Transfer of Unmanned Aircraft Systems Technology to SCDOT for Enhanced Bridge Inspections

Final Report

by

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16. Abstract

This project aimed to enhance bridge inspection processes by leveraging unmanned aircraft systems (UAS) technology, building on a successful 2018 pilot study that demonstrated the potential of UASs to improve inspection efficiency, safety, and cost-effectiveness. Key objectives included the development of a comprehensive UAS flight proficiency assessment tool, the implementation of a robust training program, and the provision of commercial-grade UAS equipment to SCDOT bridge inspection engineers across all seven districts. The assessment tool, designed to complement the FAA's Part 107 knowledge test, included scenario-based questions and aircraft control exercises to evaluate UAS pilots' capabilities comprehensively. The training program combined online and in-person instruction. Online training prepared participants for the Part 107 exam and covered regulatory compliance and basic flight control using simulators. In-person training consisted of three intensive two-day bootcamps held at Clemson University's Experiential Learning Lab, providing hands-on experience with the equipment. The program achieved significant success, with 20 out of 21 participants passing the Part 107 exam. In a post-workshop satisfaction survey, 92% of the participants indicated that they strongly agreed with the statement that “Overall, I am satisfied with the workshop and would recommend it to other bridge inspectors.”

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EXECUTIVE SUMMARY

This project, "Transfer of Unmanned Aircraft Systems Technology to SCDOT for Enhanced Bridge Inspections," funded by the Center for Connected Multimodal Mobility (C2M2) and the South Carolina Department of Transportation (SCDOT), aimed to improve bridge inspection processes using unmanned aircraft systems (UASs). Building on a 2018 C2M2 pilot study, this project sought to develop and implement a comprehensive UAS flight proficiency assessment tool and training program tailored to SCDOT bridge inspection engineers.

A comprehensive training program was established, combining online and in-person training to prepare SCDOT personnel for UAS operations. The online training covered FAA Part 107 knowledge, regulatory compliance, and basic flight control using a computer simulator. The in-person training consisted of three intensive two-day bootcamps conducted in June and July at Clemson University's Experiential Learning Lab, providing hands-on experience and equipment training. Impressively, 20 out of 21 participants passed the Part 107 exam.

The project successfully developed a flight proficiency assessment tool to complement the FAA's Part 107 knowledge test by assessing field operations and aircraft control skills based on ASTM F3266 standards. This tool included scenario-based questions and aircraft control exercises to ensure a comprehensive evaluation of UAS pilots' capabilities. The assessment tool is included in Appendix A of this document.

SCDOT adopted the Basic UAS Reference Guide and Manual (B.U.R.G. manual) currently used at Clemson University as part of their drone program. The B.U.R.G. manually includes preflight checklists, illustrated tutorials, and workflow procedures for SCDOT UAS pilots. Commercial-grade UASs were issued to SCDOT bridge inspection teams in all seven districts, with training and certification provided, including the Airborne Public Safety Association's BPERP flight certification. Seven of the participants earned their APSA BPERP certification.

The impact and benefits of this project are significant. Utilizing UAS technology lowers bridge inspection costs by reducing the need for specialized equipment and minimizing public disruptions. It enhanced safety for bridge inspectors by enabling remote inspections, thereby reducing the risk of collisions and falls. Drones support superior-quality inspection records through high-resolution imagery and comprehensive data collection from previously inaccessible vantage points. By enabling SCDOT bridge inspection engineers across all districts to deploy UAS technology immediately, the project replicated the benefits observed in the 2018 pilot study. In a post-workshop satisfaction survey, 92% of the participants indicated that they strongly agreed with the statement, “Overall, I am satisfied with the workshop and would recommend it to other bridge inspectors.” The project successfully transferred state-of-the-art UAS technology to SCDOT bridge inspection engineers, providing them with the necessary tools, training, and resources to enhance their inspection processes. The outcomes of this work highlight the extensive potential of UAS technology and establish a strong foundation for future research and technology transfer initiatives within the transportation sector.

CHAPTER 1

Introduction

1.1 Unmanned Aircraft Systems

The development of Unmanned Aircraft Systems (UAS) can be traced back to Great Britain's creation of the first pilotless aircraft in the early 20th century. Historically, drones have been predominantly used in military applications, but small UAS have recently seen a surge in popularity within the public domain (Dronethusiast, 2019). UAS are divided into two main categories: recreational and commercial aircraft. The FAA began issuing commercial permits for drones in 2006, marking the start of their commercial use. Initially, the growth was slow, with an average of just two new commercial permits granted annually until 2014 (Desjardins, 2016). However, interest significantly increased after Amazon's 2013 announcement about exploring drone-based delivery services (Dronethusiast, 2019).

The rise in the popularity of UAS led to the establishment of federal regulations governing their use. In 2005, the FAA introduced basic guidelines for UAS, and by 2007, it had implemented specific operational policies. These regulations mandated that all commercial operators obtain a Certificate of Waiver or Authorization (COA) for their drone activities—a process that was both complex and time-consuming (Speicher, 2016). Public pressure to streamline this process prompted the government to enact the Reform Act of 2012, which required the FAA to develop more efficient policies and regulations for commercial UAS. Following extensive public consultation and research, the FAA published Part 107 of Title 14 of the Code of Federal Regulations in 2016, outlining the rules for UAS operation, use, and certification. In 2017, the FAA launched the Integration Pilot Program (IPP) to foster collaboration between public and private sectors, identify new UAS operations, address security and privacy concerns, and expedite the safe integration of drones into the National Airspace System (FAA, 2017). As of October 2023, the FAA estimates that there are nearly 900,000 drones registered and approximately 330,000 pilots who have earned their remote pilot certificate (FAA, 2024). On a global scale, annual spending on UAS is anticipated to double to $11.5 billion within the next decade (Gray et al., 2018).

To operate a commercial drone, the operator must obtain a Remote Pilot Certification from the FAA. By mid-2018, over 100,000 pilots had been certified. To support the growing commercial use of UAS, the number of certified remote pilots is projected to exceed 400,000 by 2022 (Plaza, 2018; FAA, 2018). According to the FAA's 2018 report, commercial UAS were primarily used for data collection and aerial imagery. The main applications included real estate photography (48%), industrial and utility inspection (28%), agricultural uses (17%), and activities by state DOT and local governments (3%) (FAA, 2018).

Many construction companies utilize drones for various purposes, including surveying, construction site inspections, safety inspections, project reporting, marketing, live feed/virtual tours, site logistics, BIM modeling, thermal imaging, and quantity take-offs (Ayemba, 2019). Research on the utilization of UAS has demonstrated that effectively integrating drones into commercial applications can enhance safety, improve efficiency, and reduce costs (McGuire et al., 2016). The recognition of this technology's potential has led to a significant increase in the adoption of drones for both commercial and public operations. This rapid growth has driven demand, intensified competition, and subsequently lowered the cost of advanced drone systems. One of the fastest-growing sectors has been the construction industry, which saw a 239% increase in drone use in 2017 (Zitzman, 2018).

1.2 UAS and Transportation Infrastructure

In 2017, the World Road Association published a research report titled "A Report on the Use of UAS to Remotely Collect Data for Road Infrastructure" (REDNOA, 2017), which predicted significant potential for UAS applications in roadway infrastructure. A 2016 study by the American Association of State Highway and Transportation Officials (AASHTO), conducted by Ni and Plotnikov, titled "The State of the Practice of UAS Systems in Transportation," revealed that 17 state agencies had studied or were actively using drones in some capacity. An additional 16 states were exploring or supporting drone research (Ni and Plotnikov, 2016).

A follow-up AASHTO study by Ni and Plotnikov in 2018 showed increased interest in drones among state Departments of Transportation (DOTs). Of the 44 states participating in the study, 35 (80%) were using or investigating the use of drones. Twenty state DOTs had integrated drones into their operations, while another 15 were conducting research and testing potential applications (Dorsey, 2018).

The use of UAS (drones) by state transportation agencies has continued to grow. Various studies by universities, state DOTs, and federal agencies have been conducted to assess the current interest and application of drones by state DOTs. However, inconsistencies in study methodologies and participation rates, which never encompass all 50 state DOTs, pose challenges to obtaining a comprehensive understanding of drone use by DOTs across the United States from any single study.

1.3 Project

This project builds on a successful 2018 pilot study that demonstrated the potential of UAS technology to improve bridge inspection efficiency, safety, and cost-effectiveness. The current project aimed to extend these benefits to all seven SCDOT districts by developing a comprehensive UAS flight proficiency assessment tool, implementing a robust training program, and equipping bridge inspection engineers with state-of-the-art UAS technology.

The initiative was structured around several key components: the creation of a flight proficiency assessment tool, the adoption of a field guide for UAS operations, a comprehensive training program combining online and in-person instruction, and the provision of commercial-grade UAS equipment to SCDOT bridge inspection teams. The training program included preparation for the FAA Part 107 exam, regulatory compliance, basic flight control using simulators, and hands-on training through bootcamps held at Clemson University.

The project not only aimed to improve the technical skills and operational efficiency of the SCDOT bridge inspection teams but also to ensure that the integration of UAS technology would result in safer, more efficient, and cost-effective bridge inspections. This report documents the methodologies, implementation, results, and impacts of the project, providing a comprehensive overview of how UAS technology was successfully transferred and integrated into SCDOT's bridge inspection processes. The lessons learned, and outcomes of this project are expected to serve as a valuable resource for other state DOTs and agencies considering similar technology adoption initiatives.

1.4 Summary of Precursor 2018 Pilot Project

The 2018 pilot study served as a foundational project to evaluate the potential of UAS for SCDOT operations, specifically focusing on bridge inspection and land surveying. The study demonstrated significant benefits, including enhanced safety, reduced costs, and improved efficiency. Key findings highlighted that over 90% of bridge inspection points could be effectively observed using drones, reducing the reliance on under-bridge inspection trucks and minimizing disruptions to traffic. Additionally, cost savings of approximately $1,500 per bridge inspection were estimated to be saved due to reduced equipment and labor needs.

The land surveying portion of the study showed that drone-based models could achieve exceptional accuracy, with positional deviations as low as 0.09 cm vertically and 0.68 cm horizontally under ideal conditions. These results underscored the capability of drones to augment traditional workflows and enhance precision in tasks like stockpile volume estimation. Although challenges, such as limited tactile inspections and navigation in GPS-denied environments, were noted, the overall conclusion strongly supported the expanded use of UAS technology in SCDOT's operations. This pilot set the stage for the broader implementation and further advancements explored in the current project.

CHAPTER 2

Development of a Flight Proficiency Assessment

2.1 14 CFR Part 107

14 CFR Part 107, commonly referred to simply as "Part 107," provides a comprehensive framework for the commercial operation of small unmanned aircraft systems (sUAS) in the United States. These regulations apply to drones weighing less than 55 pounds and cover a variety of operational, certification, and safety requirements. Key provisions include the necessity for operators to obtain a Remote Pilot Certificate by passing an aeronautical knowledge test, ensuring the drone remains within visual line-of-sight at all times, and restricting flights to daylight hours or civil twilight with appropriate lighting. Additionally, operations are generally limited to a maximum altitude of 400 feet above ground level and a speed of no more than 100 mph.

Part 107 also addresses specific operational limitations and conditions to ensure public safety and privacy. Operators must avoid flying over people not directly involved in the drone operation and near emergency response efforts. The rules permit operations in Class G airspace without prior authorization but require FAA permission for flights in Class B, C, D, and E airspace. Furthermore, the regulations stipulate that drones must yield the right of way to manned aircraft, and operators must conduct a preflight inspection to ensure the drone is safe for operation. Waivers are available for certain restrictions if the operator demonstrates that the proposed operation can be conducted safely.

2.2 Limitation with the FAA's Aeronautical Knowledge Test

As previously indicated, in order for a UAS pilot to earn their FAA remote pilot certificate they must pass an Aeronautical Knowledge Test. This is a 60-question, multiple-choice exam given at testing sites across the country. The Part 107 knowledge test covers topics such as airspace classification, aviation weather, emergency procedures, radio communication, airport operations, drone performance, maintenance, preflight inspection, and FAA regulations. The exam is well-named as it only evaluates the pilot's "knowledge" and does not assess the pilot's ability to operate a drone. The Part 107 knowledge test does not cover practical flight training, risk assessment, mission planning, or crew resource management, all of which are critical for mastering the skills necessary for safe and effective drone operation. An essential component of this project was the development a flight Proficiency Assessment to augment the existing Part 107 knowledge test.

2.3 ASTM F3266-18

ASTM F3266-18: Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement provides comprehensive guidelines for training individuals to become proficient remote pilots of UAS (ASTM, 2018). This guide is intended for both educators developing curricula and training courses and for individual pilots looking to enhance their knowledge and skills for commercial UAS operations. It outlines the essential knowledge, skills, and abilities necessary for safe UAS operation and can be used by various agencies and organizations to support the development of regulations. The guide covers various UAS types, including fixed-wing and rotorcraft, but excludes other categories such as gliders and lighter-than-air vehicles. It emphasizes the need for remote pilots to obtain a blend of aeronautical knowledge and system-specific training to ensure safety and compliance with regulatory requirements.

Key areas of knowledge detailed in the guide include applicable regulations, airspace classification, weather effects on UAS performance, emergency procedures, crew resource management, and maintenance protocols. The guide also addresses the importance of proficiency in practical skills such as pre-flight inspections, emergency response, and effective communication. It highlights that while this guide provides a foundational framework, additional training and experience are necessary for specific mission-critical operations. This standard serves as a benchmark for evaluating and developing UAS training programs, ensuring they meet the rigorous requirements for pilot competency and safety.

In essence, this standard provides a comprehensive list of required competencies for operating a UAS. Many of the competencies are assessed using the FAA's Part 107 Knowledge Test. However, this project created an assessment to address the proficiency items not covered by the existing test.

2.4 Examination Development

The Flight Proficiency Examination criteria are derived from ASTM F3266: Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement, which outlines the necessary knowledge, skills, and abilities for safe commercial unmanned aircraft operation. The key areas of knowledge, skills, and abilities are detailed in Section 5: General Knowledge Subject Matter Requirements, and Section 6: Indoctrination Curriculum Requirements. Section 5 indicates that "General Knowledge" can be gauged through written exams, citing the FAA's Knowledge Exam as an example. Therefore, this assessment will primarily focus on developing methods to gauge proficiency in the areas outlined in Section 6. The standard categorizes proficiency topics under "Tasks" and "Knowledge." Proficiency in a task requires "Task Performance" and "Task Knowledge" skills. A 4-tier matrix in "Table 1" is provided for Exam Proctors to assess flight proficiency, with Task Performance rated on a scale of 1 (is limited) to 4 (is proficient), and Task Knowledge measured from "a" (knows nomenclature) to "d" (understands advanced theory). ASTM F3266-18 Table 1 is shown in Figure 1 below. Both Task Performance and Task Knowledge are evaluated concurrently. "Subject Knowledge" is similarly rated on a four-tier scale from "A" (knows facts) to "D" (knows evaluation). ASTM F3266 sets minimum proficiency levels using this 4-tier matrix. This assessment includes questions on each flight proficiency topic from the standard and equips Exam Proctors with the means and context to determine whether a UAS pilot meets the standard's criteria for minimum proficiency.

TABLE 1 Task and Knowledge Levels

Scale Value		Definition: The Individual
Task Performance Levels	1	***IS LIMITED***. (Can do simple parts of the task. Needs to be told or shown how to do most of the task.)
	2	***IS PARTIALLY PROFICIENT***. (Can do most parts of the task. Needs only help on hardest parts.)
	3	***IS COMPETENT***. (Can do all parts of the task. Needs only a spot check of completed work.)
	4	***IS PROFICIENT***. (Can do the complete task quickly and accurately. Can tell or show others how to do the task.)
Task Knowledge Levels	a	***KNOWS NOMENCLATURE***. (Can name parts, tools, and simple facts about the task.)
	b	***KNOWS PROCEDURES***. (Can determine step-by-step procedures for doing the task.)
	c	***KNOWS OPERATING PRINCIPLES***. (Can identify why and when the task must be done and why each step is needed.)
	d	***KNOWS ADVANCED THEORY***. (Can predict, isolate, and resolve problems about the task.)
Subject Knowledge Levels	A	***KNOWS FACTS***. (Can identify basic facts and terms about the subject.)
	B	***KNOWS PRINCIPLE***. (Can identify relationship of basic facts and state general principles about the subject.)
	C	***KNOWS ANALYSIS***. (Can analyze facts and principles and draw conclusions about the subject.)
	D	***KNOWS EVALUATION***. (Can evaluate conditions and make proper decisions about the subject.)

Figure 1: ASTM F3266-18 Table 1

2.5 Overview of Examination

The Flight Proficiency Examination comprises four Parts: 1) Pre-Mission Ground School Assessment, 2) Pre-Flight Ground School Assessment, 3) Check Ride Assessment, and 4) Flight Control Assessment, all to be conducted by an Exam Proctor with one UAS Pilot at a time. The first part focuses on pre-mission preparations that are typically conducted off-site, such as airspace identification, maintenance checks, and mission planning. The second part assesses the UAS Pilot's theoretical knowledge, skills, and ability to execute a mission. The first two parts are administered orally and do not necessitate flying the aircraft. The third part requires the UAS Pilot to perform basic flying maneuvers under the guidance of the Exam Proctor, to evaluate their skills in mission planning, flight operations, and piloting. The examination culminates in the fourth part, where the UAS Pilot undertakes the National Institute of Standards and Technology's (NIST's) Basic Proficiency Evaluation for Remote Pilots (BPERP) test, demonstrating their overall UAS control proficiency. The Flight Proficiency Examination can be found in Appendix A.

2.6 Grading Assessment Questions

Parts 1, 2, and 3 of the Flight Proficiency Examination include open-ended questions that the Exam Proctor will pose orally to the UAS Pilot. Each question correlates with at least one section of ASTM F3266, establishing the fundamental level of understanding or skill required for demonstrating competency. This required level is depicted as a four-tier matrix in ASTM F3266 Table 1 (Figure 1). Evaluation of tasks is based on two metrics: "Task Performance," indicated by a numeric value, and "Task Knowledge," represented by a lowercase letter. The evaluation of Subject Knowledge utilizes a single standard, marked by an uppercase letter. Exam Proctors are responsible for assessing the UAS Pilot's answers against the "assessment criteria" specified in the question, aligned with the ASTM task and knowledge level matrix. Each question is accompanied by a scoring table, which should be utilized to document the evaluation of the UAS Pilot's response. The cell highlighted in bold indicates the minimum level of understanding required.

Scoring Example: In the example below, the Exam Proctor assessed that the pilot "Is competent" and "Knows operating principles" of the task. This meets the requirement of the "task performance" and exceeds the requirement of the "task knowledge." See an example of the how a question will be scored in Figure 2.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

Figure 2: Scoring Example

2.7 Limitations of the Flight Proficiency Assessment

ASTM F3266-18 outlines a comprehensive set of competencies required for the operation of all types of UAS, including fixed-wing, helicopter, and multi-rotor platforms. In the context of the SCDOT bridge inspection program, inspectors are exclusively equipped with multi-rotor drones, and there are no plans to incorporate other UAS types in the future. Consequently, the training and proficiency evaluations for SCDOT bridge inspectors have been tailored specifically to multi-rotor drones, omitting any competencies that are not relevant to this type of UAS.

Additionally, the study involved a targeted group of bridge inspection engineers from SCDOT, with training provided to ensure participants had foundational knowledge of UAS operations. However, the sample size may not fully capture the diversity of skill levels, experience, or learning preferences that exist among bridge inspectors nationally. The participants were selected based on availability and their direct involvement in bridge inspection workflows, which may introduce selection bias. Future studies should consider incorporating a broader and more representative sample of inspectors, potentially including personnel from different regions and varying levels of experience. This approach would provide a more comprehensive understanding of how diverse skill sets and learning preferences influence the integration and effectiveness of UAS technology in bridge inspections.

CHAPTER 3

Online Training

3.1 Introduction

This project provided SCDOT bridge inspectors the opportunity to receive training and equipment so that they could begin to use UAS technology to support their operations. The training was divided into an online training course and an in-person bootcamp. This section will describe the online training.

3.2 Logistics and Structure

The course had two primary objectives. The first was to prepare participants to pass the Part 107 knowledge exam and earn their FAA Remote Pilot Certificate (drone pilot's license). The second objective was to familiarize participants with drone operation using a simulator. Although there is no substitute for in-person flight experience, the simulator taught participants how to operate the controls and helped develop the muscle memory necessary to be effective pilots. The course material was divided into six weeks. The first four weeks were dedicated to preparing for the Part 107 exam, while the last two weeks focused on using the flight simulator. Weekly Zoom calls were held on Mondays at 9:00 AM to review the week's material and answer any questions. Figure 3 show a screenshot from the recording. For those unable to attend these calls, a recording link was provided. Additionally, assistance with any of the material was available as needed. Upon completion of this online course, participants were ready to attend a two-day UAS bootcamp at Clemson University, where they engaged in simulated missions using equipment that was handed over to the SCDOT.

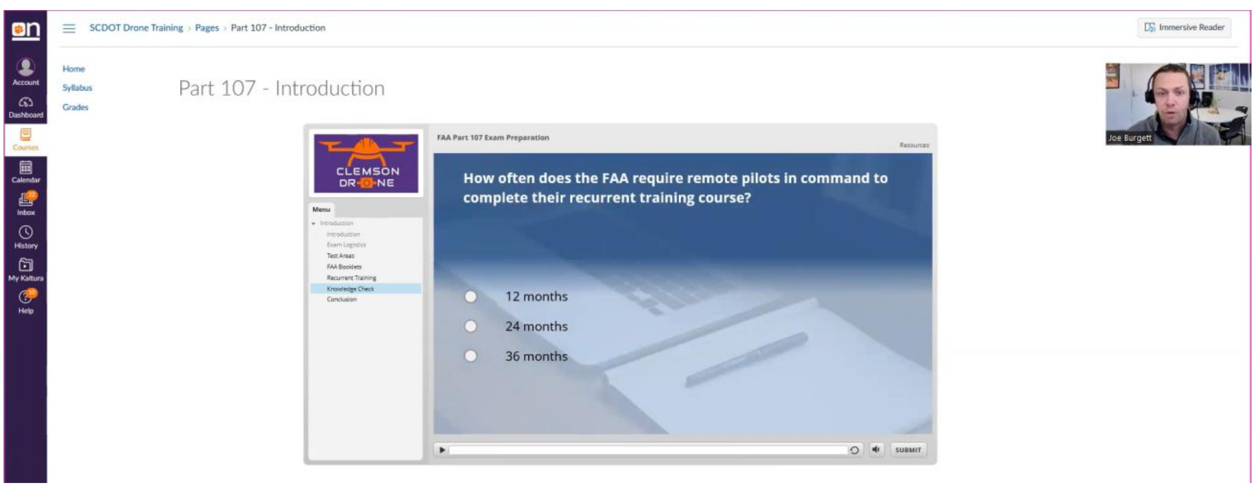

Figure 3: Example of Weekly Zoom Call with SCDOT Participants

The topical outline based on the 5-week completion schedule was as follows:

- Week 1: Reviewed material from Chapter 1 of the Part 107 Study Guide.
- Week 2: Reviewed material from Chapter 2 of the Part 107 Study Guide.
- Week 3: Reviewed material from Chapter 3a - 8 of the Part 107 Study Guide.
- Week 4: Reviewed material from Chapters 9 - 12 of the Part 107 Study Guide and took the Part 107 Exam.
- Week 5: Reviewed mission checklists for safe drone operation, created a flight plan in Aloft, and learned basic flight skills with a simulator.

- Week 6: Learned about UAS privacy, completed a comprehensive suite of flight exercises with the UAS simulator, and completed the BPERP Flight Proficiency exam to earn APSA Certification.
- The course material included the FAA Study Guide, FAA Test Supplement, Basic UAS Reference Guide and Manual (B.U.R.G. Manual), flight simulator controller, and Zephyr Flight Simulation Software.

Evaluation was based on the following percentages: 35% from the Part 107 Exam and 65% from assignments throughout the course. A passing score was set at greater than 80%. Those completing the course with a passing score received a certificate of completion. This was a non-credit course offered through Clemson University, and it did not appear on transcripts, serving purely for professional development.

3.3 Performance

Originally, 22 SCDOT employees enrolled in the UAS program; however, one employee quickly needed to withdraw and did not participate in the class. Of the 21 employees who participated in the online course, 19 passed the course with an 80% or higher. Additionally, 20 of the participants passed the FAA Part 107 knowledge exam and earned their remote pilot certificate. See Table 1.

Table 1: Online Class Participants Performance.

Item	Number of Participants
Participated in Program	21
Passed Course	19
Earned Part 107 Remote Pilot Certificate	20
Earned APSA BPERP	9

The Airborne Public Safety Association (APSA) Basic Proficiency in Evaluation for Remote Pilots (BPERP) certificate is a credential that signifies that the holder has demonstrated essential skills and knowledge in operating UAS in emergency response scenarios. This certification involves completing a comprehensive set of flight exercises and passing a proficiency exam, ensuring that the pilot is capable of safely and effectively managing UAS operations in critical situations. Participants were given the option to earn their APSA BPERP certification as part of the course. This was not a requirement of the course. A total of nine SCDOT inspectors took and passed the test.

At the end of the bootcamp, an online survey was distributed to the participants. The majority of the questions had a 5-point Likert Scale where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. A total of 20 people attended the workshop for a 60% completion rate. Table 2 provides a summary of the questions and responses.

Table 2: Survey Result of Online Class.

#	Question	Ave.	Min.	Max.	N
Q19	The online portion of the workshop was an effective way to prepare for the Part 107 exam,	4.6	4	5	12
Q21	The length of the online portion of the workshop (five weeks) was appropriate to cover the topics effectively.	3.3	3	5	12
Q20	The simulator was an effective way to begin learning how to fly a drone.	4.9	4	5	12

The feedback from the online portion of the recent workshop on drone technology and bridge inspections indicates a positive reception among participants, particularly regarding the preparation for the Part 107 exam and the initial drone flying experience using the simulator. Participants found the online portion of the workshop to be an effective way to prepare for the Part 107 exam, with an average rating of 4.6. This suggests that the content and structure of the online materials were beneficial in helping participants understand and retain the necessary information for the exam.

The effectiveness of the simulator as a learning tool for drone flying received an exceptionally high average rating of 4.9. This indicates that participants found the simulator to be a highly valuable component of the workshop, providing a realistic and practical introduction to drone operation.

Regarding the length of the online portion, which spanned five weeks, the average rating was 3.3. Similar to the in-person portion of the workshop, the ideal feedback for this question is a 3, suggesting that the duration was appropriate for covering the topics effectively. However, the range of responses, from 3 to 5, indicates that while most participants found the length suitable, there were some who felt it could either be shortened or extended.

In conclusion, the online portion of the workshop received positive feedback, particularly for its effectiveness in preparing participants for the Part 107 exam and the use of the simulator for initial drone flying training. The length of the online portion was generally seen as appropriate, though there was some variation in responses. Overall, the high ratings demonstrate the success of the online portion in enhancing participants' knowledge and skills in drone technology and operation.

CHAPTER 4

In-Person UAS Bootcamp

4.1 Introduction

The second part of the UAS training was conducted as an intensive two-day bootcamp at Clemson's Experiential Learning Yard. The first day focused on reviewing mission preparation and equipment training specific to the UASs that were issued to the participants at the conclusion of the bootcamp. Accommodations were provided for the engineers to stay overnight in a hotel. On the second day, several mock missions were conducted, and the flight proficiency assessment tool was pilot-tested.

4.2 Logistics and Structure

The first day of the bootcamp was structured into three distinct parts. The initial segment focused on various components of mission planning, including the review of multiple checklists, mission planning discussions, regulatory compliance tools, and operational techniques. The second segment involved hands-on training with the aircraft. While a manufacturer's representative provided the training during the first bootcamp, subsequent sessions were conducted by the Principal Investigator (PI), who is well-versed in the specifics of the aircraft. The third segment involved issuing equipment to the participants and conducting flight missions in a controlled environment. NIST open test lanes were set up, allowing participants to execute NIST-prescribed maneuvers.

Figure 4: Bootcamp #1, Day 1, Classroom Training

Figure 5: Bootcamp #1, Day 1, NIST Training

Figure 6: Bootcamp #2, Day 1, NIST Training

The objective of the second day of the bootcamp was to simulate the inspection of four distinct bridges in the Clemson area under the guidance of the PI. In the morning, participants convened at the CSM XL yard, where the PI divided them into two groups, each assigned to a specific bridge. The groups were tasked with planning their missions, assigning roles, and completing the necessary checklists and flight logs. After planning their missions, they collectively discussed their strategies, with the PI providing feedback and suggestions to refine the plans. Following the completion of their planning, participants proceeded to the bridge sites to conduct their missions. After inspecting two bridges in the morning, they returned to the CSM XL yard for a debrief and lunch. This process was repeated in the afternoon for the remaining bridges.

Figure 7: Bootcamp #1, Day 2, 6 Mile Hwy Bridge

Figure 8: Bootcamp #1, Day 2, Madden Bridge

Figure 9: Bootcamp #1, Day 2, Seneca Creek Bridge

Figure 10: Bootcamp #2, Day 2, Madden Bridge

4.3 Performance

As indicated in the previous section, at the end of the bootcamp an online survey was distributed to the participants. The survey provided a series of Likert Scale questions where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = Strongly Agree. A total of 20 people attended the workshop for a 60% completion rate. Table 3 provides a summary of the questions and responses.

Table 3: Survey Result of In-Person Bootcamp.

#	Question	Ave.	Min.	Max.	N
Q3	The instructor was knowledgeable about drone technology and bridge inspections.	4.9	3	5	12
Q1	The workshop objectives were clearly defined.	4.4	1	5	12
Q2	The content of the workshop was relevant to my work as a bridge inspector.	4.8	4	5	12
Q4	This workshop and the use of drones will impact the efficiency and safety of your bridge inspections?	4.8	4	5	12
Q5	The hands-on drone flying sessions were helpful in understanding how to inspect bridges.	4.9	4	5	12
Q6	The workshop materials (e.g., slides, handouts) were useful and well-organized.	4.8	3	5	12
Q7	The length of the in-person portion of the workshop (two days) was appropriate to cover the topics effectively.	3.3	3	5	12
Q8	The technology and equipment used during the workshop were up-to-date and functional.	4.8	4	5	12
Q10	Overall, I am satisfied with the workshop and would recommend it to other bridge inspectors.	4.9	4	5	12
Q9	I feel confident in my ability to use drones for bridge inspections after participating in the workshop.	4.5	4	5	12

The feedback from the recent workshop on drone technology and bridge inspections indicates a high level of satisfaction among participants. The responses demonstrate that the workshop was well-received across various aspects, highlighting the instructor's expertise, the relevance of the content, the impact on inspection efficiency and safety, and the usefulness of hands-on sessions. The instructor's knowledge about drone technology and bridge inspections received an average rating of 4.9, with most participants giving the highest possible score, underscoring the instructor's ability to convey complex information effectively. While the workshop objectives were generally found to be clearly defined, with an average rating of 4.4, there was a wider range of responses, including one rating of 1, indicating some room for improvement in how the objectives are communicated at the outset.

Participants felt that the content was highly relevant to their work as bridge inspectors, with an average rating of 4.8, suggesting the workshop successfully addressed their specific needs and interests. The workshop was perceived to have a significant positive impact on the efficiency and safety of bridge inspections, also reflected in an average rating of 4.8. The hands-on drone flying sessions were particularly well-received, with an average rating of 4.9, indicating that practical exercises greatly enhanced the learning experience and understanding of bridge inspections using drones. The materials provided, such as slides and handouts, were considered useful and well-organized, contributing positively to the overall learning experience, with an average rating of 4.8.

The length of the workshop received an average rating of 3.3. Unlike other questions where a higher rating is preferable, the ideal feedback for this question is a 3, indicating that the length of the workshop was appropriate. This suggests that most participants found the duration suitable, though there were some who felt it could be adjusted. The technology and equipment used during the workshop were rated very highly, with an average rating of 4.8, affirming that the tools provided were up-to-date and functional. Overall satisfaction with the workshop was extremely high, with participants willing to recommend it to other bridge inspectors, reflected in an average rating of 4.9. Participants reported a high level of confidence in their ability to use drones for bridge inspections after the workshop, with an average rating of 4.5, which is crucial for the practical implementation of the skills learned.

In conclusion, the feedback indicates that the workshop was highly effective in meeting its objectives and providing valuable, relevant training to bridge inspectors. The only notable area for potential improvement is the length of the workshop, where feedback was more varied. Overall, the high ratings across most questions demonstrate the workshop's success in enhancing participants' knowledge, skills, and confidence in using drone technology for bridge inspections.

CHAPTER 5

Conclusions

5.1 Introduction

The "Transfer of Unmanned Aircraft Systems Technology to SCDOT for Enhanced Bridge Inspections" project has been a significant success, achieving its primary goals of improving the efficiency, safety, and cost-effectiveness of bridge inspections through the integration of advanced UAS technology. This initiative, funded by the Center for Connected Multimodal Mobility (C2M2) and the South Carolina Department of Transportation (SCDOT), has demonstrated the potential for transformative change in infrastructure inspection methodologies. The training was particularly well received by the SCDOT bridge inspectors. Group photos of each of the in-person bootcamps are provided in Figure 11, 12, and 13.

Figure 11: Group Photo of Bootcamp #1

Figure 12: Group Photo of Bootcamp #2

Figure 13: Group Photo of Bootcamp #3

5.2 Summary of Achievements

The following is a summary of the key project achievements.

1) Development and Implementation of Training Programs:

- A comprehensive training program was developed, combining online coursework and in-person bootcamps. The online training focused on preparing participants for the FAA Part 107 exam and familiarizing them with basic drone operations using simulators.
- In-person bootcamps provided hands-on experience and practical training, crucial for mastering UAS technology.

2) High Certification Success Rates:

- Out of 22 participants, 20 successfully passed the FAA Part 107 exam, highlighting the effectiveness of the training program.
- Participants also earned the Airborne Public Safety Association's BPERP flight certification, further enhancing their operational capabilities.

3) Creation of UAS Flight Proficiency Assessment Tool:

- A robust flight proficiency assessment tool was developed to complement the FAA's Part 107 knowledge test, ensuring a comprehensive evaluation of UAS pilots' capabilities.
- The assessment tool included scenario-based questions and aircraft control exercises, tailored to meet ASTM F3266 standards.

4) Provision of Commercial-Grade UAS Equipment:

- Commercial-grade UAS equipment was distributed to SCDOT bridge inspection teams across all seven districts, enabling immediate operational deployment.
- The equipment included advanced features and capabilities essential for detailed and accurate bridge inspections.

5) Positive Feedback and High Satisfaction Rates:

- Survey results indicated strong approval of both the online and in-person training components, reflecting the program's success in meeting participants' needs.
- In a post-workshop satisfaction survey, 92% of the participants indicated that they strongly agreed with the statement that "Overall, I am satisfied with the workshop and would recommend it to other bridge inspectors."

5.3 Impact and Benefits

The integration of UAS technology into SCDOT's bridge inspection processes has yielded substantial benefits:

- Enhanced Safety: UAS technology allows for remote inspections, significantly reducing the risk to inspectors by minimizing the need for manual inspections in hazardous locations.
- Increased Efficiency: The use of drones has streamlined the inspection process, enabling quicker data collection and reducing the time required for inspections.
- Cost Savings: By eliminating the need for specialized equipment and minimizing public disruptions, UAS technology has resulted in considerable cost savings for bridge inspections.
- Improved Data Quality: High-resolution imagery and comprehensive data collection from previously inaccessible vantage points have led to superior-quality inspection records.

5.4 Regulatory Considerations for Broader Implementation

The availability and application of UAS technology are influenced by local regulations, which can vary significantly across regions and states. While the methodologies developed for SCDOT were tailored to South Carolina's regulatory framework, adapting these approaches to other jurisdictions will require careful consideration of regional airspace restrictions, operational permissions, and compliance requirements. Future implementations should include a thorough evaluation of local regulatory constraints and incorporate flexible strategies to ensure alignment with differing legal and operational standards.

5.5 Future Research

The successful development of the flight proficiency assessment tool during this project highlighted a critical gap in the SCDOT's current drone program: the absence of a comprehensive Standard Operating Procedure (SOP). The creation of an SOP is the foundational step towards building a more sophisticated and effective drone program. An SOP provides structured guidelines and procedures, ensuring consistency, safety, and compliance with regulatory standards. It serves as a critical reference for drone operators, outlining best practices and operational protocols. It is strongly recommended that the SCDOT initiate a new project focused on developing a comprehensive SOP tailored to their specific needs. This project should be based on the best practices of other state departments of transportation but customized to fit the unique requirements of the SCDOT.

Additionally, it is important to evaluate the sustained impact of UAS technology on bridge inspection processes over time to ensure that initial benefits are not only maintained but also optimized as the technology matures and becomes more integrated into standard practices.

Long-term assessments should investigate how UAS technology influences inspection outcomes across multiple disciplines and address critical factors that impact the sustainability of the program. These studies should evaluate the technology's effectiveness in consistently identifying structural deficiencies over repeated inspection cycles, while also exploring how inspectors adapt to and integrate drone technology into their workflows. Additionally, an in-depth analysis of operational efficiency, cost-effectiveness, and scalability is essential, particularly when expanding this initiative to larger-scale operations or implementing it in other states or departments. Future research should emphasize the ongoing logistical challenges and costs associated with equipment maintenance, software updates, and the management of a sustainable UAS program. Such studies must also consider external factors, including advancements in drone technology, changes in regulatory requirements, and evolving inspection needs, to ensure the program remains dynamic and effective over time. This comprehensive approach will provide valuable insights into the real-world performance and longevity of UAS integration in infrastructure management.

Building on the foundational work of this project, future studies should explore real-world operational challenges that extend beyond basic flight proficiency and regulatory compliance. These challenges include evaluating UAS performance in diverse weather conditions, navigating complex and hard-to-reach inspection locations, and operating under time constraints during live bridge inspections. Addressing these practical considerations will provide a deeper understanding of the operational limitations and capabilities of UAS technology in real-world settings. Insights gained from such research will help refine training programs, enhance standard operating procedures, and further optimize the integration of drones into bridge inspection workflows, ensuring their effectiveness across varying scenarios.

Future research should focus on:
1. Reviewing Best Practices: Conducting a comprehensive review of SOPs from other state DOTs and relevant organizations to gather insights and identify best practices.
2. Customizing the SOP: Tailoring the SOP to address the specific operational, regulatory, and environmental conditions of South Carolina.
3. Pilot Testing: Implementing a pilot program to test and refine the SOP, ensuring it meets the needs of SCDOT's drone operations.
4. Training and Dissemination: Developing training programs to ensure all drone operators are well-versed with the new SOP and understand its application in various scenarios.
5. Comprehensive Long-term Studies on UAS Integration: Examine the sustained impact of UAS technology on bridge inspections, focusing on quality, safety, and cost-efficiency over an extended period. This study should analyze how the integration of drones affects inspection workflows, resource allocation, and inspector safety metrics in real-world settings.
6. Real-World Operational Challenges: Investigating UAS performance under diverse weather conditions, in complex inspection environments, and during time-constrained live operations to refine operational strategies and improve overall system reliability.

In conclusion, the "Transfer of Unmanned Aircraft Systems Technology to SCDOT for Enhanced Bridge Inspections" project has successfully demonstrated the transformative potential of UAS technology. Through effective training, comprehensive assessment, and the provision of state-of-the-art equipment, this project has set a new standard for bridge inspection processes, paving the way for safer, more efficient, and cost-effective infrastructure management.

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APPENDICES

Appendix A: UAS Flight Proficiency Examination

Found on the following page.

South Carolina Department of Transportation

UAS Flight Proficiency Examination

Overview

Introduction

To legally operate Unmanned Aircraft Systems (UAS) or "drones," pilots must obtain a remote pilot certificate from the Federal Aviation Administration (FAA). This certification involves passing a multiple-choice knowledge exam that covers various topics, including regulations, airspace classification, weather, loading and performance, and operational procedures. While the Part 107 knowledge exam evaluates theoretical understanding, it does not test the operator's practical flight operations skills or aircraft handling abilities. The Flight Proficiency Examination aims to complement the Part 107 knowledge exam by offering a voluntary evaluation of flight operations and skills.

Examination Development

The Flight Proficiency Examination criteria are derived from ASTM F3266: Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement, which outlines the necessary knowledge, skills, and abilities for safe commercial unmanned aircraft operation. The key areas of knowledge, skills, and abilities are detailed in Section 5: General Knowledge Subject Matter Requirements, and Section 6: Indoctrination Curriculum Requirements. Section 5 indicates that "General Knowledge" can be gauged through written exams, citing the FAA's Knowledge Exam as an example. Therefore, this assessment will primarily focus on developing methods to gauge proficiency in the areas outlined in Section 6. The standard categorizes proficiency topics under "Tasks" and "Knowledge." Proficiency in a task requires "Task Performance" and "Task Knowledge" skills. A 4-tier matrix in "Table 1" is provided for Exam Proctors to assess flight proficiency, with Task Performance rated on a scale of 1 (is limited) to 4 (is proficient), and Task Knowledge measured from "a" (knows nomenclature) to "d" (understands advanced theory). Both Task Performance and Task Knowledge are evaluated concurrently. "Subject Knowledge" is similarly rated on a four-tier scale from "A" (knows facts) to "D" (knows evaluation). ASTM F3266 sets minimum proficiency levels using this 4-tier matrix. This assessment includes questions on each flight proficiency topic from the standard and equips Exam Proctors with the means and context to determine whether a UAS pilot meets the standard's criteria for minimum proficiency.

Overview of Examination

The Flight Proficiency Examination comprises four Parts: 1) Pre-Mission Ground School Assessment, 2) Pre-Flight Ground School Assessment, 3) Check Ride Assessment, and 4) Flight Control Assessment, all to be conducted by an Exam Proctor with one UAS Pilot at a time. The first part focuses on pre-mission preparations that are typically conducted off-site, such as airspace identification, maintenance checks, and mission planning. The second part assesses the UAS Pilot's theoretical knowledge, skills, and ability to execute a mission. The first two parts are administered orally and do not necessitate flying the aircraft. The third part requires the UAS Pilot to perform basic flying maneuvers under the guidance of the Exam Proctor, to evaluate their skills in mission planning, flight operations, and piloting. The examination culminates in the fourth part, where the UAS Pilot undertakes the National Institute of Standards and Technology's (NIST's) Basic Proficiency Evaluation for Remote Pilots (BPERP) test, demonstrating their overall UAS control proficiency. NIST has provided a fabrication guide with detailed instructions for building the Open Test lane. The fabrication guide can be downloaded here.

Grading Assessment Questions

Parts 1, 2, and 3 of the Flight Proficiency Examination include open-ended questions that the Exam Proctor will pose orally to the UAS Pilot. Each question correlates with at least one section of ASTM F3266, establishing the fundamental level of understanding or skill required for demonstrating competency. This required level is depicted as a four-tier matrix in ASTM F3266 Table 1 below. Evaluation of tasks is based on two metrics: "Task Performance," indicated by a numeric value, and "Task Knowledge," represented by a lowercase letter. The evaluation of Subject Knowledge utilizes a single standard, marked by an uppercase letter. Exam Proctors are responsible for assessing the UAS Pilot's answers against the "assessment criteria" specified in the question, aligned with the ASTM task and knowledge level matrix. Each question is accompanied by a scoring table, which should be utilized to document the evaluation of the UAS Pilot's response. The cell highlighted in bold indicates the minimum level of understanding required.

TABLE 1 Task and Knowledge Levels

Scale Value		Definition: The Individual
Task Performance Levels	1	***IS LIMITED***. (Can do simple parts of the task. Needs to be told or shown how to do most of the task.)
	2	***IS PARTIALLY PROFICIENT***. (Can do most parts of the task. Needs only help on hardest parts.)
	3	***IS COMPETENT***. (Can do all parts of the task. Needs only a spot check of completed work.)
	4	***IS PROFICIENT***. (Can do the complete task quickly and accurately. Can tell or show others how to do the task.)
Task Knowledge Levels	a	***KNOWS NOMENCLATURE***. (Can name parts, tools, and simple facts about the task.)
	b	***KNOWS PROCEDURES***. (Can determine step-by-step procedures for doing the task.)
	c	***KNOWS OPERATING PRINCIPLES***. (Can identify why and when the task must be done and why each step is needed.)
	d	***KNOWS ADVANCED THEORY***. (Can predict, isolate, and resolve problems about the task.)
Subject Knowledge Levels	A	***KNOWS FACTS***. (Can identify basic facts and terms about the subject.)
	B	***KNOWS PRINCIPLE***. (Can identify relationship of basic facts and state general principles about the subject.)
	C	***KNOWS ANALYSIS***. (Can analyze facts and principles and draw conclusions about the subject.)
	D	***KNOWS EVALUATION***. (Can evaluate conditions and make proper decisions about the subject.)

Scoring Example: In the example below, the Exam Proctor assessed that the pilot "Is competent" and "Knows operating principles" of the task. This meets the requirement of the "task performance" and exceeds the requirement of the "task knowledge."

Task Performance	1	2	**3** ✓	4	n/a
Task Knowledge	a	**b**	c ✓	d	n/a

END OF SECTION

Part 1: Pre-Mission Ground School Assessment

Instructions: For this portion of the exam, the Exam Proctor will ask the UAS Pilot a series of questions related to pre-mission activities. The UAS Pilot is permitted to use appropriate tools and resources that would be available during mission planning. These include websites and applications; however, they would not include other UAS Pilots or operators. This portion of the exam does not need to be completed at the mission site. The Exam Proctor will evaluate their answer to determine if their performance meets the level prescribed in ASTM F3266 Table 1

Question #1

Field Question: Identify the closest airport in controlled airspace to your current location. Assume you have been tasked with a UAS mission that is located 3 miles west of the runway. The mission area has a radius of 300 feet. What are the lateral and vertical boundaries of the airspaces at the mission site and the surrounding area?

Assessment Criteria: The UAS Pilot will likely use an online tool or app to complete this question. They should be able to identify the lateral and vertical boundaries of the controlled airspace. The UAS Pilot may show the Exam Proctor on their screen or device to demonstrate their understanding. However, they should also verbally explain the boundaries to demonstrate a 3b level at task performance and knowledge.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a
Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.6 The RPIC shall understand the following topics as appropriate to the UA type and flight operations:
6.2.7 Classes and types of controlled and uncontrolled airspace.
6.2.7.1 The altitude or height, or both, restrictions of each type of airspace (Level B)
6.3.7.7 The RPIC shall know how to ensure that all necessary operating permissions and authorizations are obtained for the mission from the regulatory agencies (Leve 3b)

Additional Instructor Notes: The instructor can use a different airport or location if appropriate.

Question #2

Field Question: Identify the closest airport in controlled airspace to your current location. Assume you have been tasked with a UAS mission that will require you to operate a drone in an area that has a 300-foot radius with the center 3 miles due west of the runway. What is the maximum altitude allowable for immediate LAANC air traffic control authorization at this mission site?

Assessment Criteria: The UAS Pilot will likely use an online tool or app to complete this question. They should be able to identify the maximum altitudes allowable as described by the FAA's facility maps. The UAS Pilot may show the Exam Proctor on their screen or device to demonstrate their understanding. However, they should also verbally explain the boundaries to demonstrate a 3b level at task performance and knowledge.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a
Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.6 The RPIC shall understand the following topics as appropriate to the UA type and flight operations:
6.2.7 Classes and types of controlled and uncontrolled airspace.
6.2.7.1 The altitude or height, or both, restrictions of each type of airspace (Level B)
6.3.7.7 The RPIC shall know how to ensure that all necessary operating permissions and authorizations are obtained for the mission from the regulatory agencies (Leve 3b)

Additional Instructor Notes: The instructor can use a different airport or location if appropriate.

Question #3

Field Question: Identify the closest airport in controlled airspace to your current location. Assume you have been tasked with a UAS mission that will require you to operate a drone in an area that has a 300-foot radius with the center 3 miles due west of the runway. Demonstrate how you would request LAANC authorization to conduct this mission 24 hours from now. Only demonstrate the steps. Do not submit a LAANC authorization at this time.

Assessment Criteria: The UAS Pilot will likely use an online tool or app to complete this question. They should be able to identify the steps to submit a LAANC ATC authorization request. The UAS Pilot may show the Exam Proctor on their screen or device to demonstrate their understanding.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a
Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.6 The RPIC shall understand the following topics as appropriate to the UA type and flight operations:
6.2.7 Classes and types of controlled and uncontrolled airspace.
6.2.7.1 The altitude or height, or both, restrictions of each type of airspace (Level B)

Additional Instructor Notes: The instructor can use a different airport or location if appropriate. Task Performance and Task Knowledge exceed ASTM standard requirements.

Question #4

Field Question: Identify the closest airport in controlled airspace to your current location. Assume you have been tasked with a UAS mission that will require you to operate a drone in an area that has a 300-foot radius with the center 3 miles due west of the runway. What special operations, such as ballooning or parachuting, often occur at this airport?

Assessment Criteria: The UAS Pilot will likely need to review an FAA section chart to answer this question. They will likely use an electronic source; however, could provide the information via a hard copy section chart. The UAS Pilot may show the Exam Proctor on their screen, device, or hard copy chart to demonstrate their understanding. However, they should also verbally explain any special operations or lack thereof to demonstrate a 3b level at task performance and knowledge.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a
Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.6 The RPIC shall understand the following topics as appropriate to the UA type and flight operations:
6.2.7 Classes and types of controlled and uncontrolled airspace.
6.2.7.2 UAS operations permitted in each type of airspace, and (Level B)

Additional Instructor Notes: The instructor can use a different airport or location if appropriate. Task Performance and Task Knowledge exceed ASTM standard requirements.

Question #5

Field Question: Identify the closest airport in controlled airspace to your current location. Assume you have been tasked with a UAS mission that will require you to operate a drone in an area that has a 300-foot radius with the center 3 miles due west of the runway. Are there any Notice to Air Missions (NOTAMs) or Temporary Flight Restrictions (TFRs) at this time?

Assessment Criteria: The UAS Pilot will likely use an online tool or app to complete this question. They should be able to identify if a NOTAM or TFR is present at this time. The UAS Pilot may show the Exam Proctor on their screen or device to demonstrate their understanding. However, they should also verbally explain what is being shown to demonstrate a 3b level at task performance and knowledge.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.6 The RPIC shall understand the following topics as appropriate to the UA type and flight operations:
6.2.7 Classes and types of controlled and uncontrolled airspace.
6.2.7.2 UAS operations permitted in each type of airspace, and (Level B)

Additional Instructor Notes: The instructor can use a different airport or location if appropriate. Task Performance and Task Knowledge exceed ASTM standard requirements.

Question #6

Field Question: Identify all of the controlled and restricted airspaces as well as any air space that may significantly impact mission planning in the geographic area in which your agency operates.

Assessment Criteria: The UAS Pilot should be able to list the relevant airspaces but does not need to memorize the classification or specific details about the airspace to demonstrate a "B" level of subject knowledge.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.6 The RPIC shall understand the following topics as appropriate to the UA type and flight operations:
6.2.7 Classes and types of controlled and uncontrolled airspace.
6.2.7.3 Regulations and restrictions that may apply to sUA operating in the CAA airspace.

Question #7

Field Question: Show the Exam Proctor the manufacturer's specifications and describe the operational limitations of the aircraft. These limitations should include the maximum altitude, range, temperature range, wind speed, precipitation, GPS dependence, and other factors particular to anticipated missions.

Assessment Criteria: The UAS Pilot should indicate in the aircraft's specifications all relevant operating limitations. Showing the specifications is insufficient. They should be able to locate the relevant information to satisfy level 2 of the task performance criteria.

Task Performance	1	**2**	3	4	n/a
Task Knowledge	a	**b**	c	d	n/a

ASTM Section: 6.3.2 The RPIC shall be familiar with:
6.3.2.1 Manufacturers operating limitations (Level 2b)

Question #8

Field Question: What are the weather conditions that must be met, based on your agency's operating procedures, before a UAS mission can begin? Your answer must include all relevant weather conditions including wind speed, visibility, precipitation, max/min temperatures, cloud cover, and fog.

Assessment Criteria: Part 107 indicates that a minimum of 3 statute miles of visibility must be maintained; UAS must maintain 500 feet below and 2,000 feet laterally to clouds, including fog. The agency may have other environmental conditions that must be met as part of its operating procedures. Examples include maximum sustained wind speed of 15 mph, no precipitation, minimum temperature of 25 degrees and maximum temperatures of 95 degrees.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.10.1 The RPIC shall have a sufficiently detailed understanding of the following subject matter to assure safe flight operations with regards to prevailing weather conditions:
6.2.10.2-12 Aviation and surface weather, wind, visibility, cloud cover, icing, precipitation static, turbulence, temperature, air pressure, density altitude, and air mass characteristics.

Question #9

Field Question: What are the current weather conditions where you are currently located? Your answer must include wind speed, visibility, precipitation, temperatures, the elevation of the lowest cloud cover, and any other conditions relevant to a UAS mission.

Assessment Criteria: The UAS Pilot can use any tool, including the internet or application, to retrieve the required information. Retrieving and interpreting the METAR or TAF of a nearby airport is one method for answering the question. The UAS Pilot may show the Exam Proctor on their screen or device to demonstrate their understanding. However, they should also verbally explain what is being shown to demonstrate a 3b level at task performance and knowledge.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a
Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.10.1 The RPIC shall have a sufficiently detailed understanding of the following subject matter to assure safe flight operations with regards to prevailing weather conditions: (Level B)
6.2.10.2-12 Aviation and surface weather, wind, visibility, cloud cover, icing, precipitation static, turbulence, temperature, air pressure, density altitude, and air mass characteristics. (Level B)

Additional Instructor Notes: Task Performance and Task Knowledge exceed ASTM standard requirements.

Question #10

Field Question: What are the specified performance metrics provided by the manufacturer for the following aspects of the aircraft you are being evaluated on? Provide estimates or performance descriptions if exact numbers or specifications are not known.

a. Flight Time: Duration the drone can stay airborne on a single charge or fuel tank.
b. Range: Maximum distance from the controller the drone can fly.
c. Speed: The top speed the drone can achieve in flight.
d. Payload Capacity: The weight the drone can carry in addition to its own weight.
e. Wind Resistance: Ability to operate effectively in windy conditions.
f. Altitude Ceiling: Maximum altitude the drone can reach.
g. GPS Accuracy: Precision of the drone's GPS for location and navigation.
h. Camera Quality (if applicable): Resolution and capabilities of any onboard camera.
i. Automated Features: Capabilities like auto-takeoff, auto-landing, and waypoint navigation.
j. Communication System: Quality of the link between the drone and its controller.
k. Sensors and Data Processing: Types and quality of sensors (e.g., LIDAR, thermal) and the drone's ability to process collected data.

Assessment Criteria: The UAS Pilot should be able to "state general principles" about the flight performance of the UAS they are being tested on. Memorizing exact numbers is not required to have a "B" level subject knowledge. Exam Proctor should determine if their response demonstrates the UAS Pilot has sufficient knowledge about the aircraft's performance for safe operations. Not all conditions listed in the question will be appropriate for the aircraft the UAS pilot is being qualified to use.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.1 (1) RPIC shall be familiar with all available manufacturer aircraft performance data. (2) In the absence of manufacturer provided performance data, refer to Specification F3298

Question #11

Field Question: If the propellers on the aircraft are not from the manufacturer, or if there are multiple types of propellers available for the aircraft, describe how the current propeller(s) performance differs from the propellers recommended by the manufacturer. This question can be skipped if the UAS Pilot is using the manufacturer's recommended propellers.

Assessment Criteria: The UAS Pilot should demonstrate their understanding of how the use of multiple or non-standard propellers has on the performance of the aircraft.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.2 (1) Understanding of motors including proper rotational direction depending on flight controller and airframe configuration (2) Understanding the relationship between motor specifications (for example, diameter, windings, kV rating), propeller selection, and operating current and voltage and the detrimental effects of improper operation (3) Understanding damaging effects of excessive heat and mitigation strategies.

Question #12

Field Question: Demonstrate how to verify and update the aircraft firmware.

Assessment Criteria: The UAS Pilot will need to show the instructor on the controller or computer screen that the UAS has the latest firmware.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.3 (1) Understanding of safe charging, discharging, storage, proper operating techniques, firmware updating, transportation by air, pre-flight inspection, effect of ambient temperature on charge capacity and delivery, and proper disposal at end of life.
6.3.1.7. (2) Understanding all aspects of firmware updating procedures

Question #13

Field Question: Describe the method for safe charging, discharging, storing, updating firmware, and operating the batteries.

Assessment Criteria: The answer to this question will depend on the aircraft. Generally, batteries should be fully charged immediately before the mission, partially charged when stored and never allowed to fully deplete. Many batteries self-discharge over time. Batteries should be stored in a cool, dry location away from sunlight or extreme conditions. The UAS Pilot should describe how the battery's firmware is updated and any other operational procedures.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.3 (1) Understanding of safe charging, discharging, storage, proper operating techniques, firmware updating, transportation by air, pre-flight inspection, effect of ambient temperature on charge capacity and delivery, and proper disposal at end of life.

Question #14

Field Question: How often should batteries be visually inspected by the remote pilot in command? What are common indications of a defective battery?

Assessment Criteria: The batteries should be inspected before every flight. Common symptoms of defective batteries include physical damage, bulging, leakage, an odor, or being warm. Other symptoms include reduced runtime, slow charging or excessive heating during charging.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.3 (1) Understanding of safe charging, discharging, storage, proper operating techniques, firmware updating, transportation by air, pre-flight inspection, effect of ambient temperature on charge capacity and delivery, and proper disposal at end of life.

Question #15

Field Question: Explain each open field in the agency's maintenance logbook and how to file it per the agency's operating procedures.

Assessment Criteria: The UAS Pilot should demonstrate that they understand all aspects and fillable fields of the agency's standard maintenance logbook and detail any discrepancies and corrective actions made to the UAS.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a

ASTM Section: 6.3.3.3 The RPIC shall understand the need for and how to create an accurate, up-to-date, aircraft maintenance logbook detailing any discrepancies and corrective actions made to the UAS.

Additional Instructor Notes: ASTM does not have a task subject knowledge level associated with this article. A level of 3b is voluntarily being complied with to meet the intent of this article.

Question #16

Field Question: Identify common hazards and risks that should be evaluated during a site survey of a common mission site.

Assessment Criteria: The UAS Pilot should be able to identify common hazards associated with mission sites that they are likely to fly. These include structures, antennas, low-flying aircraft, wildlife, EM fields, pedestrians, and traffic, among others.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a

ASTM Section: 6.3.5.1 The RPIC shall know how to perform a site survey for each location where flight operations are to be performed paying specific attention to structures, antennas, and aerial hazards that may affect safe flight operations.

6.3.7 The RPIC shall know how to assess operational risk including:

6.3.7.3 operational limitations considering the flight path, the terrestrial and solar

Question #17

Field Question: What are the major elements that should be included in a mission plan?

Assessment Criteria: The UAS Pilot should list the following items. Other items may be applicable based on the type of mission they are expected to perform.

- Mission objective(s)
- Hazards
- Weather considerations
- Interactions with terrain and structures
- Payload details, risks and mitigations for risks
- Emergency procedures

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a

ASTM Section: 6.3.6 The RPIC shall know how to prepare a mission planning document that shall

6.3.6.1 the overall objective for specific flights,
6.3.6.2 all hazards observed during the site survey,
6.3.6.3 weather considerations both in terms of solar and terrestrial weather
6.3.6.4 and in interactions with terrain, and structures.
6.3.7.5 Payload details: The RPIC shall know how to include in the mission planning document details of each type of payload to be used for flight operations and, where appropriate, any risks thus caused and the mitigations for those risks.

Question #18

Field Question: How would you assess the operational risk associated with the mental and physiological conditions of the RPIC, the VO and other crewmembers?

Assessment Criteria: Here are several methods that the RPIC can use to assess the operational risk associated with themselves and their crew

- Pre-flight health checks
- Signs of obvious impairment
- Signs of obvious physical impairment, discomfort or lack of performance
- Awareness of chronic and acute work and life stress events
- Awareness of training completed
- Monitoring workload and crew scheduling
- Recent medical issues
- Recent new or changes to existing medicines
- Maintain good communications

- Impact of extreme weather conditions such as high heat

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.7 The RPIC shall know how to assess operational risk including: 6.3.7.1 mental and physiological condition of the RPIC, the VO and the crewmembers

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Question #19

Field Question: How would you determine the operational risk associated with the piloting skills of an RPIC?

Assessment Criteria: Here are several methods that the RPIC can use to assess the operational risk associated with themselves and their crew:

- Score associated with their last flight assessment
- Date last assessment was performed
- Frequency of training or operational missions
- Date training or operation mission

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.7 The RPIC shall know how to assess operational risk including: 6.3.7.2 the degree of remote piloting skills required

END OF SECTION

Part 2: Pre-Flight Ground School Assessment

Instructions: For this portion of the exam, the Exam Proctor will ask the UAS Pilot a series of questions based on a multi-rotor aircraft the pilot seeks authorization to use. The UAS Pilot should provide as much detail as necessary to fully answer the question. Many of the questions are situationally based and should be conducted at the check-ride mission site. The Exam Proctor will evaluate the UAS Pilot's answer and indicate the level of performance/knowledge based on the matrix prescribed in ASTM F3266 Table 1. The minimum level of understanding is in the bolded box.

Question #1

Field Question: Identify the major components of the aircraft and describe their function to the Exam Proctor.

Assessment Criteria: The answer will depend on the model. However, for a multi-rotor UAS, the UAS Pilot should be able to identify and describe the function of the propellers (lift and control), sensors (data collection and navigation), gimble (stabilize sensor), battery (power unit), and landing gear such as struts.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.3 The RPIC shall be familiar with the individual airframe and system components of the sUA as detailed in the following sections and be able to readily identify them and possess a basic understanding of their operation.

Question #2

Field Question: Explain to the Exam Proctor the action the aircraft will take when the stick control is moved in the following direction.

a. Left stick positioned up and down
b. Left stick positioned left and right
c. Right stick positioned up and down
d. Right stick positioned left and right

Assessment Criteria: The UAS Pilot should indicate that the aircraft will move in the following ways:

a. Aircraft will ascend and descend.
b. Aircraft will yaw left and right.
c. Aircraft will pitch forward and backward
d. Aircraft will roll left and right.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.3 The RPIC shall be familiar with the individual airframe and system components of the sUA as detailed in the following sections and be able to readily identify them and possess a basic understanding of their operation.

Question #3

Field Question: You are conducting a routine mission observing the traffic flow at a four-way stop. Your altitude will be 200ft AGL, and you will be within 50 feet of obstructions. Which flight mode is the most appropriate and why?

Assessment Criteria: This answer will depend on the UAS model. For example, the answer for a DJI Mavic 2 Pro would likely be "P-Mode" unless the proctor believed the test taker provided a compelling reason for an alternative mode.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.4 Automated Flight Control System—Understanding of flight modes and stability augmentation technology (Level B)

Additional Instructor Notes: Many drones have preprogrammed flight modes that adjust control sensitivity and overall speed of the aircraft. For example, DJI's drone controllers feature three primary modes to cater to various flying needs. The default P-Mode (Positioning flight mode) is a frequently used setting that utilizes an extensive range of GPS signals to maintain a stable connection between the drone and the remote control and to support the Vision Systems in obstacle detection, stabilization, and precise flight mode operations. It offers a balance of responsiveness and control sensitivity, ideal for standard filming and flight operations. S-Mode (Sport Mode) increases the responsiveness of the control sticks and disables Vision Systems and Sensors, favoring GPS for positioning; this mode is best used in obstacle-free environments due to its increased control sensitivity. Lastly, T-Mode (Tripod Mode) is optimized for video production, reducing the drone's speed to approximately 1 meter per second for enhanced stability and smooth, cinematic shot capture, providing a secure operating condition for close proximity flying. Each mode is designed to enhance the drone's performance under different flight conditions and user requirements.

Question #4

Field Question: You have been tasked to inspect a tower that is known to emit a large amount of electromagnetic (EM) interference. How would this impact the method for which you collect data, and what mitigation strategies should you deploy?

Assessment Criteria: The test taker should indicate that the EM interference could impact the drone telemetry data (compass, GPS location, etc.) and disrupt communications (video feed and loss of control). Mitigation strategies include keeping a distance from the source of the EM interference and never placing the source of the interference between the aircraft and the controller.

Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.5 GNSS Navigation Control System—Understanding of:
6.2.5.2 Impact of solar weather and terrestrial interference on GNSS

Question #5

Field Question: List various mechanical or environmental factors that could impact the functionality of onboard GNSS/GPS telemetry data.

Assessment Criteria: The test taker should be able to list a minimum of five factors and demonstrate an objective understanding that GNSS/GPS telemetry data is not absolute and subject to degradation based on mechanical and/or environmental conditions. Acceptable factors include urban canyons, dense forests, large amounts of metal, EM fields, overhead coverings, loss of the satellite, mechanical failures in the GNSS/GPS unit, solar winds, and others at the Exam Proctors' discretion.

Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.5 GNSS Navigation Control System—Understanding of:
6.2.5.3 GNSS limitations

Question #6

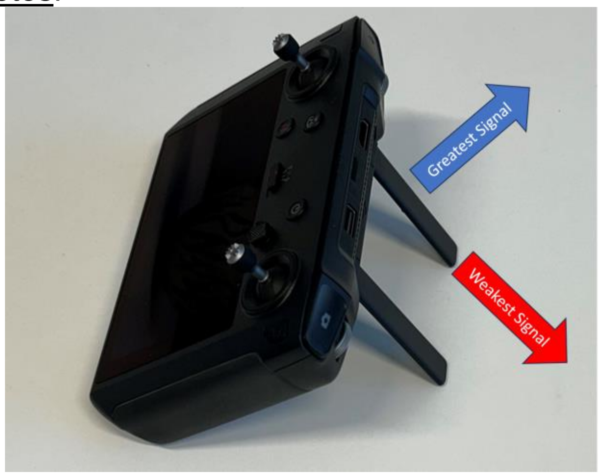
Field Question: How should the controller or antenna be positioned to have the greatest lateral range of control on the aircraft?

Assessment Criteria: The long edge of the controller should be perpendicular to the aircraft to have the maximum range.

Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.3.6 Understanding of radio control including transmitters, receivers, propagation/shielding, antennae types and orientation, frequency bands, signal strength and UAS behavior on loss of link.

Additional Instructor Notes:



Question #7

Field Question: What is the maximum distance that the aircraft can be reliably controlled by the controller or the maximum distance allowed by your agency's operating procedures?

Assessment Criteria: The answer will depend on the aircraft or the agency's operating procedures. The UAS Pilot is required to state the distance +/-10% to be evaluated at a "B" level of subject knowledge.

Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.3.6 Understanding of radio control including transmitters, receivers, propagation/shielding, antennae types and orientation, frequency bands, signal strength and UAS behavior on loss of link.

Question #8

Field Question: Describe potential factors that could reduce the range in which a controller can effectively communicate with the aircraft.

Assessment Criteria: Examples of factors that could reduce the range include physical obstructions, EM interference, low battery, weather conditions (rain, fog, heavy clouds), antenna orientation, signal crowding and atmospheric conditions (solar flares or ionospheric disturbances).

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.3.6 Understanding of radio control including transmitters, receivers, propagation/shielding, antennae types and orientation, frequency bands, signal strength and UAS behavior on loss of link.

Question #9

Field Question: Describe what the UAS Pilot would observe on the controller when the maximum UAS range from the controller is exceeded. What are the appropriate steps when these conditions are observed?

Assessment Criteria: Typically, the information that requires the most amount of data transferred, such as remote video, will be lost first. When these conditions are observed, the UAS Pilot should reduce the distance from the controller. If unable to do this manually, the UAS Pilot should engage the aircraft's emergency return to home feature.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.3.6 Understanding of radio control including transmitters, receivers, propagation/shielding, antennae types and orientation, frequency bands, signal strength and UAS behavior on loss of link.

Question #10

Field Question: Does this UAS restrict flight operations in specific geographic locations, such as restricted areas or prisons? The feature is commonly referred to as "geo-fencing." If it does, how do you identify and unlock geo-fenced areas?

Assessment Criteria: This answer is dependent on the aircraft. The UAS Pilot should be able to accurately indicate if the UAS has a geo-fencing feature, how to identify it, and the conceptual means for disabling it.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.5 GNSS Navigation Control System—Understanding of:
6.2.5.4 Geo-fencing (Level B)

Question #11

Field Question: Indicate what strategies you would take to prevent excessive heat on the components of the UAS.

Assessment Criteria: A common source of excessive heat for exterior UAS missions comes from exposure to direct sunlight. The UAS Pilot should indicate an awareness of this and identify strategies for keeping UAS equipment (controller, batteries, chargers, etc.) in the shade and away from other external heat sources.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.2 (1) Understanding of motors including proper rotational direction depending on flight controller and airframe configuration (2) Understanding the relationship between motor specifications (for example, diameter, windings, kV rating), propeller selection, and operating current and voltage and the detrimental effects of improper operation (3) Understanding damaging effects of excessive heat and mitigation strategies.

Question #12

Field Question: Assume a battery were to catch fire in the UAS case at your current location. Describe the emergency procedures for this situation.

Assessment Criteria: The emergency procedures may include the following items (1) evacuate the area, (2) use an appropriate fire extinguisher, (3) do not inhale fumes, (4) contain the fire in a noncombustible container, (5) inspect for secondary damage, and (6) report the incident.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a
Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.3 (1) Understanding of safe charging, discharging, storage, proper operating techniques, firmware updating, transportation by air, pre-flight inspection, effect of ambient temperature on charge capacity and delivery, and proper disposal at end of life. (Level B)
6.3.2 The RPIC shall be familiar with:
6.3.2.3 Emergency procedures (Level 2B

Additional Instructor Notes: Task Knowledge level of 3 exceeds ASTM standard requirements for 2.

Question #13

Field Question: Demonstrate to the Exam Proctor how to adjust the following programmable features of the flight control system.

a. Binding/linking controller to aircraft
b. Frequency band
c. Aircraft behavior on the loss of link to controller
d. Return to home altitude and multi-pathing
e. Set new return to home point
f. Latitude and longitude position
g. Waypoints
h. Auto-takeoff
i. Auto-land
j. Other applicable intelligent automatic flight features
k. Geo-fencing
l. Lost link presets

Assessment Criteria: The UAS Pilot should be able to satisfactorily demonstrate their ability to navigate to the settings, understand the setting options, and make adjustments.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a
Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.3.1.7 (1) Understanding of the programmable features including those of automated flight control system, power distribution, and the use of computer software to configure Automatic Flight Control System parameters. (Level B) (2) Understanding all aspects of firmware updating procedures (Level 2b) (3) Understanding of how to set all user adjustable parameters (Level 2b)

6.3.1.8 Understanding of radio control including: (1) Binding/linking specific transmitters to receivers (2) Frequency bands (3) UAS behavior on loss of link.

6.3.1.9 (1) Multi-pathing, (2) Latitude and longitude, (3) Waypoints, (4) Position hold/loiter,(5) Auto-takeoff, (6) Auto-land, (7) Return to home, (8) Other intelligent automatic flight features, and (9) Geo-fencing.

6.4.1.4 Including when possible: (1) return-to-home, (2) set new home point, (3) manual override of return-to-home, (4) GNSS-based waypoint navigation programming and mission execution, (5) lost link presets, and (6) re-establishment of control from lost link

Question #14

Field Question: Explain to the instructor where telemetry data is located on the controller. Specifically include the following if applicable:

a. Altitude
b. Distance from controller
c. Compass direction
d. Location of drone in relation to the controller
e. Battery charge
f. Controller charge
g. Controller signal strength
h. GPS satellite strength/count
i. Camera settings
j. Warning and notifications

Assessment Criteria: The UAS Pilot should be able to demonstrate on the controller screen all controls and parameters including their effects, nominal settings, and typical adjustments.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.3.1.10 Understanding of all controls and parameters, including their effects, nominal settings and typical adjustments, and uplink and downlink telemetry values (normal and abnormal).

Question #15

Field Question: Describe the actions you would take if the aircraft experienced a malfunction after liftoff that significantly reduced your ability to control the aircraft.

Assessment Criteria: The UAS Pilot should describe a plan to ground the aircraft as quickly as possible that minimizes the likelihood of injuring people first and secondarily damage to property. The answer should demonstrate that the UAS Pilot places a higher value on preventing injury than damaging the aircraft.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a

ASTM Section: 6.3.2 The RPIC shall be familiar with:
6.3.2.3 emergency procedures (Leve 2b)
6.4.1.5 The recognition of all likely flight mode failures and the appropriate recovery from or mitigation of those failures. (Leve 3b)
6.4.2.8 (1) Engine Failure after liftoff (2) Engine failure approach to landing (3) Lost link (4) Autorotation – if applicable. (Level 3b)

Question #16

Field Question: Describe the actions you would take if the aircraft became non-responsive to controls and began to fly away.

Assessment Criteria: The UAS Pilot should indicate that they would make note of the drone's last known position, the direction it is flying in, and battery life. They should then attempt to regain control by engaging the return-to-home feature (if possible) or restarting the controller. After efforts to regain control fail, they should track the UAS's path and identify the GPS position from the controller if possible. The UAS Pilot can also show competency by indicating they would notify the ground crew of the situation and ask them to track the drone.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.2 The RPIC shall be familiar with:
6.3.2.3 emergency procedures
6.4.1.4 Including when possible: (1) return-to-home, (2) set new home point, (3) manual override of return-to-home, (4) GNSS-based waypoint navigation programming and mission execution, (5) lost link presets, and (6) re-establishment of control from lost link (Level 2b)
6.4.2.8 (1) Engine Failure after liftoff (2) Engine failure approach to landing (3) Lost link (4) Autorotation – if applicable. (Level 3b)

Question #17

Field Question: Describe the actions you would take if the aircraft experienced a rapid loss of battery power.

Assessment Criteria: The UAS Pilot's response should indicate an immediate attempt to decrease the altitude of the aircraft. The specific altitude would depend on the situation but would not interfere with a safe landing. The UAS Pilot should describe a plan to ground the aircraft as quickly as possible that minimizes the likelihood of injuring people first and secondarily damage to property. The answer should demonstrate that the UAS Pilot places a higher value on preventing injury than damaging the aircraft.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.2 The RPIC shall be familiar with:
6.3.2.3 emergency procedures (Level 2b)
6.4.2.8 (1) Engine Failure after liftoff (2) Engine failure approach to landing (3) Lost link (4) Autorotation – if applicable. (Level 3b)

Question #18

Field Question: What is the minimum level of battery charge before the UAS must return for a replacement battery? What is the minimum level of battery charge for the UAS to be on the ground per your agency's operating procedures?

Assessment Criteria: The UAS Pilot should indicate that the minimum level of battery charge before returning home is based on the mission and the location of the drone when the threshold is reached. However, the agency should have a recommended level of battery charge that a drone must be grounded by. Exceptions may be justified based on the mission and mitigation procedures put in place.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.4.1.6 1) Perform dead reckoning navigation, (2) perform visual line of sight navigation, (3) perform map reading, (4) identify appropriate visual landmarks, (5) correlate position with map, (6) compare actual and planned ground speeds, (7) compare actual and planned rate of fuel consumption or battery usage, (8) calculate actual fuel consumption or battery usage, (9) perform in-flight navigation planning, (10) calculate/compensate for in-flight winds, (11) calculate new estimated time of arrival (ETA), (12) perform time and fuel/battery usage management, (13) calculate back azimuth in order to manually navigate back to the home point or point of landing.

Question #19

Field Question: Describe the appropriate pre-flight procedures of a routine UAS mission starting when you arrive at a typical mission site.

Assessment Criteria: The answer to this question will vary based on the specifics of the mission site; however, there will be many actions routinely taken and included on the agency's checklist and standard operating procedures. The pre-flight procedures should at a minimum, include the following:

- Pre-flight inspection, take-off data
- Pre-start, start, and after-start procedures
- Flight instruments and navigation aids set and checked
- Taxi and aerodrome procedures
- Take-off briefing

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.4.2.2 (1) Pre-flight inspection, take-off data (2) Pre-start, start, and after start procedures (3) Flight instruments and navigation aids set and checked (4) Taxi and aerodrome procedures (5) Take-off briefing

Question #20

Field Question: Complete the agency's pre-flight checklist and describe how it is filed per the agency's operating procedures for the check ride assessment.

Assessment Criteria: The UAS Pilot should demonstrate that they understand all aspects and fillable fields of the agency's standard pre-flight checklist. They should also be able to complete the pre-flight checklist for the check-ride assessment.

Task Performance	1	2	3	4	n/a

Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.3.1 The RPIC shall know how to create or obtain an accurate, up-to-date aircraft flight manual and a flight operations manual in the format and with the content as required by the CAA.
6.4.1.1 Consistent use of checklists and normal operating procedures to ensure safe operations.

Question #21

Field Question: What physical features of the aircraft are required to be inspected before the mission begins? What should the RPIC look for to determine if an aircraft is airworthy?

Assessment Criteria: The answer will depend on the aircraft, payload, and mission. However, common answers include anomalies with the battery, chipped propellers, loose struts, damage to the hull, non-illuminated lights, and a clean camera/sensor lens.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.4.2.2 (1) Pre-flight inspection, take-off data (2) Pre-start, start, and after start procedures (3) Flight instruments and navigation aids set and checked (4) Taxi and aerodrome procedures (5) Take-off briefing
6.4.1.1 Consistent use of checklists and normal operating procedures to ensure safe operations.

Question #22

Field Question: Review the site location and identify any hazards as well as corresponding mitigation measures to those hazards.

Assessment Criteria: The UAS Pilot must be able to conduct a site survey at the mission site with a particular focus on identifying structures, antennas, and other aerial hazards that could impact the safety of the flight operations.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.5.1 The RPIC shall know how to perform a site survey for each location where flight operations are to be performed paying specific attention to structures, antennas, and aerial hazards that may affect safe flight operations.
6.4.1.1 Consistent use of checklists and normal operating procedures to ensure safe operations.

END OF SECTION

Part 3: Check Ride Assessment

Instructions: For this portion of the exam, the UAS Pilot will be asked to perform a series of scenario-based maneuvers to test their fight proficiency at the check-ride mission site. The Exam Proctor will evaluate their answer to determine if their performance meets the level prescribed in ASTM F3266 Table 1.

Question #1

Field Question: Assume the check-ride mission will have three visual observers, one of which will be the Exam Proctor. Conduct a pre-flight mission briefing covering all relevant topics, tasks the crew should perform, risk assessment and documentation.

Assessment Criteria: The UAS Pilot should be able to conduct a pre-flight briefing addressing all of the topics below and any additional items specific to the mission.

- Agency's checklists
- Mission planning details
- Effectively communicate VO and other crew member responsibilities.
- Mission weather conditions
- Airspace restrictions that may affect flight operations
- Airspace clearances required
- Details of decision-making responsibilities, operational considerations when in proximity to people, property on the ground, infrastructure, emergency procedures and responsibilities

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.7.6 The RPIC shall know how to: (1) assign specific mission responsibilities to the VO and other crew members when applicable, (2) conduct a pre-flight mission briefing to ensure that everyone involved is aware of their responsibilities.

6.3.8 The RPIC shall know how to:

6.3.8.1 conduct a pre-flight mission briefing for the VO and other crew members to ensure that everyone involved is aware of the mission plan,

6.3.8.2 mission weather conditions,

6.3.8.3 hazards to the mission identified in the site survey,

6.3.8.4 airspace restrictions that may affect flight operations,

6.3.8.5 contact procedures for ATC and additional clearances required,

6.3.8.6 the specific responsibilities for the VO and other crew members before, during, and after flight operations.

6.3.8.7 This briefing shall also include details of decisions making responsibilities, operational considerations when in proximity to people, property on the ground, infrastructure, emergency procedures and responsibilities.

6.4.1.1 Consistent use of checklists and normal operating procedures to ensure safe operations.

Question #2

Field Question: Demonstrate how to attach the payload associated with all mission types you would be asked to fly with this aircraft.

Assessment Criteria: The UAS Pilot should be able to attach the payload securely and within the manufacturer's guidelines. For UASs that have permanently affixed payloads, the UAS Pilot can demonstrate proficiency in this area with a visual inspection of the payload.

Task Performance	1	**2**	3	4	n/a
Task Knowledge	a	**b**	c	d	n/a

ASTM Section: 6.3.2 The RPIC shall be familiar with:
6.3.2.4 weight and balance calculations

Question #3

Field Question: Start the drone, climb to an altitude of 50 feet, test all of the stick maneuvering controls to test responsiveness, land the aircraft and power down.

Assessment Criteria: Evaluate the UAS Pilot to determine if they have a “3b” level of task performance and knowledge of the controller and how to operate the aircraft. This specifically includes take-off, climb procedures, stick control, descent, arrival, and landing procedures.

Task Performance	1	2	**3**	4	n/a
Task Knowledge	a	**b**	c	d	n/a

ASTM Section: 6.3.2 The RPIC shall be familiar with
6.3.2.2 Normal operating procedures (Leve 2b)
6.4.1.2 (1) All switches, rotary controls, sliders, control sticks and their function,
(2) radio range checks, (Level 3b)
6.4.2.3 (1) Take-off technique (T/O roll, speeds, rotation, transition to instruments) (2) Initial climb-off (speed and direction), after take-off checks and en route climb including altimeter setting procedures (if applicable) (3) Climb profile (Level 3b)

Question #4

Field Question: Turn your back to the UAS. Navigate to an altitude of 200 ft AGL and 200 ft to the north of the pilot and then return home and land using only the telemetry data shown on the UAS controller.

Assessment Criteria: Review the telemetry data on the controller to verify that the drone is 200 ft AGL and 200 ft to the north of the pilot's location. Additionally, determine if the UAS Pilot demonstrated a "3b" level of task performance and knowledge of the controller and how to operate the aircraft. This specifically includes take-off, climb procedures, stick control, descent, arrival, and landing procedures.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a
Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.5 GNSS Navigation Control System—Understanding of:

6.2.5.1 GNSS technology used to provide position and altitude. (Level B): knows principles,

6.4.1.6 1) Perform dead reckoning navigation, (2) perform visual line of sight navigation, (3) perform map reading, (4) identify appropriate visual landmarks, (5) correlate position with map, (6) compare actual and planned ground speeds, (7) compare actual and planned rate of fuel consumption or battery usage, (8) calculate actual fuel consumption or battery usage, (9) perform in-flight navigation planning, (10) calculate/compensate for in-flight winds, (11) calculate new estimated time of arrival (ETA), (12) perform time and fuel/battery usage management, (13) calculate back azimuth in order to manually navigate back to the home point or point of landing. (Leve 2b)

6.4.2.3 (1) Take-off technique (T/O roll, speeds, rotation, transition to instruments) (2) Initial climb-off (speed and direction), after take-off checks and en route climb including altimeter setting procedures (if applicable) (3) Climb profile (Level 3b)

Question #5

Field Question: For this exercise, do not use the telemetry data on the screen. Navigate to an altitude of 100 ft AGL and 100 ft to the south of the pilot and then return home and land using only visual line-of-sight navigation.

Assessment Criteria: Review the telemetry data on the controller to verify that the drone is approximately 100 ft AGL and 100 ft to the south of the pilot's location. Additionally, determine if the UAS Pilot demonstrated a "3b" level of task performance and knowledge of the controller and how to operate the aircraft. This specifically includes take-off, climb procedures, stick control, descent, arrival, and landing procedures.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a
Subject Knowledge	A	B	C	D	n/a

ASTM Section: 6.2.5 GNSS Navigation Control System—Understanding of:
6.2.5.1 GNSS technology used to provide position and altitude. (Level B): knows principles,
6.4.1.6 1) Perform dead reckoning navigation, (2) perform visual line of sight navigation, (3) perform map reading, (4) identify appropriate visual landmarks, (5) correlate position with map, (6) compare actual and planned ground speeds, (7) compare actual and planned rate of fuel consumption or battery usage, (8) calculate actual fuel consumption or battery usage, (9) perform in-flight navigation planning, (10) calculate/compensate for in-flight winds, (11) calculate new estimated time of arrival (ETA), (12) perform time and fuel/battery usage management, (13) calculate back azimuth in order to manually navigate back to the home point or point of landing. (Leve 3b)
6.4.2.3 (1) Take-off technique (T/O roll, speeds, rotation, transition to instruments) (2) Initial climb-off (speed and direction), after take-off checks and en route climb including altimeter setting procedures (if applicable) (3) Climb profile (Level 3b)

Additional Instructor Notes: At their option, the Exam Proctor can place a sticky-note on the controller screen to obstruct the UAS pilot's view of the telemetry data.

Question #6

Field Question:
Part 1: Start this exercise with the drone powered off. Power up the drone and position the aircraft so that it is 200 ft AGL and 200 ft to the north.
(Instructor: Wait until Part 1 is complete before reading Part 2)
Part 2: Engage the aircraft's autonomous emergency return-to-home function. When the aircraft is within 100 ft of the landing site, regain manual control of the aircraft and land the drone.

Assessment Criteria: To complete this activity satisfactorily, the pilot must (1) give the drone sufficient time to establish GPS lock while on the ground, (2) be able to activate the return to home feature within 5 seconds, and (3) be able to return manual control within 5 seconds.

Subject Knowledge	A	**B**	C	D	n/a

ASTM Section: 6.2.5 GNSS Navigation Control System—Understanding of:
6.2.5.3 GNSS limitations
6.4.1.4 Including when possible: (1) return-to-home, (2) set new home point, (3) manual override of return-to-home, (4) GNSS-based waypoint navigation programming and mission execution, (5) lost link presets, and (6) re-establishment of control from lost link.

Question #7

Field Question: Complete the agency's flight log and file per the agency's operating procedures for the check ride assessment.

Assessment Criteria: The UAS Pilot should demonstrate that they understand all aspects and fillable fields of the agency's standard flight log. They should also be able to complete the flight log for the check-ride assessment.

Task Performance	1	2	3	4	n/a
Task Knowledge	a	b	c	d	n/a

ASTM Section: 6.3.3.1 The RPIC shall understand the need for and how to create an accurate, up-to-date, flight logbook showing all flights made under the responsibility of the RPIC.

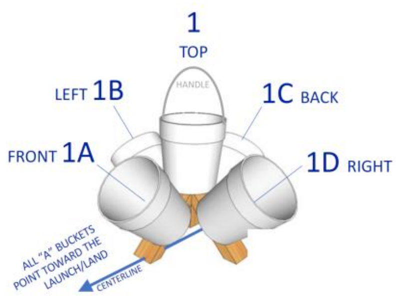
Additional Instructor Notes: ASTM does not have a task subject knowledge level associated with this article. A level of 3b is voluntarily being complied with to meet the intent of this article.

END OF SECTION

Part 4: Flight Control Assessment

Instructions: For this portion of the exam, the UAS Pilot will be asked to perform a flight proficiency assessment based on the National Institute of Standards and Technology's (NIST's) Basic Proficiency Evaluation for Remote Pilots (BPERP) test. The Exam Proctor will administer the exam by reading out the instructions script below. The UAS Pilot is encouraged to be familiar with the target location and nomenclature prior to starting the exam. BPERP instructions provided by NIST can be downloaded here. The UAS Pilot may complete one practice run prior to the start of the exam. The proficiency assessment meets the requirements of ASTM 6.4.2.1 and 6.4.2.6.

Assessment Criteria: The target green ring must be uninterrupted, as indicated in the NIST image below, for the target to be considered "aligned" and the points awarded. Aircraft must have one leg within 12" of the center of the landing platform for the point to be awarded. The UAS Pilot must be able to record aligned images of 80% of the targets within 5 minutes from take-off to pass this assessment.



Exam Proctor Script	Captured
Launch and hover at 10 feet over stand 1. Capture image of target 1.	1
Angle camera up and capture image of target 2A.	2A
Rotate left 360 degrees over stand 1 and capture image of target 1.	1
Angle camera up and capture image of target 2A.	2A
Rotate right 360 degrees over stand 1 and capture image of target 1.	1
Angle camera up and capture image of target 2A.	2A
Climb vertically to 20 feet over stand 1 and capture image of target 1.	1
Angle camera up and capture image of target 3A.	3A
Descend vertically to 10 feet over stand 1 and capture image of target 1.	1
Angle camera up and capture image of target 2A.	2A
Move forward to hover over stand 2 and capture image of target 2.	2
Angle camera up and capture image of target 3A.	3A
Move backward to hover over stand 1 and capture image of target 1.	1
Angle camera up and capture image of target 2A.	2A
Move forward to stand 2 then rotate left 180 degrees. Capture image of target 2.	2
Angle camera up and capture image of target 1C.	1C
Move forward over launch platform then rotate 180 degrees. Capture image of launch platform.	Launch Platform
Angle camera up and capture image of target 1A.	1A
Land in circle of launch platform.	Land
Launch and hover at 10 feet over launch platform. Capture image of target 1A.	1A
Orbit 90 degrees leftward around stand 1. Capture image of target 1B.	1B
Traverse leftward to stand 2. Capture image of target 2B.	2B
Traverse leftward to stand 3. Capture image of 3B.	3B
Orbit 90 degrees leftward around stand 3. Capture image of target 3C.	3C
Orbit 90 degrees leftward around stand 3. Capture image of target 3D.	3D
Traverse leftward to stand 2. Capture image of target 2D.	2D
Traverse leftward to stand 1. Capture image of target 1D.	1D
Orbit 90 degrees leftward around stand 1. Capture image of target 1A.	1A
Land in circle of launch platform.	Land
Launch and hover at 10 feet over launch platform. Capture image of target 1A.	1A
Orbit 90 degrees rightward around stand 1. Capture image of target 1D.	1D
Traverse rightward to stand 2. Capture image of target 2D.	2D
Traverse rightward to stand 3. Capture image of target 3D.	3D
Orbit 90 degrees rightward around stand 3. Capture image of target 3C.	3C
Orbit 90 degrees rightward around stand 3. Capture image of target 3B.	3B
Traverse rightward to stand 2. Capture image of target 2B.	2B

Traverse rightward to stand 1. Capture image of target 1B.	1B
Orbit 90 degrees rightward around stand 1. Capture image of target 1A.	1A
Land in circle of launch platform.	Land
Total Score	

END OF SECTION

Flight Proficiency Assessment

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END OF SECTION