS, disaster response, data & airworthiness validation, forestry & agriculture, health & safety "operations beyond those allowed under Part 107"	Testing and training. Targeted industries: Package delivery, urban environments, counter UAS, agriculture, wildlife management, infrastructure, real estate, inspection of powerlines etc. https://www.nasa.gov/aero/nasa-drone-traffic-management-tests-take-off-in-reno	Flight tests, certification http://www.new-mexico-space-industry.com/html/uav_center_of_excellence_progr.html	Testing UAS from small cetegory to full scale fixed wing aircraft. Test focus on sensors for scouting of agricultural fields, forestry, wildlife, power line inspection. NASA tests with multiple USA https://www.youtube.com/watch?v=ss8h11xVLcM

32	33	34	35
USA Corpus Christi (Texas, TX) South-USA, Corpus Christi Bay / Gulf of Mexico	**USA** Blacksburg (Virginia, VA) East-USA	**Canada** Foremost (Alberta, AB) Middle Southwest-Canada close to US boarder	**Canada** Alma (Quebec, QC) Eastern Canada
Lone Star UAS Center Test Site **LSUASC Test Site** lsuasc.tamucc.edu/	**Mid Atlantic Aviation Partnership** **MAAP** http://maap.ictas.vt.edu/ https://www.aoe.vt.edu/research/facilities/keas.html http://insideunmannedsystems.com/faa-test-sites-virginia-autonomous-technology/	**Canadian Centre for Unmanned Vehicle Systems** **CCUVS** http://www.ccuvs.com/ http://canadianunmanned.com/foremost-centre	**UAS Centre of Excellence** **Centre d'excellence sur les drones** **UASCE (CED)** http://cedalma.com/en/ https://www.canada.ca/en/transport-canada/news/2017/06/transport_canadaapprovesdronetestrangeinalmaqc.html
2014	2013	2007 (since 2014 own airspace)	2011 (since 2015 own airspace)
Texas A&M Corpus Christi University (TAMU-CC)	Virginia Polytechnic Institute and State University (VT)	Canadian Centre for Unmanned Vehicle Systems (non-profit organization)	Unmanned Aerial System Centre of Exellence (non-profit organization)
		X (City of Foremost)	X (City of Alma, Alma Airport)
X (TAMU-CC)	X (VT)		
		X (Canadian Unmanned Inc. - CUI), same postal address as CCUVS	X (UASCE, numerous small and large members: Companies, scientists)
US-Navy & FAA: www.faa.gov/uas/research/test_sites	NASA & FAA: www.faa.gov/uas/research/test_sites		
TAM Flight Test Station Airport (Bryan, north of Houston) Charles R. Johnson (CRJ) Airport (Port Mansfield) Port Isabel-Cameron County Airport (Los Fresnos) Chase Field Industrial Airport (former military airfield) Robert Gray Army Airfield (Fort Hood)	Kentland Experimental Aerial Systems Laboratory (KEAS) https://www.aoe.vt.edu/research/facilities/keas.html NASA Langley Research Center & Wallops Flight Facility https://www.nasa.gov/langley/nasa-langley-drone-flying-site-open-for-testing	Foremost Aerodrome (no ICAO-Code) https://en.wikipedia.org/wiki/Foremost_Airport only partially Medicine Hat Airport (CYXH) https://en.wikipedia.org/wiki/Medicine_Hat_Airport	Alma Airport (CYTF) https://en.wikipedia.org/wiki/Alma_Airport Airspace controlled by nearby Air Force Base Bagotville https://en.wikipedia.org/wiki/CFB_Bagotville
Largest (Panhandle Range): 54.200 NM² (140.377km²), smaller others		2.400 km²	Largest subsite: 4.276 km² (CY-R 657)
12 different (partially connected) areas	approximately 4 different sites, partially with NASA	3 subsites	8 different subsites
400, 2.000, 3.000, 6.000, 17.999, 19.999 ft		G, 10.000ft / 18.000 ft ASL	Highest sites: 18.000 ft (CY-R 657), 28.000ft (CY-R 658) ASL
		Low population in the north, south and west City (Medicine Hat) in the northeast	City of Alma in the north, otherwise sparsely populated
Forests, bushes, grassland, coast, landscape of hills		Flat, prairie, famland	grassland, farmland, forests
Land and sea	Land and sea	Land (~ 3.000ft ASL)	Land and lakes (Lac Saint-Jean)
	BVLOS	BVLOS	BVLOS
COA, Military Operations Area (MOA) Kingsville		**CY-R 234, 235, 236**	**CY-R 651, 652, 653, 654, 655, 656, 657, 658 (ALMA)**
Corpus Christi International Airport, Subsites in whole Texas		3,5 hours by car from Calgary International Airport	Alma Airport, or 2,5 hours by car from Quebec
Electronics Lab, Mission Control Center (MCC), tests and evaluation, engineering support, environmental analysis. Multiple sites with asphalt runway, hangars and warehouses, offering chase-plane operations	300ft asphalt airstrip (KEAS - Kentland Experimental Aerial Systems Laboratory). Services: Flight operation support, pilots, engineers, maintainers, observers and safety officers available. Weather station.	RWY: Paved (914m asphalt) as well as catapult. Services: Assistance in applying for Canadian Special Flight Operating Certificates. Training, assistance for flight operations, consultancy.	RWY: 1.534x30m, asphalt, with lights. Hangar and office space available. Security on site. 2 Work stations, internet access, aviation radios, satellite phone, long-range communication, omnidirectional antenna, power supply, de-icing service, maintenance staff, refuelling, conference room, dining room
		Restricted airspace available from 1st August to 31st May (agricultural reasons). Special Flight Operating Certificate required as well as Safety Officer during flights.	Airspace activation via NOTAM with 48 hours prior notice
Test & evaluation, training, certificaton, licensing	Test and evaluation, airworthiness certification, operations over people, BVLOS tests, UAS Communications, Large UAS, multiple aircraft control, night time operations. Operations within urban, rural and maritime environments. Power line inspection	BVLOS tests, training, certification, research, development, testing and evaluation, help/consultancy with SFOC (Special Flight Operating Certificate)	BVLOS tests, training, flight testing, R&D

36	37	38	39
Australia Woomera, South Australia (Northwest of Adelaide)	**Australia** Beecroft Weapons Range (Peninsula South of Sydney)	**South-Africa** Overberg, Southern coast of South Africa	**Malawi** Kasungu Airport (Central Malawi, Southeast-Africa)
Woomera Test Range - WTR (Military) **(part of Woomera Range Complex - WRC)** http://www.news.com.au/travel/australian-holidays/australias-top-secret-sites-uncovered-by-google-earth/news-story/e4e8ebe7b987896c8c5ec668b93d7390 http://www.defence.gov.au/woomera/about.htm https://en.wikipedia.org/wiki/Woomera_Test_Range	**Beecroft Weapons Range (Military)** http://www.pointperp.com/PDF/Welcome_to_Beecroft_Weapons_Range.pdf https://www.facebook.com/Beecroft-Weapons-Range-and-Peninsula-482375931942986/	**Denel Overberg Test Range (Military)** http://www.denelotr.co.za/home www.af.mil.za/bases/afb_overberg/TFDC.htm https://en.wikipedia.org/wiki/Denel_Overberg_Test_Range 34.649857 S, 20.219904 E	**UNICEF Drone Corridor** http://unicefstories.org/2017/07/03/malawis-unique-drone-corridor/ http://unicefstories.org/2017/06/29/africas-first-humanitarian-drone-testing-corridor-launched-in-malawi-by-government-and-unicef/
1947	1800	1991	2017 (temporary, planned for 1-2 years)
Royal Australian Air Force (RAAF) Woomera Prohibited Area (WPA) Advisory Board	Royal Australian Navy (RAN)	Denel SOC Ltd	Government of Malawi, UNICEF
X	X	X (SA Air-Force, TFDC: Test Flight & Development Centre)	X
		X (Denel Aerospace Group, defence equipment, state-owned)	
			X (UNICEF)
Woomera Airfield, Prohibited military test area (YPWR) https://en.wikipedia.org/wiki/RAAF_Woomera_Airfield	Military Weapon Test Area	Air force base Overberg (FAOB: 34.554861 S, 20.250681 E) https://en.wikipedia.org/wiki/Air_Force_Base_Overberg https://en.wikipedia.org/wiki/Test_Flight_and_Development_Centre_SAAF	Kasungu Airport, Malawi (FWKG) https://en.wikipedia.org/wiki/Kasungu_Airport
more than 100.000km² possible (Woomera Restricted Airspace - WRX)	42km² over land (peninsula), much times more over sea	13.200 km² (240 km x 55 km)	5.000 km² (r=40km)
		2 sectors	
2.100ft, UNL (unlimited)	Always announced via NOTAM	FL 195 (almost 6.000m)	400m AGL (Airport itself ~ 1.000m above Mean Sea Level)
Almost no population, village of Woomera in the south, partially Aborigines	Almost unpopulated (partially touristic use if no testing) Village of Currarong in the North	Unpopulated, farmland (ceral and fruit)	Very low, some villages in the southeast
Australian outback, (former) mines	Cliffs, coast, forests, grassland, rocks	Various: From flat dunes to rocky coast line, strong winds	Savanna, dry forests (partially Kasungu National Park)
Land	Land and sea	Land and sea	Land
YM-R222, 237, 246, 273, 275, 281, 287 (WOOMERA)	**YM-R453 (diverse segmentation) and others**	**FA-R 147 (Overberg Military airspace), CTR FA-OB**	**CTR Kasungu Airport (FW-KG)**
5 hours by car from Adelaide	3 hours by car from Sydney or Canberra	Reachable via N2 and R316, 2,5 hours by car from Cape Town	2 hours by car from airport of capital Lilongwe
Land: 122.000 km² (almost equals England) with comprehensive infrastructure (2 runways: 2,3 km asphalt - 1,6km gravel), Hangars, own tower, accommodation etc., no electromagnetic fautl zones (remotely)	Helipad, certain military buildings Within a range of 10km: Jervis Bay Airport (YJBY) by Navy (RAN) https://en.wikipedia.org/wiki/Jervis_Bay_Airport (2 runways: 1,5 & 2 km asphalt)	2 runways (2km & 3km asphalt), results with trajectories, telemetry recording, photographic documentation, meteorological profiles. Optical systems for tracking, telemetry systems, radar, meteorology, communication, logistics support. Office areas, laboratory / workshop, accommodations	RWY 1.200m (asphalt)
Not opened for externals except for tests in the defense branch	Entirely under administration of the Australian military		Open to industry, universities and individuals in the humanitarian sector (UNICEF innovation principles: open source, open data, sharable, designed for scale)
Military tests (according to own description the largest military test area worldwide) 1950/60ies also nuclear tests (contamination possible)	Military tests of all weapon types, especially NAVY and airforce (also for UAS-Tests)	Air to air tests Air to surface tests (mostly for defence systems)	Drones for humanitarian use Imagery (Aerial images) Connectivity (WiFi, cellphone signals in difficult terrain) Transport (delivery of small low-weight supplies)

40	41	42
India Challakere (District Chitradurga, Province of Karnataka) Southern India	**Singapore**	**South-Korea** Goheung-gun (Province Jeollanam-do) South Korea (at the most southern end)
Challakere Aeronautical Test Range (Military) **Challakere ATR** http://www.deccanchronicle.com/nation/current-affairs/260516/challakere-drdo-s-test-range-may-open-in-june.html http://www.centraledrone.com/single-post/2017/06/11/This-is-why-Challakere-is-the-new-destination-of-unmanned-aircrafts	**RP Drone Training Centre** **RP** http://www.channelnewsasia.com/news/singapore/taking-flight-rp-to-launch-drone-training-centre/3402652.html https://www.mis-asia.com/tech/emerging-technology/singapores-republic-polytechnic-establishes-a-uav-training-centre/	**Goheung Aeronautical/Aviation/Aerospace Center** **GAC** http://www.kari.re.kr/eng/sub03_01_04.do#link 34.611° N, 127.207° E
2017	2017 - Under development	2015
Defence Research and Development Organisation (DRDO) Dep.: Aeronautical Development Establishment (ADE) https://en.wikipedia.org/wiki/Aeronautical_Development_Establishment	University Republic Polytechnic (RP) www.rp.edu.sg	KARI (Korean Aerospace Research Institute) https://en.wikipedia.org/wiki/Korea_Aerospace_Research_Institute
X (ADE - also develops own UAS)		X
	X (RP)	
		X (KARI - also UAS developer)
Challakere ATR (land bought by MOD) https://en.wikipedia.org/wiki/Chitradurga_Aeronautical_Test_Range		
		98,5 km^2 (circle with radius of 5,6km)
		500ft AGL
Low population apart from the city of Challakere itself		Very low
		Flat, farmland, sea
Land		Artificially created land, sea
No entry in Indian AIP (seems not at all complete)		**RK-UA 22 (GOHUNG)**
200km from Bangalore (3 hours by car), 14.387051 N, 76.570613 E	In the north of Singapore	
2.200m RWY, range control center, hangar, radar, rail link, technical unit, medical center Ground of approximately 16 km^2		RWY for piloted and unmanned aircraft. New RWY (1200x45m) in planning. Main rotor and tail rotor whirl tower, landing system drop test equipment, tethering chain (to test safety straps), test-bed aircraft (2-passenger manned aircraft) as well as hangars available
		"The Aviation Center is used by some 10,000 people from 14 agencies and commercial enterprises annually, 85% or more of whose activities were dedicated to flight testing."
UAS development and testing, also weapons	Consultancy & training-courses (mostly for industry professionals) ... also tests planned prospectively Further UAS test projects planned in Singapore (among others with Airbus/DHL) and a "Autonomous Innovation Center"	Flight testing, performance testing of communication equipment Further UAS-Test areas according to AIP: UA 31 (Cheonga), UA 32 (Toechon), UA 33 (Byeoncheon-Cheon), UA 34 (Miho-Cheon), UA 35 (Gimhae), UA 36 (Miryang), UA 37 (Changwon)

4. Test Requirements of Austrian UAS Developers

The following chapter begins with an overview of selected UAS stakeholders and developments in Austria, to later introduce their current practice and specific needs or expectations regarding UAS testing (as expressed during the study UAST by AAI). The final subsection emphasizes these needs in a consolidated form for their subsequent comparison with existing UAS test areas in chapter 5.

4.1. Selected UAS Stakeholders and Developments in Austria

There is a large variety of UAS stakeholders in Austria, which range from large companies or even industrial enterprises (mostly OEMs that are well known worldwide), smaller enterprises and startups, to universities or research institutions, and operators and other stakeholders like civil and military authorities. About 50 of these stakeholders work together in the UAS-Working Group of AAI (see 1.3), but there are certainly even more that are influential, and there is also always some turnover – new SMEs enter the sector while others leave it.

For the above reasons, the following information about the UAS community in Austria (categorized into six different subgroups) is intended as a first overview about some representative Austrian stakeholders and their key competencies, to highlight the already existing diversity of the community and to understand their various needs, which are presented later in this section. There are certainly more companies of interest, but a full report of all of them would exceed the focus of this master thesis.

As these stakeholders all are active in various fields and thus have different individual testing requirements, they were examined and clustered during Project UAST by AAI (see 1.3).

All further details about the key UAS stakeholders in Austria presented in the following subsections can be found in the members list of the AAI-UAS-WG, the list of interviewees of project Austrian UcM and Project UAST, and the RPAS Yearbook 2016 (Blyenburgh & Co, 2016).

4.1.1. Major Enterprises and Industry (OEM)

(1) Schiebel

Founded in 1951, Schiebel is one of the most internationally well-known manufacturers of entire UAS systems. They have various offices not only in Austria, but also in Abu Dhabi, USA, and Cambodia. Beneath the manufacturing of mine detection systems, the company focuses on the development of the CAMCOPTER® S-100 (shown in Figure 14), which is a multirotor that has an endurance of six hours while carrying a 34kg payload. It is applicable for both civil purposes and beyond. In addition, a special area of its application is the ability to operate it under difficult meteorological conditions, which makes it especially suitable for maritime applications. According to Schiebel, this UAS can cover a distance of up to 200km while automatically navigating via waypoints. Furthermore, it is capable of autonomously fulfilling its missions.

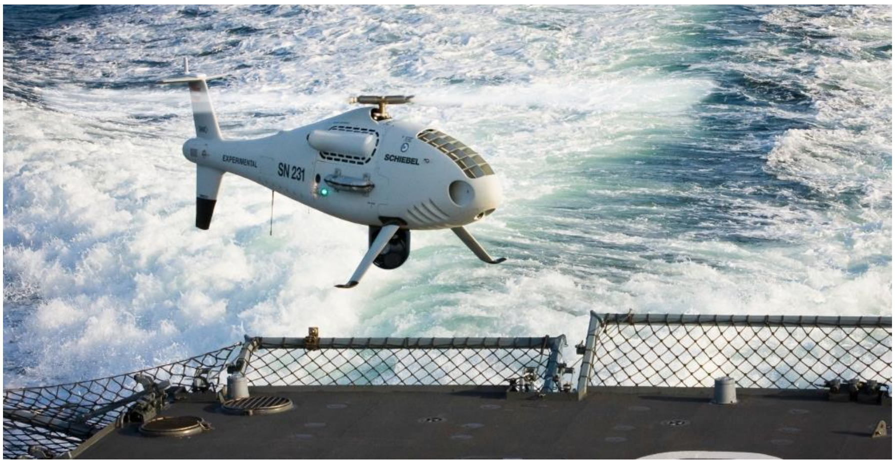

Figure 14: The Schiebel CAMCOPTER® S-100 in maritime environment
(Schiebel, "Image Gallery," https://schiebel.net/image-gallery/)

According to Schiebel, the CAMCOPTER® has various possible applications: Within the civil area, it has landlocked applications such as the inspection of infrastructure (e.g., powerlines), airborne laser scanning, and photogrammetry, and it can also be used for maritime tasks like the prevention of smuggling, search and rescue, and patrolling along coast lines. As Schiebel suggests, the advantages of using a UAS for such missions results in lower risks for humans, higher possible speeds, lower costs, more efficiency, and less invasion during filming. Moreover, the CAMCOPTER® is also suitable for dual-use applications such as surveillance, long-range reconnaissance, and mission support. Its multi-sensor capability enhances the UAS to be able to operate in maritime environments with strong winds. Furthermore, it is capable of automatically starting and landing on various types of ships.

(2) Diamond Aircraft Industries

Although Diamond is not a manufacturer of conventional UAS, the company is still an important Austrian stakeholder due to their research and development within the area of assistance systems and optionally piloted vehicles (OPV), wherefore they are also mentioned in this subchapter.

The company, which was initially founded in 1981 as “Hoffmann Flugzeugbau” as a manufacturer of gliders, began to produce motorized aircraft in 1991 under new ownership. With the DA42 Multi-Purpose Platform (MPP), the company provides an aircraft which can be either manned or unmanned (as OPV). The advantages of the OPV operation are comparable to those offered by conventional UAS, especially the option to support a plane via various assistance systems.

Figure 15: Interior of a DA42 MPP with visible experimental OPV electronics
(AbsInt, "User story: TU Munich, Institute of Flight System Dynamics," https://www.absint.com/tum_fsd.htm)

The DA42 MPP is additionally used for other research projects on assistance systems: Within the project “eSAFE” (which was executed by Diamond in cooperation with TTTech and the Joanneum University of Applied Sciences), the company aimed to develop systems that not only activate an emergency flight control but also perform an automatic landing in the event the pilot becomes incapable of operating the aircraft.

(3) Riegl Laser Measurement Systems

A further developer of entire UAS systems is Riegl. Nevertheless, the development of laser scanning devices is the main competence of the company, which has offices in Austria, USA, Japan, and China. Such devices can be mounted on their self-developed RiCOPTER (see Figure 16), which is an octocopter with a maximum payload of 16kg (including power supply) and an MTOM of 25kg that has a flight endurance of 30 minutes. According to Riegl, since different types of sensors (e.g., cameras, infrared cameras, hyperspectral cameras, etc.) can be used, the foldable UAS is applicable for various tasks such as precision farming, forestry, mining, terrain and canyon mapping, inspecting of infrastructure, monitoring of construction sites, and surveying of urban environments. As Riegl states, the RiCOPTER entails the advantage of gathering images and other data in dangerous and inaccessible terrain, in addition to a favorable cost-to-benefit ratio.

Figure 16: RiCOPTER developed by Riegl with laser-scanning equipment
(Riegl, "UAS/UAV Gallery," http://www.riegl.com/nc/products/unmanned-scanning/gallery/)

A derivative of the RiCOPTER is Riegl's BathyCopter, which is suitable for hydrographic applications. For these applications, the RiCOPTER was equipped with additional sensors such as a bathymetric depth finder and a floating support so the UAS is capable of taking off and landing on water. According to Riegl, these adaptations make the device suitable for missions like the creation of profiles of inland waterbodies (rivers, lakes, etc.), the survey of water resources, and hydraulic engineering work.

A key asset of Riegl in the UAS domain is its extensive experience in the domain of laser scanning and the corresponding data processing, which allows for the generating of very detailed models of entire landscapes after even short laser scanning flights.

(4) FREQUENTIS

Finally, the company **Frequentis,** which specializes in the development of control centers and communication links as well as information systems in the aeronautics domain (ATM, ATC, AIM), also offers solutions for UAS traffic management (UTM), tracking, and surveillance. Hannu Juurakko, Vice President ATM Civil at Frequentis, therefore states:

> "*Drones are causing a major disruption in today's air traffic management [ATM] systems. We see many new stakeholders that would like to fly in controlled and uncontrolled airspace. As a leading provider of advanced ATM solutions, Frequentis is contributing to the development of new concepts for unmanned aircraft systems traffic management (UTM)"*

4.1.2. Major Enterprises (Tier-1)

Major enterprises from or in Austria that contribute to the UAS community as Tier-1 suppliers include the following:

(1) BRP Rotax

The engine manufacturer BRP Rotax, which specializes in "power sport" applications (e.g., motorbikes, go-karts, jet boats, etc.) also develops engines (such as the Rotax 582 UL) for manned microlight aircraft. However, their engines can also be found in unmanned aircraft: As the Kurier (2013) states, Rotax engines are also used for driving not only the "Predator" UAS which are used by the United States, but also the "Harfang" (France) as well as the "Heron" UAS (Israel).

(2) Pankl Aerospace Systems

In manned aviation, Pankl Aerospace Systems (beneath other developments for the motorsport branch) primarily focuses on the manufacturing of safety-critical parts for propulsion systems and respective single components (e.g., driveshaft, gearboxes, etc.) for customers such as Airbus Helicopter or Sikorsky. Their products can also be found in UAS (e.g., main rotor shaft). In addition, Pankl delivered transmission systems for the CAMCOPTER® S-100 by Schiebel in 2007, as stated by Der Standard (2005).

(3) TTTech

TTTech is a manufacturer of networked computer systems and safety controls for applications including automotive, railway, industrial, and aerospace. Beyond further avionic components, the company also develops failure-tolerant network technologies such as communication systems for numerous customers. While they supply communication systems for the cabin pressure system of the Airbus A380, they also develop data communication platforms for the Boeing 787 as well as further communication solutions for Bombardier, Embraer, and even NASA. Moreover, TTTech is also active in the UAS branch, such as cooperating with Diamond Aircraft Industries on the project "eSafe" (see 4.1.1).

(4) Peak Technology

Besides other branches (e.g., automotive, racing, and energy production), Peak Technology is also active within the aerospace industry by manufacturing lightweight components made of fiber-reinforced plastics, such as high-pressure tanks, propulsion shafts of flaps, and lightweight rotor blades for the tail rotors of helicopters.

(5) PIDSO

Within the aviation sector, PIDSO produces antennas and respective radio systems in numerous forms and variations and for diverse applications (e.g., WLAN supply, long-range data links, remote control, and more). In terms of UAS applications, the company focuses on the reduction of the size, weight, and energy consumption of data transmission systems as well as on the integration of antennas into the aircraft structure.

4.1.3. Small or Micro Enterprises and Startups (OEM & Tier-1)

(1) Dynamic Perspective (including UA Robotics)

Through their development of highly-stabilized gimbals with the capability of quick camera exchange, the Dynamic Perspective company focuses on the film and photogrammetry branch. In addition to the gimbal system, the company also developed the DP Copter, which is a rotorcraft UAS for precision applications (specifically film and photogrammetry applications) with an endurance of 60 minutes and the capability of fully autonomous flight (personal statement). It can carry payloads up to 20kg (including a camera and self-developed gimbal). Furthermore, the company also offers infrastructure inspection and solutions for UTM.

(2) Twins

Beyond developing entire UAS systems, Twins further offers the execution of flying missions for their customers and corresponding data processing with a focus on UAS-based gathering of geodata. The company thus offers the self-developed twinHEX, which is a regular-sized hexacopter capable of transporting a 2kg payload for 30 minutes, and the twinMAX (see Figure 17), which is an octocopter designed for the transportation of heavy payloads up to 20kg for 30 minutes.

Figure 17: twinMAX developed by TWINS for the transportation of heavy payloads
(Twins, "Flugplattformen," http://www.twins.co.at/de_DE/produkte/flugplattformen/)

According to Twins, the possibility of equipping their UAS with different kind of sensors makes them suitable for various tasks such as (hazard) monitoring tasks, photogrammetry, survey, the creation of digital surface models, volume calculation, archeology tasks, inspection of infrastructure, and the simple transportation of payloads.

(3) GRID-IT

GRID-IT focuses on the capturing and the processing of geoscience data (e.g., scanning three-dimensional structures, environmental analysis etc.). Since 2011, the company has also included UAS for photogrammetry tasks (complementary to terrestrial methods). They offer both the preparation and the execution of flights as well as the accompanying data processing.

(4) EyeAero (aka SG concepts)

A further Austrian enterprise within the UAS branch is EyeAero, which focuses on the development of UAS with a high degree of portability and quick deployment. The EyeXX family covers hexacopters and octocopters using familiar structures and components. Equipped with different payloads, they are suitable for first responder missions, tasks related to the building industry, precision farming, surveying, and photogrammetry.

(5) Drone Rescue

The development of drone rescue systems is the main competency of the aptly named Drone Rescue company. In order to recover multicopters that have run into the danger of crashing down, the system either manually (after a respective pilot input) or automatically (after an algorithm-based decision according to certain flight parameters) deploys a parachute to enable a safe landing. For this reason, the rescue system is adapted to the respective multicopter (size, weight, number of rotors, etc.) and its flight behavior. There is also an included black box system, which records certain flight data such as altitude, speed, acceleration, and orientation. As Dax (2017) furtherly mentions, this black box is not only responsible for making the decision of parachute deployment, but can also be used for accident investigations comparable to manned aviation (e.g., for insurance issues) as well as for the improvement of pilot performance, as the data is visible on a web platform.

Further small or micro enterprises (or startups) that are significant in the UAS branch are companies that specialize in the development and operation of UAS for TV productions (e.g., Bladescape, Viewcopter, Video-TV-Produktion etc.), for which not only consulting but also the execution of flights and the respective data processing are offered.

4.1.4. Universities, Other Teaching Facilities, and Research Institutions

(1) Austrian Institute of Technology (AIT)

There are several research institutions in Austria (educational or non-educational) which approach the development of new UAS technologies. Austria's largest non-educational research institution, the Austrian Institute of Technology (AIT), regularly executes a large number of different research projects that are typically in the area of infrastructure). Within the UAS branch, AIT states that they conduct research on data processing, sensor technology, UAV integration, assistance systems (for partial autonomy), sense and avoid technology, and more. Furthermore, AIT executes research on advanced navigation (in cooperation with Schiebel) as well as on tracking antenna systems (in cooperation with Pidso) and the application of UAS for the assistance of emergency services (first responders) in the event of disasters.

(2) Joanneum University of Applied Sciences

The Joanneum University of Applied Sciences (FHJ), which has both a bachelor and a master degree program for aviation (see 1.2), claims to be the only Austrian educational research partner for entire aircraft systems. They perform research on various UAS-related topics (e.g., autonomy, flight control, stabilization), and they also execute the development and building of their own fixed-wing and multirotor UAS for research purposes (e.g., the JXP-V, see Figure 18).

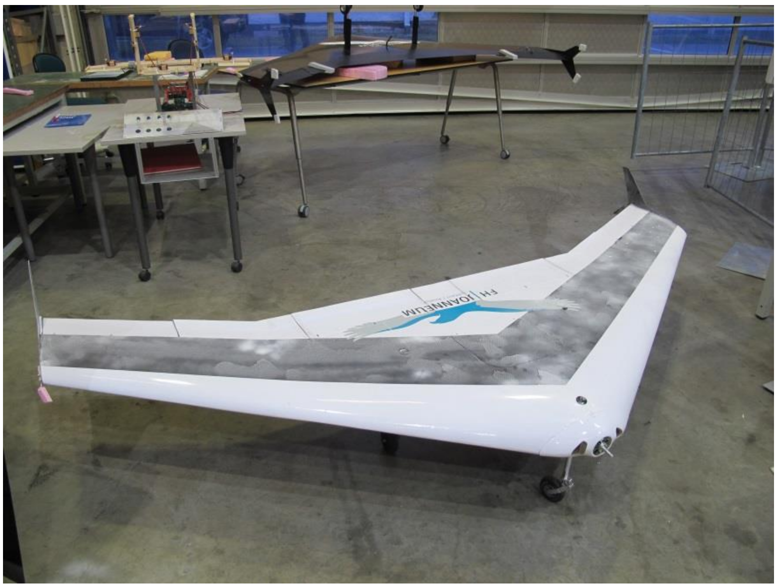

Figure 18: JXP-V fixed-wing UAS developed by the Joanneum University of Applied Sciences

(3) Carinthia University of Applied Sciences

As Kotrba (2017) said, within the research project "Drone Zone," the Carinthia University of Applied Sciences (FHK) performs research on possible areas for the operation of UAS in Austria. Therefore, different factors such as population density, restricted or closed airspaces, danger areas, nature conservation areas, and control zones of airports are taken into consideration in order to determine the remaining suitable areas where the operation of UAS can be performed unscrupulously. The necessary data is based on geodata obtained from public administrations.

(4) Other research institutions

Further Austrian research institutions with UAS-related projects are **Joanneum Research** (a non-educational research institution which – within the UAS branch – performs research on optical sensors, data processing, and analysis), the **University Graz** (which conducts UAS-based environmental monitoring, photogrammetry, and remote sensing), the **Technical University of Graz – TU Graz** (which research on the analysis of image data as well as on autonomy), the **Vienna University of Technology – TU Wien** (with research projects on propulsion systems and geosciences), the **University of Salzburg** (annually hosting the AGIT, which is the Symposium and Exhibition for Applied Geoinformatics and approaches with their own summit on the uses of UAS within geosciences), the **Johannes Kepler University Linz – JKU** (providing legal expertise in the areas of both manned and unmanned aviation), the **RTA – Vienna Climatic Wind Tunnel** (executing simulations of cold starts or performing icing tests, especially for rotorcraft), and the **Austrian Research Centre for Forests – BFW** (whose specialization is alpine UAS applications, especially for natural disasters).

4.1.5. Operators (Institutional & Private)

As the inspection and protection of critical infrastructure is both a significant field in suitable UAS applications and highly necessary in order to establish and maintain public safety and order, the operators of such infrastructure who intend to perform its corresponding inspection with the help of UAS are also part of Austrian UAS stakeholders. Such operators may be organizations like the **ASFINAG** (operator of the Austrian motorway network), the **Verbund** (electric company and operator of numerous hydroelectric power plants and wind turbines), the **Austrian Power Grid** (subsidiary of the Verbund, operator of the Austrian power line network), and the **ÖBB** (Austrian Federal Railways, operator of the national railway system in Austria).

A further important group among Austrian UAS stakeholders are the countless **photographers** and **specialists from the Austrian film** industry who operate drones with high-resolution cameras and often specialized gimbals (in the film industry) for widespread photographing and filming purposes. According to some studies in different Western countries worldwide, photographers and filmmakers currently constitute the great majority of civil UAS operators. Consequently, their official association in Austrian (**FAMA**) is an important stakeholder.

Aside from the aforementioned large players, smaller UAS stakeholder groups include **geo-scientists** and respective companies (as operators), but also exotic users like **real-estate agents** who use pictures from UAS to sell houses or **winegrowers** like in the Austrian region around the Lake Neusiedl who employ UAS to scare away birds and for other purposes.

4.1.6. Other Stakeholders including Authorities

In addition to industrial enterprises, micro enterprises, and research institutions, there are also other kinds of stakeholders that participate in the Austrian UAS branch. The **Austrian Ministry for Transport, Innovation and Technology (BMVIT)** participates with two of its departments. While the department of aviation is responsible for the (legal) regulations of Austrian air traffic, the department of telecommunications is responsible for organizing, assigning, and approving different radio frequencies. In terms of UAS, such radio frequencies are needed for command, control, and data links between the ground control station and the UAV. Finally, even the department for innovation funding is also involved in the UAS domain.

Consequently, a further important UAS stakeholder among authorities is the **Austro Control (ACG),** which is an outsourced subsidiary of the ministry BMVIT that is responsible for the technical and operational approval of any aircraft to be used within Austrian airspace and for administrating and organizing airspace in order to ensure safe air traffic. Especially considering the existent and upcoming UAS regulations (see chapter 2.2.3), interactions with the ACG are vital in order to set up both legal and safe UAS operations.

The Austrian **Aeroclub** acts as the representing organization for both model builders and private model aircraft operators (fiercely disputing any relations to UAS), and it also executes authority tasks such as the approval of model aircraft with a weight of more than 25kg, as well as supportive (expert) tasks for ACG during the certification process of class 1 UAS.

At last, the **Austrian MoD – Ministry of Defense (BMLVS)**, as head of the Austrian armed forces (ÖBH) must be acknowledged as a UAS stakeholder not only as a UAS operator (for the purpose of national defense), but also as the operator of airspace and already existing potential UAS test areas (due to the possible use of military test facilities).

As the steadily increasing usage of UAS also entails an increased risk potential due to possible UAS-assisted assaults (e.g., acts of terror) or espionage, the **Austrian Ministry of Interior** must be considered as a UAS stakeholder. Following the fact that its tasks include the maintenance and protection of public safety, the Ministry of Interior must be able to intervene against the misuse of UAS in order to protect critical infrastructure such as power lines, power plants, reservoir dams, and others. Furthermore, UAS can be actively used to monitor and protect public events and road traffic, assist in the field of criminalistics, or help first responders to analyze specific situation via UAS images (e.g., after accidents or natural disasters).

4.2. *Actual Practice of UAS Flight Testing in Austria*

New technologies in the rapidly growing UAS area also demand appropriate testing in order to validate adequate functionality and the fulfillment of manifold safety requirements. As there is currently no official and consistent possibility for executing UAS tests in the civilian airspace of Austria, domestic UAS developers need to find alternative ways to execute their tests, as illustrated by the first ranking of test areas currently used by Austrian UAS stakeholders in Figure 19 (derived from Project UAST, Fortner et al., 2017, see section 1.3). As the ranking is based on "voluntary" statements, it is more preliminary than final (and only includes real flight testing, while all other pre-tests are done on the ground or in laboratories).

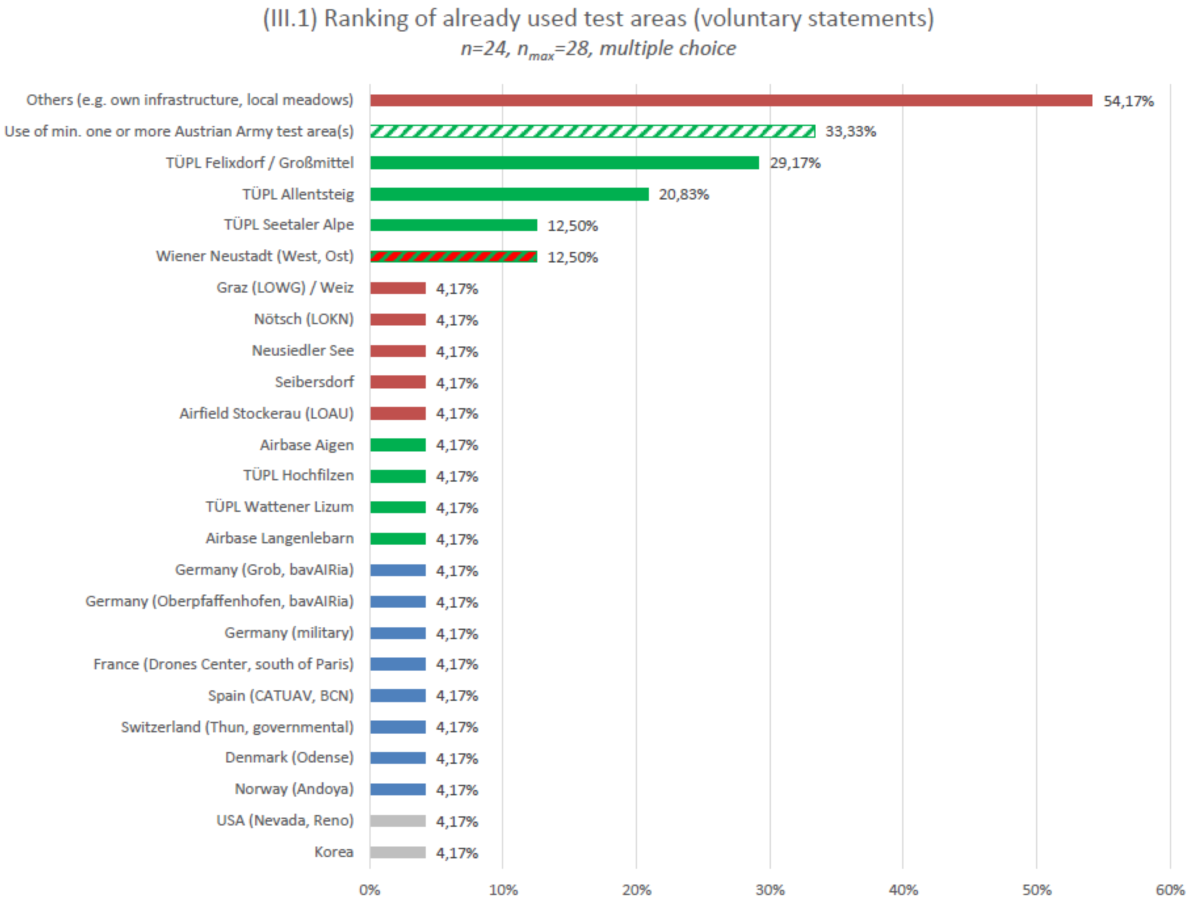

Figure 19: Ranking of already used civil (red), military (green), European (blue) and other international (grey) test areas by Austrian UAS stakeholders
(Study UAST, Fortner et al., 2017, p.38)

As mentioned in the UAST study by Fortner et al. (2017), the majority of today's UAS test flights are still performed within VLOS using small UAS. They also pointed out that developers currently focus on the testing of different payloads, communication (links), avionics, and navigation, while prospective tests in the future (or for future developments) also focus on BVLOS operations, adequate sense and avoid systems, and (semi-)autonomy.

4.2.1. Civil Airspace below 150kg MTOM

As the research in the UAST study by Fortner et al. (2017) expressed, Austrian UAS stakeholders (no matter if developers, research institutions, or operators) with UAS under a MTOM of 150kg tend to execute their tests on their own property, such as small airfields, at their own infrastructure in order to test infrastructure inspections, rudimental grasslands, and more. A remarkably smaller fraction also performs their tests at already existing international test areas. As visible in Figure 19, the majority of those stakeholders also perform UAS tests in military airspace (see 4.2.3).

4.2.2. Civil Airspace above 150kg MTOM

As the testing of UAS with an MTOM above 150kg needs permission on behalf of EASA and more space (both lateral and vertical), such tests can most probably not be performed on (small) company-owned properties anymore. Beyond the testing at existent international test areas or within military areas in Austria and beyond (which is currently the choice of the majority stakeholders, see Figure 19), another solution is to execute tests with experimental permission issued by Austro Control (likely on behalf of EASA). While Schiebel performs their tests (also) with such experimental permissions, Diamond executes a different approach and performs their test flights as OPV (manned aircraft with assistance systems) for already certified CS-23 aircraft.

4.2.3. Military Airspace

The fact, that since decades military tests (e.g., weapons tests or military flight tests) are either considered as dangerous for uninvolved humans or meant to be performed secretly, makes military test areas an attractive alternative for testing also civil UAS. First of all, those test areas tend to be located in well-isolated places that are far away from cities, villages, and other civilization, therefore also from highly populated areas. Therefore, UAS stakeholders do not need to consider issues concerning adversarial residents or potential restrictions due to environmental protection, as those issues have already been resolved by the military. Furthermore, possible issues concerning the airspace do not need to be taken into account as there is likely the possibility to temporarily activate the airspace, which has already officially been published in the AIP and respective ICAO charts via NOTAM and thus prevent interference with participants of the regular (civil) air traffic.

On the other hand, military airspace entails various constraints: As those areas are primarily designated for executing military tests, the availability of such airspaces for other purposes strongly depends on the frequency of the military's tests. In the UAST study, Fortner et al. (2017) show that the military test area of Allentsteig in Lower Austria bears the possibility of executing (BVLOS) tests on a continuous airspace length of 20km, depending on the flight altitude AGL. Nevertheless, the Austrian Armed Forces utilize the test area for their own training purposes on 200 days per year (see Bonavida in DiePresse, 2012), which makes it difficult for developers to adequately schedule their tests. Furthermore, access to military tests areas might be difficult to obtain if there is no respective framework agreement which lessens the bureaucratic efforts. In summary, it can be said that, when considering potential advantages and disadvantages, the use of military airspace can be a convenient and adequate way of testing UAS as long as the necessary framework and acceptance by the military are provided.

4.3. Advanced and Additional Test Requirements in the Future

In addition to the current scenarios tested by developers (mentioned in section 4.2), test areas also need to be capable of meeting prospective test requirements for the coming years. Such requirements include flight tests of the UAS themselves as “aircraft” (their avionics, flight dynamics, or control link) but also tests which are purely focused on the payload or various mission systems. Particularly for Austrian UAS developers, the UAST study by Fortner et al. (2017) listed the most important test requirements for the future, which are displayed as follows:

- BVLOS
- Operation under aggravated conditions (meteorological, topographical and/or error simulation)
- (New) Sensor technology and payload
- Autonomous flying, starting, and landing
- Data links, communication, ground control station
- Sense and Avoid
- Counter-UAV
- Precision and navigation tests
- UTM, surveillance

As the survey by AAI during the UAST project showed, the majority of the Austrian UAS stakeholders have the necessity of prospectively executing tests for BVLOS technologies (including sense-and-avoid systems, appropriate control links, sensor technology, etc.). Therefore, this special test requirement is the most demanded by Austrian stakeholders, as visible in study UAST, Fortner et al. (2017). This observation supports the theory that the trends of newly developed UAS technologies are heading towards BVLOS and (partial) autonomy. As far as the regulatory framework is given one day (see the long-time perspective in the ICAO RPAS Manual 2015) this could be a standard technology available for UAS, one day.

Another test requirement shown in study UAST by Fortner et al. (2017) that has been demanded by more than a half of Austrian UAS stakeholders is the possibility to test the UAS under difficult conditions, like aggravated weather situations (e.g., strong winds, storms, extreme temperatures, etc.), difficult geographical terrain (e.g., mountainous surfaces, alpine environments, etc.), or the simulation of errors during flight (e.g., the loss of command and control links).

The need for testing under "difficult conditions" might even develop further in the future, as – in contrast to the flight performance of a UAS under such aggravated conditions – the basic abilities of a UAS to perform conventional flights under normal conditions with undisturbed radio connection may fall behind more sophisticated testing of new payloads, design, various electronic systems, and the aforementioned difficult conditions.

As the UAST study by Fortner et al. (2017) demonstrated, further prospective test scenarios planned by Austrian UAS stakeholders include additional autonomy-related technologies (e.g., autonomous starting and landing, sense and avoid) and basic technologies such as sensors and payload, data link, communication and ground control station, and navigation. Furthermore, Austrian stakeholders also plan to execute tests on assisting technologies, like counter-UAV and UTM.

In addition, more than one third of the respondents state that the testing of sensor technologies and different payloads is intended in the future.

4.4. Summary of Austrian Developers' Practical Needs

The actual requirements and needs of Austrian UAS stakeholders on test areas emerged from the sum of test requirements for current and prospective UAS technologies. Due to the fact that UAS technologies and their regulatory frameworks are still in early stages, the majority of currently performed tests focus on basic technologies. In this way, the testing of prospective technologies partially already occurs "somehow" and "somewhere" (BVLOS, autonomy, sense and avoid, etc.).

The need to execute tests within a designated test area is present in all areas, as not only tests on individual properties but also the perpetual (effortful) request for special authorizations by the CAA (Austro Control) for each specific design change will not be a sufficient base for appropriately and efficiently executing UAS tests in the future.

Within study UAST by Fortner et al. (2017), the Austrian stakeholders' requirements for UAS test areas were determined following 29 stakeholder interviews, which also led to a ranking of the most important aspects (also revisited in the following chapter):

- ***BVLOS***

The most important test requirement selected by the interviewed stakeholders is the permission of the corresponding CAA for legally executing flight tests and performing BVLOS flights, which also equals the advanced test requirements mentioned in section 4.3. Followed by that, Austrian stakeholders also required an adequate extension of the airspace, accessibility of the test area, clarification of insurance issues, a beneficial (topographic) position of the test area, reasonable costs, and more, as the following paragraphs illustrate.

- ***Airspace, Population density, Segmentation***

As the interviews executed during the UAST study by Fortner et al. (2017) showed, the necessary altitude for the test airspace as mentioned by one third of the stakeholders accounts for up to 150m. Nevertheless, a further quarter of the respondents required a higher vertical extension of up to 500m, while almost another third required 2000m or more. This result expresses that more than half of Austrian stakeholders require more than 150m vertical extension.

Almost two thirds of the respondents required a horizontal (lateral) extension of up to 40km², while almost another third needs up to 1000km². Only a small minority of the respondents (5%) expect more than 1000km² of airspace. Furthermore, the overwhelming majority of respondents (95%) not only prefer a test area with segregated airspace, but also the possibility to execute BVLOS flights, which makes it a core requirement of Austrian stakeholders when considering the high prospective potential of this technology and its increasing demand.

More than 90% of the respondents expect problems with local residents when executing tests, which is the reason why the major part prefers a test area with very low or even no population. Furthermore, more than 70% expressed a desire for a diverse test area which is segmented into multiple subsites.

- ***Surface, Topography, Accessibility***

As stated by the respondents, the test areas' topography is required to be diverse and preferably mountainous to fulfill various tests of the aircraft itself and also for various payloads, especially sensor technology for geosciences and other purposes. Furthermore, the desired presence of forests and areas of water was mentioned within the interviews. Adequate accessibility of the test area is considered to be important (93%) in which the connection to roads should be mostly sufficient, although the close proximity to motorways is preferred.

- ***Costs of usage and Services***

The costs which are “acceptable” for Austrian UAS stakeholders are close to international standards of medium-sized civil UAS test areas (as far as data about costs was accessible for international UAS test sites): While 44% of the interviewed stakeholders are willing to pay between €500 and €1000 per day, at least 12% would pay a higher amount, though perhaps for larger areas or airspaces. While the actual calculation of the costs should follow the developer’s effective utilization of the test area, services should be included.

- ***Military background***

As Figure 19 shows, currently a significant part of Austrian UAS testing is performed at military areas. Unfortunately, there are often constraints in this scenario, such as very few time slots for civil tests (see 4.2.3). However, as long as this option does not involve further constraints, this method of UAS testing could often be used by Austrian UAS stakeholders, as numerous potential issues (local residents, population density, environmental protection, etc.) have already been solved and the tests can thus be executed in a shielded manner. This is the reason why (aside of a mountainous test area with good accessibility and low population density) also a test area with military background was found to be acceptable during the interviews of the study UAST by Fortner et al. (2017). Nevertheless, the problems already mentioned in section 4.2.3 should be solved, including no quick access, too limited access, not enough time slots, and even considerations about military involvement in civil UAS testing.

5. Rankings:
Austrian Developer Needs vs. Existing UAS Test Sites

The following comparison of the developer-oriented test aspects (see section 3.3) at the researched 42 international UAS test areas (for details, see section 3.4) with the practical needs of Austrian UAS developers (see section 4.4) shows how well the Austrian needs are met by international test sites. It should be noted, though, that most of the data is based on the statements of the respective tests sites (e.g., on their website or in press releases), so even if the research included re-checks of the given facts, **this thesis cannot assume liability for data given by third parties**. At the end of each subchapter, interested readers or stakeholders can find a worldwide ranking, followed by a ranking focused on European UAS test areas that most adequately fulfil the respective requirements.

5.1. Airspace and Population Density

(1) Horizontal extension (max. lateral dimensions)

In particular, UAS test areas located in the US and Scandinavia (e.g. Sweden, Finland) show the largest availability of airspace dimensions, which follows the notion that there are huge areas in those countries that are neither populated nor utilized. The largest airspaces for UAS testing can be found in America (Lone Star UAS Center Test Site, 140,377km²) followed by Australia (Woomera Test Range, though it is not open for civil tests) and the United States again (83,000km² at the Tillamook Test Range in Oregon, 39,000km² at the New Mexico State University UAS Test Site, etc.). Nevertheless, large test areas with low population density can also be found in Europe. While the Vidsel Test Range in Sweden claims to be capable of providing 24,000km² of airspace, the Robonic Arctic Test UAV Flight Center, which is a test center focused on weapon tests but is also suitable for conventional UAS testing, offers up to 11,000km² of airspace, followed by the Wales UAS Environment with 8,600km² (1,500km² over land, 7,100km² over sea), and the ATLAS Center in Spain (1,000km²). Considering that according to the UAST study by Fortner et al. (2017), more than 70% of the Austrian UAS stakeholders' (horizontal) airspace requirements can be covered with a horizontal extension of 100km², also the UAS Test Center Denmark (867km²), as well as the Grottaglie Airport in Italy (370km²), and the BOFORS Test Center in Sweden (200km²) can be taken into account as suitable for this requirement. Additionally, the Drone Port in Belgium (84km²), the CESA Drones Test Center in France (28km²), and the BCN Drone Center in Spain (25km²) still meet the requirements of at least two thirds of Austrian UAS stakeholders (up to 50km²).

For the respective rankings of UAS test areas (worldwide and in Europe) according to their horizontal extension, see table 1:

	Worldwide	European
Rank	Name	Name
1	Lone Star UAS Center Test Site *140,377km² – Texas, USA*	Vidsel Test Range *24,000km² – Sweden*
2	Woomera Test Range *10,.000km² – Australia*	Robonic Arctic Test UAV Flight Center *11,000km² – Finland*
3	Tillamook Test Range *83,000km² – Oregon, USA*	Wales UAS Environment *8,600km² – Wales, UK*
4	New Mexico State University *39,000km² – New Mexico, USA*	ATLAS Center *1,000km² – Spain*
5	Pendleton Test Range *36,000km² – Oregon, USA*	UAS Test Center Denmark *867km² – Denmark*
6	Vidsel Test Range *24,000km² – Sweden*	Grottaglie Airport Test Bed *370km² – Italy*
7	New York UAS Test Site *18,000km² – New York, USA*	BOFORS Test Center *200km² – Sweden*

Table 1: Worldwide and European ranking of test areas according to their horizontal extension

(2) Vertical extension (max. altitude)

Including the Andoya Test Range in Norway, the Swedish Vidsel Test Range, and the military Woomera Test Range in Australia, which all **claim** to have infinite vertical airspace extension available, 16 researched test areas meet the maximum requirement of Austrian stakeholders concerning vertical airspace (at least 2,000m vertical extension or more): The Tillamook Test Range in Oregon, USA (almost 40,000m) is followed by the New York UAS Test Site (22,800m on request), the Swedish BOFORS Test Center (10,000m), the UAS Centre of Excellence in Canada (8,500m), and the Wales UAS Environment (6,800m, unlimited over sea). Beneath further American test areas (University of Maryland UAS Test Site, Lone Star UAS Center Test Site, New Mexico State University UAS Test Site, Canadian Centre for Unmanned Vehicle Systems, Warm Springs UAS Test Range, and the Northern Plains Unmanned Aircraft Systems Test Site), the South African Denel Overberg Test Range (6,000m) and the Finnish Robonic Arctic Test UAV Flight Center (3,000m) meet this requirement.

Furthermore, numerous European UAS test areas, such as the Spanish ATLAS Center (1,524m), the Grottaglie Airport Test Bed (1,524m), the BCN Drone Center (1,219m but expandable), the UAS Test Center Denmark (1,066m), the French CESA Drones Test Center (914m), the CEEMA Test Center (762m), and the Test Area Oberpfaffenhofen (600m with authorization) meet the requirements of 75% of Austrian UAS stakeholders (max. 2,000m vertical extension needed).

The respective rankings of UAS test areas according to their vertical extension (max. altitude) are visible in table 2.

	Worldwide	European
Rank	Name	Name
1	Andoya Test Range *Unlimited – Norway* Vidsel Test Range *Unlimited – Sweden* Woomera Test Range *Unlimited – Australia*	Andoya Test Range *Unlimited – Norway* Vidsel Test Range *Unlimited – Sweden*
2	Tillamook Test Range (PPUTRC) *40,000m – Oregon, USA*	BOFORS Test Center *10,000m – Sweden*
3	New York UAS Test Site *22,800m – New York, USA*	Wales UAS Environment *6,800m – Wales, UK*
4	BOFORS Test Center *10,000m – Sweden*	Robonic Arctic Test UAV Flight Center *3,000m – Finland*
5	UAS Centre of Excellence *8,500m – Canada*	ATLAS Center *1,524m – Spain* Grottaglie Airport Test Bed *1,524m – Italy*
6	Wales UAS Environment *6,800m – Wales, UK*	BCN Drone Center *1,219m – Spain*
7	University of Maryland UAS Test Site *6,096m – Washington, USA*	UAS Test Center Denmark *1,066m – Denmark*

Table 2: Worldwide and European ranking of test areas according to their vertical extension

(3) Own and/or Segregated Airspace

The ranking for the criteria of “own/segregated” airspace would be unrewarding, because, apart from the Toulouse Francazal Test Area and the RP Drone Training Centre in Singapore (which do not meet this requirement), all other researched test areas are equipped with (temporary) segregated airspace for testing. This segregation is either realized by an own entry of the airspace into the respective Aeronautical Information Publication (AIP) as temporary segregated area (TSA, e.g., BCN Drone Center), restricted area (e.g., CESA Drones Center), or danger area (e.g., Wales UAS Environment). Furthermore, existent military airspace or (extended) control zones of regional airports (e.g., UAS Test Center Denmark) or local airfields are used. As the study UAST, by Fortner et al. (2017) also describes, the Certificate of Waiver or Authorization (CoA), which is especially issued for UAS activities, is occasionally used in the US in order to establish airspace for UAS tests.

However, even for some UAS test areas where no AIP entry was found in the general research, such as the Arctic Centre for Unmanned Aircraft in Norway, it can nevertheless be assumed that UAS tests can be safely performed there. As the site in Norway is the northernmost known test area worldwide, its remote location renders both population and air traffic (and resulting threats) at virtually zero. For this reason, restricted airspace is not needed in order to execute tests. A similar assumption can be made for the Warm Springs Test Range, which is over Indian territory, where the local tribes even obtained the right by the FAA to certify drones on their own (see section 3.4) and the Mid Atlantic Aviation Partnership, both of which are located in the US.

5.2. Surface and Topography

The majority of the researched test areas offer flat topography with agricultural farm lands, grasslands, and woods. While the Austrian requirement of performing UAS tests also situated in **alpine** topography cannot be fulfilled by a single test area worldwide, the Spanish BCN Drone Center, the ATLAS Center, the American Tillamook Test Range, and the Warm Springs Test Range (height of more than 3,000m) at least offer mountainous terrain. Furthermore, both the Australian Beecroft Test Range and the Denel Overberg Test Range in South Africa are (partially) located at rocky coast lines with cliffs, which therefore also provide a significant elevation difference. Additionally, the Lone Star UAS Center Test Site in Texas, which is partially located on hilly terrain, can also be considered for this requirement.

The (minor) requirement of **areas of water** for UAS tests can be fulfilled by numerous test areas: The UAS Test Center Denmark, CESA Drones Center, Wales UAS Environment, Grottaglie Airport Test Bed, Arctic Centre for Unmanned Aircraft, Andoya Test Center, Tillamook Test Range, University of Maryland UAS Test Site, Lone Star UAS Center Test Site, Mid Atlantic Aviation Partnership, Beecroft Weapons Range in Australia, and Denel Overberg Test Range are all partially located within maritime environments. Furthermore, both the BOFORS Test Center in Sweden and the UAS Centre of Excellence in Canada include numerous lakes, while the American Pendleton Test Range offers large rivers for UAS tests.

The Alaska Center for Unmanned Aircraft Systems Integration, the Arctic Centre for Unmanned Aircraft, the Robonic Arctic Test UAV Flight Center, the BOFORS Test Center, and the Andoya Test Center are located within arctic environments and therefore offer **challenging weather conditions** with cold temperatures. In contrast, the ATLAS Center, the New Mexico State University UAS Test Site, and the Nevada Institute for Autonomous Systems are located in desert-like environments with respective hot temperatures. Additionally, the Wommera Test Range, which is located in the Australian outback, offers similar weather conditions.

The respective rankings of UAS test areas according to their surface and topography, which is **more subjective than the earlier rankings** due to unquantifiable nature of these factors, are visible in table 3. Taking the requirements of Austrian UAS stakeholders into account, test areas with mountainous topography were preferred. As a second criteria, the diversity of not only the surface (e.g., areas of water) but also the vegetation (woods, farmland, grassland, etc.) had a positive influence on the ranking of the respective test area.

	Worldwide	European
Rank	Name	Name
1	Warm Springs Test Range (PPUTRC)	ATLAS Center
2	New Mexico State University UAST	BCN Drone Center
3	ATLAS Center	CEEMA
4	Nevada Institute for Autonomous Sys.	Wales UAS Environment
5	BCN Drone Center	CESA Drones Center
6	Tillamook Test Range (PPUTRC)	UAS Test Center Denmark
7	Woomera Test Range	Arctic Centre for Unmanned Aircraft

Table 3: Worldwide and European ranking of test areas according to their surface and topography (based on specific Austrian criteria like alpine/mountains, areas of water, and challenging weather)

5.3. *Segmentation and Diversity of Subsites*

The segmentation of test areas into multiple subareas enables the utilization of the advantages of different locations (different weather conditions, surfaces, topography, vegetation, also different categories of airspace and aircraft), which cannot all be found simultaneously at one single location. As a consequence, **a test area with multiple subareas can offer a more diversified test situation and is therefore more attractive for developers**, as also shown by the requirements of Austrian UAS stakeholders that prefer diversified topography.

The concept of segmentation is used by numerous test areas: The Droneport in Belgium boasts (on its website) an alleged seven different subareas in order to provide possibilities for indoor testing and for adapting the tests to different aircraft types (smaller areas for rotorcraft, large areas for fixed-wing) and purposes (special area for BVLOS tests, for agricultural tests etc.). Additionally, the French CESA Drones Test Center has five very different subareas in order to offer suitable conditions according to different aircraft types, to include maritime (coastal) testing environments, and to make use of the advantages of military facilities and airspace. Thanks to the concept of segmentation, the Pan-Pacific UAS Test Range Complex is able to cover seven different climate zones, which enables developers to test in arctic (in cooperation with the Alaska Center for Unmanned Aircraft Systems Integration), tropic, and arid conditions under the administration of one single test area coordinator. Moreover, the Lone Star UAS Center Test Site offers twelve different subareas in order to not only specialize in different UAS applications (e.g., firefighting, search and rescue, agriculture) but also to offer diverse topography and vegetation (e.g., farmland, grassland, bushland, hilly terrain etc.) as well as different airspace categories (e.g., segregated airspace in order to enable BVLOS tests).

In order to include certain areas of water (oceans, lakes, rivers, etc.) into their offer, numerous test areas have used the concept of segmentation, including the UAS Test Center Denmark (three connected areas over land and sea), the Wales UAS Environment (six connected areas over land and sea), the Grottaglie Airport Test Bed (one airspace over land, one transfer corridor, one airspace over sea), the Arctic Center for Unmanned Aircraft (three different areas to cover the Norwegian Sea, the Barents Sea, and the Arctic Ocean towards the north pole for research and emergency preparedness applications), the Northern Plains UAS Test Site, the University of Maryland UAS Test Site, the New York UAS Test Site, the Mid Atlantic Aviation Partnership, the Denel Overberg Test Range, the Canadian Centre for

Unmanned Vehicle Systems, and the Canadian UAS Centre of Excellence (eight subareas over land and lakes).

The respective rankings of UAS test areas according to their surface and topography are visible in table 4. The ranking of the test area depends on the degree of diversity that was achieved due to the segmentation in terms of surface, topography, vegetation, weather conditions, and also specializations on certain UAS types or sizes and fields of application.

	Worldwide	European
Rank	Name	Name
1	Pan-Pacific UAS Test Range Complex (= PPUTRC) *10 subsites (coastal, mountain) – USA*	Wales UAS Environment *6 subsites – Wales, UK*
2	Lone Star UAS Center Test Site *12 subsites (big, #airfields) – TX, USA*	CESA Drones Center *5 subsites – France*
3	UAS Centre of Excellence *8 subsites (over water, etc.) – Canada*	Droneport – *Belgium* *5 subsites (in/outdoor, BVLOS)*
4	Wales UAS Environment *6 subsites (big, land and sea) – UK*	Arctic Center for Unmanned Aircraft *3 subsites (quite remote) – Norway*
5	CESA Drones Center – *France* *5 subsites (div. sizes, coast BVLOS)*	UAS Test Center Denmark Grottaglie Airport Test Bed – *Italy* *both 3 subsites (land and sea)*

Table 4: Worldwide and European ranking of test areas according to the diversity due to subsites (based on the number but also the specific diversity of subsites)

5.4. *Accessibility and Geographical Position*

In order to make UAS test areas attractive for developers, adequate accessibility including sufficient connections to roads and international airports is essential. In order to still have as few restrictions as possible due to local residents, a compromise between being closely located to populated areas (for adequate accessibility) and being far away enough for reasonable test conditions must be made. Due to practical reasons for international test site accessibility, the requirements of Austrian stakeholders as stated in section 4.4 were considered (access by car), but also the **reachability via international airports was taken into account**.

The **European test areas show outstanding accessibility** concerning travel time from an international airport: The CESA Drones Center (directly located at Bordeaux International Airport), as well as the BOFORS Center (30 minutes from Örebro Airport), the Drones Center Bretigny (30 minutes from Paris), the Test Area Oberpfaffenhofen (30 minutes from Munich), the UAS test area of ONERA (40 minutes from Toulouse), the Grottaglie Airport Test Bed (40 minutes from Brindisi Airport), the CEEMA Test Center (45 minutes from Marseille), the German BUVUS Test Center (45 minutes from Bremen), the Droneport in Belgium (1 hour from Brussels), the Robonic Arctic UAV Flight Center (1 hour from Kuusamo), the UAS Testzentrum Nord (1 hour from Hannover), the Netherlands RPAS Test Centre (1 hour from Amsterdam), and even the BCN Drone Center (a bit over 1 hour from Barcelona) are within a suitable distance of **approximately 1 hour by car from international airports**.

Furthermore, the UAS Test Center Denmark (2 hours from Copenhagen), the ATLAS Center (2 hours – but from Granada), and the Wales UAS Environment (2 hours from Cardiff) are reachable within **maximum 2 hours**, while the Finland UAS Centre can be reached from an international airport (Helsinki) in about 2.5 hours.

Also, numerous American and Canadian UAS test areas are reachable from international airports (by car) within comparable times to European test areas (not including the transatlantic flight times). Nevertheless, it must be considered that for Austrian UAS developers, any journey to the USA, Canada, or other areas outside of Europe is associated with a considerable increase in time and effort, such that, on the condition that the given affordances are equal, **Austrian developers might prefer European test areas. This preference may also be due to their possible accessibility by car directly from Austria (which would lead to a different ranking)**. However, such a “car distance from Austria” ranking would be unfair for an international overview, as only neighboring countries of Austria could be in consideration.

While the Lone Star UAS Center Test Site (Corpus Christi International Airport) is directly located at an international airport, the New York UAS Test Site, located at Griffiss International Airport that does not offer commercial flights though, can be reached in 45 minutes (from Syracuse International Airport), and the University of Maryland UAS Test Site can be reached within 1.5 hours by car (from Washington). Furthermore, the Tillamook Test Range and the Warm Springs Test Range can be reached within 2 hours from Portland, while travelling to the Canadian UAS Centre of Excellence requires 2.5 hours from Quebec. Access to the Pendleton Test Range (also located in Oregon) takes a journey of 3 hours by car also from Portland, and the Canadian Centre for Unmanned Vehicle Systems is reachable in 3.5 hours from Calgary. Australian test areas (both under military administration and not primarily intended for civil UAS testing) can be reached in 3 hours from Sydney or Canberra (Beecroft Weapons Range) and in 5 hours from Adelaide (Woomera Test Range).

The respective rankings of UAS test areas according to their accessibility and geographical position are presented in table 5:

	Worldwide	European
Rank	Name	Name
1 (0')	Lone Star UAS Center – *Texas, USA* CESA Drones Center – *Spain* *Both directly located at int'l airports*	CESA Drones Center – *France* *Directly located at Bordeaux Airport* *(although some remote subsites)*
2 (30')	Test Area Oberpfaffenhofen – *Germany* Drones Center Bretigny – *France* BOFORS Test Center – *Sweden* *All 30 minutes from int. airports*	Test Area Oberpfaffenhofen – *Germany* Drones Center Bretigny – *France* BOFORS Test Center – *Sweden* *All 30 minutes from int'l airports*
3 (40')	ONERA Test Area – *France* Grottaglie Airport Test Bed – *Italy* *Both 40 minutes from int. airports*	ONERA Test Area – *France* Grottaglie Airport Test Bed – *Italy* *Both 40 minutes from int'l airports*
4 (45')	CEEMA Test Center – *France* BUVUS Test Center – *Germany* New York UAS Test Site – *NY, USA* *All 45 minutes from int'l airports*	CEEMA Test Center – *France* BUVUS Test Center – *Germany* *All 45 minutes from int'l airports*
5 (60')	Droneport – *Belgium* Robonic Arctic (RATUFC) – *Finland* UAS Testzentrum Nord – *Germany* Netherlands RPAS Test Centre BCN Drone Center – Spain *All 1 hour from int'l airports*	Droneport – *Belgium* Robonic Arctic (RATUFC) – *Finland* UAS Testzentrum Nord – *Germany* Netherlands RPAS Test Centre BCN Drone Center – Spain *All 1 hour from int'l airports*

Table 5: *Worldwide and European ranking of test areas according to their accessibility and position (Driving time by car from the next international airport)*

5.5. *Costs of Usage and Services*

Most of the UAS test areas **have not published any public information about the costs** for executing tests, which can lead to the assumption that the actual costs can be negotiated in most cases. Nevertheless, it was possible to find respective **information for a few test areas**:

- The Deutsches Erprobungsgelände UAS (operated by bavAIRia) and the BUVUS Test Area in Germany are operated by local aerospace clusters with the objective of enabling UAS tests for their respective members. Consequently, it is necessary to be a member of these clusters and pay the annual membership fees in order to execute tests.

- The membership fee for BUVUS depends on the member category (private person, student, soldier, or enterprise). If the member is an enterprise, the cost is based on its annual revenue, which results in a possible membership fee ranging from €60 to €3,600 per year. The further costs for the actual testing at the local airfield Rotenburg (Wümme) are not published though.

- A similar cost model can be found at the test area of bavAIRia: The fee for the necessary membership of the cluster depends on the type of member (private person, university, or enterprise). If the member is an enterprise, the cost is based on the number of employees and therefore can be from €100 to €5,000. While the respective test area was located at the Grob company (German aircraft manufacturer) until spring 2017, a new location is being established at the special airfield Oberpfaffenhofen under administration of the EDMO company. Likely for this reason, fees for the actual use of the test area are not published yet. Nevertheless, the fees for using the test area at Grob Aircraft ranged from €250 per day (for UAS up to 25kg) to €950 per day (for UAS up to 150kg).

- As Austrian UAS stakeholders state (see study UAST), the costs for executing tests at the BCN Drone Center account for about €900 per day, which meets the requirements of more than 50% of the interviewed Austrian UAS stakeholders. Other test areas charge between €500 and €1500 for tests depending on the specific test site used, where the lower limit meets the requirements of more than a half of the respondents and the upper limit at least meets the requirements of 12% of respondents.

- CEEMA Test Center solely announced the costs for theoretical trainings: €2,500 for 8 days.

- The Netherlands RPAS Test Centre only published the costs for UAS certification flights for CAA approval: €2,200 per certificate.

- The New Mexico University UAS Test Site states on an internet forum that the costs of an entire flight campaign range from $5,000 to $500,000, depending on the number of flights, the complexity of the system, and other factors.

All of this information leads to the conclusion that the costs generally cannot be predetermined and are calculated on an individual basis. Therefore, a **serious ranking of the costs was not possible due to the lack of concrete public information** about the real costs for flying at the various UAS test sites.

5.6. Civil and / or Military Background

As already mentioned in section 4.4, numerous Austrian stakeholders have already executed UAS tests at military facilities and airspaces as they, despite their disadvantages, also entail the mentioned advantages for developers. As the worldwide survey shows, the practice of involving the military, its infrastructure, or airspace into UAS tests is a common way of establishing ideal testing conditions with low effort due to the military infrastructure and the necessary segregated airspace are already given and issues concerning local residents or environmental protection do either not occur or are already resolved. In total, **24 of the 42 researched UAS test areas (which equals 57%) have some military background**, whereas 10 test areas (24%) are either directly operated by the military or have primarily military purposes.

Furthermore, 14 test areas (33%) showed a mixed organization form of civil test areas in cooperation with military institutions, which results in the advantage for the military that **under-utilized or even abandoned (former) military airfields and other facilities find new applications**. The Drones-Center Bretigny, the BOFORS Test Center, the Denel Overberg Test Range, and the Challakere Aeronautical Test Range in India are operated by civil operators on, or in cooperation with, (former) military facilities, while the Andoya Test Center, the Swiss Army Test Center, the Vidsel Test Range, the Woomera Test Range, and the Beecroft Weapons Range are directly operated by militaries.

In addition, the Belgian Droneport, the Robonic Arctic Test UAV Flight Center, the CESA Drones Center, the Wales UAS Environment, the German UAS Test Center North, the BUVUS Test Center, the Grottaglie Airport Test Bed, the Netherlands RPAS Test Centre, the Tillamook Test Range, the Pendleton Test Range, the University of Maryland UAS Test Site, the New Mexico State University UAS Test Site, the New York UAS Test Site, and the Lone Star UAS Center Test Site are **mixed form, wherein both (former) civil as well as military airfields are used for primarily civil testing purposes**.

From the remaining **18 UAS test areas**, 9 test areas (UAS Test Center Denmark, Finland UAS Centre, German Test Area UAS, Northern Plains Unmanned Aircraft Systems Test Site, Warm Springs Test Range, Nevada Institute for Autonomous Systems, Canadian Centre for Unmanned Vehicle Systems, UAS Centre of Excellence Canada, and the UNICEF Drone Corridor in Malawi) **use abandoned or under-utilized civil airports or airfields** for executing tests, which entails similar advantages as the utilization of military facilities, apart from the fact that civil facilities are not necessarily located remotely from highly-populated areas.

The **remaining test areas** (BCN Drone Center, ATLAS Center, CEEMA Test Center, ONERA Test Center, Arctic Centre for Unmanned Aircraft, Alaska Center for Unmanned Aircraft Systems Integration, Mid Atlantic Aviation Partnership, RP Drone Training Centre, and Goheung Aeronautical/Aviation/Aerospace Center) **use neither existent civil nor military airfields** and therefore **need to set up all required infrastructure and organize the necessary airspace on their own**.

As the detected backgrounds of the existing UAS test sites – military and civil – revealed both advantages and disadvantages, a quantified ranking of these various backgrounds (especially of the respective infrastructure) is difficult to find. Because “old” (but well-established) infrastructure can be as useful as “new” ones (that still need to pick up pace). Additionally, the use of well-established (military) airspaces may compensate for the manifold constraints and burdens that often accompany the usage of military facilities. Therefore, it is finally a **very individualized decision regarding the preferred kind of environment and background**.

5.7. *Capability and Permission for BVLOS Tests*

As mentioned in sections 4.3 and 4.4, considering that the majority of Austrian UAS stakeholders require the possibility of executing BVLOS flights, as it is the most promising research field for the future, it is vital that a test area suitable for Austrian UAS stakeholders has the spatial and legal capabilities for BVLOS and more. In total, **12 (29%) of the researched UAS test areas officially stated that they offer the capability to execute BVLOS tests** (Droneport, UAS Test Center Denmark, BCN Drone Center, CESA Drones Center, Wales UAS Environment, Northern Plains Unmanned Aircraft Systems Test Site, Tillamook Test Range, Nevada Institute for Autonomous Systems, New Mexico State University UAS Test Site, Mid Atlantic Aviation Partnership, Canadian Centre for Unmanned Vehicle Systems, UAS Centre of Excellence). However, it **can be assumed that**, following the spatial dimensions**, BVLOS flights are also theoretically possible in 13 further test areas** (ATLAS Center, Grottaglie Airport Test Bed, Robonic Arctic Test UAV Flight Center, Vidsel Test Range, BOFORS, Warm Springs Test Range, Pendleton Test Range, New York UAS Test Site, Lone Star UAS Center Test Site, Woomera Test Range, Beecroft Weapons Range, Denel Overberg Test Range, UNICEF Drone Corridor), although not officially stated.

It must be noted that the operators' information about BVLOS capabilities must be treated with caution, as the real suitability might not be as high as stated (depending on the actual available airspace for BVLOS or mountainous topography). This possibility is considered in the rankings in table 6: Test areas with a larger airspace for official BVLOS tests are preferred, while those which did not state an official BVLOS airspace were not considered at all. Overall, the **ranking is focused on areas with official BVLOS airspace**.

	Worldwide	European
Rank	Name	Name
1	Tillamook test ranges (PPUTRC) *83,000km² – OR, USA*	Wales UAS Environment – *UK* *8.600km²*
2	New Mexico State University *39,000 km² – USA*	Denmark UAS Test Center – *Denmark* *867km²*
3	Wales UAS Environment *8,600 km² – UK*	Droneport – *Belgium* *84km²*
4	UAS Centre of Excellence *4,276km² – Canada*	CESA Drones – *France* *28km²*
5	Canadian Centre of UVS *2,400km² – Canada*	BCN Drone Test Center – *Spain* *25km²*

Table 6: *Worldwide and European ranking of test areas according to their BVLOS capability (Only sites with official BVLOS airspace ranked by lateral airspace dimension: see 5.1, table 1)*

5.8. *Test Area Ranking according to Austrian Requirements*

The overall test area ranking of the 42 worldwide analyzed UAS test areas (see section 3.4) is based on the individual rankings for diverse needs of Austrian developers (see section 4.4) as presented in the previous sections 5.1-5.7. Each of these "sub-ranking" points were awarded rank 1 (7 points), rank 2 (5 points), and so on. The aggregated total (sum) of those achieved points was the basis of the overall ranking presented in table 7 and 8:

	Worldwide
Rank	Name
1	**Pan-Pacific UAS Test Range Complex** (PPUTRC), including: - Tillamook Test Range - Warm Springs Test Range - Pendleton Test Range - Alaska Center for UAS Integration - and also Hawai UAS test facility (in development)
2	**Lone Star UAS Center Test Site** – *TX, USA*
3	**New York UAS Test Site** – *NY, USA*
4	**Woomera Test Range** – *Australia*
5	**UAS Centre of Excellence** – *Canada*
6	**Wales UAS Environment** – *UK*
7	**CESA Drone Center** – *France* **New Mexico State University UAS Test Site** – *NM, USA*

Table 7: Overall ranking of the researched UAS test areas – Worldwide

	European
Rank	Name
1	**Wales UAS Environment –** *UK*
2	**CESA Drone Center** – *France*
3	**UAS Test Center *Denmark***
4	**ATLAS Center** – *Spain* **Vidsel Test Range** – *Sweden* **BCN Drone Center** – *Spain*
5	**Robonic Arctic Test UAV Flight Center** – *Finland* **BOFORS Test Center** – *Sweden* **Grottaglie Airport Test Bed** – *Italy* **Droneport** – *Belgium*

Table 8: Overall ranking of the researched UAS test areas – Europe

A textual analysis of these results is given in the following conclusion (see section 6.1).

6. Conclusions and Outlook

6.1. Conclusions

This thesis has demonstrated the rapid development of new (potential) UAS applications and also highlighted the current regulatory challenges and developments on the international, European, and Austrian level, especially efforts by ICAO and EASA. Supporting the focus of this thesis, the **evident need for UAS testing for further technological improvements by Austrian UAS stakeholders was illustrated in section 4** (see Figure 19). In addition, this thesis has also presented the **current needs of Austrian stakeholders to execute UAS tests for prospective applications** such as BVLOS, sense and avoid, autonomy, operation of UAS under aggravated conditions (meteorological or loss of radio link), counter-UAS technologies, and also manifold payloads (see 4.4).

The rapid progress and evolvement of civil UAS testing and the need for appropriate test sites is illustrated by the high number of researched test sites, which also follows the stakeholders' increasing demand for both the execution of tests and the availability of suitable test facilities. **An important outcome of this thesis is the explication of 42 international UAS test areas** (presented in section 3.4), which have been compared and ranked according to the specific requirements of Austrian UAS developers (as presented in chapter 4, especially section 4.4). **The final result of this process are the rankings of the top 10 test areas worldwide that are best suited for Austrian developers and the top 10 areas in Europe (see 5.8).**

While the overall ranking in section 5.8 approaches the respective placement of each test area within the international environment and competition according to a mixed set of criteria, **the individual rankings** (sections 5.1-5.7) **focus the overall test area ranking on specific practical aspects** (e.g., airspace and spatial extension, capability of BVLOS tests, surface and topography, etc.) and serve as assistance for UAS developers in search of the best test area for their specific needs. Further research about a certain test area may still be necessary, as most of the research for the international overview was based on own statements by the test areas

The rankings of the test areas show that **many U.S. test areas best meet the diverse developer-relevant requirements** (see sections 5.1-5.8). As shown in section 5.1, the **major asset of U.S. test areas is huge available lateral airspace extension within low populated areas** (e.g., in deserts, over oceans). Furthermore, some U.S. test areas seem to have a low-threshold approach for gathering official approval for BVLOS flights, while the comparison of Austrian developers' need for tests in (pre-)alpine areas with the given topography at the researched test areas shows that no test area in Europe fulfills this requirement.

As the research shows, the majority of test areas are endeavored with the task to meet current testing requirements on the one hand, but also prospective test requirements (e.g., BVLOS, sense and avoid, autonomy) on the other hand. While **European test areas tend to be oriented toward developers and therefore intensively promote their facilities** (e.g., via webpages, displaying materials, presence at exhibitions, etc.) in order to attract potential clients, U.S. test areas, which are more likely operated by universities or research institutions and often with military cooperation, seem to rather orient themselves towards executing internal research, which means they present less (or even no) test-relevant data about their facilities. Nevertheless, even during this research, a deviation from this attitude was notable, as a few U.S. test areas began to expand to external developers.

The **use of already existent infrastructure and segregated airspace** (e.g., at military or airport facilities) seems to be a common concept, as numerous test areas have shown. The establishment of test areas at infrequently used airports and airfields is a method that contributes to their re-vitalization and also effortlessly (and quickly) provides a high-quality test environment.

The observation that a **significant part of the researched test areas therefore also cooperates with military institutions** suggests that within civil UAS testing, a link to the military is not only present but partially also necessary as the military progress regarding UAS technology development and the respective expertise is known to be far ahead compared to civil developments.

Furthermore, the majority of civil UAS test areas have been found to be **operated by consortia of manufacturers, governmental or military institutions, research institutions, and local clusters,** while none of the researched civil UAS test areas are operated by one single operator solely dedicated to earn money from this test area (so at least it provides sufficient test possibilities). This notion also suggests that the operation of a civil UAS test area may not be suitable for profit-oriented intentions.

In order to execute tests, the **great majority of test areas must have (temporarily) segregated airspace available,** which is either due to the use of existent control zones or an agreement with the local CAA for own segregated airspace. Such airspace is marked in the respective AIP charts and therefore increases the safety for testers, the “normal” air traffic, and local residents.

6.2. Outlook

Due to the increasing technological developments and the simultaneously growing need for tests it **can be expected, that, in addition to those which currently exist, more civil UAS test areas will be established in the future all over the world**. Nevertheless, the test requirements are expected to change according to the degree of technological sophistication, since new technologies lose the need to be tested once they are sophisticated and proven to be safe and functional. This development **might also lead to the disappearance of test areas which fail to successfully position themselves according to changing test requirements**. Nevertheless, the research has shown that **extensive airspace formally ensured by the respective aviation authorities (civil or military) is the best "life insurance" during this future process of UAS test site consolidation**.

Considering the results of this thesis, especially the 42 examples of international UAS test areas (see 3.4) compared to the needs of the Austrian UAS developers (see 4.4), **future development of UAS testing in Austria or conducted by Austrian companies will be quite interesting**. It can be expected that **Austrian UAS developers will try to intensify their domestic UAS testing, particularly because foreign UAS test areas that fulfill important criteria are quite far away and using Austrian military airspace (or installations) can often be quicker and easier** (see Figure 19). If any party takes the risk of establishing a civil UAS test area in Austria, with all of the business case risks that accompany it (the AAI study UAST by Fortner et al. in 2017 did not find any profitable civil UAS test areas in the world), this area will be quite unpredictable and may be dependent on unpaid work by idealists or public funding.

In the meantime, this thesis provides all interested Austrian UAS stakeholders – developers, researchers, operators, and more – with widespread background information about their possibilities abroad, particularly the extensive overview of 42 test areas worldwide (see section 3.4), the Austrian-oriented ranking of the top 10 UAS test areas worldwide, and the top 10 UAS test sites in Europe (see section 5.8).

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