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Legal perspectives on the cross- border operations of unmanned aircraft systems

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1 THE HISTORY, DEFINITION, USES AND TECHNOLOGICAL CHALLENGES OF UNMANNED AIRCRAFT SYSTEMS

1.1 HISTORICAL OVERVIEW

Even though the idea of unmanned flight was conceived 2500 years ago, unmanned aviation began in the same era as manned aviation The *Pigeon* is the first known self-propelled unmanned flying device. This invention has been attributed to Archytas[1] in Tarantas, Greece, around 425 BC[2] At that time, the *Pigeon* was an advanced machine designed to understand how birds fly. Later, humans experimented with other types of flying machines.

The use of UAS in warfare began near the end of the 19th century. On August 22, 1894, Austria deployed two hundred unmanned balloons with attached bombs over the city of Venice. Although the attack was unsuccessful, Austria received strikes back with the same devices in military reciprocity.[3] Despite the technological limitations of the time, UA grew during WWI (1914-1918). Missile and bomb delivery and training for anti-aircraft gun operators include some examples of the early applications of UAS. In Germany, between 1915 and 1918, Wilhelm von Siemens developed the Siemens Torpedo Glider. This device was launched from larger aircraft, such as Zeppelins and were then directed towards the desired target through a thin cable that controlled the Torpedo Glider.[4] The US also developed UAS. In 1917, Elmer Sperry and Peter Hewitt built a radio-controlled aircraft without a pilot on board called the Hewitt-Sperry automatic aeroplane. This machine could carry a 135 kg bomb and had a range of 80 km. The success and potential of the Hewitt-Sperry automatic aeroplane resulted in the US Army ordering the Kettering Aerial Torpedo. The operation of such

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1 Archytas of Tarentum was a Greek mathematician, political leader and philosopher, active in the first half of the fourth century BC (i.e., during Plato's lifetime). He was the last prominent figure in the early Pythagorean tradition and the dominant political figure in Tarentum, being elected general seven consecutive times. A great number of works were forged in Archytas' name starting in the first century BC, and only four fragments of his genuine work survive, although these are supplemented by a number of important testimonials.

2 Konstantinos Dalamagkidis, Les A. Piegl, and Kimon P. Valavanis. *On Integrating Unmanned Aircraft Systems into the National Airspace System: Issues, Challenges, Operational Restrictions, Certification, and Recommendations.* (Dordrecht: Springer, 2009), 12.

3 Russell Naughton. *Remote Piloted Aerial Vehicles.* Accessed April 25, 2018. http://www.ctie.monash.edu/hargrave/rpav_home.html

4 Benjamyn Ian Scott. 'Chapter 1 Overview'. In *The Law of Unmanned Aircraft Systems: An Introduction to the Current and Future Regulation under National, Regional and International Law* (Alphen Aan Den Rijn: Wolters Kluwer, 2016), 3.

a machine was novel. Pre-programmed mechanisms, enabled after a pre-determined flight time, caused the aircraft's engines to stop, their wings to detach and the rest of the fuselage to descend to the surface at high speed. Its 80 kg bomb exploded on impact with its target.[5] The interest in UAS was temporarily lost due to technical problems and the lack of accuracy. However, its potential for military applications survived, and further developments took place after the end of WWI.

In September 1924, the British performed the first successful radio-controlled unmanned flight without a safety pilot on board. The British used the modified RAE 1921 Target, which flew 39 minutes for gunnery practice. Although the Americans and British were the only ones to train their military forces with radio-controlled UA in WWII, the Germans also developed UAS technology. In 1944, Germany used the Fi-103 *Vergeltungswaffe* V-1, known as the buzz-bomb, in the cruise missile role. The pre-programmed UA exploded on impact with the selected target. Germans launched around 10,500 V-1s from coastal ramps, reaching their targets in London. The V-1 did not prove to be devastating, nor did it play a decisive role during WWII.[6]

In April 1946, the converted Northrop P-61 Black Widow performed the first unmanned flight into thunderstorms on a mission for science and research purposes to collect meteorological data for the US Weather Bureau.[7] The first unmanned flight for reconnaissance occurred in 1955 with the Northrop radio-plane SD-1 Falconer/Observer, later fielded by the US and the British armies.[8]

UAS also proved its potential for surveillance during the Cold War. The US used lightning bugs, a pre-programmed or remotely controlled UA, for surveillance over the airspaces of Cuba, North Korea and China. It also used these vehicles to observe Vietnamese territory during the war between the US and Vietnam, which ended in 1968.[9]

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5 Benjamyn Ian Scott. 'Chapter 1 Overview'. In *The Law of Unmanned Aircraft Systems: An Introduction to the Current and Future Regulation under National, Regional and International Law* (Alphen Aan Den Rijn: Wolters Kluwer, 2016), 4.

6 *The V1.* History Learning Site. Accessed April 29, 2018. https://www.historylearningsite.co.uk/world-war-two/world-war-two-in-western-europe/the-v-revenge-weapons/the-v1/

7 Konstantinos Dalamagkidis, , Les A. Piegl, and Kimon P. Valavanis. *On Integrating Unmanned Aircraft Systems into the National Airspace System: Issues, Challenges, Operational Restrictions, Certification, and Recommendations* (Dordrecht: Springer, 2009), 12.

8 Konstantinos Dalamagkidis, Les A. Piegl, and Kimon P. Valavanis. *On Integrating Unmanned Aircraft Systems into the National Airspace System: Issues, Challenges, Operational Restrictions, Certification, and Recommendations* (Dordrecht: Springer, 2009), 15.

9 *History of U.S. Drones.* Understanding Empire: Technology, Power, Politics. January 23, 2017. Accessed April 29, 2018. https://understandingempire.wordpress.com/2-0-a-brief-history-of-u-s-drones/.

Between 20 and 21 August 1998, Insitu Group's Aerosonde Laima performed the first trans-Atlantic unmanned flight between Bell, Newfoundland, Canada and Benbecula, Outer Hebrides, Scotland.[10]

UAS have expanded during the last 100 years. Due to their precise performance in military operations, the use of these aircraft is increasing. States prefer to use this technology in armed conflicts because they substantially reduce collateral damage, while the risk of losing their pilots in combat is nil. For example, in its first deployment in the Balkans in the mid-1990s, the Predator grew from an unmanned surveillance aircraft to one with lethal destruction capabilities. The Predator, a symbol of the US Air Force, is an aircraft used by that country in armed conflicts in the Middle East, Afghanistan, Pakistan, Bosnia and Kosovo. Other nations likewise use the Predator to fulfil their military objectives. For instance, the UK employs the Predator both to destroy targets of its enemies and for surveillance operations. However, a more powerful UA, the MQ-9 Reaper replaced the Predator in 2018.[11]

As military uses of UAS are growing, so are the new applications in civil functions. The 21st century is when UAS reached a significant development, distinct from military use. These advancements now include cartographic photography, cinematography, media reporting and sporting events. States are likewise using UAS in various ways, such as law enforcement patrol, border and surveillance of the sea and search and recovery. They also engage in the use of UAS to track disaster relief actions, such as floods, forest fires, earthquakes, volcanic explosions and chemical vapours, safety inspection for rail lines, dams and dikes and energy terminals, among others. However, the condition of civil or State UA will depend on who performs the tasks. If private organisations carry out these activities, it is thus an unmanned civil aircraft, whereas if the State performs them, the UA will have State status.[12] Chapter Two addresses these situations in greater depth.

Between 2013 and 2018, UAS have also ventured into innovative activities, such as spray crops, delivery of depot-to-depot packages and internet signals broadcasting to remote locations. For instance, DDC offers a depot-to-depot delivery logistics solution using UAS. This logistics delivery solution

10 Konstantinos Dalamagkidis. *Aviation History and Unmanned Flight.* SpringerLink. Accessed April 29, 2018. https://link.springer.com/referenceworkentry/10.1007/978-90-481-9707-1_93

11 Iain Thomson. *"US Air Force Terminates Predator Drones. Now You Will Fear the Reaper."* The Register® – Biting the Hand That Feeds IT. Accessed April 29, 2018. https://www.theregister.co.uk/2017/02/27/us_air_force_put_predator_drones/.

12 Benjamyn Ian Scott. 'Chapter 1 Overview'. In *The Law of Unmanned Aircraft Systems: An Introduction to the Current and Future Regulation under National, Regional and International Law* (Alphen Aan Den Rijn: Wolters Kluwer, 2016), 5

is ideal for rural areas to transport goods to and from warehouses.[13] The Amazon PrimeAir project is developing a delivery system designed to get packages to customers safely in 30 minutes or less, using UA.[14] Google is testing solar-powered UA at Spaceport America in New Mexico to explore ways to deliver high-speed internet from the air.[15] On June 28, 2017, Facebook completed the first successful flight of Aquila, its solar-powered UA that will beam internet service to remote parts of the world, and broke the record for the longest airborne UA.

Unmanned machines have already reached the stars. These vehicles not only act as satellites but also as unmanned spaceplanes, which can fly both in Earth's atmosphere and outer space. The US Air Force's unmanned X-37B, also known as the Orbital Test Vehicle (OTV), is a reusable unmanned spacecraft. The robotic vehicle resembles the National Aeronautics and Space Administration's (NASA) former space shuttle but is smaller. This space plane flies top-secret missions carrying classified payloads on flights of long duration in Earth orbit and cross the airspace of several nations while re-entering the atmosphere.[16]

Further, States may employ space drones to weaken potential adversaries. The Economic and Security Review Commission of the US (the Commission) and China reported to the Congress of the United States in November 2015 that since 2008, China has proven to have complex space proximity capabilities and its space activities show that China is developing co-orbiting anti-satellite systems to target American space assets. The Commission also found that in 2013, a Chinese satellite with a robotic arm successfully grabbed another Chinese satellite.[17] Space drones could also perform as service terminals in orbit. The Defence Advanced Research Projects Agency (DARPA) and NASA are developing technologies to prolong the life of space infrastructure in critical conditions. The space drones would inspect,

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13 *"Depot to Depot Drone Delivery."* Depot to Depot Drone Delivery. Accessed April 29, 2018. http://www.dronedeliverycanada.com/depot-to-depot-drone-delivery/

14 *Amazon Prime Air.* Robot Check. Accessed April 29, 2018. https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011

15 Mark Harris. *Project Skybender: Google's Secretive 5G Internet Drone Tests Revealed.* The Guardian. January 29, 2016. Accessed April 29, 2018. https://www.theguardian.com/technology/2016/jan/29/project-skybender-google-drone-tests-internet-spaceport-virgin-galactic

16 Wall, Mike. *'X-37B: The Air Force's Mysterious Space Plane.'* Space.com. August 08, 2017. Accessed April 30, 2018. https://www.space.com/25275-x37b-space-plane.html.

17 *Op-Ed | China's Well-crafted Counterspace Strategy.* SpaceNews.com. July 10, 2017. Accessed April 30, 2018. http://spacenews.com/op-ed-chinas-well-crafted-counter-space-strategy/

refuel and repair satellites through automatic arms and cameras to extend their operational lifetime in space.[18]

Model aircraft also played an important role in the current uses of UAS, because they are perhaps the aircraft that the public most prefers and uses because their prices are steadily dropping and becoming more accessible. Due to the growing use of UA for recreational purposes, the States and people have realised their risks for safety, security and privacy. The number of States regulating UAS for recreational purposes is also rising.

Ultimately, the flight of a UA with persons on board is no longer a fiction. The Jetstream 31 aircraft took off in April 2013, from Lancashire, England and landed in Inverness, Scotland, UK, as the first pilotless round-trip flight over British controlled airspace with two persons on board. On February 7, 2018, the world's first autonomous aircraft for passengers made its first public flight in China, taking off from Guangzhou City. These extraordinary achievements are the key to future developments of unmanned flights aimed at transporting passengers and cargo.[19]

UAS have the potential to build innovative civil applications, and they are the key to the future of civil aviation. The following section explains the classification and definitions applied to UAS.

1.2 DEFINING UNMANNED AIRCRAFT SYSTEMS

1.2.1 TERMINOLOGY

It is common to use various names to deal with UAS. While drafting this study, it was a challenge to apply a consistent term that has international recognition and that, at the same time, embodies the different categories of this unique machine. Except for the terms Remotely Piloted Aircraft (RPA) and Remotely Piloted Aircraft Systems (RPAS),[20] the absence of a standardised definition takes place in a moment of arduous work undertaken by States to write regulations expediting these technological innovations to fit into manned aviation while lessening the associated threats to the greatest extent.

18 Christian Davenport. *'Why DARPA and NASA Are Building Robot Spacecraft Designed to Act like Service Stations on Orbit'*. The Washington Post. December 22, 2017. Accessed April 30, 2018. https://www.washingtonpost.com/news/the-switch/wp/2017/12/22/why-darpa-and-nasa-are-building-robot-spacecraft-designed-to-act-like-service-stations-on-orbit/?utm_term=.ee40969a8a6c

19 *'Passenger Drone: Unmanned Plane Takes Maiden Flight over UK Skies'*. RT International. Accessed April 30, 2018. https://www.rt.com/news/uk-passenger-drone-flight-206/

20 Annex 2 Rules of the Air to the Chicago Convention 1944 provides official definitions for the terms RPA and RPAS.

The term *drone* is the most popular use by the media, industry and general population. In the common lexicon, *drone* means buzzing. The word comes from the Old English *drān* or *drǣn*, which means 'male bee'.[21] *Drone* is the oldest official denomination adopted by the US Army to refer to aircraft piloted by remote control. Commander Delmer Fahrney of the Radion Division of the Naval Research Laboratory of the US used the term in 1935 to characterise the system he was building for the US Navy, which emulated the Royal Navy's new DH 82B (Queen Bee), used for anti-aircraft gunnery practice in the UK. *Drone* became, therefore, the official US Navy name for UA for many decades.[22]

As the word *drone* is associated with lethal weapons and destruction in armed conflicts, it had negative tones that contributed to losing field even in the political sphere. States and private entities favoured more technical terminology to bypass political sensibilities.[23] For example, neither ICAO nor the US Federal Aviation Administration (FAA) use this term in their official documents and enacted regulations. However, EASA used *drone* in its Advanced Notice Proposed Amendment (A-Notice of Proposed Amendment (NPA)) on the *Introduction of a Regulatory Framework for the Operation of Drone* of July 31, 2015.[24]

There are alternative terms to point out UAS that have no universal applicability, such as unmanned aerial vehicles (UAV),[25] remotely operated aircraft (ROA),[26] unmanned drones (UD)[27] and remotely piloted aerial vehicles

21 Steven Robertson. *How Did Drones Get Their Name?*, Accessed on July 39, 2019. *Quadcopter Cloud*, 18 July 2016, www.quadcoptercloud.com/drones-get-name/

22 *History Tuesday: The Origin of the Term Drone.* Intercepts | Defense News. January 16, 2014. Accessed April 30, 2018. http://intercepts.defensenews.com/2013/05/the-origin-of-drone-and-why-it-should-be-ok-to-use/

23 Mark Edward Peterson. *The UAV and the Current and Future Regulatory Construct for Integration into the National Airspace System.* LL.M. thesis, McGill University, 2007 (Ottawa: Library and Archives Canada = Bibliothèque et Archives Canada), 521-612.

24 Benjamyn Ian Scott. 'Chapter 1 Overview'. In *The Law of Unmanned Aircraft Systems: An Introduction to the Current and Future Regulation under National, Regional and International Law* (Alphen Aan Den Rijn: Wolters Kluwer, 2016), 10.

25 The Canadian Aviation Regulation refers to unmanned aircraft as Unmanned Aerial Vehicle (UAV) See section 602.41: 'No person shall operate an unmanned air vehicle in flight except in accordance with a special flight operations certificate or an air operator certificate.' Also, this term has been witnessed in media reports and in some legal literature. See Stefan A. Kaiser, 'UAVs and Their Integration into Non-segregated Airspace, (2011), *Air and Space Law*, Issue 2, 161–172.

26 The FAA and the National Aeronautics and Space Administration (NASA) have in the past referred to RPAS as 'remotely operated aircraft' (ROA).

27 These have been defined by the European Commission as UAS that are automatically programmed without being piloted, even remotely. See European Commission Remotely Piloted Aviation System (RPAS): Frequently Asked Questions, Memo. Brussels (April 8, 2014).

(RPAV).[28] Further, the title of Article 8 of the Chicago Convention 1944 utilises the term *pilotless aircraft* to deal with aircraft capable of flying without a pilot but, interestingly, ICAO does not use these words. Instead, ICAO adopted the use of UA and UAS as general terminologies that cover a range of aircraft and their components, which have no pilot at all or where the pilot is in an isolated station. These aircraft include unmanned balloons, model aircraft , RPA , RPAS and autonomous aircraft . Hence, there are no better terms than UA and UAS to fit the different categories of this unique device. This is the reason why the author uses UAS and UA throughout this academic work when necessary to point out the aircraft only or its associated componets, which come from a global organisation specialised in international civil aviation in which practically all the countries of the world are the member States.

The technology already available for UAS is, to a certain extent, autonomous. For example, RPA use detect and avoid systems (DAA)[29] and autopilot technology, which analyses air streams to secure stability and can begin a default landing when it senses it is not capable of continuing a safe flight whereas a fully autonomous aircraft, such as the Ehang 184, has embedded a fail-safe system where, if any components malfunction or disconnect, makes the aircraft land at the nearest location to ensure safety.[30] The autonomous system itself decides to land the aircraft when it senses that the flight is in danger. To make such decisions, UAS use artificial intelligence (AI) technology.[31] However, because UAS are machines, they have no life to risk. Therefore, AI in UAS should incorporate artificial consciousness technology as well. Although AI makes autonomous operations possible, autonomous aircraft lack artificial consciousness[32] to deal with ethical decisions related to life and death that only humans can make. Autonomous aircraft do precisely what the software commands, whereas the software is

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28 The Italian Civil Aviation Authority (ENAC) issued in December 2013 a regulation titled 'Remotely Piloted Aerial Vehicles' (Mezzi Aerei a Pilotaggio Remoto) (RPAV), which provides legal framework for the operation of unmanned aircraft in the Italian airspace.

29 "*Detect and Avoid' System for Safe Integration of RPAS in Airspace*." Netherlands Aerospace Centre. January 30, 2018. Accessed May 02, 2018. http://www.nlr.org/news/detect-avoid-system-safe-integration-rpas-airspace/

30 *"EHANG | Official Site-EHANG 184 Autonomous Aerial Vehicle."* EHANG | 亿航官网. Accessed May 02, 2018. http://www.ehang.com/ehang184/

31 Artificial Intelligence: The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. See "Artificial Intelligence." Artificial Intelligence – Oxford Reference. June 16, 2017. Accessed May 02, 2018. http://www.oxfordreference.com/view/10.1093/oi/authority.20110803095426960.

32 A new generation of robots and softbots aimed at interacting with humans in an unconstrained environment shall need a better awareness of their surroundings and of the relevant events, objects, and agents. In short, the new generation of robots and softbots shall need some form of "artificial consciousness". See Consciousness and Artificial Intelligence. Accessed May 02, 2018. http://www.consciousness.it/CAI/CAI.htm.

a set of pre-set human algorithms that enable autonomous aircraft to fly in myriad scenarios.

Therefore, the complete absence of human intervention in autonomous operations is yet unclear. As both UA and autonomous aircraft use autonomous technology in their operations, no precise separation between the two categories of UA exists. This situation may create a multifaceted legal regime with complex legal effects that ICAO and States should pay particular attention.[33]

1.2.2 ICAO'S DEFINITIONS

ICAO defines UA as "an aircraft which is intended to operate with no pilot on board", whereas UAS means "an aircraft and its associated elements which are operated with no pilot on board."

Such definitions, incorporated in ICAO's Circular 328 on Unmanned Aircraft Systems (UAS), have no binding effects on States because the Circular only provides guiding interpretation for UA and UAS, along with a description of their operational conditions. Circular 328 also apprises States of the ICAO's emerging perspective on integrating UAS into non-segregated airspaces and at aerodromes. It considers the challenges that such integration will confront and encourage States to help produce ICAO's policy on UAS by providing relevant information regarding their experiences with UAS.[34]

Section 2.2 of Annex 7 on Aircraft Nationality and Registration Marks to the Chicago Convention 1944 provides that an aircraft intended to be operated with no pilot on board shall be further classified as unmanned.[35] Section 2.3 also states that UA shall include unmanned free balloons and RPA.[36] Also, ICAO also asserts that all UA, whether remotely piloted, fully autonomous or in combination, are subject to Article 8 of the Chicago Convention 1944.[37] It classifies UA into three categories accordingly: RPA, unmanned free balloons and autonomous aircraft.

Annex 2, which contains the Rules of the Air to the Chicago Convention

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33 Scott, Benjamyn Ian. 'Chapter 1 Overview'. In *The Law of Unmanned Aircraft Systems: An Introduction to the Current and Future Regulation under National, Regional and International Law* (Alphen Aan Den Rijn: Wolters Kluwer, 2016), 12.

34 ICAO Circular 328–*Unmanned Aircraft Systems (UA)*. Accessed April 19, 2018. https://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf

35 See Appendix 1.

36 "*Annex 7 – Aircraft Nationality & Registration Marks* Sixth Edition – July 2012 – Printed." ICAO Store. Accessed April 20, 2018. https://store.icao.int/annex-7-aircraft-nationality-and-registration-marks-chinese-printed.html.

37 ICAO Doc 10019 AN/507, *Manual on Remotely Piloted Aircraft Systems (RPAS)*, (Montreal: International Civil Aviation Organization, 2015), 1-1.

1944, provides official definitions for the terms RPA, RPAS and unmanned free balloons:

> "**Remotely piloted aircraft (RPA).** An unmanned aircraft which is piloted from a remote pilot station."
>
> "**Remotely piloted aircraft system (RPAS).** A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design."
>
> "**Unmanned free balloon.** A non-power-driven, unmanned, lighter-than-air aircraft in free flight."

For the term *autonomous aircraft*, which has no official status within ICAO, Doc 10019 AN507 on Manual on RPAS suggests the following definition:

> "**Autonomous aircraft**. An unmanned aircraft that does not allow pilot intervention in the management of the flight."[38]

Except for autonomous aircraft and unmanned free balloons that do not require human intervention, RPAs are aircraft, albeit remotely piloted. Just as with manned aircraft, the pilot is essential for safe and predictable flight because the RPA must interact with other civil aircraft and the air traffic management system (ATM). Accordingly, the RPA pilot shall hold a licence and is responsible for monitoring the aircraft at all times. To this end, the RPA pilot must be able to respond adequately to the instructions issued by the air traffic control (ATC), communicate by voice or data link as appropriate and be responsible for the safe conduction of the UA throughout the entire flight.

Another class of aircraft that merits consideration is model aircraft. In this respect, many States classify model aircraft as those designed, built and intended for sport or recreational applications and for which international regulations are not necessary.[39] Hence, the Chicago Convention 1944 and its Annexes do not apply to model aircraft. Nonetheless, this type of aeroplane is subject to national or regional laws and regulations. It would seem that the main reason for this aircraft to fall outside the Chicago Convention 1944 and its SARPs is that, due to its operational attributes, it could not carry out international flights, at least realistically. Regulating this aircraft remains, therefore, at the discretion and sovereign convenience of States.

ICAO stated that all UA, whether remotely piloted, fully autonomous or

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38 ICAO Doc 10019 AN/507, *Manual on Remotely Piloted Aircraft Systems (RPAS)*, (Montreal: International Civil Aviation Organization, 2015), *iv.*

39 ICAO Doc 10019 AN/507, *Manual on Remotely Piloted Aircraft Systems (RPAS)*, Montreal: International Civil Aviation Organization, 2015), 1-8.

a combination of both are subject to Article 8 of the Chicago Convention 1944. However, it also asserted that only RPA would join the international civil aviation system in the future. Entirely autonomous aircraft operations are not in this endeavour, nor are unmanned free balloons or other types of aircraft that cannot be managed on a real-time basis during flight.[40] By deduction, this contradiction proves that ICAO is putting its efforts into accommodating only RPAS into the international airspace and leaving outside autonomous aircraft, which also fit into the scope of Article 8 of the Chicago Convention 1944.

Bodies other than ICAO have also adopted the terms UA and UAS in their drafted or enacted regulations for UAS such as EASA and the US FAA

1.2.3 EASA'S DEFINITIONS

EASA, for instance, developed the Notice of Proposed Amendment (NPA) 2017-05 (A) in line with the Basic Regulation (EC) No 216/2008 of the European Parliament and of the Council of February 20, 2008, on common rules in civil aviation and the Rule-making Procedure. This rule-making activity includes the EASA 5-Year Rule-making Programme under the rule-making task (RMT) 0230.[41] EASA developed the referred NPA based on the input of the UAS expert group and gave the following definitions to UA and UAS:

> "**Unmanned aircraft (UA)** means any aircraft operated or designed to be operated without a pilot on board, which has the capacity to operate autonomously or to be piloted remotely;"
>
> "**Unmanned aircraft system (UAS)** means the UA and any equipment, apparatus, appurtenance, software or accessory necessary for the safe operation of the UA."

It is not clear if this term will turn into law, as the proposed EU Parliament and Council Regulation must still go through the full EU legislative process.[42]

1.2.4 FAA'S DEFINITIONS

Part 107 of the Federal Aviation Regulations (FAR) of the US apply to non-hobbyist small UA operations. The regulations cover a broad spectrum of

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40 ICAO Circular 328 – *Unmanned Aircraft Systems (UA).* Accessed April 19, 2018. https://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf

41 NPA 2017-05. EASA. December 08, 2017. Accessed May 01, 2018. https://www.easa.europa.eu/document-library/notices-of-proposed-amendment/npa-2017-05

42 Benjamyn Ian Scott. 'Chapter 1 Overview'. In *The Law of Unmanned Aircraft Systems: An Introduction to the Current and Future Regulation under National, Regional and International Law* (Alphen Aan Den Rijn: Wolters Kluwer, 2016), 10

commercial uses for UAS weighing less than 55 pounds.[43] The FAA defines UA and UAS as follows:

> "**Unmanned aircraft** means an aircraft operated without the possibility of direct human intervention from within or on the aircraft."

> "**Small unmanned aircraft system** (small UAS) means a small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system."

1.2.5 CONCLUDING REMARKS

Because of the consensus in the international community materialised through ICAO on the most appropriate terms that merge the different categories of unmanned aircraft, this study will use the acronyms UA and UAS: UA when referring only to the unmanned aircraft or, when necessary, UAS to refer to both the aircraft and the system. As the following chapters cover the legal implications of the cross-border operation of UA, it is necessary to understand and apply these terms correctly.

1.3 CIVIL USES OF UNMANNED AIRCRAFT

1.3.1 CLASSIFICATION OF AIRCRAFT

UA have a countless list of civil uses other than military, customs and police services, which the Chicago Convention 1944 classifies as State aircraft.[44] An aircraft is classified as State or civil, depending upon the use to which the aircraft is being put.[45] Further, the function for which the aircraft serves will determine its status of State or civil, regardless of the technical design, registration marks, ownership or crew of the aircraft.[46] Thus, a commercial air carrier's Boeing 747 flying troops might be classified as a military aircraft, while an F-14 flying emergency serum to arrest an outbreak of disease might be considered a civil aircraft.[47]

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43 *Part 107—Small Unmanned Aircraft Systems.* ECFR Code of Federal Regulations. Accessed May 01, 2018. https://www.ecfr.gov/cgi-bin/text-idxSID=e331c2fe611df1717386d29eee38b000&mc=true&node=pt14.2.107&rgn=div5#se14.2.107_13

44 See Article 3 of the Convention on International Civil Aviation of 1944.

45 Pablo Mendes de Leon. *Introduction to Air Law*. (Alphen Aan Den Rijn: Kluwer Law International, 2017), 15.

46 Milde, Michael. *International Air Law and ICAO*. Hague, The Netherlands: Eleven International Pub.), 2012. 73

47 Milde, Michael. 'The Chicago Convention – Are Major Amendments Necessary or Desirable 50 Years Later? XIX Annals of Air & SPACE (1994), 401-418.

1.3.2 THE POTENTIAL USE OF UNMANNED AIRCRAFT SYSTEMS IN THE INTERNATIONAL CIVIL AVIATION

For the purposes of this study, it is crucial to consider UAS improvements, not only from the perspective for potential cross-border operations described in the introduction of this study but also from the context of a new element in international civil aviation.

The civil uses of UA go beyond surveillance, photography or videos. UAS are transforming daily activities in some industries. For example, insurance corporations use UA to inspect damaged assets. Farmers are sending UA to monitor crops and collect soil data. UA also has a spot in entertainment and advertising, whether pulling banners or setting light shows. The latest progress in the civil functions of UA is the delivery of goods and air taxis for commuters. Even more exciting is UA equipped to beam radio or video signals of bandwidth to extend connectivity to inaccessible locations or enhancing connectivity when demand grows.[48]

The International Air Transport Association (IATA) is also studying how UAS can be a facilitator for commercial airlines. In this endeavour, IATA works to discuss the benefits and opportunities of air freight services using UA.

UAS technology is creating a range of opportunities to enhance efficiencies across the aviation industry, such as launching new routes, cutting costs, boosting revenues and serving new markets on the cargo side. IATA looks forward to helping embrace this growing division of air cargo as IATA believes there are real business opportunities for the aviation industry in three main areas:

1. <u>Airport and ground operations:</u> Ground for safety checks and maintenance for aircraft and runways, airport perimeter monitoring, bird and wildlife control and warehouse operations, such as sorting and inventory.
2. <u>Transport of goods:</u> Transport of parcels, general and special cargo in urban space and rural and remote locations.
3. <u>Transport of passengers:</u> UA for tomorrow's travel by air, including urban mobility.[49]

UA can have a crucial role in carrying persons safely or delivering goods efficiently to remote places, whether medicines for a critical patient or

48 Pamela Cohn, Alastair Green, Meredith Langstaff, and Melanie Roller. '*Commercial Drones Are Here: The Future of Unmanned Aerial Systems*. McKinsey & Company. Accessed May 03, 2018. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/commercial-drones-are-here-the-future-of-unmanned-aerial-systems

49 *Cargo Drones.* IATA. Accessed May 03, 2018. http://www.iata.org/whatwedo/cargo/Pages/cargo-drones.aspx

urgent spare parts for a shut-down oil rig. UA could also offer first- and last-mile delivery and enhance overall performance in the supply chain of cargo transport. The cross-border operations of UA could assist in deliveries in neighbouring countries, particularly in regions that lack adequate road transport infrastructure. With these developments, the potential for the civil use of more advanced generations of UA within a country and across borders is therefore realistic.

1.4 COMMONALITIES AND DIFFERENCES BETWEEN THE OPERATIONS OF MANNED AND UNMANNED AIRCRAFT

1.4.1 SAFETY STANDARDS IN MANNED AND UNMANNED AIRCRAFT ALIKE

The association of commonalities and differences in the operation of manned aircraft and UAS is essential not only to address legal and regulatory challenges but also to achieve an adequate level of safety in integrating UAS into the civil aviation industry. An adequate level of safety implies a situation where the cross-border operations of UAS must be as safe as manned civil aircraft, to the degree that UAS shall not render any harm or risk to people and property that is any greater than operating manned aircraft. UAS shall operate, therefore, under the rules governing the flight of manned aircraft and meet the technical and operational requirements relevant to the airspace within which they will fly.

1.4.2 COMMON AERODYNAMIC FEATURES

A UA has the same aerodynamic features as a manned aircraft. A UA being an aircraft is, therefore, a machine that can derive support in the atmosphere from the reactions of the air, other than the reactions of the air against the earth's surface.[50] The status of aircraft is not affected by the condition of manned or unmanned, civil or State aircraft. A UA is an aircraft because it relies on its wings, whether rotatory or fixed, for lift.

1.4.3 THE ROLE OF THE CABIN CREW

Special consideration is necessary regarding the cabin crew present in manned aircraft. Although UAS technology and rules are not yet mature enough to engage in the international carriage of persons, depending on the number of seat passengers in the UA, the cabin crew will continue to be necessary for the equation, as its role is fundamental in the interest of the

50 See definition of 'aircraft' in Annex 7 – Aircraft Nationality and Registration Marks – to the Chicago Convention 1944.

safety of the passengers on board.[51] This statement is consistent with *section 12.1, Assignment of Emergency Duties of Annex 6 – Operation of Aircraft to the Chicago Convention 1944*, which provides that the operator shall establish, to the satisfaction of the State of the Operator,[52] the minimum number of cabin crew required for each type of aeroplane, based on seating capacity or the number of passengers carried in order to effect a safe and expeditious evacuation of the aeroplane and the necessary functions to be performed in an emergency or a situation requiring emergency evacuation. The operator shall assign these functions to each type of aeroplane. Therefore, passenger UAS manufacturers and passenger UAS operators must be able to demonstrate such competencies to the civil aviation authority of the corresponding State to an extent similar to manned aircraft.

1.5 CONTRIBUTIONS OF UNMANNED AIRCRAFT SYSTEMS TO CIVIL AVIATION

1.5.1 THE REPORT OF RESEARCH & MARKETS

In February 2018, *Research & Markets* published a report on the UAV Market to 2025—Global Analysis and Forecasts by Component by Type and Application, which predicts that the UAS market will grow from US $11.45 billion in 2016 to US $51.85 billion by 2025[53]. In 2017, the civil uses of UA grew, resulting in businesses rendering better services and heightened products to the users. Increases in sales together with software improvements for UAS created not only aggressive competition in the market but also company layoffs and low market entry barriers. The report suggests that the lack of a defined regulatory framework for the civil operations of UAS is the leading factor for the average performance of the UAS industry.

Among the driving agents contributing to the market growth are the rise of government budgets for military UA and the increasing uses of UA in the commercial sector such as mining, oil & gas, telecommunications and retail

51 Annex 6 Operation of Aircraft to the Chicago Convention 1944 provides the following definition for cabin crew member: a crew member who performs, in the interest of safety of passengers, duties assigned by the operator or the pilot-in-command of the aircraft, but who shall not act as a flight crew member.

52 Annex 6 Operation of Aircraft to the Chicago Convention 1944 provides the following definition for State of the Operator. The State in which the operator's principal place of business is located or, if there is no such place of business, the operator's permanent residence.

53 Based in Dublin, Ireland, Research & Markets is the largest market research store connecting global information professionals with market insights and analysis from 1,700 research teams based across 81 countries. See Research and Markets, Ltd. 'About Us – Research and Markets'. Research and Markets – Market Research Reports – Welcome. Accessed May 04, 2018. https://www.researchandmarkets.com/info/about.asp

industries. The report estimates that UA delivery services will reinforce the market in the forecast period. African countries like Cameroon, Malawi, Rwanda and Tanzania are performing UA delivery services. UA delivery service in the US is still in the trial stage, while the government continue making changes in UAS regulations. Emerging economies with lack of transportation infrastructure will also enjoy the UA delivery service.[54]

1.5.2 THE REPORT OF GLOBAL MARKET INSIGHTS, INC.

A more conservative study concerning economic performance from Global Market Insights, Inc. determines that the commercial UAS market will reach $17bn by 2024.[55] The report addresses UAS market size and covers data by uses, product, mode of operation and current level of the industry. The analysis outlook encompasses multiple markets, such as the US, Canada, UK, Germany, France, Italy, Spain, Australia, China, India, Japan, South Korea, Brazil, Mexico, Argentina, UAE, Israel and South Africa. The report confirms that drives for revenue in the UAS market include advanced machine learning algorithms and AI to unlock new avenues for UA civil uses.

The autonomous commercial UAS market will gain substantial growth during the forecast period, as they can operate on their own and do not require human intervention. Their ability to perform hazardous tasks with higher accuracy and cost-effectiveness is one of the major factors driving their demand. For instance, the Zipline company uses its fleet of autonomous aircraft to deliver blood in Rwanda and render medical relief in remote areas of East Africa. It also gives attention to emerging UA services in the agriculture industry as one of the principal end-users in the UA service demand. Applications like soil analysis, crop monitoring, health assessment, planting, crop spraying and irrigation are among the activities with high demand.

The North America region leads the civil UA market due to increasing adoption for innovative capture and discovery of events through filming, video and aerial photography. However, the Asia-Pacific region will grow

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54 Research and Markets, Ltd. 'Unmanned Aerial Vehicle (UAV) Market to 2025 – Global Analysis and Forecasts by Component by Type and Application'. Research and Markets – Market Research Reports – Welcome. Accessed May 03, 2018. https://www.researchandmarkets.com/research/vx2jd5/global_unmanned?w=5

55 Global Market Insights Inc., an American-based company, is a global market research and management consulting company catering to leading corporations, non-profit organisations, universities and government institutions. Their main goal is to assist and partner organisations to make lasting strategic improvements and realize growth targets. Their industry research reports are designed to provide granular quantitative information, combined with key industry insights, aimed at assisting sustainable organisational development. See *About Us, Global Market Insights Delaware.* Accessed May 04, 2018. https://www.gminsights.com/about-us.

during the forecast period due to the rapid increase in knowledge for civil UA applications and the escalating support of governments in UA commercial activities.

Chinese UA manufacturers, such as DJI and Xiaomi, will contribute to the growth of the commercial UA aviation market. Finally, Global Market Insights' report also identifies the most important sales companies contributing to the civil UA market. The list includes 3D Robotics, AeroVironment, Airobotics, Airware, Amazon PrimeAir, BAE Systems, Cyberhawk Innovations Ltd., DroneDeploy, DJI, Ehang Inc, Hoverfly Technologies, Intel Corporation, Parrot, PrecisionHawk, senseFly and Yuneec International.[56]

1.6 TECHNOLOGICAL AND OPERATIONAL CHALLENGES

1.6.1 ICAO'S VIEW

The complete absence of a pilot to manage the flight or a pilot on board the aircraft produces challenges regarding safety and security-related responsibilities. To overcome such challenges, ICAO assessed that the introductions of technologies to detect and avoid (DAA), command and control (C2) link, communications with ATC and avoidance of unintended or unlawful interference, such as data link spoofing, hijacking and jamming are necessary.[57]

Despite current technological developments, the cross-border operations of civil UA also require certified technology to fly beyond the visual line of sight (BVLOS) and beyond the radio line of sight (BRLOS).

1.6.2 DETECT AND AVOID (DAA)

Annex 2, on Rules of the Air to the Chicago Convention 1944, defines DAA as "the capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action.[58] In its Manual on RPAS, ICAO states that this capability intends to ensure the safe flight of an RPA and facilitate its full integration in all airspace classes with all airspace users. For this purpose, the RPA needs suitable technology and procedures analogous to those pilots of manned aircraft have, such as vision, hearing, touch and associated cognitive processes.

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56 "Commercial Drone Market Outlook – UAV Industry Size Forecast 2024." Accessed May 04, 2018. https://www.gminsights.com/industry-analysis/unmanned-aerial-vehicles-UAV-commercial-drone-market

57 ICAO Circular 328 – *Unmanned Aircraft Systems (UAS).* Accessed April 19, 2018. https://skybrary.aero/bookshelf/content/bookDetails.php?bookId=3202

58 ICAO. Annex 2 *Rules of the Air: International Standards* (Montreal: International Civil Aviation Organization, 2005), 1-5.

RPA may combine several systems and sensors to detect and avoid different hazards under a variety of environmental conditions. The systems may need to be interoperable when the RPAS has more than one DAA system to assure a proper and coordinated avoidance action when different hazards present simultaneously, such as conflict traffic vs terrain or obstacles. For airspace different from airspaces where ATC provide separation services between all aircraft, DAA equipment and associated procedures may also be necessary for hazards other than mid-air collisions (MAC).[59]

1.6.3 AIR TRAFFIC CONTROL (ATC)

Remote pilots have the same requirements as pilots on board the aircraft for communications with the ATC. Besides the very high frequency (VHF)[60] voice, the ATC data link is also necessary for RPA, according to ICAO's Manual on RPAS . As the remote pilot is not on board the aircraft, alternative communication architectures are available:

- Via the RPA, which is direct to ATC and needs no further infrastructure or equipment. The ATC may need broad bandwidth on the C2 link to support voice and data relay; or,
- Via a new broadcast, private or networked communications link between the ATC unit and the remote pilot.[61]

The ATC communications shall satisfy the performance for the airspace in which the RPA is flying. It could also include a telephone backup if allowed by the ATC units involved.[62]

1.6.4 COMMAND AND CONTROL (C2) LINK

The C2 link, which connects the RPS and the RPA to conduct the flight, may be simplex or duplex. It may also be in radio line of sight (RLOS) or beyond radio line of sight (BRLOS) as described in ICAO's Manual on RPAS: [63]

- RLOS: Applies to the situation in which the transmitters and receivers are within mutual radio link coverage and therefore can reach out directly or through a ground network, provided that the remote trans-

59 ICAO. *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015), 10-1.

60 The VHF frequency is shared by all aircraft within range.

61 ICAO. *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015), 10-1.

62 ICAO. *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal, Canada: International Civil Aviation Organization, 2015), 12-1.

63 *Command and control (C2) link.* The data link between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight. See ICAO, *Manual on Remotely Piloted Aircraft Systems (RPAS)* (Montreal: International Civil Aviation Organization, 2015), xv.

mitter has RLOS to the RPA and transmissions are completed in a comparable timeframe; and,
- BRLOS: Refers to any configuration in which the transmitters and receivers are not in RLOS. BRLOS thus incorporates all satellite systems and perhaps any system where an RPS communicates with one or more ground stations via a terrestrial network that cannot perform transmissions in a timeframe analogous to that of an RLOS system.

The difference between RLOS and BRLOS concerns whether any part of the communications link introduces a noticeable or variable delay into the communications than the architecture of the link.[64]

1.6.5 THE OPERATIONS OF UNMANNED AIRCRAFT SYSTEMS BEYOND THE VISUAL LINE OF SIGHT (BVLS) AND BEYOND THE RADIO LINE OF SIGHT (BRLOS)

According to ICAO's Manual on RPAS, the BVLOS operations take place when neither the remote pilot nor RPA observers can keep direct unaided visual contact with the RPA. BRLOS operation occurs when any part of the configuration of the transmitters and receivers are not in RLOS. Minimal equipment requirements to support BVLOS and BRLOS operations grow as the range and complexity of such operations increase, as does the cost associated with ensuring the robustness of the C2 link. Further, the ability to identify conflicting traffic or obstacles and take proper action to avoid them is also fundamental.[65]

Also, according to ICAO's RPAS manual, to conduct flights BVLOS of the remote pilot or RPA observer must have available a means to access DAA traffic and all other hazards, such as hazardous meteorological conditions, terrain and obstacles to the remote pilot.[66] Before conducting a controlled BVLOS operation, coordination is necessary with the ATC units involved. The coordination shall include at least the following elements:

a. Any operational performance limitations or restrictions unique to the RPA, such as the impossibility to perform standard rate turns;
b. Any pre-programmed lost C2 link flight profile and flight termination procedures; and,
c. Direct telephone communication between the RPS and the ATC units for contingency use unless otherwise approved by the ATC units involved.[67]

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64 ICAO. *Manual on Remotely Piloted Aircraft Systems (RPAS)* (Montreal: International Civil Aviation Organization, 2015), 2-1.

65 ICAO. *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015), 2-5.

66 ICAO, *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015), 9-2.

67 ICAO, *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015), 9-3.

Also, communication between the RPS and the ATC units should be under the class of airspace in which operations occur and should utilise standard ATC communications equipment and procedures unless otherwise approved by the ATC units involved. C2 link transaction time should be minimal so as not to inhibit the remote pilot's ability to interface with the RPA compared to that of a manned aircraft. The nature of the C2 link, whether RLOS or BRLOS, will also influence the design of the RPAS.[68]

RPS engaged in BVLOS operations shall match the C2 link's performance, whether BRLOS or RLOS, with which they will operate, as the more time-critical the control functions, the higher the level of RPA automation necessary to maintain safe flight.[69]

Admission of BVLOS operations under visual flight rules (VFR) will apply only under the following conditions:

1. The State of the Operator and the State in whose airspace the operation occurs approved the operation;
2. The RPA remains in visual meteorological conditions (VMC) throughout the flight; and,
3. The RPA uses a DAA capability or other mitigation to assure the RPA remains well clear of all other traffic; or,
4. The area is void of other traffic; or,
5. The operation occurs in the delimited or segregated airspace.[70]

1.7 CONCLUSIONS

The concept of the use of unmanned aviation is ancient. Its most significant progress took place in the last 100 years in State and civil uses. New technology developments using unmanned machines now perform in outer space. Cross-border operations carrying passengers and cargo via UA will soon be a reality.

Because the use of UAS is real and is exponentially outpacing the law, there is an urgent need for regulation that expedites the cross-border operations of this revolutionary machine. For this purpose, a joint effort is imminent between ICAO, States, academia and the leading actors of the aviation industry.

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68 ICAO, *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015, 9-3.

69 ICAO, *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015), 9-4.

70 ICAO, *Manual on Remotely Piloted Aircraft Systems (RPAS)*. Montreal: International Civil Aviation Organization, 2015), 9-4.

Several terms refer to UAS. For conceptual accuracy and to gain international acceptance, the acronyms used in this study that refer to all categories of unmanned aircraft are UA and UAS. According to ICAO, UA includes the following aircraft: RPA/RPAS, model aircraft, unmanned balloons and autonomous aircraft. ICAO dedicates its efforts to regulate only RPAS. It is a matter of attention that autonomous aircraft stand outside the scope of work developed by ICAO on UAS. As highlighted in the previous sections, the potential for both cargo and passenger operations using UAS are mostly autonomous. ICAO must, therefore, act urgently, so that autonomous aircraft can also incorporate into the airspace for cross-border operations.

UAS technology is producing myriad opportunities to increase capabilities across the aviation business, such as introducing new routes, decreasing costs, boosting revenues and serving new markets, particularly on the cargo side. With the technology in place, which several companies are building, cross-border flights of UA will be a reality in the coming years. Owing to its adaptability and high operational efficiency, it is likely that cargo operations will lead flights of UA in foreign airspaces. In the second phase, they will venture into the carriage of passengers.

Both *Research and Markets* and *Global Market Insights* market studies on commercial uses of UA, analysed in section 1.5, concluded that the impact of these machines on the global economy is positive. Studies predict that the market will grow in the coming years, mainly in the areas of delivery of products and agricultural services. Its success will depend on the speed of ICAO and the States in adopting adequate regulations that boost their growth.

As there is no pilot on board a UA, it is imperative to address technological and operational challenges in the cross-border operations of UAS. For this purpose, introducing certified technology in areas like DAA, C2 link and ATC are crucial, because those technologies will enable UA to fly BVLOS and BRLOS. Since under the laws, regulations and procedures of the States in which the flight takes place, UA pilots have the same essential responsibilities as manned aircraft pilots, such as regulations to address the required training, medical certification and competency of the UA pilot before issuing a licence are also necessary.

Finally, the preliminary conclusion of this research is that the Chicago Convention 1944, ICAO's SARPs and other ICAO regulations form the legal and regulatory foundations on which new rules for cross-border operations of UAS will be, as established in this study.