APPENDIX F—UAS PILOT AND VISUAL OBSERVER TRAINING AND CERTIFICATION LITERATURE REVIEW

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LIST OF SELECTED DEFINITIONS[1]

Beyond visual Line Of Sight (BVLOS). Means flight crew members (i.e., remote pilot in command (PIC), the person manipulating the controls, and visual observer (VO), if used) are not capable of seeing the aircraft with vision unaided by any device other than corrective lenses (spectacles and contact lenses).

Crewmember (UAS). A person assigned to perform an operational duty during operations. A UAS crewmember includes the remote PIC, person manipulating the controls, and VOs, but may include other persons as appropriate or required to ensure safe operation of the UAS.

Extended Visual Line Of Sight (EVLOS). Means observing an extended area of airspace by utilizing observers at the boundary of the area, who are in direct contact with the pilot/operator. The observers provide separation from other aircraft by ensuring no other traffic enters the operational area (CAA 2015).

Pilot In Command (PIC). Means the person who:

(1) Has final authority and responsibility for the operation and safety of the flight;
(2) Has been designated as pilot in command before or during the flight; and
(3) Holds the appropriate category, class, and type rating, if appropriate, for the conduct of the flight (FAR Part 1.1 (2017).

Small Unmanned Aircraft. A UA weighing less than 55 pounds on takeoff, including everything that is onboard or otherwise attached to the aircraft.

Small Unmanned Aircraft System (sUAS). A small UA and its associated elements (including communication link and the components that control the small UA) that are required for the safe and efficient operations of the small UA in the NAS (including launch and recovery systems and equipment).

Unmanned Aircraft System (UAS). A UA and associated elements (including communication links and the components that control the UA) that are required for the remote PIC to operate safely and efficiently in the NAS. (Note: For purposes of this report, the term UAS will be further defined as being an unmanned aircraft weighing 55 pounds or greater).

Visual Line Of Sight (VLOS). Means that any flight crew member (i.e., remote PIC, the person manipulating the controls, and visual observer, if used) is capable of seeing the aircraft with vision unaided by any device other than corrective lenses, spectacles or contact lenses in order to know the UA's location, determine the UA's attitude, altitude, and direction of flight, observe the

[1] All definitions, unless otherwise cited, are taken from FAA Order 8900.1, Vol 16, Ch. 1, Sec.2, change 510, Definitions and Acronyms (Feb. 3, 2017).

airspace for other air traffic or hazards, and determine that the UA does not endanger the life or property of another.

Visual Observer (VO). A person who is designated by the PIC to assist the remote PIC and the person manipulating the flight controls of the sUAS [and larger than small UAS] to supplement situational awareness and Visual Line of Sight (VLOS), assisting with seeing and avoiding other air traffic or objects aloft or on the ground. The visual observer (VO) must be able to effectively communicate:

(1) The small [or larger than small] UA location, attitude, and direction of flight;
(2) The position of other aircraft or hazards in the airspace; and
(3) The determination that the UA does not endanger the life or property of another.

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EXECUTIVE SUMMARY

The Statement of Work issued to the University of North Dakota (UND) by the Federal Aviation Administration (FAA) states that UND will perform a literature review focused on the issue of what the recommended Unmanned Aircraft Systems (UAS) crewmember training and certification minimum requirements for both pilot and visual observer should be. Additionally, this research effort was to concentrate on UAS of (i.e. ≤ 55 pounds), and operations in both visual line-of-sight (VLOS) and beyond visual line of sight (BVLOS).

This review included existing Federal Aviation Regulations (FARs), legislative material (public laws and acts), Advisory Circulars, the Aeronautical Information Manual, and FAA Orders, manuals, and policy statements. Other Federal agency and academic sources were also sought. The military, with an established history in pilot training and operations, added depth to this research. Foreign research and regulatory efforts were also reviewed. A number of nations have UAS regulations in place, while others are in the final regulatory development stage.

This document summarizes the content found in these various publications that focus on pilot and visual observer training and certification. General and specific recommendations derived from the content and rationale provided in these sources are offered.

Briefly, a significant number of authorities have argued for having existing manned FAR Part 61 subjects included in future UAS pilot training syllabi. Topics unique to UAS could be added, and those topics with no application to UAS could be deleted. More diversity was found in material and research related to pilot certification. Some sources put in place, or recommended, multiple levels of pilot certification, while others recommended fewer. To accommodate the demands of BVLOS and positive control, an instrument rating was commonly recommended.

Very few documents were identified that focused on visual observer training and certification. This may be due to the expected operating environment of UAS, which envisions higher operating altitudes and operations BVLOS.

1. INTRODUCTION

The Federal Aviation Administration (FAA) has directed that as part of the Alliance for System Safety of UAS Through Research Excellence (ASSURE) Project A7, the University of North Dakota (UND) conduct a literature review focused on pilot training and certification for unmanned aircraft systems (UAS). Specifically, UND is charged with examining operations involving UAS, which are those weighing 55 pounds or more. This literature review is to include both visual line-of-sight (VLOS) and beyond-visual-line-of-sight (BVLOS) operations. The review will apply to unmanned aircraft/remote piloted aircraft (UA/RPA) pilots and other crewmembers.

2. RESEARCH QUESTIONS

Consistent with the FAA direction for this assignment, the following research-related issues arise:

- What are the recommended topics, areas or strategies for the training of UAS pilots? Specifically, what is transferrable from manned aviation training and certification, and what is recommended that is unique to unmanned aviation?
- What are the recommended levels of pilot certification, and the recommended processes for that certification?
- What is the source of instruction, whether from a person holding ground/flight instructor rating, peer to peer, or self-study?
- What are the recommended levels and processes for certification of visual observers?

3. LITERATURE REVIEW AND EVALUATION APPROACH

The objective is to respond to the research questions proposed above through a comprehensive identification and review of existing research and literature that address these areas.

At the outset, our research was broad enough to include FAA advisory circulars, manuals and regulatory material, and legislative and statutory sources. Military studies, reports and recommendations that focused on training and operation of military UAS were also found germane to this effort. Foreign sources were also included. Some countries, including the United States, are in the process of formulating regulatory structure for UAS training and operation, while some have regulations currently in place, such as New Zealand, Australia, and Ireland.

4. BACKGROUND OF CURRENT PILOT TRAINING AND CERTIFICATION

For the first time, operating aircraft in the United States required a pilot certificate when Congress passed the Air Commerce Act of 1926. In addition to requiring a pilot certificate, the Act established what would become known as the National Airspace System (NAS), thereby giving authority for certification and control of the NAS and aircraft operations under the authority of the Federal Government. Over the last 90 years, an intricate system of knowledge, skills and abilities for pilot certification has developed. These requirements are contained in the Federal Aviation Regulations (FARs). Their goal is to ensure that those operating aircraft in the NAS have the training and skills to do so safely. The FARs have been in a continuing state of change and have been amended over the years to accommodate many significant changes. Examples of these changes including new categories of aircraft, development of new aircraft systems and technology, air traffic control and new navigation aids. The only aspect of these regulations that has remained constant is that they have focused exclusively on manned aircraft operations. A review of the pilot training and certification for an entry level private pilot provides an example of the complex arena for existing airman training and certification. This training and certification is summarized below:

4.1 PILOT TRAINING (FAR PART 61)

Part 61 is that part of the FARs that sets out the specific requirements for the certification of pilots to operate civil aircraft in the NAS. It demands a combination of aeronautical knowledge, flight proficiency, and aeronautical experience.

As an example of aeronautical knowledge, §61.105(b)[2] provides that an applicant for a private pilot certification must have received ground training, that applies to the aircraft category and class rating sought. These areas are:

- Federal Aviation Regulations
- Accident reporting
- Use of Aeronautical Information Manual (AIM) and Advisory Circulars
- Navigation and use of charts
- Radio communications
- Weather
- Safe and efficient aircraft operation
- Density altitude and weight and balance
- Aerodynamic concepts, including stalls and spin recovery
- Aeronautical decision making (ADM)
- Preflight actions, including takeoff/landing distances and fuel requirements
- Planning for flight changes or delays

Under §61.107[3] an applicant for a private pilot certificate must receive and log ground and flight training from an authorized instructor that applies to the aircraft category and class rating sought. These areas of operation are:

- Preflight preparation and procedures
- Airport operations
- Performance and ground reference maneuvers
- Navigation
- Slow flight and stalls
- Basic instrument maneuvers
- Emergency operations
- Night operations
- Postflight procedures

[2] 14 C.F.R. §61.105(b), Aeronautical Knowledge (2016).
[3] 14 C.F.R. §61.107, Flight Proficiency (2016).

Who may provide this training is specifically provided for under Part 61. An applicant for the written knowledge test is required to obtain ground training, which training is defined as that received from an "authorized instructor".[4] In addition, to take the written test an endorsement from an authorized instructor is required.[5] Under Part 61, an "authorized instructor" is defined as either a certified flight instructor (CFI), certificated ground instructor, or a person specifically authorized by the FAA Administrator to provide ground or flight training.[6]

Further, under §61.109§[7], the private pilot applicant for an airplane single-engine class rating, must show aeronautical experience of at least 40 hours of flight time to include:

- 3 hours cross-country
- 3 hours night
- Cross-country flight of over 100 nautical distance
- 10 takeoff and landings to full stop
- 3 hours maneuvering aircraft solely by reference to instruments
- 3 hours of flight training with an authorized instructor in preparation for the practical test
- 10 hours solo flight, of which 5 hours solo and one flight over 150 nautical miles with 3 takeoffs/landings enroute.

Armed with all this ground training and flight experience the applicant for a private pilot certificate with an airplane category and single-engine class rating must demonstrate the skill to safely preform the required flight tasks as part of a practical flight test.[8] Similar requirements are contained in Part 61 for all other class or categories of aircraft.

4.2 PILOT CERTIFICATION (FAR PART 61)

The FARs offer various levels of pilot certification, each with clearly defined privileges and limitations. As one advances in experience, higher levels of certification offer greater privileges, including passenger transportation. Briefly, the current pilot certificates include:

1. *Student Pilot* (§61.89) – For airplanes, an applicant must be 16 years of age. This certificate allows airman to take flight instruction and fly solo when approved. No passengers or flights for compensation or hire are permitted.
2. *Sport Pilot* (§61.315) – This certificate limits the pilot to operations of light-sport aircraft (1320 lbs or less) with only two seats, limiting to only one passenger. Unlike other certificate levels, a medical certificate under the FARs is not required, but holder must have a valid driver's license, thereby, meeting any medical qualifications for a driver's license (i.e. vison).
3. *Recreational pilot* (§61.101) - A holder of this certification is restricted to carrying only one passenger in a four place, or smaller, single-engine aircraft with limited horsepower. They are restricted to 50 nautical miles (NM) unless additional training is received.

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[4] 14 C.F.R. §61.1, Applicability and definitions (2016).
[5] 14 C.F.R. §61.35, Knowledge test: Prerequisites and passing grades (2016).
[6] 14 C.F.R. §61.1, Applicability and definitions (2016).
[7] 14 C.F.R. §61.109, Aeronautical Experience (2016).
[8] 14 C.F.R. §61.43, Practical tests: General procedures (2016).

4. *Private Pilot* (§61.113) – Requirements for a private pilot are set out above. Private pilots may carry more than one passenger, though carriage cannot be for compensation or hire.
5. *Commercial Pilot* (§61.133) – the certificate recognizes significantly more training and flight experience and allows the holder to operate an aircraft carrying passengers or cargo for compensation or hire.
6. *Airline Transport Pilot* (§61.167) – The certificate also requires significant additional flight experience and offers the same privileges as a commercial certificate plus an instrument certificate. Within the last few years, operations of larger Part 121 and 135 aircraft require the Pilot In Command (PIC) to have this level of certification.

Certified Flight Instructor (§61.195) – This certificate authorizes the holder to conduct student flight training and endorse student log books authorizing expanded privileges, such as solo flight.

4.3 INSTRUMENT RATING (FAR PART 61)

FAR 61.65[9] sets out the requirements to obtain an instrument rating. Briefly, these requirements are:

1. Hold at least a private pilot certificate.
2. Able to read, speak, write, and understand English, unless medically unable, which requires restrictions.
3. Receive and log ground training from an "authorized instructor" or home-study course on topics under paragraph (b) of this regulation.
4. Receive an endorsement to take the required knowledge test.
5. Receive and log ground training from an "authorized instructor" on the areas covered under (c) of this regulation.
6. Receive an endorsement to take the required practical test.
7. Pass both the knowledge and practical tests.

In addition, flight experience is also required for this rating. This consists generally of 50 hours cross-country flight time as PIC, and 40 hours of actual or simulated instrument time, of which 15 hours were with an authorized instructor. A 250 nautical mile flight with various approaches rounds out flight experience.

4.4 VISUAL OBSERVER TRAINING AND CERTIFICATION

Having no counterpart in the manned community, the employment of visual observers (VO) does not share a well-established history. Indeed, the FARs offered no regulatory consideration of VO training or certification requirements until the sUAS final rule was promulgated on June 28, 2016. Of course, this effort is limited to VO requirements for small UAS operated at low altitudes and within visual line of sight.

With the exception of the new FAR Part 107, the most current FAA policy for the utilization of VOs is contained in FAA Order 8900.1 Volume 16 (6/28/16) which states that a Visual Observer

[9] 14 C.F.R. §61.65, Instrument rating requirements (2016).

is a person who is designated by the PIC to assist the remote PIC and the person manipulating the flight controls of the sUAS to supplement situational awareness and Visual Line of Sight (VLOS), assisting with seeing and avoiding other air traffic or objects aloft or on the ground. The visual observer (VO) must be able to effectively communicate:

1) The small UA location, attitude, and direction of flight;
2) The position of other aircraft or hazards in the airspace; and
3) The determination that the UA does not endanger the life or property of another.

The Order then states that VLOS means that any flight crew member (i.e., remote PIC, the person manipulating the controls, and visual observer, if used) is capable of seeing the aircraft with vision unaided by any device other than corrective lenses, spectacles or contact lenses in order to know the UA's location, determine the UA's attitude, altitude, and direction of flight, observe the airspace for other air traffic or hazards, and determine that the UA does not endanger the life or property of another.

While providing for use of VOs, FAA Order 8900.1 defines no specific training or certification for VOs.

4.5 SUMMARY AND DISCUSSION

The foundation of existing US regulations governing manned aircraft operations has only recently acknowledged the newest entrant into the NAS: unmanned aircraft. This introduction was facilitated by the notice of proposed rulemaking (NPRM) for the regulation of small UAS (sUAS) in 2015.[10] Subsequently, after FAA consideration of over 4,000 public comments, the sUAS Final Rule was published on June 28, 2016, with an effective date of August 29, 2016. Diverging significantly from manned training and certification procedures, the new Part 107 adopts an abridged training and certification process, requiring the following:

Pilot Training

- Passing an initial aeronautical test; or
- If a holding a Part 61 pilot certificate (other than student), complete a flight review within previous 24 months, and complete a small UAS online training course.[11]

Pilot Certification

- Must be at least 16 years old;[12]
- Issued a Remote Pilot Certificate with a small UAS rating.[13]

Significantly, Part 107 applies only to small UAS (sUAS), weighing less than 55 pounds. While authorizing their operation in the NAS, in addition to weight limitations, Part 107 provides for quite restrictive operating conditions, yielding a lower likelihood of risk. Realizing the focus of

[10] 80 Fed. Reg. 9544, Operation and Certification of Small Unmanned Aircraft Systems (Feb. 23, 2015).
[11] 81 Fed. Reg. 42,161 – 42,164, Operation and Certification of Small Unmanned Aircraft Systems; Final Rule (June 28, 2016).
[12] Id. At 42,158.
[13] Id. At 42,155.

this report is literature directed towards training and certification for UAS, some discussion of sUAS will be necessary, in that overlap is inevitable.

5. UAS

Turning to UAS training and certification, a representative number of published studies and academic research papers offering insight and recommendations for pilot training and certification for UAS have been identified (Gildea, Williams, & Roberts, 2015; Mirot, 2013; Society of Automotive Engineers, 2016; UND Aerospace, 2015; Weeks, 2000). In addition, a significant number of military documents, manuals, and research papers addressing pilot training and certification are included ("Air Force Instruction 11-502," 2012, "Air Force Instruction 11-502, Volume 2," 2012, "Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011, "NAVMC 3500.107," 2012, "TC 1-600," 2014). Foreign studies and UAS-related aviation regulations from nations with large UAS regulations in place are also considered ("Advisory Circular (Australia) 101-1," 2002, "Advisory Circular (Australia) 101-1 (Annex C)," 2014, "CAP 722 Unmanned aircraft system operations in UK airspace-guidance," 2015, *The Swedish Transport Agency's Statute Book*, 2009).

In reviewing these representative sources of data and recommendations, one recognizes that there is more similarity than difference in their approach to pilot training. With respect to pilot certification, there are more differences. The following discussion summarizes the body of literature focused on UAS, with respect to pilot training and pilot certification.

5.1 UAS PILOT TRAINING

One might believe the diversity of sources would result in significant differences in approaches to pilot training. This was not the case.

This research has revealed that most sources would propose beginning with the existing FAR Part 61 formula of training. They acknowledge that a difference between manned and UAS operations exists and, given the differences, many offer what topic areas should be omitted as not applicable to UAS operations, and recommend inclusion of areas not applicable to manned operations. For example, pilot and passenger considerations, shoulder harnesses, emergency procedures directed at onboard occupants have no counterpart in UAS operations. In contrast, topics applicable to UAS, such as lost link, detect-and-avoid, and flyaway are recommended to be added to ground training. The common premise appears to be that manned training should form the core for ground training, with additions or deletions of topics by virtue of lack humans onboard or the possibility of direct human intervention from within or on the aircraft.

Also typical, nearly all recommend some degree of UAS aeronautical experience and flight proficiency testing to supplement ground training and academic examinations. The majority imply approved or authorized instructors. In contrast, other sources were silent on the source of training, while one offered that self-study training would be acceptable for certification ("Advisory Circular (Australia) 101-1 (Annex C)," 2014, p. 7).

A common rationale for adopting Part 61-like aeronautical knowledge, aeronautical experience and flight proficiency testing recommended by these reports is these have been in place and scrutinized for decades; they allow UAS pilots to be familiar and integrate with ATC; and support familiarity with manned aircraft with whom they share the NAS.

5.2 UAS PILOT CERTIFICATION

Unlike pilot training, recommendations for pilot certification were more diverse. This research has revealed two broad approaches to certification of UAS pilots.

The first approach would require UAS pilots to be the holder of some level of manned pilot certificate to operate unmanned aircraft. Operators of UAS would be required to be holders of either private[14], commercial, instrument, or some combination of these certificates UND Aerospace, 2015; Weeks, 2000). A few would adopt the military equivalent of FAA certificates as acceptable for military service connected UAS operations (Weeks, 2000; FAR 61.73).

It was noted that publications supporting this concept were generated during a time that the FAA had not promulgated UAS specific regulations, and stood by the proposition that most aircraft operations in the NAS required a pilot's certificate issued under Part 61. The recent FAA sUAS rule, effective August 29, 2016, deviates from this policy, requiring a newly designated remote pilot certificate. A subject matter expert (SME) associated with University of North Dakota's (UND) UAS Operations Course, was asked about the UND requirement contained in the course's Training Course Outline (TCO) that required commercial single and multi-engine, and instrument ratings. It was the SME position that manned flight experience was important to enable the UAS operator to understand and anticipate the actions of manned users sharing the NAS; further, the SME felt the majority of flights would likely be for commercial purposes and in class A airspace, accordingly, he felt a commercial single-engine and instrument rating should be continued at UND (UND Aerospace, 2015).

The second approach would require UAS pilots to obtain a UAS specific pilot certificate, but would not be required to obtain and hold a manned certificate. However, where sources embracing this approach differ is in the types of certificates proposed, or the basis for issuing these certificates. Basically, UAS pilot certification was found to be based on 3 general concepts:

1. Aircraft Classification
2. Mission/conditions of flight
3. A combination of factors

5.2.1 Certification Based on Weight

The first method of pilot certification would be based on aircraft classification, typically by weight. The new Part 107 adopts this method and will issue remote pilot certificates based on an aircraft classification defined by weight, less than 55 pounds including everything that is on board or otherwise attached to the aircraft. ("Advisory Circular 107-2," 2016). A second classification of UAS being considered by the FAA is micro UAS class. A micro UAS Aviation Rule Committee

[14] The FAA notice does not specify that a particular pilot certification is required, such as a glider or balloon pilot certification will meet this requirement.

(ARC) issued its final report in April 2016, recommending this new class, again based on weight ("Micro Unmanned Aircraft Systems Aviation Rulemaking Committee Final Report," 2016).

New Zealand offers another example of weight forming the basis for certification of UAS pilots ("Advisory Circular AC 102-1," 2015). New Zealand has three levels of classification, all based on weight. Operations of small UAS, under 25 kg, are covered by Part 101 of their regulations. No pilot certificate is identified for this classification. Interestingly, Part 101 makes no distinction between recreational and commercial operations. UAS over 25 kg would fall under Part 102 which would require an Unmanned Aircraft Operating Certificate. A third group includes aircraft weighing between 15 kg and 25 kg. These may be operated under Part 101 if constructed and operated under the authority of an approved organization.

5.2.2 Certification Based on Kinds of Operations

The second method of pilot certification is based on the mission or conditions of the operation. A prime example of this method is operations under instrument flight rules (IFR) conditions. If flight is to be under instrument meteorological conditions (IMC), or in Class A airspace, an IFR flight plan is required. Virtually all civil aviation authorities call for an instrument rating under these circumstances. Another condition of flight recommended for instrument rating certification is operations beyond visual line of sight (BVLOS).

5.2.3 Certification Based on Multiple Factors

The third method of pilot certification is one based on a combination of factors. These factors were found to include weight, speed, mission, operating altitude, and operating airspace classes. Many sources, as well as foreign nations with regulatory structures in place, have adopted this combined approach to pilot certification.

For example, DOD adopted four distinct operator qualification (certification) levels which are then linked to five classes of UAS. These classes are based on weight, altitude, speed, and VFR or IFR operations. DOD UAS operators are trained and "certificated" to operate UAS in a specific aircraft class ("Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011). Another research product recommended certification that parallel the traditional manned classifications of the private, commercial and instrument certificate (Gildea et al., 2015)[15]. Entry level for general operations would be a private UAS certificate. This certificate would be defined by operating limitations to Class B, C, and D, E airspace, and within VLOS. In contrast, a commercial UAS certificate would authorize flights for compensation or hire. The instrument certification would be based on BVLOS operations; operations conducted under an IFR flight plan; and operations in Class A positive control airspace. The Swedish regulatory structure utilizes a combination of factors. Its four classes of UAS certification are based on combinations of weight, kinetic energy, and whether VLOS or BVLOS. Each class requires its own operator approval, which appears equivalent to traditional manned pilot certification (*The Swedish Transport Agency's Statute Book*, 2009).

[15] Note: this report was provided by the FAA, however, its status is currently under review by that agency.

5.3 VISUAL OBSERVERS

At the outset, literature related to visual observers (VO) for UAS operations was limited. One reason is that UAS by design are generally able to operate at altitudes not conducive to observation from the ground; and favor operations BVLOS most likely under the positive control of ATC. VOs would not be applicable throughout the majority of flight regimes of these UAS.

Publications are consistent in the proposition that the purpose of VOs is to fulfill the "see and avoid" other aircraft and objects on the ground. Observation can be achieved through the use of ground or airborne visual observers.

6. ANNOTATED BIBLIOGRAPHY: SELECTED DOCUMENTS

The following summarizes individual studies, reports, papers and regulatory structures deemed relevant to pilot training, pilot certification, and utilization of visual observers.

SAE International (2016) ARP 5707: Pilot Training Recommendations for Unmanned Aircraft Systems Civil Operations.

This document favors adoption of the existing Part 61 formula and recommends practices for the training and certification of commercial and instrument ratings for UAS pilots.

It begins with the premise that operations of UAS are different than manned, and these differences will influence individual pilot training syllabi. Examples are:

- Human factors - issues arise, such as the absence of sensory cues.
- Crew resource management (CRM) - differs with various workloads depending on specific UAS.
- Aviation weather – even for VFR operations, realities such as wind shear, turbulence, and inadvertent IMC must be considered.
- Aircraft performance and size – UAS have a much broader range of size, from micro to commercial airline size. Control performance also varies greatly, from fully autonomous to direct manipulation.

In comparing the manned private and commercial pilot practical test standards, it was noted that "[t]he commercial standard includes more performance maneuver topics while the private standard includes more ground reference maneuver topics" (Society of Automotive Engineers, 2016, p. 15). The document goes forward to recommend commercial UAS PTS topics. These relate directly with training subjects necessary to meet the PTS standards. SAE recognizes that some manned topics are irrelevant and should be eliminated. An example might include the securing of loose items or briefing passengers on the use of seat belts. Other UAS specific topics are recommended for addition. These are data link technology, control handoff procedures, and launch and recovery techniques. Table 1[16] summarizes training topics for commercial PTS topics.

[16] NOTE: Table numbering is that contained in the original document to assist locating them in those documents.

Table 1. Commercial Proposed UAS PTS Topics[17]

Commercial Pilot Topics	**Notes**
I. Preflight Preparation	Includes control station hand-offs when applicable. Also includes local waypoint flights
A. Certificates and Documents	
B. Airworthiness Requirements	
C. Weather Information	
D. Flight Planning	
E. National Airspace System	
F. Performance and Limitations	
G. Operations and Systems	
H. Aeromedical Factors	
I. Data Link Requirements	Unique to UAS
II. Preflight Procedures	
A. Preflight Inspection	
B. Control Station Management	Replaces cockpit management
C. Engine Starting	
D. Taxiing or Pre-Launch Procedures	Pre-Launch procedures are unique to UAS
E. Before Takeoff Checklist	
III. Airport Operations	
A. Radio Communications and ATC Light Signals	
B. Traffic Patterns	
C. Airport Runway Marking and Lighting	
IV. Takeoffs, Landings, and Go-Arounds	
A. Normal and Crosswind Takeoff and Climb	
B. Normal and Crosswind Approach and Landing	
C. Soft-Field Takeoff and Climb	If relevant for system
D. Soft-Field Approach and Landing	If relevant for system
E. Maximum Performance Takeoff and Climb	If relevant for system
F. Short-Field Approach and Landing	If relevant for system
G. [K in original] Forward Slip to a Landing	If relevant for system
Table 1 (Table 5 in the Original): Commercial Proposed UAS PTS Topics Continued	

[17] Reprinted with Permission from SAE International.

H. [L in original] Go-Around Rejected Landing	If relevant for system
I. [M in original] Power-Off 180 degree Accuracy Approach and Landing	If relevant for system
V. Performance Maneuvers	
A. Steep Turns	
B. Steep Spiral	
C. Chandelles	
D. Lazy Eights	
VI. Ground Reference Maneuvers	
A. Rectangular Course	
B. S-Turns	
C. Turns Around a Point	
D. Eights on Pylons	Many experts say this maneuver is obsolete
VII. Navigation	
A. Navigation Systems and Radar Services	If relevant for system
B. Pilotage and Dead Reckoning	In the event of GPS failure
C. Diversion	If relevant for system
D. Lost Procedures and Lost Link Procedures	Lost Link unique to UAS
VIII. Slow Flight and Stalls	
A. Maneuvering During Slow Flight	
B. Power-Off Stalls	
C. Power-On Stalls	
D. Spin Awareness	
IX. Basic instrument Maneuvers	For more automated systems, these maneuvers would be all that were required to demonstrate that the pilot could safely operate the aircraft.
A. Straight and Level Flight	
B. Constant Airspeed Climbs	
C. Constant Airspeed Descents	
D. Turns to a Heading	
E. Recovery From Unusual Flight Attitudes	If relevant for system
F. Radio Communications, Navigation Systems/Facilities, and Radar Services	
X. Emergency Operations	
A. Emergency Approach and Landing (Simulated)	
B. Systems and Equipment Malfunctions	Also includes lost link procedures

C. Emergency Equipment and Survival Gear	
D. Flight Termination Procedures	Unique to UAS
E. Emergency Dive (To Avoid Imminent Collision)	Unique to UAS
XI. Night Operations	If relevant for system
A. Night Preparation	
B. Night Operations	
XII. Post Flight Procedures	
A. After Landing, Parking, and Securing	
XIII. Special Emphasis Topics	
A. Positive Aircraft Control	
B. Procedures for Positive Exchange of Flight Controls	Includes control handoff within the control station and between stations
C. Collision Avoidance	Sense and Avoid
D. Wake Turbulence Avoidance	
E. Land and Hold Short Operations (LAHSO)	If relevant for system
F. Runway Incursion Avoidance	If relevant for system
G. Controlled Flight Into Terrain (CFIT) Avoidance	
H. Aeronautical Decision Making (ADM)	
I. Checklist Usage	

Acknowledging that some UAS will operate in Class A airspace, under IMC conditions, and BVLOS an instrument rating was recommended. Table 2 summarizes training topics recommended for a UAS instrument rating.

Table 2. PTS Topics for a UAS Instrument Rating[18]

Instrument Rating	**Notes**
I. Preflight Preparation	
A. Weather Information	
B. Flight Planning	Includes local and waypoint planning
II. Preflight Procedures	
A. Aircraft Systems Related to IFR Operations	

[18] Reprinted with Permission from SAE International. (Note: Practical Test Standards are no longer valid for an Instrument Rating. There is no evaluation by SAE International for Airman Certification Standards.

B. Control Station Flight Instruments and Navigation Equipment	
C. Instrument Control Station Check	
III. Air Traffic Control Clearances and Procedures	
A. Air Traffic Control Clearances	
B. Compliance with Departure, En Route, and Arrival Procedures and Clearances	
C. Holding Procedures	
IV. Instrument Approach Procedures	
A. Non-Precision Approach	
B. Precision Approach	
C. Missed Approach	
D. Circling Approach	
E. Landing From a Straight –In or Circling Approach	
V. Emergency Operations	
A. Loss of Communications or Loss of Data Link	
B. Approach with Loss of Primary Flight Indicators	Probably not applicable to UAS
C. Flight Termination	
VI. [VIII in the original] Post-Flight Procedures	
A. Checking Instruments and Equipment	

Recognizing the vast differences in UAS systems, SAE acknowledged that training can vary widely. For example, an operator flying in off-airport conditions would not necessarily gain experience for airport operations. In this example, a restriction on the UAS certificate for off-airport operations only would be appropriate. This document recommends the following examples of commercial UAS restrictions (SAE International, 2016, p. 22):

- Off-airport operations only
- Daytime operations only
- Automated landings only
- Restricted range operations only
- Single control station operations only
- No flight skills operations only

As a final matter, this document addresses training for the UAS pilot who currently holds a manned certificate. It acknowledges that much of the training contained in Table 5 has already been learned by this individual. Accordingly, in Table 3 an "X" indicates which topics are unique to UAS and should be addressed in future UAS training topics:

Table 3. Topics to be covered for someone in Possession of a Manned Certification.[19]

	Commercial Pilot Topics	Notes
	I. Preflight Preparation	Includes control station hand-offs when applicable. Also includes local waypoint flights
	A. Certificates and Documents	
X	B. Airworthiness Requirements	
	C. Weather Information	
X	D. Cross Country Flight Planning	
	E. National Airspace System	
X	F. Performance and Limitations	
X	G. Operations and Systems	
	H. Aeromedical Factors	
X	I. Data Link Requirements	Unique to UAS
	II. Preflight Procedures	
X	A. Preflight Inspection	
X	B. Control Station Management	Replaces cockpit management
	C. Engine Starting	
X	D. Taxiing or Pre-Launch Procedures	Pre-Launch procedures are unique to UAS
X	E. Before Takeoff Checklist	
	III. Airport Operations	
	A. Radio Communications and ATC Light Signals	
	B. Traffic Patterns	
	C. Airport Runway Marking and Lighting	
	IV. Takeoffs, Landings, and Go-Arounds	
X	A. Normal and Crosswind Takeoff and Climb	
X	B. Normal and Crosswind Approach and Landing	
X	C. Soft-Field Takeoff and Climb	If relevant for system
X	D. Soft-Field Approach and Landing	If relevant for system
X	E. Maximum Performance Takeoff and Climb	If relevant for system

[19] Reprinted with Permission from SAE International.

X	F. Short-Field Approach and Landing	If relevant for system
X	G. [K in original] Forward Slip to a Landing	If relevant for system
X	H. [L in original] Go-Around Rejected Landing	If relevant for system
X	I. [M in original] Power-Off 180 degree Accuracy Approach and Landing	If relevant for system
	V. Performance Maneuvers	
X	A. Steep Turns	
X	B. Steep Spiral	
X	C. Chandelles	
X	D. Lazy Eights	
	VI. Ground Reference Maneuvers	
X	A. Rectangular Course	
X	B. S-Turns	
X	C. Turns Around a Point	
X	D. Eights on Pylons	Many experts say this maneuver is obsolete
	VII. Navigation	
	A. Navigation Systems and Radar Services	If relevant for system
	B. Pilotage and Dead Reckoning	In the event of GPS failure
X	C. Diversion	If relevant for system
X	D. Lost Procedures and Lost Link Procedures	Lost Link unique to UAS
	VIII. Slow Flight and Stalls	
X	A. Maneuvering During Slow Flight	
X	B. Power-Off Stalls	
X	C. Power-On Stalls	
X	D. Spin Awareness	
	IX. Basic instrument Maneuvers	For more automated systems, these maneuvers would be all that were required to demonstrate that the pilot could safely operate the aircraft.
X	A. Straight and Level Flight	
X	B. Constant Airspeed Climbs	
X	C. Constant Airspeed Descents	
X	D. Turns to a Heading	
X	E. Recovery From Unusual Flight Attitudes	If relevant for system

X	F. Radio Communications, Navigation Systems/Facilities, and Radar Services	
	X. Emergency Operations	
X	A. Emergency Approach and Landing (Simulated)	
X	B. Systems and Equipment Malfunctions	Also includes lost link procedures
	C. Emergency Equipment and Survival Gear	
X	D. Flight Termination Procedures	Unique to UAS
X	E. Emergency Dive (To Avoid Imminent Collision)	Unique to UAS
	XI. Night Operations	If relevant for system
X	A. Night Preparation	
X	B. Night Operations	
	XII. Post Flight Procedures	
X	A. After Landing, Parking, and Securing	
	XIII. Special Emphasis Topics	
	A. Positive Aircraft Control	
X	B. Procedures for Positive Exchange of Flight Controls	Includes control handoff within the control station and between stations
X	C. Collision Avoidance	Sense and Avoid
	D. Wake Turbulence Avoidance	
	E. Land and Hold Short Operations (LAHSO)	If relevant for system
	F. Runway Incursion Avoidance	If relevant for system
	G. Controlled Flight Into Terrain (CFIT) Avoidance	
	H. Aeronautical Decision Making (ADM)	
	I. Checklist Usage	

This report stated that the issue of an instructor rating or a discussion of who would provide UAS training was outside the scope of that report.

Gildea, K. M., Williams, K. W., Roberts, C.A. (2015) A Review of Training Requirements for UAS, sUAS, and Manned Operations. FAA Civil Aerospace Medical Institute.[20]

[20] NOTE: A draft copy of this report was provided by the FAA. However, as noted earlier, it is currently under review by that agency. Accordingly, it does not constitute FAA training or certification policy, or endorsement.

The purpose of this recent draft paper was to analyze existing UAS training protocols of DoD and CASA Australia, and compare them with PTS, oral, and knowledge testing for manned flight contained in FAR Part 61. The report found factually that many categories of training/testing for UAS tracked with Part 61 for manned private, commercial, instrument, and ATP ratings. It also found that there are aspects of manned training with no application to UAS, and similarly, aspects of UAS that do not apply to manned flight.

The report found support for using manned training standards as a jumping off point for UAS training. This support included:

1. Knowledge and skills constituting manned training and testing have a long history of supporting safe operations in the NAS.
2. Allows UAS pilots to operate in a manner familiar to ATC and manned aircraft, thereby minimizing challenges to NAS integration.
3. Wealth of existing training materials and instructors with manned experience constitute on hand sources of training/testing information to reduce costs.

The categories of knowledge and flight proficiency forming Part 61 for manned operations were identified. The relationship between manned and UAS, including sUAS, allowed establishment of a common set of training and testing categories. These common categories are:

1. Policy and responsibilities
2. Preflight preparation
3. Communications
4. Weather information
5. Flight authorization, approval, and clearance authority
6. Preflight procedures
7. Airport Operations (launch/landing area)
8. General flight operations
9. Takeoff and departure
10. Maneuvers
11. Emergency Operations
12. Slow flight and stalls
13. Navigation
14. Landings and approaches to landing (Recovery)
15. Postflight procedures
16. Visual flight rules (VFR)
17. Instrument flight rules (IFR)
18. Normal operating procedures
19. Safety/Operational risk management
20. Reporting procedures

Evaluating existing training programs, the individual categories of training were assigned to one of four new categories. These four categories are:

1. Present in current UAS training with no equivalent in manned.
2. Present in current UAS training with an equivalent in manned.

3. Not present in UAS training but present in manned, with little likelihood it will be required of UAS.
4. Not present in UAS training but present in manned, with a high probability that such training will be required of UAS to operate safely in the NAS.

Appendix B of that document evaluates each of the above common sets of training elements for sUAS, UAS, and manned operations, showing whether it applies to manned, UAS, sUAS, or any combination of these three. Appendix B of that report summarizes the results of that evaluation.

With respect to UAS pilot certification, the report suggests adopting private, commercial and instrument UAS certifications/ratings. A UAS private certification would include the privilege to fly at night in class B, C and D airspace, but with limits to VLOS if the UAS pilot was not holder of a UAS instrument rating. The UAS instrument rating would allow BVLOS, with reference to an instrument display. The UAS instrument rating would support operations under an IFR flight plan and in Class A airspace. The UAS Commercial certification would permit flights for compensation or hire. Appendix C, D, and E of that document offers the specific language for recommended UAS private, UAS commercial and UAS instrument certifications/ratings, respectively. These, too, are based on manned Part 61 standards, adjusted for UAS differences. The report states it does not address visual observer training.

Mirot, A. (2013). The Future of Unmanned Aircraft Systems Pilot Qualification. *Journal of Aviation/Aerospace Education & Research* 22 (3): 19-30.

This report proposes four levels of pilot qualifications that were believed necessary to ensure safe UAS integration into the NAS. These levels are based on DOD's formula for first establishing categories of UAS based on factors of weight, airspeed, and operational altitude. These proposed categories are shown in Table 4.

Table 4. Proposed Categories for the Purpose of Pilot Certification[21]

UAS Category	Maximum Takeoff Weight (pounds	Maximum operating altitude	Maximum Speed (KIAS)	Example UAS
Category 1	0 - 25	<400 AGL	<87 kts	RQ-11 Raven
Category 2	26-55	<2000 AGL	<87 kts	Scan Eagle
Category 3	56-1320	2000-18000 MSL	87-250 kts	RQ-7 Shadow
Category 4	>1320	>18000 MSL	No limit	MQ-9 Reaper

Four corresponding levels of pilot requirements were then proposed. These are (Mirot, 2013, p. 24):

1. *Level 1* pilot would operate category 1 aircraft. The pilot would attend an authorized private pilot ground school and pass the FAA written examination.

[21] This paper predates the establishment of the sUAS regulations.

2. *Level 2* would require a pilot to meet level 1 qualifications and hold at least an FAA sport pilot certificate. Flights would be limited to VMC conditions.
3. *Level 3* would require a pilot to meet level 1 qualifications and hold at least an FAA private pilot certificate. Again, flights would be limited to VMC under VFR.
4. *Level 4* would require a pilot to meet level 1 standards and hold at least a private pilot certificate with an instrument rating.

Ground and airborne visual observers were discussed. Ground based VOs must maintain unaided visual line of sight. Airborne visual observers could not pilot the chase plane. In both cases, VOs would be required to meet level 1 qualifications, above, including attending private pilot ground school.

Williams, K.W. (2004). A Summary of Unmanned Aircraft Accident/Incident Data: Human Factors Implications. FAA Civil Aerospace Medical Institute.

This report examined accident/incident data and identifies UAS training areas that are unique to UAS.

> Data from the Hunter program indicated that 15 of the 32 accidents (47%) had one or more human factors issues association with them. . . .By far the largest human factors issue is the difficulty experienced by [external pilots] during landings. . . Control difficulties are at least partially explainable by the fact that when the aircraft is approaching the [external pilot] the control inputs to maneuver the aircraft left and right are opposite what they would be when the aircraft is moving away from the EP" (p. 2).

"For both the Hunter and Shadow, at least one accident involved the transfer to control of the aircraft from one GCS to another during flight, an activity unique to UA" (p. 3).

Micro Unmanned Aircraft Systems Aviation Rulemaking Committee Final Report (April, 2016). Federal Aviation Administration.

Obviously not focused on large UAS, this report does make a unique observation that testing for UAS certification should consider risk of harm and the burdensome nature of traditional FAA testing. "Faced with burdensome requirements, it would not be unusual for even well-meaning operators to fly the smallest UAS without traveling to a test center to satisfy knowledge and other requirements. In that case, rather than enhancing safety, the requirements would be an impediment to safety" ("Micro Unmanned Aircraft Systems Aviation Rulemaking Committee Final Report," 2016, p. 12)

ICAO Circular 328-AN/190. (2011). International Civil Aviation Organization. Montreal, Canada.

The stated purpose is to apprise State members of ICAO's position on the integration of UAS into non-segregated airspace and airports. With respect to facilitating UAS introduction, ICAO's position is that manned and UAS pilots have the same level of responsibility for safety, and this is served through training in the following subjects:

- Air law
- Flight performance
- Planning and loading (weight and balance)
- Human performance
- Meteorology
- Navigation
- Operations procedures
- Principles of flight and communication (ICAO, p. 5)

In addition, a UAS pilot must obtain flight instruction, demonstrate skill, and have a certain level of flight experience. Lastly, the pilot must be licensed (ICAO, p. 5). For international flights the UAS pilot must be licensed in the country his aircraft is registered (ICAO, p. 13).

The remote UAS pilot and other remote crewmembers must be trained and licensed in accordance with ICAO Annex 1 (ICAO, p.34). In reviewing Annex 1, knowledge training, proficiency (skill) flight check, and experience were focused on manned operations. No discussion was made distinguishing or distancing UAS certification procedures from those of manned.

Advisory Circular 101-1(0). (July 2002). Australian Civil Aviation Authority.

This Advisory Circular was developed to guide UAS pilots, who they refer to as controllers, with a means of compliance with legislation and regulations under CASR Part 101 for UAS operations.

Under CASR §101.295, to be designated a UAV controller, one must have:

a. A radio operators certificate, and
b. Passed aviation license theory examination, and
c. Passed an instrument rating theory examination, and
d. Completed a training course in the UAV to be operated; and
e. Have at least 5 hours experience operating a UAV outside controlled airspace.

CASR §101.240 defines a large UAS as an airplane over 150 kg (330 pounds), or a helicopter over 100 kg (220 pounds).

Generally, if operating in controlled airspace in which ATC services provided ". . . UAVs should be operated in accordance with the rules governing the flights of manned aircraft as specified by the appropriate ATC authority" ("Advisory Circular (Australia) 101-1," 2002, p. 2).

Conduct of BVLOS operations should be done:

a) in accordance with conditions specified in an approval issued by CASA;
b) in an approved operating area; or
c) in a known traffic environment – in accordance with regulations governing the flight of manned aircraft ("Advisory Circular (Australia) 101-1," 2002, p. 3).

Chase planes are not required for BVLOS operations when UAV is operated on an IFR flight plan and in accordance with this advisory circular. Otherwise, a VO onboard a chase plane would be implied ("Advisory Circular (Australia) 101-1," 2002, p. 7).

Regarding training requirements, ground training, flight training, and proficiency/currency training. Ground training topics would include, but not limited to:

a. aerodynamics, including effects of controls;
b. aircraft systems;
c. performance;
d. navigation;
e. meteorology;
f. airspace;
g. rules of the air;
h. radio telephony procedures; and
i. emergency procedures management ("Advisory Circular (Australia) 101-1," 2002, p. 16).

Pursuant to this circular, training would be conducted by qualified individuals acceptable to the CASA. In addition, initial certification of UAV controllers would require a combination of oral, written examinations, and a flight check.

Draft Advisory Circular 101-4: Annex C. (May, 2014). Australian Civil Aviation Authority.

As of this writing, CASA Draft Advisory Circular 101-4 has been released only as a draft product. It parallels AC 101-1in most respects, including requiring certification be accomplished according to CASR §101.295. However, it broadens the scope of pilot training to allow applicants to self-study in addition to using an approved training courses ("Advisory Circular (Australia) 101-4 (Annex C)," 2014, p. 7).

Advisory Circular AC 102-1. (July, 2015). Civil Aviation Authority of New Zealand.

Similar to Australia, New Zealand has in place regulations relating to the operation of UAS, Civil Aviation Rule (CAR) Parts 101 and 102. This advisory circular provides information regarding standards, practices, and procedures acceptable for compliance with the CARs.

Part 101 applies to "remotely piloted aircraft" weighing less than 25 kg. No distinction is made between commercial and recreational operations ("Advisory Circular AC 102-1," 2015, p. 5). CAR Part 102 is focused on "unmanned aircraft" not operated under CAR Part 101, and weighing over 25 kg. Two classes of unmanned aircraft were established: ("Advisory Circular AC 102-1," 2015, p. 5)[22].

1. Medium unmanned aircraft – 25 kg to 150 kg.

[22] NOTE: Remotely piloted aircraft weighing between 15 kg to 25 kg may only be operated under CAR 101 if constructed and operated under the authority of an approved organization, of which only one is approved, Model Flying New Zealand. ALSO NOTE: Weight shown are gross weight, including payloads.

2. Large unmanned aircraft – over 150 kg

CAR Part 102 does not prohibit operations BVLOS. However, it states a "strong safety case" must be presented if this is intended, to include ("Advisory Circular AC 102-1," 2015, p. 9):

1. identification of the airspace class to be used and associated requirements and how they will be met; and
2. ability to provide separation from other traffic, such as segregated airspace or a technological solution (e.g. seek, detect and avoid systems); and
3. mitigate risk to persons, property and terrain

Extended visual line of sight (EVLOS) can be approved with a number of VO support crews if separation from other aircraft is ensured and all are in direct contact with the operator ("Advisory Circular AC 102-1," 2015, p. 9). Observers should not be impaired visually or aurally, and be able to show competence in the following areas:

1. methods of communicating with the pilot both directly; and
2. action and backup action to take if communications fail; and
3. methods of division of the sky into sectors so any intruder's position is instantly known once reported to the pilot; and
4. emergency procedures should any event take place ("Advisory Circular AC 102-1," 2015, p. 17)

Regarding pilot training, this AC states that New Zealand does not prescribe specific requirements for operation of a UAS. However, it implies that the Director of CAA would need to be satisfied that the operator is competent in . . . "(1) general aviation knowledge (incorporating such things as airspace and air law); and (2) specific knowledge to remotely piloted aircraft/unmanned aircraft (including aircraft handling)" ("Advisory Circular AC 102-1," 2015, p. 16).

What would be acceptable for demonstrating an understanding of general aviation knowledge, would include the following ("Advisory Circular AC 102-1," 2015, p. 16):

- a pilot license issued under Part 61, or recreational micro-light or glider pilot certificate issued by a Part 149 organization:
- a remotely piloted aircraft licence (or equivalent) issued by a competent foreign aviation authority acceptable to the Director:
- a pass in the private pilot licence (PPL) air law exam; flight radio telephone operator(FRTO) exam; an FRTO rating2[SIC]; five hours of air experience [focused} on airspace and flight radio use:
- a certificate of achievement issued by a Part 141 training organisation, which indicates—
    - a pass in aviation law theory; and
    - competency in operating unmanned aircraft; and
    - competency in the use of aviation radios (if applicable)

***The Swedish Transport Agency's Statute Book.* TSFS 2009:88. (2009). Swedish Transport Agency**

The Swedish regulatory structure identifies four categories of UAS (*The Swedish Transport Agency's Statute Book*, 2009, p. 4):

Category 1A: Unmanned aircraft with maximum take-off weight of less than or equal to 1.5 kg, which develops a maximum kinetic energy of 150 J and is flown only within the visual line of sight of the pilot.

Category 1B: Unmanned aircraft with maximum take-off weight of more than 1.5 kg but less than or equal to 7 kg, which develops a maximum kinetic energy of 1000 J and is flown only within the visual line of sight of the pilot.

Category 2: Unmanned aircraft with maximum take-off weight of more than 7 kg which is flown only within the visual line of sight of the pilot.

Category 3: Unmanned aircraft which is certified to fly and be controlled beyond the visual line of sight of the pilot

Interestingly, category 1A and 1B UAS are classified by weight and maximum kinetic energy calculated by mass and speed. This is the only classification found that utilizes kinetic energy. Both categories fall below 7 kg.

Categories 2 and 3 apply to UAS, though under Swedish rules this would be from 7 kg and up. To be authorized to operate a category 2 UAS, the pilot would need to have knowledge of aviation systems and flight safety standards contained in the private pilot's course. In addition, the pilot would need to have training on a relevant UAS type and complete an approved skill test (*The Swedish Transport Agency's Statute Book*, 2009, p. 9).

For category 3 operations the UAS pilot would need to complete what they term as theoretical training required of a commercial pilot's license, and have an approved instrument rating for IFR flights (*The Swedish Transport Agency's Statute Book*, 2009, p. 16).

The last two categories require training courses paralleling manned flight, and instrument ratings for BVLOS operations.

Statutory Instruments S.I. No. 563: Irish Aviation Authority Small Unmanned Aircraft (Drones) and Rockets. (2015). Irish Aviation Authority.

This brief, 7-page document provides guidance for operating UAS having a mass of up to 150 kg, without fuel. The document is silent on Pilot training and certification, except to say operations of 25 kg to 150 kg shall not be flown without permission of the IAA. Whether that permission requires specific training is not stated. (IAA, §7(8)).

Staff Instruction (SI) No. 623-001: Review and Processing of an Application for a Special Flight Operations Certificate for the Operation of an Unmanned Air Vehicle (UAV) System (November, 2014). Transport Canada.

Pilot

This instruction provides Air Canada inspectors the information, procedures and guidelines to process Special Flight Operations Certificates (SFOC) for permitting UAS operations in Canadian airspace. This instruction is directed at both small UAS (25 kg or less), l UAS, and visual observers. The small UAS training discussions contained in this publication are warranted, in that this training forms the foundation for large UAS training. This publication acknowledges that currently Canada has no minimum qualification standards for organizations providing training. However, it emphasizes that the focus should be on existing manned training:

> "The training to safely operate a UAV system can be received from a variety of sources including UAV operators, manufacturers, manned aviation flight training organizations or third parties. The approach to training, however, should not differ significantly from that currently applied to manned aviation since fundamental knowledge, experience and skills are basic requirements to assure a safe and effective operating environment for all airspace user." (Canada SI 623-001, para. 4.2.2).

Training for small UAS includes a knowledge of:

(A) [Transport Canada] TC policies, guidance material and the applicable UAV related regulations in the CARs;
(B) The class of airspace in which they intend to operate including the vertical and horizontal airspace boundaries and determining adjacent classes of airspace;
(C) Aeronautical charts and the Canada Flight Supplement;
(D) Air Traffic Control (ATC) services and procedures (where the operation is conducted in, or near, controlled airspace);
(E) The effect of weather on UAV performance and the ability to identify critical weather situations;
(F) The identification of hazardous in-flight situations and collision avoidance requirements and procedures; and
(G) Type-specific UAV systems, limitations, normal procedures and emergency procedures. (Canada SI 623-001, para. 4.2.3).

With respect to issuing a SFOC for large UAS, in addition to subjects for sUAS, pilot qualification focuses on manned training experience:

> "For pilots of all other UAV operations (i.e. not small UAVs operated within VLOS), *additional pilot knowledge, skill and proficiency will be required* and evaluated on a case-by-case basis. UAVs that share the airspace with manned aircraft and pose the same risks as a manned aircraft must require a similar level of pilot qualifications. As the level of complexity of the UAV operation increases, so does the training requirement. For example, to conduct Instrument Flight Rules

(IFR) operations a pilot license endorsed with an IFR rating is required" (Canada SI 623-001, para. 4.2.4) (emphasis added).

As a final matter, this instruction provides that training for UAV pilots of small UAV shall be based on TP 15263E, *Knowledge Requirements for Pilots of Unmanned Air Vehicle Systems.* Though focused on sUAS, Staff Instruction 623-001 clearly implies that this same knowledge and training is intended to be carried forward into the operation of large UAS, where it clearly states will require "additional pilot knowledge", not different pilot knowledge. TP 15263E is also discussed in this summary, below.

Visual Observer

The evaluation of visual observers is also a part of this Staff Instruction. Minimum requirements for a visual observer who is utilized as part of a SFOP include:

3. Visual acuity sufficient to conduct their duties.
    (A) Visual scanning techniques;
    (B) Inter-crew communication requirements;
    (C) Hazardous in-flight weather conditions;
    (D) Actions to be taken in the event a risk of collision develops;
    (E) The vertical and horizontal boundaries of the operation;
    (F) The class of airspace in which they intend to operate including the vertical and horizontal airspace boundaries and determining adjacent classes of airspace;
    (G) Right of way rules as specified in the SFOC; and
    (H) The UAV system limitations (Canada SI 623-001, para. 4.3).

TP 15263E Knowledge Requirements for Pilots of Unmanned Air Vehicle Systems. (August, 2014). Transport Canada.

Transport Canada intended that this document ". . . provide guidance of organizations or individuals intending to provide ground school instruction to pilots seeking compliance with the Best Practices for pilots of small UAV systems." It acknowledges that future Canadian regulations and standards are expected, however, until that time the material contained in this document is controlling.[23]

The intent of this document is to ensure that applicants for SFOC acquire certain aviation-related knowledge and be able to pass a written examination confirming their knowledge. Accordingly, organizations or individuals conducting ground school training are expected to cover the following examination subjects:

[23] Canadian Aviation Regulations Advisory Council (CARAC) issued a *Notice of Proposed Amendment NPA): Unmanned Air Vehicles*, dated May 28, 2014. Comments were invited on its proposals for small UAV pilot training, knowledge, and experience. It states that Canada indents to have regulations in place in 2016. Interestingly, throughout this document, positive reference is made to TP 15263E.

Table 5. Canadian UAV Knowledge Requirements

Mandatory Subjects	Related Subjects in this Guide	Page Number
Air Law	Air Law and Procedures – Section 1	1
Navigation	Navigation and Radio Aids – Section 2	10
Meteorology	Meteorology – Section 3	14
Aeronautics: General Knowledge	Airframes, Engines, and Systems – Section 4	19
	Theory of Flight – Section 5	22
	Flight Instruments – Section 6	26
	Flight Operations – Section 7	28
	Human Factors – Section 8	33
Radiotelephony	Aeronautical and Crew – Section 9	35

While the above listings are broad topics, this publication provides a very detailed table that lists specific knowledge areas, and sample learning objectives for these topics. Due to its detail and length, the table containing this material is attached as Appendix F3 to this report.

CAP 722 Unmanned Aircraft System Operations in UK Airspace-Guidance. (March, 2015). Civil Aviation Authority.

Under Chapter 4, Civil UAS Remote Pilot Competency, the United Kingdom appears at this time to defer to ICAO standards and EASA regulations ("CAP 722 Unmanned aircraft system operations in UK airspace-guidance," 2015, p. 44):

> 4.3 The requirements for the licensing and training of United Kingdom Civil Remote Pilots have not yet been fully developed. It is expected that United Kingdom requirements will ultimately be determined by ICAO Standards and Recommended Practices (SARPs) and EASA[24] regulations.
>
> 4.4 ICAO is currently developing standards for a Remote Pilot's License (RPL). However, until formal licensing requirements are in place the CAA will determine the relevant requirements on a case-by-case basis. In determining whether to permit a person to act as pilot or commander of a UAS, the CAA will consider a number of factors (based upon the ConOps approach) such as pilot experience, maximum aircraft mass, flight control mode, operational control and safety assessment.

Chairman of the Joint Chiefs of Staff Instructions No. 3255.01. (October, 2011). Joint Chiefs of Staff, Washington, D.C.

The stated purpose of this document was to provide standardized knowledge and qualifications for military UAS crewmembers that "...meet or exceed existing manned aircraft Federal Aviation

[24] European Aviation Safety Agency

Administration (FAA) standards to facilitate UAS access into the National Airspace System (NAS)" ("Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011, p. 1). As will be seen, training and certification of military UAS crewmembers under this guidance draws heavily on the existing regime of manned training and certification.

DOD has established five groups of UA. These are based on a combination of weight, airspeed, airspace class, and altitude ("Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011, p. 4). The following table illustrates:

Table 6. DOD UAV Classification System

GROUP	WEIGHT	AIRSPEED	AIRSPACE (CLASS))	OPERATING ALTITUDE
1	0 - 20 lbs	<100 kts	VFR in E, G, restricted,	Below 1220' AGL
2	21-55 lbs	<250 kts	VFR in D, E, G, and restricted.	Below 3500' AGL
3	56-1320 lbs	<250 kts	VFR in D, E, G, and restricted.	Below 18000' MSL
4	>1320 lbs	No limits	VFR in all classes	Below 18000' MSL
5	>1320 lbs	No limits	Class A	Above 18000" MSL

Having established the UAS groups, this report creates four Basic UAS Qualification (BUQ) levels. Training for each successive level builds on the training of the previous level and certifies crewmembers to operate higher groups of UAS described above. These four levels of pilot certification are ("Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011, p. 2):

(a) BUQ Level I. BUQ-I is the minimum recommended training level for UASC who perform duties other than pilot (e.g. Aircraft Operator/Sensor Operator). Possess required aviation knowledge and UAS knowledge-based skills to fly under Visual Flight Rules (VFR) in Class E, G, and restricted/combat airspace <1200' above ground level (AGL).

(b) BUQ Level II. Possess required aviation knowledge and UAS knowledge-based skills to fly under VFR in Class D, E, G, and restricted/combat airspace <18,000' mean sea level (MSL).

(c) BUQ Level III. Possess required aviation knowledge and UAS knowledge-based skills to fly under VFR in all classes of airspace except U.S. and ICAO Class A.

(d) BUQ Level IV. Possess required aviation knowledge and UAS knowledge-based skills to fly in all weather conditions and classes of airspace up to Flight Level (FL) 600

This approach adopts the existing framework of manned training and certification. Flight training is to be provided by an approved training program that includes flight and/or simulator experience. Operators will be required to demonstrate UAS control via flight check. Ongoing proficiency and currency are to be maintained ("Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011, p. 5).

As an example of the knowledge based skills required for certification, the standards for BUQ level IV are shown below in Table7. Level IV requires that training ". . . meet or exceeds the knowledge requirements of 14 CFR Sub-part F 61.125 and 61.127 for an FAA private pilot license with instrument rating" ("Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011, p. A-8).

Table 7. Basic UAV Qualifications Level IV

Basic UAV Qualification Level IV (BUQ Level IV)	
All BUQ Level I, II, and III Tasks	
Mission Preparation	
Global Flight Operations Knowledge	
Communications	
Satellite Communications (SATCOM)	
Aircraft Operations	
Global Navigation Procedures	
Air Operations	
Search and Rescue (SAR)	
1. Before Flight	
No New Tasks	
2. Contact Category	
No New Tasks	
3. Instrument Category	
Auto/Instrument takeoff, climb, & departure procedures	Departing a holding pattern
Instrument cross check	Procedure turns
Intercepting a heading at a predetermined angle	Transitioning from Minimum Descent Altitude (MDA) to runway
Establishing and maintaining appropriate heading	ATC/Approach Control clearances
Determination of lead point	Standard instrument approach plate procedures
Course interception	Procedure turn airspace
IFR navigation	En Route descents
Fix to Fix navigation	Appropriate landing configuration
Maintaining selected course with wind correction	Descent gradients
Knowledge of establishing arc	Instrument Meteorological Conditions (IMC) penetration
Arc interception	ATC clearance
Arc maintenance	ATC procedures
Radial intercept from arc	Remaining within cleared airspace
Holding/loitering	Controlling rate of descent

Understanding holding instructions	Instrument approach procedures
Holding pattern entry	Radar patterns
Maintaining position within holding pattern airspace	Following Ground Control Approach (GCA) controller's directions
Wind analysis in holding pattern airspace	Turning to directed headings
Maintaining directed altitudes	Glide slope control
Maintaining proper airspace	Course control
Establishing proper holding configuration	Transitioning from instruments to visual references
Precision radar approach	Visual Descent Point (VDP)
Non-Precision radar approach	Circling approach procedures
Gyro-out instrument pattern	Missed approach procedures
Half-Standard Rate turns on final	ATC missed approach clearances
Gyro-out precision radar approach	Missed approach checks
Corrections to aircraft headings	Transitioning from glide path to runway
In-Flight IFR clearance	
4. Navigation Category	
No New Tasks	
5. Emergency Category	
No New Tasks	
6. After Flight Category	
No New Tasks	

TC 3-04.61 (TC 1-600): Unmanned Aircraft System Commander's Guide and Aircrew Training Manual. (2014). Department of the Army.

This is the U.S. Army's standardization manual for its UAS aircrew training program. It offers a table of subjects that UAS pilots must demonstrate a working knowledge of to pass an academic evaluation. The requirement to be knowledgeable in these areas presupposes training has been provided in these areas.

These subjects are shown on the following pages. In addition to academic evaluation, the manual provides for a flight performance evaluation (pp. 3–10).

I. Regulations and Publications (AR 95-23, AR 95-2 DA PAM 738751, TC 3-25.26, local SOP, Army command supplements and regulations). Topics in this subject area are:
    A. ATP requirements (TC 3-04.61)
    B. DOD FLIPS and maps
    C. Flight plan preparation and filing
    D. Local airspace usage
    E. Crew coordination
    F. SOP/TACSOP requirements
    G. Map reading
    H. VFR minimums and procedures
    I. Weight and Balance requirements
    J. Forms and records

K. Publications required for using the UA
L. IATF/IFRF

II. Aircraft systems, avionics, and mission equipment description and operation (Operator's Manual). Topics in this subject area are:
A. GCS, data link, interface box, ground data terminal (GDT), Tactical Automated Landing System (TALS), launcher.
B. Emergency equipment
C. Engines and related systems
D. Fuel system
E. Flight control system
F. Lighting
G. Anti-Ice/de-ice (as applicable)
H. Control panels/flight instruments
I. Sensors (such as POP 300 payload)
J. Communications
K. Navigation equipment
L. Transponder and radar

III. Operating limitations and restrictions (applicable technical manuals). Topics in this subject area are:
A. System limits
B. Power/engine limits
C. Engine over-temperature limitations
D. Loading/weight limits
E. Generator limitations
F. Electrical limits
G. Airspeed limits
H. Altitude limitations
I. Crosswind limitations
J. Maneuvering limits
K. Weather/environmental limitations/restrictions
L. Performance data/charts
M. Laser limitations
N. Other limitations

IV. Aircraft emergency procedures and malfunction analysis (applicable TMs). Topics in this subject area are:
A. Emergency terms and their definitions
B. Caution and warning emergency procedures
C. Engine malfunctions
D. Fires
E. Fuel system malfunctions
F. Electrical system malfunctions
G. Landing procedures
H. Flight control malfunctions
I. Mission equipment

V. Aeromedical factors (AR 40-8, Technical Bulletin (TB) MED 524, FM 6-22.5, and TC 3-04.93). Topics in this subject area are:

A. Flight restrictions due to exogenous factors
B. Stress
C. Fatigue
D. Unit/Crew endurance program
E. Combat stress
F. Laser hazards

VI. Fundamentals of flight (FM 3-04.203). Topics in this subject area are:
A. Physical laws and principles of airflow
B. Flight mechanics
C. In-flight forces
D. Factors affecting performance
E. Stalls
F. Maneuvering flight (rate of climb)
G. Crosswind landings
H. Fixed wing environmental flight (cold weather or mountainous terrain)

VII. Tactical and Mission operations (FM 3-04.111, FM 3-04.126, FM 3-04.513, ATP 3-09.30, FM 3-04.140, and unit SOP). Topics in this subject area are:
A. Mission statement and employment methods
B. Aerial observation
C. Forms of reconnaissance
D. Tactical airspace coordination
E. Reconnaissance operations (purpose and fundamentals)
F. Terrain analysis
G. Navigational chart, map, and tactical overlay interpretation
H. Battlefield environment
I. Fratricide prevention
J. Tactical reports
K. Call for fire and artillery adjustment
L. Downed UA procedures
M. Mission equipment
N. Tactical airspace coordination
O. Laser operations
P. Levels of interoperability
Q. Cooperative engagements
R. Aviation mission planning

VIII. Weapon system operation and employment (FM 3-04.126, FM 3-04.140). Topics in this subject area are:
A. Laser operations (range/designator)
B. Laser performance detectors
C. Fire control/fire commands
D. Techniques of fire and employment
E. Visual search and target detection
F. Ordinance identification
G. Weapons initialization, arming, and safety

IX. Night mission operation for Hunter UAS Eos only (FM 4-03.203, FM 4-03.240). Topics in this subject area are:

A. Types of vision
B. Dark adaptation, night vision protection, and central night blind spot
C. Distance estimation and depth perception
D. Visual illusions
E. Night vision limitations and techniques

X. SO, IO, and UT (FAA-H-8083-9). Topics in this subject area are:
A. The learning process
B. Effective communication
C. Teaching methods
D. Types of evaluation
E. Planning instructional activity
F. Flight instructor characteristics and responsibilities
G. Techniques of flight instruction
H. Human behavior
I. Teaching process
J. The instructor as a critic
K. Instructional aids
L. Critique and evaluations
M. Levels of learning
N. Principles of learning

XI. Instrument planning and procedures (as applicable). The following is a guide for the administration of the evaluation. The examinee is allowed to access references during the oral evaluation (AR 95-23, FM 3-04.240, Operator's Manual, AR 95-10, DOD flight information publications, FAR/Aeronautical Information Manual (AIM), general procedures guide, area procedures, local regulations and unit SOP). Topics under this subject area are:
A. Departure procedures
B. Required weather for takeoff, en route, destination, and alternate
C. NOTAM
D. Terminal Aerodrome Forecasts (TAF)
E. Aviation routine reports
F. DOD FLIP symbology
G. Fuel requirements
H. Weather hazards
I. Army aviation flight information bulletin
J. Opening and closing flight plans
K. Airspace – types, dimensions and requirements to operate in
L. VFR requirements
M. Flight plan preparation
N. Position reports
O. En-route weather services

Two additional topics for this list are: 1) Transponder requiremnts; and, 2) Arrival procedures.

Federal Aviation Administration (August, 2016). FAA Order 8900.1 Vol. 16 CHG 468.

This order establishes the Flight Standards Information Management System. Volume 16 provides information and policy on how operators of civil UAS, including sUAS, are authorized to conduct flight operations that will comply with the FARs.

Chapter 1 of Volume 16 provides definitions and acronyms that are used by the FAA and other organizations to ". . . describe relevant differences between UAS operations and those of manned aircraft" (FAA, para. 16-1-2-1).

Chapter 3 contains the process by which remote pilot certificates with a sUAS ratings are applied for pursuant to FAR Part 107. Regarding training, an applicant not holding a current Part 61 airman certificate, must pass an initial aeronautical written test at an FAA-approved test center. That test will cover:

- Applicable regulations relating to sUAS rating privileges, limitations, and flight operation;
- Airspace classification, operating requirements, and flight restrictions affecting small unmanned aircraft operation;
- Aviation weather sources and effects of weather on small unmanned aircraft performance;
- Small unmanned aircraft loading;
- Emergency procedures;
- Crew Resource Management (CRM);
- Radio communication procedures;
- Determining the performance of small unmanned aircraft;
- Physiological effects of drugs and alcohol;
- Aeronautical decision making and judgment;
- Airport operations; and
- Maintenance and preflight inspection procedures (FAA para. 16-3-1-13A)

Advisory Circular 107-2. (June, 2016). Federal Aviation Administration.
Acknowledging that AC 107-2 applies to Part 107 small UAS, it does offer current agency insight and possible implications and rationale that may carry over into larger UAS.

To receive a remote pilot certificate with small UAS rating, an applicant must obtain aeronautical knowledge and pass an initial test at an FAA approved knowledge testing center (KTC). Chapter 6 of AC 107-2 elaborates on the aeronautical knowledge required for initial and recurrent tests ("Advisory Circular 107-2," 2016, pp. 6-4-5).

> **6.6.1** Initial Test. As described in paragraph 6.4, a person applying for remote pilot certificate with a sUAS rating must pass an initial aeronautical knowledge test given by an FAA-approved KTC. The initial knowledge test will cover the aeronautical knowledge areas listed below:
>
> 1. Applicable regulations relating to sUAS rating privileges, limitations, and flight operation;

2. Airspace classification and operating requirements, and flight restrictions affecting small UA operation;
3. Aviation weather sources and effects of weather on small UA performance;
4. Small UA loading and performance;
5. Emergency procedures;
6. Crew Resource Management (CRM);
7. Radio communication procedures;
8. Determining the performance of small UA;
9. Physiological effects of drugs and alcohol;
10. Aeronautical decision-making (ADM) and judgment;
11. Airport operations; and
12. Maintenance and preflight inspection procedures.

6.6.1.1 A part 61 certificate holder who has completed a flight review within the previous 24 calendar-months may complete an initial online training course instead of taking the knowledge test (see paragraph 6.7).

6.6.1.2 Additional information on some of the knowledge areas listed above can be found in Appendix F2.

6.6.2 Recurrent Test. After a person receives a remote pilot certificate with an sUAS rating, that person must retain and periodically update the required aeronautical knowledge to continue to operate a small UA in the NAS. To continue exercising the privileges of a remote pilot certificate, the certificate holder must pass a recurrent aeronautical knowledge test within 24 calendar-months of passing either an initial or recurrent aeronautical knowledge test. A part 61 pilot certificate holder who has completed a flight review within the previous 24 calendar-months may complete a recurrent online training course instead of taking the knowledge test.

The AC references supplemental information contained in Appendix B of the AC. These additional knowledge areas of Appendix B of AC 107-2 are attached as Appendix F2 to this report.

The new Part 107 does not require flight proficiency or aeronautical experience for airman certification. Rationale was that sUAS “. . . will operate in a confined area of operation. As a result of this confined area and due to the very low weight of the small unmanned aircraft, UAS operations conducted under part 107 will generally pose a very low risk as compared to manned aircraft. As such, flight proficiency and aeronautical experience requirements (which apply to part 61 pilots) are unnecessary for remote pilots of a small UAS. Flight proficiency testing is also not necessary for small UAS operations because, unlike a manned aircraft pilot, the remote pilot of a small UAS can easily terminate flight at any point.” (81 Fed. Reg., p. 42160)

Regarding source of training, AC 107-2 provides that “[t] his aeronautical knowledge can be obtained through self-study, taking on online training course, taking an in-person training course, or any combination thereof” (“Advisory Circular 107-2,” 2016, p. paragraph 6.6, 6-4).

Weeks, J.L. (March, 2000). Unmanned Aerial Vehicle Operator qualifications. Air Force Research Laboratory.

This article's focus is on qualifications required for five large UAS airframes. The Pioneer, operated by the U.S. Navy and Marine Corps. The Hunter, operated by the U.S. Army. The Predator and Global Hawk, both operated by the U.S. Air Force. Also considered is the Phoenix operated by the British Army.

It must be pointed out that this is an older study of training requirements and some of its content maybe subject to amendment by more recent changes of policy. It is included to illustrate that the military relied on manned flight experience for its most complex UAS platforms.

The Pioneer may be piloted by enlisted personnel who do not have an aviation background. However, the mission commander for Navy and Marine Corps operations must be a rated aviation officer, either fixed-wing or helicopter pilot, or navigator. The mission commander has overall responsibility for Pioneer missions.

Only the Hunter may be flown by enlisted non-rated aviators, and with a staff noncommissioned officer serving as mission commander (Weeks, 2000, p. 6).

At the time of this report, Air Force policy required that the Predator pilot be a rated fixed-wing pilot or a navigator who holds an FAA commercial pilot's certificate with an instrument rating. For Global Hawk operations, the U.S. Air Force assumed new students would be a military rated fixed-wing or rotary-wing pilot, or an FAA certificated pilot with an instrument rating (Weeks, 2000, p. 9).

Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap. (2013). Federal Aviation Administration.

> UAS training standards will mirror manned aircraft training standards to the maximum extent possible, including appropriate security and vetting requirements, and will account for all roles involved in UAS operation. This may include the pilot, required crew members such as visual observers or launch and recovery specialists, instructors, inspectors, maintenance personnel, and air traffic controllers ("Integration of civil unmanned aircraft systems in the National Airspace System roadmap," 2013, p. 28).

Bridewell, J. (2015). Medium Altitude Long Endurance, UAS Initial Competency Sets (ICS)[SM.] University of North Dakota and Air Force Research Laboratory[25].

Initial Competency Sets **(**ICS), equivalent to PTS, were designed to identify knowledge and skills appropriate for students in a Medium Altitude Long Endurance (MALE) training program. "The

[25] The authors of this document restrict distribution without prior permission. Materials may be requested through Dr. John Bridewell at the University of North Dakota, Department of Aviation.

entry requirements specified when developing the ICS are … (i.e., baseline knowledge and skill upon starting training): Commercial Instrument rated pilot" (Bridewell, 2015, p. 3).

In the development of this program, SME's identified priority experiences for pilot development. One high priority skill set they identified was working with manned aircraft, and requiring a commercial pilot rating was found to satisfy this experience requirement (Bridewell, 2015, p. 24). This program was developed around MQ-1/9 large UAS.

Training Course Outline, MALE RPA Operations, 5th Ed. (2015). University of North Dakota.

This training course outline is an outgrowth of the Initial Competency Sets (ICS)℠ report discussed above. Individual ground and simulator flight lessons for Medium Altitude Long Endurance (MALE) training focus on the Predator and Reaper (MQ-1/MQ-9). The course is being offered for the first time Spring semester, 2017. UND is using a Predator Reaper Integrated Networked Computer Environment (PRINCE) simulator. Consistent with the ICS, student entry requirements require a Commercial certificate and an Instrument rating (University of North Dakota, 2015). This course builds on the foundation of the course mentioned below.

Training Course Outline, UAS Operations Course, 4th Ed. (2015). University of North Dakota.

This academic course offered at UND provides initial training in operations of UAS through the use of a ScanEagle simulator. The ScanEagle is an airframe that straddles the line between sUAS and UAS depending on the configuration, which varies with weight. Enrolment in this course requires students to have "[a] commercial pilot certificate with an airplane category rating and single/multi engine land class ratings" (UND Aerospace, 2015, p. 7). In addition, "[t]he students will demonstrate through oral examinations, written and practical tests; an ability to safely and efficiently operate an Unmanned Aircraft System in the National Airspace System" (UND Aerospace, 2015, p. 7).

Wallace, R.W., Bills, C.G., Hinkle, W.A., Weathers, C.J. (2011). Enhancing Remotely Piloted Vehicle Training. American Institute of Aeronautics and Astronautics. St. Louis, Missouri.

This paper discusses the use of simulation to improve RPV training.

> Simulation has known capabilities that only a training device can support, such as repeated reset and predetermined conditions. Simulation can be used to regulate complexity or cognitive load by applying a simple to complex building block strategy. Simulation can be paused for providing feedback and then re-entered to apply this redirection in the situation. Simulation can also be used for training rarely occurring events such as emergencies or abnormal procedures that might take years to experience similar situations in real world training operations (Wallace, Bills, Hinkle, & Weathers, 2011, p. 3).

"[Researchers] studying simulator training compared to in-flight training showed that during a two-hour period in simulation there was an increase of 20-100% more opportunities than in the aircraft to experience critical events, which could be sequences repetitively until proficiency was achieved" (Wallace et al., 2011, p. 3).

Nullmeyer, R., Herz, R., Montijo, G. (2009). Training Interventions to Reduce Air Force Predator Mishaps. Air Force Research Laboratory, Dayton, OH.

Based on earlier research on class A[26] predator mishaps, ". . . crew resource management training was developed for both the Predator formal school and for continuing Crew Resource Management training that was given to mission qualified crews" (Nullmeyer, Herz, & Montijo, 2009, p. 2).

> Mishap rates per 100,000 flying hours decreased substantially (from 23 Class A mishaps per 100,000 flying hours from fiscal years 1997-2003 to less than 11 in fiscal years 2004-2007) … Training is one of several tools than can be used to meet safety and capability objectives, but other changes such as equipment modifications and altered procedures may also be integral parts of an effective overall error mitigation strategy" (Nullmeyer et al., 2009, p. 5).

Air Force Instruction 11-502. (April, 2012). Secretary of the Air Force. Washington D. C.

Small UAS under DOD's five tier classification system includes Class 3 aircraft with weights from 56 – 1320 pounds.

Without detailing specific course topics (with the exception of a mention of CRM), this Air Force instruction provides that pilot certification for aircraft up to 1320 pounds will involve formal ground training, written examinations, and a flight training requirement ("Air Force Instruction 11-502," 2012, p. 14).

> **3.4. Ground Training Requirements.**
>
> 3.4.1. **Academic Training.** Accomplish academic training requirements as directed in the applicable AFSOC-approved syllabus.
>
> 3.4.2. **Written Examinations.** Satisfy requirements of AFI 11-502, Volume 2, *Small Unmanned Aircraft System Standardization/ Evaluation Program* and applicable UAS Group-Specific instructions.
>
> 3.4.3. **Ground Training.** Applicable ground training accomplished at the formal school (i.e., simulators, aircraft systems, etc.) establishes due dates for subsequent continuation training. If completion dates are unknown, use the date on the formal school-generated Certificate of Qualification.

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[26] Class A mishaps are ones with at least $1 million damage or involve a fatality.

3.5. Flying Training Requirements.

3.5.1. Every effort will be made to complete qualification training requirements within the prescribed time period with no significant break in training.

Williams, K. W., Gildea, K.M. (2014). A Review of Research Related to Unmanned Aircraft System Visual Observers. FAA Civil Aerospace Medical Institute.

"[T]here is the possibility that fatigue or boredom could affect the ability of the observer to perform the task adequately … [H]uman vision is often unreliable, even under the most ideal conditions." (K.W. Williams & Gildea, 2014, p. 2).

> [T]he real world presents a number of non-trivial factors that will influence visibility and detectability but cannot be easily included in a visual model. These factors include contrast between the target and the background, navigation and other artificial lights in day and night environments, size, orientation, visual clutter, and the location of the image on the retina … At maximum contrast, Cessna 172 and MQ-9 sized aircraft are only visible when within 10 km (6 miles) or less (K.W. Williams & Gildea, 2014, p. 2,4).

"[S]uccessful detection of the aircraft does not ensure that there is enough time to alert a pilot and for the pilot to perform a collision avoidance maneuver … (Edmunson, 2012) suggests that 'at least 12 seconds are required for a pilot to determine the need for, and perform a collision avoidance maneuver'" (p. 4).

Summarizing the research of (Baldwin, 1973) regarding forward observer research, the following conclusions were offered (p. 4):

1. "Limiting the extent of the search sector had a strong effect on the distance at which aircraft detection occurred. . .
2. The use of hand-held binoculars did not assist in detection. . .
3. Aircraft approaching at 500 ft (152 meters) above the ground level (AGL) were detected more quickly than aircraft approaching at 1,500 ft (457 meters) AGL.
4. Aircraft were detected earlier when the observer was offset from the path of flight.
5. Attempts to teach specific search pattern techniques yielded equivocal results, with training assisting some observers but hampering others."

> The body of research for this paper ". . . suggests that the ability of a human, either pilot or observer to see aircraft is problematic even under ideal visual conditions … Given these research findings, it could be argued that the use of visual observers is not very effective … For these operations, the use of visual observers is still the best way to provide an extra level of safety in regard to separation from other air traffic (p. 8).

This report makes the following recommendations (p. 10):

Operational Recommendations

1. Position VO so they have most unobstructed view of sky.
2. Ensure communications equipment is not impeded with high noise levels.
3. Monitor ATC, tower, and CTAF frequencies if operating close to airports.
4. Provided rest breaks if operating longer than one hour (10 minutes).
5. If obstacles, avoid low light or limited visibility operations.

Training Recommendations

1. VO should know cardinal directions.
2. VO provided training on scan patterns.
3. Common set of terms for all crewmembers.
4. VOs should be aware of location of airports and flight corridors

Schreiber, B., Lyon, D., Martin, E., Confer, H. (2002). Impact of Prior Flight Experience on Learning Predator UAV Operator Skills. Air Force Research Laboratory, Mesa, AZ.

This report reflects the USAF position at this time that required Predator pilots to be experienced pilots with operational duty in combat aircraft. The purpose of this report ". . . was to determine how much, if any, flying experience was necessary to successfully operate the Predator UAV" (Schreiber, et al, 2002). The objective was to evaluate how well and quickly various groups of pilots and non-pilots with varying levels of aeronautical experience, or none, could learn Predator stick-and-rudder skills. These groups included:

1. **Experienced Predator Pilots**. All had experience operating Predator UAV.
2. **Predator Selectees**. These were officers with manned aircraft flight experience and at least one tour of duty in operational aircraft. Four navigators with commercial instrument ratings were included.
3. **T-38 Graduates.** This aircraft is a supersonic airplane used for advanced pilot training for fighter or bomber aircraft.[27] These pilots had completed advanced pilot training in this aircraft and were tested just prior to graduation.
4. **T-1 Graduates.** This group had completed advanced pilot training in the T-1[28] aircraft and were tested just prior to graduation.
5. **Civilian Instrument Pilots.** This group were pilots who had completed civilian single-engine instrument courses.
6. **Civilian Private Pilots.** This group consisted of pilots who had completed the requirements for a civilian private pilot certificate, typically in a single-engine land aircraft.
7. **ROTC Students.** These students were non-pilots without flight experience.

This research measured the number of trials participants needed to achieve a certain criterion for basic maneuvering and landing tasks. This number represented the relative amount of flight

[27] The T-38 is a supersonic airplane used for advanced pilot training for fighter and bomber aircraft. See, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104569/t-38-talon.aspx.
[28] The T-1 is a twin engine jet used by the USAF for training tanker and airlift pilots, as well as navigators. See, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104542/t-1a-jayhawk.aspx.

proficiency training required of each group to satisfy a stick-and-rudder proficiency level for the Predator.

The report found that Predator pilots required the least number of training trials to achieve the desired criterion, while ROTC students without aeronautical experience required the most. Predator selectees did not perform significantly better than T-38 graduates and civilian instrument pilots. This report suggested that 150 – 200 hours of recent flight experience was sufficient to prepare a pilot to learn basic maneuvers and landing of a Predator simulator. A caveat was that this experience was obtained in an aircraft with handling similar to the Predator.

T-38 pilots performed well, which was attributed to the similarity to the Predator handling characteristics. In contrast, the T-1 pilot's performance was less than other groups with similar number of flight hours. This was attributed to the T-1 having few identifiable similarities to the Predator. Civilian instrument pilot results were felt to be suitable for Predator training. However, except for the ROTC students, civilian private pilots were found to be the least suitable. Their lack of instrument flight experience was given for this low rating.

Two propositions are drawn from this research. First, 150 – 200 flight hours of aeronautical experience is desirable. Second, an instrument rating favorably affects Predator performance.

Tobin, K.E. (1999), Piloting the USAF's UAV Fleet Pilots, Non-Rated Officers, Enlisted, or Contractors? Air University Maxwell AFB, AL.

This report is a thesis associated with studies at the USAF's School of Advanced Airpower Studies Air University. The report's objective was to examine four staffing options for operating the Predator UAS within airspace containing manned aircraft.

The alternative staffing levels included using:

1. Rated officers, which included pilots and navigators;
2. Non-rated officers;
3. Enlisted; and
4. Contractors.

At the time of this report, USAF command required the use of rated officers (pilots or navigators) for Predator operations. Citing an AFRL study[29] current UAV operators held that manned flying experience was necessary to the effective operation of the Predator. Supporting the use of rated pilots was their prior training. In fact, Predator operators rated 70% of their manned training items "absolutely necessary" and 25% "nice to have but not necessary" (Tobin p. 24).

Regarding non-rated officers, their use was not rejected. However, the report opined that their training would need to look like manned pilot training and require, at a minimum, the FAA training requirement for an instrument certificated pilot (Tobin, p. 59).

[29] Hall, E.M. and Tirre, W. C., Air Force Research Laboratory Human Effectiveness Directorate, USAF Air Vehicle Operator Training Requirements Study, (1998).

Utilizing enlisted personnel also raised the issue of training. While other USAF specialties had successfully converted officer position to enlisted, the enlisted member was provided the exact training as that received by an officer. In the case of a UAV operator, the author felt conversion to enlisted would require the enlisted airman to also go through undergraduate pilot training (UPT) before commencing UAV qualification training (Tobin, p. 58).

Using contractors was given little support by the author based on tactical or collateral issues unrelated to training or qualifications.

7. RECOMMENDATIONS

7.1 PILOT TRAINING

7.1.1 General Recommendations

A significant number of authorities propose developing UAS pilot training built on the existing aeronautical knowledge subjects and PTS (or ACS) of manned Part 61, making topic adjustments for areas with no counterpart in unmanned, and adding areas not applicable to manned but found in unmanned ("Chairman of the Joint Chiefs of Staff Instruction No. 3255.01," 2011; Gildea et al., 2015; Society of Automotive Engineers, 2016). Some even go one step further, requiring a manned pilot certificate as entry level for UAS certification ("Air Force Instruction 11-502," 2012; UND Aerospace, 2015; Air Canada Staff Instruction No. 623-001, 2014).

In contrast, there are arguments to streamline training by some operators on the proposition that their operations are very limited with respect to altitudes, airspace, and mission, and not This reflective of general training and testing. One source cautions implementing this position. The basis for that caution is that current operations may indicate limited training needs, however, future operations permitted by certification may demand broader knowledge (Gildea et al., 2015).

Overall, it cannot be ignored that current training and PTS and new ACS standards represent decades of safe operations in the NAS. In addition, manned and UAS pilots would share common body of procedures to facilitate safe integration into the NAS. For example, a review of FARs applicable to UA/UAS, found that just looking at Part 91, 73% of its provisions clearly apply, or may apply by interpretation to UAS. Only, 23% did not apply outright. (Kirk et.al. 2009). Finally, it has been proposed that utilizing existing training materials and qualified instructors supports a ready and cost effective training program transition (Gildea et al., 2015, p. 32). Even though the final product may ultimately differ from the current formula, development of UAS pilot training should begin with a sound footing in known precedent and safety. This last point is exemplified by New Zealand, which gives credit to holders of manned pilot certificates for possessing the necessary general aviation knowledge. (CAA p. 16). The FAA, with respect to sUAS, also permits expedited sUAS certification for holders of a private pilot certificate.[30]

With respect to aeronautical experience, one study suggested that ". . . 150-200 hours of recent previous flight experience is sufficient, on average, to prepare a pilot to learn to fly a high-fidelity

[30] 14 C.F.R.§107.61(d)(2) (2016).

Predator simulation—if this experience is obtained in an aircraft with handling characteristics similar to those of the Predator." (Schreiber, et al., 2002, p.37). Therefore, simulator and actual flight experience is an effective training combination (Schreiber, et al.,2002; UND, 2015).

7.1.2 Specific Recommendations

The documents considered in this literature review, as well as recommendations from SMEs, support the adoption of the following topics in future training for large UAS pilot certification (SAE 2016, Gildea, et.al. 2015, CJCSI 2011, Transport Canada TP 15263E 2014). These include, but should not be necessarily limited to, the following topics:

Pilot Training common with manned including, but not limited to:

1. Regulations and publications (Including AIM, ACs, etc.)
2. Flight performance and limitations (i.e. maneuvers including slow flight, stalls, etc.)
3. Weight and Balance
4. Meteorology/Weather
5. National Airspace System
6. Navigation
    A. Maps
    B. Enroute nav aids
    C. GPS
    D. Radar
7. Aerodynamics of flight (helicopter if applicable)
8. Power plant and systems operations
9. Communications (including ATC clearances and communication)
10. Airport operations (including lighting, patterns, etc.)
11. Crew resource management (CRM)
12. Aeronautical Decision Making (ADM)
13. Night Operations
14. Emergency
    A. System/Equipment malfunctions
    B. Aircraft and terrain avoidance
    C. Wake turbulence, icing, crosswinds
    D. Runway incursion avoidance
15. Aeromedical (i.e. drugs and alcohol, fatigue, sensory inputs, etc.)

Pilot training unique to unmanned but not in manned (VFR and IFR):

1. Lost link (L2)
2. Data Links (includes Command and Control concepts)
3. Backup systems (i.e. alternative recovery, parachutes, navigation, etc.)
4. UAS Mission Building and management
    A. Frequency spectrum
    B. Launch and recovery
5. Certificates of Authorization and waivers
6. UAS Airworthiness and Maintenance logs

7. Alternative Sense and Avoid (or detect and avoid) measures
8. Aeromedical (i.e. lack of direct sensory input from the aircraft)
9. Handovers (Handoffs)

Pilot training IFR rating[31]:

1. IFR regulations
2. ATC practices and communication
3. ATC clearances
4. IFR navigation
5. IFR approaches

The UAS community is currently very diverse and the above listing may not be exhaustive. Even the difference in helicopter versus fixed wing will demand adjustments in training. Added to this diversity are differences in weight, operating altitudes, airspeeds, propulsion, mission demands, etc. Accordingly, a recommendation that training be revisited as experience and development of UAS advances is in order.

7.1.3 Nature of Training

Another aspect of UAS pilot training deserving of future consideration is the source of that training. That is, should the training be conducted by certificated approved instructors, which is the case now under FAR Part 61 and Part 141, or accept some form of self-study? The studies and reports reviewed for this paper are divided on this issue. For example, there are those that would require retaining the traditional use of certificated or approved instructors (Mirot, 2013; CASA AC 101(0), 2002; Swedish Transport Agency's Statute Book, 2009; New Zealand AC 102-1, 2015). In contrast, a developing group would recognize formal training provided through approved Part 61 or 141-type programs, but also accept self-study (Air Canada NPA, 2015; CASA Draft AC 1001-4, 2014; FAR Part 107, 2016). A third group remained silent on the source of training (Ireland, IAA 2015; CAA, CAP 722, 2015), or refrained from taking a position on the premise the topic was considered outside the scope of their report (SAE International, 2016). Due to the complexity, diversity, and lack of supporting discussions, it is problematic to make a recommendation on the nature or source of training. This issue would be a prime subject for future research.

7.2 VISUAL OBSERVER TRAINING

Visual observers (VO) can contribute to the "see and avoid" requirement. However, their contribution appears limited for UAS, which are expected to fly BVLOS in both distance and altitude. Due to the many factors affecting an observer's ability to see and track a UAS, visual observer training for UAS operations also appears fitting (Williams & Gildea, 2014, p. 10).

If VOs are utilized, there is a need for some level of knowledge and training. Few authorities addressed VO training or certification. One recommended a course of training requiring VOs for

[31] Presumes previously identified pilot training accomplished.

UAS operations complete the private pilot level ground instruction and pass a written examination. (ERAU, p. 24).

7.2.1 Specific Recommendations

Visual observer training relating to large UASs does not appear to be as well developed or explored by research efforts as pilot training. While material is limited, the following topics have been identified for VO training (, Williams and Gildea 2014, SME):

1. Applicable knowledge areas of FAR Part 91
2. Communications (pilot, ATC, airport)
3. Human factors in ground observation (or chase plane if applicable)
4. Recommended scan patterns
5. Terminology
6. Airport and flight corridor awareness

7.3 PILOT CERTIFICATION

7.3.1 General Recommendations

A number of authorities recommend, or incorporate, flight experience (some combination of simulator and/or actual), and a performance evaluation for their pilot certification requirements(“Advisory Circular AC 102-1,” 2015, "ICAO, Circular 328, 2011", “Advisory Circular (Australia) 101-1(0),” 2002, “Chairman of the Joint Chiefs of Staff Instruction No. 3255.01,” 2011, “,” 2013, “Integration of civil unmanned aircraft systems in the National Airspace System roadmap,” 2013). Their rationale focused on the well-established and successful use of this formula with manned aircraft. One caveat is that other than small or “UAS, from 55 pounds and up, encompass a broad range of airframes (current and prospective), missions, and airspace operations. By virtue of this broad range of capabilities of UAS, some form of aircraft classification scheme may be warranted. Diverse missions and conditions of flight, weight, altitude, distance, etc. all have a potential impact on specific pilot training and pilot certification choices. Accordingly, a recommendation that aircraft classification be investigated is in order.

An instrument rating, or equivalent, with associated training and experience, was identified as important for UAS by virtue of their presumed operations BVLOS and at higher altitudes. Accordingly, a recommendation for instrument certification is indicated.

Agencies operating public aircraft are generally not required to comply with FAR Part 61 for airmen certification. However, the SME supporting this paper offers that applicants for Customs and Border Protection UAS operations are required by that agency to hold a FAR Part 61 Commercial Pilot Certificate, and an Instrument Rating. Historically, 1500 hours of flight experience has been the minimum flight experience requirement.

One last item, under the current manned certification process, candidates for certification are required to pass written and oral examinations, and a flight proficiency test. In addition, a certain amount of flight experience is required for manned certification. Nearly all authorities adopt this formula. Accordingly, written examinations or aeronautical knowledge should be required.

Consistent with most authorities, a practical flight test and demonstration of a certain level of proficiency are recommended.

7.3.2 Specific Recommendations

Most, but not all, authorities recommend more than one level of pilot certification. Benefiting from a long history of UAS operations, the Joint Chiefs of Staff has established four basic qualification levels. Each succeeding level authorizes greater responsibility, including the authority to operate under IFR conditions (CJCSI, 2012). In a recent report, two levels of certification are proposed, private and commercial, with the later authorizing operations for compensation or hire. (Gildea, et al, 2015). In contrast SAE International would have only one level, commercial. (SAE, 2016).

Balancing these authorities, it appears that a two-tiered system will achieve the desirable level of safety without generating unnecessary complexity. These recommended levels are:

1. Private UAS certificate. This could be considered as the entry level. It is recommended that this certificate permits operations in circumstances with the least risk. Restrictions may include VLOS only; limited to Class B, C, D, E and G airspace; no congested area operations; limited to VFR night and day without an instrument rating; and, no flights for compensation or hire.
2. Commercial UAS certificate. This certificate could authorize commercial operations for compensation and hire, operations in Class A airspace with an instrument rating, and operations over congested areas. Like its manned counterpart, this authorization should require greater experience and flight proficiency. Sources of this experience could be as a private UAS certificated pilot, and possibly incorporating FAR Part 107 operating experience.

Adopting a four tier certification formula[32] would introduce a level of complexity that does not appear necessary. The U.S. military's method would have additional training and requalification necessary to move to the next level. In the civil arena this would demand that a pilot add some additional courses and recertification. These subjects could easily be incorporated into the initial commercial training syllabus. In addition, recertification could be administratively cumbersome for the pilot and the FAA. If the additional course and subjects were made a part of the commercial certification process, the applicant would be qualified and certified to operate current model aircraft as well as future aircraft without the added complexity.

Precedent exists for a two-tiered formula under FAR Part 137. A private pilot can fly for a Private Agricultural Aircraft Operation.[33] However, restrictions include no compensation or hire; no operations over a congested area; or over property not owned or leased by the operator.[34] In contrast, a commercial pilot certificate is required to fly for a Commercial Agricultural Aircraft Operation and the above restrictions do not apply.[35]

[32] See JJCSI Tables 6 and 7, and BUQ levels I–IV
[33] 14 C.F.R. §137.19(b) (2016).
[34] 14 C.F.R. §137.35 (2016).
[35] 14 C.F.R. §137.19(c) (2016).

The requirement for flight experience, whether simulator or actual, may be difficult to obtain. A UAS SME observes that obtaining experience is mostly limited to working for a manufacturer or through the public use, or military, unlike manned experience where many aircraft are available for training. This would be problematic for pilots attempting to gain necessary flight experience.

However, while it is currently difficult to obtain civil UAS flight experience, options are possible. For example, a viable solution to flight training is presented by Part 141/142 programs, which are able to obtain simulator or airframe resources, and are capable of providing actual or Flight Training Devices or higher fidelity simulators for UAS (See for example, UND Aerospace, [TCO UAS Operations Course], 2015; Bridewell, 2015; and UND Aerospace [TCO MALE RPA Operations], 2015). These select courses are based on the ScanEagle and Predator simulators varying in levels of fidelity. As civil UAS operations and training mature, additional options may develop.

3. Instrument Rating. Virtually all sources indicate that an instrument rating is necessary for BVLOS operations, and in Class A airspace. Whether holding a private or commercial certificate; IFR, Class A and BVLOS operations demand this rating.

7.3.3 Visual Observers

No sources were identified that recommended actual certification.

8. DISCUSSION POINTS AND RECOMMENDATIONS FOR FUTURE RESEARCH

1. Is a single classification of 55 pounds and greater too diverse to be functional? Should classes reflect differences in:
    - A. Weight
    - B. Propulsion (battery, piston, turbine)
    - C. Airspeed
    - D. Operating Airspace
    - E. Mission (commercial, BVLOS, LOS)
    - F. Configuration (helicopter v. fixed wing)
2. While pilot training is overwhelmingly recommended, the means of conducting that training is diverse. Some entities recommend using approved or certified instructors, while others would accept self-study. While resolution is beyond the scope of this research, future efforts should explore whether some form of self-study or FAA approved student pilot program would be the most appropriate to develop the needed aeronautical knowledge, aeronautical experience, and flight proficiency to fly UAS.
3. While some sources recommend a combination of simulator and actual flight experience, future research could center upon what ratio of simulator and flight experience is necessary depending on aircraft classification, control system, mission, etc.? At this time it appears that the U.S. military classification system is the most highly developed and should be considered for civilian use.
4. Does requiring the passing of a written test, without follow up practical testing, diminish safety? Would this permit those who pass a written exam to be authorized to operate large UAS without further verification of KSA?

5. Many publications recommend some degree of unmanned flight experience, which is not expected to be easy to obtain particularly in UAS. Even simulators are in the development stage. Future research efforts should explore this aspect of pilot certification to recommend a desirable mix of actual and simulated flight experience.
6. Many authorities recommend flight checks be given to ensure compliance with KSA. Additional research should pursue details of what should be a part of flight checks, if flight checks are to be administered.
7. Control Station Management and understanding use of high levels of automation
    a. Proliferation of displayed information (pilot instrument overload)
    b. Advanced designs (automation compromising hands-on control)
    c. Control station designs not in accordance with regulations or standards. (Lack of platform continuity yielding need for operational error training)
8. While this Literature Review focuses on the pilot crewmember, there are two different skill sets for UAS aircraft: the launch and recovery component and the in-flight component. Future research should specifically examine the differences and requirements between the components and the corresponding training and certification requirements.

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10. APPENDIX F1: PILOT CERTIFICATION AND LITERATURE REVIEW

Pilot Training and Certification Literature Review

Article	Pilot Training	Pilot Certification	Visual Observer,
SAE International, ARP5707, Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations (2010; reaffirmed 2016)	1) Training Certification for commercial ops is new, so initial framework is proposed (p.2). 2) Report assumes no manned experience necessary (p.2). 3) VFR & IMC training topics (p.6). 4) Train based on UAS's: • Intended use • Op environment • A/C systems • Pilot requirements (p.7-11). 5) No classification scheme (only sUAS and Large), which could define training (p.10). 6) Manned PTS used as training basis (p.14). 7) PTS private/comm manned (p.14-16). 8) Eliminate irrelevant PTS (p.27). 9) Additional UAS specific topics p.16-17) 10)Communication UAS PTS topics-Tab. 5 (p.17-19).	1) Table 3 manned op privileges and limits. 2) Cert restrictions -Tab 8 (p.22). 3) Type ratings (p.23). 4) Cert restrictions examples: • Restricted range UAS (p.23); • Extended (BLOS) range (p.24); • Multi control station (p.27). 5) Recommendations for holders of manned cert (p.24-26). 6) No specific aircraft classification scheme (only sUAS and Large), which could define training and Cert. (p.10).	

	11) Inst rating PTS standards for UAS-Tab. 7(p.21). 12)Topics for UAS cert if manned cert held -Tab. 9(p.25-26) 13) Who will provided training is outside scope of report (i.e. self or CFI) (p.27).		
FAA CAMI, A Review of Training Requirements for Unmanned Aircraft Systems, Small Unmanned Aircraft Systems, and Manned Operations. (Gildea, Williams, and Roberts 2015) (Under review)	1 UAS specific training requirements, Tab. 2 (p.9) 2) Training topics for UAS and manned aircraft, Tab. 3 (p.11-14). 3) Probable additional training for UAS, Tab. 5 (p. 23-24). 4) Arguments for no certificate: • AC 91-57 & model ops • Ultralight experience (p. 27) 5) UAS should tightly adhere to manned training and test standards: • These vetted for safe ops over time; • Operated in manned familiar to ATC and manned pilots; • Training material available (p. 32) 6) Avoid the argument that current ops do not necessitate all KSA. Do not train for current ops but for future ops demands. (p. 37). Further Rationale:	1) Recommends pilot cert for non-sUAS (i.e. for controlled airspace and BVLOS ops) (p.44-45) 2) KSA, proficiency and PTS: • Private – with training standards (App. C); • Commercial –training standards (App. D); • Instrument- training standards (App. E).	

	• Will know how other pilots in NAS will act (p. 62-63); • Will permit pilot to expand future operations (p. 37).		
ERAU, The Future of Unmanned Aircraft System Pilot Qualification. Journal of Aviation/Aerospace Education & Research. (spring 2013)	DoD leading the way in UAS training/qual (p.22) 1) 5 categories of UAS, and 2) 4 categories of pilot cert (P.23) (CJCS, 2009).	Four levels of pilot Cert based on wt, alt, & speed. (p.23)	DoD observers are either ground or airborne, and need level 1 pilot training (p.24).
A Summary of Unmanned Aircraft Accident/Incident Data: Human Factors Implications (Williams 2004)		47% Hunter accidents caused by lack of proficiency of EP in landing and T/O. (P.2)	1) Use of both an EP and IP. 2) Chase Aircraft (p. 17).
FAA ARC, Micro Unmanned Aircraft Systems ARC Committee Final Report (2016)	ARC recommended only on-line tests to satisfy knowledge requirement. Even for Micro, ALPA, HAI etc. disagreed and recommended Part 107 training and cert be retained for micro. (p.13)		
CASA Australia, AC 101-1(0) Unmanned Aircraft and Rockets (July 2002)	1) In controlled A/S UAS to be operated iaw rules for manned A/C. *REGS* (p. 2) 2) BLOS requires chase plane or IFR clearance. (p.6) 3) **Ground Training subjects:** • Aerodynamics;	1) Initial cert demonstrate satisfactory knowledge of ground and flt ops via oral/written exam and initial flt check. (p.16) 2) Subject to periodic theoretical and practical exams. (p.16).	

	• Aircraft systems; • Performance; • Navigation; • Meteorology; • Airspace; • Rules of the air; • Communication procedures; • Emergency procedures. (p.15-16). 4) **Flt Training:** Practical and sim training, enable to demonstrate proficiency. (p.16) 5) Ground and flt Training to be given by person qualified and acceptable to CASA. (p.16)	3) Cert suspended, revoked if operator no longer maintain safe ops. (p.22) *Note: CASA 101.240 defines "large" airplane UAS as >150 kg, and Helo UAS as >100 kg. Micro as 100 grams or less and "small" as not large or micro.*	
CASA, ***DRAFT*** AC 101-1,-4,& -5, Remotely Piloted Aircraft Systems (May 2014)	**101-4**: 1) ICAO guidance for crew licensing (p.6). 2) For RP cert for over 2 kg, attend approved RPAS training program or self-study and apply to CASA direct. See CASA 101.295. (p.7)	1) **101-1**; ICAO classification hierarchy table (p.7). 2) **101-4**: For RP cert for over 2 kg.; • pass an aviation theory exam. • complete training course in ops of type RPA, and • pass a practical test on competency of RPA. (p.8) 3) RPA categories: • micro- 100 gr or less; small- 2 kg and below; • medium- 2 – 150 kg; • large->150 kg. (p. 9)	1) CASA not plan to cert VO or Sensor Operators (p.10) 2) VOs should complete training appropriate to RPV (p. 17)

		4) Existing cert accepted until CASR 101 completed to take into account ICAO SARPs. (p.9). **5) 101-5**: • UAS Operator's Cert. will vary depending on category and intended ops (p. 9). • Will not apply to <2kg, which is handled under 101-1 (p. 9).	
CAA New Zealand, AC 102-1, Unmanned Aircraft – Operator Certification (2015)	1) Two key areas of knowledge required for licensing: -general aviation knowledge and -specific knowledge to RPA (handling). 2) Licensing PIC includes: - Part 61 pilot cert; -acceptable foreign RPA license; -a pass in private pilot air law exam; -flight radio exam; 5 hours air experience; -cert issued by part 141 org, including pass in aviation law and operating competency and radio competency. (p. 16) 3) Specific knowledge can be demonstrated by –MFNZ wins badge for UA. –Cert of training from manufacturer; -cert of training from part 141	1) Aircraft weight determines compliance standards: -**Small UAS** (<25kg); -**Medium UAS** (25-150 kg) -**Large UAS** >150 kg (p. 5) 2) Pilot cert mandatory for >25 kg, but may go down to 15 kg. (p. 7).	1)Observers/support crew not impaired visually or aurally in any way (glasses ok). (p.17) 2. Demonstrate competency with: • communication methods; • action if communication fails; • methods of setting up sectors for reporting to PIC; • emergencies (p. 17).

	organization authorized to conduct UAS training.(p.17)		
The Swedish Transport Agency's regulations on unmanned aircraft systems (UAS) (TSFS 2009:88, 2009)	1) Kinetic energy one facet of UAS classification (Ch 2, §1) 2) Pilot must have knowledge of aviation system and flight safety standards iaw regulations for private pilot's license training course. (Ch. 3, §7) 3) Pilot shall successfully pass approved skill test. (Ch.3, §7) 4) Approved Inst Rating required for IFR flight.(Ch. 5, §21)		
Ireland (IAA), Small Unmanned Aircraft (Drones) and Rockets Order Statutory Instrument 563 (S.I No. 563, 2015)	1) Small UAS up to 150 KG. 2) UAS 25 – 150 kg not to be flown without written permission of IAA §2, §8 and §9.		
Canada, Staff Instruction No. 623-001, Review and Processing of an Application for a SFOC for the operation of UAV Systems. (2014)	1) Pilot training based on TP 15263E for small UAV. (4.2.3) 2) For large UAV, additional knowledge, skill and proficiency will be required. (4.1.4) 3) Pilot training should not differ significantly from manned aviation. Fundamental knowledge, experience, skills are basic to safe environment for all airspace users (4.2.2)	Special Flight Operations Certificate (SFOC) required for all operation at this time. (1.1)	Visual observer limitations and requirements set out.(4.1.3)
Canada, Knowledge Requirements for Pilots of Unmanned	1) Provides best practices for organizations and individuals providing UAS training. (p. iv)		

Air Vehicle Systems.(TP 15263E) (2014)	2) Mandatory examination subjects to be trained for set out, along with related subjects. (p. v) 3) Table of Specific training knowledge areas and sample learning objectives set out. (p.1-35)		
United Kingdom (CAA), Unmanned Aircraft System Operations in UK Airspace-Guidance (CAP 722, 2015)	1) Requirements for licensing and training not yet developed. 2) These will be determined by ICAO standards and EASA regulations. (Ch. 4, §4.3 and 4.4)		
Joint Unmanned Aircraft Systems Minimum Training Standards. CJCSI 3255.01. (2009; current to 2012)	1) Purpose is min. training standards for UAS. (p.1). 2) Must complete training similar to civil. Training elements include: • Weather • Aerodynamics • Human Factors • Operational risk management • Flt regulations for A/S • See encl. A (p.4) Approved flt training in flight/simulators (p.4-5). Encl. A lists as general knowledge: • Airspace and operating regulations • ATC rules, procedures, regulations • Aerodynamics	Will certificate after performance checks for ground and flight ops.p.5) Shall remain proficient and currency via periodic exams (p.5)	

	• A/C systems & emer. procedures • Performance (weight/Bal) • Navigation • Meteorology • Comm. procedures • Mission prep/planning (p.A-2) Additional with bigger A/C: • Instrument training (A-8).		
USA, TC 3-04.61 (TC 1-600), Unmanned Aircraft System Commander's Guide and Aircrew Training Manual (2014)	1) All UAC to receive training and demonstrate working knowledge of topics under para. 3-32. 2) Flight training and proficiency required para. 3-33. 3) Based on Hunter (725 lbs) and shadow (375 lbs) UAS, (App. A & B). 4) Aircraft operators, and payload operators, must demonstrate understanding in areas contained in Para. 3-31. These include regulations; VFR minimums, weight & Bal, limitations, emergencies, medical, aerodynamics, night vision. 5) Flt eval. may also be required. (p.3-10). 6) To qualify as UA crewmember must have completed academic training in topics of para. 3-32;		1) Payload and mission commander must also pass evaluations. (p.3-3) 2) Demonstrate proficiency with mission tasks. (p. 2-7)

	have flight training; and demonstrated proficiency. (para. 2-104) 7) Based on accident history, crew coordination stressed.(p.4-1)		
FAA, AC 107-2, Small Unmanned Aircraft Systems (sUAS) (2016)	1) Applies to sUAS under new part 107. (para 1.1) 2) To obtain remote pilot certificate, applicant must: • Pass initial test (Para. 6.6.1) • If part 61 certificated, complete an online training course (para 6.6.1.1) 3)Recurrent testing required every 24 months (para 6.6.2) 4) Knowledge areas for tests are appendix B. 5) No flight proficiency or flt experience due to limited authorized operating areas (81 Fed. Reg. 42160). 6) Self-study authorized (para. 6.6)	Established remote pilot certificate with the passing or initial test, or if certificated and current under part 61, with completion of online course. (para 6.6.1 and 6.6.1.1)	
Unmanned Aerial Vehicle Operator Qualifications (Weeks, AFRL 2000)	1) US Army Hunter and USMC Pioneer IP can be enlisted and no manned A/C experience. (p. 4) 2) Due to lower alt allowing ops in Restricted A/S. (p. *v*). Mission commander must be rated pilot (p.4). 3) USAF Predator and Global Hawk in class A require	1) USAF requires instrument rating due to ops in Class A airspace. (p.11) 2)Issue: HF research needed to support programs similar to manned including: • Physical Standards • Simulator training	1) USMC mission commanders must be pilots because mission requires understanding of air environment and ops near manned A/C. (p.10)

	rated pilot or navigator with FAA cert and Instrument rating. (p. *v* & 7,9) Difference is operations under FARs in NAS.	• CRM (p.12) 3) TABLE 1: Pilot qualifications and special training. (p.13)	
FAA, Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap (2013)	UAS training will mirror manned training standards to maximum extent possible. (p. 28)		Training will account for all roles, including visual observers. (p. 28)
Medium Altitude Long Endurance UAS Initial Competency Sets UND (2011) & TCO (Ed. 5) (2015)	Entry level requirements for MALE is commercial & Instrument rating (p.2). Manned training therefore prerequisite.	Commercial certificate & Instrument rating. (p.2)	
UND, UAS Operations Course TCO (Ed. 4), for AVIT 399. (2015)	1) Course based on Scan Eagle airframe, which according to SME straddles the weight between sUAS and large (55lbs). 2) Enrollment requires training courses and certification for commercial SE/Multi airplane be completed. (p.7) 3) SME recommended minimum of Commercial SE and Inst, training.	Requires Commercial cert with SE/ME ratings in airplane. (p. 7). Requires stage check completion (p. 5+).	
Enhancing Remotely Piloted Vehicle Training (AIAA Infotech@Aerospace 2011)	1)Benefits of use of sim vs. manned (p.3) 2)Benefits/drawbacks of real RPV training vs. simulation (p.4) 3) Focus of report is on simulator vs inflight.		

Training Interventions to Reduce Air Force Predator Mishaps (Nullmeyer, et.al. AFRL 2009)	1)2004 report-67% predator mishaps human error. (p. 2) 2) Mishap rates 2004-2007 were less than one half 1/2 1997-2003 rate, 11 and 21, respectively. See Fig. 1 (p.5). 3) Training-related problem areas were: • Situation awareness & maintenance; • Task management; • Decisional making training; • Crew coordination (p.3). 4) Based on findings, crew resource training developed for both initial and continuing crew training.		
Small UAS Aircraft Systems Training (AFI 11-502, Vol 1, 2012).	1) USAF small UAS includes aircraft up to 1320 lbs.(para. 1.1) and Fig. A2.1) 2) Initial Training requirements: • Academic training • Written Exam iaw AFI 11-502, Vol 2 • Ground training • Flt training (p. 14). 3) Annual CRM training required (p.17).	UAS classification, DOD UAS groups chart, Fig. A2.1(p.26)	
FAA, Operation and Certification of Small Unmanned Aircraft	1) Flt proficiency and Aeronautical experience not required. (p.42160). 2) Rationale:		1) VO not required to have cert. (p. 42098). 2) Rationale:

Systems; Final Rule. (Fed. Reg. June 2016).	- Operate in confined area; - Low weight, very low risk; - easily terminate flight (p.42160) 3) No specific training imposed, including formal training (p. 42161). 4) Initial and recurrent tests deem adequate. 5) FAA proposed that Competency be addressed via §44709 and §107.7(b) reexam authority. (p 42161) 6) Training by self-study, training seminars, or online; no instructor endorsement required. (p.42162). 7) Initial Test will cover 11 areas of knowledge (see p.42164). Recurrent test covers 7 of previous 11 areas (see p.42164). FAA added maintenance and inspection areas via comments (p.42168) 8) Areas such as principles of flight, aerodynamics & electrical theory not considered critical for safe UAS ops (p. 42168).		-optional crewmember, not mandatory; - limited to communicating what VO is seeing; - not permitted independent judgment, or - no operational control (p. 42100-101). 3) May use comm.-assisting device, such as radio (p. 42098).
Unmanned Aircraft Systems (UAS), (ICAO Circular 328-AN/190, 2011)	Same training standards for manned and UAS pilots: • Air law • Flight performance • Planning and loading • Human performance • Meteorology • Navigation	1) For international flight pilot must be licensed and aircraft registered from same country. 2) Certification requires: • Flight instruction • Demonstration of skill • A level of experience • Licensing	

	• Operational procedures • Principles of flight • Radiotelephone	3) UAS pilot and crewmembers must be trained and licensed iaw ICAO Annex 1.	
A Review of Research Related to Unmanned Aircraft System Visual Observers (Williams and Gildea, FAA, 2014)			1) Possible fatigue/boredom affect ability of observe. (p. 2) 2) Human vision often unreliable, even in ideal conditions. (p. 2) 3) Non-trivial factors influence visibility. Factors include background, navigation/artificial lights in day and night environments, size, orientation, visual clutter, and location on the retina. (p. 2) 4) Detection of aircraft does not ensure collision avoidance. Need at least 12 seconds for pilot to see need and perform collision avoidance maneuver. (p. 5) 5) Research on forward observer conclusions: • Limiting search sector had positive effect. • Binoculars did not assist. • Lower aircraft detected quicker than high. • Detection earlier when position offset. • Teaching search patterns limited results. (p 4) 6) Ability of pilot or VO to see aircraft problematic. (p. 8)

			7) Operational recommendations: • Position VO so unobstructed view of sky. • Ensure communications equipment is OK. • Monitor ATC, etc. frequencies. • Provide VO rest breaks. • If obstacles, avoid low light operations. (p. 10) 8) Training Recommendations: • VO know cardinal directions. • VO training on scan patterns. • Common terms for all members. • VO knowledgeable of location of airports and flight corridors. (p. 10)
FAA, Order 8900.1, Flight Standards Information Management System (2016)	1) Pursuant to Part 107, applicant not holding a current Part 61 airman certificate must have sufficient training to pass a test administered at an FAA-approved test center. Test covers subjects contained in Ch. 3, Para. 16-3-1-13A. 2) Definitions and acronyms describing differences between US and manned aircraft in Ch. 1, para. 16-1-2-1.		

Impact of Prior Flight Experience on Learning Predator UAV Operator Skills (Schreiber, Lyon, Martin and Confer, AFRL 2002)	1) USAF required Predator pilots to have completed flight training and have operations duty in combat aircraft. 2) Evaluated 7 groups with varying amounts of aeronautical experience, including none, to learn Predator stick-and-rudder skills. 3) Found 150-200 flight hours of experience desirable. 4) Also found an instrument rating favorably affects Predator performance.		
Piloting the USAF's UAV Fleet Pilots, Non-Rated Officers, Enlisted, or Contractors? Tobin, 1999)	1) USAF required use of rated pilots, or navigators, for Predator operations. 2) Study evaluated the use of Non-Rated officers, enlisted and contractors for Predator operations, and found training for these would need to go through manned pilot training, including the training for an instrument rated pilot.		

11. APPENDIX F2: COPY OF MATERIAL CONTAINED IN APPENDIX B OF FAA ADVISORY CIRCULAR 107-2 (2016)

THE FOLOWING IS A COPY OF MATERIAL CONTAINED IN APPENDIX B OF AC 107-2 (2016)

APPENDIX B. SUPPLEMENTAL OPERATIONAL INFORMATION

B.1 Determining Operational Performance. The manufacturer may provide operational and performance information that contains the operational performance data for the aircraft such as data pertaining to takeoff, climb, range, endurance, descent, and landing. To be able to make practical use of the aircraft's capabilities and limitations, it is essential to understand the significance of the operational data. The use of this data in flying operations is essential for safe and efficient operation. It should be emphasized that the manufacturers' information regarding performance data is not standardized. If manufacturer-published performance data is unavailable, it is advisable to seek out performance data that may have already been determined and published by other users of the same sUAS manufacturer model and use that data as a starting point.

B.2 sUAS Loading and Its Effects on Performance.

B.2.1 Weight and Balance (W&B). Before any flight, the remote PIC should verify the aircraft is correctly loaded by determining the W&B condition of the aircraft. An aircraft's W&B restrictions established by the manufacturer or the builder should be closely followed. Compliance with the manufacturer's W&B limits is critical to flight safety. The remote PIC must consider the consequences of an overweight aircraft if an emergency condition arises.

- Although a maximum gross takeoff weight may be specified, the aircraft may not always safely take off with this load under all conditions. Conditions that affect takeoff and climb performance, such as high elevations, high air temperatures, and high humidity (high density altitudes) may require a reduction in weight before flight is attempted. Other factors to consider prior to takeoff are runway/launch area length, surface, slope, surface wind, and the presence of obstacles. These factors may require a reduction in weight prior to flight.

- Weight changes during flight also have a direct effect on aircraft performance. Fuel burn is the most common weight change that takes place during flight. As fuel is used, the aircraft becomes lighter and performance is improved, but this could have a negative effect on balance. In UAS operations, weight change during flight may occur when expendable items are used on board (e.g., a jettisonable load).

B.2.2 Balance, Stability, and Center of Gravity (CG). Adverse balance conditions (i.e., weight distribution) may affect flight characteristics in much the same manner as those mentioned for an excess weight condition. Limits for the location of the CG may be established by the manufacturer. The CG is not a fixed point marked on the aircraft; its location depends on the distribution of aircraft weight. As variable load items are shifted or expended, there may be a resultant shift in CG location. The remote PIC should determine how the CG will shift and the resultant effects on the aircraft. If the CG is not within the allowable limits after loading or do not remain within the allowable limits for safe flight, it will be necessary to relocate or shed some weight before flight is attempted.

B.3 Sources of Weather Information for Small UA Operations. Remote PICs are encouraged to obtain weather information prior to flight from Flight Service by using the Web site www.1800wxbrief.com. Remote PICs can create a free account in order to use the briefing service. While Flight Service does offer a telephone-based service, it is intended for manned aircraft pilots only.

B.3.1 National Weather Service (NWS). Remote PICs are also encouraged to visit the NWS's Aviation Weather Center (AWC) at www.aviationweather.gov. This free, Web-based service does not require registration and offers all of the weather products important to a remote PIC, such as Aviation Routine Weather Reports (METAR) and Terminal Aerodrome Forecast (TAF). While reviewing the weather for your intended operation, it is also critical that the remote PIC review any temporary flight restrictions (TFR) at the FAA's TFR Web site, which can be found at http://tfr.faa.gov.

B.4 Weather and the Effects on Performance. Weather is an important factor that influences aircraft performance and flying safety. Atmospheric pressure and density, wind, and uneven surface heating are factors that affect sUAS performance and must be considered prior to flight.

B.4.1 Wind. Wind speed and direction are important as they affect takeoff, landing, and cruise of flight operations. Geological features, trees, structures, and other anomalies can affect the wind direction and speed close to the ground. In particular, ground topography, trees, and buildings can break up the flow of the wind and create wind gusts that change rapidly in direction and speed. The remote PIC should be vigilant when operating UAS near large buildings or other man-made structures and natural obstructions, such as mountains, bluffs, or canyons. The intensity of the turbulence associated with ground obstructions depends on the size of the obstacle and the primary velocity of the wind. This same condition is even more noticeable when flying in mountainous regions. While the wind flows smoothly up the windward side of the mountain and the upward currents help to carry an aircraft over the peak of the mountain, the wind on the leeward side does not act in a similar manner. As the air flows down the leeward side of the mountain, the air follows the contour of the terrain and is increasingly turbulent. This tends to push an aircraft into the side of a mountain. The stronger the wind, the greater the downward pressure and turbulence become. Due to the effect terrain has on the wind in valleys or canyons, downdrafts can be severe.

B.4.2 Surface Heat. Different surfaces radiate heat in varying amounts. Plowed ground, rocks, sand, and barren land give off a larger amount of heat, whereas water, trees, and other areas of vegetation tend to absorb and retain heat. The resulting uneven heating of the air creates small areas of local circulation called convective currents, which creates bumpy, turbulent air. Convective currents, with their rising and sinking air can adversely affect the controllability of the small UA.

B.5 Battery Fires. Lithium-based batteries are highly flammable and capable of ignition. A battery fire could cause an in-flight emergency by causing a LOC of the small UA. Lithium battery fires can be caused when a battery short circuits, is improperly charged, is heated to extreme temperatures, is damaged as a result of a crash, is mishandled, or is simply defective. The remote PIC should consider following the manufacturer's recommendations, when available, to help ensure safe battery handling and usage.

B.6 sUAS Frequency Utilization. An sUAS typically uses radio frequencies (RF) for the communication link between the CS and the small UA.

B.6.1 Frequency spectrum (RF) Basics. The 2.4 GHz and 5.8 GHz systems are the unlicensed band RFs that most sUAS use for the connection between the CS and the small UA. Note the frequencies are also used for computer wireless networks and the interference can cause problems when operating a UA in an area (e.g., dense housing and office buildings) that has many wireless signals. LOC and flyaways are some of the reported problems with sUAS frequency implications.

- To avoid frequency interference, many modern sUAS operate using a 5.8 GHz system to control the small UA and a 2.4 GHz system to transmit video and photos to the ground. Consult the sUAS operating manual and manufacturers recommended procedures before conducting sUAS operations.

- It should be noted that both RF bands (2.4 GHz and 5.8 GHz) are considered line of sight and the command and control link between the CS and the small UA will not work properly when barriers are between the CS and the UA. Part 107 requires the remote PIC or person manipulating the controls to be able to see the UA at all times, which should also help prevent obstructions from interfering with the line of sight frequency spectrum.

B.6.2 Spectrum Authorization. Frequency spectrum used for small UA operations are regulated by the Federal Communications Commission (FCC). Radio transmissions, such as those used to control a UA and to downlink real-time video, must use frequency bands that are approved for use by the operating agency. The FCC authorizes civil operations. Some operating frequencies are unlicensed and can be used freely (e.g., 900 MHz, 2.4 GHz, and 5.8 GHz) without FCC approval. All other frequencies require a user-specific license for all civil users, except federal agencies, to be obtained from the FCC. For further information, visit https://www.fcc.gov/licensing-databases/licensing.

12. APPENDIX F3: PILOT REQUIREMENTS FOR UNMANNED AIR VEHICLES (CANADA) TP 15263E

AIR LAW

SECTION 1: AIR LAW AND PROCEDURES

Knowledge Area	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
CARs Some Canadian Aviation Regulations (CARs) refer to their associated standards. Questions from the CARs may test knowledge from the regulation or the standard. **PART I – GENERAL PROVISIONS** 101 – INTERPRETATION 101.01 Interpretation (Definitions) 3 – ADMINISTRATION AND COMPLIANCE COMPLIANCE 103.2 Inspection of Aircraft, Requests for Production of Documents and Prohibitions 103.3 Return of Canadian Aviation Documents 103.4 Record Keeping	• State who may demand to inspect aviation documents. • State the definition of “operator” with respect to aircraft operations and the holder of a SFOC. • Define common terms used in UAV system operations such as: command and control link, pilot, operator, handover, lost link.
PART III – AERODROMES AND AIRPORTS 300 – INTERPRETATION 300.01 Interpretation 301 – AERODROMES	• Explain that persons, vehicles, obstacles and operations at aerodromes are subject to the approval of the aerodrome operator and the appropriate air traffic control unit.

301.01 Application 301.8 Prohibitions 301.9 Fire Prevention 302 – AIRPORTS 302.10 Prohibitions 302.11 Fire Prevention	
PART IV - PERSONNEL LICENSING AND TRAINING (*) 421.** Requirements for UAV Pilots – Small UAVs Restricted to VLOS – Age (18) – Medical fitness (Cat 4, valid for 60 months) – Knowledge (this document) – Experience	• State the minimum age and recommended best practices for medical fitness of UAV pilots.
PART VI – GENERAL OPERATING AND FLIGHT RULES 600 – INTERPRETATION 600.01 Interpretation 601 – AIRSPACE AIRSPACE STRUCTURE, CLASSIFICATION AND USE 601.1 Airspace Structure 601.2 Airspace Classification 601.3 Transponder Airspace 601.4 IFR or VFR Flight in Class F Special Use Restricted Airspace or Class F Special Use Advisory Airspace (*) 601.08 VFR Flight in Class C Airspace	• Describe the horizontal and vertical limits of the various classifications of airspace, control areas, special use airspace. • Describe the communications required with Air Traffic control (ATC) for operating a small UAV within VLOS in class C or D airspace. • Describe the circumstances when a small UAV is permitted to be operated in the vicinity of a forest fire. • Describe the process required to legally use a LIDAR (Light Detection and Ranging) on a small UAV.

(*) 601.09 VFR Flight in Class D Airspace AIRCRAFT OPERATING RESTRICTIONS AND HAZARDS TO AVIATION SAFETY 601.14 Interpretation 601.15 Forest Fire Aircraft Operating Restrictions 601.16 Issuance of NOTAM for Forest Fire 601.17 Exceptions 601.20 Projection of Directed Bright Light Source at an Aircraft 601.21 Requirement for Notification 601.22 Requirement for Pilot-in-command	

602 – OPERATING AND FLIGHT RULES GENERAL Reckless or Negligent Operation of Aircraft Fitness of Flight Crew Members Alcohol or Drugs – Crew Members (*) 602.05 Compliance with Instructions 602.07 Aircraft Operating Limitations (*) 602.08 Portable Electronic Devices 602.10 Starting and Ground Running of Aircraft Engines 602.11 Aircraft Icing 602.12 Overflight of Built-up Areas or Open-air Assemblies of Persons during Take-offs, Approaches and Landings (as revised) (*) 602.13 Take-offs, Approaches and Landing within Built-up Areas of Cities and Towns (as revised) 602.14 Minimum Altitudes and Distances 602.15 Permissible Low Altitude Flight (*) 602.19 Right-of-Way – General 602.20 Right-of-Way – Aircraft Manoeuvring on Water	• Recall the prohibitions against reckless operations. • Explain that pilots have a duty to prevent hazards or injury to others. • Recall that all crew members must comply with the instructions of the pilot in command. • State that UAVs may not be left unattended if the engine or motor could start. • State the minimum distances from people not involved in the UAV operation. • Explain which aircraft has the right of way with respect to small UAVs and other aircraft. • Describe the requirements for communications between the pilot-in-command and visual observers. • List the operational and emergency equipment that must be available to UAV crew members (checklists, operating manual, fire extinguishers, etc.). • State that pilots of small UAVs shall avoid flying the UAV in the traffic pattern at an aerodrome. • Recall the minimum conditions for VFR flight in uncontrolled airspace.

602.21 Avoidance of Collision 602.22 Towing 602.23 Dropping of Objects 602.24 Formation Flight 602.27 Aerobatic Manoeuvres – Prohibited Areas and Flight 602.30 Fuel Dumping 602.31 Compliance with Air Traffic Control Instructions and Clearances 602.32 Airspeed Limitations (*) 602.40 Landing at or Take-off from an Aerodrome at Night 602.41 Unmanned Air Vehicles (*) 602.** UAV Visual Observers (*) 602.** UAV Lost Link OPERATIONAL AND EMERGENCY EQUIPMENT REQUIREMENTS 602.58 Prohibition 602.59 Equipment Standards (*) 602.** Requirements for Small UAVs FLIGHT PREPARATION, FLIGHT PLANS & FLIGHT ITINERARIES 602.70 Interpretation – Definitions 602.71 Pre-flight Information 602.72 Weather Information PRE-FLIGHT AND FUEL REQUIREMENTS 602.86 Carry-on Baggage, Equipment and Cargo 602.87 Crew Member Instructions	• Describe the actions to be taken in the event of a two-way radiocommunications failure when flying in class C and D airspace.

OPERATION AT OR IN THE VICINITY OF AN AERODROME (*) 602.96 General 602.97 VFR and IFR Aircraft Operations at Uncontrolled Aerodromes within a Mandatory Frequency (MF) Area 602.98 General MF Reporting Requirements 602.99 MF Reporting Procedures before Entering Manoeuvring Area 602.100 MF Reporting Procedures on Departure 602.101 MF Reporting Procedures on Arrival 602.102 MF Reporting Procedures when Flying Continuous Circuits 602.103 Reporting Procedures when Flying Through an MF Area VISUAL FLIGHT RULES 602.114 Minimum Visual Meteorological Conditions for VFR Flight in Controlled Airspace 602.115 Minimum Visual Meteorological Conditions for VFR Flight in Uncontrolled Airspace 602.117 Special VFR Flight RADIOCOMMUNICATIONS 602.136 Continuous Listening Watch 602.138 Two-way Radiocommunication Failure in VFR Flight	
603 – SPECIAL FLIGHT OPERATIONS MISCELLANEOUS SPECIAL FLIGHT OPERATIONS Application Certification Requirements	• Recall the requirements for an SFOC when operating a UAV. • Interpret the contents of Operator Certificate (Air Operator Certificate, Flight Training Unit Operator Certificate, Private Operator Certificate, Special Flight Operations Certificate)

603.67 Issuance of a Special Flight Operations Certificate 603.68 Contents of a SFOC	• State that the declarations made in the application are binding under the SFOC.
605 – AIRCRAFT REQUIREMENTS GENERAL 605.04 Availability of Aircraft Flight Manual 605.06 Aircraft Equipment Standards and Serviceability 605.08 Unserviceable and Removed Equipment – General (*) 605.09 Unserviceable and Removed Equipment – Aircraft with a Minimum Equipment List 605.10 Unserviceable and Removed Equipment – Aircraft without a Minimum Equipment List AIRCRAFT EQUIPMENT REQUIREMENTS (*) 605.30 De-icing or Anti-icing Equipment 605.35 Transponder and Automatic Pressure Altitude Reporting Equipment (*) 605.38 ELT (*) 605.** System Capability Requirements for UAVs (*) 605.** Radio Frequency Interference - UAV AIRCRAFT MAINTENANCE REQUIREMENTS (*) 605.85 Maintenance Release and Elementary Work (*) 605.88 Inspection After Abnormal Occurrences TECHNICAL RECORDS (*) 605.92 Requirement to Keep Technical Records 605.93 Technical Records – General	• State that a system may not be operated with unserviceable equipment that is otherwise required by the manufacturer. • State the minimum capability requirements for UAV systems. • Recall that aircraft must have a transponder in transponder airspace, unless approved by ATC. • State the requirements to keep technical records. • Explain why UAVs must never be flown with ELTs on board. • State the required content of a UAV Journey Log. • Give examples of Elementary Work that can be accomplished by the UAV crew. • Explain the lighting requirements for VLOS UAV night operations.

605.94 Journey Log Requirements (*) 605.95 Journey Log 605.97 Transfer of Records	
606 – MISCELLANEOUS Munitions of War Liability Insurance	

New CAR Subpart – UAV OPERATIONS new– SMALL UAV - VLOS OPERATIONS GENERAL (*) new Application FLIGHT OPERATIONS (*) new Operating Instructions (*) new Operational Control (*) new Operational Flight Plan (*) new Maintenance of Aircraft (*) new VFR Flight Minimum Flight Visibility – Uncontrolled Airspace (*) new Built-up Areas and Aerial Work Zones PERSONNEL REQUIREMENTS (*) new Designation of Pilot-in-command (*) new Flight Crew Member Qualifications TRAINING (*) new Training Program (*) new Training and Qualification Record MANUALS (*) new Distribution of Company Operations Manual (*) new Standard Operating Procedures	• Explain that an Operating Certificate (SFOC) is required for commercial operations. • Describe the recommended best practices for an Operational Flight Plan. • Identify circumstances that require an Aerial Work Zone Plan. • Explain why there is always a pilot-in-command when a UAV is in flight. • Explain that a crew member must complete the company training program before being assigned duties. • Explain that operations must be conducted in accordance with the Company Operations Manual. • Give examples of the information found in a Company Operations Manual. • Identify the documents that must be accessible to the flight crew during operations
TRANSPORTATION SAFETY BOARD OF CANADA (TSB) – (TC AIM - GEN 3.0)	• State that the purpose of accident investigation is to prevent recurrence. • State the types of accidents and incidents that must be reported to the Transportation Safety Board of Canada. • State that accident sites must not be disturbed except to

	protect lives or prevent further damage.
AIR TRAFFIC SERVICES AND PROCEDURES 1 Air Traffic and Advisory Services 2 Flight Service Stations, Flight Information Centres 3 Communication Procedures 5 ATC Clearances/Instructions/ Mandatory Readback Procedures 7 Aerodrome Operations – Controlled 8 Aerodrome Operations – Uncontrolled 9 Mandatory and Aerodrome Traffic Frequencies	• Determine who provides coordination or air traffic control service for the airspace being used (if applicable). • Determine the MF/ATF and enroute frequencies (if applicable) for the operating area. • Explain any traffic patterns of passing aircraft. • Anticipate patterns of manned aircraft sharing the airspace. • Determine the aeronautical radio frequencies in use for this airspace. • Use appropriate phraseology in radio communication. • Recognize clearances and instructions aimed at other aircraft. • Interpret the CFS with respect to airspace and location procedures.
OTHER LEGISLATION 1 Air Transportation Regulations (sections 3 and 7) 2 Canada Labour Code Part II - Occupational Safety & Health, Employee Rights & Duties (sections 126, 127 and 128)	• Explain that both the employer and employee are responsible for safe working conditions. • State that employees shall report unsafe working conditions to their supervisors, and may refuse dangerous work unless that refusal puts others at risk.

NAVIGATION

SECTION 2: NAVIGATION AND NAVIGATION AIDS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
DEFINITIONS 1 Meridian 2 Prime Meridian 3 Longitude 4 Equator 5 Latitude 6 Variation 7 Deviation 8 Track 9 Heading 10 Airspeed 11 Ground Speed 12 Air Position 13 Ground Position 14 Bearing 15 Wind Velocity 16 Drift	
MAPS AND CHARTS 1 VTA 2 VNC 3 Topographical Symbols 4 Elevation and Contours (Relief) 5 Aeronautical Information 6 Scale and Units of Measurement 7 Locating Position by Latitude and Longitude	• Describe the possible effects of mixing map projections and datums. • Give examples of the different projections and datums that can be used in a ground control station. • Locate your positions on an aeronautical chart. • Interpret topographical information from aeronautical charts. • Interpret aeronautical information from aeronautical charts.

8 GIS Datum, WGS84 Datum, other datums	• Determine the validity/currency of aeronautical charts.
TIME AND LONGITUDE 1 24 Hour System 2 Conversion of UTC to Local and Vice Versa 3 Sunrise and sunset	• Convert UTC to local time & vice versa. • Determine local time of sunrise/sunset.
PILOT NAVIGATION 1 Use of Aeronautical Charts 2 Measurement of Track and Distance 3 Map Reading 4 Ground Speed Checks and E.T.A. Revisions 5 Variation 6 True Track/Magnetic Track 7 True/Magnetic/ Headings 8 True Airspeed/Ground Speed (TAS, G/S)	• Explain how to use the software to determine position and plot a track. • Using simple mental calculations, estimate, crab angles while tracking in a cross wind. • Use appropriate average winds and airspeeds for navigation. • Explain the difference between track and heading. • Explain the difference between true and magnetic heading. • Describe location and activities referring to appropriate aeronautical charts and aeronautical reference points. • Identify the class of airspace and proximity of aerodromes to the operating location using aeronautical charts. • Verify that the map loaded in the control station uses the same reference as the mission plan, aircraft navigation system and tracking antenna if applicable. • Describe the possible problems if a visual observer is not correctly oriented.
TRIANGLE OF VELOCITIES 1 True Airspeed and Heading 2 Wind Velocity 3 Ground Speed and Track	• Given wind speed and air speed, estimate ground speed and distance covered.

PRE-FLIGHT PREPARATION 1 Factors Affecting Choice of Route 2 Navigation Plan 3 NOTAM 4 Fuel Requirements 5 Weight and Balance 6 Use of Canada Flight Supplement 7 Documents to be available at the GCS 8 Aircraft Serviceability, configuration	• Describe the factors that will influence your choice of route (built-up areas, restricted airspace, property lines, etc.). • Obtain NOTAMS, and interpret them. • Identify the NOTAM issuing office and describe the contents of a NOTAM. • Demonstrate how to use the CFS to determine type and radius of airspace, frequencies, aerodrome operator contact information, nearest FIC/ATS unit for emergency contact, etc. • Determine the contact information for EMS and local authorities. • List the documents that must be available at the Ground Control Station. • Determine the serviceability of o Aircraft. o Control Station. o RF equipment. o Launch and recovery equipment. o Software loads and versions. o Correct databases (e.g. maps) loaded. o Batteries (capacity (i.e. due to age), history, charge status). • Demonstrate how to verify the flight plan data file is correct and complete in the autopilot.
RADIO THEORY 1 Characteristics of Low/High and Very & Ultra High Frequency Radio Waves 2 Frequency Bands Used in Navigation and Communication 3 Operational Limitations	• Explain the characteristics of radio wave propogation. • Describe the factors that affect radio reception range. • Identify sources of RF interference. • Describe how to assess an RF environment. • Explain the function of RF spectrum analyzer.

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS/GPS) 1 Principles of Operation 2 Serviceability Checks	• Describe how GNSS systems may be enhanced by augmentation systems. • Provide an example of how DGPS might be used for landing. • Discuss the significance of GPS loss in flight. • Describe what can affect GPS performance (number of satellites, weather).
OTHER RADIO AND RADAR AIDS – BASIC PRINCIPLES AND USE 1 Transponder 2 Locator devices	• Describe the function of an ATC RADAR transponder. • Describe the function of ADS-B.

METEOROLOGY

SECTION 3: METEOROLOGY

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
THE EARTH'S ATMOSPHERE 1 Composition and Physical Properties 2 Vertical Structures 3 The Standard Atmosphere 4 Density and Pressure 5 Mobility 6 Expansion and Compression	• Describe the physical composition of the atmosphere. • Explain the change in weather with expansion of air. • Define Standard Atmosphere.
ATMOSPHERIC PRESSURE 1 Pressure Measurements 2 Station Pressure 3 Sea Level Pressure 4 Pressure System and their Variations 5 Effects of Temperature 6 Isobars 7 Horizontal Pressure Differences	• Define atmospheric pressure, station pressure, sea level pressure. • Explain the atmospheric pressure variation with height. • Explain movement of air masses as resulting from high and low pressure systems, convergence, and divergence • Relate weather characteristics to pressure systems.
METEOROLOGICAL ASPECTS OF ALTIMETRY 1 Pressure Altitude 2 Density Altitude 3 Altimeter Settings	• Assess weather and density altitude for anticipated performance (take-off and launch) and flight envelope limitations. • Calculate pressure altitude and density altitude.

TEMPERATURE 1 Temperature Scale – Fahrenheit/ Celsius 2 Heating/Cooling of the Atmosphere – Convection/Advection/ Radiation 3 Horizontal Differences 4 Temperature Variations with Altitude	• Convert temperature between Celsius and Fahrenheit. • Explain the mechanisms of atmospheric heating and cooling. • Describe the effects that temperature can have when flying near a shoreline.
MOISTURE 1 Relative Humidity/Dewpoint 2 Change of State 3 Sublimation/Condensation 4 Cloud Formation 5 Precipitation 6 Saturated/Dry Adiabatic Lapse Rate	• Explain the effect of moisture and temperature on the formation of clouds, height of cloud base. • Calculate the height of cloud base given dewpoint, and temperature. • Discuss the significance of cloud base height on potential air traffic.
STABILITY AND INSTABILITY 1 Lapse Rate and Stability 2 Modification of Stability 3 Characteristics of Stable/Unstable Air 4 Surface Heating/Cooling 5 Lifting Processes 6 Subsidence/Convergence	• Characterize the effects of stable and unstable air masses (visibility, smoothness, smog layers).
CLOUDS 1 Classification 2 Formation and Structure 3 Types and Recognition 4 Associated Precipitation and Turbulence	• Identify cloud types and their impact on flying operations. • Discuss the significance of observed vertical cloud development.

SURFACE BASED LAYERS 1 Fog Formation 2 Fog Types (Including Mist) 3 Haze/Smoke 4 Blowing Obstruction to Vision	• Explain how fog is formed. • Identify the factors that can dissipate fog.
TURBULENCE 1 Convection 2 Mechanical 3 Orographic 4 Wind Shear	• Explain the sources of mechanical turbulence. • Describe the formation of turbulence around large objects and mountain tops.
WIND 1 Definition 2 Pressure Gradient 3 Deflection Caused by the Earth's Rotation 4 Low Level Winds – Variation in Surface Wind 5 Friction 6 Centrifugal Force 7 Veer/Back 8 Squall/Gusts 9 Diurnal Effects 10 Land/Sea Breezes 11 Katabatic/Anabatic Effects 12 Topographical Effects	• Explain the effect of pressure gradient and coriolis force on the horizontal movement of air. • Explain how wind changes in the friction layer. • Define wind shear and its effect on turbulence. • Explain the formation of land/sea breezes. • Use a picture to explain anabatic and katabatic winds.

AIR MASSES 1 Definition and Characteristics 2 Formation/Classification 3 Modification 4 Factors that Determine Weather 5 Seasonal/Geographic Effects 6 Air Masses Affecting North America	
FRONTS AND FRONTAL WEATHER 1 Structure 2 Types 3 Formation 4 Cross-sections 5 Frontogenesis/Frontolysis 6 Cold Front 7 Warm Front	• Discuss the relationship between air masses and creation of weather fronts. • Describe the changes in weather as a front approaches and passes over your location.
AIRCRAFT ICING 1 Formation 2 In-flight – Freezing Rain 3 Hoar Frost 4 Effect of frost and ice on launch and recovery systems	• Explain how icing is formed and the conditions that cause it. • Discuss the impact of having frost on flying surfaces.
THUNDERSTORMS 1 Requirements for Development 2 Structure/Development 3 Types – Air Mass/Frontal 4 Hazards – Updrafts/ Downdrafts/Gust Fronts/ Downbursts/Microbursts/Hail/ Lightning/Antennas 5 Squall Lines	• Describe the three stages of thunderstorm development. • Describe the surface weather characteristics of an approaching thunderstorm.

METEOROLOGICAL SERVICES AVAILABLE TO PILOTS 1 Flight Information Centres (FIC) 2 Aviation Weather Web Site 3 Pilot's Automatic Telephone Weather Answering Service (PATWAS) 4 Automatic Terminal Information Service (ATIS)	• Identify the sources for local weather information.
AVIATION WEATHER REPORTS 1 Decoding 2 Aviation Routine Weather Report (METAR) 3 Automated Weather Observation Station (AWOS) 4 Limited Weather Information System (LWIS)	• Compare reported weather with the SFOC limitations. • Demonstrate awareness of coded weather information, and identify methods of decoding. • Identify sources of weather reports (websites etc.).
AVIATION FORECASTS 1 Times Issued and Validity Periods 2 Decoding 3 Graphic Area Forecasts (GFA) 4 Aerodrome Forecasts (TAF) 5 Airman's Meteorological Advisory (AIRMET) 6 Significant In-flight Weather Warning Messages (SIGMET)	• Compare forecast weather with the SFOC limitations. • Assess forecast ceiling, wind, turbulence, precipitation and visibility against operational objectives. • Assess forecast vs. control station requirements (e.g. lightning). • Assess forecast and density altitude for anticipated performance and flight envelope limitations. • Demonstrate awareness and sources for AIRMETs and SIGMETs.

AERONAUTICS - GENERAL KNOWLEDGE

SECTION 4: AIRFRAMES, ENGINES AND SYSTEMS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
AIRFRAMES 1 Handling/Care/Securing	• Indicate how manufacturers identify the repairs and work that can be undertaken by the operator vs. what must be addressed by an authorized repair facility (e.g. how to find your applicable OEM guidelines). • Describe the importance of identifying propellor damage, surface contamination, wiring damage, structural damage. • Identify the parts of an airframe.
ENGINES 1 Two/Four Stroke Cycle 2 Methods of Cooling 3 Effects of Density Altitude/ Humidity 4 Limitations and Operations 5 Instruments and GCS information	• Identify the type of engine (2/4 stroke) or electric motor used on the UAV. • Explain the difference between 2 and 4 stroke engines/cycles.
ELECTRICAL SYSTEM 1 Typical Electrical System Components 2 Servo motors	• Describe typical electrical system components. • Describe the actions of a servo. • Describe the indications of a failed servo.
FUEL SYSTEMS AND FUELS 1 Types – Properties 2 Density/Weight 3 Additives 4 Contamination and Deterioration 5 Grounding/Bonding	• Discuss the importance of Material Safety Data Sheet in understanding fuel hazards. (note : this is comparably relevant to health and safety…)
DATA LINKS 1 Frequency bands (licensed and unlicensed) 2 Line-of-Sight	• Describe how to assess the RF environment or conduct and RF sweep. • List the parameters of a computer data port.

3 Antennas and tracking systems 4 Interference 5 Data protocols and data rates	• Discuss the importance of radio line-of-sight. • Discuss the importance of GCS antenna placement. • Discuss the causes of lost link and methods of recovery.
BATTERIES 1 Types and hazards 2 Battery parameters (Ah, voltage, charge and discharge rates ("C")) 3 Battery configurations (parallel, series) 4 Charge cycles, storage, and maintenance 5 Discharge curves 6 Transportation of batteries (dangerous goods regulations)	• Interpret maintenance log history. • Describe the variables affecting batteries (capacity e.g. due to age, history, charge status). • Assess battery voltages (understand discharge curves) • Describe the regulations applicable to taking lithium-ion batteries on board a commercial flight.
AUTOPILOTS 1 The role of an autopilot 2 Software version control (GCS and UAV) 3 Different levels of control (e.g. stabilization vs. waypoint) 4 Flight termination systems (internal and remote)	• Describe the types of pilot intervention possible during flight. • Describe the re-flight preparation related to flight termination systems • Discuss the possible consequences of improper software version control.
PAYLOADS 1 sensor types (EO, IR, RF, atmospheric…infinite list)	• Define what comprises the payload vs. the rest of the system.
ELECTRIC MOTORS (propulsion) 1 Types of motors (brush, brushless, inrunner, outrunner) 2 Speed controllers	• Describe the characteristics of different motor types.
LAUNCH AND RECOVERY SYSTEMS 1 Types of launchers 2 Types of recovery systems 3 Safety areas and templates for launch and recovery	• Identify the different danger areas of a safety template.
MAINTENANCE AND RECORD KEEPING 1 Technical Log Requirements	• List the pilot`s requirements for record-keeping

SECTION 5: THEORY OF FLIGHT

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
PRINCIPLES OF FLIGHT 1 Bernoulli's Principle 2 Newton's Laws	• Describe how lift is produced.
FORCES ACTING ON AN AEROPLANE 1 Lift 2 Drag– Induced/Parasite/Profile 3 Relationship of Lift and Drag to Angle of Attack 4 Thrust 5 Weight 6 Equilibrium 7 Centre of Pressure (C of P) 8 Centrifugal/Centripetal Forces 9 Forces Acting on an Aircraft during Manoeuvres	• Identify the 4 forces acting on an aeroplane in flight. • Describe how the 4 forces are balanced during manoeuvres and steady flight.
AEROFOILS 1 Pressure Distribution about an Aerofoil 2 Relative Airflow and Angle of Attack 3 Downwash 4 Wing Tip Vortices 5 Angle of Incidence	• Describe wingtip vorticies. • Define angle of attack, incidence, chord, etc. • Explain how lift is controlled.
PROPELLERS 1 Propeller Efficiency at Various Speeds 2 Propellor Handling/Care	• Describe how different propeller pitches affect aircraft performance.
DESIGN OF THE WING	• Describe how the design of the wing affects performance and

1 Wing Planform 2 Area/Span/Chord 3 Aspect Ratio 4 Camber 5 Dihedral/Anhedral 6 Spoilers 7 Flaps 8 Winglets	control response.
ROTOR DESIGN 1 Number / Speed of Blades 2 Rotor Blade Vortices 3 Limitations to Forward Speed and Vibrations 4 Autorotations 5 Tail Rotor	• Describe how lift is created with a rotary wing (powered and autorotation). • Describe how multiple rotors can be used for stability and control.
LOAD FACTOR 1 Centrifugal Force/Weight 2 Load Factor – Turns 3 Relationship of Load Factor to Stalling Speed (fixed wing) 4 Structural Limitations 5 Gust Loads	• Describe what can affect the load factor on an aircraft. • Explain that aircraft have structural limitations. • State that increasing the load factor produces a requirement for increased lift, thus producing increased drag.
STABILITY 1 Longitudinal, Lateral, Directional Stability 2 Inherent Stability 3 Methods of Achieving Stability, Effect of C of G Position	• Explain how the centre of gravity affects longitudinal stability.
AEROPLANE FLIGHT CONTROLS 1 Aeroplane Axes and Planes of Movement 2 Functions of Controls	• Explain the function of trim. • Describe the function of different control surfaces. • Explain how variations in airspeed change the effect of control

3 Relationship Between Effects of Yaw and Roll 4 Adverse Yaw/Aileron Drag 5 Trim	surface deflection.
HELICOPTER FLIGHT CONTROLS 1 Cyclic 2 Collective 3 Tail Rotor 4 Aids to Stability	• Describe how lift is controlled. • Describe the function of the tail rotor, counter-rotating rotors.
AIRCRAFT COMPONENTS 1 Rotor 2 Landing skid 3 Engine 4 Tail rotor 5 Tail boom 6 Stabilizer/elevator	• Identify the main/common components of rotary wing and fixed wing aircraft.
HELICOPTER AERODYNAMICS 1 Four Basic Forces 2 Blade Design 3 Pressure Distribution about an Aerofoil 4 Rotor Systems (Main/Tail) 5 Translational Lift/Flight 6 Transitions 7 Tail Rotor Drift/Roll 8 Theory of Autorotation and Flare 9 Reverse Flow 10 Blade Stall 11 Over Pitching 12 Settling with Power 13 Recirculation 14 Vortex Ring State	• Describe lift and collective control. • Describe the dangers of recirculating flow through a rotor. • Explain the hazard of loose surface cover when in ground effect.

15 Ground Effect	
MULTI-ROTOR COPTOR DYNAMICS	• Describe how flight is controlled in a multi-rotor helicopter.
AIRSHIPS	• State the advantages/disadvantages of airships.
RECOVERY SYSTEMS 1 parachute, deep stall, arresting system/hook, normal landing	• Explain the different methods employed to recover unmanned aircraft.

SECTION 6: FLIGHT INSTRUMENTS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
PITOT STATIC SYSTEM 1 Pitot 2 Static 3 Anti-Icing	• Describe a pitot-static system and the uses of the data. • Verify air data and inertial sensors.
AIRSPEED INDICATOR 1 Principles of Operation 2 Errors/Malfunctions 3 Definitions -IAS/CAS/TAS	• Explain the errors that occur with a blocked/faulty pitot-static system. • Explain the principles of operation of an Airspeed Indicator.
ALTIMETER 1 Principles of Operation 2 Errors/Malfunctions	• Explain the principles of operation of an Altimeter.
MAGNETIC COMPASS 1 Principles of Operation 2 Variation 3 Factors Adversely Affecting Compass Operation 4 Deviation	• Explain the difference between magnetic and true north. • Explain what can affect compass operation and reliability.
HEADING INDICATOR 1 Markings	• Determine aircraft heading.
ATTITUDE INDICATOR 1 Markings	• Determine aircraft attitude.

INSTRUMENT FLYING 1 Instrument Scan/Interpretation	• Interpret aircraft attitude/heading using instrument displays.
CONTROL STATION (CS) AND SIMULATION 1 File management a. Operating system and environment b. Physical connectivity c. Configuration management (hardware, software, operating system) 2 Diagnostics and test	• Explain that different configurations may require changes in software/database. • Describe the main aspects of configuration management of the CS computer (operating system, software version). • Explain the importance of pre-flight diagnostics and tests. • Explain how simulation can be used to verify the flight plan and map data.

SECTION 7: FLIGHT OPERATIONS

Knowledge Areas	**Sample Learning Objectives** The pilot operating small UAVs within visual line of sight must be able to:
GENERAL 1 Pilot-In-Command Responsibilities 2 Aircraft Defects 3 Winter Operations 4 Thunderstorm Avoidance 5 Mountain Flying Operations 6 Wildlife Hazards 7 Wildlife Conservation 8 Collision Avoidance – Use of Lights 9 Runway Numbering 10 Aerodrome Operations (Procedures for the Prevention of Runway Incursions and conflicts) 11 Taxiing, Hover taxi 12 Radio/Electronic Interference, Portable Electronic Devices	• Describe the hazards that can occur in different geographic or topographical areas. • Describe the normal flow of manned aircraft traffic at an aerodrome (circuit, taxiing, etc.). • Explain how local and portable devices might be controlled to reduce interference.
AIRCRAFT PERFORMANCE 1 Lift/Drag Ratio 2 Effects of Density Altitude/ Humidity 3 Best Angle of Climb (V_x) 4 Best Rate of Climb (V_y) 5 Cruising Speed Maximum Normal Operating Speed (V_{no}) 6 Never Exceed Speed (V_{ne}) 7 Flying for Range 8 Flying for Endurance 9 Stalls 10 Spins	• Explain the importance of lift/drag ratio on climb and glide performance. • Describe the effect of density altitude on launch and climb performance. • Describe situations where best angle of climb and best rate of climb should be used. • Describe how speed affects range and endurance. • Describe the effect of airspeed on radius of turn. • Explain the need for an operating margin above stall speed (turbulence and turns). • Determine parachute recovery drift distance based on altitude

11 Bank/Speed vs Rate/Radius of Turn 12 Use of Aircraft Flight Manual 13 Parachute Recovery performance 14 Deep Stall Recovery performance	and wind.
PERFORMANCE CHARTS/DATA 1 Launcher Charts 2 Cross-wind Limits 3 Factors affecting Performance (battery, wind, speeds, climb power, etc.) 4 (V) Speeds – V_a, V_{no}, V_{ne}, V_s, V_x, V_y 5 Factors affecting Launcher Performance (Ice, Temperature) 6 Effect of Various Runway Surfaces on Take-off and Landing Run 7 Hover ceiling, in and out of Ground Effect	• Describe the effect of temperature on bungee cord launchers. • Identify cross-wind limits. • Explain the relationship between climb height and remaining power/fuel. • Explain how runway surface affects takeoff performance.
WEIGHT AND BALANCE 1 Terms – e.g. Datum/Arm/ Moment 2 Locating CG 3 CG Limits 4 Weights – e.g. Empty/Gross 5 Load Adjustment	• Describe methods of determining Centre of Gravity. • Describe how to return a C of G to within limits.
AIRCRAFT CRITICAL SURFACE CONTAMINATION 1 Effects of Aircraft Critical Surface Contamination on Performance 2 Types of Contaminants (water, frost, snow, condensation, duct tape)	• Recognize weather conditions that can cause surface contamination. • Describe the effects of surface contamination on airfoils
EXTERNAL LOADS 1 Effect on stability and performance	• Describe the effect of slung loads on stability.
OCCUPATIONAL SAFETY AND HEALTH	• List the safety equipment necessary for the operation (fire

1 Equipment 2 Weather 3 Communications 4 Operating Area 5 People	extinguisher, first aid, etc.). • Assess weather threats vs. ground station operations. • Identify and evaluate access routes • Assess public access and determine crowd control requirements • List typical emergency contacts appropriate to flying site (flyaways, EMS etc.) • Identify legal site access issues (landowner permission). • List typical personal safety equipment. • Describe the hazards of launchers and recovery systems.

UAV VLOS OPERATIONS
1 Fueling areas, charging areas
2 Launch Points, Recovery Points
3 Obstacles
4 Emergency Procedures
5 Responsibilities
6 Communications
7 Post Flight Actions
	• Identify typical functional areas in a VLOS site (e.g. launch, observer)
	• Identify desirable characteristics of alternate recovery areas
	• Identify the requirements of visual observer locations
	• List the typical items is a crew briefing
	  ○ Orientation (north etc.)
	  ○ Who is doing what
	  ○ Mission objectives and plan
	  ○ Operational timeline
	  ○ Aircraft performance limitations (density altitude, temperature etc.)
	  ○ Emergency procedures
	  ○ Airspace conflicts and avoidance maneuvers (manual or pre-programmed)
	  ○ Flyaways
	  ○ Public interference procedure
	  ○ Recovery area
	  ○ Communicate procedures with any clients, public etc. at the operation
	  ○ Identify the Ground Supervisor
	  ○ Safe areas
	  ○ Expectations of what the crew will observe
	  ○ EM (cell phone) restrictions

	○ "clean cockpit" (e.g. no interferences or distraction with the crew) ○ Roles and responsibilities if a client is interacting with the pilot or crew • Check for all crew and bystanders in safe position (pre-takeoff) • Communicate who has control and direction of crew • Describe the launch sequence when using a launcher • Describe the launch sequence when hand launching. • Describe the take-off sequence when ground launching. • Identify the typical communications that take place during VLOS operations taking off from the ground ○ Communicate countdown and take-off command ○ Emergency abort communications (e.g. radio silence) ○ Communicate any transfer of control immediately after takeoff (e.g. manual to computer control) ○ Communicate abort in the event of any abnormal flight behavior or equipment behavior ○ Communicate status of takeoff to the crew ○ Pass all air traffic contact to flight crew ○ Communicate aircraft progress and expected manoeuvers (pilot to crew members) ○ Communicate visual contact status and visual handoffs (crew to crew and crew to pilot) ○ Communicate with clients who have a role in directing the flight • Describe Emergency procedures ○ Airspace conflicts and avoidance maneuvers (manual or pre-programmed) ○ System faults (GPS etc.) ○ Lost link ○ Flyaways ○ Abnormal behaviours (evaluate, respond, troubleshoot) e.g. Is it a downdraft or a command anomaly or a

	mechanical failure? o Public interference • Operate according to checklists • Other procedures per SOPs and system manual (need to teach appreciation of the problem and some examples) • List recommended post-flight actions. o Download data (post-flight) o Check for damage ○ Clean and dry as needed ○ Remove excess fuel (as applicable) ○ Remove batteries (as applicable) ○ Record information to data logs ○ Disassemble and pack per system manual ○ Aircraft ○ GCS ○ Launcher ○ Landing system

SECTION 8: HUMAN FACTORS

Knowledge Areas	Sample Learning Objectives The pilot operating small UAVs within visual line of sight must be able to:
AVIATION PHYSIOLOGY 1 Vision/Visual Scanning Techniques 2 Hearing 3 Orientation/Disorientation (Including Visual Perspective/Parallax Illusions) 4 Body Rhythms/Jet Lag 5 Sleep/Fatigue 6 Anaesthetics	• Describe good scanning techniques (visual, audio) for visual observers (conflicting aircraft). • Describe "Perspective Illusion" when looking at distant aircraft. • Describe factors that affect alertness.
THE PILOT AND THE OPERATING ENVIRONMENT 1 Medications (Prescribed and Over-the-counter) 2 Substance Abuse (Alcohol/ Drugs) 3 Heat/Cold 4 Noise 5 Toxic Hazards (Including Carbon Monoxide – GCS vehicle)	• Describe the effects of a hangover on pilot performance. • Describe the effects of exposure to cold and excessive heat on pilot performance. • Describe the symptoms of carbon monoxide poisoning.
AVIATION PSYCHOLOGY 1 Factors That Influence Decision-Making 2 Situational Awareness 3 Stress 4 Managing Risk 5 Attitudes 6 Workload – Attention and Information Processing	• List factors that interfere with effective decision-making. • List the factors that affect situational awareness. • Describe how a given operational risk might be managed.
PILOT – EQUIPMENT/MATERIALS RELATIONSHIP	• Explain the benefits of Standard Operating Procedures and

1 Controls and Displays – Errors in Interpretation and Control 2 Standard Operating Procedures – Rationale/Benefits 3 Correct Use of Check-lists and Manuals 4 Automation and complacency	Lessons Learned. • Explain how to manage an interruption to a checklist.
INTERPERSONAL RELATIONS 1 Communications with Flight Crew/Maintenance Personnel/Air Traffic Services/Passengers 2 Operating Pressures – Family Relationships/Peer Group 3 Operating Pressures – Employer	• Resolve differences peacefully. • Promote open communications. • Place safety requirements over hierarchy/position in organization/politics.

RADIOTELEPHONY

Knowledge Areas	**Sample Learning Objectives** The small UAV pilot operating Visual Line of Sight must be able to:
AERONAUTICAL RADIO-TELEPHONE COMMUNICATIONS 1 Operator's Certificate (Aeronautical) - (ROC-A course) 2 Terminology 3 Common frequencies 4 Emergencies	• Interpret aeronautical radiocommunication (position, phase of flight) • Communicate using standard radio terminology. • Give an example of a routine blind broadcast. • List the contents of a routine call to ATC. • Give an example of an emergency (flyaway) broadcast.
GROUND CREWMEMBER RADIOS 1 Terminology 2 Reception performance	• Give an example of an advisory describing a possible aircraft conflict. • Describe factors affecting radio reception range.