ASSURE A27 – Establish Risk-Based Thresholds for Approvals Needed to Certify UAS for Safe Operation: Final Report

December 1, 2022

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<table>
<tr><td colspan="2">1. Report No.
A11L.UAS.71</td><td>2. Government Accession No.</td><td>3. Recipient’s Catalog No.</td></tr>
<tr><td colspan="3">4. Title and Subtitle
ASSURE A27 – Establish Risk-Based Thresholds for Approvals Needed to Certify UAS for Safe Operation: Final Report</td><td>5. Report Date
December 1, 2022
6. Performing Organization Code</td></tr>
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11. Contract or Grant No.
A11L.UAS.71: Establish risk-based thresholds for approvals needed to certify UAS for safe operation</td></tr>
<tr><td colspan="3">12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Aviation Administration
Washington, DC 20591</td><td>13. Type of Report and Period Covered
Final Report; Task 4 (Sep 9, 2019 – December 5, 2022
14. Sponsoring Agency Code
5401</td></tr>
<tr><td colspan="4">15. Supplementary Notes
N/A</td></tr>
<tr><td colspan="4">16. Abstract
Given the distinct differences between Unmanned [Uncrewed] Aircraft Systems (UAS) and conventionally piloted aircraft, questions arise about the nature of remote pilot knowledge and skillsets for UAS, and how they differ from that of conventionally piloted aircraft. This is especially true for expanded UAS flight operations, such as Beyond Visual Line-of-Sight (BVLOS) and operations over people, which carry more risk. Similarly, airworthiness considerations help to shape how and where UAS operate. This research addresses questions regarding remote pilot training and airworthiness for UAS. Through this project, the team arrived at a series of recommendations for the FAA’s remote pilot ACS. Additionally, the research team was able to identify recommended process improvements for the Durability and Reliability (D&R) Type Certification (TC) process and participate in industry standard development.</td></tr>
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17. Key Words		18. Distribution Statement	
Durability and Reliability, D&R, Low-Risk, Risk-Based, sUAS Type Certification, TC		No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161. Enter any other agency mandated distribution statements. Remove NTIS statement if it does not apply.	
19. Security Classification (of this report)	**20. Security Classification (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	36	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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AC	Advisory Circular
ACO	Aircraft Certification Office
ACS	Airman Certification Standards
AE	Associated Elements
ASTM	ASTM International
BVLOS	Beyond Visual Line-of-Sight
CFI	Certified Flight Instructor
CFR	Code of Federal Regulations
COTS	Commercial Off-the-Shelf
D&R	Durability and Reliability
FAA	Federal Aviation Administration
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
KSA	Knowledge, Skills, and Abilities/Attitudes
KSU	Kansas State University
LAANC	Low Altitude Authorization and Notification Capability
MoC	Means of Compliance
NAS	National Airspace System
OEM	Original Equipment Manufacturer
PC	Production Certificate
PSP	Partnership for Safety Plan
PTS	Practical Test Standard
RPC	Remote Pilot Competency
RTCA	Radio Technical Commission for Aeronautics
sUAS	Small Unmanned [Uncrewed] Aircraft System
TC	Type Certification
UA	Unmanned Aircraft
UAS	Unmanned [Uncrewed] Aircraft System
UFM	Unmanned [Uncrewed] Flight Manuals
UND	University of North Dakota
WSEG	Waiver Safety Explanation Guidelines

EXECUTIVE SUMMARY

Given the distinct differences between Unmanned [Uncrewed] Aircraft Systems (UAS) and conventionally piloted aircraft, questions arise about the nature of remote pilot knowledge and skillsets for UAS, and how they differ from that of conventionally piloted aircraft. This is especially true for expanded UAS flight operations, such as Beyond Visual Line-of-Sight (BVLOS) and operations over people, which carry more risk. Similarly, airworthiness considerations help to shape how and where UAS operate. This research addresses questions regarding remote pilot training and airworthiness for UAS.

ASSURE A27 examined the role of remote pilot training as a risk mitigation for UAS flights BVLOS and operations over people. The project also exercised the Federal Aviation Administration's (FAA's) Durability and Reliability (D&R) Type Certification (TC) process. This enabled an examination of a new TC process, and it offered an opportunity to translate findings into an industry consensus standard. Kansas State University (KSU) served as the leading research institution, with the University of North Dakota (UND) and Sinclair Community College (Sinclair) supporting the research effort.

The initial literature review explored existing literature regarding existing regulations for UAS; 14 Code of Federal Regulations (CFR) Part 107, pilot certification standards from 14 CFR Part 61, airworthiness standards, and applicable industry consensus standards. This allowed the research team to identify differences between approaches to pilot training for conventionally piloted aircraft and UAS. It also shed light on concepts regarding the management of operational risk, offering an exploration of concepts surrounding airworthiness and pilot training as risk mitigation factors. The literature review enabled the research team to develop a conceptual approach to identifying recommended UAS remote pilot training for BVLOS flight and operations over people. It also provided insight into existing pathways for UAS airworthiness and type certification.

Following the literature review, the research team pursued a deeper exploration of remote pilot training, referencing existing industry standards, recommendations from international industry groups, and guidance from the FAA's Airman Certification Standards (ACS). This enabled the research team to develop a series of recommendations aimed at addressing additional risks and operational requirements associated with BVLOS and operations over people. The resulting eleven recommendations reflect a potential area for remote pilot training requirements to grow to suit UAS operations beyond those normally conducted under 14 CFR Part 107.

Additionally, this research exercised the FAA's D&R TC process. The research team followed multiple applicants through the process for 23 months. During this time, the research team documented applicants' successes and challenges, and tracked procedural elements of D&R for the sake of providing guidance. The research team arrived at eleven recommendations for process improvement for D&R.

This research answered questions regarding remote pilot knowledge, skills, and abilities/attitudes for certain operational paradigms and explored the FAA's new D&R TC process. Through this project, the team arrived at a series of recommendations for the FAA's remote pilot ACS. Additionally, the research team identified recommended process improvements for the D&R TC process and participated in industry standards development.

1 INTRODUCTION & BACKGROUND

ASSURE A27 investigated two key aspects of Unmanned [Uncrewed] Aircraft Systems (UAS) required for broader incorporation of UAS into the National Airspace System (NAS); (1) remote pilot training requirements for expanded operations, and (2) important considerations for airworthiness and type certification for small Unmanned [Uncrewed] Aircraft Systems (sUAS). This research consisted of three primary research tasks, which enabled the research team to explore the ramifications of remote pilot training for BVLOS and operations over people while also understanding how UAS type certification, specifically the FAA's Durability and Reliability (D&R), contribute to integrating UAS into the NAS.

Research Tasks:

- Literature Review
- Durability and Reliability Type Certification Use Case Applications
- Operational Training

Key research questions in the following section drove the direction of this project. These questions informed the overall research methodology, individual taskings, and deliverables.

2 RESEARCH QUESTIONS

The following questions guided this research project. Most importantly, these questions provided important context and scope, informing the tasks and key deliverables. The research team used these questions as both a means to structure research tasks and as guidance to define research goals.

Research Questions

- What Knowledge, Skills, and Abilities/Attitudes (KSAs) are required of UAS operators for complex expanded and non-segregated UAS operations in the National Airspace System?
- In manned aviation, various ratings exist, having specific KSAs and Practical Test Standards (PTS) associated with them. Examples of ratings include instrument; commercial; multi-engine; and instructor. Should various ratings exist for a range of UAS operations, and if so:
    - What are they?
    - What are the associated KSAs?
    - What is the associated PTS?
    - What are the minimum training thresholds required in order to obtain them?
- Do 14 Code of Federal Regulations (CFR) Parts 61 and 141 serve well as a foundation to establish future UAS pilot training, certification, and standards requirements?
- What is the level of overlap, essentially the transfer of knowledge, between manned and unmanned flight?
- What dependencies does UAS training have on manned training?
    - What level of previous manned pilot training (if any) should serve as a prerequisite for UAS pilot certification?
    - Additional UAS training could be used in lieu of manned pilot training. In other words, if the research suggests that a manned instrument rating may be used to

reduce the number of hours required for a UAS remote pilot to obtain a Beyond Line-of-Sight rating, could that manned instrument rating experience be replaced with UAS-only training standards, and if so, what is the difference in training required?

- Performance-based type/airworthiness certification: Process Approach: No specific research question.

The tasks described in the following section represent the research team's approach to answering the questions above. As mentioned, this research focused on questions regarding remote pilot training and sUAS airworthiness/type certification.

3 RESEARCH TASKS

The research team consisting of KSU, UND, and Sinclair performed the following research tasks as part of the ASSURE A27 research effort. These tasks defined the team's overall approach to satisfy research requirements while answering guiding research questions. Additionally, these tasks provided deliverables to assist the FAA in answering questions regarding remote pilot training and offered insight into the successes and pitfalls associated with the D&R TC approach for low-risk UAS.

3.1 Task 1 – Literature Review

ASSURE A27 began with a thorough literature review. This in-depth review of applicable literature consisted of foundational literature regarding (1) pilot training, and (2) civil aircraft airworthiness and type certification, and (3) risk assessment methodologies. The goal of this literature review was to explore the applicability of existing remote pilot training, airworthiness standards, and risk assessment methodologies to expanded sUAS flight operations, particularly BVLOS and operations over people.

3.1.1 Remote Pilot Training

A review of the literature on remote pilot training requirements began with an overview of existing qualifications and regulatory requirements for conventionally piloted aircraft. An initial review of 14 CFR Part 61 highlighted levels of certification and ratings tied to various levels of knowledge, skills, and abilities. This formed the conceptual baseline for investigating whether any unique remote pilot requirements may be applicable to BVLOS flight operations and/or operations over people. 14 CFR Part 61 establishes pilot certificates and ratings such that additional ratings add to a baseline level of pilot certification.

The literature review touched upon six levels of pilot certification and outlined some of their associated privileges and limitations. This tiered level of certification provided insight into how levels of pilot certification advance in a manner that is commensurate with requirements for aeronautical knowledge, skills, and demonstrated abilities.

The first level of pilot certification the research team explored was the student pilot certificate, outlined within 14 CFR Part 61 Subpart C – Student Pilots. With this level of certification, student pilots may not operate an aircraft for compensation or hire and may only fly solo under certain conditions and/or under the supervision of a Certified Flight Instructor (CFI). Once a student pilot completes the required training and meets the requirements specified in 14 CFR §61.87, they may

then be issued a pilot certificate with fewer restrictions, such as the ability to fly solo, carry passengers, etc.

The research team also explored the requirements for recreational pilot certificates, private pilot certificates, commercial certification, Airline Transport Pilot certification, and CFI certification. The trends within the regulatory framework and existing guidance were an increase of knowledge, skill, and demonstrated ability as the level of certification increased. Requirements for aeronautical knowledge, practical skills, and ability to perform specific tasks increased with the level of certification.

The research team also reviewed existing regulations and guidance for remote pilot training with 14 CFR Part 107 and associated Advisory Circulars (ACs). The research team found little in the way of remote pilot training or other requirements. Instead, 14 CFR Part 107 conveys simple eligibility requirements for remote pilots within 14 CFR §107.61. These requirements are as follows:

> §107.61 Eligibility.
> Subject to the provisions of §107.57 and 107.59, in order to be eligible for a remote pilot certificate with a sUAS rating under this subpart, a person must:
>
> (a) Be at least 16 years of age;
>
> (b) Be able to read, speak, write, and understand the English language. If the applicant is unable to meet one of these requirements due to medical reasons, the FAA may place such operating limitations on that applicant's certificate as are necessary for the safe operation of the small unmanned aircraft;
>
> (c) Not know or have reason to know that he or she has a physical or mental condition that would interfere with the safe operation of a small unmanned [uncrewed] aircraft system; and
>
> (d) Demonstrate aeronautical knowledge by satisfying one of the following conditions:
>
> (1) Pass an initial aeronautical knowledge test covering the areas of knowledge specified in §107.73(a); or
>
> (2) If a person holds a pilot certificate (other than a student pilot certificate) issued under part 61 of this chapter and meets the flight review requirements specified in §61.56, complete an initial training course covering the areas of knowledge specified in §107.74(a) in a manner acceptable to the Administrator (Eligibility, 2021).

While these requirements outline certain characteristics that remote pilots must meet to obtain a remote pilot certificate under 14 CFR Part 107, there are no specific requirements for obtaining a remote pilot certificate beyond a demonstration of aeronautical knowledge. As such, there are no established requirements for practical skills or other demonstrated abilities beyond baseline knowledge to earn a remote pilot certificate.

Despite little in the way of practical requirements or skillsets for remote pilots within 14 CFR Part 107, the research team found precedent for the use of additional remote pilot knowledge for use as risk mitigation for sUAS flight operations conducted under waivers granted under 14 CFR §200.

> §107.200 Waiver policy and requirements.
>
> (a) The Administrator may issue a certificate of waiver authorizing a deviation from any regulation specified in §107.205 if the Administrator finds that a proposed sUAS operation can safely be conducted under the terms of that certificate of waiver.
>
> (b) A request for a certificate of waiver must contain a complete description of the proposed operation and justification that establishes that the operation can safely be conducted under the terms of a certificate of waiver.
>
> (c) The Administrator may prescribe additional limitations that the Administrator considers necessary.
>
> (d) A person who receives a certificate of waiver issued under this section:
>
> (1) May deviate from the regulations of this part to the extent specified in the certificate of waiver; and
>
> (2) Must comply with any conditions or limitations that are specified in the certificate of waiver (Waiver Policy and Requirements (2016).

As of the date of the literature review, December 2019, there were approximately 3,327 waivers for operation at night (14 CFR §107.29; formerly referred to as *Daylight Operation*) granted by the FAA out of the total of approximately 3,500 petitions for waiver or exemptions from 14 CFR Part 107. The research team reviewed a subset of fifty (50) of these waivers to try and identify what specific provisions, if any, may set a precedent for additional training requirements for remote pilots. The research team chose to analyze waivers for 14 CFR §107.29 because, at the time, the largest percentage of waivers the FAA had granted were for operation at night.

The analysis of waivers for 14 CFR §107.29 highlighted the following common language for common and technical provisions of waivers granted by the FAA.

> *Training:*
>
> "*Prior to conducting operations that are the subject of this Waiver, the remote PIC and VO must be trained, as described in the Waiver application, to recognize and overcome visual illusions caused by darkness, and understand physiological conditions which may degrade night vision. This training must be documented and must be presented for inspection upon request from the Administrator or an authorized representative.*"

This provision commonly found within 14 CFR §107.29 waivers highlighted the FAA's approach to addressing the increased risk associated with flying sUAS at night through requirements for

additional remote pilot and crew training. The research team would use this conceptual approach to pursue requirements for remote pilot training as part of Task 3 – Operational Training.

3.1.2 Risk Assessment Methodologies

The research team also explored various risk assessment methodologies as a component of the literature review, to include a comparison of FAA safety management system concepts and the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) Specific Operation Risk Assessment. The exploration of risk in these assessment methodologies provided an opportunity to perform a comparison while assessing their usefulness regarding pilot training and sUAS flight operations. This approach contributed to remote pilot training recommendations for Task 3 – Operational Training, while providing points of comparison for regulatory requirements within 14 CFR Part 107. Key findings of this element of the literature review were differences in scope between risk assessment methodologies when applied to sUAS flight operations of given operational complexities. As operational complexity increases, the scope of a given approach to risk assessment must increase as well. Figure 1 highlights this relationship[1].

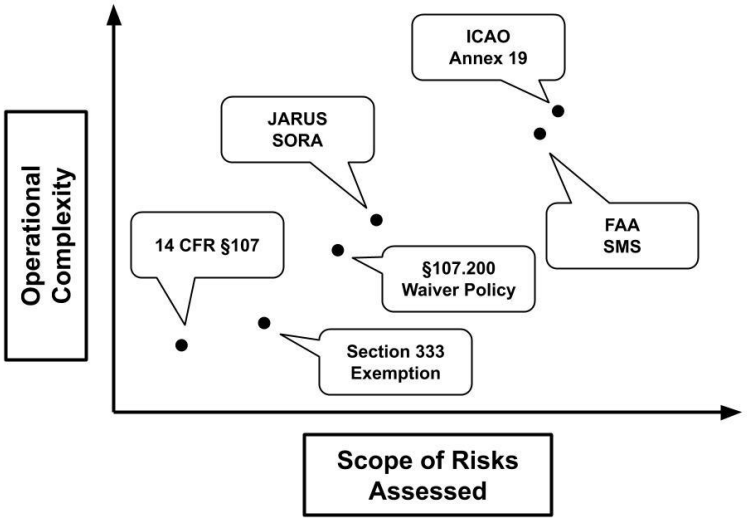

Figure 1. Operational Risk and Scope of Risks Assessed.

Additionally, this portion of the literature review compared JARUS remote pilot recommendations against 14 CFR Part 107. This comparison highlighted differences and similarities between JARUS remote pilot recommendations and regulatory constructs present within 14 CFR Part 107. This comparison was able to draw parallels between 14 CFR Part 107 and JARUS Category A (Open) and Category B (Specific) operations, equating 14 CFR Part 107 to Category A (Open) and operations conducted under a waiver to Category B (Specific).

[1] Note: The Section 333 Exemption process referenced in Figure 1 has been replaced with a comparable process through 49 United States Code (U.S.C.) §44807.

3.1.3 Standards for sUAS Airworthiness and Type Certification

An additional component of the literature review was an overview of the concepts and approaches to aircraft airworthiness and type certification. The literature review began with an overview of conventional type certification approaches, touching upon methods available to conventional piloted aircraft, as shown in Figure 2.

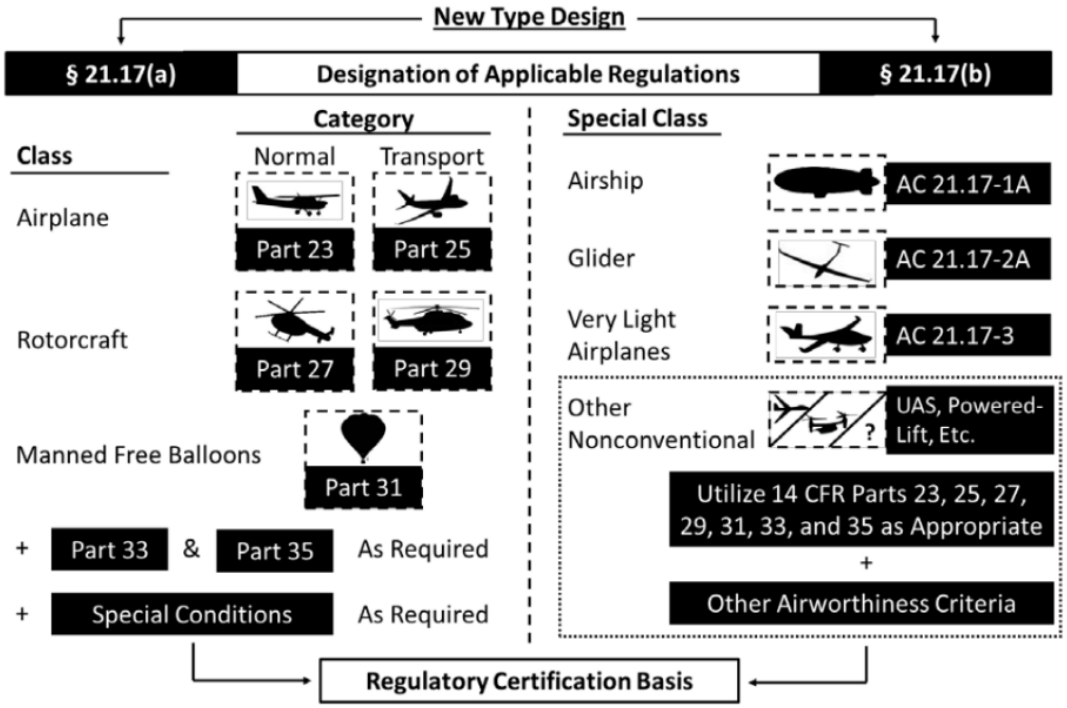

Figure 2. Model of the Type Certification Process (Johnson & Foltz, 2019).

While the approach depicted in 14 CFR §21.17(a) has proven sufficient for conventional piloted aircraft, there are disconnects when applying this methodology to sUAS, as they cannot rely on the same robust regulatory framework to address all elements of risk inherent to their design. A different approach for sUAS airworthiness and type certification using 14 CFR §21.17(b) offers an avenue for flexibility. It also offers the ability to utilize novel processes and industry consensus standards to define a certification basis. The literature review underscored the importance of the 14 CFR §21.17(b) pathway while highlighting the role of industry consensus standards, such as those from the Radio Technical Commission for Aeronautics (RTCA), ASTM International, and JARUS.

3.1.4 Primary Findings of Literature Review

The research team identified several key takeaways from the literature review that helped to frame follow-on tasks for this research. These findings helped to (1) enable engagement with standards bodies for Task 2, and (2) provide a starting point for identifying remote pilot requirements for operations over people and BVLOS flights.

1. Standards bodies, such as ASTM International and RTCA will continue to play a role in contributing to the FAA's ability to meet regulatory challenges;

2. The scope of risk assessment methodologies must be commensurate with the risks involved with a given sUAS flight operation; and
3. Supporting the development of additional standards and approaches to addressing risk – through remote pilots and/or airworthiness certification, is essential to furthering integration and providing a reliable, consistent pathway toward expanded operations.

3.2 Task 2 – Durability and Reliability Type Certification Use Case Application

The purpose of Task 2 was to exercise the FAA's new D&R TC. The research team accomplished this by:

1. Following several Original Equipment Manufacturers (OEMs) through the TC process to provide feedback, and
2. Providing lessons learned from that process to aid in the development of industry consensus standard(s) for sUAS airworthiness and type certification.

The following subsections describe the basic elements of the D&R process, the research team's methodology, limitations, issues, and recommendations.

3.2.1 Task 2-1: Procedural Documentation and Guidance

This task took an observational approach to analyze the FAA's D&R TC process for low-risk UAS. For this task, the research team followed multiple sUAS OEMs, also referred to as 'applicants,' through the FAA's D&R TC process. The research team documented the applicants' experiences along the way, highlighting deliverables, and other important milestones that they encountered. The research team also documented successes and challenges faced by both applicants and FAA stakeholders. The intent was for feedback from this task to inform improvements to D&R while providing guidance to the FAA on how to prepare applicants to navigate the D&R process.

What follows is an overview of the applicability and regulatory justification for D&R, an overview of the research team's methodology, and important findings from this research. This report also contains a series of recommendations that resulted from the research team's multi-year effort in following D&R applicants. The recommendations in this report are reflective of the research team's observations of applicant and FAA stakeholder experiences through direct engagement over the course of this project. The research team omitted direct references to specific applicants and stakeholders in this report to protect confidentiality.

3.2.1.1 Applicability and Regulatory Justification for D&R Airworthiness Criteria

The D&R TC process is not open to all UAS. OEMs meeting specified criteria may use the D&R process as a Means of Compliance (MoC). As such, there are specific criteria and regulatory requirements that an applicant must consider prior to entering the D&R process.

3.2.1.1.1 D&R Applicability

The D&R airworthiness and TC process is a novel means of demonstrating airworthiness for UAS deemed to be "low risk" according to the FAA. This process relies on demonstrations of overall system reliability, capacity to respond to likely failures, and meeting certain baseline design criteria rather than emphasizing costly and time-consuming testing that is normally associated with larger type certification programs. Per the D&R MoC, a UAS must meet a series of criteria for

D&R to apply. The criteria specified in the MoC narrow the scope of D&R to apply to UAS that have characteristics that lend themselves to presenting a low risk to the airspace and ground environment. The D&R MoC lists the following as defining a low risk UAS that meets the requirements to seek airworthiness and type certification using D&R:

a) The UAS has a command and control link that enables the pilot-in-command to take contingency action.

b) The unmanned aircraft (UA) has a kinetic energy of ≤25,000 ft-lbs.

c) The UA is operated ≤400ft AGL.

d) No operations over open-air assemblies (operations over people are acceptable).

e) No flight into known icing.

f) Maximum of 20:1 aircraft to pilot ratio.

g) The UA must be electrically powered or have a reciprocating engine (no turbines, fuel cells, etc.) (Federal Aviation Administration, 2021).

If a UAS does not meet the requirements listed above, then D&R is not applicable, and an applicant must use other airworthiness criteria with a different means of compliance as part of the certification basis. Additionally, there is a requirement to obtain a Production Certificate (PC) as part of this process as well.

3.2.1.1.2 D&R Regulatory Justification

UAS are unique when compared to conventionally piloted aircraft in that they can differ in size, capability, and configuration. There is little in the way of a set archetype for what a UAS must be. Given their size, the lack of an onboard pilot, and the novelty associated with their designs, UAS require different considerations for airworthiness and reliability that suit their unique nature. The D&R MoC addresses the unique nature of UAS through performance-based metrics aimed at demonstrating overall system reliability.

14 CFR §21.17(b) serves as the regulatory point of entry for the FAA's D&R process and addresses the designation of applicable regulations for special classes of aircraft. 14 CFR §21.17(b) states,

> For special classes of aircraft, including the engines and propellers installed thereon (e.g., gliders, airships, and other nonconventional aircraft), for which airworthiness standards have not been issued under this subchapter, the applicable requirements will be the portions of those other airworthiness requirements contained in Parts 23, 25, 27, 29, 31, 33, and 35 found by the FAA to be appropriate for the aircraft and applicable to a specific type design, or such airworthiness criteria as the FAA may find provide an equivalent level of safety to those parts (Designation of Applicable Regulations, 2016).

Language within 14 CFR §21.17(b) provides a sort of "catch all" for novel aircraft, providing an alternative to avenues available to more conventional aircraft that fall under 14 CFR §21.17(a). The 14 CFR §21.17(b) path offers applicants the flexibility to pursue type and/or airworthiness certification through applicable portions of existing Parts or through a means that is acceptable to the FAA, providing that means offers an equivalent level of safety. Figure 2, shown in Section

3.1.3, outlines the regulatory structure surrounding the designation of applicable regulations, including 14 CFR 21.17(b).

3.2.1.2 Methodology

The research team took an observational approach to this study, participating in D&R TC meetings with applicants and FAA stakeholders and documenting findings over the course of the task. This allowed the research team to gain an understanding of what applicants experience when pursuing a TC under D&R and document any gaps or challenges faced by all parties involved. This approach provided valuable insight into the D&R process and offered the opportunity to observe the process as a neutral third party. More importantly, it offered the research team an opportunity to inform the FAA on areas of improvement for the benefit of all involved.

3.2.1.3 Limitations

Due to the dynamic nature of the TC process, the research team was unable to follow any TC applicants through completion. This being the case, the observations and recommendations resulting from this research pertain to only the portions of the D&R TC process the research team observed. There were discussions and branching aspects of the processes in which the research team was unable to take part. This includes some of the deeper discussions regarding production certification.

3.2.1.4 Observations

Observations listed in this section are general in nature and arose from the research team's participation in industry standards bodies (Task 2-2) and from participation in the D&R process itself (Task 2-1). These observations are not tied to any specific deliverable of the D&R process. These observations also allude to some of the unique challenges faced by both the applicants and FAA stakeholders throughout the process. It is also important to note that the D&R TC process is comparatively new. The FAA is learning about the process from a different perspective than applicants.

For the sake of brevity, this report provides summaries of in-depth discussions of the research team's observations. The ASSURE A27 Task 2 Report contains a detailed overview of the findings from this task. What follows is a summary of high-level observations the research team found noteworthy.

- **The TC process evolved into a full Airworthiness Certification program** – D&R covers more than basic airworthiness, encompassing full type and production certification. While the process is simplified compared to conventional piloted aircraft, it still relies on many of the same processes and procedures.
- **Most applicants followed for this study were not aviation companies –** The background of applicants varied. Some applicants had a background in aviation while others were new to aviation and manufacturing UAS.
- **The FAA has a map of the D&R TC process** – Although it is much different than what the FAA promoted initially; the FAA now has a firm grasp of how they envision the D&R process playing out for applicants.

- **The FAA made it clear to the applicant(s) that the D&R TC process was new** – FAA stakeholders were up-front regarding the status of D&R. They acknowledged that it is a new process, and there were bound to be some adjustments throughout the process.
- **Initial estimates of a 90-day TC process were not accurate** – The initial estimate of a full D&R TC process taking 90 days was significantly underestimated. To the research team's knowledge, only a few companies have reached the midway point, the critical flight test stage, of the TC process after 2½ years.
- **The FAA revised the D&R MoC mid-process** – There were revisions to the process and new requirements for procedural documentation introduced during this study; 14 CFR Part 36 noise requirements and new definitions of Associated Elements (AE).
- **The D&R TC process is platform-agnostic** – The D&R process was platform agnostic, favoring no system, aircraft configuration, or platform. This was important because UAS have a high degree of variability. The FAA has standardized the D&R Process itself.

3.2.1.5 Issues

This section captures issues the research team identified as they navigated the D&R TC process with applicants and FAA stakeholders. The issues listed in this section are not exhaustive, but instead are representative of the more common and/or significant obstacles encountered by researchers, applicants, and the FAA. What follows is a summary of the research team's list of D&R TC issues identified through this research. The research team lists suggested resolutions and improvements for these issues in additional sections of this report. For more details regarding the issues themselves, see the ASSURE A27 Task 2 Report.

3.2.1.5.1 D&R Process – General Issues

Issues identified as "general issues" were those that were non-specific to any part of the D&R TC process. These issues were broad in scope, and some were external to the D&R process itself. The team captured these issues as they helped to form the basis for recommendations to the FAA regarding process improvement. A more detailed breakdown of general issues, issue coding, and explanations exist within the ASSURE A27 Task 2 Report.

- The research team had challenges engaging with the Los Angeles Aircraft Certification Office (ACO) at the start of the project. This made it difficult to observe initial familiarization briefings with all applicants as part of this project.
- Applicants were unfamiliar with FAA processes/procedures upon entering the TC process. The D&R process seemed more daunting to applicants without a robust aviation background. While applicants were able to keep pace, there were definite disconnects along the way.

  As a result, the companies, although anticipating the original elements of the TC process, were not prepared to meet, from a financial and human resource perspective, the demands of the full airworthiness and TC program. Some applicants dropped out of the process altogether due to the time/resource commitment required to undergo a full certification.

The one OEM that does have military supply manufacturing experience found the FAA process to be overly burdensome for products deemed to be "low risk," resulting in low return on investment.

- The FAA reassigned project managers multiple times throughout the process. Changes in FAA personnel created bottlenecks at times. It was not always clear which FAA directorate or branch was present in meetings. This included project managers. Applicants noticed missing personnel. OEMs that entered the process at a much later date than the original group found that although a the ACO had assigned a project manager, regular status meetings were difficult to get scheduled.
- Chains of custody for documents and other deliverables were often long and unclear. Tracking the path of TC deliverables once an applicant turned them in for review was often difficult. From the applicant's perspective, it was not always clear who would review a document or how long they could expect to receive feedback. Although the FAA's Knowledge Service Network is an appropriate method of file management, OEMs could not upload files directly to their folder. Instead, they emailed the documents to the FAA's point of contact, together with the appropriately worded cover letter, who would then upload the files. Any extra step is an opportunity for disconnects and seems unnecessary.
- Document (deliverable) review periods were often quite long, sometimes exceeding periods of three months or more. As stated above, document review periods for TC deliverables could be quite long. For such things as manuals or other deliverables, it created multiple critical paths that led to slowdowns as applicants progressed through D&R.
- Requirements/specifications for specific process documents – e.g., maintenance manuals, flight manuals, and mechanical drawings were often unclear to the applicants. A later requirement for detailed drawings of all third-party parts installed on the aircraft created a hardship for several OEMs, as they did not have access to, nor were they given authority to use, this level of detail.
- Changes in document templates were confusing to applicants. Changes to requirements for such things as concepts of operation, project specific certification plan, G-1 (certification basis) issue papers and G-2 (means of compliance) documents caused scenarios where applicants had to rework documents that the FAA previously approved/accepted. In other instances, the applicant submitted documents based on the FAA's updated template, then told that a new template existed. The apparent lack of document review by the FAA created confusion on the part of the applicant as to what template version to follow.
- Changes to foundational D&R process documents – e.g., G-1 issue paper via a policy memo, created slowdowns and stoppages for applicants within the D&R TC process. Changes to foundational guidance and deliverables early in the process created work stoppages and hesitancy among applicants.
- Delays in the TC process that resulted from various internal and external factors represented an opportunity cost for applicants. Applicants were unable to create a realistic timeline going into the D&R TC process. This resulted in schedule overruns beyond the planned 90 days. Some applicants dropped out of the process as a result.

- Issues arose around changes to guidance and unclear documentation. Applicants were often unclear when receiving guidance from FAA stakeholders. The lack of clarity and other inconsistencies in guidance were compounded when guidance would change throughout the TC process.
- The requirements for flight test hours changed from a population density basis to a "reliability category" basis. This, among other changes, created challenges for applicants in drafting both budgets and test plans.

3.2.1.5.2 Specific Issues

Specific issues are issues identified by the research team that relate to more focused topic areas of specific task deliverables. The list identified in this report is not exhaustive, but it provides an excellent starting point for understanding the research team's recommendations. This section provides a summary of content areas. The ASSURE A27 Task 2 Report contains more detailed explanations of specific issues.

Issues identified in this section fall into the following categories:

- FAA Oversight
- Applicant knowledge
- TC Process/Procedure
- PC Process/Procedure

For the sake of brevity, each section contains a summary of findings for each subject area.

3.2.1.5.2.1 FAA Oversight

Issues regarding FAA oversight centered on challenges with FAA processes from the applicants' perspective. Issues identified in this category included tracking TC documents following submittal, receiving timely feedback on TC/PC process documents and deliverables, and other disconnects in communication and coordination.

3.2.1.5.2.2 Applicant Knowledge

Differing levels of applicant knowledge created issues throughout the TC process as well. These issues stemmed from levels of experience and/or knowledge of the nuances associated with navigating the regulatory framework associated with type/airworthiness/production certification. A lack of familiarity with regulations, experience/lack of experience with aviation standard practices, and disconnects regarding expectations for TC process documents and deliverables played a role here. A member of the research team noted that applicants with a background in conventional aviation fared better overall.

3.2.1.5.2.3 TC Process/Procedure

The research team also identified issues with the TC process/procedure itself as part of this research. These issues were the result of process or policy disconnects that created challenges when addressing an applicant's use case through the D&R TC process itself. It is important to note that since the time of the initial Task 2 Report, the FAA addressed issues regarding document templates for G-1 and G-2 issue papers, and/or are in the process of finding alternatives/solutions for defining requirements for the G-3 issue paper. However, some of the delays experienced by applicants in this area are noteworthy and captured for the sake of process improvement.

TC process/procedural issues were often the result of changing requirements within the D&R process itself. These consisted of such things as changes to the G-1 issue paper mid-process, prompting changes to foundational certification documents and deliverables. Unclear timelines, and delays in receiving guidance regarding G-3 noise testing processes also caused stoppages. There were also questions regarding D&R for BVLOS, which was not within the scope of the D&R TC process at the time the research team drafted this report.

3.2.1.5.2.4 Production Certification (PC) Process/Procedure

Issues in this category were far more difficult for the research team to track since the team was not heavily involved in discussions regarding UAS production. However, the research team identified noteworthy issues of interest to both applicants and the FAA.

PC process/procedural issues surrounded the management of Commercial Off-The-Shelf (COTs) parts. At the time the study took place, there was no consensus on how to address COTs parts handled within D&R. Sourcing COTs parts with a measure of reliability was a challenge, and the research team observed applicants face issues with conformity with internationally sourced parts. Additionally, there were questions regarding conformity with UAS sourced from outside of the United States. This raised questions about the level of production oversight required for a UAS. The FAA was able to provide guidance to applicants on how to handle sourced parts, pointing them to FAA Order 8100.11D and Advisory Circular 21-55 for guidance. While applicants inevitably solved the issues surrounding conformity and production challenges by sourcing parts from within the US, these discussions were common, and they have implications for OEMs within and outside of the continental United States.

3.2.1.6 Recommendations

Issues identified by the research team led to a series of recommendations aimed at refining the D&R TC process. Recommendations derived by the research team provide a starting point for addressing challenges faced by applicants and FAA stakeholders alike, and they are simple steps that could yield positive outcomes. The following section summarizes the team's recommendations from the ASSURE A27 Task 2 report.

Recommendation 1: *Develop a Durability and Reliability (D&R) Advisory Circular (AC).* An AC would provide an excellent starting point for applicants to become informed on the D&R TC process prior to contacting the FAA. While Order 8110.4C offers an excellent overview of the TC process, there are significant differences between D&R and processes for conventionally piloted aircraft. Additional guidance could be of great assistance to applicants. This is especially true of applicants who may not have a great deal of experience in aviation.

Recommendation 2: *Promote early engagement with TC applicants.* From the research team's observations, there is no FAA engagement with an applicant prior to the FAA's acceptance of the applicant's formal TC application. At this stage, early engagement with applicants may help to mitigate challenges further in the TC process. This is especially true since applicants may not have as much of a background in aviation or aviation concepts as typical applicants for a more conventional TC process.

Recommendation 3: *Make the D&R MoC publicly available.* Similar to publishing an AC, making the D&R MoC publicly available would be helpful to applicants and the FAA. This would

allow applicants to study the process prior to engaging with the FAA, understand how to lay out demonstration plans, and come into the process better prepared. This, in turn, could assist the FAA with allocating resources more effectively, as it would mean that applicants could exercise increased autonomy due to having a better knowledge of the process from the start. Similarly, applicants with an increased knowledge of the process and familiarity with expectations could be more adept at navigating the TC process and require less direct FAA oversight.

Recommendation 4: *Provide a straightforward means of entry into the D&R TC process – e.g., an entry portal.* Providing a simplified means of entry into the D&R TC process would benefit applicants and the FAA. A means of entry, such as a web portal, could serve as a single point of access to promote early engagement between applicants and the FAA while simultaneously providing a place to present vital information and process documentation. Like DroneZone (Figure 3), a web portal to access the TC process could streamline existing processes and help applicants to be better prepared to interface with the FAA.

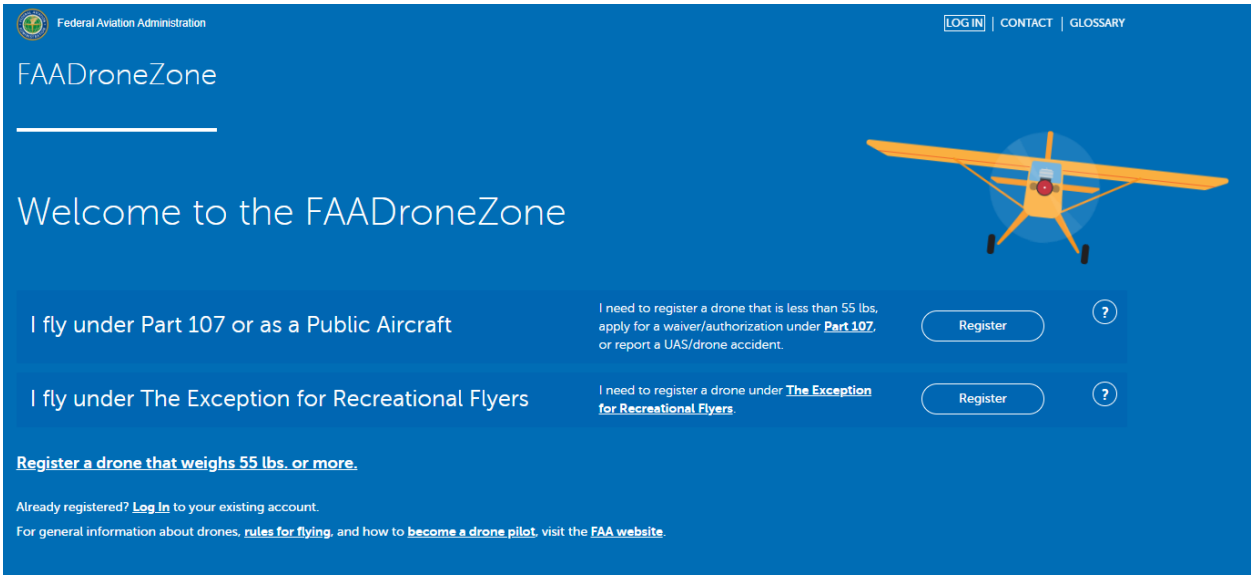

Figure 3. FAADroneZone Portal (Federal Aviation Administration, 2022).

Recommendation 5: *Continue to Adapt/Adopt industry standards, and/or revise existing industry guidance to address policy and knowledge gap.* Throughout this study, the research team noted that applicants faced challenges when generating documentation such as maintenance manuals, Instructions for Continued Airworthiness, and other documents. This was due to specific requirements for such documents being unclear. Guidance regarding content, style, and baseline information would aid applicants here. The FAA provided example documents as guidance, but those documents were often representative of conventional crewed aircraft, and they did not represent the ideal level of detail and rigor sufficient for D&R.

The D&R MoC provides guidance for Unmanned [Uncrewed] Flight Manuals (UFMs), parachutes, avionics, and software within its appendices, referencing the following standards:

- ASTM F2908-18 *Standard Specification for Unmanned Aircraft Flight Manual (UFM) for an Unmanned Aircraft System (UAS)*
- GAMA Specification No. 1 *Specification for Pilot's Operating Handbook*

- ASTM F3322-18 *Standard Specification for Small Unmanned Aircraft System (sUAS) Parachutes*
- ASTM F3153-15 *Standard Specification for Verification of Avionics Systems*
- Radio Technical Commission for Aeronautics (RTCA) DO-178C *Software Considerations in Airborne Systems and Equipment Certification*

In instances where applicants had ample guidance, proper context, and information regarding expectations for documentation and certification deliverables, they were successful in meeting FAA expectations for required documentation. While there were still challenges in meeting some of the content expectations, particularly for UFMs, applicants fared better with proper guidance.

In addition, the research team recommends the FAA maintain involvement with Standards Development Organizations to promote the continued development of applicable industry standards. Guidance from industry will assist in ensuring that applicants are prepared to enter D&R and can successfully navigate the process once initiated. The inclusion of D&R within the *FAA and Industry Guide to Product Certification* would also be highly beneficial, as D&R is a subset of a broader airworthiness/type certification process – with some noteworthy differences from a conventional TC project in scope and scale. This would be in keeping with the objective of the *FAA and Industry Guide to Product Certification*, in that it would promote, "broader and more consistent use of the principles and expected operating norms for efficient design approval processes consisting of TC, STC [supplemental type certification], TSOA [technical standard order authorization], and Parts Manufacturer Approval (PMA)" (AIA et al., p. i, 2017).

Recommendation 6: *Address incompatibilities with ICAO Annex 8.* During the process, FAA stakeholders noted inconsistencies between the D&R TC requirements and ICAO Annex 8 – *Airworthiness of Aircraft*. These inconsistencies may disincentivize potential applicants to pursue a TC for a low-risk UAS if they have the intent to export. Addressing any inconsistencies, particularly regarding AE, may eliminate this gap.

Recommendation 7: *Revise estimated timelines for the D&R TC process*. Initial estimates to complete the D&R TC process were approximately 90 days. This timeline was inaccurate according to the research team's observations. The team followed one applicant for a total of 20 months before the applicant eventually withdrew from the process without a TC. Another applicant pursued a TC for 25 months and had still not begun D&R demonstration flights at the time Task 2 had been completed. It is imperative that applicants have a complete understanding of the expectations, requirements, timelines, and deliverables so they may budget time, personnel, and other resources for TC activities before beginning the process. Applicants must be fully aware of the commitment up front.

Recommendation 8: *Develop a status tracking system for key deliverables in the D&R TC process.* One of the more noteworthy challenges throughout the D&R TC process was tracking deliverables and determining their status after applicant submission. This was problematic for the applicant and the FAA alike, creating slowdowns when reviewing UFMs, technical drawings, and other deliverables. A means to outline exactly where a document will go – e.g., directorates and personnel, as part of the review process will assist in ensuring transparency during document review.

Recommendation 9: *FAA set time limits for reviewing deliverables.* Similar to the recommendation above, the research team noted that the time to review D&R TC process deliverables was excessive, sometimes exceeding 3 months or more for a single manual. The research team recommends setting limits for document review up front, providing the applicant with an idea of how long the review cycle will take. This will set expectations and reinforce that the TC process is, in fact, a collaborative effort.

It is also important to note that this recommendation is the result of following multiple TC processes. It points to a need to establish operating norms between the FAA and applicants – either through a Partnership for Safety Plan (PSP) or independently. It is worth noting that a formal PSP was not part of the D&R TC process. A PSP, or something serving the same purpose, would be beneficial for all involved.

Recommendation 10: *FAA stakeholders display their name, directorate, and office in online teleconferences in a plain language format – e.g., not "AIR-60x."* This is a simple recommendation that could assist with adding transparency and clarity to applicant interactions with FAA stakeholders. The ability to quickly identify all stakeholders on a call can aid both applicants and the FAA in using resources and identifying important lines of communication for given TC tasks.

Recommendation 11: *Clarify the sUAS maintenance requirements.* In some cases, the cost to maintain a sUAS may exceed the cost of replacement. This is especially true with taking a given system's operational usage and age into account. When obtaining a TC, defining maintenance requirements for components and parts that are not cost-prohibitive to replace is essential. It should be clear where responsibilities fall when maintaining a UAS.

3.2.2 Task 2-2: ASTM D&R Working Group Participation

An important aspect of ASSURE A27 was to collaborate with industry to develop standards for airworthiness and type certification for sUAS. This task offered an opportunity to translate lessons learned from literature and ongoing research into consensus standards. For this task, a member of the KSU research team participated in the ASTM International F38 Committee Working Group for WK70877 *Standard Specification for Development of a Durability and Reliability Flight Demonstration Program for Low-Risk Unmanned Aircraft Systems (UAS) under FAA Oversight.*

The research remained engaged with the ASTM International working group through November of 2020. During this period, a member of the KSU research team attended regular meetings, contributed content, and provided editorial support for drafting the standard. In November of 2020, ASTM International's F38 committee accepted the draft standard during a remote session. ASTM International published the new standard as F3478-20 *Standard Specification for Development of a Durability and Reliability Flight Demonstration Program for Low-Risk Unmanned Aircraft Systems (UAS) under FAA Oversight.*

3.3 Task 3 – Operational Training

This task explored operational training for remote pilots for expanded operations, specifically considering BVLOS flight and operations over people[2]. This task combined findings from the

[2] The FAA's official rule for operations over people (Title 14 CFR Subpart D; Amdt. No. 107-8, 86 FR 4382, Jan. 15, 2021) was published during the period of performance of this project.

literature review from Task 1 with findings from additional sources of literature, such as the FAA's Waiver Trend Analysis for 14 CFR §107.39(a), Waiver Trend Analysis for 14 CFR §107.31, and the FAA Waiver Safety Explanation Guidelines (WSEG). The goal of this task was to identify potential requirements for remote pilot operational training regarding expanded sUAS flight operations and make recommendations on what those requirements may be. The research team's recommendations were based upon a comparison of baseline requirements for remote pilots for operations under 14 CFR Part 107 and industry consensus standards. The following sections highlight the team's methodology and findings.

3.3.1 Methodology

The research team began by reviewing the FAA Remote Pilot Airman Certification Standards (ACS) for remote pilot knowledge, skill, and abilities. This provided a baseline for remote pilot knowledge as well as a point of comparison for any additional areas that may exceed the accepted baseline, such as BVLOS and/or operations over people. For comparison, the research team consulted the JARUS *Recommendation for Remote Pilot Competency (RPC) for UAS Operations in Category A (Open) and Category B (Specific)* and F3266-18 *Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement*. These documents offered different perspectives regarding remote pilot knowledge, skills, and abilities from independent sources that addressed both industry consensus and international perspectives. More importantly, these documents provided differing perspectives to the existing remote pilot ACS and offered points of comparison. Upon further review of the JARUS *Recommendation for Remote Pilot Competency*, the research team found it provided a means to organize individual elements. It prescribed requirements for knowledge, skills, or practical ability, and facilitated easy comparisons. Using this concept, the research team devised a process to sort and compare individual elements within remote pilot training documents using a matrix. Figure 4 outlines the research team's approach.

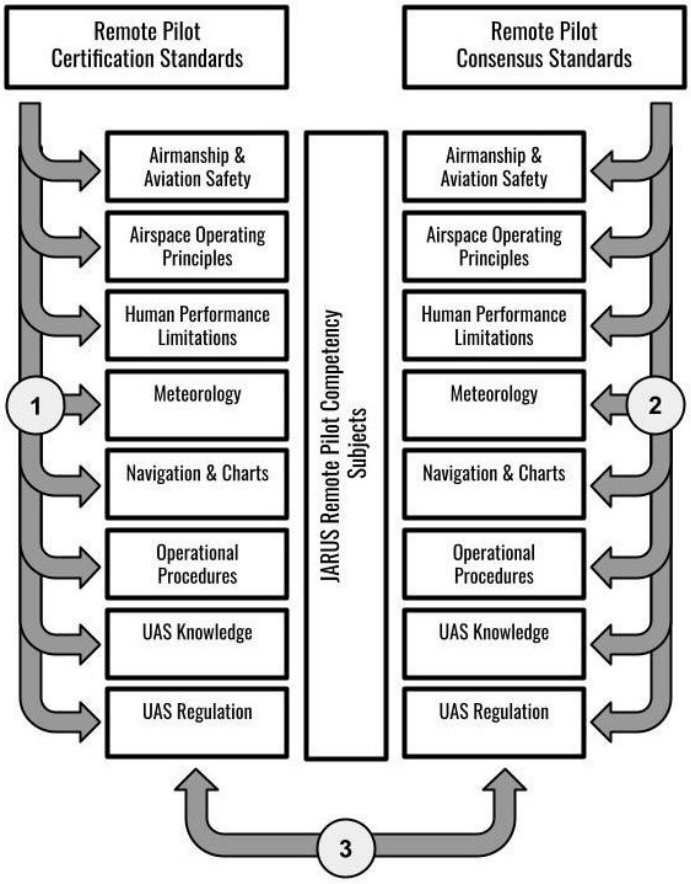

Figure 4. Remote Pilot Training Methodology Flow Chart.

Using the process highlighted in Figure 4, the research team grouped elements from the Remote Pilot ACS (1), elements from ASTM F3266-18 (2), and made comparisons using categories from the JARUS remote pilot competency subject areas (3). The research team used four simplifying assumptions to enable these comparisons:

1. The remote pilot training standards of the ACS and ASTM can be reduced to individual elements.
2. The eight subject areas proposed by the JARUS RPC (i.e., UAS Regulations, UAS Knowledge, Operational Procedures, etc.) represent sUAS operations[3] and each contains unique content.
3. Each element of (1) the FAA's Remote Pilot – sUAS ACS, and (2) ASTM's Standard Guide for Training for Remote Pilot in Command of Standard sUAS Endorsement can be reduced to address a single JARUS RPC subject.
4. Greater element counts in a JARUS RPC subject will relate to the relative importance – or emphasis – of that subject.

[3] The eight subject areas from Appendix A of the JARUS RPC recommendations were used to categorize training content for remote pilots. While the JARUS RPC recommends several types of endorsements – including those for night operations – these operation-specific competencies are described as "… additional theoretical knowledge" and were considered separately from the general classification of recommended theoretical knowledge.

These assumptions enabled the research to sort content from the FAA Remote Pilot ACS and ASTM F3266-18 into the eight categories shown in Figure 4 and provided a snapshot of areas of emphasis for remote pilot knowledge, skills, and experience.

The research team used an inter-rater reliability assessment to assign classifications of individual elements within the source documentation. Using this method, the research team was able to rely on internal subject matter expertise and to place elements within the specified categories. This approach provided a means to check initial assumptions and ensure consistent sorting across the research team.

3.3.2 Findings

Using the process described in Figure 4, the research team categorized elements within the FAA Remote Pilot ACS and ASTM F3266-18. Using this breakdown, the research team determined which remote pilot training subjects each document emphasized. The research team used this information to identify areas where additional remote pilot training could supplement remote pilot knowledge, skill, or practical abilities that could serve as additional training requirements for expanded sUAS flight operations.

Figure 5 highlights a breakdown of elements classifications within the FAA Remote Pilot ACS.

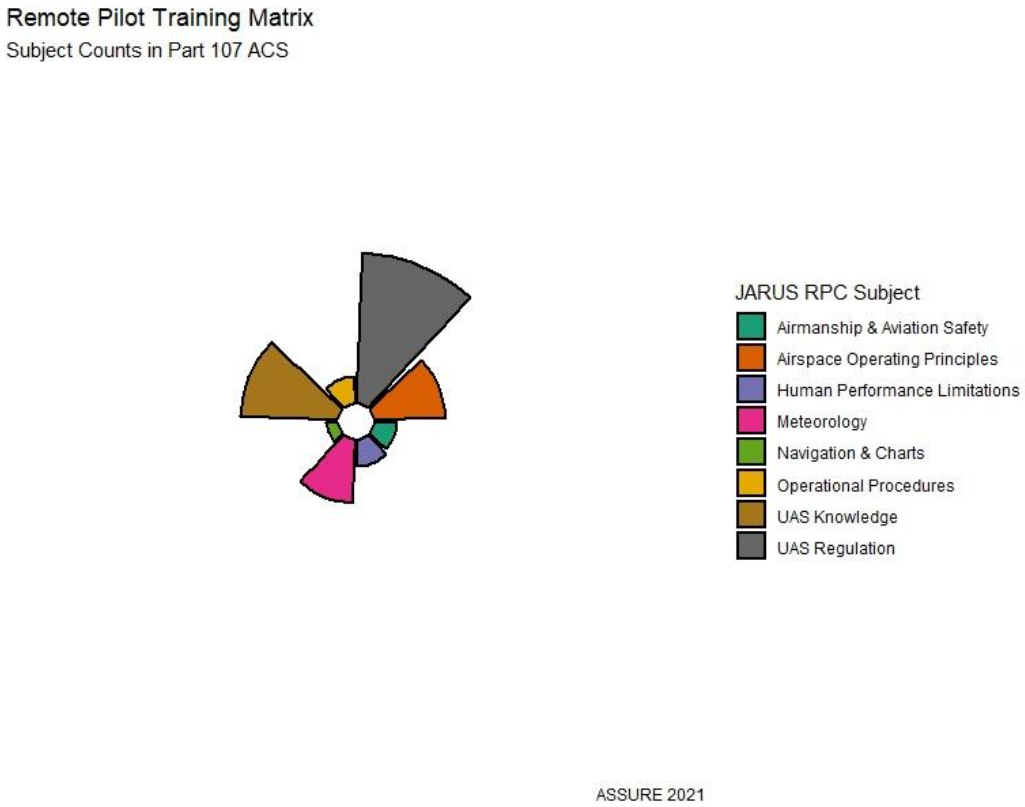

Figure 5. Classification of Elements in FAA Part 107 Remote Pilot ACS.

As shown in Figure 5, the Part 107 Remote Pilot ACS emphasizes:

1. UAS Regulation,
2. Airspace and Operating Principles,

3. Meteorology, and
4. Navigation and Charts.

This is in keeping with the notion that remote pilot knowledge and training requirements for Part 107 operations do not require practical skills, but instead emphasize knowledge of regulations, airspace, weather, and the ability to understand aeronautical charts and relevant documents.

In contrast, Figure 6 outlines the classification of individual elements within ASTM F3266-18. ASTM F3266-18 is an international standard by ASTM International that sets training standards for remote pilots. The differences between ASTM F3266-18 and the FAA Remote Pilot ACS are immediately apparent.

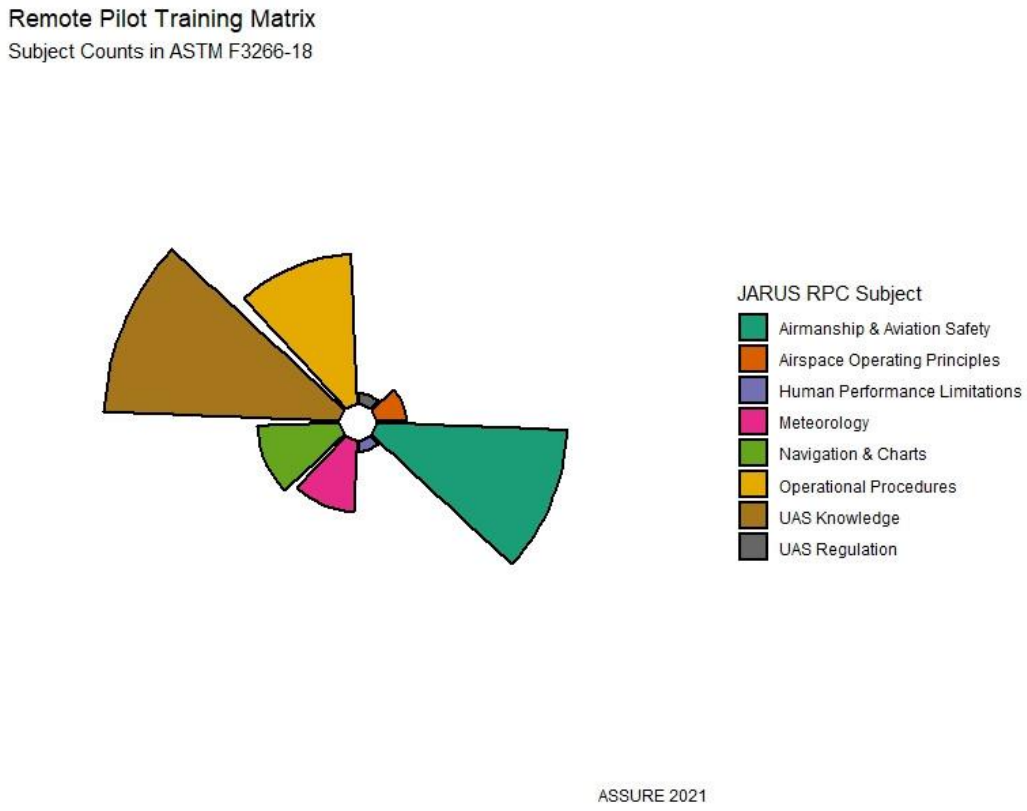

Figure 6. Classification of Elements in ASTM F3266-18.

Figure 6 shows that ASTM F3266-18 places a higher emphasis on:

1. Airmanship and aviation safety,
2. UAS knowledge,
3. Operational procedures, and
4. Meteorology.

The lack of emphasis on regulatory requirements and structures within ASTM F3266-18 is reflective of its international applicability, as the standard does not favor any single regulatory body. Moreover, additional standards support ASTM F3266-18 for such things as unmanned aircraft flight manuals (ASTM F2908), specifications for batteries (ASTM F3005), and operational risk assessment (ASTM F3178).

A composite of the FAA remote pilot ACS and ASTM F3266-18 shows the distinct differences between the two. Figure 7 shows this comparison.

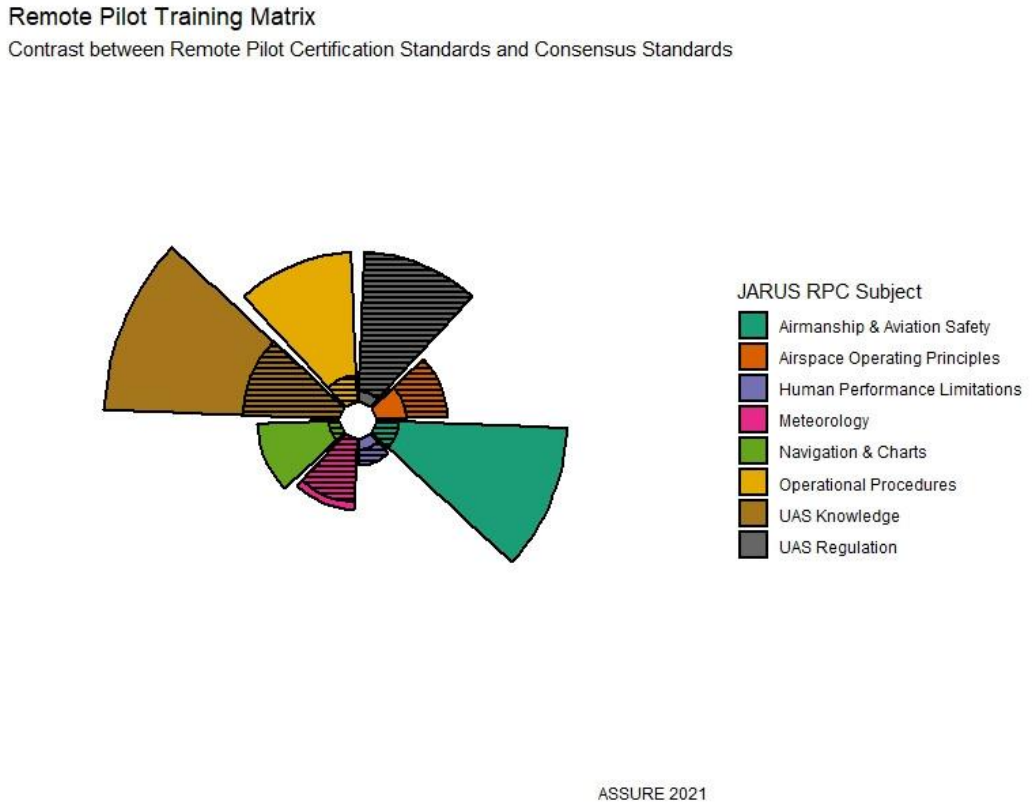

Figure 7. Comparison of Remote Pilot Training Elements between FAA Remote Pilot ACS and ASTM F3266-18.

As Figure 7 illustrates, there are different areas of emphasis between the FAA Remote Pilot ACS and ASTM F3266-18. While this was not entirely unexpected, it helped the research team to identify areas of interest relevant to expanded operations. Furthermore, these differences drove a series of 11 recommendations for remote pilot training for operations over people[4] and BVLOS flight.

3.3.2.1 ACS Content Recommendations for Operations Over Human Beings

The following recommendations for operations over people stemmed from the analysis of the FAA Part 107 Remote Pilot ACS, ASTM F3266-18, and findings from the literature review. Recent rulemaking from the FAA regarding operations over people favors aircraft certification standards and operational limitations without additional requirements for remote pilots. Furthermore, the FAA's formal position on requirements for additional training for such operations is, "… a practical test for the issuance of a Part 107 remote pilot certificate, and testing requirements similar to those for Part 61 commercial pilot certificates, are not necessary" (Operation of Small Unmanned Aircraft Systems Over People (Final Rule), 2021, p. 4360). However, the following recommendations consider the fact that existing regulations are still subject to waiver. These

[4] The research team arrived at these recommendations prior to the passage of Title 14 CFR Subpart D – Operations over Human Beings.

recommendations still offer a potential means for risk mitigation for operations over human beings and are a starting point for offering elements of an alternate means of compliance with existing regulations.

1. The applicant demonstrates an understanding of: authorizations issued under the Low Altitude Authorization and Notification Capability (LAANC), and the manual process to apply for an authorization with the Airspace Authorization Request Form.
2. The applicant demonstrates the ability to: identify controlled airspace at or below 400 feet and request access using the LAANC when available.
3. The applicant demonstrates the ability to: apply safety practices such as mission, crew, and safety briefings.
4. The applicant demonstrates the ability to identify, assess and mitigate risks, to encompass operational risk assessments, site surveys, and mission planning.
5. The applicant demonstrates the ability to: plan and execute basic maneuvers (e.g., flight, ground reference, and loss of control recovery) to demonstrate mastery of the unmanned aircraft[5].

3.3.2.2 Support for Recommendations 1 – 5

The recommended FAA Remote Pilot ACS content listed above aligns with concepts and content from the JARUS RPC, the FAA's WSEG, and gaps identified in the FAA's Waiver Trend Analysis for 14 CFR §107.39(a). While the FAA stops short of requiring practical tests for issuing remote pilot certificates (Operation of Small Unmanned Aircraft Systems Over People (Final Rule), 2021, p. 4360), there is still precedent for requiring increased remote pilot knowledge and skills for flight operations conducted under waiver or authorization. Recommendations 1-5 emphasize the importance of remote pilot knowledge and skills as a form of risk mitigation and provide a means to close information gaps identified in 14 CFR §107.39(a) waiver submissions.

The JARUS RPC highlights the importance of knowledge areas for overflight of populated areas, covering topics such as, "Optimizing flight paths to reduce risk of exposure," and "extraordinary restrictions such as segregated airspace…" (Joint Authorities for Rulemaking on Unmanned Systems, 2019, p.24). Such requirements highlight a remote pilot's need to understand the makeup of airspace, ground environments, and mission planning. Recommendations 1-5 underscore the importance of understanding these concepts.

The FAA's Waiver Trend Analysis for 14 CFR §107.39(a) also supports these recommendations. The Waiver Trend Analysis identified that statements surrounding remote pilot knowledge and skills were often lacking, citing that waiver applicants offered, "no other qualifications or experience to show the FAA the pilot could safely operate over people" (Federal Aviation Administration, 2019b). Recommendations 1-5 address this gap and offer a means to address risks associated with operations over people through the introduction of additional knowledge and skills for remote pilots.

[5]These maneuvers would assist in meeting similar requirements of current certification under Part 61.43 to include: (1) Performing the tasks specified in the areas of operation for the airman certificate or rating sought; (2) Demonstrating mastery of the aircraft by performing each task successfully; (3) Demonstrating proficiency and competency within the approved standards; and (4) Demonstrating sound judgment.

Finally, the FAA WESG supports these recommendations through conceptual alignment. While the WSEG does not require any specific training for operations over people, it does highlight recommended considerations and thought processes for addressing risk. The WESG prompts questions such as, "What minimum level of experience will the Remote Pilot in Command (Remote PIC) have to fly under this waiver?" and "What kind of training, if any, will personnel (e.g., visual observer(s)) have prior to flying under the waiver" (Federal Aviation Administration, 2022)? Such questions are in alignment with the idea that sUAS flight operations under a Part 107 waiver may impose additional requirements on a remote pilot. Recommendations 1-5 that resulted from this research align well with considerations for pilots/personnel in the FAA's WSEG.

3.3.2.3 ACS Content Recommendations for Beyond Visual Line of Sight Operations

The research team derived recommended ACS content for BVLOS flight operations with the intention that recommended operational training be in addition to recommendations 1-5 above. This intention is based upon the assumption that BVLOS flight will include operations over people while requiring additional knowledge and skills to interface with other entities in the airspace. Recommended ACS content that follows reflects the assessed differences between baseline Part 107 flight operations and BVLOS.

6. The applicant demonstrates the ability to: navigate the sUAS by means of waypoints or flight-planned route. Verify position as well as the aircraft's attitude, altitude, and direction of flight.
7. The applicant demonstrates the ability to: manage automation by utilizing installed, available, or airborne equipment such as autopilot, avionics and systems displays, and/or system-specific Global navigation satellite system features (e.g., geofencing, Return to Home, Auto-Takeoff, Auto-Land, etc.).
8. The applicant demonstrates the ability to identify, assess, and mitigate risks encompassing: Distractions, loss of situational awareness, and improper task management, normalization of deviance, and automation dependency.
9. The applicant demonstrates an understanding of command-and-control link principles (e.g., transmitters, receivers, antenna types and orientation, and propagation)
10. The applicant demonstrates the ability to: utilize Crew Resource Management and effective communication.
11. The applicant demonstrates an understanding of common maintenance practices and unique maintenance requirements for their specific system.

3.3.2.4 Support for Recommendations 6 – 11

Like recommendations 1-5, the JARUS RPC, the FAA's WSEG, and the FAA's Waiver Trend Analysis for 14 CFR §107.31 support ACS recommendations 6-11. The knowledge, skills, and other experience/competencies captured in the research team's findings are rooted in the notion that BVLOS requires knowledge and skillsets well beyond the baseline established by 14 CFR Part 107. Supporting documents reflect this notion, and FAA guidance material echoes this concept.

In addition to recommendations for the overflight of people, the JARUS RPC offers remote pilot subject areas for BVLOS flight regarding "Operation planning: airspace, terrain, obstacles,

expected air traffic and restricted areas," "roles and responsibilities for remaining well clear," and "crew resource management" (Joint Authorities for Rulemaking on Unmanned Systems, 2019, pp. 24-25), among other subject areas. These subjects imply that a remote pilot in a BVLOS environment must have knowledge of airspace, interact with air traffic, and may function as part of a crew. The research team's recommended ACS additions reflect these knowledge areas, skills, and competencies.

The FAA's Waiver Trend Analysis for 14 CFR §107.31 also supports the research team's recommendations. Like the Waiver Trend Analysis for 14 CFR Part §107.39(a), the Waiver Trend Analysis for 14 CFR Part §107.31 cites rejected waivers for BVLOS as lacking in detail regarding remote pilot qualifications. The §107.31 Waiver Trend Analysis cites that a, "provision of a method of assuring all required persons participating in [the] operation have knowledge in all aspects of BVLOS not evident" (Federal Aviation Administration, 2019a). The research team's recommended ACS additions 6-11 help to address this gap.

Finally, the recommended ACS additions for BVLOS align well with the FAA's WSEG. The recommendations from the research team overlap with subject areas covering operational details, details about the sUAS itself, specific details about the remote pilot [and other personnel], and operational risks. More importantly, the team's recommendations 6-11 fit the conceptual approach for addressing operational risk, offering areas of "additional training" when describing operational risks and mitigations per the WSEG (Federal Aviation Administration, 2022).

4 CONCLUSIONS

ASSURE A27 explored requirements for pilot training for expanded operations, the development of standards for UAS type certification under the FAA's D&R process, and the application of the D&R type certification process itself. As a result of this work, the research team:

1. Identified additional training areas for remote pilots for BVLOS and operations over people,
2. Offered recommendations for process improvement for the FAA, and
3. Participated in the development of industry standards for use in D&R.

The recommendations listed in this report represent a starting point for addressing challenges regarding expanded operations and UAS type certification. Furthermore, they address the research questions that prompted this research.

What knowledge, skills, and abilities/attitude (KSAs) required of UAS operators for complex expanded and non-segregated UAS operations in the National Airspace System?

The research team collaborated with the sponsor to scope this question to address specific remote pilot qualifications for a set of expanded operational scenarios – BVLOS and operations over people. To that end, the research team was able to formulate eleven recommended training areas to address risk associated with these operational paradigms.

In manned aviation, various ratings exist, having specific KSAs and practical test standards (PTS) associated with them. Examples of ratings include instrument; commercial; multi-engine; and instructor. Should various ratings exist for a range of UAS operations, and if so: What are they,

what are the associated KSAs, what is the associated PTS, and what are the minimum training thresholds in order to obtain them?

The research team answered these questions through reference to the FAA's existing remote pilot ACS while exploring additional remote pilot training concepts through industry standards and recommended remote pilot competencies from JARUS. Through a comparison of existing competencies and training standards, the research team made recommendations to address risks associated with BVLOS and operations over people.

Do 14 CFR parts 61 and 141 serve well as a foundation to establish future UAS pilot training, certification, and standards requirements?

While the research team cannot state that Part 61 or 141 serve as foundational elements for establishing future UAS pilot training, certification, and standards requirements in and of themselves, the research team suggests that the value of a conceptual approach to imparting knowledge and practical skills increases with operational risk. Through a review of existing industry standards and consensus body recommendations for remote pilots, the research team discovered a higher emphasis on knowledge and practical skills beyond the existing requirements for 14 CFR Part 107. This implies that for sufficient risk, increased training, relevant knowledge, and practical skills may serve to mitigate risk. The FAA's provisions for night waivers reinforce this concept, and it reflects the notion that remote pilot training serves as a risk mitigation for operations that reach beyond the baseline framework of 14 CFR Part 107.

What is the level of overlap, essentially the transfer of knowledge, between manned and unmanned flight?

There is no exact quantity for the transfer of knowledge between manned and unmanned [uncrewed] flight. However, a rational assessment conveys that overlap exists where knowledge and skills overlap. For example, recommendations 6-11 in Section 3.3.2.3 reflect common skillsets in manned aviation, ranging from managing automation to risk assessment and performing navigation tasks.

What dependencies does UAS training have on manned training […] if the research suggests that a manned instrument rating may be used to reduce the number of hours required for a UAS remote pilot to obtain a Beyond Line of Sight rating, could that manned instrument rating experience be replaced with UAS-only training standards, and if so, what is the difference in training required?

The research team did not encounter any remote pilot training standards or consensus opinions that directly referenced this concept. While there is overlap in some knowledge and skill areas, the research team cannot make a recommendation regarding the direct translation of knowledge, skills, and abilities. The literature and research findings support knowledge requirements and practical skills where appropriate to meet operational risk, but this research did not identify specific thresholds for the translation of knowledge between manned [crewed]/unmanned [uncrewed] pilot training.

Performance-based type/airworthiness certification – Process Approach

The research team followed several sUAS system manufacturers through the FAA's D&R TC process and was able to generate a series of recommendations for process improvement. Furthermore, the research team was able to provide guidance to applicants. Exercising the new D&R TC process for UAS provided a unique opportunity to provide feedback toward the development of a novel means to TC equally novel aircraft.

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