

UC Berkeley

Recent Work

Title

A Legal and Regulatory Assessment for the Potential of Urban Air Mobility (UAM)

Permalink

<https://escholarship.org/uc/item/49b8b9w0>

Authors

Serrao, Jacqueline

Nilsson, Sarah

Kimmel, Shawn

Publication Date

2018-11-21

DOI

10.7922/G24M92RV

Final Report

A Legal and Regulatory Assessment for the Potential of Urban Air Mobility (UAM)

Jacqueline Serrao
Sarah Nilsson
Shawn Kimmel

SUBMISSION DATE:

November 21, 2018

SUBMITTED TO:

National Aeronautics and Space Administration

Attn: Nancy Mendonca
Jonnelle Goff

SUBMITTED BY:

Booz Allen Hamilton
8283 Greensboro Drive
McLean, VA 22102

Contract Number:
BPA No. NNH13CH54Z
TIN: 36-2513626
DUNS: 00-692-8857
CAGE: 17038

doi:10.7922/G24M92RV

TABLE OF CONTENTS

1.0	INTRODUCTION	4
2.0	LEGAL AND REGULATORY ASSESSMENT	4
2.1	Methodology	4
2.2	Legal and Regulatory Barriers	4
2.2.1	Federal versus State “Tug of War”	5
2.2.2	UAS Integration Pilot Program (UAS IPP)	6
2.3	State and Local Regulatory Arena	6
	Arizona	6
	California	7
	Colorado	7
	Florida	7
	Hawaii	8
	New York, NY	8
	Texas	8
	Washington, D.C. Metropolitan Area	9
2.4	International Regulations	9
2.4.1	European Aviation Safety Agency (EASA)	9
	United Kingdom	10
	Ireland	10
	New Zealand	10
	Canada	11
	United Arab Emirates	11
	Germany	11
2.5	Airworthiness Certification Standards and Regulations	11
2.5.1	Airworthiness Certification Approaches	12
2.5.2	International UAM Certification Landscape	14
2.5.3	Domestic UAM Certification Landscape	18
2.5.4	FAA Part Certification Process	19
2.5.5	How Consensus Standards Support Certification: Means of Compliance	21
2.5.6	Current Standards Provide Means of Compliance	22
2.5.7	Gaps in Standards	24
2.5.8	Potential Gaps in Means of Compliance for UAM: General and Propulsion/ Energy Storage	24
2.5.9	Potential Certification Approaches for Air Taxi and Air Ambulance	26
2.5.10	Enabling Strategies	27
3.0	SUMMARY AND KEY FINDINGS	<i>Error! Bookmark not defined.</i>

LIST OF FIGURES

Figure 1: Trade-off between risk tolerance and level of certification rigor with FAA certification categories	13
Figure 2: NATO STANAG level of certification rigor increases with lower risk acceptance	13
Figure 3: International UAS regulatory field (Cuerno-Rejado, 2010)	14
Figure 4: Comparison for FAA and EASA Regulatory Framework Independence Metric	16
Figure 5: Paths to FAA airworthiness certification	18
Figure 6: Range of certification approaches for hybrid fixed wing and rotary aircraft	19
Figure 7: The type design approval process.....	20
Figure 8: Part 21.17(b) certification process	21
Figure 9: Sample means of compliance from Part 23	22
Figure 10: Sample results from the ASTM F38 standards gap analysis for UAS	24
Figure 11: UAM concept vehicles may fall along a spectrum ranging from resembling fixed wing or rotary aircraft	27

LIST OF TABLES

Table 1: International Type Certification Comparison	16
Table 2: Summary of key standards, gaps, and activities	25

1.0 INTRODUCTION

Urban Air Mobility (UAM) is an emerging concept of air transportation where small package delivery drones to passenger-carrying air taxis operate over populated areas, from small towns to the largest cities are being considered. This could revolutionize the way people move within and around cities by shortening commute times, bypassing ground congestion, and enabling point-to-point flights across cities. In recent years, several companies have designed and tested enabling elements of this concept, including; prototypes of Vertical Take-Off Landing (VTOL) capable vehicles, understanding of operational concepts, and development of potential business models. While UAM may be enabled by the convergence of several factors, several challenges could prevent its mainstreaming, such as legal and regulatory barriers.

2.0 LEGAL AND REGULATORY ASSESSMENT

Technology very quickly outpaces regulation. With Urban Air Mobility, as with other disruptive technologies, federal, State, and local-level governments must find a “sweet spot” where innovation is not stifled, and the public is reasonably protected. Urban Air Mobility operations raise novel and valid concerns, namely in terms of safety and privacy, and some legal barriers exist which can discourage the use of such technology. However, these legal barriers are accompanied by collaborative opportunities such as the UAS Integration Pilot Program, FAA Rulemaking Committees, the UAM Grand Challenge, and others, which allow for the alignment of technology and regulation, creating new enabling rules that allow for more complex operations.

2.1 Methodology

This assessment identified the legal and regulatory requirements (existing and anticipated) that must be met for the selected three focus UAM markets. It also captured variations in requirements observed at the State and local level, international developments, certification issues, and existing opportunities to address legal barriers and gaps.

Our team examined the law and regulatory conditions needed for the UAM markets to perform in selected urban areas under the following operations: (1) onboard pilot, (2) remotely operated, and (3) partial or fully automated piloting system. We analyzed the rules associated with the three types of UAM operations, including: (1) federal Acts, (2) federal regulations, (3) state laws and local ordinances for each of the ten urban markets, and (4) international and foreign law. It is important to note that the analysis draws a comparison of the legal and regulatory challenges for UAM with those of the Unmanned Aircraft Systems (UAS), especially as to how it relates to remotely piloted and autonomous vehicles.

As a summary, our analysis shows that the remotely piloted and autonomous Air Taxi, Ambulance, and Airport Shuttle UAM markets share common regulatory barriers. However, state and local laws range from disallowing drones to protecting UAS operations, which might be problematic considering the “patchwork” of laws it can create. Similarly, other nations integrate UAS into their airspace in varying degrees. Moreover, there will be challenges in determining which of the existing FAA certification standards apply to the types of vehicles being considered for the Air Taxi or Air Ambulance UAMs, and/or how existing certification standards can be met or should be amended. Air Ambulances will require further evaluation due to the requirements of an operator’s air ambulance procedures and sections of their General Operations Manual (GOM) specific to air ambulance. Lastly, gaps in current certifications indicate that new standards will need to be developed, especially in areas related to system redundancy and failure management.

2.2 Legal and Regulatory Barriers

Critical legal and regulatory challenges must be addressed to bring UAM transportation to the market. Air Taxi, Ambulance, and Airport Shuttle UAM Markets share common regulatory barriers. This analysis draws a comparison of legal and regulatory challenges for enabling UAM with Unmanned Aircraft Systems (UAS). Many of the UAM areas are being addressed to some extent with the emergence of UAS operations, and UAS research has helped reduce gaps towards enabling UAM. The laws for operations using an onboard pilot are clearer as they already exist under 14 Code of Federal Regulations (CFR) Parts 21, 23, 25, 27, 36, 61, 91, and 119. However, remotely piloted and autonomous UAM operations require the following aviation regulations (either modification of existing regulations, or new regulations):

- Regulations for beyond visual line of sight (currently only with lengthy waiver process to 14 CFR Part 107.31)
- Regulations for operations over people, streets, etc. (currently only with lengthy waiver process to 14 CFR 107.39)
- Regulations for when air cargo is being carried commercially and across state lines (this is addressed in Section 348 of the FAA Reauthorization Act of 2018¹ whereby Congress tasks the FAA within the year with making regulations for the carriage of property for compensation or hire)
- Regulations for when a passenger or patient is being transported in a UAM either within visual line of sight or beyond (airworthiness potentially addressed in 14 CFR Part 23)
- Regulations for flight in instrument conditions (not addressed in the FAA Reauthorization Act of 2018)
- Regulations for airworthiness certification of remotely piloted and autonomous aircraft
- Training and knowledge requirements for pilots and operators (FAA Reauthorization Act of 2018 Section 349 whereby Congress tasks the FAA with creating an aeronautical knowledge test for certain recreational UAS operators)

Additionally, a legal framework for addressing privacy concerns should be developed outside of the aviation regulatory framework. The recently passed FAA Reauthorization Act of 2018 makes a step in that direction by mandating the Department of Transportation and National Telecommunications and Information Administration (NTIA) of the Department of Commerce “to identify any potential reduction of privacy specifically caused by the integration of unmanned aircraft systems into the national airspace system.”²

2.2.1 Federal versus State “Tug of War”

A dynamic legal environment exists with many unresolved challenges, especially establishing where federal, State, and local authorities take lead. Where the Federal government occupies a field, federal laws preempt state laws and local ordinances. The 1958 Federal Aviation Act delegated the safe and efficient use of the airspace to the FAA requiring it to create and enforce federal regulations (under Title 14 of the CFR). As such, the FAA has exclusive authority over the national airspace. With respect to UAS, the FAA issued its first rule governing commercial drone operations in 2016.

On the other hand, the 10th Amendment to the Constitution gives States/local government the rights and powers “not delegated to the United States.” States are granted the power to establish and enforce laws protecting the welfare, safety, and health of the public (police powers). This authority can prevent trespass, nuisance, invasion of privacy, and a slew of other issues that UAS can cause. However, although state and local governments have passed laws of their own, a drone cannot fly freely across city and state lines if inconsistent laws interfere with its path.

A “tug of war” exists between federal preemption and state/local police power as each government entity is vying for the power to regulate. Not many courts across the country have settled this power struggle. In aviation tort law there is some clarity, but in UAS operations there is only one case of first impression: *Singer vs. City of Newton, MA* (Sept. 2017).³

In December 2016, the City of Newton, MA passed a local ordinance banning UAS below 400 feet and requiring operators to register their UAS and receive permission from public and private residence owners in order to fly their UAS over their homes. This local ordinance was drafted “for the principal purpose of protecting the privacy interests of Newton’s residents,” according to a court document.

¹ Federal Aviation Administration Reauthorization Act of 2018, §348.

² *Id.* §335.

³ *Singer v. City of Newton*, No. CV 17-10071, 2017 WL 4176477 (D. Mass. Sept. 21, 2017).

In September 2017, a federal judge ruled against this local ordinance, allowing operators to use UAS that fly below 400 feet and without permission of city residence owners, in accordance with 14 CFR 107 regulations. The ruling in this case was the first of its kind, setting a legal precedent that says when it comes to certain UAS operations disputed in this case, federal law preempts local regulations. A city cannot regulate flight operations, and it may not effectively ban drone flights against the express congressional intent to encourage drone use.⁴ Even though the ordinance intended to protect the city citizens' privacy, portions of it extended into the FAA's operational safety and licensing authority and was struck down.

2.2.2 UAS Integration Pilot Program (UAS IPP)

In what appears to be a way to settle the above mentioned "tug of war", and more importantly to prevent the painfully slow lawmaking process from stifling the growth and development of the emergent UAS industry, the UAS IPP encourages the FAA to work closely with State, local, and Tribal governments and private sector entities such as UAS operators or manufacturers, to accelerate safe UAS integration. This program will help FAA craft new enabling rules that allow more complex operations governing the carriage of passengers and cargo, flights over people, and flights beyond visual line of sight. This process was started in November 2017 as is ongoing as of this writing.

2.3 State and Local Regulatory Arena

As stated earlier, the analysis on UAM draws a comparison to the UAS legal and regulatory achievements as many of the UAM areas are being addressed to some extent with the emergence of UAS operations. Similarly, UAS research has helped reduce the gap towards enabling UAM. As stated above in Section 7.2.1, the FAA has exclusive authority over the national airspace, and no State or local UAS registration law may relieve a drone owner or operator from complying with the federal drone regulations. However, local concerns such as those pertaining to the welfare, safety, and health of the public (police powers), such as land use, law enforcement, zoning, privacy, and trespass issues are usually not subject to federal regulations.

Though most of the attention paid to drones has focused on the FAA and its regulatory authority, much of the impact is at the ground level. This will be the case with UAM as well. As such, States and local governments have been passing drone-related laws since 2013, citing the need to protect the health and safety, including privacy, of residents. These state and local drone laws can be seen as the precursor to UAM local laws, especially when it pertains to remotely-piloted and autonomous vehicles.

A review of the State and local laws and regulations is important to showcase the evolution of legislation which UAM could benefit from and face. UAS have many applications including law enforcement, search and rescue, border patrol, disaster response, land surveillance, wildlife tracking, and photography. Due to the wide variety of benefits, States and local governments since 2013 have been pushing for regulations, ordinances, and resolutions which consider the benefits and potential economic benefit of using UAS, while weighing privacy concerns. It is important to note that States do not regulate or govern manned aviation. State policy does guide where, when, and how much air commerce it attracts. Additionally, airports and heliports and the cities who own them enter into agreements for service at the local level, not at the Federal level.

Below is an overview of regulations enacted by each of the selected ten (10) urban areas. State and local laws range from banning drones to protecting UAS operations. These regulations apply to remotely piloted or autonomous operations, which is seen as a precursor to similarly operated UAM vehicles.

Arizona

Arizona has a law favoring first responders.

- **SB 1449:** Prohibits certain operation of UAS, including operation in violation of FAA regulations and operation that interferes with first responders. The law prohibits operating near, or using UAS to take images of, a critical facility. It also preempts any locality from regulating UAS.⁵

⁴ 49 U.S.C. § 40101.

⁵ Arizona, SB1449, <https://www.azleg.gov/legtext/52leg/2r/bills/sb1449p.pdf> (last visited Nov. 14, 2018).

California

California has laws favoring first responders.

- **SB 807** was chaptered (entered into law): Limits the exposure to civil liability of an emergency responder for damage to a UAS if the damage was caused while the emergency responder was performing specific emergency services and the UAS was interfering.⁶
- **AB 1680**: UAS going to the scene of an emergency or stopping at the scene of an emergency, for the purpose of viewing the scene or the activities is a misdemeanor.⁷

Colorado

Colorado has no laws regarding the use of UAS.

- **HB1070**: Requires the center of excellence within the department of public safety to perform a study. The study must identify ways to integrate UAS within local and state government functions relating to firefighting, search and rescue, accident reconstruction, crime scene documentation, emergency management, and emergencies involving significant property loss, injury or death. The study must also consider privacy concerns, costs, and timeliness of deployment for each of these uses. The legislation also creates a pilot program, requiring the deployment of at least one team of UAS operators to a region of the state that has been designated as a fire hazard where they will be trained on the use of UAS for the above specific functions.⁸

Florida

- **HB 1027**: Preempts local governments from regulating the operation of unmanned aircraft systems but does allow them to enact or enforce local ordinances relating to illegal acts arising from the use of unmanned aircraft systems if the ordinances are not specifically related to the use of a drone for the commission of the illegal acts.⁹
- **SB 92**: Law enforcement may use a drone if they obtain a warrant, there is a terrorist threat, or swift action is needed to prevent loss of life or to search for a missing person. The law also enables someone harmed by an inappropriate use of drones to pursue civil remedies.¹⁰
- **SB 766**: Prohibits a person, a state agency, or a political subdivision from using a drone to capture an image of privately owned real property or of the owner, tenant, occupant, invitee, or licensee of such property with the intent to conduct surveillance without his or her written consent if a reasonable expectation of privacy exists.¹¹
- **Miami Ordinance 37-12**: Regulates the use of UAS within a half-mile radius around stadiums and sport facilities when these devices are in use, and over other large venue special events in public parks, public facilities, streets, plazas, open spaces and the like that will attract large groups of people.¹²

⁶ California, SB 807, <https://legiscan.com/CA/bill/SB807/2015> (last visited Nov. 14, 2018).

⁷ California, AB1680, http://www.leginfo.ca.gov/pub/15-16/bill/asm/ab_1651-1700/ab_1680_bill_20160929_chaptered.pdf (last visited Nov. 14, 2018).

⁸ Colorado, HB1070, <https://openstates.org/co/bills/2017A/HB17-1070/> (last visited Nov. 14, 2018).

⁹ Florida, HB 1027, <https://www.flsenate.gov/Session/Bill/2017/1027> (last visited Nov. 14, 2018).

¹⁰ Florida, SB 92, <https://www.flsenate.gov/Session/Bill/2013/0092> (last visited Nov. 14, 2018).

¹¹ Florida, SB 766, <https://www.flsenate.gov/Session/Bill/2015/0766> (last visited Nov. 14, 2018).

¹² Miami Ordinance 37-12, https://library.municode.com/fl/miami/codes/code_of_ordinances?no-deld=PTIITHCO_CH37OFIS_S37-12PUSAUNAISYCOKNDR (last visited Nov. 14, 2018).

Hawaii

Has a law that prohibits UAS except for law enforcement.

- **SB 2608:** Prohibits the use of unmanned aircraft, except by law enforcement agencies, to conduct surveillance and establishes certain conditions for law enforcement agencies to use an unmanned aircraft to obtain information.¹³

New York, NY

Drones are more formally known as unmanned aerial vehicles (UAV) and are illegal to fly in New York City.

- **SB975:** Prohibits municipalities from regulating UAS. It allows a municipality that is also a water company to enact ordinances that regulate or prohibit the use or operation of UAS over the municipality's public water supply and land.¹⁴

Texas

- **SB840:** Telecommunications providers may use UAS to capture images. Only law enforcement may use UAS to capture images of real property that is within 25 miles of the U.S. border for border security purposes.¹⁵
- **HB 1424:** Prohibits UAS operation over correctional and detention facilities. It also prohibits operation over a sports venue except in certain instances.¹⁶
- **HB 1481:** Makes it a Class B misdemeanor to operate UAS over a critical infrastructure facility if the UAS is not more than 400 feet off the ground.¹⁷
- **HB1643:** Adds telecommunications services structures, animal feeding operations, and oil and gas facilities to the definition of critical infrastructure as it relates to UAS operation. Prohibits localities from regulating UAS except during special events and when the UAS is used by the locality.¹⁸
- **HR 3035:** Identifies 19 legitimate commercial purposes for UAS operations and prohibits UAS photography and filming of property or persons without prior consent.¹⁹

¹³ Hawaii, SB 2608, https://www.capitol.hawaii.gov/Archives/measure_indiv_Archives.aspx?billtype=SB&billnumber=2608&year=2014 (last visited Nov. 14, 2018).

¹⁴ New York, SB975, <https://openstates.org/ct/bills/2017/SB975/> (last visited Nov. 14, 2018).

¹⁵ Texas, SB840, <http://www.capitol.state.tx.us/tlodocs/85R/billtext/pdf/SB00840F.pdf#navpanes=0> (last visited Nov. 14, 2018).

¹⁶ Texas, HB1424, <http://www.capitol.state.tx.us/tlodocs/85R/billtext/pdf/HB01424F.pdf#navpanes=0> (last visited Nov. 14, 2018).

¹⁷ Texas, HB1481, <https://capitol.texas.gov/BillLookup/History.aspx?LegSess=84R&Bill=HB1481> (last visited Nov. 14, 2018).

¹⁸ Texas, HB1643, <http://www.capitol.state.tx.us/tlodocs/85R/billtext/pdf/HB01643F.pdf#navpanes=0> (last visited Nov. 14, 2018).

¹⁹ Texas, HR 3035, <http://www.statutes.legis.state.tx.us/Docs/GV/htm/GV.423.htm> (last visited Nov. 14, 2018).

Washington, D.C. Metropolitan Area

- Maryland:
 - **SB 370:** Specifies that only the state can enact laws to prohibit, restrict, or regulate the testing or operation of unmanned aircraft systems. This preempts county and municipal authority. The bill also requires a study on specified benefits.²⁰
- Washington, D.C. is a no drone zone.
- Virginia:
 - **HB 412:** Provides that no locality may regulate the use of privately owned, unmanned aircraft systems within its boundaries.²¹
 - **HB 2350:** Makes it a Class 1 misdemeanor to use UAS to trespass upon the property of another for the purpose of secretly or furtively peeping, spying, or attempting to peep or spy into a dwelling or occupied building located on such property.²²
 - **SB 1301:** Requires that a law enforcement agency obtain a warrant before using a drone for any purpose, except in limited circumstances.²³

2.4 International Regulations

International harmonization of regulations may be important as countries consider similar operating concepts and UAM manufactures, operators, and service providers seek consistency in a potential worldwide market. The following depicts several organizations and Nation-States who have developed regulations in furtherance of UAS, with such UAS research and regulatory movement helping to reduce the gap towards enabling UAM activities.

2.4.1 European Aviation Safety Agency (EASA)

After a four-month consultation period on the Notice of Proposed Amendment (NPA) 2017-05²⁴, EASA published Opinion 01/2018²⁵, including a proposal for a new Regulation for UAS operations in 'open' and 'specific' category.

- 'Open' category is a category of UAS operation that, considering the risks involved, does not require a prior authorization by the competent authority nor a declaration by the UAS operator before the operation takes place;
- 'Specific' category is a category of UAS operation that, considering the risks involved, requires an authorization by the competent authority before the operation takes place, taking into account the

²⁰ Maryland, SB 370, <https://legiscan.com/MD/bill/SB370/2015> (last visited Nov. 14, 2018).

²¹ Virginia, HB 412, <https://legiscan.com/VA/bill/HB412/2016> (last visited Nov. 14, 2018).

²² Virginia, HB 2350, <http://lis.virginia.gov/cgi-bin/legp604.exe?171+ful+HB2350ER+pdf> (last visited Nov. 14, 2018).

²³ Virginia, SB 1301, <http://lis.virginia.gov/cgi-bin/legp604.exe?ses=151&typ=bil&val=sb1301> (last visited Nov. 14, 2018).

²⁴ NPA 2017-05. *Introduction of a regulatory framework for the operation of drones — Unmanned aircraft system operations in the open and specific category.* <https://www.easa.europa.eu/document-library/notices-of-proposed-amendment/npa-2017-05> (Accessed on Nov. 14, 2018).

²⁵ Opinion 01/2018. *Unmanned aircraft system (UAS) operations in the 'open' and 'specific' categories.* <https://www.easa.europa.eu/document-library/opinions/opinion-012018>. (Accessed on Nov. 14, 2018).

mitigation measures identified in an operational risk assessment, except for certain standard scenarios where a declaration by the operator is sufficient or when the operator holds a light UAS operator certificate (LUC) with the appropriate privileges; and

- 'Certified' category is a category of UA operation that, considering the risks involved, requires the certification of the UAS, a licensed remote pilot and an operator approved by the competent authority, in order to ensure an appropriate level of safety.

Additionally, on October 15, 2018, EASA proposed a rule to cover VTOL aircraft.²⁶ VTOL aircraft have unique features that "significantly differentiate them from traditional rotorcraft or aeroplanes and therefore necessitate this dedicated special condition." This proposed rule for the certification small-category VTOL applies to an aircraft with a passenger seating configuration of 5 or less and a maximum certified take-off mass of 2,000kg or less. This proposed rule could pose difficulties for VTOL weighing more than 2,000kg.

United Kingdom

Under the United Kingdom (UK) Civil Aviation Authority (CAA) rules²⁷, National Qualified Entities (NQEs) are established to assess the competence of people operating small unmanned aircraft as part of the CAA's process in granting operating permissions. Assessment by an NQE is necessary for those with no previous aviation training or qualifications. To achieve this, NQEs may offer a short educational course/program prior to the competency assessment aimed at bringing an individual's knowledge up to the required level (but please note that these are not CAA approved training courses). A typical NQE full-course involves:

- pre-entry/online study
- 1-3 days of classroom lessons and exercises
- a written theory test
- a flight assessment

Ireland

In Ireland, visual line of sight is quantified as 300m and UAS must stay 30m away from any person, vessel, vehicle or structure not under the direct control of the operator.²⁸

New Zealand

The New Zealand Civil Aviation Authority defines a shielded operation as a flight where an aircraft remains within 100m of, and below the top of, a natural or man-made object such as a building, tower, or trees.²⁹ When flying as a shielded operation, an aircraft is allowed to fly at night, or within controlled airspace without ATC clearance, as other aircraft are unlikely to be flying so low and close to structures.

- Shielded operations within 4 km of aerodromes - If relying on the shielded operation provision to fly an unmanned aircraft within 4 km of an aerodrome, then in addition to remaining within 100m of, and below the height of the object providing the shield (e.g., a building or tree), there must also be a physical barrier like a building or stand of trees between the unmanned aircraft and the aerodrome. This barrier must be capable of stopping your aircraft in the event of a fly-away.

²⁶ Proposed Special Condition for VTO. <https://www.easa.europa.eu/document-library/product-certification-consultations/proposed-special-condition-vtol>. (Accessed on Nov. 14, 2018).

²⁷ Guidance on Using Small Drones for Commercial Work. <https://www.caa.co.uk/Commercial-industry/Aircraft/Unmanned-aircraft/Small-drones/Guidance-on-using-small-drones-for-commercial-work/>. (Accessed on Nov. 14, 2018).

²⁸ Drones. <https://www.iaa.ie/general-aviation/drones>. (Accessed on Nov. 14, 2018).

²⁹ Intro to Part 101. https://www.caa.govt.nz/unmanned-aircraft/intro-to-part-101/#Shielded_Operations. (Accessed on Nov. 14, 2018).

Canada

Under Canadian law,³⁰ if the drone weighs over 250g and under 35kg and flying for fun, it must be flown:

- below 90 m above the ground
- at least 30 m away from vehicles, vessels and the public (if drone weighs over 250 g and up to 1 kg)
- at least 76 m away from vehicles, vessels and the public (if drone weighs over 1 kg and up to 35 kg)
- at least 5.6 km away from aerodromes (any airport, seaplane base or area where aircraft take off and land)
- at least 1.9 km away from heliports or aerodromes used by helicopters only
- outside of controlled or restricted airspace
- at least 9 km away from a natural hazard or disaster area
- away from areas where its use could interfere with police or first responders
- during the day and not in clouds
- within sight at all times
- within 500 m of pilot
- only if clearly marked with pilot's name, address and telephone number

United Arab Emirates

Key authorities in the United Arab Emirates include General Civil Aviation Authority (GCAA), Dubai Civil Aviation Authority (DCAA), and Roads and Transport Authority (RTA). The UAE contracted Volocopter for a 5-minute public test flight and announced plans for a 5-year path to UAM certification. The rules for UAS include (1) Registration, (2) Tracking and ID (Exponent Skytrax), (3) Insurance requirements, (4) Zones: 5 km from aerodromes, <400 ft, (5) No video or image capturing, (6) No BVLOS, (7) Certification, (8) Operator exam for commercial operations, and (9) COA for each commercial flight.

Germany

The Volocopter VC200 was granted provisional certification from German Ultralight Flight Association as an ultralight aircraft.

As the above listing of organizations and countries demonstrates, international harmonization of regulations is important to ensure consistency across the globe and to avoid a patchwork of laws and regulations. The next section will discuss standards and regulations for certification, and some efforts the International Civil Aviation Organization (ICAO), among other organizations, are undergoing to harmonize the patchwork of rules.

2.5 Airworthiness Certification Standards and Regulations

Airspace authorities use certification to manage the safety of aircraft, operators, and operations. All of these aspects of certification are important to UAM, and UAM will face challenges in each of these areas³¹. This analysis focuses on airworthiness certification, which addresses safety risks by setting requirements for aircraft design, manufacturing, performance, failure response, and maintenance. This applies to safety critical features, such as aircraft structure, engines, propellers, software, and electronics. Regulatory agencies

³⁰ Flying your Drone Safely and Legally. <http://www.tc.gc.ca/en/services/aviation/drone-safety/flying-drone-safely-legally.html>. (Accessed on Nov. 14, 2018).

³¹ Lascara, Brock, et. al. (April 2018). *Urban Air Mobility Landscape Report: Initial Examination of a New Air Transportation System*. https://www.mitre.org/sites/default/files/publications/pr-18-0154-4-urban-air-mobility-landscape-report_0.pdf.

develop requirements for airworthiness. Applicants must meet these requirements through “means of compliance”, which may be based on regulatory guidance. In some cases, the certification authority will accept industry consensus standards developed by American Society for Testing and Materials (ASTM), Society of Automotive Engineers (SAE), Radio Technical Commission for Aeronautics (RTCA), and others as means of compliance.

Aircraft certification can act as a barrier for promoting rapid integration of emerging technologies for UAM. UAM aircraft challenge the existing certification process due to novel features and combinations of features, such as distributed electric propulsion / tilt-wing propulsion, VTOL, autonomy software, optionally piloted, energy storage, and ratio of aircraft to pilots being below 1. Certification can delay deployment of the technologies as they go through certification process that may take several years and can increase costs of deployments if the burden of compliance is high. Certification can also be an enabler as it provides passengers comfort that the standard for safety is sufficiently high. Our research identified trust in the technology as a critical societal barrier (see next chapter for more on societal barriers).

Questions considered in this analysis:

- How are new aircraft certified?
- What is the preferred path to certification for UAM aircraft (e.g., Part 23, 27, 21.17(b))?
- What are the gaps in requirements and means of compliance (e.g., RTCA DO-178C, ASTM F39)?
- What is being done to address these gaps?

2.5.1 Airworthiness Certification Approaches

Certification is a risk-based process. There is no such thing as zero risk aircraft operation. The certification framework is driven by questions about how society views the operations, such as: “What is society’s risk tolerance for certain applications?”, and “How strong is the desire for a low-cost solution?”. For example, Part 107 for UAS includes no airworthiness certification for the aircraft. The aircraft and operation are deemed low risk, and there is a strong desire for low cost solutions. As the vehicle size increases, so does the risk and the need for more rigor. As the operation increases in risk, for example by carrying passengers that expect a certain level of safety, the level of rigor is further increased.

Aircraft are organized by category and class, which determines the risk regime that they reside in. The FAA and the North Atlantic Treaty Organization (NATO) certification categories are shown in Figure 1 and Figure 2. Certification requirements differ by class, and influence design of aircraft and heliports. For example, the following are requirements after critical loss of thrust:

- Transport category, airplane class: Certified to 2.4 – 3 percent climb gradient
- Transport category A, rotorcraft class: Certified to 100 ft/min climb rate
- Normal category, rotorcraft class: no min climb rate

NATO’s risk calculation is based on a Military standard handbook for a casualty model based on current reliability data compared to the planned test flight route and population densities in areas along the planned flight route. Additional requirements are imposed on operations where less risk is accepted. Higher certification rigor means more cost and more time. Certification for Light Sport Aircraft can be in the hundreds of thousands of dollars, where Part 23 commercial aircraft can be in the tens to hundreds of millions of dollars. This tradeoff between risk tolerance and cost will drive the UAM certification approaches.

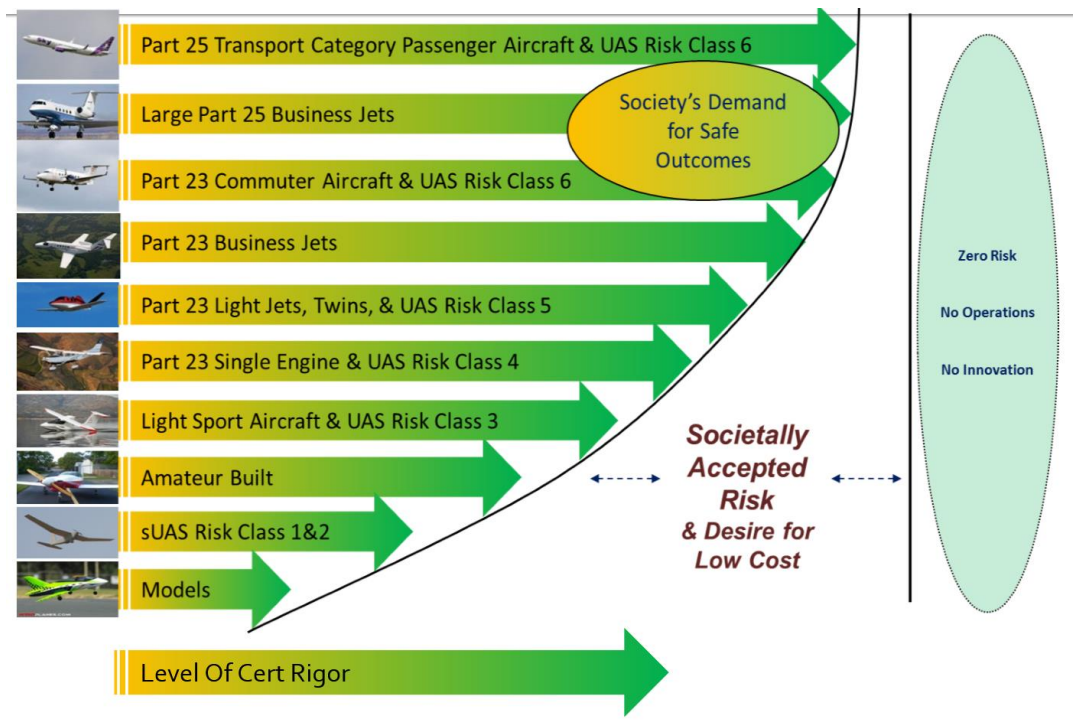


Figure 1: Trade-off between risk tolerance and level of certification rigor with FAA certification categories³²

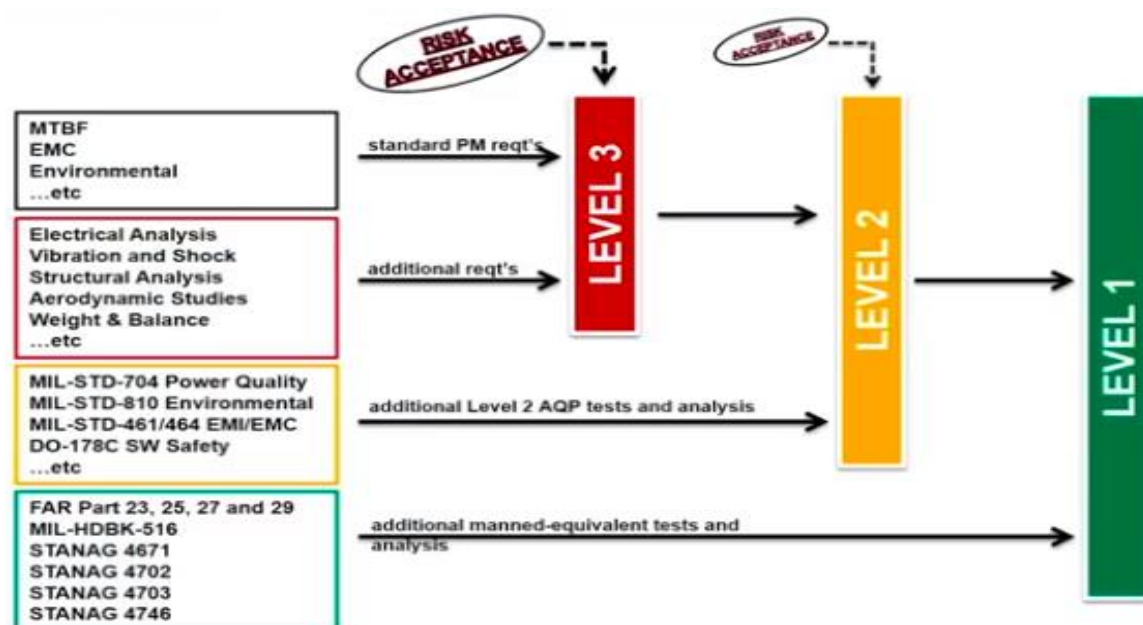


Figure 2: NATO STANAG level of certification rigor increases with lower risk acceptance³³

³² Gunnarson, Tom, (Jan. 2018). *Aircraft Type Certification Considerations*. AHS TVF Workshop. <https://vtol.org/files/dmfile/13-TVF5-2018-Gunnarson-ASTM-Jan191.pdf>.

³³ Webber, David of FAA (May 2018, Time 38:17). *Flight Qualification and Certification of Advanced VTOL Aircraft*. Vertical Flight Society 74th Annual Forum. <https://www.youtube.com/watch?v=Jf4u4MTiFs&feature=youtu.be>.

2.5.2 International UAM Certification Landscape

Figure 3 summarizes international players and interactions for certification by capturing international activities, policies, standards, and working groups. This section describes more considerations of the potential paths to UAM certification, such as active governing bodies by domain.

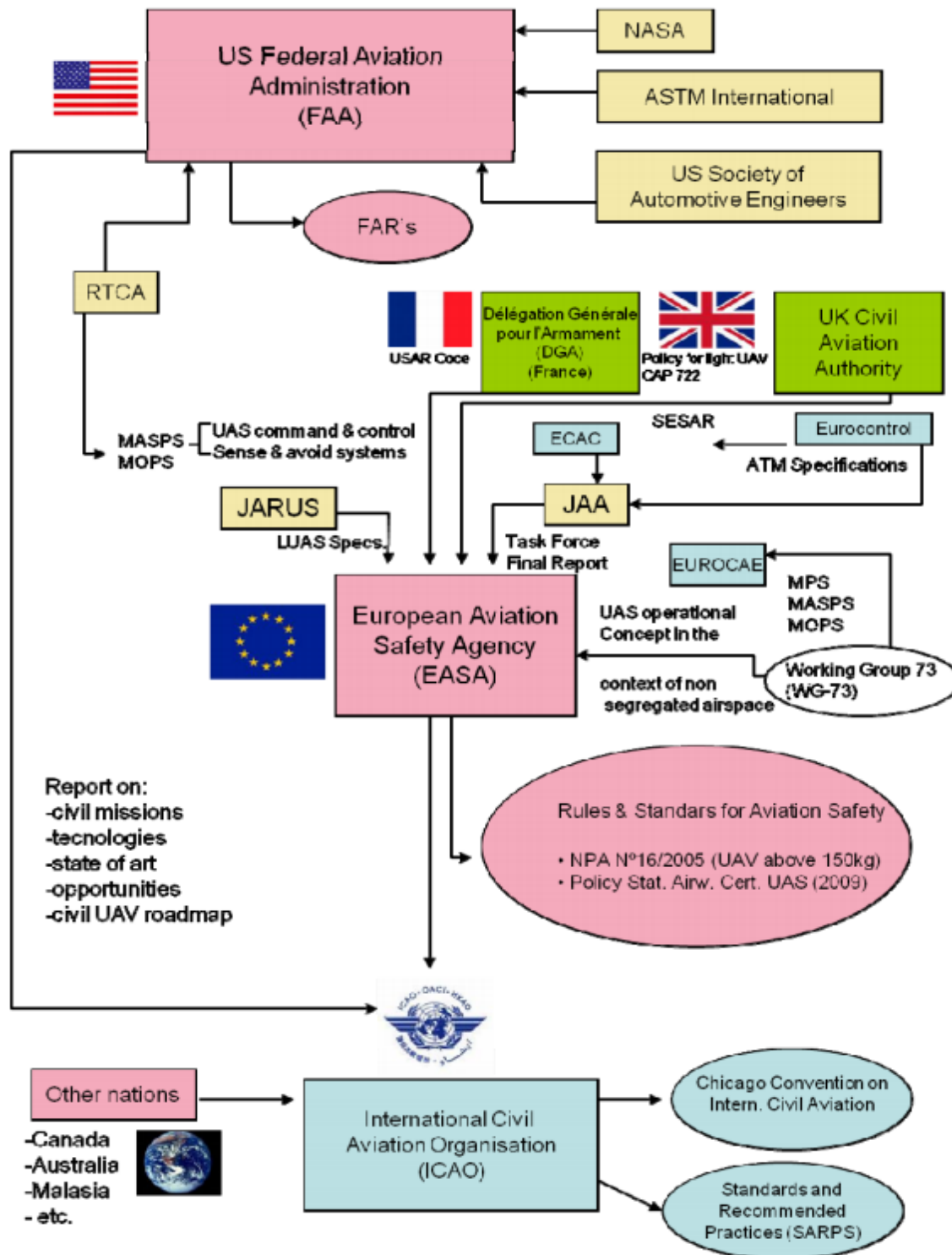


Figure 3: International UAS regulatory field (Cuerno-Rejado, 2010)

FAA certification is supported by activities and standards at NASA, SAE, and ASTM. ICAO is supported by bodies such as the Joint Authorities for Rulemaking on Unmanned Systems (JARUS), Joint Aviation Authorities (JAA), Single European Sky ATM Research (SESAR), as well as accepting guidance from other nations, including FAA and EASA. This is a quickly evolving ecosystem, and some recent developments are not reflected in this figure. For example, ICAO has established the Remotely Piloted Aircraft Systems Panel, Unmanned Aircraft Systems Advisory Group (UAS-AG), and Unmanned Aircraft System Task Force/Working Group (UAS-TF/WG) in the Legal Committee³⁴. In Germany, the Volocopter VC200 was granted provisional certification from German Ultralight Flight Association as an ultralight aircraft, which provided a basis for a public test in Dubai. Also of note, Dubai has mandated a remote identification and tracking technology, Skytrax.

Another consideration in the regulatory landscape is the level of independence of the regulatory frameworks within specific countries. In this instance, independence is described as the degree to which the individuals overseeing compliance are independent from the product development process.

Figure 4 compares the EASA and FAA regulatory frameworks. FAA has more independent Product Certification. Airworthiness relates to multi dimensions of framework including Process, Product, and Behavior. The level of independence may influence decision of where to certify. For reference, the Independence Levels are defined as follows:

- “5 – An independent regulatory organisation or person with authority underpinned by Government legislation. Alternatively, the regulatory organisation or person is fully independent from the owner/operator with independent lines of command. They are an external regulator.
- 4 – A regulatory organisation or person who is as independent as possible from the owner/operator, but still within the owner/operator lines of command. They are an internal regulator.
- 3 – A management organisation or person removed from the task/attestation development.
- 2 – A supervisor, organisation or a person who is independent from the task/attestation development.
- 1 – A person charged with the responsibility for performing the task, the practitioner.”

FAA, EASA, and NATO airworthiness share many common elements and standards. Significant standards differences (SSD) exist and are described in SSD documentation³⁵. For example, comparison of EASA CS-25 and FAA Part 25 Proof of Structure terminology reveals a key wording difference, which has resulted in different interpretations on the need for and the extent of static strength testing, including the load level to be achieved. The NATO Standardization Agreement (STANAG) 4702 is based on Parts 23, 27, and CS-23. CS-VLA has similarities to PART 21.17B. Draft STANAG 4746 is based on EASA Essential Airworthiness and is harmonized with STANAG 4703. STANAG 4746 and 4703 use EASA CS-VLR as a basis. CS-E shares similar standards to Part 33, and testing covers all thrust ratings. CS-P shares similar standards to Part 35, including demonstration that the propeller can withstand the impact of a 4-pound bird for all airplanes. International type certifications are compared in Table 1 below.

³⁴ ICAO Legal Committee – 37th Session (Sept. 2018). *Establishing UAS Task Force/Working Group within the Legal Committee*. Doc. LC/37-WP/2-2 13/7/18.

³⁵ EASA and FAA Comparison. <https://www.easa.europa.eu/document-library/bilateral-agreements/eu-usa/easa-significant-standards-differences-ssd-between-cs-codes-and-faa-14-cfr-codes>. (Accessed on Nov. 14, 2018).

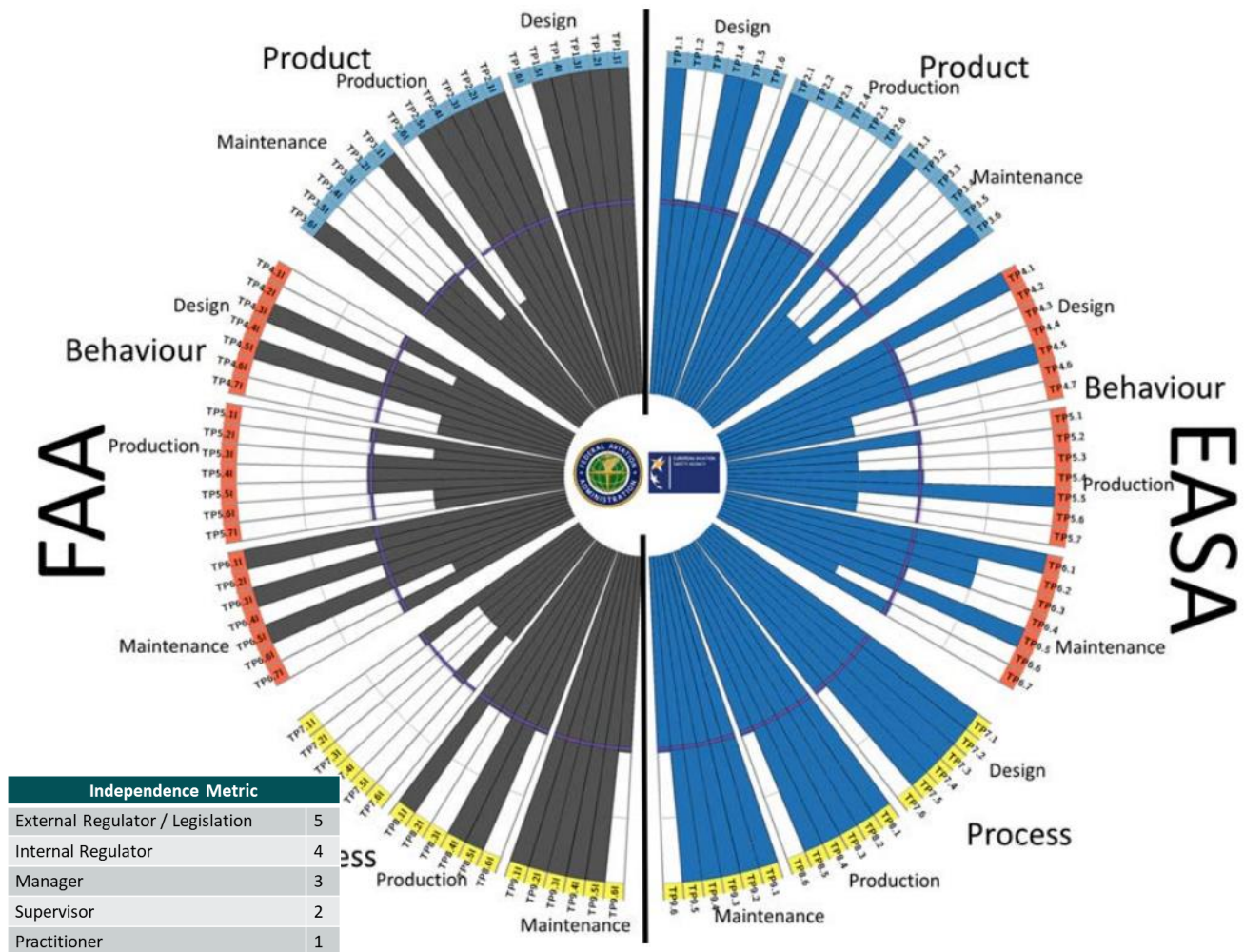


Figure 4: Comparison for FAA and EASA Regulatory Framework Independence Metric

Table 1: International Type Certification Comparison³⁶

	Fixed Wing	Rotary	Hybrid or Special	Engines	Propellers
FAA	Part 21 – Certification Procedures for Products and Parts Part 23 – Small Fixed Wing	Part 27 – Small Rotor-wing	Part 21.17(b) – Designation of applicable regulations	Part 33 – Aircraft Engines	Part 35 – Aircraft Propellers

³⁶ CS-E vs Part 33. https://www.faa.gov/aircraft/air_cert/design_approvals/engine_prop/engine_prop_regs/engine_prop_tvalidation/media/SEI_Turbine_Engines_List_14_CFR_33_and_CS-E.pdf. (Accessed on Nov. 14, 2018); CS-P vs Part 35. https://www.faa.gov/aircraft/air_cert/design_approvals/engine_prop/engine_prop_regs/engine_prop_tvalidation/media/SSD_Propellers_List_14_CFR_35_Amdt_9_and_CS-P_Amdt_1.pdf. (Accessed on Nov. 14, 2018).

	Part 25 –Transport Category Airplanes	Part 29 – Transport Category Rotorcraft			
EASA	CS-22 -Sailplanes and Powered Sailplanes CS-23 - Normal, utility, aerobatic, and commuter aeroplanes CS-25 – Large Aeroplanes	CS-27 – Small Rotorcraft CS-29 – Large Rotorcraft	CS-VLA - Very light aircraft CS-VLR - Very Light Rotorcraft	CS-E - Engines	CS-P -Propellers
NATO	STANAG 4671 – UAV System Airworthiness Requirements (USAR), Fixed wing aircraft weighing 150kg to 20,000 kg STANAG 4703 – Light unmanned aircraft systems	STANAG 4702 – Rotary wing unmanned aircraft systems	Draft STANAG 4746 - Vertical Take-off and landing (VTOL)	Referenced in STANAG 4703 STANAG 3372	Referenced in STANAG 4703

2.5.3 Domestic UAM Certification Landscape

UAM aircraft may vary in weight, type of service, propulsion, number of passengers, and speed, which may change their path to certification. New aircraft designs for UAM may have multiple paths to certification with FAA, as depicted in Figure 5. The traditional Part 21.17(a) method can be used for aircraft that fall within existing categories. Additional requirements and special conditions may apply. For example, aircraft certifying under Part 23 or 25 must also comply with Part 33 Engine and Part 35 Propeller if applicable. For aircraft that do not fall into existing categories, Part 21.17(b) may be used. This path is not meant for mass production, so eventually an update to the regulatory framework may be needed for large-scale UAM deployments for aircraft that take this path.

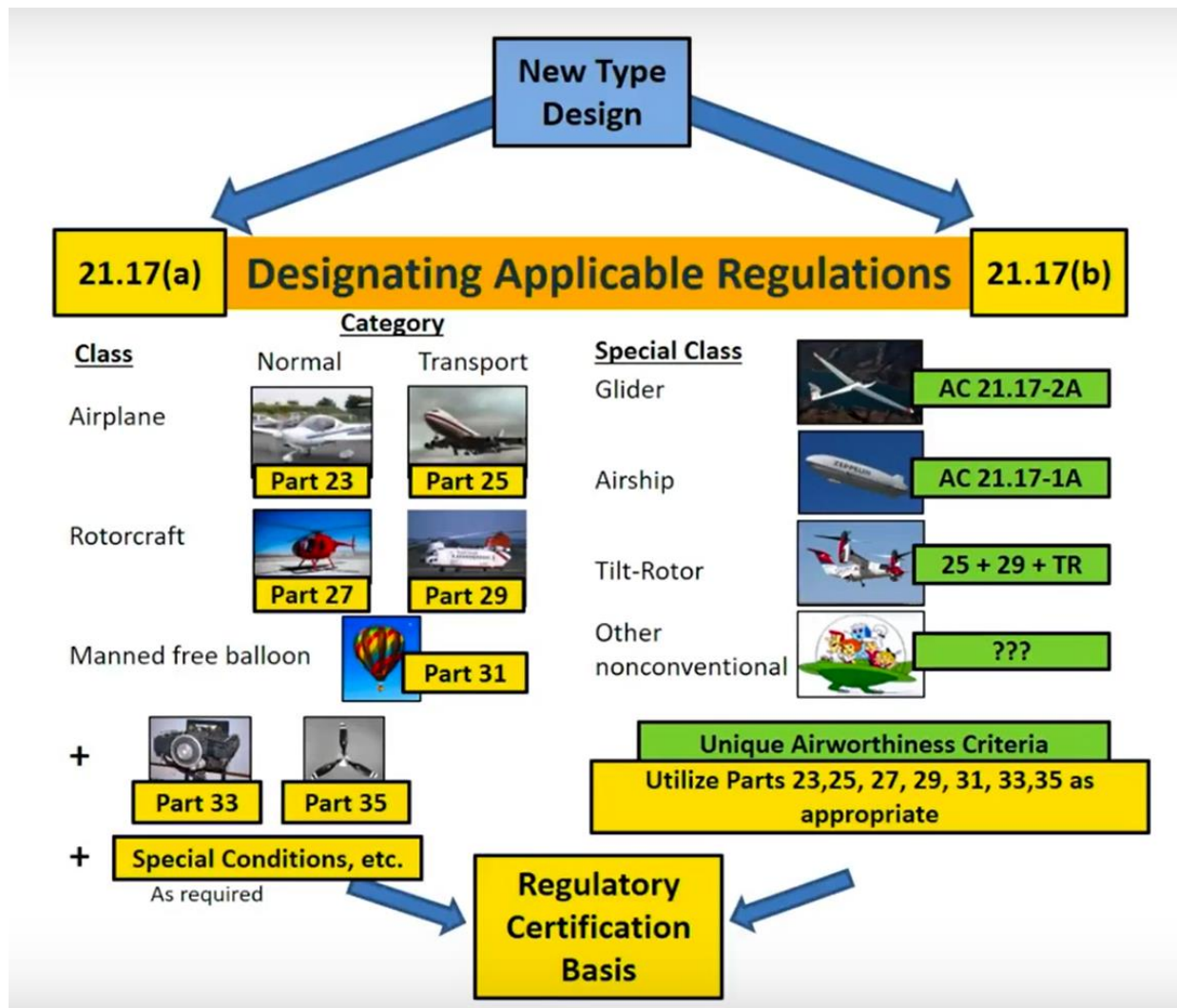


Figure 5: Paths to FAA airworthiness certification³⁷

The General Aviation Manufacturers Association (GAMA) suggests that there are “regimes” for certification paths based on an aircraft’s likeness to a wing-borne aircraft or a rotorcraft (Figure 6). Some examples of where typical aircraft might fall on this spectrum:

- Cirrus SR22: Part 23, with Part 33 engine, Part 35 propeller

³⁷ Webber, David of FAA (May 2018. Time 1:28:20). *Flight Qualification and Certification of Advanced VTOL Aircraft*. Vertical Flight Society 74th Annual Forum, <https://www.youtube.com/watch?v=Jf4u4MTiFs&feature=youtu.be>.

- Bell 429: Part 29 with Part 33 powerplant
- AgustaWestland AW609: Part 21.17(b)

UAM platforms targeting the *Special* class may consider using standards from the following:

- Multiple: 21.187
- Limited Category: 21.189
- Experimental: 21.191 (R&D, Exhibition)
- Experimental: 21.193 (General)

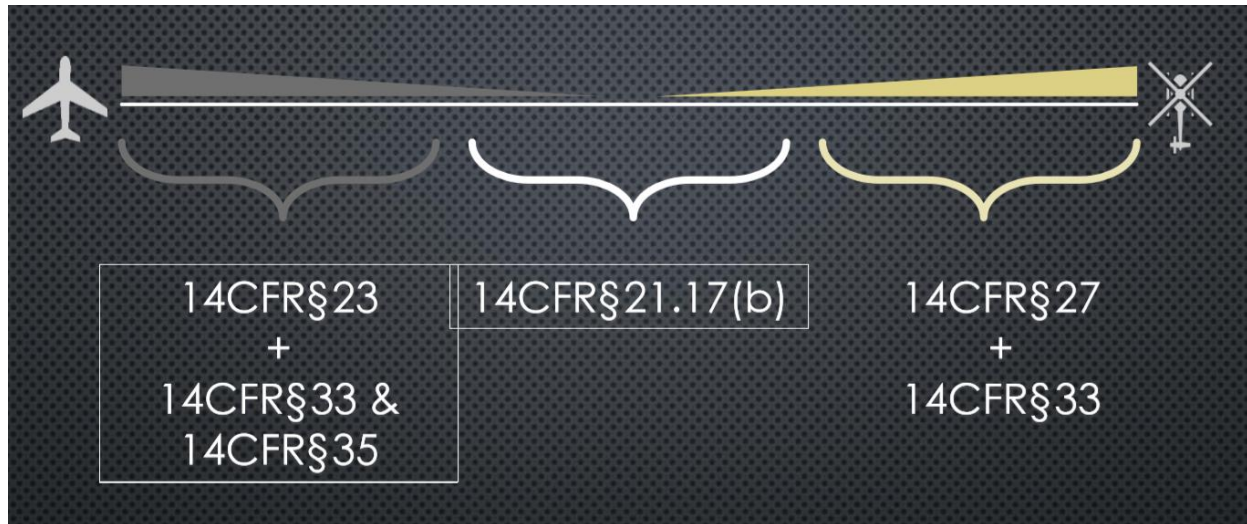


Figure 6: Range of certification approaches for hybrid fixed wing and rotary aircraft³⁸

The FAA is constantly reviewing and updating this regulatory framework. For example, there are three experimental type certification projects underway ranging from 10 to 6000 lbs., including manned and unmanned. Part 23 Amendment 64 was updated Aug 2017 to provide higher level requirements and allow industry consensus standards to fill in the more detailed requirements. The amendment reduced 377 regulations to 71. The FAA recently came out with Order 8000.71 that defines Hybrid Lift as a vehicle with VTOL capabilities and uses wings during horizontal flight.

2.5.4 FAA Part Certification Process

The type certification generally follows the process depicted in Figure 7, and principles and best practices for efficient design approval processes of type certification and design are discussed in the source document. The duration and exact process details can differ by Part Regulation. For example, Part 23 generally freezes current regulations for the applicant for 3 years, while Part 25 freezes regulations for 5 years.³⁹ Organizational Designation Authorizations (ODA) and Designated Engineering Representative (DER) serve as representatives to oversee the certification process ensure that the applicant meets the ‘airworthy’ term as defined by FAA Order 8130.2. The ODA and DER assess compliance from *Standard* or *Special* certification request, as defined by 14 CFR 183, Order No 8100.8D. Technical standards (RTCA, SAE, ASTM, etc.) can provide means of compliance.

³⁸ GAMA (AHS TVF Workshop, Jan. 2018). *Path to Certification*. <https://vtol.org/files/dmfile/13-TVF5-2018-Gunnarson-ASTM-Jan191.pdf>.

³⁹ Thurber, Matt (Dec. 2006). *The Aircraft Certification Process*. <https://www.ainonline.com/aviation-news/aviation-international-news/2006-12-18/aircraft-certification-process#>.

Type Design Approval

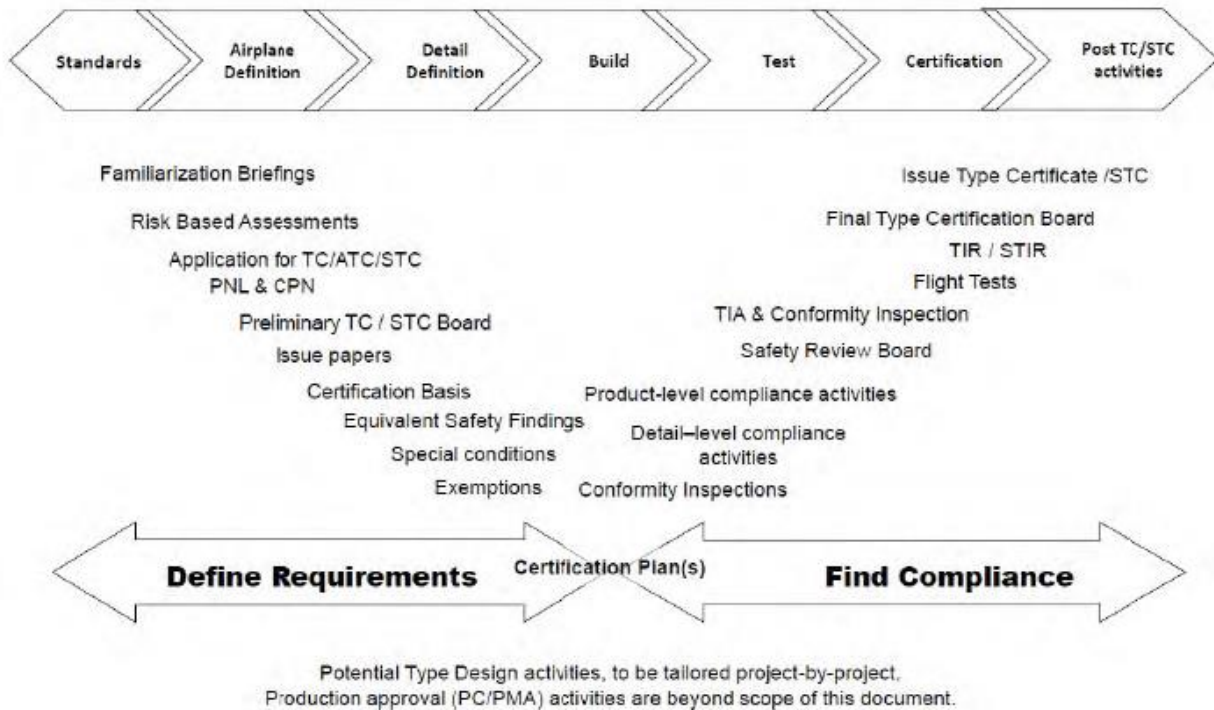


Figure 7: The type design approval process⁴⁰

A draft summary of the Part 21.17(b) certification process for UAS is summarized in Figure 8. The Safety Risk Management (SRM) is applied by the FAA when developing regulations. The FAA uses the information and data supplied by the approval holders and other sources to develop airworthiness regulations under this certification process. The process is driven by identifying risks, which may be based on the aircraft and its intended operation, typically organized by classification. Safety requirements are transformed into risk controls for a product or article. A safety requirement in the form of an airworthiness regulation is a safety risk control that, when complied with, constitutes acceptable risk. Airworthiness Regulations are developed when systematic hazards are discovered and the related outcome(s) have unacceptable risk. Acceptable level of risk is determined as part of the rulemaking process and summarized in 25.561 per Amendment 25-64. There may be aspects of existing regulatory requirements that cannot be clearly applied to new designs. There may also be new risks that must be addressed through new requirements. For example, Part 33 Engines is written with references to piston or turbine engine, so we will need to determine how electric motors will be handled. This leaves questions about what requirements apply, and what are potential means of complying with requirements. This may require developing new means of compliance (e.g., technical standards or regulation).

⁴⁰ AIA, AEA, GAMA, and the FAA Aircraft Certification Service and Flight Standards Service (May 2017). *The FAA and Industry Guide to Product Certification*, Pg. 15. https://www.faa.gov/aircraft/air_cert/design_approvals/media/CPI_guide.pdf.

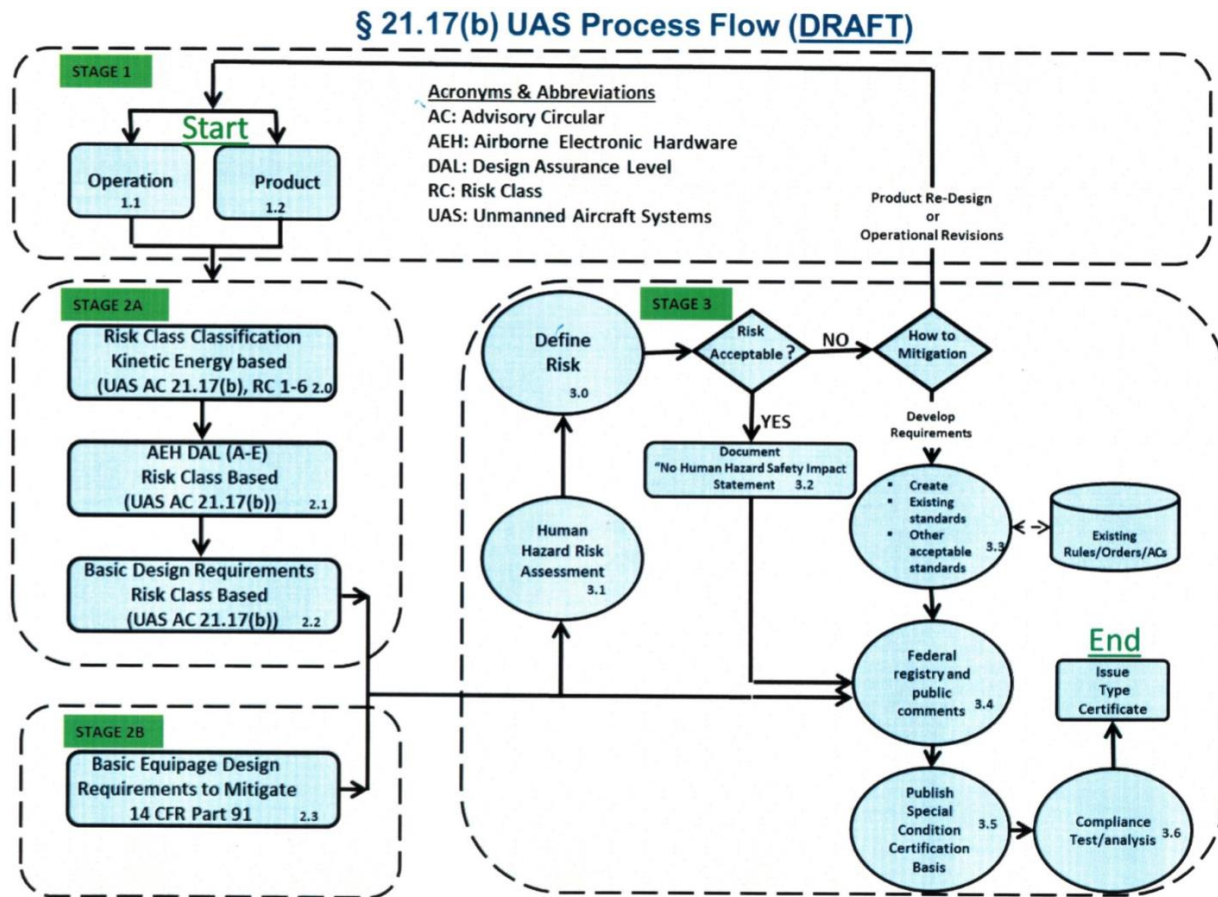


Figure 8: Part 21.17(b) certification process⁴¹

2.5.5 How Consensus Standards Support Certification: Means of Compliance

A requirement set forth in regulation may be met through more than one means of compliance that may include regulation, advisory circulars, or consensus standards. Figure 9 shows a set of requirements from Part 23, and an acceptable means of compliance through ASTM standards. Some Part regulations depend more on industry standards than others. For example, the Part 23 Amendment 64 shifted from prescribing detailed regulatory requirements to prescribing high-level requirements. It does not prescribe specific technical solutions nor does it have tiers or categories. Many in the aviation community see this as an opportunity to develop detailed design standards through consensus standards for flight characteristics, performance, operating limits, structures, design, powerplant, propulsion, and energy storage.

Consensus standards could accelerate UAM certification through the following activities:

- Making tiers where it makes sense
- Providing specific technical solutions
- Providing test specifications
- Providing specific compliance methods

⁴¹ Gunnarson, Tom (Jan. 19, 2018). *Aircraft Type Certification Considerations Urban Air Mobility*. <https://vtol.org/files/dmfile/13-TVF5-2018-Gunnarson-ASTM-Jan191.pdf>.

Part 23 Accepted Means of Compliance Based on ASTM Consensus Standards
Updated May 11, 2018

Part 23 Rule		Accepted MOC ¹		Potential Supplemental MOC ² and additional notes						
Section	Title	ASTM Standard	FAA Changes							
23.2135	Controllability	F3264-17, Section 5.8	<table border="1"> <tr> <td>Replace:</td> <td>With:</td> </tr> <tr> <td>ASTM F3173/F3173M-17, Sections 4.9.1.1 and 4.9.1.2</td> <td>FAA 4.9.1.1 and 4.9.1.2: 4.9.1.1: "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 5 seconds from initiation of roll and" 4.9.1.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+500) / 1300 seconds, but not more than 10 seconds, where W is the weight in pounds."</td> </tr> <tr> <td>ASTM F3173/F3173M-17, Sections 4.9.3.1 and 4.9.3.2</td> <td>FAA 4.9.3.1 and 4.9.3.2: 4.9.3.1: "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 4 seconds from initiation of roll and" 4.9.3.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+2,800) / 2,200 seconds, but not more than 7 seconds, where W is the weight in pounds."</td> </tr> </table>	Replace:	With:	ASTM F3173/F3173M-17, Sections 4.9.1.1 and 4.9.1.2	FAA 4.9.1.1 and 4.9.1.2: 4.9.1.1: "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 5 seconds from initiation of roll and" 4.9.1.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+500) / 1300 seconds, but not more than 10 seconds, where W is the weight in pounds."	ASTM F3173/F3173M-17, Sections 4.9.3.1 and 4.9.3.2	FAA 4.9.3.1 and 4.9.3.2: 4.9.3.1: "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 4 seconds from initiation of roll and" 4.9.3.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+2,800) / 2,200 seconds, but not more than 7 seconds, where W is the weight in pounds."	
Replace:	With:									
ASTM F3173/F3173M-17, Sections 4.9.1.1 and 4.9.1.2	FAA 4.9.1.1 and 4.9.1.2: 4.9.1.1: "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 5 seconds from initiation of roll and" 4.9.1.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+500) / 1300 seconds, but not more than 10 seconds, where W is the weight in pounds."									
ASTM F3173/F3173M-17, Sections 4.9.3.1 and 4.9.3.2	FAA 4.9.3.1 and 4.9.3.2: 4.9.3.1: "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 4 seconds from initiation of roll and" 4.9.3.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+2,800) / 2,200 seconds, but not more than 7 seconds, where W is the weight in pounds."									
23.2140	Trim	F3264-17, Section 5.9	None							
23.2145	Stability	F3264-17, Section 5.10	None							
23.2150	Stall characteristics, stall warning, and spins	F3264-17, Section 5.11	None							

Figure 9: Sample means of compliance from Part 23⁴²

2.5.6 Current Standards Provide Means of Compliance

This section provides a sample of some RTCA, SAE, and ASTM standards that support means of compliance. These standards support aspects such as design, testing, testing tools, software considerations, and verification. We have included some standards non-specific to aircraft that may potentially inform UAM certification such as SAE work on testing automated driving systems, which includes work on validation and verification and test scenarios that address identified risks for autonomous systems.

Many of these means of compliance may continue to support UAM aircraft, however some will be inadequate. The **bolded text** illustrates standards needed to enable UAM, and that may prove to be challenging to which to certify. For example, a clear standard regarding software and integrated equipment onboard UAM aircraft will need to be identified for manufacturers and certification entities to enforce. Modifications to the aircraft certification heavily rely on guidance from a regulatory body.

RTCA: Example RTCA standards that relate to UAM:

- **DO-160** - Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments
- **DO-178C** - Software Considerations in Airborne Systems and Equipment Certification
- **DO-254** - Design Assurance Guidance for Airborne Electronic Hardware
- **DO-362** - Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS)(Terrestrial)

⁴² Part 23 Accepted Means of Compliance Based on ASTM Consensus Standards (May 11, 2018). https://www.faa.gov/aircraft/air_cert/design_approvals/small_airplanes/small_airplanes_regs/media/part_23_moc.pdf.

- **DO-365** - Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems
- **DO-366** - Minimum Operational Performance Standards (MOPS) for Air-to-Air Radar for Traffic Surveillance
- **DO-278** – Software Integrity Assurance Considerations for Communication, Navigation, Surveillance, and Air Traffic Management (CNS/ATM) Systems
- Supplement DOs (used as applicable):
 - **DO-248C** - Supporting Information for DO-178C and DO-278A
 - **DO-330** - Software Tool Qualification Considerations
 - **DO-331** - Model-Based Development and Verification Supplement to DO-178C and DO-278A
 - **DO-332** - Object-Oriented Technology and Related Techniques Supplement to DO-178C and DO-278A
 - **DO-333** - Formal Methods Supplement to DO-178C and DO-278A

Examples of ongoing activities:

- **SC-228** - Minimum Ops Performance Standards for UAS
- **SC-214** - Air Traffic Data Communications
- **SC-186** - ADS-B

SAE: Example SAE standards that relate to UAM:

- **ARP-4761** - Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment; In conjunction with ARP4754, ARP4761
- **ARP-4754A** - Certification Considerations for Highly-Integrated or Complex Aircraft Systems
- **ARP94910 Aerospace** - Vehicle Management Systems - Flight Control Design, Installation and Test of, Military Unmanned Aircraft, Specification Guide For
- **ARP6461** - Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft
- **AS-1212** – Electric Power, Aircraft, Characteristics, and Utilization

Leveraging of standards efforts in other domains may be beneficial, such as:

- **SAE J3016:** Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems – known for the “5 Levels of Automation.”
- **SAE J3092:** Dynamic Test Procedures for Verification & Validation of Automated Driving Systems (ADS)

ASTM: Example ASTM standards that relate to UAM:

- **F3264-17** - Standard Specification for Normal Category Aeroplanes Certification
- **F3201 – 16** - Standard Practice for Ensuring Dependability of Software Used in Unmanned Aircraft Systems (UAS)
- **F3269 – 17** - Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions
- **F3298 – 18** - Standard Specification for Design, Construction, and Verification of Fixed-Wing Unmanned Aircraft Systems (UAS)

- **F2295-10** – Standard Practices for Continued Operational Safety Monitoring of a Light Sport Aircraft
- **F39.05** Standard Practice for Design and Manufacture of Electric Propulsion Units
- **F44.40** Powerplant

Examples of ongoing activities:

- Committee F38, F39, F44

2.5.7 Gaps in Standards

Efforts are underway to identify and address gaps in standards for emerging technologies that relate to UAM. In particular, ASTM F38 on Unmanned Aircraft Systems conducted a gap analysis for UAS that is particularly informative as shown in Figure 10. Gaps were identified in relation to Airframe, Power Plant, and Avionics in three overarching categories of certification: Airworthiness, Operations, and Crew Qualifications.

Airworthiness			UAS Operations			Crew Qualifications		
Airframe		Power Plant	Avionics	Power Plant	Ground	Airframe	Maintainers	Crew
Materials Structures Landing Gear Launch Devices Maintenance Environmental General	Reciprocating Turbine Generators Launch Devices Fuels General Electric	Comm/NAV Data Links General Safety /SA	Reciprocating Turbine Generators Launch Devices Fuels General Electric	Reciprocating Turbine Generators Launch Devices Fuels General Electric	Taxi Takeoff Landings	Reciprocating Turbine Generators Launch Devices Fuels General Electric		Pilot Non-Pilot Schools Human Factors
	- Batteries - Solar - Radioisotope	- De-Anti-Icing - Transponders - See & Avoid		- Batteries - Solar - Radioisotope	- GSE	- Batteries - Solar - Radioisotope		- Certificates - Ratings
ASTM F2111-04 Standard Specification for Design & Performance UAS Airborne Sense and Avoid System								Certificates and Ratings Issued for UAV

Roadmap Key:
ASTM F38 standards in progress - in orange
ASTM approved standards – in yellow
Outstanding needs – in red

Figure 10: Sample results from the ASTM F38 standards gap analysis for UAS⁴³

2.5.8 Potential Gaps in Means of Compliance for UAM: General and Propulsion/ Energy Storage

Table 2 details some of the standards gaps in detail and captures efforts underway that may help create a viable path to certification for UAM. The functional hazards arise from the need to better understand the potential hazards of the technology and use case. One example of ongoing work in this space is with automated driving systems. ISO-26262 is a functional safety standard that follows systems engineering processes to address functional safety of vehicles, but this framework. ISO 21448, Safety of the Intended Function (SOTIF) is a new standard being developed to support vehicle automation. Risk assessment is a challenge, which stems from new flight modes and characteristics. For new technologies, sometimes these are identified through scenario analysis, such as for the BNSF EVLOS risk analysis. Note that it can be challenging to assess progress of these efforts, as standards organizations do not typically share works in progress.

⁴³ ASTM. *UAS Standards Gap Analysis*. Committee F38.

Table 2: Summary of key standards, gaps, and activities

Requirement	Relevant Documents	Gap	Relevant Activities
All Aircraft: Functional Hazards	FAA 23.1309-1E, AR 70-62, MIL-HDBK-516C	Identification of hazards, design methods to address hazards, and testing methods	ISO-21448 SOTIF
All Aircraft: Risk Assessment and Management	FAA Order 8040.4A, SAE ARP 4761, MIL-STD-882E	New flight modes and characteristics, unclear risk profiles	
Part 33/ CS-E: Electric Propulsion	ASTM F39.05 <i>Electric Propulsion Units</i>	Design and manufacture issues	Proposed Revision (WK47374)
Part 33/ CS-E: Electric Propulsion	ASTM F44.40 <i>Powerplant</i>	Integration issues for hybrid-electric propulsion	Proposed Revision (WK41136)
Part 33/ CS-E: Electric Propulsion	ASTM F39.05 <i>Electric Propulsion Units</i>	Energy storage systems	Proposed Revision (WK56255)
All Aircraft: Software Design Assurance	RTCA DO-178C	The methods are unable to handle the large number of states and decisions that autonomy algorithms can take	
Detect and Avoid (DAA)		Minimum Operational Performance Standards (MOPS) to specify DAA equipment to support BVLOS UAS operations in Class D, E, and perhaps G, airspace.	RTCA SC-228
Command and Control (C2)	RTCA DO-362	Normative performance standards for C2 link systems and constituent subsystems, including beyond radio line of sight (BRLOS).	

There may be some gaps in the certification process where specific approaches and tools need to be developed, particularly along system redundancy and failure management. There is an increasing awareness of current gaps, and potential strategies for certification for UAM. This was recently discussed at a Congressional hearing on 7/24/2018⁴⁴.

- **Autonomous and highly complex software** - Software is becoming increasingly complex. Machine learning and other algorithms used for automation are non-deterministic, which means that

⁴⁴ House Committee on Science, Space, and Technology (July 24, 2018). *Full Committee Hearing - Urban Air Mobility – Are Flying Cars Ready for Take-Off?*. <https://www.youtube.com/watch?v=2US-SoC8wibA>.

even for the same input, the algorithm may exhibit different behaviors on different runs. This problem is not specific to aviation and falls under the broader topic of explainable and verifiable artificial intelligence (AI). It is considered a major challenge worthy of significant investment at the National Science Foundation (NSF), Defense Advanced Research Projects Agency (DARPA), and USDOT to name a few.

- **Distributed electric propulsion/ Electric powerplant** - Both propulsion and energy storage pose challenges in an industry that has traditionally worked with engines and liquid fuels. The failure modes will look different. How will multi-copters handle prop failures, motor failures, electrical system failures, and energy storage failures? What redundancies and mitigation measures are needed?
- **Unmanned/ optionally piloted** - The end goal for many UAM business models is to have these aircraft operate without an onboard pilot. Zee Aero is targeting certification for optionally piloted UAM. Because of the operational risks, there are additional airworthiness requirements. There is considerable work going on in the UAS domain attempting to address these challenges, which UAM may benefit from, but the UAM use case may still generate specific requirements.
- **Ratio of Aircraft to Operators < 1** - Several UAM business models include a transition period to full autonomy that may include operations centers with remote operators controlling multiple aircraft. The operational risk of this use case will need to be considered in airworthiness. The FAA is holding a meeting in September that I am attending that will explore potential impacts of multiple operations.

2.5.9 Potential Certification Approaches for Air Taxi and Air Ambulance

Potential certification approaches for Air Taxi and Air Ambulance markets depends on vehicle characteristics and intended use. There are a range of UAM concepts and some may be closer to a fixed wing (e.g., Part 23) or a rotary craft (e.g., Part 27) depending on their configuration, as depicted in Figure 11.

There will be challenges in determining which of the existing FAA certification standards apply to the types of vehicles being considered for the Air Taxi or Air Ambulance UAMs, and/or how existing certification standards can be met or should be amended.

Air Taxi UAMs: Given their sizes, they could be compared to “light civil”, which would be FAA Part 23 (normal airplanes) or a Part 27 (normal rotorcraft). However, given the mission of passenger transport, it could be argued that Part 25 (airplane) or Part 29 (rotorcraft) could apply. Part 23 Amendment 64 may be an attractive option if industry consensus standards can be developed to appropriately tier UAM platforms, define technical solutions, test methods, and means of compliance. If existing categories are insufficient, Part 21.17(b) offers certification for special aircraft, which may include leveraging elements from multiple categories in the existing airworthiness regulatory framework, as well as defining new requirements.

Air Ambulances UAMs: In addition to the certification standards listed above for Air Taxis, Air Ambulance UAMs will require detailed guidance for the evaluation of an operator’s air ambulance procedures, specific sections of their General Operations Manual (GOM) related to air ambulance, and the unique requirements an operator must meet prior to being issued Operations Specification (OpSpec) for Helicopter, Airplane, or a new category depending on how the UAM is classified.

The question of classification is critical. The certification path will influence time to market and associated costs. Part 23 may offer more flexibility due to its extensive use of industry consensus standards – but those standards still need to be developed. We also discussed the potential for Part 21.17(b) for special aircraft, which may borrow portions of 23 and 27, but this is not meant for mass production.

This space is continuing to evolve. FAA has Type Certification projects ongoing. ASTM is identifying and addressing standards gaps. International entities are taking the lead on experimenting with new UAM certification (e.g., Volocopter).

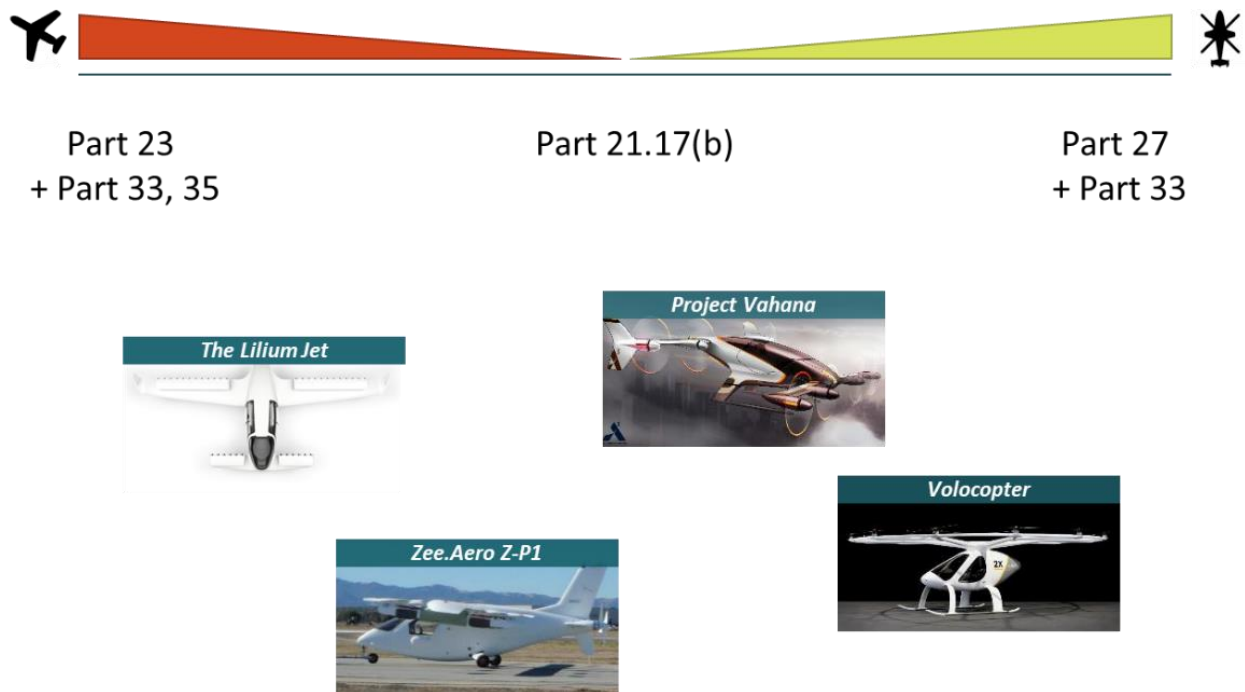


Figure 11: UAM concept vehicles may fall along a spectrum ranging from resembling fixed wing or rotary aircraft

2.5.10 Enabling Strategies

As this space evolves, it may be helpful to develop roadmaps for certification paths, gaps, and needs for the various UAM sizes and use cases. The FAA UAS Integration Office recently started developing a roadmap, but it is currently unclear how the outputs will benefit the UAM market. Tracking progress of international entities could help build a more complete picture of gaps and efforts to address those gaps. For example, opportunities for coordination and collaboration may exist. Tracking developments in the automated vehicle space may inform the development of test methods, software considerations, and risk frameworks. While this report focused on airworthiness, that is only part of the certification challenges. There are many important challenges in the areas of operator (crew) and operations certification that will need to be addressed as well.

3.0 SUMMARY AND KEY FINDINGS

The legal and regulatory analysis demonstrates that though lawmaking is usually slow and tedious, legislation is moving quickly to keep pace with the advancements in UAS technology, which helps reduce the gap towards enabling UAM. During the course of this study, we saw the introduction of the UAS IPP which is helping drive enabling rules that would allow more complex operations, the passing of the FAA Reauthorization Act of 2018 which mandates FAA to make regulations within the year for the UAS carriage of property for compensation or hire, among other items, and movements within EASA to regulate VTOL aircraft with a passenger seating configuration of 5 or less and a maximum certified take-off mass of 2,000kg or less. What stood out as barriers at the beginning of the study have eased into opportunities as many of these developments unfolded near the end of this project. With that in mind, we recommend that any future studies emphasize the need to be agile in a quickly changing legal environment, and that the focus on “barriers” be shifted to “opportunities” so that NASA can find ways to design, develop, and test advanced UAM technologies that will translate into enabling legislation.

Key Findings	<p>Legal, regulatory, and certification challenges and opportunities exist in order to bring UAM to the market. The analysis on UAM draws a comparison to the UAS legal and regulatory achievements as many of the UAM areas are being addressed to some extent with the emergence of UAS operations. Similarly, UAS research has helped reduce the gap towards enabling UAM. Some of the challenges involve the dynamic legal environment which include many unresolved challenges, especially establishing where federal, state, and local authorities take lead. Additionally, UAM poses legal challenges that touch on most aspects of aviation, especially in the areas of air traffic control and management, and flight standards, but also environmental policy, public use, land use, and local restrictions. However, the current legal framework is starting to evolve to match the technology, especially in light of the FAA Reauthorization Act of 2018. That being said, assured autonomy remains a challenging technical and legal problem.</p> <p>Moreover, a diversity in approaches exists whereby States and locales are undertaking legal experiments through a mix of approaches, ranging from designating UAS launch sites to hyperlocal restrictions. Additionally, State and local laws range from laws prohibiting drones to laws protecting UAS operations. Similarly, diverse regulations have appeared internationally as well.</p> <p>With respect to certification, many efforts are underway at FAA, ASTM, RTCA, SAE, and elsewhere to provide methods of aircraft certification for UAM, but there is still no clear certification path and several gaps in means of compliance. However, opportunities may exist to:</p> <ul style="list-style-type: none"> • Develop a roadmap to airworthiness that considers the range of potential UAM aircraft and paths to certification. • Study and leverage international efforts (e.g., ICAO, EASA, NATO). • Study and leverage efforts from similar domains, such as autonomous cars (e.g., SAE Validation and Verification Task Force). • Explore other certification challenges for operator and operations certification. <p>More importantly, however, are the strategies which currently exist to help the UAM technology move forward. Enabling strategies can be employed to accelerate the development of a UAM legal framework such as:</p> <ul style="list-style-type: none"> • NASA – FAA cooperation, such as the Research Transition Team • FAA Aviation Rulemaking Committee • FAA UAS Integration Pilot Program
---------------------	--

- Leveraging strategies from automobile automation, such as voluntary standards may help UAM deployment
- FAA Reauthorization act of 2018 provides much needed support for industry and ensuing economy

