UAS REMOTE PILOT FLYING HANDBOOK

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Preface

The *UAS Remote Pilot Flying Handbook* is designed as a technical manual to introduce basic UAS Remote Pilot skills and knowledge that are essential for piloting UAVs. It provides information on transition to other UAVs and the operation of various UAV systems.

This book can be used independently or in conjunction with classes as offered at www.suaspro.com. These classes offer video and LMS delivered content.

This handbook is developed to assist student UAS pilots learning to fly UAV's. It is also beneficial to pilots who wish to improve their flying proficiency and aeronautical knowledge, those pilots preparing for additional certificates or ratings, and flight instructors engaged in the instruction of both student and certificated pilots. It introduces the future pilot to the realm of flight and provides information and guidance in the performance of procedures and maneuvers required for pilot certification. Topics such as navigation and communication, meteorology, use of flight information publications, regulations, and aeronautical decision making are available in other UAS Consulting Publications.

This handbook conforms to UAS pilot NIST training and certification concepts. There are different ways of teaching, as well as performing flight procedures and maneuvers, and many variations in the explanations of aerodynamic theories and principles. This handbook adopts the NIST concept of flying UAV's. National Institute of Standards and Technology (NIST) can be reviewed at www.nist.gov. The discussion and explanations reflect the most used practices and principles. Occasionally the word "must" or similar language is used where the desired action is deemed critical. The use of such language is not intended to add to, interpret, or relieve a duty imposed by Title 14 of the Code of Federal Regulations (14 CFR) nor by FAR Part 107.

It is essential for persons using this handbook to also become familiar with and apply the pertinent parts of 14CFR and the *Aeronautical Information Manual (AIM)*. The AIM is available online at http://www.faa.gov/atpubs. Performance standards for demonstrating competence required for UAV Remote Pilot certification are prescribed in the appropriate UAV practical test standard.

We greatly acknowledge the valuable assistance provided by many individuals and organizations throughout the aviation community whose expertise contributed to the preparation of this handbook.

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CHAPTER 1. Introduction to UAS Flight Training

Purpose of Flight Training

The overall purpose of primary and intermediate flight training, as outlined in this handbook, is the acquisition and honing of **basic airmanship skills. Airmanship** can be defined as:

1. A sound acquaintance with the principles of flight.
2. The ability to operate an UAV with competence and precision both on the ground and in the air.
3. The exercise of sound judgment that results in optimal operational safety and efficiency.

Learning to fly an UAV has often been likened to learning to drive an automobile. This analogy is misleading. Since an UAV operates in a different environment, three dimensional, it requires a type of motor skill development that is more sensitive to this situation such as:

Coordination:	The ability to use the hands and feet together subconsciously and in the proper relationship to produce desired results in the airplane.
Timing:	The application of muscular coordination at the proper instant to make flight, and all maneuvers incident thereto, a constant smooth process.
Control Touch:	The ability to sense the action of the UAV and its probable actions in the immediate future, with regard to attitude and speed variations, by the sensing and evaluation of varying pressures and resistance of the control surfaces transmitted through the cockpit flight controls.
Speed Sense:	The ability to sense instantly and react to any reasonable variation of airspeed.

The Remote becomes one with the UAV rather than a machine operator. An accomplished airman demonstrates the ability to assess a situation quickly and accurately and deduce the correct procedure to be followed under the circumstance; to analyze accurately the probable results of a given set of circumstances or of a proposed procedure; to exercise care and due regard for safety; to gauge accurately the performance of the UAV; and to recognize personal limitations and limitations of the UAV and avoid approaching the critical points of each. The development of airmanship skills requires effort and dedication on the part of both the student pilot and the flight instructor, beginning with the very first training flight where proper habit formation begins with the student being introduced to good operating practices.

Every UAV has its own particular flight characteristics. The purpose of primary and intermediate flight training, however, is not to learn how to fly a particular make and model UAV. The purpose of the flight training is to develop skills and safe habits that are transferable to any UAV. Basic airmanship skills serve as a firm foundation for this. The pilot who has acquired necessary airmanship skills during training, and demonstrates these skills by flying training-type UAVs with precision and safe flying habits, will be able to easily transition to more complex and higher performance UAVs. It should also be remembered that the goal of flight training is a safe and competent pilot, and that passing required practical tests for pilot certification is only incidental to this goal.

Role of the FAA

The Federal Aviation Administration (FAA) is empowered by the U.S. Congress to promote aviation safety by prescribing safety standards for civil aviation. This is accomplished through the Code of Federal Regulations (CFRs) formerly referred to as Federal Aviation Regulations (FARs).

Title 14 of the Code of Federal Regulations (14CFR) Part 61 pertains to the certification of pilots, flight instructors, and ground instructors. 14CFR Part 61 prescribes the eligibility, aeronautical knowledge, flight proficiency, and training and testing requirements for each type of pilot certificate issued.

14CFR Part 67 prescribes the medical standards and certification procedures for issuing medical certificates for airmen and for remaining eligible for a medical certificate.

14CFR Part 91 contains general operating and flight rules. The section is broad in scope and provides general guidance in the areas of general flight rules, visual flight rules (VFR), instrument flight rules (IFR), aircraft maintenance, and preventive maintenance and alterations.

Part 107 is the primary operating and flight rules for the Remote UAS Pilot.

The Federal Aviation Administration (FAA) is amending its regulations to adopt specific rules for the operation of small Unmanned Aircraft Systems (sUAS) in the National Airspace System (NAS) through a final rule. These changes address the classification of sUAS, certification of sUAS remote pilots, and sUAS operational limitations. This advisory circular (AC) provides guidance for conducting sUAS operations in the NAS in accordance with Title 14 of the Code of Federal Regulations (14CFR) part 107.

Role of the Pilot Examiner

Pilot and flight instructor certificates are issued by the FAA upon satisfactory completion of required knowledge and practical tests. The FAA, however, presently does not require a Pilot Examiner related to UAS Remote Pilots.

To satisfy the public and commercial needs, we require designated individuals to act as Pilot Examiner's.

We select only highly qualified individuals to be designated pilot examiners. These individuals must have good industry reputations for professionalism, high integrity, a demonstrated willingness to serve, the public, and adhere to FAA policies and procedures in certification matters. A designated pilot examiner is expected to administer practical tests with the same degree of professionalism, using the same methods, procedures, and standards as an FAA aviation safety inspector. It should be remembered, however, that a DPE is not an FAA aviation safety inspector. A DPE cannot initiate enforcement action, investigate accidents, or perform surveillance activities on behalf of the FAA. However, the majority of our practical tests at the commercial pilot level are administered by the designated pilot examiners. We carefully follow NIST and ASTM standards (see following Chapters).

Role of the Flight Instructor

The flight instructor is the cornerstone of aviation safety. The FAA has not adopted an operational training concept for UAS Remote Pilots. We have adopted a policy to designate Remote Flight Instructors.

These individuals are the cornerstone of our training. This training will include airmanship skills, pilot judgment and decision making, and accepted good operating practices. The Flight Instructor assumes the total responsibility for training the student in all the knowledge areas and skills necessary to operate safely and competently as a certified UAS Remote Pilot.

Our flight instructors have to meet broad flying experience requirements, pass rigid knowledge and practical tests, and demonstrate the ability to apply recommended teaching techniques before being designated. In addition, the flight instructor must be tested by the Chief Pilot every six months by showing continued success in training pilots, or by satisfactorily completing a flight instructor's refresher course or a practical test designed to upgrade aeronautical knowledge, pilot proficiency, and teaching techniques.

A pilot training program is dependent on the quality of the ground and flight instruction the student pilot receives. A good flight instructor will have a thorough understanding of the learning process, knowledge of the fundamentals of teaching, and the ability to communicate effectively with the student pilot.

A good flight instructor will use a syllabus and insist on correct techniques and procedures from the beginning of training so that the student will develop proper habit patterns. The syllabus should embody the "building block" method of instruction, in which the student progresses from the known to the unknown. The course of instruction should be laid out so that each new maneuver embodies the principals involved in the performance of those previously undertaken. Consequently, through each new subject introduced, the student not only learns a new principle or technique but broadens his / her application of those previously learned and has his / her deficiencies in the previous maneuvers emphasized and made obvious.

The flying habits of the flight instructor, both during flight instruction and as observed by students when conducting other pilot operations, have a vital effect on safety. Students consider their flight instructor to be a paragon of flying proficiency whose flying habits they, consciously or unconsciously, attempt to imitate. For this reason, a good flight instructor will meticulously observe the safety practices taught the students.

Additionally, a good flight instructor will carefully observe all regulations and recognized safety practices during all flight operations.

Sources of Flight Training

The sources of flight training vary as it is presently unregulated. We recognized this lack of quality training and has defined expectation parallel with 14CFR Part 141 (and 14CFR part 61 – non-certified) flight schools. Our school follows stringent requirements for personnel, equipment and facilities. The school operates in accordance with an established curriculum, which include a training course outline.

Practical Test Standards

Practical test for the FAA Remote Pilot Certification written test are administrated by our Flight Instructors, Examiners and Chief Pilot in accordance with the FAA (written) and NIST (Flight Test) developed test standards and specifies the area of operation in which knowledge and skill must be demonstrated by the applicant.

Flight Safety Practices

In the interest of safety and good habit pattern formation, there are certain basic flight safety practices and procedures that must be emphasized by the flight instructor and adhered to by both the instructor and the student, beginning with the very first instruction of flight. These include, but are not limited to, collision avoidance procedures including proper scanning techniques and clearing procedures and cockpit workload management.

Use of Checklists

Checklists have been the foundation of pilot standardization and safety for years. The checklist is an aid to the memory and helps to ensure that critical items necessary for the safe operation of the UAV are not overlooked or forgotten. However, checklists are of no value if the remote pilot is not committed to its use. Without discipline and dedication to using the checklist at the appropriate times, the odds are on the side of error. Pilots who fail to take the checklist seriously become complacent and the only thing they can rely on is memory.

The importance of consistent use of checklists cannot be overstated in pilot training. A major objective in primary UAV flight training is to establish habit patterns that will serve pilots well throughout their entire flying career.

The flight instructor must promote a positive attitude toward the use of checklists, and the student pilot must realize its importance. At a minimum, prepared checklists should be used for the following phases of flight:

1. Preflight Inspection
2. Before Engine Start
3. Engine Starting
4. Before Taxiing
5. Before Takeoff
6. After Takeoff
7. Cruise

8. Descent
9. Before Landing
10. After Landing
11. Engine Shutdown and Securing

CHAPTER 2.
Ground Operations

Visual Inspection

The accomplishment of a safe flight begins with a careful visual inspection of the UAV. The purpose of the preflight visual inspection is twofold: to determine that the UAV is airworthy, and that it is in condition for safe flight. The airworthiness of the UAV is determined, in part, by the following documents, which must be assessable:

1. Maintenance Log
2. Pilot Log book
3. UAV operating limitations, which may be in the form of a Flight Manual and / or placards, markings, or any combination thereof.

UAV logbooks are not required to be kept with the UAV when it is operated. However, they should be inspected prior to flight to show that the Drone has had required tests and inspections. Maintenance records for the UAV are required to be kept. There may be additional propeller records.

At the minimum, there should be an annual inspection within the preceding 12-calendar months.

The determination of whether the UAV is in a condition for safe flight is made by a preflight inspection of the airplane and its components. The preflight inspection should be performed in accordance with a printed checklist provided by the airplane manufacturer for the specific make and model airplane. However, the following general areas are applicable to all UAV's.

Figure 1.
Pre-Flight Inspection

The preflight inspection of the UAV should begin while approaching the UAV on the ramp. The pilot should make note of the general appearance of the Drone, looking for obvious discrepancies such as a landing gear out of alignment, structural distortion, skin damage, and battery appearance. Upon reaching the UAV, all control locks should be removed including gimbal locks.

Cockpit Management

Levels of Control

Any useful discussion of aircraft control must include the concept of levels of control. The goal of aircraft control is to cause the aircraft to reach a specific location at a particular point in time.

Aircraft position is four-dimensional and can be described in terms of latitude, longitude, altitude, and time. The term "level of control" refers to the fact that the attainment of a particular position is not (usually) specified directly by the pilot but indirectly through the manipulation of lower levels of control. So, for example, to attain a particular latitude and longitude, one option is to place a waypoint on a moving-map display that corresponds to that latitude and longitude.

This is the highest level of control for the pilot. Alternatively, the pilot could manipulate the aircraft heading to achieve a particular latitude and longitude. Heading manipulation is the next lower level of control from direct manipulation of latitude and longitude (through waypoints). To attain a particular heading, the pilot must control the turn rate. To attain a particular turn rate, the pilot must command bank angle. To achieve a certain bank angle the pilot must manipulate the roll rate.

Finally, to achieve a specific roll rate, the pilot must control the roll acceleration. In traditional aircraft configurations, roll acceleration is manipulated directly by positioning the ailerons through movement of the yoke. From the final goal state of position, described by latitude and longitude, there can be as many as five lower levels (or "orders") of control that must be integrated to achieve this goal state.

Control Architecture Inventory

Based on the analysis of control levels, a taxonomy of control levels was developed for categorizing any UAS control architecture. The taxonomy contains three types of control: horizontal movement, vertical movement, and speed.

For each of these control types, the pilot can interact with the system at various levels of control, as was discussed above. Horizontal movement of the aircraft can occur at one of four control levels in the taxonomy:

1. Roll acceleration through direct manipulation of the ailerons.
2. Bank angle / turn rate.
3. Heading.
4. Waypoint positioning.

Vertical movement of the UA can also occur at one of four control levels. These levels are:

1. Pitch acceleration through direct manipulation of the aircraft surfaces.
2. Vertical speed.
3. Altitude.
4. Waypoint altitude.

These levels we have been as P, V, A, and W, respectively. As with horizontal movement, some possible levels of control were not included.

In addition, since altitude can be entered in conjunction with waypoint position or independently, these options were treated as two separate control levels. Aircraft speed can be manipulated at three levels of control:

1. Thrust.
2. Airspeed / groundspeed.
3. Waypoint time / airspeed.

These levels are abbreviated as T, A, W. Some systems, such as the Predator, present a viewpoint to the pilot as though inside of the aircraft looking out. This viewpoint is called an egocentric viewpoint. Other systems present a viewpoint to the pilot as though looking at the aircraft from the outside.

This viewpoint is called an exocentric viewpoint. Typical exocentric viewpoints include depicting the aircraft on a (north-up) moving map display or flying the aircraft using direct line-of-sight from the ground. Some systems have both egocentric and exocentric viewpoints available to the pilot, so the egocentric / exocentric viewpoint might be thought of as a continuous variable. The viewpoint column in the architecture table indicates whether primary flight control is mainly accomplished using an egocentric (G) or exocentric (X) viewpoint.

Exocentric vs. Egocentric Viewpoint

The full set of ramifications of removing the pilot from the aircraft is unknown. However, when the pilot is removed from the aircraft, the control station can either be designed to make the pilot feel as though the operational perspective is within the aircraft looking outside (egocentric) or outside the aircraft watching it from afar (exocentric).

The Predator UA is an example of an egocentric control station. The Predator UA is flown by reference to a forward “out-the-window” camera view. The Shadow UA is an example of an exocentric control station. This UA is flown by reference to a north-up moving-map display. There is no “out-the-window” view for the pilot.

Whether the difference between an egocentric and exocentric design has an effect on pilot decision making, flight performance, or awareness of flight and system parameters, has not been explored. The majority of systems inventoried use an exocentric pilot viewpoint for en route navigation. Nine of the systems use an exocentric viewpoint exclusively. In addition, several systems that use an egocentric viewpoint (e.g., Helios) only do so for landing and takeoff of the aircraft.

Most of the flight is accomplished using the moving-map display and other flight instruments in an exocentric fashion. The current trend for UA is to automate takeoffs and landings. This trend means that egocentric viewpoints are being eliminated from most systems.

Control Devices

Current UA employ a wide variety of control architectures. While there are still a few systems that use direct control of aircraft surfaces, this level of control is used only by external (i.e., direct line-of-sight) pilots during landing and takeoff.

Most of the systems inventoried employ some level of automation at all available levels of control, and all of the systems have a waypoint level of control that allows the aircraft to fly at least a portion of the flight without pilot intervention. The viewpoint of the pilot for a majority of the systems is exocentric.

There is no research to suggest that an exocentric viewpoint has any negative effect on the pilot in terms of decision-making, piloting skills, or awareness of flight parameters. However, it has been suggested that there might be negative consequences from the pilot not having a shared fate with the aircraft (McCarley & Wickens, 2005).

Whether an exocentric viewpoint diminishes the feeling of shared fate or not is unknown. Attitude information is sometimes given in the form of an outside-in display and sometimes as an inside-out display. The outside-in display has been shown to be more effective for recovery from unusual attitudes (Previc & Ercoline, 1999), but the level of automation employed for UAS should prevent the onset of unusual attitudes from ever occurring.

There is no empirical support in regard to which format is the most effective for the types of piloting activities expected for UAS.

Future Efforts

The specification of the required level of control for a particular UAS requires a full understanding of all the flight contingencies for the type of operations that can be accomplished (or allowed) with the aircraft.

In addition, it is important that we develop an understanding of how interactions at various levels of control affect pilot performance in terms of precision of flight, awareness of flight parameters, and decision-making. There might also be an interaction with levels of control of the general type of input device employed (e.g., a physical control such as a knob vs. a virtual control manipulated with a mouse).

If multiple levels of control are available to the pilot, there is a potential problem of mode confusions, as have been observed with manned aircraft (Sarter & Woods, 1997). One way to avoid this problem is to create an interface that does not require separate modes to access the various levels of control.

Such a “modeless” interface would require clearly defined procedures for accessing all of the required control levels without having to establish a flight mode. The most likely interface would probably use waypoint manipulation, along with other virtual controls for accessing lower-level control commands.

It is unreasonable to insist that the pilot be able to specify a range of vertical speeds or turn rates if all flight contingencies can be accommodated using a standard climb or turn rate.

However, the specification of flight contingencies might require certain flight restrictions that limit the number of contingencies needed for operation of the systems.

For example, aircraft that have a restricted climb rate might not be placed in the traffic pattern with certain other types of aircraft and might be barred from certain types of airspace (e.g., class B). There is, unfortunately, no simple solution for the appropriate control architecture for these systems.

The solution to this problem requires the simultaneous consideration of human factors issues, operational requirements, and rule-making efforts.

Ground Operations

UAS Pilot Responsibilities

The following figure presents a high-level model of the responsibilities of the UAS pilot, consistent with FAA assumptions, adapted from Mutuel, Wargo and DiFelici (2015). The model can act as a checklist to ensure that all areas of human-system interaction are considered when developing guidelines for the human-machine interface. In some cases, broad areas of responsibility are common to both conventional and unmanned aviation, yet may present special challenges for the UAS pilot. These include monitoring and controlling the status of radio links, control hand-offs, and flight termination.

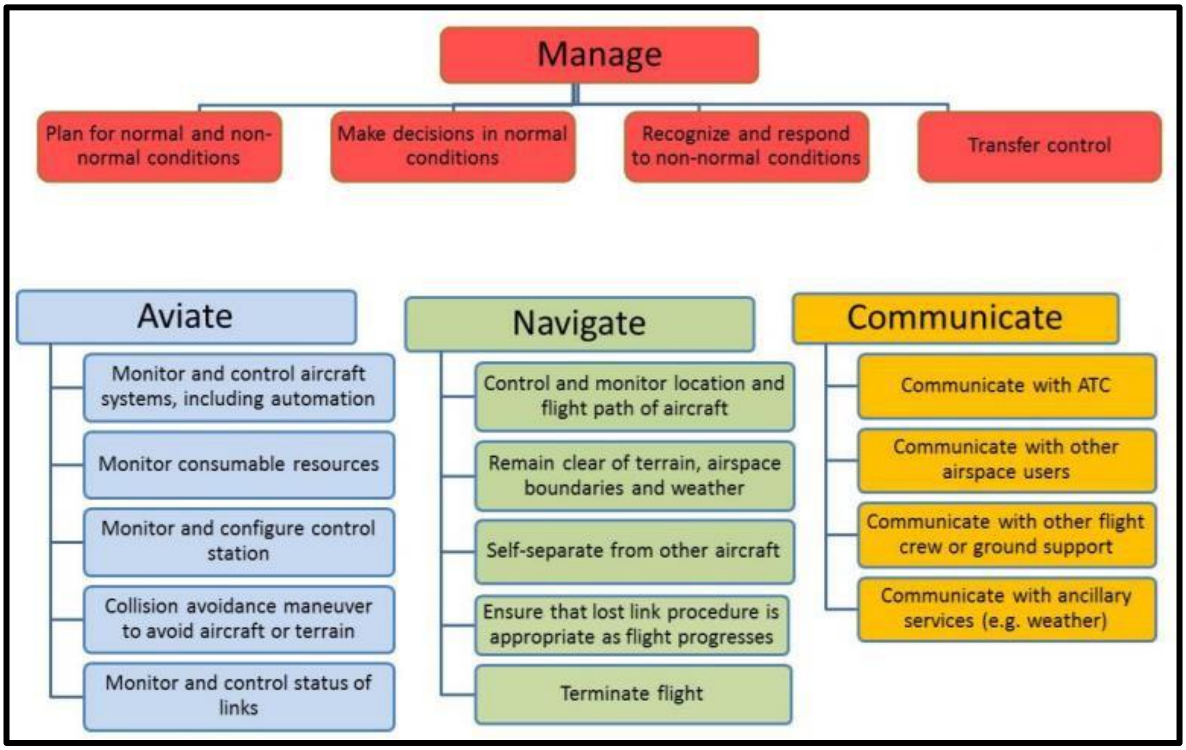


Figure 2.
Responsibilities of the UAS Pilot

MANAGE

The "Manage" category includes the overall planning, decision-making, and management responsibilities that must be accomplished by the pilot, supported by the human machine interface. For ease of presentation, management responsibilities are shown separately in **Figure 4**, although they overlap and cut-across other responsibilities.

AVIATE

These responsibilities include tactical, or short-term, control of the air vehicle and its ground- based equipment, and the control link. In most cases, the continuous control functions necessary for the maintenance of stable flight are allocated to on-board automation, however the pilot is still required to provide supervisory oversight and control the configuration of systems. Maneuvers to avoid collisions with other aircraft or objects are included in these responsibilities.

NAVIGATE

The navigation responsibilities involve strategic, or longer-term, control of the air vehicle and its ground-based equipment. Controlling and monitoring the location and flight path of the aircraft includes ensuring that the aircraft navigates with respect to airspace boundaries, terrain and other considerations. The self-separation responsibility must be accomplished in the absence of an out-the-window view, necessitating reliance on a traffic situation display in the GCS. The two final responsibilities listed under "Navigate" are specific to unmanned aviation. The pilot must maintain an awareness of the aircraft's pre-programmed lost link maneuver, and ensure that the maneuver is updated as necessary as the flight progresses. Finally, in the event of a serious in-flight anomaly, the pilot may be required to terminate the flight, possibly by directing the aircraft to a suitable location for a controlled impact or ditching, or by deploying a parachute system. In either case, the pilot must minimize risk to people and property.

COMMUNICATE

The pilot in command must communicate with ATC, other airspace users, other members of the flight crew or support team, and ancillary services such as weather briefers. Communication and coordination within the UAS operating team is critical and the UAS human system interface must be designed to enable team situation awareness to be achieved. If the UA is operating far from the GCS, pilot-ATC communications may be relayed using ground infrastructure, satellite, or air-to-air relays. Relays have the potential to introduce time delays, with disruptive implications for verbal communication.

Pre-Flight Operations (Example)

Preflight activities are the duty of the RPIC before the start of the flight operation. Activities include inspection of the aircraft, assessment of the operating location, briefing crew members involved in the operation, and equipment checkouts. All flight operations should be conducted in accordance with the provision of 14CFR Part 107, state and local regulations, and the operator’s manual for the subject aircraft.

Planning

1. The flight crew should be familiarized with all available information pertaining to the flight such as; takeoff / landing, including but not limited to the operational limitations of Part 107, weather conditions, hazards, no fly zones, etc.
2. North Carolina state statues require land-owner approval before operations take place.
3. RPIC will ensure the location for take-off and emergency landing is adequate upon arrival at the location. At least one emergency landing area should be identified before the start of operations.
4. RPIC should be aware of all surroundings in the event that an emergency landing is necessary. This includes the ability to recover the UAS.

Inspection

1. Before the first flight of the day, verify all batteries are fully charged.
2. Check the airframe for signs of damage, and its overall condition.
3. Check the entire aircraft per the pre-flight inspection instructions in the manual for the specific aircraft to make sure it is in good structural condition and no parts are damaged, loose, or missing.
4. Check the propeller or rotor blades for chips, cracks, looseness and any deformation.
5. Check that camera(s) and mounting systems are secure and operational.
6. Perform an overall visual check of the aircraft prior to arming any power systems.
7. Repair or replace any part found to be unsuitable to fly during the pre-flight procedures prior to takeoff.

Weather

1. Before each flight the RPIC and observer should ensure that he / she gathers enough information about the existing and anticipated near-term weather conditions throughout the entire mission environment. As a best practice he / she should utilize FAA approved weather resources such as; Meteorological Terminal Aviation Weather Reports (METARS), Terminal Area Forecasts (TAF), etc. to obtain the best information. In order to obtain the latest and most current weather conditions, Notices to Airmen (NOTAMs), and Temporary Flight Restrictions (TFRs) the RPIC should obtain a local aviation briefing at; 1-800-WXBRIEF or www.1800WXBRIEF.com.

2. Wind direction plays a major factor in flight operations. Operators should take precautions to ensure that wind conditions do not exceed the aircraft limits stated in the aircraft operations manual / specifications. An anemometer (pocket anemometers are available from a variety of sources) is a low-cost and simple to use tool that can be utilized in order to better estimate the wind speed and determine if it is within the necessary limits of the UAS being flown. Use of an anemometer is highly recommended, in particular in cases where wind conditions and whether they are within limits may be questionable.

3. The RPIC should ensure that the flight will occur within the weather requirements specified in Part 107.51 (c-d), three statute miles, the UA must be kept at least 500 feet below a cloud and at least 2,000 feet horizontally from a cloud. While the FAA can obtain waivers under Part 107 for certain types of operations in particular locations for night- time or beyond line-of-sight operations, the vast majority of authorizations are for FAA VFR conditions and require Visual Line of Sight (VLOS) between the aircraft and the UAS Operator as well as between the aircraft and the Visual Observer at all times.

Checklist

Preflight inspection is required under Part 107.49; the RPIC is required to develop a preflight inspection checklist if the manufacture has not developed one.

FLIGHT CHECKLIST

PRE FLIGHT →	DURING FLIGHT →	POST FLIGHT
At office	**After launch**	**After landing**
☐ Aircraft Documentation ☐ NOTAM ☐ Local regulations and permissions. ☐ Proximity to the airport. ☐ Weather condition permits flying. ☐ All Batteries Charged ☐ Flight Gear check	☐ Aircraft reached safe altitude. ☐ Confirm observer has the aircraft in sight. ☐ All systems green ☐ Satellite and GPS check ☐ Check Battery remaining	☐ Power down UAV ☐ Remove and safely store batteries ☐ Airframe inspection ☐ Check camera/ sensor to ensure data collected ☐ Transfer data and flight log ☐ Make logbook entry
In the field	**Before Landing**	**Back at office**
☐ Scan area for obstacles, e.g. take-off and landing area. ☐ Wind check ☐ Daily Flight Report filled. ☐ Assemble UAV, ensure screws are tight and propeller check ☐ Sensor/ Camera setting check ☐ Batteries securely mounted ☐ Ensure GPS fix ☐ Confirm Mission flight plan ☐ Operators checklist (integrated) ☐ RC remote check (if used) ☐ Final airframe inspection ☐ Flight Crew briefings, e.g. flight mission and safety ☐ Wind check again for launch.	☐ Ensure UAV flight done according to mission plan. ☐ Scan landing area for obstacles. ☐ Wind check ☐ Observer briefing for landing ☐ All systems green	☐ Flight and Maintenance Report ☐ Charge Batteries ☐ SD card cleaned and ready to use ☐ Airframe checked ☐ Data processed

Figure 3.
Flight Checklist

The checklist is usually integrated into the UAS flight software or can be obtained from the UAS vendor. In case that is not available, a standard Flight Checklist (example above) should be made and followed by the flight crew. RPIC should utilize the checklist to ensure the highest level of safety. At a minimum, this pre-flight checklist should contain the information shown in the above example.

Documentation

Once the RPIC confirms the location is safe to fly and becomes familiarized with the surroundings, it is recommended that he / she document all the details in a Pre-Flight Report.

The Pre-Flight Report can often be filled out prior to arrival at the site as a part of mission planning and then signed off by the RPIC once on site and the RPIC has confirmed that the operation can be conducted safely at the site.

PRE FLIGHT REPORT	
Documents	
Land Owner Permission	XXXXX
Aircraft Registration	XXXXX
Plan	
Call signs & Phraseology	Loiter, RTL
Altitude to be flown	100 meters
Mission Overview	Crop data
Frequencies	2.4 ghz
Planned Flight time, including reserve	30 mins
Contingency procedure: lost link, divert, etc.	Return to land
Hazards unique to the flight being flown	Variable winds
Closest Airport	KRDU
Emergency Contact	
Law Enforcement	911
Closest Tower Frequency	127.450
Site Manager	James B.
Roles	
Pilot	Marc A.
Observer 1	Rachel J.
Observer 2	none
Data Analyst	Peter S.

Figure 4.
Pre-Flight Report

An example of what the report should contain is:

1. Altitudes to be flown.
2. Mission overview.
3. Frequencies to be used.
4. Planned flight time, including reserve fuel requirements.

During Flight Operations

1. The UAS RPIC should launch, operate, and recover from preset locations so that the aircraft will fly according to the mission plan.
2. After the UAS is launched, the flight crew should have a clear view of the aircraft at all times, called Visual Line of Sight (VLOS). Observation locations should be selected for the maximum line of sight throughout the planned flight operations area (Part 107.31).
3. All flight operations must be conducted using a minimum of a RP and PMC per Part 107.31. However it is advisable to utilize one or more VOs, as outlined in Part 107.33, depending on the complexity of the flight mission to perform general safety, visual observation, hazard and traffic avoidance (Part 107.37).
4. To ensure the flight is going according to the flight plan, the RP, PMC and VO (if used) must be able to maintain effective communication with each other at all times (Part 107.33).
5. The visual observer should be informed on what the aircraft is supposed to be doing and the altitude of the aircraft above ground level.
6. Part 107.39 does not permit UAS flights over persons not directly involved in the operations. Flights taking place over populated areas, heavily trafficked roads, or an open-air assembly of people is not allowed under regulation (unless through waiver). If the mission dictates that flight operations be conducted in such areas, the RPIC will need to obtain a waiver before conducting a flight.
7. The observer should make the pilot aware of any possible flight hazards during the flight.
8. Upon any failure during the flight or any loss of visual contact with the UAS, the RPIC should command the aircraft back to the recovery location or utilize the built-in fail-safe features to recover the aircraft. Emergency procedures as defined in the specific UAS operator's manual should be followed.

Post-Flight Operations

1. RPIC should scan the landing area for potential obstruction hazards and recheck weather conditions.
2. RPIC should announce to the observer and any other people around that the aircraft is on final approach and inbound to land.
3. RPIC should always be prepared to reject or abort a take-off or landing, called a “go- around,” if the PMC becomes aware that such an operation cannot be safety made due to an unexpected weather situation, emergency, hazard or miscalculation.
4. Carefully land the aircraft away from any obstructions and people.
5. After landing:
    - Shut down the UAS and disconnect the batteries;
    - Power down the camera or sensors;
    - Visually check aircraft for signs of damage and / or excessive wear;
    - Verify that mission objectives have been met;
    - If imagery or other data are recoded onboard the aircraft during flight, transfer the data as necessary to the Ground Control Station (GCS) or a backup storage devise. If all data and imagery is transmitted to the GCS and recorded on the GCS during the flight, then operators may wish to consider backing up the data prior conducting additional flight operations;
    - Enter logbook entries recording flight time and other flight details;
    - In case there are multiple flights to be conducted, repeat checklist steps to prepare the aircraft for launch again.

CHAPTER 3. Beginning Flight Maneuvers

The Four Fundamentals

When learning how to fly a quadcopter, the controls will become your bread and butter.

They will become second nature once you know how they act individually and how they interact together to form a complete flying experience.

With any of these controls, the harder you push the stick, the stronger your quadcopter will move in either direction.

When you first start out, push the sticks very gently so the quadcopter performs slight movements. As you get more comfortable, you can make sharper movements.

There are four main quadcopter controls:

1. Roll
2. Pitch
3. Yaw
4. Throttle

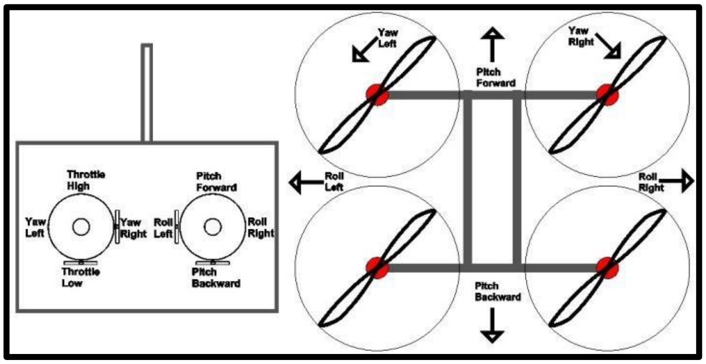


Figure 5.
Four Main Quadcopter Controls

Simple sketch of roll, pitch, yaw, and throttle on a transmitter (left image) and quadcopter (right image).

Roll

Roll moves your quadcopter left or right. It’s done by pushing the right stick on your transmitter to the left or to the right.

It’s called “roll” because it literally rolls the quadcopter.

For example, as you push the right stick to the right, the quadcopter will angle diagonally downwards to the right.

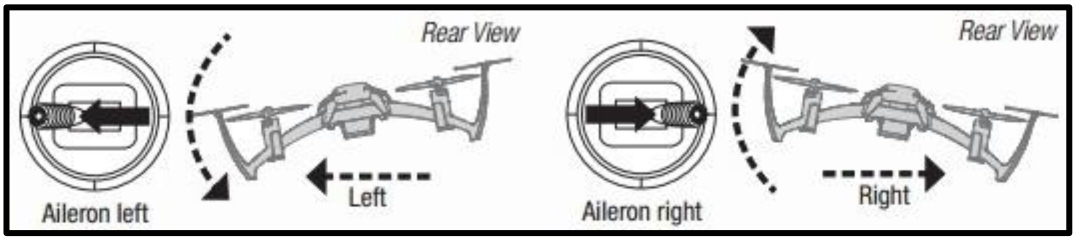


Figure 6.
Example of Quadcopter Rolling Left and Right

NOTE: Notice the tile of the quadcopter and the angle of the propellers.

Image Source (Best Quadcopter Spot): Here, the bottom of the propellers will be facing to the left. This pushes air to the left, forcing the quadcopter to fly to the right. The same thing happens when you push the stick to the left, except now the propellers will be pushing air to the right, forcing the copter to fly to the left.

Pitch

Pitch is done by pushing the right stick on your transmitter forwards or backwards. This will tilt the quadcopter, resulting in forwards or backwards movement.

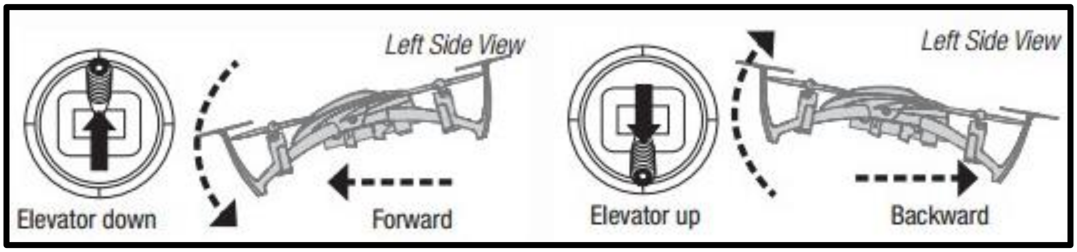


Figure 7.
Example of Quadcopter Pitching Forwards and Backwards

NOTE: This view is from the left side.

Yaw

Essentially, it rotates the quadcopter clockwise or counterclockwise.

This is done by pushing the left stick to the left or to the right. aw is typically used at the same time as throttle during continuous flight. This allows the pilot to make circles and patterns. It also allows videographers to follow objects that might be changing directions.

Throttle

Throttle gives the propellers on your quadcopter enough power to get airborne. When flying, you will have the throttle engaged constantly.

To engage the throttle, push the left stick forwards. To disengage, pull it backwards.

Make sure not to disengage completely until you're a couple inches away from the ground. Otherwise, you might damage the quadcopter, and your training will be cut short.

IMPORTANT NOTE*:* When the quadcopter is facing you (instead of facing away from you) the controls are all switched. This makes intuitive sense…

1. **Pushing the right stick to the right moves the *quadcopter* to the right (roll).**
2. **Pushing the right stick forward moves the *quadcopter* forward (pitch).**
3. **Pushing the right stick backward moves the *quadcopter* backward (pitch).**
4. **And so on.**

So pay attention to that as you start changing directions. Always be thinking in terms of how the quadcopter will move, rather than how the copter is oriented towards you.

Controls

NOTE: For simplicity's sake, we will assume that the left stick controls yaw and throttle, and the right stick controls roll and pitch. Some transmitters allow the pilot to switch these controls based on what's most comfortable.

Roll:	Done by pushing the right stick to the left or right. Literally rolls the quadcopter, which maneuvers the quadcopter left or right.
Pitch:	Done by pushing the right stick forwards or backwards. Tilts the quadcopter, which maneuvers the quadcopter forwards or backwards.
Yaw:	Done by pushing the left stick to the left or to the right. Rotates the quadcopter left or right. Points the front of the copter different directions and helps with changing directions while flying.
Throttle:	To increase, push the left stick forwards. To decrease, pull the left stick backwards. This adjusts the altitude, or height, of the quadcopter.
Trim:	Buttons on the remote control that help you adjust roll, pitch, yaw, and throttle if they are off balance.
The Rudder:	You might hear this term thrown around, but it's the same as the left stick. However, it relates directly to controlling yaw (as opposed to the throttle).
Aileron:	Same as the right stick. However, it relates directly to controlling roll (left and right movement).
The Elevator:	Same as the right stick. However, it relates directly to controlling pitch (forwards and backwards movement).

Maneuvering

Bank Turn:	A consistent circular turn in either the clockwise or counterclockwise direction.
Hovering:	Staying in the same position while airborne. Done by controlling the throttle.
Figure 8:	Flying in a "figure 8" pattern.

Flight Modes

NOTE: Flight modes can typically be adjusted with certain buttons on your remote control / transmitter.

Manual:	Similar to flying a helicopter. Once you tilt the quadcopter (roll) it will **not** auto-level itself back to its original position. Even if you let go of the stick and it returns to the middle, the quadcopter will stay tilted.
Attitude (Auto-Level):	Once the sticks are centered, the copter will level itself out.
GPS Hold:	Returns the quadcopter's position once the sticks have been centered. The same as attitude mode (auto-level) but using a GPS.

Effects and Use of the Controls

Any useful discussion of aircraft control must include the concept of levels of control. The ultimate goal of aircraft control is to cause the aircraft to reach a specific location at a particular point in time. Aircraft position is four-dimensional and can be described in terms of latitude, longitude, altitude, and time.

The term "level of control" refers to the fact that the attainment of a particular position is not (usually) specified directly by the pilot but indirectly through the manipulation of lower levels of control. So, for example, to attain a particular latitude and longitude, one option is to place a waypoint on a moving-map display that corresponds to that latitude and longitude. This is the highest level of control for the pilot.

Alternatively, the pilot could manipulate the aircraft heading to achieve a particular latitude and longitude. Heading manipulation is the next lower level of control from direct manipulation of latitude and longitude (through waypoints). To attain a particular heading, the pilot must control the turn rate. To attain a particular turn rate, the pilot must command bank angle. To achieve a certain bank angle the pilot must manipulate the roll rate.

Finally, to achieve a specific roll rate, the pilot must control the roll acceleration. In traditional aircraft configurations, roll acceleration is manipulated directly by positioning the ailerons through movement of the yoke. From the final goal state of position, described by latitude and longitude, there can be as many as five lower levels (or "orders") of control that must be integrated to achieve this goal state.

Current UA employ a wide variety of control architectures. While there are still a few systems that use direct control of aircraft surfaces, this level of control is used only by external (i.e., direct line-of-sight) pilots during landing and takeoff. Most of the systems inventoried employ some level of automation at all available levels of control, and all of the systems have a waypoint level of control that allows the aircraft to fly at least a portion of the flight without pilot intervention.

The viewpoint of the pilot for a majority of the systems is exocentric. There is no research to suggest that an exocentric viewpoint has any negative effect on the pilot in terms of decision- making, piloting skills, or awareness of flight parameters.

However, it has been suggested that there might be negative consequences from the pilot not having a shared fate with the aircraft (McCarley & Wickens, 2005). Whether an exocentric viewpoint diminishes the feeling of shared fate or not is unknown.

Attitude information is sometimes given in the form of an outside-in display and sometimes as an inside-out display. The outside-in display has been shown to be more effective for recovery from unusual attitudes (Previc & Ercoline, 1999), but the level of automation employed for UAS should prevent the onset of unusual attitudes from ever occurring. There is no empirical support in regard to which format is the most effective for the types of piloting activities expected for UAS.

Feel of the UAV

Flying a quadcopter continuously requires you to rotate and change directions simultaneously. This will take some getting used to, because the quadcopter will be facing different angles in relation to how you're facing, so you will need to pay close attention to how each movement of the sticks will affect the quadcopter's flight.

First, take off and hover. Rotate (yaw) your copter to a slight angle. Use the right stick to fly it left / right and forwards / backwards. Get comfortable flying the quadcopter while it faces a different direction. Rotate it to another angle, and use the right stick to maneuver it again.

Keep doing this until you're comfortable flying at different angles. To fly continuously, slowly push the right stick forward. As you are pushing the right stick forward, push the right stick slightly to the left or to the right at the same time.

Fly in different directions by pushing the right stick forward (pitch) and adjusting it left and right, and using the left stick (yaw) to change the direction the copter is facing. Then, try adjusting the quadcopter's height by moving the left stick forward and backward (throttle).

Keep practicing until you can direct your quadcopter at will.

Beginner Flying Techniques

1. Hover in place.
2. Hover and rotate the quadcopter.
3. Rotate the quadcopter to different angles, and fly it left / right and forwards / backwards until you're comfortable flying a quadcopter without it facing the same direction as you.
4. Fly your quadcopter in a square pattern.
5. Fly your quadcopter in a circle.
6. It is important you master these basic beginner steps before conducting basic training (NIST).

CHAPTER 4.
Takeoff and Departure

General

When learning how to fly a quadcopter, it's important to understand the machine you're commanding.

If something goes wrong, you want to be able to diagnose and fix the issue. You also want to understand the capabilities of each part and how they play into flying a quadcopter.

Here are the main parts of a quadcopter:

1. The Frame
2. Motors
3. Electronic Speed Control (ESC)
4. Flight Control Board
5. Radio Transmitter and Receiver
6. Propellers
7. Battery and Charger

The frame connects all of the other components. For a quadcopter, it's shaped in either an X or a + shape:

- If you're building your own quadcopter, you want to consider the size and weight of the frame and how it will affect your flying experience.

The motors spin the propellers. A quadcopter needs four motors, because one motor powers a single propeller:

- The higher the kV, the faster the motor will spin. Kv is often quoted in RPM per volt, which means that a 1000 Kv motor on a 10V supply will rotate just under 10,000 rpm at no load.

Electric Speed Controls (ESCs) are wired components that connect the motors and the battery. They relay a signal to the motors that tells them how fast to spin:

- At any one time, each of your motors could be spinning at different speeds. This is what lets you maneuver and change direction. It's all conducted by the Electronic Speed Controls, so they're very important.

The Flight Control Board is the "commander of operations". It controls the accelerometer and gyroscopes, which control how fast each motor spins.

The Radio Transmitter is your remote control, and **the receiver** is the antenna on the copter that talks to the remote control. When you make an adjustment on the transmitter, the receiver is what understands that adjustment and sends it to the rest of the quadcopter system.

A quadcopter has four propellers, and each one helps determine which direction the quadcopter flies or whether it hovers in place.

The battery is the power source for the whole quadcopter. This needs to be charged and recharged, because without a battery, you cannot fly your quadcopter.

The charger charges your battery so you can take multiple flights.

Pre-Flight Checklist

Going through a pre-flight checklist will keep you and your copter safe.

It will also make sure you don't waste time fixing components and getting things ready, when you could be having a blast flying your quad.

Here's a checklist you can use before each flight:

Weather and Site Safety Check

1. Chance of precipitation less than 10%.
2. Wind speed under 15 knots (less than 20 mph).
3. Cloud base at least 500 feet.
4. Visibility at least three statute miles (SM).
5. If flying at dawn / dusk, double-check civil twilight hours.
6. Establish take-off, landing, and emergency hover zones.
7. Potential for electromagnetic interference?
8. Look for towers, wires, buildings, trees, or other obstructions.
9. Look for pedestrians and / or animals and set up safety perimeter if needed.
10. Discuss flight mission with other crew members if present.

Visual Aircraft / System Inspection

1. Registration number is displayed properly and is legible.
2. Look for abnormalities—aircraft frame, propellers, motors, undercarriage.
3. Look for abnormalities—gimbal, camera, transmitter, payloads, etc.
4. Gimbal clamp and lens caps are removed.
5. Clean lens with microfiber cloth.
6. Attach propellers, battery / fuel source, and insert SD card / lens filters.

Powering Up

1. Turn on transmitter / remote control and open up DJI Go 4 app.
2. Turn on aircraft.
3. Verify established connection between transmitter and aircraft.
4. Position antennas on transmitter toward the sky.
5. Verify display panel / FPV screen is functioning properly.

6. Calibrate Inertial Measurement Unit (IMU) as needed.
7. Calibrate compass before every flight.
8. Verify battery / fuel levels on both transmitter and aircraft.
9. Verify that the UAS has acquired GPS location from at least six satellites.

Taking Off

1. Take-off to eye-level altitude for about 10 to 15 seconds.
2. Look for any imbalances or irregularities.
3. Listen for abnormal sounds.
4. Pitch, roll, and yaw to test control response and sensitivity.
5. Check for electromagnetic interference or other software warnings.
6. Do one final check to secure safety of flight operations area.

CHAPTER 5. Emergency or Abnormal Situations

An emergency situation is one in which the safety of the aircraft or of persons on board or on the ground is endangered for any reason.

An abnormal situation is one in which it is no longer possible to continue the flight using normal procedures but the safety of the aircraft or persons on board or on the ground is not in danger.

Emergency or abnormal situations may develop as a result of one or more factors within or outside an aircraft, for example:

1. Fire on board the aircraft.
2. Aircraft component failure or malfunction.
3. Shortage of fuel (loss of battery power, etc.).
4. Flight crew uncertain of position.
5. Worsening weather.
6. Pilot incapacitation (e.g., as a result of illness).
7. Aircraft damage (e.g., as a result of collision, bird strike or extreme weather.
8. Illegal activity (e.g., bomb-threat, willful damage or hi-jacking).

An emergency or abnormal situation may result in it being impossible to continue the flight to destination as planned, resulting in one or more of the following outcomes:

1. Loss of altitude.
2. Diversion.
3. Forced landing.

The operator shall provide operations staff and flight crew with an aircraft operating manual, for each aircraft type operated, containing the normal, abnormal and emergency procedures relating to the operation of the aircraft. The manual shall include details of the aircraft systems and of the emergency or abnormal checklist (EAC) to be used. The design of the manual shall observe human factors principles.

An operator shall establish and maintain a ground and flight training program, approved by the State of the Operator, which ensures that all flight crew members are adequately trained to perform their assigned duties. The training program ... shall include proper flight crew coordination and training in all types of emergency or abnormal situations or procedures caused by powerplant, airframe or systems malfunctions, fire or other abnormalities. The training for each flight crew member, particularly that relating to abnormal or emergency procedures, shall ensure that all flight crew members know the functions for which they are responsible and the relation of these functions to the functions of other crew members. The training program shall be given on a recurrent basis, as determined by the State of the Operator.

In practice, immediate actions in response to certain emergency or abnormal situations (e.g. fire, engine failure or bird strike) are carried out from memory; action taken is then confirmed by reference to the EAC, which also contains subsequent action and considerations.

Lost Link / GPS Procedures

Lost link is an interruption or loss of the control link between the control station and the unmanned aircraft, preventing control of the aircraft resulting in the UAS performing pre-set lost link procedures such as the following:

In the event of a lost link while operating in controlled airspace, which cannot be reestablished within 10 seconds, a designated crewmember will immediately notify the appropriate ATC.

When possible, lost link and lost GPS procedures should comply with the following:

1. The aircraft autopilot will enter a lost link mode within 10 seconds of the lost link condition being detected, return to the LZ or other defined lost link waypoint within the sUAS OP AREA, and land.

If the aircraft loses GPS, the PIC should immediately attempt to land the aircraft in a safe location by controlling it manually or landing at the current location within the OP AREA.

If both GPS and data link are lost, the aircraft must automatically land at the current position.

The UAS lost link mission should avoid transit or orbit over populated areas.

Emergency or Fly-Away Procedures

In the event of a fly-away or other emergency scenario while operating in controlled airspace, designated crew member will immediately notify ATC or nearest controlling facility.

The crewmember will state PIC intentions, and provide the following:

1. The nature of the emergency.
2. Last known UAS position, altitude, and direction of flight.
3. Maximum remaining flight time.

Lost Sight

If a VO loses sight of the UAS, the VO will notify the PIC immediately.

If the UAS is visually reacquired promptly, the mission may be continued. If not, the PIC must immediately abort the flight and land the UAS.

Lost Communications

The PIC must land the UAS if communication with the VO is lost and the PIC cannot gain VLOS.

CHAPTER 6.
Pilot Performance Maneuvers

Drone Maneuvers

Training Maneuvers Overview

NIST STANDARD TEST METHODS FOR SMALL UNMANNED AIRCRAFT SYSTEMS

Introduction

These test methods for Small Unmanned Aircraft Systems (sUAS) are being developed by the National Institute of Standards and Technology (NIST) with sponsorship from the Department of Homeland Security (DHS) Science and Technology Directorate (S&T).

They are being standardized through the ASTM International Standards Committee on Homeland Security Applications; Response Robots (ASTM E54.09). They are referenced in the National Fire Protection Association Standard for Small Unmanned Aircraft Systems Used for Public Safety Operations (NFPA 2400) as Job Performance Requirements to focus training and evaluate remote pilot proficiency.

NIST Project Objective was to develop the measurements and standards infrastructure necessary to quantitatively evaluate robotic system capabilities and **remote pilot proficiency**.

The Outcomes was a Test Method, Performance metrics and data collection tools that help apply emerging technologies toward mission tasks.

This section has used the NIST standard test method for small unmanned aircraft systems to create this recommended flight evaluation. It is the best formalized method to evaluate pilot proficiency and to standardize requirement of maneuvers.

The reader can review the original document at the NIST website:

www.robotestmethods.nist.gov

Overview

NIST's approach revolves around a "mechanism" or a Standardized "structure' to establish reproducible test methods. Their "structure" is easy to build and inexpensive. The instructions to build the apparatus is outlined in the original document found at www.robotestestmethods.nist.gov.

The Test Method designed by NIST focus on repeatable task to measure and compare proficiency.

This document focus' on the Test Methods and the grading for Maneuvering. This establishes the Pilot's Proficiency and assist in training to achieve acceptable levels.

Maneuvering Functionality includes:

1. Position Alignments and Identifications:
    - Maintain Position and Rotate;
    - Climb and Descend;
    - Fly Straight and Level;

- Move and Rotate;
- Land Accurately.

2. Traverse Alignments and Identifications
3. Orbit Alignments and Identifications
4. Spiral Alignments and Identifications
5. Sustain Speed / Deliver Payload

Reviewing the NIST documentation there are test methods for Logistics, Durability (hardware testing), Radio Communications and Sensing. These methods can be found at the NIST website.

NIST has developed a very flexible test structure that consist of one tall structure and two smaller structures. These structures can be easily built following the NIST instruction found in the documentation located at www.RobotTestMethods.nist.gov.

This “scalable test lane” is the basic configuration of the structure and establishes the flight exam lane.

Remote Pilot Flight Certifications

As of this day, the FAA does not require flight exams to exercise your right to fly (however, everyone must conform to FAA Part 107). Most Remote Pilots are earning flight certifications through NIST collaborators as AUVSI (see https://www.auvsi.org/topoperator) or APSA (https://publicsafetyaviation.org/). The following section provides information on the various flight exams as defined by NIST. We encourage you to seek out a proctor examiner and take the flight exams.

Your certification will allow you to stand out among other remote pilots, making you more desirable to prospective employers and giving you a competitive advantage when it comes to negotiating rates / salaries. Your certification designation shows that you have demonstrated a high level of experience, skill and knowledge as well as a commitment to professional development

NIST Flight Testing Requirements

General Information

You will find a guide on how to fabricate a NIST sUAS Open Test Lane in the Appendix of this Handbook.

There are five test levels. Each level uses a different set of maneuvering functionalities. These five levels are:

Level 1:	Safety Check Ride
Level 2:	Open Lane – Maneuvering
Level 3:	Open Lane – Payload
Level 3:	Open Lane – Scenarios
Level 4:	Obstructed – Payload
Level 4:	Obstructed – Scenarios
Level 5:	Confined – Payload
Level 5:	Confined – Scenarios

Level 1 is considered the Basic Proficiency Evaluation for Remote Pilots (BPERP). We will classify Levels 2 to 3 Intermediate training and Level 4 to 5 Advanced training.

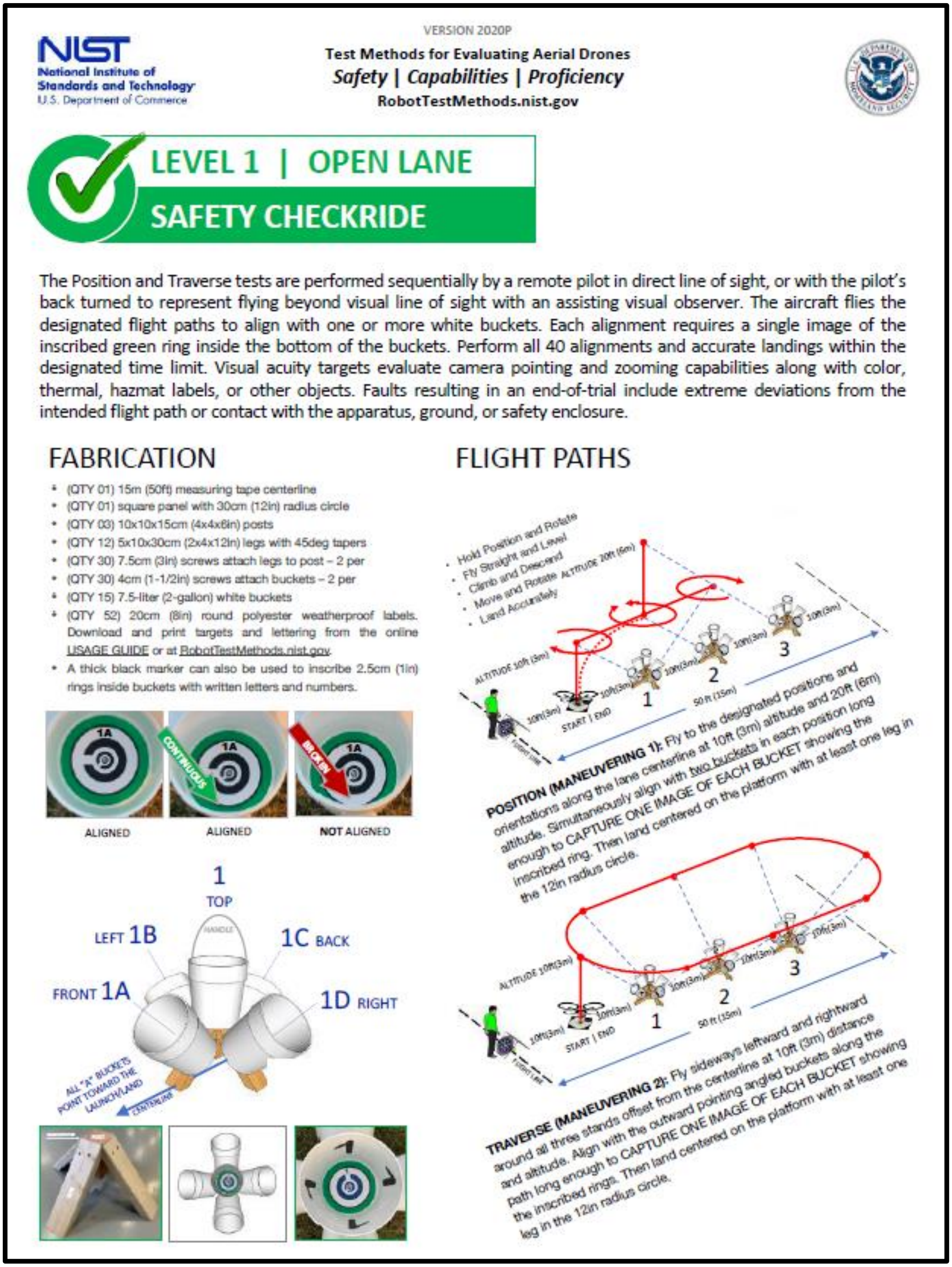
Note that the level's indicating "Payload" do require a drone with some zoom capability in order to pass the test.

In the following sections, each level contains two pages, a description, and a scoring page. This allows the pilot to understand what is required and how they will be scored.

For more details about the NIST aerial program and its forms go to:

https://www.nist.gov/el/intelligent-systems-division-73500/standard-test-methods-response-robots/aerial-systems

Level 1: Safety Check Ride



VERSION 2020P

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Test Methods for Evaluating Aerial Drones
Safety | Capabilities | Proficiency
RobotTestMethods.nist.gov

LEVEL 1 | OPEN LANE
SAFETY CHECKRIDE

The Position and Traverse tests are performed sequentially by a remote pilot in direct line of sight, or with the pilot's back turned to represent flying beyond visual line of sight with an assisting visual observer. The aircraft flies the designated flight paths to align with one or more white buckets. Each alignment requires a single image of the inscribed green ring inside the bottom of the buckets. Perform all 40 alignments and accurate landings within the designated time limit. Visual acuity targets evaluate camera pointing and zooming capabilities along with color, thermal, hazmat labels, or other objects. Faults resulting in an end-of-trial include extreme deviations from the intended flight path or contact with the apparatus, ground, or safety enclosure.

FABRICATION

- (QTY 01) 15m (50ft) measuring tape centerline
- (QTY 01) square panel with 30cm (12in) radius circle
- (QTY 03) 10x10x15cm (4x4x6in) posts
- (QTY 12) 5x10x30cm (2x4x12in) legs with 45deg tapers
- (QTY 30) 7.5cm (3in) screws attach legs to post – 2 per
- (QTY 30) 4cm (1-1/2in) screws attach buckets – 2 per
- (QTY 15) 7.5-liter (2-gallon) white buckets
- (QTY 52) 20cm (8in) round polyester weatherproof labels. Download and print targets and lettering from the online USAGE GUIDE or at RobotTestMethods.nist.gov.
- A thick black marker can also be used to inscribe 2.5cm (1in) rings inside buckets with written letters and numbers.

1A CONTINUOUS BROKEN
ALIGNED ALIGNED NOT ALIGNED

1 TOP
LEFT 1B
1C BACK
FRONT 1A
1D RIGHT
HANDLE
ALL "A" BUCKETS POINT TOWARD THE LAUNCH/LAND
CENTERLINE

FLIGHT PATHS

- Hold Position and Rotate
- Fly Straight and Level
- Climb and Descend
- Move and Rotate
- Land Accurately

ALTITUDE 20ft (6m)
ALTITUDE 10ft (3m)
10ft(3m)
START | END
50 ft (15m)
1 2 3

POSITION (MANEUVERING 1): Fly to the designated positions and orientations along the lane centerline at 10ft (3m) altitude and 20ft (6m) altitude. Simultaneously align with two buckets in each position long enough to CAPTURE ONE IMAGE OF EACH BUCKET showing the inscribed ring. Then land centered on the platform with at least one leg in the 12in radius circle.

ALTITUDE 10ft(3m)
10ft(3m)
START | END
50 ft (15m)
1 2 3

TRAVERSE (MANEUVERING 2): Fly sideways leftward and rightward around all three stands offset from the centerline at 10ft (3m) distance and altitude. Align with the outward pointing angled buckets along the path long enough to CAPTURE ONE IMAGE OF EACH BUCKET showing the inscribed rings. Then land centered on the platform with at least one leg in the 12in radius circle.

VERSION 2020P

National Institute of Standards and Technology
U.S. Department of Commerce

Test Methods for Evaluating Aerial Drones
Safety | Capabilities | Proficiency
RobotTestMethods.nist.gov

LEVEL 1 | OPEN LANE
SAFETY CHECKRIDE

Pilot LAST Name ____________

Pilot FIRST Name ____________

Pilot Organization ____________

Drone Make ____________

Drone Model ____________

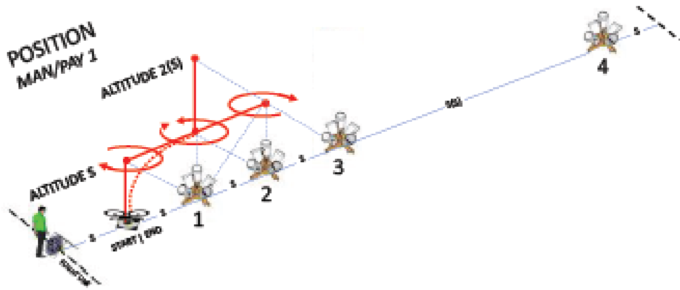
Facility Location ____________

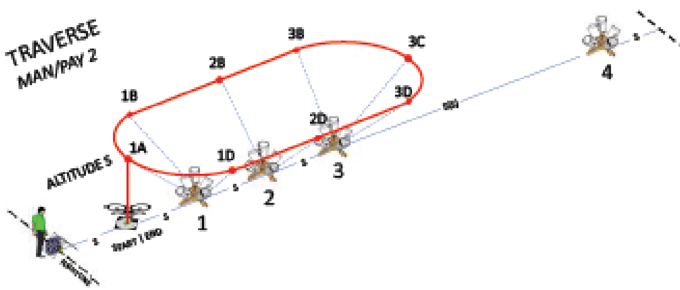
Date (YYYY/MM/DD) ____________ Team #: ______

PROCTOR NAME ____________

LANE SPACING (S)	LIGHTING	WIND	PILOT VIEW	TIME LIMIT
10 FT 20 FT 30 FT _____ FT (CIRCLE ONE or FILL IN)	DAYLIGHT 1000+ LUX LIGHTED 300+ LUX DARK < 1 LUX (CIRCLE ONE)	AVERAGE ____ MPH GUSTS ____ MPH (FILL IN)	LINE OF SIGHT: FACING LANE, OPTIONAL V.O. INTERFACE ONLY: BACK TO LANE, MANDATORY V.O. (CIRCLE ONE)	5 MIN 10 MIN ____ MIN (CIRCLE ONE)

ALIGNMENT SCORE: Circle bucket identifiers for images with UNBROKEN RINGS. Strike through all BROKEN RINGS and incomplete buckets.





CAPTURE ONLY ONE IMAGE OF EACH BUCKET – CIRCLE ALIGNED IMAGES AND LANDINGS

CAPTURE PRE-LAUNCH CLOCK IMAGE – LAUNCH TIME (HH:MM:SS)		: :
POSITION TEST – FLYING ALONG CENTERLINE		CIRCLE ALIGNED
1	LAUNCH AND HOVER OVER STAND #1 TO ALIGN WITH	1 & 2A
2	YAW LEFTWARD 360° OVER STAND #1 TO ALIGN WITH	1 & 2A
3	YAW RIGHTWARD 360° OVER STAND #1 ALIGN WITH	1 & 2A
4	CLIMB VERTICALLY OVER STAND #1 TO ALIGN WITH	1 & 3A
5	DESCEND VERTICALLY OVER STAND #1 TO ALIGN WITH	1 & 2A
6	PITCH FORWARD OVER STAND #2 TO ALIGN WITH	2 & 3A
7	PITCH BACKWARD OVER STAND #1 TO ALIGN WITH	1 & 2A
8	PITCH FORWARD OVER STAND #2 THEN YAW LEFT 180°	2 & 1C
9	PITCH FORWARD OVER LANDING THEN YAW RIGHT 180°	L & 1A
10	LAND IN CIRCLE (ONE OR MORE LEGS) – WORTH 2 POINTS	1pt & 1pt
TRAVERSE TEST – FLYING LEFTWARD		CIRCLE ALIGNED
11	HOVER OVER THE LAUNCH PLATFORM TO ALIGN WITH	1A
12	ORBIT 90° LEFTWARD AROUND STAND #1 TO ALIGN WITH	1B
13	ROLL LEFTWARD TO STAND #2 TO ALIGN WITH	2B
14	ROLL LEFTWARD TO STAND #3 TO ALIGN WITH	3B
15	ORBIT 90° LEFTWARD AROUND STAND #3 TO ALIGN WITH	3C
16	ORBIT 90° LEFTWARD AROUND STAND #3 TO ALIGN WITH	3D
17	ROLL LEFTWARD TO STAND #2 TO ALIGN WITH	2D
18	ROLL LEFTWARD TO STAND #1 TO ALIGN WITH	1D
19	ORBIT 90° LEFTWARD AROUND STAND #1 TO ALIGN WITH	1A
20	LAND IN CIRCLE (ONE OR MORE LEGS) – WORTH 1 POINT	1pt
TRAVERSE TEST – FLYING RIGHTWARD		CIRCLE ALIGNED
21	HOVER OVER THE LAUNCH PLATFORM TO ALIGN WITH	1A
22	ORBIT 90° RIGHTWARD AROUND STAND #1 TO ALIGN WITH	1D
23	ROLL RIGHTWARD TO STAND #2 TO ALIGN WITH	2D
24	ROLL RIGHTWARD TO STAND #3 TO ALIGN WITH	3D
25	ORBIT 90° RIGHTWARD AROUND STAND #3 TO ALIGN WITH	3C
26	ORBIT 90° RIGHTWARD AROUND STAND #3 TO ALIGN WITH	3B
27	ROLL RIGHTWARD TO STAND #2 TO ALIGN WITH	2B
28	ROLL RIGHTWARD TO STAND #1 TO ALIGN WITH	1B
29	ORBIT 90° RIGHTWARD AROUND STAND #1 TO ALIGN WITH	1A
30	LAND IN CIRCLE (ONE OR MORE LEGS) – WORTH 1 POINT	1pt
CAPTURE CLOCK IMAGE AFTER LANDING – LAND TIME (HH:MM:SS)		: :
STOP THE TIMER OR CALCULATE RESULT – ELASPED TIME (MM:SS)		:
_______ / 40 MINIMUM PASSING SCORE – TOTAL SCORE (POINTS)		
CIRCLE ONE: FAIL (SCORE | TIME | SAFETY) OR PASS		

Level 2: Open Lane – Maneuvering

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Test Methods for Evaluating Aerial Drones

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M LEVEL 2 | OPEN LANE

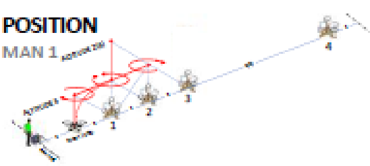
MANEUVERING ONLY

Perform 5 different flight paths around the omni bucket stands. Each flight path includes as sequence of alignments with one or more buckets. Capture a SINGLE IMAGE of the inscribed ring inside each bucket and land accurately.

- Score ALIGNMENT POINTS after trial from images with UNBROKEN RINGS (5 pts) or BROKEN RINGS (1 pt).
- Land CENTERED (5 pts) with the aircraft center inside the designated 60 cm (24 inch) diameter circle, or OFFSET (1 pt) with at least one propeller motor inside the circle.
- Start timer at launch and end after the last task is completed. Trial time limits are typically 5 minutes each (25 minutes to complete all 5 tests) although organizations may set their own trial time limits and passing scores.
- Extreme deviations from the intended flight path, or contact with any object, ends the trial to ensure safety.

POSITION

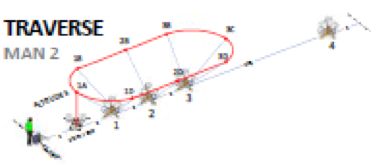
MAN 1



- Demonstrate basic flight maneuvers between designated hover positions, orientations, and altitudes along the lane centerline at altitudes S and 2(S).
- Climb, descend, yaw, pitch, and roll to simultaneously align with downward buckets to check position then forward buckets to check altitude.
- **Complete 10 positions along the lane centerline with 18 alignments and 1 accurate landing (counts double) to score up to 100 points.**

TRAVERSE

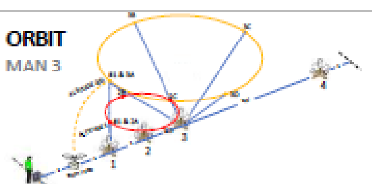
MAN 2



- Fly sideways parallel to objects while looking forward to identify features as if along a road, truck, bus, building, fence, tree line, etc.
- Maintain altitude S flying leftward and rightward around the first three bucket stands to align with all the designated buckets.
- **Complete 1 lap leftward then 1 lap rightward with 18 alignments and 2 accurate landings to score up to 100 points.**

ORBIT

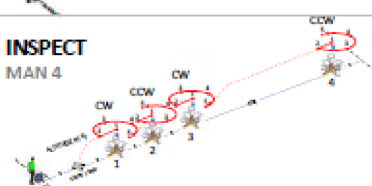
MAN 3



- Fly circular orbits around designated bucket stands while looking inward to identify features on all four sides. Fly altitude 2(S) leftward and rightward around stand #3 (white), then altitude S leftward and rightward around stand #2 (black).
- Each orbit has 5 bucket alignments starting with 1 downward radius check then 4 altitude checks around the orbit looking inward at the angled buckets.
- **Complete 4 orbits with 20 alignments to score up to 100 points.**

INSPECT

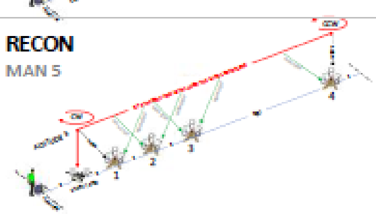
MAN 4



- Fly in closer proximity around objects to inspect detailed features on top and all four sides of the bucket stands.
- Maintain altitude 1/2(S) starting on top of each bucket stand with alternating leftward and rightward rotations to inspect all four sides of each bucket stand.
- **Complete all 4 stands with 20 alignments to score up to 100 points.**

RECON

MAN 5



- Fly straight and level over the centerline to establish a stable hover over an object down range to perform reconnaissance tasks.
- Maintain altitude S to align with buckets and the landing at each end of the lane. Reconnaissance tasks are performed every 8(S) over a total distance of 80(S).
- **Complete 5 laps (or 10 lane lengths) with 20 alignments to score up to 100 points.**

Level 3: Open Lane – Payload

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LEVEL 3 | OPEN LANE

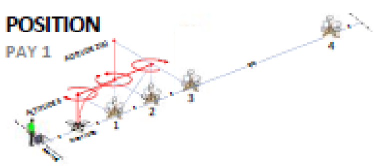
PAYLOAD FUNCTIONALITY

Perform 5 different flight paths around the omni bucket stands. Each flight path includes a sequence of alignments with one or more buckets. While aligned with each bucket, control camera zoom and exposure to capture a SINGLE IMAGE of the inscribed ring and IDENTIFY TARGETS inside each bucket.

- Score ALIGNMENT POINTS after the trial from images with UNBROKEN RINGS (5 pts) or BROKEN RINGS (1 pt).
- Score ACUITY POINTS by calling out the 5 increasingly small VISUAL ACUITY TARGET GAPS (1 pt each).
- Land CENTERED (5 pts) with the aircraft center inside the designated 60 cm (24 inch) diameter circle, or OFFSET (1 pt) with at least one propeller motor inside the circle.
- Start timer at launch and end after the last task is completed. Trial time limits are typically 5 minutes each (25 minutes to complete all 5 tests) although organizations may set their own trial time limits and passing scores.
- Extreme deviations from the intended flight path, or contact with any object, ends the trial to ensure safety.

POSITION

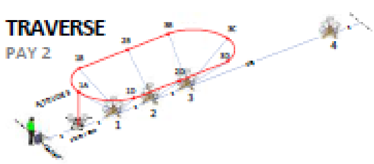
PAY 1



- Demonstrate basic flight maneuvers between designated hover positions, orientations, and altitudes along the lane centerline at altitudes S and 2(S).
- Climb, descend, yaw, pitch, and roll to simultaneously align with downward buckets to check position then forward buckets to check altitude.
- **Complete 10 positions along the lane centerline with 18 alignments and 1 accurate landing (counts double) to score up to 100 points.**

TRAVERSE

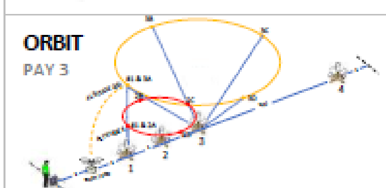
PAY 2



- Fly sideways parallel to objects while looking forward to identify features as if along a road, truck, bus, building, fence, tree line, etc.
- Maintain altitude S flying leftward and rightward around the first three bucket stands to align with all the designated buckets.
- **Complete 1 lap leftward then 1 lap rightward with 18 alignments and 2 accurate landings to score up to 100 points.**

ORBIT

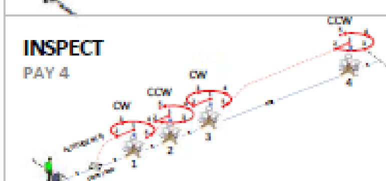
PAY 3



- Fly circular orbits around designated bucket stands while looking inward to identify features on all four sides. Fly altitude 2(S) leftward and rightward around stand #3 (white), then altitude S leftward and rightward around stand #2 (black).
- Each orbit has 5 bucket alignments starting with 1 downward radius check then 4 altitude checks around the orbit looking inward at the angled buckets.
- **Complete 4 orbits with 20 alignments to score up to 100 points.**

INSPECT

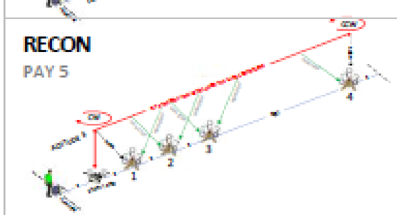
PAY 4



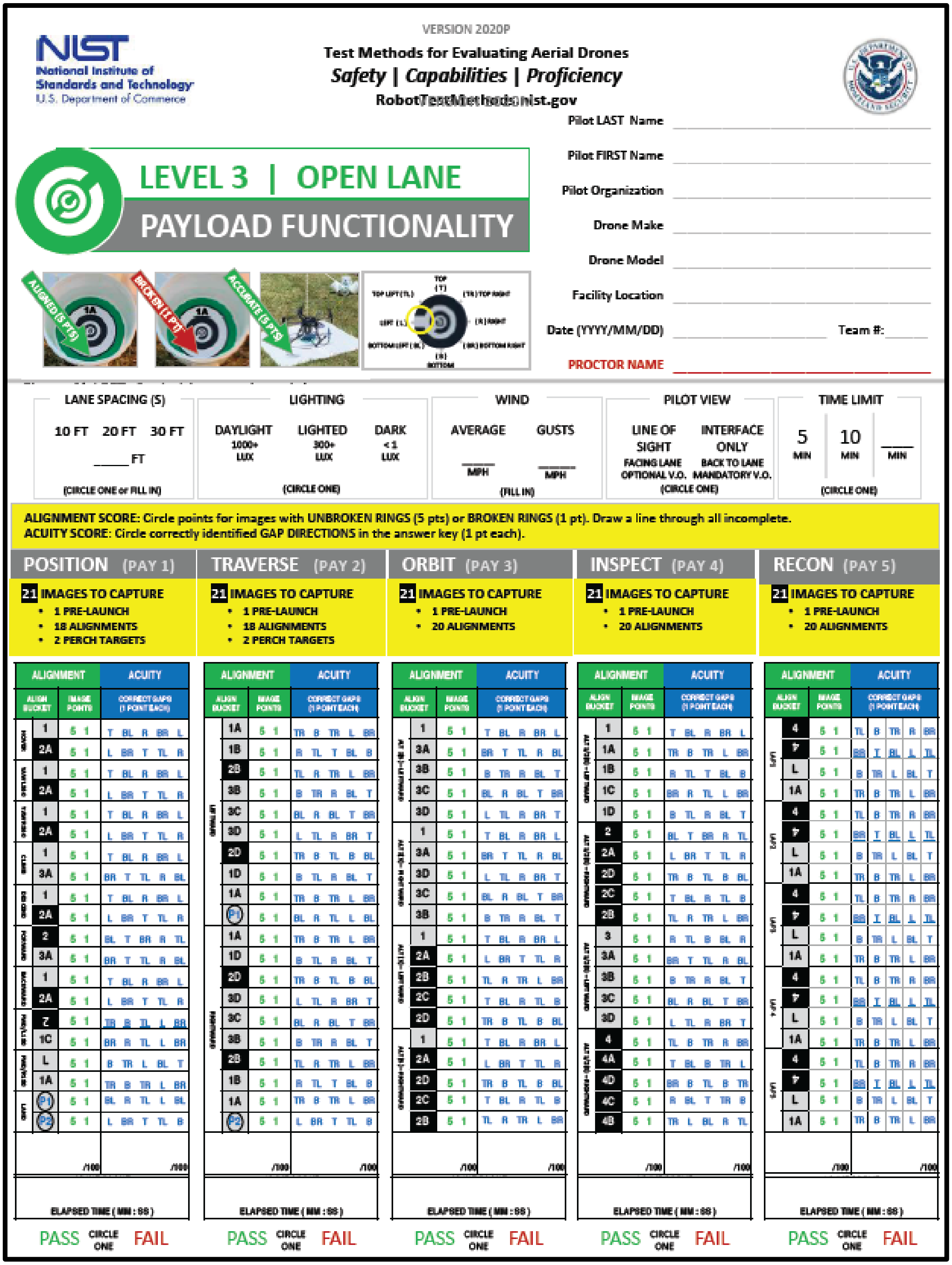
- Fly in closer proximity around objects to inspect detailed features on top and all four sides of the bucket stands.
- Maintain altitude 1/2(S) starting on top of each bucket stand with alternating leftward and rightward rotations to inspect all four sides of each bucket stand.
- **Complete all 4 stands with 20 alignments to score up to 100 points.**

RECON

PAY 5



- Fly straight and level over the centerline to establish a stable hover over an object down range to perform reconnaissance tasks.
- Maintain altitude S to align with buckets and the landing at each end of the lane. Reconnaissance tasks are performed every 8(S) over a total distance of 80(S).
- **Complete 5 laps (or 10 lane lengths) with 20 alignments to score up to 100 points.**



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Pilot LAST Name ____________
Pilot FIRST Name ____________
Pilot Organization ____________
Drone Make ____________
Drone Model ____________
Facility Location ____________
Date (YYYY/MM/DD) ____________ Team #: ______
PROCTOR NAME ____________

LEVEL 3 | OPEN LANE
PAYLOAD FUNCTIONALITY

LANE SPACING (S)	LIGHTING	WIND	PILOT VIEW	TIME LIMIT
10 FT 20 FT 30 FT ____ FT (CIRCLE ONE or FILL IN)	DAYLIGHT 1000+ LUX; LIGHTED 300+ LUX; DARK <1 LUX (CIRCLE ONE)	AVERAGE ____ MPH; GUSTS ____ MPH (FILL IN)	LINE OF SIGHT FACING LANE OPTIONAL V.O.; INTERFACE ONLY BACK TO LANE MANDATORY V.O. (CIRCLE ONE)	5 MIN; 10 MIN; ____ MIN (CIRCLE ONE)

ALIGNMENT SCORE: Circle points for images with UNBROKEN RINGS (5 pts) or BROKEN RINGS (1 pt). Draw a line through all incomplete.
ACUITY SCORE: Circle correctly identified GAP DIRECTIONS in the answer key (1 pt each).

POSITION (PAY 1)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 18 ALIGNMENTS
- 2 PERCH TARGETS

ALIGN BUCKET	IMAGE POINTS	CORRECT GAPS (1 POINT EACH)
1	5 1	T BL R BR L
2A	5 1	L BR T TL R
1	5 1	T BL R BR L
2A	5 1	L BR T TL R
1	5 1	T BL R BR L
2A	5 1	L BR T TL R
1	5 1	T BL R BR L
3A	5 1	BR T TL R BL
1	5 1	T BL R BR L
2A	5 1	L BR T TL R
2	5 1	BL T BR R TL
3A	5 1	BR T TL R BL
1	5 1	T BL R BR L
2A	5 1	L BR T TL R
Z	5 1	TR B TL L BR
1C	5 1	BR R TL L BR
L	5 1	B TR L BL T
1A	5 1	TR B TR L BR
P1	5 1	BL R TL L BL
P2	5 1	L BR T TL B
	/100	/100

ELAPSED TIME (MM:SS)

PASS (CIRCLE ONE) FAIL

TRAVERSE (PAY 2)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 18 ALIGNMENTS
- 2 PERCH TARGETS

ALIGN BUCKET	IMAGE POINTS	CORRECT GAPS (1 POINT EACH)
1A	5 1	TR B TR L BR
1B	5 1	R TL T BL B
2B	5 1	TL R TR L BR
3B	5 1	B TR R BL T
3C	5 1	BL R BL T BR
3D	5 1	L TL R BR T
2D	5 1	TR B TL B BL
1D	5 1	B TL R BL T
1A	5 1	TR B TR L BR
P1	5 1	BL R TL L BL
1A	5 1	TR B TR L BR
1D	5 1	B TL R BL T
2D	5 1	TR B TL B BL
3D	5 1	L TL R BR T
3C	5 1	BL R BL T BR
3B	5 1	B TR R BL T
2B	5 1	TL R TR L BR
1B	5 1	R TL T BL B
1A	5 1	TR B TR L BR
P2	5 1	L BR T TL B
	/100	/100

ELAPSED TIME (MM:SS)

PASS (CIRCLE ONE) FAIL

ORBIT (PAY 3)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS

ALIGN BUCKET	IMAGE POINTS	CORRECT GAPS (1 POINT EACH)
1	5 1	T BL R BR L
3A	5 1	BR T TL R BL
3B	5 1	B TR R BL T
3C	5 1	BL R BL T BR
3D	5 1	L TL R BR T
1	5 1	T BL R BR L
3A	5 1	BR T TL R BL
3D	5 1	L TL R BR T
3C	5 1	BL R BL T BR
3B	5 1	B TR R BL T
1	5 1	T BL R BR L
2A	5 1	L BR T TL R
2B	5 1	TL R TR L BR
2C	5 1	T BL R TL B
2D	5 1	TR B TL B BL
1	5 1	T BL R BR L
2A	5 1	L BR T TL R
2D	5 1	TR B TL B BL
2C	5 1	T BL R TL B
2B	5 1	TL R TR L BR
	/100	/100

ELAPSED TIME (MM:SS)

PASS (CIRCLE ONE) FAIL

INSPECT (PAY 4)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS

ALIGN BUCKET	IMAGE POINTS	CORRECT GAPS (1 POINT EACH)
1	5 1	T BL R BR L
1A	5 1	TR B TR L BR
1B	5 1	R TL T BL B
1C	5 1	BR R TL L BR
1D	5 1	B TL R BL T
2	5 1	BL T BR R TL
2A	5 1	L BR T TL R
2D	5 1	TR B TL B BL
2C	5 1	T BL R TL B
2B	5 1	TL R TR L BR
3	5 1	R TL B BL R
3A	5 1	BR T TL R BL
3B	5 1	B TR R BL T
3C	5 1	BL R BL T BR
3D	5 1	L TL R BR T
4	5 1	TL B TR R BR
4A	5 1	T BL B TR L
4D	5 1	BR B TL B TR
4C	5 1	R BL T TR B
4B	5 1	TR L BL R TL
	/100	/100

ELAPSED TIME (MM:SS)

PASS (CIRCLE ONE) FAIL

RECON (PAY 5)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS

ALIGN BUCKET	IMAGE POINTS	CORRECT GAPS (1 POINT EACH)
4	5 1	TL B TR R BR
7	5 1	BR T BL L TL
L	5 1	B TR L BL T
1A	5 1	TR B TR L BR
4	5 1	TL B TR R BR
7	5 1	BR T BL L TL
L	5 1	B TR L BL T
1A	5 1	TR B TR L BR
4	5 1	TL B TR R BR
7	5 1	BR T BL L TL
L	5 1	B TR L BL T
1A	5 1	TR B TR L BR
4	5 1	TL B TR R BR
7	5 1	BR T BL L TL
L	5 1	B TR L BL T
1A	5 1	TR B TR L BR
4	5 1	TL B TR R BR
7	5 1	BR T BL L TL
L	5 1	B TR L BL T
1A	5 1	TR B TR L BR
	/100	/100

ELAPSED TIME (MM:SS)

PASS (CIRCLE ONE) FAIL

Level 3: Open Load – Scenarios

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LEVEL 3 | OPEN AREA
SCORABLE SCENARIOS

Perform the designated flight paths around objects with omni bucket stands. Each flight path includes a sequence of alignments with one or more buckets. While aligned with each bucket, control camera zoom and exposure to capture a SINGLE IMAGE of the inscribed ring and IDENTIFY TARGETS inside each bucket or in view nearby. Identify other objects of interest within the scenario at the same time.

- Score ALIGNMENT POINTS after the trial from images with UNBROKEN RINGS (5 pts) or BROKEN RINGS (1 pt).
- Score ACUITY POINTS by calling out the 5 increasingly small VISUAL ACUITY TARGET GAPS (1 pt each).
- Land CENTERED (5 pts) with the aircraft center inside the designated 60 cm (24 inch) diameter circle, or OFFSET (1 pt) with at least one propeller motor inside the circle.
- Start timer at launch and end after the last task is completed. Trial time limits are typically 5 minutes each (25 minutes to complete all 5 tests) although organizations may set their own trial time limits and passing scores.
- Extreme deviations from the intended flight path, or contact with any object, ends the trial to ensure safety.

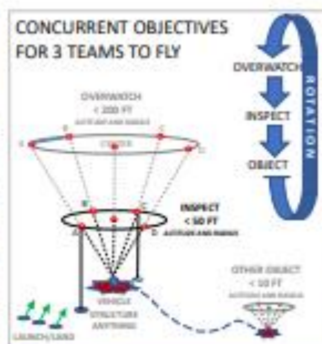
Open Area Search Scenarios

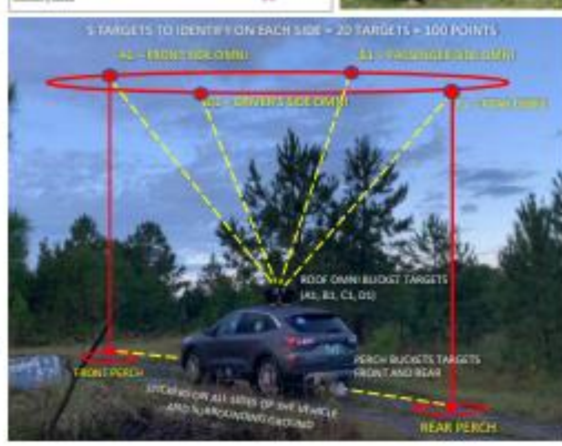
Day and Night Trials

- Teams concurrently fly separate objectives set up at safe distances and/or altitudes apart (with a clearly designated and safe return path).
- Each pilot flies for 15 minutes across 3 different objectives for 5 minutes each. Teams move as necessary to maintain sight lines and communication.
- Scenarios restart with a different rotation of Pilot, Proctor, and VO.

Open Vehicle Identification Scenarios

Day and Night Trials





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LEVEL 3 | OPEN AREA

SCORABLE SCENARIOS

Pilot LAST Name ______________________

Pilot FIRST Name ______________________

Pilot Organization ______________________

Drone Make ______________________

Drone Model ______________________

Facility Location ______________________

Date (YYYY/MM/DD) ______________ Team #: ______

PROCTOR NAME ______________________

ALTITUDE	LIGHTING	WIND	PILOT VIEW	TIME LIMIT
10 FT 20 FT 30 FT _____ FT	DAYLIGHT 1000+ LUX LIGHTED 300+ LUX DARK < 1 LUX	AVERAGE ____ MPH GUSTS ____ MPH	LINE OF SIGHT (FACING LANE, OPTIONAL V.O.) INTERFACE ONLY (BACK TO LANE, MANDATORY V.O.)	5 MIN 10 MIN ____ MIN
(CIRCLE ONE or FILL IN)	(CIRCLE ONE)	(FILL IN)	(CIRCLE ONE)	(CIRCLE ONE)

ALIGNMENT SCORE: Circle points for images with UNBROKEN RINGS (5 pts) or BROKEN RINGS (1 pt). Draw a line through all incomplete.
ACUITY SCORE: Circle correctly identified GAP DIRECTIONS in the answer key (1 pt each).

OPEN SCENARIO | SEARCH

START TIMER. CAPTURE PRE-LAUNCH IMAGE OF CLOCK.		ALIGNMENT: ALIGN BUCKET	ALIGNMENT: IMAGE POINTS	ACUITY: CORRECT GAPS (1 POINT EACH)
1 HOVER OVER STAND #1 AT CHOSEN ALTITUDE	STAND #1	1	5 1	T BL R BR L
2 PITCH BACKWARD	STAND #1	1A	5 1	TR B TR L BR
3 ORBIT LEFTWARD 90°	STAND #1	1B	5 1	R TL T BL B
4 ORBIT LEFTWARD 90°	STAND #1	1C	5 1	BR R TL L BR
5 ORBIT LEFTWARD 90°	STAND #1	1D	5 1	B TL R BL T
6 HOVER OVER STAND #2 AT CHOSEN ALTITUDE	STAND #2	2	5 1	BL T BR R TL
7 PITCH BACKWARD	STAND #2	2A	5 1	L BR T TL R
8 ORBIT RIGHTWARD 90°	STAND #2	2D	5 1	TR B TL B BL
9 ORBIT RIGHTWARD 90°	STAND #2	2C	5 1	T BL R TL B
10 ORBIT RIGHTWARD 90°	STAND #2	2B	5 1	TL R TR L BR
11 HOVER OVER STAND #3 AT CHOSEN ALTITUDE	STAND #3	3	5 1	R TL B BL R
12 PITCH BACKWARD	STAND #3	3A	5 1	BR T TL R BL
13 ORBIT LEFTWARD 90°	STAND #3	3B	5 1	B TR R BL T
14 ORBIT LEFTWARD 90°	STAND #3	3C	5 1	BL R BL T BR
15 ORBIT LEFTWARD 90°	STAND #3	3D	5 1	L TL R BR T
16 HOVER OVER STAND #4 AT CHOSEN ALTITUDE	STAND #4	4	5 1	TL B TR R BR
17 PITCH BACKWARD	STAND #4	4A	5 1	T BL B TR L
18 ORBIT RIGHTWARD 90°	STAND #4	4D	5 1	BR B TL B TR
19 ORBIT RIGHTWARD 90°	STAND #4	4C	5 1	R BL T TR B
20 ORBIT RIGHTWARD 90°	STAND #4	4B	5 1	TR L BL R TL
STOP TIMER. RECORD SCORES AND ELAPSED TIME.			/100	/100
			ELAPSED TIME (MM:SS)	

OPEN SCENARIO | VEHICLE

START TIMER. CAPTURE PRE-LAUNCH IMAGE OF CLOCK.		ALIGNMENT: ALIGN BUCKET	ALIGNMENT: IMAGE POINTS	ACUITY: CORRECT GAPS (1 POINT EACH)
ALIGN OVER OMNI BUCKET – START TIMER	#	DESCRIPTION:		
1 A1 - FRONT SIDE - ROOFTOP OMNI BUCKET	FRONT	A1	5 1	T BL R BR L
2 A2 - FRONT SIDE - WINDSHIELD CENTER	FRONT	A2	5 1	TR B TR L BR
3 A3 - FRONT SIDE - VIN #	FRONT	A3	5 1	R TL T BL B
4 A4 - FRONT SIDE - LICENSE PLATE	FRONT	A4	5 1	BR R TL L BR
5 A5 - FRONT SIDE - PERCH UNDERBODY BUCKET	FRONT	A5	5 1	B TL R BL T
6 B1 - PASSENGER SIDE - ROOFTOP OMNI BUCKET	PASSENGER	B1	5 1	BL T BR R TL
7 B2 - PASSENGER SIDE - FRONT WINDOW	PASSENGER	B2	5 1	L BR T TL R
8 B3 - PASSENGER SIDE - REAR WINDOW	PASSENGER	B3	5 1	TL R TR L BR
9 B4 - PASSENGER SIDE - EXTERIOR FEATURE	PASSENGER	B4	5 1	T BL R TL B
10 B5 - PASSENGER SIDE - SURROUNDING GROUND	PASSENGER	B5	5 1	TR B TL B BL
11 C1 - REAR SIDE - ROOTOP OMNI BUCKET	REAR	C1	5 1	R TL B BL R
12 C2 - REAR SIDE - WINDOW CENTER	REAR	C2	5 1	BR T TL R BL
13 C3 - LICENSE PLATE	REAR	C3	5 1	B TR R BL T
14 C4 - EXTERIOR FEATURE	REAR	C4	5 1	BL R BL T BR
15 C5 - PERCH UNDERBODY BUCKET	REAR	C5	5 1	L TL R BR T
16 D1 - DRIVER SIDE - ROOFTOP OMNI BUCKET	DRIVER	D1	5 1	TL B TR R BR
17 D2 - DRIVER SIDE - FRONT WINDOW	DRIVER	D2	5 1	T BL B TR L
18 D3 - DRIVER SIDE - REAR WINDOW	DRIVER	D3	5 1	TR L BL R TL
19 D4 - EXTERIOR FEATURE	DRIVER	D4	5 1	R BL T TR B
20 D5 - SURROUNDING GROUND OBJECT	DRIVER	D5	5 1	BR B TL B TR
STOP TIMER. RECORD SCORES AND ELAPSED TIME.			/100	/100
			ELAPSED TIME (MM:SS)	

Level 4: Obstructed – Payload

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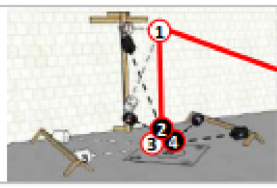
LEVEL 4 | OBSTRUCTED
PAYLOAD FUNCTIONALITY

Perform 5 different flight paths to triangulate around the dual bucket rails. Each flight path includes alignments with perpendicular buckets then angled buckets using zoom and exposure control to identify recessed targets.

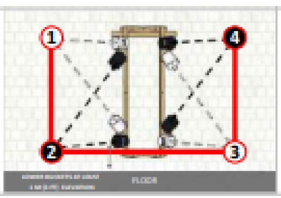
- All sequences have 10 positions with 20 buckets to score: **1 2 3 4 – 3 2 1 – 2 3 4** *(forward–reverse–forward)*
- Score ALIGNMENT POINTS by capturing a SINGLE IMAGE of the inscribed rings to verify alignments during or after the trial: UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt).
- Score ACUITY POINTS by calling out the 5 increasingly small VISUAL ACUITY TARGET GAPS (1 pt each).
- Start timer at launch and end after the last task is completed. Trial time limits are typically 5 minutes each (25 minutes to complete all 5 tests) although organizations may set their own trial time limits and passing scores.
- Extreme deviations from the intended flight path, or contact with any object, ends the trial to ensure safety.

PERCH
PAY 6



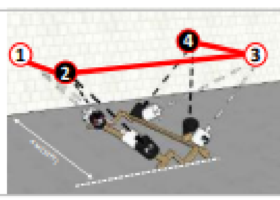
- Land or hover just above the ground within proximity to a wall or obstacle with additional ground obstacles on both sides. Launch and land repeatedly if necessary to score all buckets in the sequence of perch tasks.
- Inspect **vertical** and **horizontal** object features **all around the aircraft**.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

WALL
PAY 7



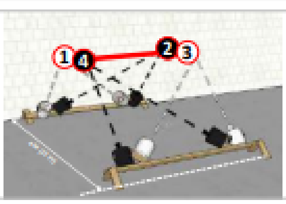
- Fly within proximity to a wall or obstacle at **45 degrees from forward** of the aircraft.
- Inspect **vertical** object features **upward** and **downward**.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

GROUND
PAY 8



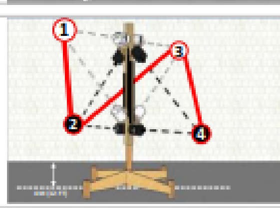
- Fly within proximity to a wall or obstacles at **90 degrees from forward** of the aircraft.
- Inspect **horizontal** object features **leftward** and **rightward**.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

ALLEY
PAY 9



- Fly within proximity to a wall or obstacle in **front of the aircraft (0 degrees)** and **behind the aircraft (180 degrees)**.
- Inspect **horizontal** object features **leftward** and **rightward**.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

POST
PAY 10



- Fly within proximity to a post and wall or obstacle and pass between the post and the wall.
- Inspect **vertical** object features **upward** and **downward** all around the post.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

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Test Methods for Evaluating Aerial Drones

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LEVEL 4 | OBSTRUCTED
PAYLOAD FUNCTIONALITY

Pilot LAST Name ____________

Pilot FIRST Name ____________

Pilot Organization ____________

Drone Make ____________

Drone Model ____________

Facility Location ____________

Date (YYYY/MM/DD) ____________ Team #: ______

PROCTOR NAME ____________

BUCKET SIZE		LIGHTING			WIND		PILOT VIEW		TIME LIMIT		
20 CM (8 IN) DIAMETER	10 CM (4 IN) DIAMETER	DAYLIGHT 1000+ LUX	LIGHTED 300+ LUX	DARK < 1 LUX	AVERAGE ____ MPH	GUSTS ____ MPH	LINE OF SIGHT FACING LANE OPTIONAL V.O.	INTERFACE ONLY BACK TO LANE MANDATORY V.O.	5 MIN	10 MIN	____ MIN
(CIRCLE ONE)		(CIRCLE ONE)			(FILL IN)		(CIRCLE ONE)		(CIRCLE ONE)		

ALIGNMENT SCORE: Circle points for images with UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt), Draw a line through all incomplete.
ACUITY SCORE: Circle correctly identified GAP DIRECTIONS in the answer key (1 pt each).

PERCH (PAY 6)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS
- FROM LANDING

ALIGNMENT: BUCKET SEQUENCE	ALIGNMENT: IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
3 / 3A	5 1	BR T TL R BL
2 / 2A	5 1	L BR T TL R
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
SCORE	/50	SCORE /50

ELAPSED TIME (MM : SS)

PASS (CIRCLE ONE) FAIL

WALL (PAY 7)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS

ALIGNMENT: BUCKET SEQUENCE	ALIGNMENT: IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
3 / 3A	5 1	BR T TL R BL
2 / 2A	5 1	L BR T TL R
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
SCORE	/50	SCORE /50

ELAPSED TIME (MM : SS)

PASS (CIRCLE ONE) FAIL

GROUND (PAY 8)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS

ALIGNMENT: BUCKET SEQUENCE	ALIGNMENT: IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
3 / 3A	5 1	BR T TL R BL
2 / 2A	5 1	L BR T TL R
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
SCORE	/50	SCORE /50

ELAPSED TIME (MM : SS)

PASS (CIRCLE ONE) FAIL

ALLEY (PAY 9)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS

ALIGNMENT: BUCKET SEQUENCE	ALIGNMENT: IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
3 / 3A	5 1	BR T TL R BL
2 / 2A	5 1	L BR T TL R
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
SCORE	/50	SCORE /50

ELAPSED TIME (MM : SS)

PASS (CIRCLE ONE) FAIL

POST (PAY 10)

21 IMAGES TO CAPTURE
- 1 PRE-LAUNCH
- 20 ALIGNMENTS

ALIGNMENT: BUCKET SEQUENCE	ALIGNMENT: IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
3 / 3A	5 1	BR T TL R BL
2 / 2A	5 1	L BR T TL R
1 / 1A	5 1	TR B TR L BR
2 / 2A	5 1	L BR T TL R
3 / 3A	5 1	BR T TL R BL
4 / 4A	5 1	T BL B TR L
SCORE	/50	SCORE /50

ELAPSED TIME (MM : SS)

PASS (CIRCLE ONE) FAIL

Level 4: Obstructed – Scenarios

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LEVEL 4 | OBSTRUCTED
SCORABLE SCENARIOS

Perform the designated flight paths to triangulate around dual bucket rails in various orientations. Align with perpendicular buckets then angled buckets. Use zoom and exposure control to identify targets inside the buckets.

- All sequences have 1–10 positions with 20 alternating white and black buckets to score:
- Score ALIGNMENT POINTS by capturing a SINGLE IMAGE of the inscribed rings to verify alignments during or after the trial: UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt).
- Score ACUITY POINTS by identifying and calling out the 5 increasingly small VISUAL ACUITY TARGET GAPS (1 pt each).
- Faults for extreme deviations from the intended flight path or contact with any object ends the trial to ensure safety.
- Timer starts at launch and ends after the last task is completed. Trial time limits are typically set to 5 minutes each (25 minutes to complete all 5 tests) although organizations may set their own trial time limits and passing scores.

Obstructed Search Scenarios

Day and Night Trials

USE SETS OF 5 "OFFSET" DUAL BUCKET RAILS
HORIZONTALS DISTRIBUTED WITH OBJECTS OF INTEREST

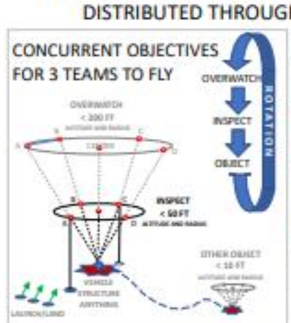
VERTICALS IN ELEVATED WINDOWS AND ON STRUCTURES

- Teams concurrently fly separate objectives set up at safe distances and/or altitudes apart (with a clearly designated and safe return path).
- Each pilot flies for 15 minutes across 3 different objectives for 5 minutes each. Teams move as necessary to maintain sight lines and communication.
- Scenarios restart with a different rotation of Pilot, Proctor, and VO.

Obstructed Vehicle Inspection Scenarios

Day and Night Trials

USE SETS OF 5 "INLINE" DUAL BUCKET RAILS
DISTRIBUTED THROUGHOUT THE SCENARIO



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LEVEL 4 | OBSTRUCTED
SCORABLE SCENARIOS

Pilot LAST Name	
Pilot FIRST Name	
Pilot Organization	
Drone Make	
Drone Model	
Facility Location	
Date (YYYY/MM/DD)	Team #:
PROCTOR NAME	

BUCKET SIZE		LIGHTING			WIND		PILOT VIEW		TIME LIMIT		
20 CM (8 IN) DIAMETER	10 CM (4 IN) DIAMETER	DAYLIGHT 1000+ LUX	LIGHTED 300+ LUX	DARK < 1 LUX	AVERAGE ___ MPH	GUSTS ___ MPH	LINE OF SIGHT FACING LANE OPTIONAL V.O.	INTERFACE ONLY BACK TO LANE MANDATORY V.O.	5 MIN	10 MIN	___ MIN
(CIRCLE ONE)		(CIRCLE ONE)			(FILL IN)		(CIRCLE ONE)		(CIRCLE ONE)		

ALIGNMENT SCORE: Circle points for images with UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt), Draw a line through all incomplete.
ACUITY SCORE: Circle correctly identified GAP DIRECTIONS in the answer key (1 pt each).

		BUCKETS	ALIGNMENT			ACUITY				
	START TIMER (CAPTURE CLOCK IMAGE) : :	NUMBER	IMAGE POINTS (5 OR 1 POINT)			CIRCLE GAPS (1 POINT EACH)				
1	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	1	5	1	0					
2	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	1A				TR	B	TR	L	BR
3	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	2	5	1	0					
4	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	2A				L	BR	T	TL	R
5	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	3	5	1	0					
6	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	3A				BR	T	TL	R	BL
7	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	4	5	1	0					
8	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	4A				T	BL	B	TR	L
9	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	5	5	1	0					
10	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	5A				BL	R	TL	L	BL
11	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	6	5	1	0					
12	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	6A				TR	B	TR	L	BR
13	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	7	5	1	0					
14	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	7A				L	BR	T	TL	R
15	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	8	5	1	0					
16	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	8A				BR	T	TL	R	BL
17	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	9	5	1	0					
18	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	9A				T	BL	B	TR	L
19	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	10	5	1	0					
20	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	10A				BL	R	TL	L	BL
	STOP TIMER. RECORD SCORES AND ELAPSED TIME.		/50			/50				
			ELAPSED TIME (MM:SS)							

		BUCKETS	ALIGNMENT			ACUITY				
	START TIMER (CAPTURE CLOCK IMAGE) : :	NUMBER	IMAGE POINTS (5 OR 1 POINT)			CIRCLE GAPS (1 POINT EACH)				
1	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	1	5	1	0					
2	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	1A				TR	B	TR	L	BR
3	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	2	5	1	0					
4	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	2A				L	BR	T	TL	R
5	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	3	5	1	0					
6	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	3A				BR	T	TL	R	BL
7	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	4	5	1	0					
8	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	4A				T	BL	B	TR	L
9	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	5	5	1	0					
10	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	5A				BL	R	TL	L	BL
11	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	6	5	1	0					
12	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	6A				TR	B	TR	L	BR
13	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	7	5	1	0					
14	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	7A				L	BR	T	TL	R
15	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	8	5	1	0					
16	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	8A				BR	T	TL	R	BL
17	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	9	5	1	0					
18	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	9A				T	BL	B	TR	L
19	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	10	5	1	0					
20	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	10A				BL	R	TL	L	BL
	STOP TIMER. RECORD SCORES AND ELAPSED TIME.		/50			/50				
			ELAPSED TIME (MM:SS)							

Level 5: Confined – Payload

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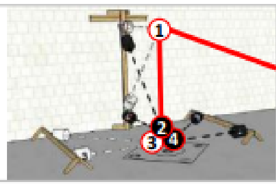
LEVEL 5 | CONFINED
PAYLOAD FUNCTIONALITY

Perform the designated flight paths to triangulate around dual bucket rails in various orientations. Align with perpendicular buckets then angled buckets. Use zoom and exposure control to identify targets inside the buckets.

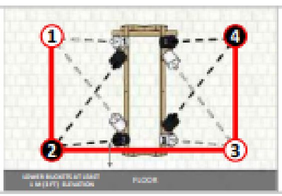
- All sequences have 10 positions with 20 buckets to score: **1 2 3 4 – 3 2 1 – 2 3 4** *(forward–reverse–forward)*
- Score ALIGNMENT POINTS by capturing a SINGLE IMAGE of the inscribed rings to verify alignments during or after the trial: UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt).
- Score ACUITY POINTS by identifying and calling out the 5 increasingly small VISUAL ACUITY TARGET GAPS (1 pt each).
- Start timer at launch and end after the last task is completed. Trial time limits are typically 5 minutes each (25 minutes to complete all 5 tests) although organizations may set their own trial time limits and passing scores.
- Extreme deviations from the intended flight path, or contact with any object, ends the trial to ensure safety.

PERCH
PAY 6



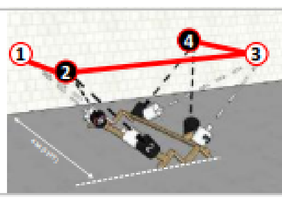
- Land or hover just above the ground within proximity to a wall or obstacle with additional ground obstacles on both sides. Launch and land repeatedly if necessary to score all buckets in the sequence of perch tasks.
- Inspect <u>vertical</u> and <u>horizontal</u> object features <u>all around the aircraft</u>.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

WALL
PAY 7



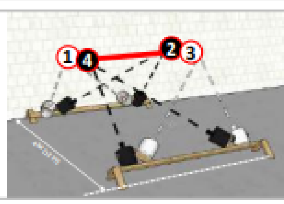
- Fly within proximity to a wall or obstacle at <u>45 degrees from forward</u> of the aircraft.
- Inspect <u>vertical</u> object features <u>upward</u> and <u>downward</u>.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

GROUND
PAY 8



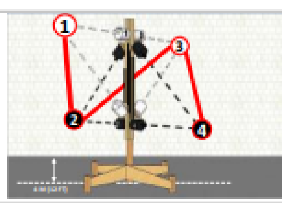
- Fly within proximity to a wall or obstacles at <u>90 degrees from forward</u> of the aircraft.
- Inspect <u>horizontal</u> object features <u>leftward</u> and <u>rightward</u>.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

ALLEY
PAY 9



- Fly within proximity to a wall or obstacle in <u>front of the aircraft (0 degrees)</u> and <u>behind the aircraft (180 degrees)</u>.
- Inspect <u>horizontal</u> object features <u>leftward</u> and <u>rightward</u>.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

POST
PAY 10



- Fly within proximity to a post and wall or obstacle and pass between the post and the wall.
- Inspect <u>vertical</u> object features <u>upward</u> and <u>downward</u> all around the post.
- **Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.**

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LEVEL 5 | CONFINED
PAYLOAD FUNCTIONALITY

Pilot LAST Name ____________________

Pilot FIRST Name ____________________

Pilot Organization ____________________

Drone Make ____________________

Drone Model ____________________

Facility Location ____________________

Date (YYYY/MM/DD) ____________________ Team #: ________

PROCTOR NAME ____________________

BUCKET SIZE		LIGHTING			WIND		PILOT VIEW		TIME LIMIT		
20 CM (8 IN) DIAMETER	10 CM (4 IN) DIAMETER	DAYLIGHT 1000+ LUX	LIGHTED 300+ LUX	DARK <1 LUX	AVERAGE ____ MPH	GUSTS ____ MPH	LINE OF SIGHT FACING LANE OPTIONAL V.O.	INTERFACE ONLY BACK TO LANE MANDATORY V.O.	5 MIN	10 MIN	____ MIN
(CIRCLE ONE)		(CIRCLE ONE)			(FILL IN)		(CIRCLE ONE)		(CIRCLE ONE)		

ALIGNMENT SCORE: Circle points for images with UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt), Draw a line through all incomplete.
ACUITY SCORE: Circle correctly identified GAP DIRECTIONS in the answer key (1 pt each).

PERCH (PAY 6)	WALL (PAY 7)	GROUND (PAY 8)	ALLEY (PAY 9)	POST (PAY 10)
21 IMAGES TO CAPTURE • 1 PRE-LAUNCH • 20 ALIGNMENTS • LANDING IS OPTIONAL	21 IMAGES TO CAPTURE • 1 PRE-LAUNCH • 20 ALIGNMENTS	21 IMAGES TO CAPTURE • 1 PRE-LAUNCH • 20 ALIGNMENTS	21 IMAGES TO CAPTURE • 1 PRE-LAUNCH • 20 ALIGNMENTS	21 IMAGES TO CAPTURE • 1 PRE-LAUNCH • 20 ALIGNMENTS

PERCH ALIGNMENT: BUCKET SEQUENCE	IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)	WALL ALIGNMENT: BUCKET SEQUENCE	IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)	GROUND ALIGNMENT: BUCKET SEQUENCE	IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)	ALLEY ALIGNMENT: BUCKET SEQUENCE	IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)	POST ALIGNMENT: BUCKET SEQUENCE	IMAGE POINTS	ACUITY: CIRCLE CORRECT GAPS (1 POINT EACH)
1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR
2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R
3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL
4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L
3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL
2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R
1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR	1 1A	5 1	TR B TR L BR
2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R	2 2A	5 1	L BR T TL R
3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL	3 3A	5 1	BR T TL R BL
4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L	4 4A	5 1	T BL B TR L
SCORE /50		SCORE /50	SCORE /50		SCORE /50	SCORE /50		SCORE /50	SCORE /50		SCORE /50	SCORE /50		SCORE /50
ELAPSED TIME (MM : SS)			ELAPSED TIME (MM : SS)			ELAPSED TIME (MM : SS)			ELAPSED TIME (MM : SS)			ELAPSED TIME (MM : SS)		
PASS CIRCLE ONE FAIL			PASS CIRCLE ONE FAIL			PASS CIRCLE ONE FAIL			PASS CIRCLE ONE FAIL			PASS CIRCLE ONE FAIL		

Level 5: Confined – Scenarios

VERSION 2020A

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LEVEL 5 | CONFINED
SCORABLE SCENARIOS

Perform the designated flight paths to triangulate around dual bucket rails in various orientations. Align with perpendicular buckets then angled buckets. Use zoom and exposure control to identify targets inside the buckets.

- All sequences have 1–10 positions with 20 alternating white and black buckets to score:
- Score ALIGNMENT POINTS by capturing a SINGLE IMAGE of the inscribed rings to verify alignments during or after the trial: UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt).
- Score ACUITY POINTS by identifying and calling out the 5 increasingly small VISUAL ACUITY TARGET GAPS (1 pt each).
- Faults for extreme deviations from the intended flight path or contact with any object ends the trial to ensure safety.
- Timer starts at launch and ends after the last task is completed. Trial time limits are typically set to 5 minutes each (25 minutes to complete all 5 tests) although organizations may set their own trial time limits and passing scores.

Confined Room-to-Room Labyrinth

Search tasks with 1 m (3ft) minimum clearances

USE SETS OF 5 "INLINE" DUAL BUCKET RAILS
HORIZONTALS FOR LEFTWARD/RIGHTWARD INSPECTIONS

VERTICALS FOR UPWARD/DOWNWARD INSPECTIONS

- Fabricated room-to-room search scenario with inspect tasks that can be replicated to track and compare scores.
- Self-standing plywood corner walls define 1.2m (4 ft) switchback hallways with a blackout tarp ceiling over top at 2.4m (8ft). Fits inside a 6m (20ft) shipping container.
- Square access "windows" measuring 1m (3ft) square provide entry/exit and interior high/low pass throughs.

Confined Vehicle Inspection Scenarios

Day and Night Trials

USE SETS OF 5 "INLINE" DUAL BUCKET RAILS
DISTRIBUTED THROUGHOUT THE SCENARIO

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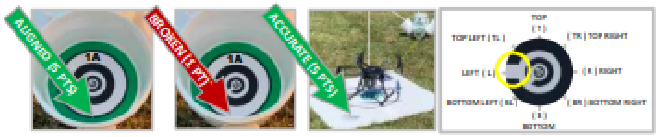
LEVEL 5 | CONFINED
SCORABLE SCENARIOS



Pilot LAST Name ____________
Pilot FIRST Name ____________
Pilot Organization ____________
Drone Make ____________
Drone Model ____________
Facility Location ____________
Date (YYYY/MM/DD) ____________ Team #: ______
PROCTOR NAME ____________

BUCKET SIZE		LIGHTING			WIND		PILOT VIEW		TIME LIMIT		
20 CM (8 IN) DIAMETER	10 CM (4 IN) DIAMETER	DAYLIGHT 1000+ LUX	LIGHTED 300+ LUX	DARK < 1 LUX	AVERAGE ___ MPH	GUSTS ___ MPH	LINE OF SIGHT FACING LANE OPTIONAL V.O.	INTERFACE ONLY BACK TO LANE MANDATORY V.O.	5 MIN	10 MIN	___ MIN
(CIRCLE ONE)		(CIRCLE ONE)			(FILL IN)		(CIRCLE ONE)		(CIRCLE ONE)		

ALIGNMENT SCORE: Circle points for images with UNBROKEN RINGS (5 pts), BROKEN RINGS (1 pt), Draw a line through all incomplete.
ACUITY SCORE: Circle correctly identified GAP DIRECTIONS in the answer key (1 pt each).

		BUCKETS	ALIGNMENT			ACUITY				
	START TIMER (CAPTURE CLOCK IMAGE) : :	NUMBER	IMAGE POINTS (5 OR 1 POINT)			CIRCLE GAPS (1 POINT EACH)				
1	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	1	5	1	0					
2	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	1A				TR	B	TR	L	BR
3	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	2	5	1	0					
4	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	2A				L	BR	T	TL	R
5	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	3	5	1	0					
6	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	3A				BR	T	TL	R	BL
7	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	4	5	1	0					
8	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	4A				T	BL	B	TR	L
9	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	5	5	1	0					
10	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	5A				BL	R	TL	L	BL
11	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	6	5	1	0					
12	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	6A				TR	B	TR	L	BR
13	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	7	5	1	0					
14	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	7A				L	BR	T	TL	R
15	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	8	5	1	0					
16	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	8A				BR	T	TL	R	BL
17	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	9	5	1	0					
18	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	9A				T	BL	B	TR	L
19	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	10	5	1	0					
20	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	10A				BL	R	TL	L	BL
	STOP TIMER. RECORD SCORES AND ELAPSED TIME.		/50			/50				
			ELAPSED TIME (MM:SS)							

		BUCKETS	ALIGNMENT			ACUITY				
	START TIMER (CAPTURE CLOCK IMAGE) : :	NUMBER	IMAGE POINTS (5 OR 1 POINT)			CIRCLE GAPS (1 POINT EACH)				
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3	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	2	5	1	0					
4	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	2A				L	BR	T	TL	R
5	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	3	5	1	0					
6	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	3A				BR	T	TL	R	BL
7	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	4	5	1	0					
8	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	4A				T	BL	B	TR	L
9	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	5	5	1	0					
10	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	5A				BL	R	TL	L	BL
11	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	6	5	1	0					
12	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	6A				TR	B	TR	L	BR
13	PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAGE	7	5	1	0					
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20	ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS	10A				BL	R	TL	L	BL
	STOP TIMER. RECORD SCORES AND ELAPSED TIME.		/50			/50				
			ELAPSED TIME (MM:SS)							

CHAPTER 7.
Night Operations

Drone pilots operating under Part 107 may fly at night, over people and moving vehicles without a waiver as long as they meet the requirements defined in the rule. Airspace authorizations are still required for night operations in controlled airspace under 400 feet.

One of the requirements says the drone must have an anti-collision light that is visible for at least three statute miles. There is aftermarket anti-collision lights you can attach to your drone if it is not equipped with sufficient lighting. It is important you review FAA Part 107.29 as follows:

FAA Part 107.29 Operations at Night

a. Except as provided in paragraph (d) of this section, no person may operate a small unmanned aircraft system at night unless -

   1. The remote pilot in command of the small unmanned aircraft has completed an initial knowledge test or training, as applicable, under § 107.65 after April 6, 2021; and

   2. The small unmanned aircraft has lighted anti-collision lighting visible for at least three statute miles that has a flash rate sufficient to avoid a collision. The remote pilot in command may reduce the intensity of, but may not extinguish, the anti-collision lighting if he or she determines that, because of operating conditions, it would be in the interest of safety to do so.

b. No person may operate a small unmanned aircraft system during periods of civil twilight unless the small unmanned aircraft has lighted anti-collision lighting visible for at least three statute miles that has a flash rate sufficient to avoid a collision. The remote pilot in command may reduce the intensity of, but may not extinguish, the anti-collision lighting if he or she determines that, because of operating conditions, it would be in the interest of safety to do so.

c. For purposes of paragraph (b) of this section, civil twilight refers to the following:

   1. Except for Alaska, a period of time that begins 30 minutes before official sunrise and ends at official sunrise;

   2. Except for Alaska, a period of time that begins at official sunset and ends 30 minutes after official sunset; and

   3. In Alaska, the period of civil twilight as defined in the Air Almanac.

Note that your eyesight has considerable limitations at night versus daylight. Your distance will be considerably reduced (observing the position and actions of the drone). It is highly recommended a pilot receives night training and takes a flight exam (NIST) to ensure competency.

Vision in Flight

Of all the senses, vision is the most important for safe flight. Most of the things perceived while flying is visual or heavily supplemented by vision. As remarkable and vital as it is, vision is subject to limitations, such as illusions and blind spots. The more a pilot understands about the eyes and how they function, the easier it is to use vision effectively and compensate for potential problems.

The eye functions much like a camera. Its structure includes an aperture, a lens, a mechanism for focusing, and a surface for registering images. Light enters through the cornea at the front of the eyeball, travels through the lens, and falls on the retina. The retina contains light sensitive cells that convert light energy into electrical impulses that travel through nerves to the brain. The brain interprets the electrical signals to form images. There are two kinds of light-sensitive cells in the eyes: rods and cones.

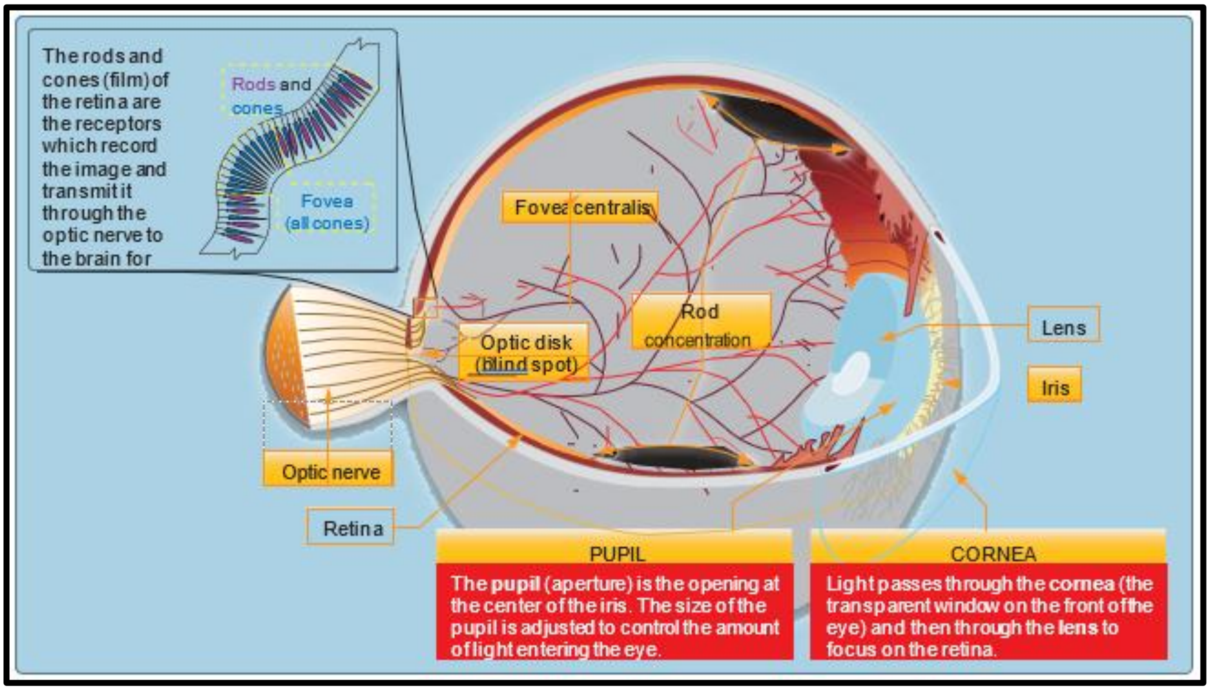


Figure 8.
The Eye

The cones are responsible for all color vision, from appreciating a glorious sunset to discerning the subtle shades in a fine painting. Cones are present throughout the retina, but are concentrated toward the center of the field of vision at the back of the retina. There is a small pit called the fovea where almost all the light sensing cells are cones. This is the area where most “looking” occurs (the center of the visual field where detail, color sensitivity, and resolution are highest).

While the cones and their associated nerves are well suited to detecting fine detail and color in high light levels, the rods are better able to detect movement and provide vision in dim light. The rods are unable to discern color but are very sensitive at low-light levels. The trouble with rods is that a large amount of light overwhelms them, and they take longer to “reset” and adapt to the dark again. There are so many cones in the fovea that are at the very center of the visual field but virtually has no rods at all. So in low light, the middle of the visual field is not very sensitive, but farther from the fovea, the rods are more numerous and provide the major portion of night vision.

Vision Types

There are three types of vision: photopic, mesopic, and scotopic. Each type functions under different sensory stimuli or ambient light conditions.

PHOTOPIC VISION

Photopic vision provides the capability for seeing color and resolving fine detail (20 / 20 or better), but it functions only in good illumination. Photopic vision is experienced during daylight or when a high level of artificial illumination exists

The cones concentrated in the fovea centralis of the eye are primarily responsible for vision in bright light. Because of the high light level, rhodopsin, which is a biological pigment of the retina that is responsible for both the formation of the photoreceptor cells and the first events in the perception of light, is bleached out causing the rod cells to become less effective.

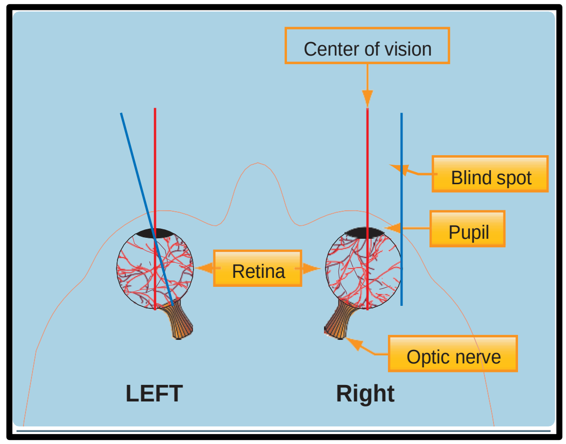


Figure 9.
Photopic Vision

MESOPIC VISION

Mesopic vision is achieved by a combination of rods and cones and is experienced at dawn, dusk, and during full moonlight. Visual acuity steadily decreases as available light decreases and color perception changes because the cones become less effective. Mesopic viewing period is considered the most dangerous period for viewing. As cone sensitivity decreases, pilots should use off-center vision and proper scanning techniques to detect objects during low-light levels.

SCOTOPIC VISION

Scotopic vision is experienced under low-light levels and the cones become ineffective, resulting in poor resolution of detail. Visual acuity decreases to 20 / 200 or less and enables a person to see only objects the size of or larger than the big “E” on visual acuity testing charts from 20 feet away. In other words, a person must stand at 20 feet to see what can normally be seen at 200 feet under daylight conditions. When using scotopic vision, color perception is lost and a night-blind spot in the central field of view appears at low light levels when the cone-cell sensitivity is lost.

Central Blind Spot

The area where the optic nerve connects to the retina in the back of each eye is known as the optic disk. There is a total absence of cones and rods in this area, and consequently, each eye is completely blind in this spot. As a result, it is referred to as the blind spot that everyone has in each eye. Under normal binocular vision conditions (both eyes are used together), this is not a problem because an object cannot be in the blind spot of both eyes at the same time. On the other hand, where the field of vision of one eye is obstructed by an object (windshield divider or another aircraft), a visual target could fall in the blind spot of the other eye and remain undetected.

The Figure above, provides a dramatic example of the eye's blind spot.

1. Hold this page at an arm's length.
2. Completely cover your left eye (without closing or pressing on it) using your hand or other flat object.
3. With your right eye, stare directly at the airplane on the left side of the picture page. In your periphery, you will notice the black X on the right side of the picture.
4. Slowly move the page closer to you while continuing to stare at the airplane.
5. When the page is about 16 inches to 18 inches from you, the black X should disappear completely because it has been imaged onto the blind spot of your right eye. (Resist the temptation to move your right eye while the black X is gone or else it reappears. Keep staring at the airplane.)
6. As you continue to look at the airplane, keep moving the page closer to you a few more inches, and the black X will come back into view.
7. There is an interval where you are able to move the page a few inches backward and forward, and the black X will be gone. This demonstrates to you the extent of your blind spot.
8. You can try the same thing again, except this time with your right eye covered stare at the black X with your left eye. Move the page in closer and the airplane will disappear.

Another way to check your blind spot is to do a similar test outside at night when there is a full moon. Cover your left eye, looking at the full moon with your right eye. Gradually move your right eye to the left (and maybe slightly up or down). Before long, all you will be able to see is the large halo around the full moon; the entire moon itself will seem to have disappeared.

Night Vision

There are many good reasons to fly at night, but pilots must keep in mind that the risks of night flying are different than during the day and often times higher. Pilots who are cautious and educated on night-flying techniques can mitigate those risks and become very comfortable and proficient in the task.

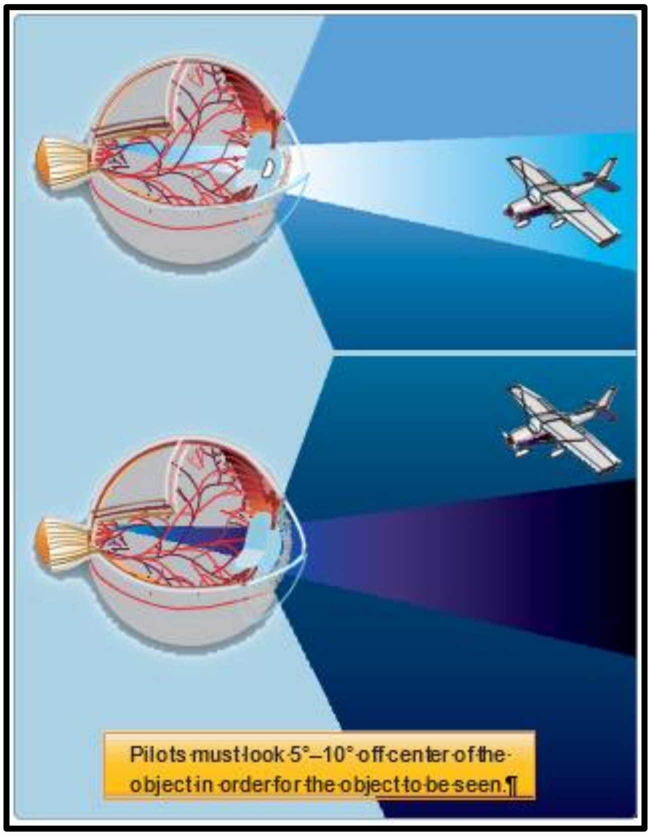


Figure 10.
Night Vision

Night Blind Spot

It is estimated that once fully adapted to darkness, the rods are 10,000 times more sensitive to light than the cones, making them the primary receptors for night vision. Since the cones are concentrated near the fovea, the rods are also responsible for much of the peripheral vision. The concentration of cones in the fovea can make a night-blind spot in the center of the field of vision. To see an object clearly at night, the pilot must expose the rods to the image. This can be done by looking 5° to 10° off center of the object to be seen. This can be tried in a dim light in a darkened room. When looking directly at the light, it dims or disappears altogether. When looking slightly off center, it becomes clearer and brighter.

When looking directly at an object, the image is focused mainly on the fovea, where detail is best seen. At night, the ability to see an object in the center of the visual field is reduced as the cones lose much of their sensitivity and the rods become more sensitive. Looking off center can help compensate for this night-blind spot. Along with the loss of sharpness (acuity) and color at night, depth perception and judgment of size may be lost.

Dark Adaptation

Dark adaptation is the adjustment of the human eye to a dark environment. That adjustment takes longer depending on the amount of light in the environment that a person has just left. Moving from a bright room into a dark one takes longer than moving from a dim room and going into a dark one.

While the cones adapt rapidly to changes in light intensities, the rods take much longer. Walking from bright sunlight into a dark movie theater is an example of this dark adaptation period experience. The rods can take approximately 30 minutes to fully adapt to darkness. A bright light, however, can completely destroy night adaptation, leaving night vision severely compromised while the adaptation process is repeated.

Scanning Techniques

Scanning techniques are very important in identifying objects at night. To scan effectively, pilots must look from right to left or left to right. They should begin scanning at the greatest distance an object can be perceived (top) and move inward toward the position of the aircraft (bottom). For each stop, an area approximately 30° wide should be scanned. The duration of each stop is based on the degree of detail that is required, but no stop should last longer than two to three seconds. When moving from one viewing point to the next, pilots should overlap the previous field of view by 10°.

Off-center viewing is another type of scan that pilots can use during night flying. It is a technique that requires an object be viewed by looking 10° above, below, or to either side of the object. In this manner, the peripheral vision can maintain contact with an object.

With off-center vision, the images of an object viewed longer than two to three seconds will disappear. This occurs because the rods reach a photochemical equilibrium that prevents any further response until the scene changes. This produces a potentially unsafe operating condition. To overcome this night vision limitation, pilots must be aware of the phenomenon and avoid viewing an object for longer than two or three seconds. The peripheral field of vision will continue to pick up the object when the eyes are shifted from one off- center point to another.

Night Vision Protection

Several things can be done to help with the dark adaptation process and to keep the eyes adapted to darkness. Some of the steps pilots and flight crews can take to protect their night vision are described in the following paragraphs.

Distance Estimation and Depth Perception

Knowledge of the mechanisms and cues affecting distance estimation and depth perception assist pilots in judging distances at night. These cues may be monocular or binocular.

The monocular cues that aid in distance estimation and depth perception include motion parallax, geometric perspective, retinal image size, and aerial perspective.

Motion Parallax

Motion parallax refers to the apparent motion of stationary objects as viewed by an observer moving across the landscape. When the pilot or crewmember looks outside the aircraft perpendicular to the direction of travel, near objects appear to move backward, past, or opposite the path of motion; far objects seem to move in the direction of motion or remain fixed. The rate of apparent movement depends on the distance the observer is from the object.

Night Vision Illusions

There are many different types of visual illusions that commonly occur at night. Anticipating and maintaining awareness of them is usually the best way to avoid them.

Autokinesis

Autokinesis is caused by staring at a single point of light against a dark background for more than a few seconds. After a few moments, the light appears to move on its own. Apparent movement of the light source will begin in about eight to 10 seconds. To prevent this illusion, focus the eyes on objects at varying distances and avoid fixating on one source of light. This illusion can be eliminated or reduced by visual scanning, by increasing the number of lights, or by varying the light intensity. The most important of the three solutions is visual scanning. A light or lights should not be stared at for more than 10 seconds.

False Horizon

A false horizon can occur when the natural horizon is obscured or not readily apparent. It can be generated by confusing bright stars and city lights. It can also occur while flying toward the shore of an ocean or a large lake. Because of the relative darkness of the water, the lights along the shoreline can be mistaken for stars in the sky.

Reversible Perspective Illusion

At night, an aircraft may appear to be moving away from a second aircraft when it is, in fact, approaching a second aircraft. This illusion often occurs when an aircraft is flying parallel to another's course. To determine the direction of flight, pilots should observe aircraft lights and their relative position to the horizon. If the intensity of the lights increases, the aircraft is approaching; if the lights dim, the aircraft is moving away.

Size-Distance Illusion

This illusion results from viewing a source of light that is increasing or decreasing in luminance (brightness). Pilots may interpret the light as approaching or retreating.

Fascination (Fixation)

This illusion occurs when pilots ignore orientation cues and fix their attention on a goal or an object. Student pilots tend to have this happen when they are concentrating on the aircraft instruments or attempting to land. They become fixated on one task and forget to look at what is going on around them. At night, this can be especially dangerous because aircraft ground- closure rates are difficult to determine, and there may be minimal time to correct the situation.

Flicker Vertigo

A light flickering at a rate between four and 20 cycles per second can produce unpleasant and dangerous reactions. Such conditions as nausea, vomiting, and vertigo may occur. On rare occasions, convulsions and unconsciousness may also occur. Proper scanning techniques at night can prevent pilots from getting flicker vertigo.

Night Landing Illusions

Landing illusions occur in many forms. Above featureless terrain at night, there is a natural tendency to fly a lower• than-normal approach. Elements that cause any type of visual obscurities, such as rain, haze, or a dark runway environment, can also cause low approaches. Bright lights, steep surrounding terrain, and a wide runway can produce the illusion of being too low with tendency to fly a higher-than normal approach. A set of regularly spaced lights along a road or highway can appear to be runway lights. Pilots have even mistaken the lights on moving trains as runway or approach lights. Bright runway or approach lighting systems can create the illusion that the aircraft is closer to the runway, especially where few lights illuminate the surrounding terrain.

Prior to flying at night, it is best to learn and know the challenges of the area in which you are flying in. Study the area and know how to navigate your way through areas that may pose a problem at night. For example, many areas near water may be obscured by low lying clouds or fog. To help deal with this type of situation, it is important to have a plan before you leave the ground. In the daytime, fly the routes and passes that you will be flying at night and determine the minimum altitude you are willing to use at night. If weather prevents you from maintaining the altitude that you planned, make a decision early to turn 180° and land at an alternate airport with better weather conditions. Always consider safer alternatives rather than hope things will work out by taking a chance.

CHAPTER 8. Transition to Complex UAVs

High-Performance UAVs

Unlike traditional aircraft and rotorcraft there is no definition of High-Performance UAV within the FAA 107 regulations. Presently is it grouped by weight and anything greater than 55 pounds falls within the regulations as "experimental" aircraft and requires a different authorization.

With the advancement of technology, the type of aircraft within the weight group of .55 pounds to 55 pounds is becoming varied. The following are a general category for these weight group.

Multi-Rotor

If you want to get a small camera in the air for a short period of time, then it is hard to argue with a multi-rotor. They are the easiest and cheapest option for getting an 'eye in the sky', and because they give you such great control over position and framing, they are perfect for aerial photography work.

The downside of multi-rotors is their limited endurance and speed, making them unsuitable for large scale aerial mapping, long endurance monitoring and long-distance inspection such as pipelines, roads and power lines.

Although the technology is improving all the time, multi-rotors are fundamentally very inefficient and require a lot of energy just to fight gravity and keep them in the air. With current battery technology they are limited to around 20 to 30 minutes when carrying a lightweight camera payload. Heavy-lift multi-rotors are capable of carrying more weight, but in exchange for much shorter flight times. Due to the need for fast and high-precision throttle changes to keep them stabilized, it isn't practical to use a gas engine to power multi-rotors, so they are restricted to electric motors. So until a new power source comes along, we can only expect very small gains in flight time.

Fixed Wing

Fixed-wing drones (as opposed to 'rotary wing'; i.e., helicopters) use a wing like a normal airplane to provide the lift rather than vertical lift rotors. Because of this they only need to use energy to move forward, not hold themselves up in the air, so are much more efficient.

For this reason they are able to cover longer distances, map much larger areas, and loiter for long times monitoring their point of interest. In addition to the greater efficiency, it is also possible to use gas engines as their power source, and with the greater energy density of fuel many fixed-wing UAVs can stay aloft for 16 hours or more.

The main downside of a fixed-wing aircraft is obviously their inability to hover in one spot, which rules them out for any general aerial photography work. This also makes launching and landing them a lot trickier, as depending on their size you can need a runway or catapult launcher to get them into the air, and either a runway, parachute or net to recover them safely again at the end. Only the smallest fixed-wing drones are suitable for hand launch and 'belly landing' in an open field.

Other downsides are their higher cost, and that it is much more difficult to learn the ropes with fixed-wing drones. One reason why multi-rotors have become so widespread is that it is easy to get started: anyone can buy a cheap quad-copter and start hovering in their back yard, practicing the skills and gradually getting more and more confident before flying further, higher and faster. That isn't the case with fixed-wing drones: the first time you launch one you need to be confident in your abilities to control it from launch, through the flight and then bring it back to a soft landing. You don't get a chance to put it into a hover and think, putting the sticks in the middle won't keep it in place: a fixed-wing drone is always moving forward and they move a lot quicker than a multi-rotor!

Another consideration of fixed-wing drone work is that it is much more about the data, not just taking pretty pictures. With a multi-rotor session you're generally done with the job when the flight is over, you only need to hand over the imagery. With fixed-wing work the flight is just the beginning, you've captured the images but it isn't yet the data the clients are looking for. The imagery is fed through the first stage processing to stitch the hundreds (or thousands) of separate images into one big tiled image, but there can be a lot more to be done after this in performing data analysis such as the stockpile volume calculations, tree counts, overlaying other data on to the maps, and so on.

Single-Rotor Helicopter

While a multi-rotor has many different rotors to hold it up, a single rotor has just one, plus a tail rotor to control its heading. Helicopters are very popular in manned aviation, but currently only fill a small niche in the drone world.

A single-rotor helicopter has the benefit of much greater efficiency over a multi-rotor, and also that they can be powered by a gas motor for even longer endurance. It is a general rule of aerodynamics that the larger the rotor blade is and the slower it spins, the more efficient it is. This is why a quad-copter is more efficient than an octo-copter, and special long-endurance quads have a large prop diameter. A single-rotor helicopter allows for very long blades which are more like a spinning wing than a propeller, giving great efficiency.

If you need to hover with a heavy payload (e.g. an aerial LIDAR laser scanner) or have a mixture of hovering with long endurance or fast forward flight, then a single-rotor helicopter is really your best bet.

The downsides are their complexity, cost, vibration, and also the danger of their large spinning blades. While a multi-rotor prop can certainly leave you with a bad scar, it is unlikely to do much more than that. The long sharp blades of a helicopter can cause more serious damage if you get in their way, and there have been a number of fatalities from RC hobby and drone helicopters.

In terms of difficulty, single-rotor helicopter drones lie somewhere between multi-rotors and fixed- wing aircraft. On one hand they can hover on the spot, so it is possible to start easy and work your way up, but on the other hand they aren't as stable or forgiving in the event of a bad landing, and they also require a lot of maintenance and care due to their mechanical complexity.

Fixed-Wing Hybrid VTOL

Merging the benefits of fixed-wing UAVs with the ability to hover is a new category of hybrids which can also take off and land vertically.

There are various types under development, some of which are basically just existing fixed-wing designs with vertical lift motors bolted on. Others are ‘tail sitter’ aircraft which look like a regular plane but rest on their tails on the ground, pointing straight up for take-off before pitching over to fly normally, or ‘tilt rotor’ types where the rotors or even the whole wing with propellers attached can swivel from pointing upwards for takeoff to pointing horizontally for forward flight.

Many of these configurations were tried in the 1950s and 1960s for manned aircraft, but they proved too complex and difficult to fly, with some disastrous results. With the arrival of modern autopilots, gyros and accelerometers, suddenly these whacky types are feasible because the autopilot can do all the hard work of keeping them stable, leaving the human pilot the easier task of guiding them around the sky.

There are only a handful of hybrid fixed-wing aircraft currently on the market, but you can expect this to be a much more popular option in the coming years as the technology is perfected. One example getting a lot of attention is Amazon’s Prime Air delivery drone shown here.

Performance Testing

Each type of UAV will have different capabilities as they serve different applications. The PIC need to understand their selected UAV and become diligent in studying the operational characteristics.

In addition, the PIC should locate an instructor for their type of drone for additional information and to observe its flight characteristics.

The following are some steps to consider when outlining your training protocols:

KNOW YOUR UAV

Get to know it well. Know how all the equipment works. Have a training field that you can regularly attend that you, and your crew, know well. Do all this even before you take to the sky.

HAVING A GOOD TRAINING SCHEDULE

There is a lot more to training than flying. Regularly work through the checklists and manuals. Practice on the simulator. Define clearly the roles for your pilot and your UA Commander. Find out more about the legal side, Flight Safety in general, operating UAVs. You will be surprised how quickly you forget stuff and how much there is to learn in becoming an experienced and safe crew member.

GET THE RIGHT TRAINING IN THE FIRST PLACE

Getting the right training will be the single best investment you make. There is a lot to learn and no matter what anyone will tell you, it cannot be learned in one go over just a couple of days.

Examine our schedules and ask “what can I do without”. The answer often is “not very much”.

DO THINGS ONE AT A TIME

Only change one thing (if possible) at a time. New camera, new flight path, new GCS setting, new location, etc., try and introduce just one thing at a time. If you can’t and there is a lot of new stuff going on then make sure you do the next thing well.

BE PATIENT

There is always lots of time after a crash to think over the factors that you should have thought about before. Its far better to put the patience in before and find out the little thing that will break the chain of events before it gets too far. Think, talk, discuss, analyze. Run whole flights and scenarios in your head lots of times before flying. And after you have flown do the same thing with your new knowledge.

DOCUMENT

Write it all down. Commit your learning, your flights and your failings to a manual or diary that you can go back to. Fail to do this and I guarantee you will fail to break so many nasty events that could be avoided with some good and honest report writing.

SHARE

Network, email, Skype, call, whatever. Especially with your crew, but also with other operators. We are in a new world with this technology and there isn't much to go on. Some may want to keep their knowledge secret, but most don't. Helping break other operator's chains will help break yours too.

CHAPTER 9. Emergency Procedures

Emergency procedures are specific to each UAS type as designed by the manufacturer. It is the responsibility of the flight crew to be proficient with the aircraft operational manual provided by the vendor before any flight operations are conducted. It is also a best and safe practice to prepare an Emergency Checklist in case of emergencies.

The RPIC should always be prepared to execute an emergency procedure in instances where there is a lost link, loss of GPS, or there are other aircraft or obstructions in the flight path. He / she should brief the flight crew before the start of the flight operations about emergency procedures and have a mission abort site for landing in the case of an emergency.

After the aircraft has safely landed, it should be documented for maintenance purposes. Some possible emergencies due to system failures are as follows:

1. Loss of Datalink communications
2. Loss of GPS
3. Autopilot Software error / failure
4. Loss of Engine power
5. Ground Control System failure
6. Intrusion of another aircraft into the UAS mission airspace

This is not meant to be a comprehensive list as the types of failures and associated emergency conditions vary for different UAS, airspace events, and crew performance.

Many UAS have a number of failsafe options in case of failures or emergency situations. These include using methods of stabilization and an automated Return to Land (RTL) or Loiter mode. Other features include fail-recovery software. The specific failsafe options available for each type of UAS should be outlined in the UAS documentation (Operator's Manual, Checklists, etc.). These fail-safe mechanisms should be tested during training and currency flights. Flying without these fail-safe mechanisms in place is not recommended.

An emergency avoidance procedure should be determined before landing. Options include land immediately, move to a predetermined location and altitude, or another approach. All possible incursions must be assessed for risk mitigation.

In the event of a lost link or fly away, the RPIC should evaluate the airspace affected and contact the appropriate controlling agency (i.e., control tower, airport manager, Center, Restricted Area agency, etc.) immediately with details of the flight such as; location, direction of flight and approximate altitude, speed and flight time remaining (remaining battery life).

In the event of an emergency the RPIC should be prepared to submit a written statement on any deviations upon the request of the Administrator (FAA) as outline in Part 107.21. Best practices suggest that the RPIC fill out a NASA Aviation Safety Reporting System (ASRS), Electronic Report Submission (ERS). More information can be found at: https://asrs.arc.nasa.gov/overview/summary.html.

NOTE: The NASA ARRS system was developed to encourage pilots, aviation maintenance technicians and other personnel to disclose mistakes in a non-punitive format in an effort to advance safety. In exchange for volunteering information the person reporting the infraction may receive a reduced penalty if the FAA pursues certificate action.

Emergency Checklist

Loss of Data link/ Ground Control System (GCS) Failure	Autopilot software failure	Battery Warnings
Result of both datalinks lost (no heartbeats) or GCS laptop and radio links fail for more than 10 seconds.	**Result if the autopilot software crashes during flight mode**	**Result of main GCS lapt… for more than 10 se…**
→ UAV will loiter for 2 minutes (check operators manual for exact time) → If datalink not re-established within this time, flight will terminate and return to land (fail safe setting)	→ Try reconnecting from GCS laptop → RC control should be established and the UAV should be landed. If no RC then flight will terminate and return to land (fail safe setting)	→ If Battery … percen… U…
Loss of GPS		
Result when UAV loses GPS signal in the flight mode	**Res…**	
→ UAV will automatically loiter around point of GPS lock loss for 20 secon… (check operators manual for … → UAV will navigate to … → RC control sh… UAV shou… fligh…		

Figure 11.
Emergency Checklist

This checklist is considered a guide and not definitive checklist for all UASs. Use common sense when operating UASs. Consult local UAS agency or vendors to ensure your checklist is appropriate.

CHAPTER 10. Aeronautical Decision-Making

Introduction

Aeronautical decision-making (ADM) is decision-making in a unique environment — aviation. It is a systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. It is what a pilot intends to do based on the latest information he or she has.

The importance of learning and understanding effective ADM skills cannot be overemphasized. While progress is continually being made in the advancement of pilot training methods, aircraft equipment and systems, and services for pilots, accidents still occur. Despite all the changes in technology to improve flight safety, one factor remains the same: the human factor which leads to errors. It is estimated that approximately 80% of all aviation accidents are related to human factors and the vast majority of these accidents occur during landing (24.1%) and takeoff (23.4%).

ADM is a systematic approach to risk assessment and stress management. To understand ADM is to also understand how personal attitudes can influence decision-making and how those attitudes can be modified to enhance safety in the flight deck. It is important to understand the factors that cause humans to make decisions and how the decision-making process not only works, but can be improved.

This chapter focuses on helping the pilot improve his or her ADM skills with the goal of mitigating the risk factors associated with flight. Advisory Circular (AC) 60-22, “Aeronautical Decision-Making,” provides background references, definitions, and other pertinent information about ADM training in the general aviation (GA) environment.

History of ADM

For over 25 years, the importance of good pilot judgment, or aeronautical decision-making (ADM), has been recognized as critical to the safe operation of aircraft, as well as accident avoidance. The airline industry, motivated by the need to reduce accidents caused by human factors, developed the first training programs based on improving ADM. Crew resource management (CRM) training for flight crews is focused on the effective use of all available resources: human resources, hardware, and information supporting ADM to facilitate crew cooperation and improve decision-making. The goal of all flight crews is good ADM and the use of CRM is one way to make good decisions.

Research in this area prompted the Federal Aviation Administration (FAA) to produce training directed at improving the decision-making of pilots and led to current FAA regulations that require that decision-making be taught as part of the pilot training curriculum. ADM research, development, and testing culminated in 1987 with the publication of six manuals oriented to the decision-making needs of variously rated pilots. These manuals provided multifaceted materials designed to reduce the number of decision-related accidents. The effectiveness of these materials was validated in independent studies where student pilots received such training in conjunction with the standard flying curriculum. When tested, the pilots who had received ADM-training made fewer in-flight errors than those who had not received ADM training. The differences were statistically significant and ranged from about 10% to 50% fewer judgment errors. In the operational environment, an operator flying about 400,000 hours annually demonstrated a 54% reduction in accident rate after using these materials for recurrency training.

Contrary to popular opinion, good judgment can be taught. Tradition held that good judgment was a natural by- product of experience, but as pilots continued to log accident-free flight hours, a corresponding increase of good judgment was assumed. Building upon the foundation of conventional decision-making, ADM enhances the process to decrease the probability of human error and increase the probability of a safe flight. ADM provides a structured, systematic approach to analyzing changes that occur during a flight and how these changes might affect the safe outcome of a flight. The ADM process addresses all aspects of decision-making in the flight deck and identifies the steps involved in good decision-making.

Steps for good decision-making are:

1. Identifying personal attitudes hazardous to safe flight.
2. Learning behavior modification techniques.
3. Learning how to recognize and cope with stress.
4. Developing risk assessment skills.
5. Using all resources.
6. Evaluating the effectiveness of one’s ADM skills.

Risk Management

The goal of risk management is to proactively identify safety-related hazards and mitigate the associated risks. Risk management is an important component of ADM. When a pilot follows good decision-making practices, the inherent risk in a flight is reduced or even eliminated. The ability to make good decisions is based upon direct or indirect experience and education. The formal risk management decision-making process involves six steps.

Consider automotive seat belt use. In just two decades, seat belt use has become the norm, placing those who do not wear seat belts outside the norm, but this group may learn to wear a seat belt by either direct or indirect experience. For example, a driver learns through direct experience about the value of wearing a seat belt when he or she is involved in a car accident that leads to a personal injury. An indirect learning experience occurs when a loved one is injured during a car accident because he or she failed to wear a seat belt.

As you work through the ADM cycle, it is important to remember the four fundamental principles of risk management:

1. Accept no unnecessary risk. Flying is not possible without risk, but unnecessary risk comes without a corresponding return. If you are flying a new airplane for the first time, you might determine that the risk of making that flight in low visibility conditions is unnecessary.
2. Make risk decisions at the appropriate level. Risk decisions should be made by the person who can develop and implement risk controls. Remember that you are pilot-in-command, so never let anyone else — not ATC and not your passengers — make risk decisions for you.
3. Accept risk when benefits outweigh dangers (costs). In any flying activity, it is necessary to accept some degree of risk. A day with good weather, for example, is a much better time to fly an unfamiliar airplane for the first time than a day with low IFR conditions.
4. Integrate risk management into planning at all levels. Because risk is an unavoidable part of every flight, safety requires the use of appropriate and effective risk management not just in the preflight planning stage, but in all stages of the flight.

While poor decision-making in everyday life does not always lead to tragedy, the margin for error in aviation is thin. Since ADM enhances management of an aeronautical environment, all pilots should become familiar with and employ ADM.

Crew Resource Management (CRM) and Single-Pilot Resource Management

While CRM focuses on pilots operating in crew environments, many of the concepts apply to single-pilot operations. Many CRM principles have been successfully applied to single-pilot aircraft and led to the development of Single-Pilot Resource Management (SRM). SRM is defined as the art and science of managing all the resources (both on-board the aircraft and from outside sources) available to a single pilot (prior to and during flight) to ensure the successful outcome of the flight. SRM includes the concepts of ADM, risk management (RM), task management (TM), automation management (AM), controlled flight into terrain (CFIT) awareness, and situational awareness (SA). SRM training helps the pilot maintain situational awareness by managing the automation and associated aircraft control and navigation tasks. This enables the pilot to accurately assess and manage risk and make accurate and timely decisions.

SRM is all about helping pilots learn how to gather information, analyze it, and make decisions. Although the flight is coordinated by a single person and not an onboard flight crew, the use of available resources such as auto-pilot and air traffic control (ATC) replicates the principles of CRM.

Hazard and Risk

Two defining elements of ADM are hazard and risk. Hazard is a real or perceived condition, event, or circumstance that a pilot encounters. When faced with a hazard, the pilot makes an assessment of that hazard based upon various factors. The pilot assigns a value to the potential impact of the hazard, which qualifies the pilot's assessment of the hazard—risk.

Therefore, risk is an assessment of the single or cumulative hazard facing a pilot; however, different pilots see hazards differently. For example, the pilot arrives to preflight and discovers a small, blunt type nick in the leading edge at the middle of the aircraft's prop. Since the aircraft is parked on the tarmac, the nick was probably caused by another aircraft's prop wash blowing some type of debris into the propeller. The nick is the hazard (a present condition). The risk is prop fracture if the engine is operated with damage to a prop blade.

The seasoned pilot may see the nick as a low risk. He realizes this type of nick diffuses stress over a large area, is located in the strongest portion of the propeller, and based on experience; he does not expect it to propagate a crack that can lead to high-risk problems. He does not cancel his flight.

The inexperienced pilot may see the nick as a high-risk factor because he is unsure of the affect the nick will have on the operation of the prop, and he has been told that damage to a prop could cause a catastrophic failure. This assessment leads him to cancel his flight.

Therefore, elements or factors affecting individuals are different and profoundly impact decision-making. These are called human factors and can transcend education, experience, health, physiological aspects, etc.

Another example of risk assessment was the flight of a Beechcraft King Air equipped with deicing and anti- icing. The pilot deliberately flew into moderate to severe icing conditions while ducking under cloud cover. A prudent pilot would assess the risk as high and beyond the capabilities of the aircraft, yet this pilot did the opposite. Why did the pilot take this action?

Past experience prompted the action. The pilot had successfully flown into these conditions repeatedly although the icing conditions were previously forecast 2,000 feet above the surface. This time, the conditions were forecast from the surface. Since the pilot was in a hurry and failed to factor in the difference between the forecast altitudes, he assigned a low risk to the hazard and took a chance. He and the passengers died from a poor risk assessment of the situation.

Hazardous Attitudes and Antidotes

Being fit to fly depends on more than just a pilot's physical condition and recent experience. For example, attitude affects the quality of decisions. Attitude is a motivational predisposition to respond to people, situations, or events in a given manner. Studies have identified five hazardous attitudes that can interfere with the ability to make sound decisions and exercise authority properly: anti-authority, impulsivity, invulnerability, macho, and resignation.

Hazardous attitudes contribute to poor pilot judgment but can be effectively counteracted by redirecting the hazardous attitude so that correct action can be taken. Recognition of hazardous thoughts is the first step toward neutralizing them. After recognizing a thought as hazardous, the pilot should label it as hazardous, then state the corresponding antidote. Antidotes should be memorized for each of the hazardous attitudes so they automatically come to mind when needed.

Risk

During each flight, the single pilot makes many decisions under hazardous conditions. To fly safely, the pilot needs to assess the degree of risk and determine the best course of action to mitigate the risk.

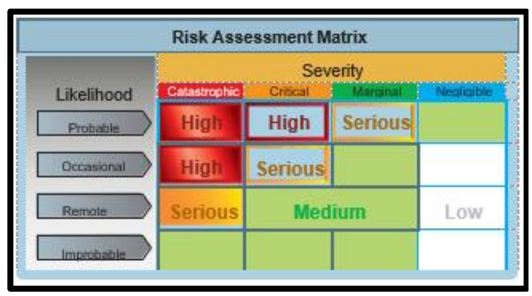


Figure 12.
Risk Assessment Matrix

Assessing Risk

For the single pilot, assessing risk is not as simple as it sounds. For example, the pilot acts as his or her own quality control in making decisions. If a fatigued pilot who has flown 16 hours is asked if he or she is too tired to continue flying, the answer may be "no." Most pilots are goal oriented and when asked to accept a flight, there is a tendency to deny personal limitations while adding weight to issues not germane to the mission. For example, pilots of helicopter emergency services (EMS) have been known (more than other groups) to make flight decisions that add significant weight to the patient's welfare. These pilots add weight to intangible factors (the patient in this case) and fail to appropriately quantify actual hazards, such as fatigue or weather, when making flight decisions. The single pilot who has no other crew member for consultation must wrestle with the intangible factors that draw one into a hazardous position. Therefore, he or she has a greater vulnerability than a full crew.

Examining National Transportation Safety Board (NTSB) reports and other accident research can help a pilot learn to assess risk more effectively. For example, the accident rate during night visual flight rules (VFR) decreases by nearly 50% once a pilot obtains 100 hours and continues to decrease until the 1,000-hour level. The data suggest that for the first 500 hours, pilots flying VFR at night might want to establish higher personal limitations than are required by the regulations and, if applicable, apply instrument flying skills in this environment.

Several risk assessment models are available to assist in the process of assessing risk. The models, all taking slightly different approaches, seek a common goal of assessing risk in an objective manner. The most basic tool is the risk matrix. It assesses two items: the likelihood of an event occurring and the consequence of that event.

Likelihood of an Event

Likelihood is nothing more than taking a situation and determining the probability of its occurrence. It is rated as probable, occasional, remote, or improbable. For example, a pilot is flying from point A to point B (50 miles) in marginal visual flight rules (MVFR) conditions. The likelihood of encountering potential instrument meteorological conditions (IMC) is the first question the pilot needs to answer. The experiences of other pilots, coupled with the forecast, might cause the pilot to assign "occasional" to determine the probability of encountering IMC.

The following are guidelines for making assignments:

Probable:	An event will occur several times.
Occasional:	An event will probably occur sometime.
Remote:	An event is unlikely to occur, but is possible.
Improbable:	An event is highly unlikely to occur.

Severity of an Event

The next element is the severity or consequence of a pilot's action(s). It can relate to injury and / or damage. If the individual in the example above is not an instrument rated pilot, what are the consequences of him or her encountering inadvertent IMC conditions? In this case, because the pilot is not IFR rated, the consequences are catastrophic. The following are guidelines for this assignment.

Catastrophic:	Results in fatalities, total loss.
Critical:	Severe injury, major damage.
Marginal:	Minor injury, minor damage.
Negligible:	Less than minor injury, less than minor system damage.

Simply connecting the two factors as shown in indicates the risk is high and the pilot must either not fly or fly only after finding ways to mitigate, eliminate, or control the risk.

Although the matrix provides a general viewpoint of a generic situation, a more comprehensive program can be made that is tailored to a pilot's flying. This program includes a wide array of aviation-related activities specific to the pilot and assesses health, fatigue, weather, capabilities, etc. The scores are added and the overall score falls into various ranges, with the range representative of actions that a pilot imposes upon himself or herself.

Mitigating Risk

Risk assessment is only part of the equation. After determining the level of risk, the pilot needs to mitigate the risk. For example, the pilot flying from point A to point B (50 miles) in MVFR conditions has several ways to reduce risk:

1. Wait for the weather to improve to good visual flight rules (VFR) conditions.
2. Take an instrument-rated pilot.
3. Delay the flight.
4. Cancel the flight.
5. Drive.

The PAVE Checklist

Another way to mitigate risk is to perceive hazards. By incorporating the PAVE checklist into preflight planning, the pilot divides the risks of flight into four categories: **P**ilot• in-command (PIC), **A**ircraft, en**V**ironment, and **E**xternal pressures (PAVE) which form part of a pilot's decision-making process.

With the PAVE checklist, pilots have a simple way to remember each category to examine for risk prior to each flight.

Once a pilot identifies the risks of a flight, he or she needs to decide whether the risk, or combination of risks, can be managed safely and successfully. If not, make the decision to cancel the flight. If the pilot decides to continue with the flight, he or she should develop strategies to mitigate the risks. One way a pilot can control the risks is to set personal minimums for items in each risk category. These are limits unique to that individual pilot's current level of experience and proficiency.

For example, the aircraft may have a maximum crosswind component of 15 knots listed in the aircraft flight manual (AFM), and the pilot has experience with 10 knots of direct crosswind. It could be unsafe to exceed a 10-knot crosswind component without additional training. Therefore, the 10-knot crosswind experience level is that pilot's personal limitation until additional training with a certificated flight instructor (CFI) provides the pilot with additional experience for flying in crosswinds that exceed 10 knots.

One of the most important concepts that safe pilots understand is the difference between what is "legal" in terms of the regulations, and what is "smart" or "safe" in terms of pilot experience and proficiency.

P = Pilot in Command (PIC)

The pilot is one of the risk factors in a flight. The pilot must ask, "Am I ready for this trip?" in terms of experience, recency, currency, physical, and emotional condition. The IMSAFE checklist provides the answers.

A = Aircraft

What limitations will the aircraft impose upon the trip? Ask the following questions:

1. Is this the right aircraft for the flight?
2. Am I familiar with and current in this aircraft? Aircraft performance figures and the AFM are based on a brand-new aircraft flown by a professional test pilot. Keep that in mind while assessing personal and aircraft performance.
3. Is this aircraft equipped for the flight? Instruments? Lights? Navigation and communication equipment adequate?
4. Can this aircraft use the runways available for the trip with an adequate margin of safety under the conditions to be flown?
5. Can this aircraft carry the planned load?
6. Can this aircraft operate at the altitudes needed for the trip?
7. Does this aircraft have sufficient fuel capacity, with reserves, for trip legs planned?

8. Does the fuel quantity delivered match the fuel quantity ordered.

V = EnVironment

WEATHER

Weather is a major environmental consideration. Earlier it was suggested pilots set their own personal minimums, especially when it comes to weather. As pilots evaluate the weather for a particular flight, they should consider the following:

1. What is the current ceiling and visibility? In mountainous terrain, consider having higher minimums for ceiling and visibility, particularly if the terrain is unfamiliar.
2. Consider the possibility that the weather may be different than forecast. Have alternative plans and be ready and willing to divert, should an unexpected change occur.
3. Consider the winds at the airports being used and the strength of the crosswind component.
4. If flying in mountainous terrain, consider whether there are strong winds aloft. Strong winds in mountainous terrain can cause severe turbulence and downdrafts and be very hazardous for aircraft even when there is no other significant weather.
5. Are there any thunderstorms present or forecast?
6. If there are clouds, is there any icing, current or forecast? What is the temperature / dew point spread and the current temperature at altitude? Can descent be made safely all along the route?
7. If icing conditions are encountered, is the pilot experienced at operating the aircraft's deicing or anti-icing equipment? Is this equipment in good condition and functional? For what icing conditions is the aircraft rated, if any?

TERRAIN

Evaluation of terrain is another important component of analyzing the flight environment:

1. To avoid terrain and obstacles, especially at night or in low visibility, determine safe altitudes in advance by using the altitudes shown on VFR and IFR charts during preflight planning.
2. Use maximum elevation figures (MEFs) and other easily obtainable data to minimize chances of an inflight collision with terrain or obstacles.

AIRPORT

What lights are available at the destination and alternate airports? VASI / PAPI or ILS glideslope guidance? Is the terminal airport equipped with them? Are they working? Will the pilot need to use the radio to activate the airport lights?

1. Check the Notices to Airmen (NOTAM) for closed runways or airports. Look for runway or beacon lights out, nearby towers, etc.
2. Choose the flight route wisely. An engine failure gives the nearby airports supreme importance.
3. Are there shorter or obstructed fields at the destination and / or alternate airports?

AIRSPACE

1. If the trip is over remote areas, is there appropriate clothing, water, and survival gear onboard in the event of a forced landing?
2. If the trip includes flying over water or unpopulated areas with the chance of losing visual reference to the horizon, the pilot must be prepared to fly IFR.
3. Check the airspace and any temporary flight restriction (TFRs) along the route of flight.

NIGHTTIME

Night flying requires special consideration:

1. If the trip includes flying at night over water or unpopulated areas with the chance of losing visual reference to the horizon, the pilot must be prepared to fly IFR.
2. Will the flight conditions allow a safe emergency landing at night?
3. Perform preflight check of all aircraft lights, interior and exterior, for a night flight. Carry at least two flashlights — one for exterior preflight and a smaller one that can be dimmed and kept nearby.

E = External Pressures

External pressures are influences external to the flight that create a sense of pressure to complete a flight — often at the expense of safety. Factors that can be external pressures include the following:

1. Someone waiting at the airport for the flight's arrival
2. A passenger the pilot does not want to disappoint
3. The desire to demonstrate pilot qualifications
4. The desire to impress someone, (Probably the two most dangerous words in aviation are "Watch this!")
5. The desire to satisfy a specific personal goal ("get- home-itis," "get-there-itis," and "let's-go-itis")
6. The pilot's general goal-completion orientation

MANAGING EXTERNAL PRESSURES

Management of external pressure is the single most important key to risk management because it is the one risk factor category that can cause a pilot to ignore all the other risk factors. External pressures put time-related pressure on the pilot and figure into a majority of accidents.

The use of personal standard operating procedures (SOPs) is one way to manage external pressures. The goal is to supply a release for the external pressures of a flight. These procedures include but are not limited to:

1. Allow time on a trip for an extra fuel stop or to make an unexpected landing because of weather.

2. Have alternate plans for a late arrival or make backup airline reservations for must-be-there trips.
3. For really important trips, plan to leave early enough so that there would still be time to drive to the destination, if necessary.
4. Advise those who are waiting at the destination that the arrival may be delayed. Know how to notify them when delays are encountered.
5. Manage passengers' expectations. Make sure passengers know that they might not arrive on a firm schedule, and if they must arrive by a certain time, they should make alternative plans.
6. Eliminate pressure to return home, even on a casual day flight, by carrying a small overnight kit containing prescriptions, contact lens solutions, toiletries, or other necessities on every flight.

The key to managing external pressure is to be ready for and accept delays. Remember that people get delayed when traveling on airlines, driving a car, or taking a bus. The pilot's goal is to manage risk, not create hazards.

Human Factors

Why are human conditions, such as fatigue, complacency and stress, so important in aviation? These conditions, along with many others, are called human factors. Human factors directly cause or contribute to many aviation accidents and have been documented as a primary contributor to more than 70% of aircraft accidents.

Typically, human factor incidents / accidents are associated with flight operations but recently have also become a major concern in aviation maintenance and air traffic management as well. Over the past several years, the FAA has made the study and research of human factors a top priority by working closely with engineers, pilots, mechanics, and ATC to apply the latest knowledge about human factors in an effort to help operators and maintainers improve safety and efficiency in their daily operations.

Human factors science, or human factors technologies, is a multidisciplinary field incorporating contributions from psychology, engineering, industrial design, statistics, operations research, and anthropometry. It is a term that covers the science of understanding the properties of human capability, the application of this understanding to the design, development and deployment of systems and services, and the art of ensuring successful application of human factor principles into all aspects of aviation to include pilots, ATC, and aviation maintenance. Human factors are often considered synonymous with CRM or maintenance resource management (MRM) but is really much broader in both its knowledge base and scope. Human factors involve gathering research specific to certain situations (i.e., flight, maintenance, stress levels, knowledge) about human abilities, limitations, and other characteristics and applying it to tool design, machines, systems, tasks, jobs, and environments to produce safe, comfortable, and effective human use. The entire aviation community benefits greatly from human factors research and development as it helps better understand how humans can most safely and efficiently perform their jobs and improve the tools and systems in which they interact.

Human Behavior

Studies of human behavior have tried to determine an individual's predisposition to taking risks and the level of an individual's involvement in accidents. In 1951, a study regarding injury-prone children was published by Elizabeth Mechem Fuller and Helen B. Baune, of the University of Minnesota. The study was comprised of two separate groups of second grade students. Fifty-five students were considered accident repeaters and 48 students had no accidents. Both groups were from the same school of 600 and their family demographics were similar.

The accident-free group showed a superior knowledge of safety, was considered industrious and cooperative with others, but were not considered physically inclined. The accident-repeater group had better gymnastic skills, was considered aggressive and impulsive, demonstrated rebellious behavior when under stress, were poor losers, and liked to be the center of attention. One interpretation of this data — an adult predisposition to injury stems from childhood behavior and environment — leads to the conclusion that any pilot group should be comprised only of pilots who are safety-conscious, industrious, and cooperative.

Clearly, this is not only an inaccurate inference, it is impossible. Pilots are drawn from the general population and exhibit all types of personality traits. Thus, it is important that good decision-making skills be taught to all pilots.

Historically, the term “pilot error” has been used to describe an accident in which an action or decision made by the pilot was the cause or a contributing factor that led to the accident. This definition also includes the pilot’s failure to make a correct decision or take proper action. From a broader perspective, the phrase “human factors related” more aptly describes these accidents. A single decision or event does not lead to an accident, but a series of events and the resultant decisions together form a chain of events leading to an outcome.

In his article “Accident-Prone Pilots,” Dr. Patrick R. Veillette uses the history of “Captain Everyman” to demonstrate how aircraft accidents are caused more by a chain of poor choices rather than one single poor choice. In the case of Captain Everyman, after a gear-up landing accident, he became involved in another accident while taxiing a Beech 58P Baron out of the ramp. Interrupted by a radio call from the dispatcher, Everyman neglected to complete the fuel cross-feed check before taking off. Everyman, who was flying solo, left the right-fuel selector in the cross-feed position. Once aloft and cruising, he noticed a right roll tendency and corrected with aileron trim. He did not realize that both engines were feeding off the left wing’s tank, making the wing lighter.

After two hours of flight, the right engine quit when Everyman was flying along a deep canyon gorge. While he was trying to troubleshoot the cause of the right engine’s failure, the left engine quit. Everyman landed the aircraft on a river sand bar but it sank into 10 feet of water.

Several years later Everyman flew a de Havilland Twin Otter to deliver supplies to a remote location. When he returned to home base and landed, the aircraft veered sharply to the left, departed the runway, and ran into a marsh 375 feet from the runway. The airframe and engines sustained considerable damage. Upon inspecting the wreck, accident investigators found the nose wheel steering tiller in the fully deflected position. Both the after takeoff and before landing checklists require the tiller to be placed in the neutral position. Everyman had overlooked this item.

Now, is Everyman accident prone or just unlucky? Skipping details on a checklist appears to be a common theme in the preceding accidents. While most pilots have made similar mistakes, these errors were probably caught prior to a mishap due to extra margin, good warning systems, a sharp copilot, or just good luck. What makes a pilot less prone to accidents?

The successful pilot possesses the ability to concentrate, manage workloads, and monitor and perform several simultaneous tasks. Some of the latest psychological screenings used in aviation test applicants for their ability to multitask, measuring both accuracy, as well as the individual’s ability to focus attention on several subjects simultaneously. The FAA oversaw an extensive research study on the similarities and dissimilarities of accident-free pilots and those who were not. The project surveyed over 4,000 pilots, half of whom had “clean” records while the other half had been involved in an accident.

Five traits were discovered in pilots prone to having accidents. These pilots:

1. Have disdain toward rules.
2. Have very high correlation between accidents on their flying records and safety violations on their driving records.
3. Frequently fall into the “thrill and adventure seeking” personality category.

4. Are impulsive rather than methodical and disciplined, both in their information gathering and, in the speed, and selection of actions to be taken.

5. Have a disregard for or tend to underutilize outside sources of information, including copilots, flight attendants, flight service personnel, flight instructors, and ATC.

The Decision-Making Process

An understanding of the decision-making process provides the pilot with a foundation for developing ADM and SRM skills. While some situations, such as engine failure, require an immediate pilot response using established procedures, there is usually time during a flight to analyze any changes that occur, gather information, and assess risks before reaching a decision.

Risk management and risk intervention is much more than the simple definitions of the terms might suggest. Risk management and risk intervention are decision-making processes designed to systematically identify hazards, assess the degree of risk, and determine the best course of action. These processes involve the identification of hazards, followed by assessments of the risks, analysis of the controls, making control decisions, using the controls, and monitoring the results.

The steps leading to this decision constitute a decision- making process. Three models of a structured framework for problem-solving and decision-making are the 5P, the 3P using PAVE, CARE and TEAM, and the DECIDE models. They provide assistance in organizing the decision process. All these models have been identified as helpful to the single pilot in organizing critical decisions.

Single-Pilot Resource Management (SRM)

Single-Pilot Resource Management (SRM) is about how to gather information, analyze it, and make decisions. Learning how to identify problems, analyze the information, and make informed and timely decisions is not as straightforward as the training involved in learning specific maneuvers. Learning how to judge a situation and "how to think" in the endless variety of situations encountered while flying out in the "real world" is more difficult.

There is no one right answer in ADM, rather each pilot is expected to analyze each situation in light of experience level, personal minimums, and current physical and mental readiness level, and make his or her own decision.

The 5Ps Check

SRM sounds good on paper, but it requires a way for pilots to understand and use it in their daily flights. One practical application is called the "Five Ps (5Ps)." The 5Ps consist of "the Plan, the Plane, the Pilot, the Passengers, and the Programming." Each of these areas consists of a set of challenges and opportunities that every pilot encounters. Each challenge and opportunity can substantially increase or decrease the risk of successfully completing the flight based on the pilot's ability to make informed and timely decisions. The 5Ps are used to evaluate the pilot's current situation at key decision points during the flight or when an emergency arises. These decision points include preflight, pre-takeoff, hourly or at the midpoint of the flight, pre-descent, and just prior to the final approach fix or for VFR operations, just prior to entering the traffic pattern.

The 5Ps are based on the idea that pilots have essentially five variables that impact his or her environment and forcing him or her to make a single critical decision, or several less critical decisions, that when added together can create a critical outcome. These variables are the Plan, the Plane, the Pilot, the Passengers, and the Programming. This concept stems from the belief that current decision-making models tended to be reactionary in nature. A change has to occur and be detected to drive a risk management decision by the pilot. For instance, many pilots complete risk management sheets prior to takeoff. These form a catalog of risks that may be encountered that day. Each of these risks is assigned a numerical value. If the total of these numerical values exceeds a predetermined level, the flight is altered or cancelled. Informal research shows that while these are useful documents for teaching risk factors, they are almost never used outside of formal training programs. The 5P concept is an attempt to take the information contained in those sheets and in the other available models and use it.

The 5P concept relies on the pilot to adopt a “scheduled” review of the critical variables at points in the flight where decisions are most likely to be effective. For instance, the easiest point to cancel a flight due to bad weather is before the pilot and passengers walk out the door and load the aircraft. So the first decision point is preflight in the flight planning room, where all the information is readily available to make a sound decision, and where communication and Fixed Base Operator (FBO) services are readily available to make alternate travel plans.

The second easiest point in the flight to make a critical safety decision is just prior to takeoff. Few pilots have ever had to make an “emergency takeoff.” While the point of the 5P check is to help the pilot fly, the correct application of the 5P before takeoff is to assist in making a reasoned go / no-go decision based on all the information available. The key idea is that these two points in the process of flying are critical go / no-go points on each and every flight.

The third place to review the 5Ps is at the midpoint of the flight. Often, pilots may wait until the Automated Terminal information Service (ATIS) is in range to check weather, yet, at this point in the flight, many good options have already passed behind the aircraft and pilot. Additionally, fatigue and low-altitude hypoxia serve to rob the pilot of much of his or her energy by the end of a long and tiring flight day. This leads to a transition from a decision-making mode to an acceptance mode on the part of the pilot. If the flight is longer than two hours, the 5P check should be conducted hourly.

The last two decision points are just prior to descent into the terminal area and just prior to the final approach fix, or if VFR, just prior to entering the traffic pattern as preparations for landing commence. Most pilots execute approaches with the expectation that they will land out of the approach every time. A healthier approach requires the pilot to assume that changing conditions (the 5Ps again) will cause the pilot to divert or execute the missed approach on every approach. This keeps the pilot alert to all manner of conditions that may increase risk and threaten the safe conduct of the flight. Diverting from cruise altitude saves fuel, allows unhurried use of the autopilot and is less reactive in nature. Diverting from the final approach fix, while more difficult, still allows the pilot to plan and coordinate better, rather than executing a futile missed approach. Let’s look at a detailed discussion of each of the Five Ps.

THE PLAN

The “Plan” can also be called the mission or the task. It contains the basic elements of cross-country planning, weather, route, fuel, publications currency, etc. The “Plan” should be reviewed and updated several times during the course of the flight. A delayed takeoff due to maintenance, fast moving weather, and a short notice TFR may all radically alter the plan. The “plan” is not only about the flight plan, but also all the events that surround the flight and allow the pilot to accomplish the mission. The plan is always being updated and modified and is especially responsive to changes in the other four remaining Ps. If for no other reason, the 5P check reminds the pilot that the day’s flight plan is real life and subject to change at any time.

Obviously, weather is a huge part of any plan. The addition of datalink weather information gives the advanced avionics pilot a real advantage in inclement weather, but only if the pilot is trained to retrieve and evaluate the weather in real time without sacrificing situational awareness. And of course, weather information should drive a decision, even if that decision is to continue on the current plan. Pilots of aircraft without datalink weather should get updated weather in flight through an FSS and / or Flight Watch.

THE PLANE

Both the “plan” and the “plane” are fairly familiar to most pilots. The “plane” consists of the usual array of mechanical and cosmetic issues that every aircraft pilot, owner, or operator can identify. With the advent of advanced avionics, the “plane” has expanded to include database currency, automation status, and emergency backup systems that were unknown a few years ago. Much has been written about single pilot IFR flight, both with and without an autopilot. While this is a personal decision, it is just that — a decision. Low IFR in a non- autopilot equipped aircraft may depend on several of the other Ps to be discussed. Pilot proficiency, currency, and fatigue are among them.

THE PILOT

Flying, especially when business transportation is involved, can expose a pilot to risks such as high altitudes, long trips requiring significant endurance, and challenging weather. Advanced avionics, when installed, can expose a pilot to high stresses because of the inherent additional capabilities which are available. When dealing with pilot risk, it is always best to consult the “IMSAFE” checklist (see page 2 to 6).

The combination of late nights, pilot fatigue, and the effects of sustained flight above 5,000 feet may cause pilots to become less discerning, less critical of information, less decisive, and more compliant and accepting. Just as the most critical portion of the flight approaches (for instance a night instrument approach, in the weather, after a four-hour flight), the pilot’s guard is down the most. The 5P process helps a pilot recognize the physiological challenges that they may face towards the end of the flight prior to takeoff and allows them to update personal conditions as the flight progresses. Once risks are identified, the pilot is in a better place to make alternate plans that lessen the effect of these factors and provide a safer solution.

THE PASSENGERS

One of the key differences between CRM and SRM is the way passengers interact with the pilot. The pilot of a highly capable single-engine aircraft maintains a much more personal relationship with the passengers as he / she is positioned within an arm’s reach of them throughout the flight.

The necessity of the passengers to make airline connections or important business meetings in a timely manner enters into this pilot's decision-making loop. Consider a flight to Dulles Airport in which and the passengers, both close friends and business partners, need to get to Washington, DC for an important meeting. The weather is VFR all the way to southern Virginia, then turns to low IFR as the pilot approaches Dulles. A pilot employing the 5P approach might consider reserving a rental car at an airport in northern North Carolina or southern Virginia to coincide with a refueling stop. Thus, the passengers have a way to get to Washington, and the pilot has an out to avoid being pressured into continuing the flight if the conditions do not improve.

Passengers can also be pilots. If no one is designated as pilot in command (PIC) and unplanned circumstances arise, the decision-making styles of several self-confident pilots may come into conflict.

Pilots also need to understand that non-pilots may not understand the level of risk involved in flight. There is an element of risk in every flight. That is why SRM calls it risk management, not risk elimination. While a pilot may feel comfortable with the risk present in a night IFR flight, the passengers may not. A pilot employing SRM should ensure the passengers are involved in the decision-making and given tasks and duties to keep them busy and involved. If, upon a factual description of the risks present, the passengers decide to buy an airline ticket or rent a car, then a good decision has generally been made. This discussion also allows the pilot to move past what he or she thinks the passengers want to do and find out what they actually want to do. This removes self-induced pressure from the pilot.

THE PROGRAMMING

The advanced avionics aircraft adds an entirely new dimension to the way GA aircraft are flown. The electronic instrument displays, GPS, and autopilot reduce pilot workload and increase pilot situational awareness. While programming and operation of these devices are fairly simple and straightforward, unlike the analog instruments they replace, they tend to capture the pilot's attention and hold it for long periods of time. To avoid this phenomenon, the pilot should plan in advance when and where the programming for approaches, route changes, and airport information gathering should be accomplished, as well as times it should not. Pilot familiarity with the equipment, the route, the local ATC environment, and personal capabilities vis-à-vis the automation should drive when, where, and how the automation is programmed and used.

The pilot should also consider what his or her capabilities are in response to last minute changes of the approach (and the reprogramming required) and ability to make large-scale changes (a reroute for instance) while hand flying the aircraft. Since formats are not standardized, simply moving from one manufacturer's equipment to another should give the pilot pause and require more conservative planning and decisions.

The SRM process is simple. At least five times before and during the flight, the pilot should review and consider the "Plan, the Plane, the Pilot, the Passengers, and the Programming" and make the appropriate decision required by the current situation. It is often said that failure to make a decision is a decision. Under SRM and the 5Ps, even the decision to make no changes to the current plan is made through a careful consideration of all the risk factors present.

Perceive, Process, Perform (3P) Model

The Perceive, Process, Perform (3P) model for ADM offers a simple, practical, and systematic approach that can be used during all phases of flight. To use it, the pilot will:

1. Perceive the given set of circumstances for a flight.
2. Process by evaluating their impact on flight safety.
3. Perform by implementing the best course of action.

Use the Perceive, Process, Perform, and Evaluate method as a continuous model for every aeronautical decision that you make. Although human beings will inevitably make mistakes, anything that you can do to recognize and minimize potential threats to your safety will make you a better pilot.

Depending upon the nature of the activity and the time available, risk management processing can take place in any of three timeframes. Most flight training activities take place in the “time-critical” timeframe for risk management. The six steps of risk management can be combined into an easy-to-remember 3P model for practical risk management: Perceive, Process, Perform with the PAVE, CARE and TEAM checklists. Pilots can help perceive hazards by using the PAVE checklist of: Pilot, Aircraft, enVironment, and External pressures. They can process hazards by using the CARE checklist of: Consequences, Alternatives, Reality, External factors. Finally, pilots can perform risk management by using the TEAM choice list of: Transfer, Eliminate, Accept, or Mitigate.

PAVE Checklist: Identify Hazards and Personal Minimums

In the first step, the goal is to develop situational awareness by perceiving hazards, which are present events, objects, or circumstances that could contribute to an undesired future event. In this step, the pilot will systematically identify and list hazards associated with all aspects of the flight: **P**ilot, **A**ircraft, en**V**ironment, and **E**xternal pressures, which makes up the PAVE checklist. For each element, ask “what could hurt me, my passengers, or my aircraft?” All four elements combine and interact to create a unique situation for any flight. Pay special attention to the pilot- aircraft combination, and consider whether the combined “pilot- aircraft team” is capable of the mission you want to fly. For example, you may be a very experienced and proficient pilot, but your weather flying ability is still limited if you are flying a 1970s-model aircraft with no weather avoidance gear. On the other hand, you may have a new technically advanced aircraft with moving map GPS, weather datalink, and autopilot — but if you do not have much weather flying experience or practice in using this kind of equipment, you cannot rely on the airplane’s capability to compensate for your own lack of experience

CARE Checklist: Review Hazards and Evaluate Risks

In the second step, the goal is to process this information to determine whether the identified hazards constitute risk, which is defined as the future impact of a hazard that is not controlled or eliminated. The degree of risk posed by a given hazard can be measured in terms of exposure (number of people or resources affected), severity (extent of possible loss), and probability (the likelihood that a hazard will cause a loss). The goal is to evaluate their impact on the safety of your flight, and consider “why must I CARE about these circumstances?”

For each hazard that you perceived in step one, process by using the CARE checklist of: **C**onsequences, **A**lternatives, **R**eality, **E**xternal factors. For example, let's evaluate a night flight to attend a business meeting:

Consequences:	Departing after a full work day creates fatigue and pressure.
Alternatives:	Delay until morning; reschedule meeting; drive.
Reality:	Dangers and distractions of fatigue could lead to an accident.
External Pressures:	Business meeting at destination might influence me.

A good rule of thumb for the processing phase: if you find yourself saying that it will "probably" be okay, it is definitely time for a solid reality check. If you are worried about missing a meeting, be realistic about how that pressure will affect not just your initial go / no-go decision, but also your inflight decisions to continue the flight or divert.

TEAM Checklist: Choose and Implement Risk Controls

Once you have perceived a hazard (step one) and processed its impact on flight safety (step two), it is time to move to the third step, perform. Perform risk management by using the TEAM checklist of: **T**ransfer, **E**liminate, **A**ccept, **M**itigate to deal with each factor:

Transfer:	Should this risk decision be transferred to some else (e.g., do you need to consult the chief flight instructor?)
Eliminate:	Is there a way to eliminate the hazard?
Accept:	Do the benefits of accepting risk outweigh the costs?
Mitigate:	What can you do to mitigate the risk?

The goal is to perform by taking action to eliminate hazards or mitigate risk, and then continuously evaluate the outcome of this action. With the example of low ceilings at destination, for instance, the pilot can perform good ADM by selecting a suitable alternate, knowing where to find good weather, and carrying sufficient fuel to reach it. This course of action would mitigate the risk. The pilot also has the option to eliminate it entirely by waiting for better weather.

Once the pilot has completed the 3P decision process and selected a course of action, the process begins anew because now the set of circumstances brought about by the course of action requires analysis. The decision- making process is a continuous loop of perceiving, processing, and performing. With practice and consistent use, running through the 3P cycle can become a habit that is as smooth, continuous, and automatic as a well-honed instrument scan. This basic set of practical risk management tools can be used to improve risk management.

Your mental willingness to follow through on safe decisions, especially those that require delay or diversion is critical. You can bulk up your mental muscles by:

1. Using personal minimums checklist to make some decisions in advance of the flight. To develop a good personal minimums checklist, you need to assess your abilities and capabilities in a non-flying environment, when there is no pressure to make a specific trip. Once developed, a personal minimums checklist will give you a clear and concise reference point for making your go / no-go or continue / discontinue decisions.
2. In addition to having personal minimums, some pilots also like to use a preflight risk assessment checklist to help with the ADM and risk management processes. This kind of form assigns numbers to certain risks and situations, which can make it easier to see when a particular flight involves a higher level of risk
3. Develop a list of good alternatives during your processing phase. In marginal weather, for instance, you might mitigate the risk by identifying a reasonable alternative airport for every 25 to 30 nautical mile segment of your route.
4. Pre-flight your passengers by preparing them for the possibility of delay and diversion, and involve them in your evaluation process.
5. Another important tool — overlooked by many pilots — is a good post-flight analysis. When you have safely secured the airplane, take the time to review and analyze the flight as objectively as you can. Mistakes and judgment errors are inevitable; the most important thing is for you to recognize, analyze, and learn from them before your next flight,

The DECIDE Model

Using the acronym "DECIDE," the six-step process DECIDE Model is another continuous loop process that provides the pilot with a logical way of making decisions. DECIDE means to **D**etect, **E**stimate, **C**hoose a course of action, **I**dentify solutions, **D**o the necessary actions, and **E**valuate the effects of the actions.

First, consider a recent accident involving a Piper Apache (PA• 23). The aircraft was substantially damaged during impact with terrain at a local airport in Alabama. The certificated airline transport pilot (ATP) received minor injuries and the certificated private pilot was not injured. The private pilot was receiving a check ride from the ATP (who was also a designated examiner) for a commercial pilot certificate with a multi-engine rating. After performing air work at altitude, they returned to the airport and the private pilot performed a single-engine approach to a full stop landing. He then taxied back for takeoff, performed a short field takeoff, and then joined the traffic pattern to return for another landing. During the approach for the second landing, the ATP simulated a right engine failure by reducing power on the right engine to zero thrust. This caused the aircraft to yaw right.

The procedure to identify the failed engine is a two-step process. First, adjust the power to the maximum controllable level on both engines. Because the left engine is the only engine delivering thrust, the yaw increases to the right, which necessitates application of additional left rudder application The failed engine is the side that requires no rudder pressure, in this case the right engine. Second, having identified the failed right engine, the procedure is to feather the right engine and adjust power to maintain descent angle to a landing.

However, in this case the pilot feathered the left engine because he assumed the engine failure was a left engine failure. During twin-engine training, the left engine out is emphasized more than the right engine because the left engine on most light twins is the critical engine. This is due to multi-engine airplanes being subject to P-factor, as are single- engine airplanes. The descending propeller blade of each engine will produce greater thrust than the ascending blade when the airplane is operated under power and at positive angles of attack. The descending propeller blade of the right engine is also a greater distance from the center of gravity, and therefore has a longer moment arm than the descending propeller blade of the left engine. As a result, failure of the left engine will result in the most asymmetrical thrust (adverse yaw) because the right engine will be providing the remaining thrust. Many twins are designed with a counter-rotating right engine. With this design, the degree of asymmetrical thrust is the same with either engine inoperative. Neither engine is more critical than the other.

Since the pilot never executed the first step of identifying which engine failed, he feathered the left engine and set the right engine at zero thrust. This essentially restricted the aircraft to a controlled glide. Upon realizing that he was not going to make the runway, the pilot increased power to both engines causing an enormous yaw to the left (the left propeller was feathered) where upon the aircraft started to turn left. In desperation, the instructor closed both throttles and the aircraft hit the ground and was substantially damaged.

This case is interesting because it highlights two particular issues. First, taking action without forethought can be just as dangerous as taking no action at all. In this case, the pilot's actions were incorrect; yet, there was sufficient time to take the necessary steps to analyze the simulated emergency. The second and more subtle issue is that decisions made under pressure are sometimes executed based upon limited experience and the actions taken may be incorrect, incomplete, or insufficient to handle the situation.

DETECT (THE PROBLEM)

Problem detection is the first step in the decision-making process. It begins with recognizing a change occurred or an expected change did not occur. A problem is perceived first by the senses and then it is distinguished through insight and experience. These same abilities, as well as an objective analysis of all available information, are used to determine the nature and severity of the problem. One critical error made during the decision-making process is incorrectly detecting the problem. In the previous example, the change that occurred was a yaw.

ESTIMATE (THE NEED TO REACT)

In the engine-out example, the aircraft yawed right, the pilot was on final approach, and the problem warranted a prompt solution. In many cases, overreaction and fixation excludes a safe outcome. For example, what if the cabin door of a Mooney suddenly opened in flight while the aircraft climbed through 1,500 feet on a clear sunny day? The sudden opening would be alarming, but the perceived hazard the open-door presents is quickly and effectively assessed as minor. In fact, the door's opening would not impact safe flight and can almost be disregarded. Most likely, a pilot would return to the airport to secure the door after landing.

The pilot flying on a clear day faced with this minor problem may rank the open cabin door as a low risk. What about the pilot on an IFR climb out in IMC conditions with light intermittent turbulence in rain who is receiving an amended clearance from ATC? The open cabin door now becomes a higher risk factor. The problem has not changed, but the perception of risk a pilot assigns it changes because of the multitude of ongoing tasks and the environment. Experience, discipline, awareness, and knowledge influences how a pilot ranks a problem.

CHOOSE (A COURSE OF ACTION)

After the problem has been identified and its impact estimated, the pilot must determine the desirable outcome and choose a course of action. In the case of the multiengine pilot given the simulated failed engine, the desired objective is to safely land the airplane.

IDENTIFY (SOLUTIONS)

The pilot formulates a plan that will take him or her to the objective. Sometimes, there may be only one course of action available. In the case of the engine failure already at 500 feet or below, the pilot solves the problem by identifying one or more solutions that lead to a successful outcome. It is important for the pilot not to become fixated on the process to the exclusion of making a decision.

DO (THE NECESSARY ACTIONS)

Once pathways to resolution are identified, the pilot selects the most suitable one for the situation. The multi-engine pilot given the simulated failed engine must now safely land the aircraft.

EVALUATE (THE EFFECT OF THE ACTION)

Finally, after implementing a solution, evaluate the decision to see if it was correct. If the action taken does not provide the desired results, the process may have to be repeated.

Decision-Making in a Dynamic Environment

A solid approach to decision-making is through the use of analytical models, such as the 5Ps, 3P, and DECIDE. Good decisions result when pilots gather all available information, review it, analyze the options, rate the options, select a course of action, and evaluate that course of action for correctness.

In some situations, there is not always time to make decisions based on analytical decision-making skills. A good example is a quarterback whose actions are based upon a highly fluid and changing situation. He intends to execute a plan, but new circumstances dictate decision-making on the fly. This type of decision-making is called automatic decision-making or naturalized decision-making.

Automatic Decision-Making

In an emergency situation, a pilot might not survive if he or she rigorously applies analytical models to every decision made as there is not enough time to go through all the options. Under these circumstances he or she should attempt to find the best possible solution to every problem.

For the past several decades, research into how people actually make decisions has revealed that when pressed for time, experts faced with a task loaded with uncertainty first assess whether the situation strikes them as familiar. Rather than comparing the pros and cons of different approaches, they quickly imagine how one or a few possible courses of action in such situations will play out. Experts take the first workable option they can find. While it may not be the best of all possible choices, it often yields remarkably good results.

The terms “naturalistic” and “automatic decision-making” have been coined to describe this type of decision- making. The ability to make automatic decisions holds true for a range of experts from firefighters to chess players. It appears the expert’s ability hinges on the recognition of patterns and consistencies that clarify options in complex situations. Experts appear to make provisional sense of a situation, without actually reaching a decision, by launching experience-based actions that in turn trigger creative revisions.

This is a reflexive type of decision-making anchored in training and experience and is most often used in times of emergencies when there is no time to practice analytical decision-making. Naturalistic or automatic decision- making improves with training and experience, and a pilot will find himself or herself using a combination of decision-making tools that correlate with individual experience and training.

Operational Pitfalls

Although more experienced pilots are likely to make more automatic decisions, there are tendencies or operational pitfalls that come with the development of pilot experience. These are classic behavioral traps into which pilots have been known to fall. More experienced pilots, as a rule, try to complete a flight as planned, please passengers, and meet schedules. The desire to meet these goals can have an adverse effect on safety and contribute to an unrealistic assessment of piloting skills. All experienced pilots have fallen prey to, or have been tempted by, one or more of these tendencies in their flying careers. These dangerous tendencies or behavior patterns, which must be identified and eliminated, include the operational pitfalls shown

Stress Management

Everyone is stressed to some degree almost all of the time. A certain amount of stress is good since it keeps a person alert and prevents complacency. Effects of stress are cumulative and, if the pilot does not cope with them in an appropriate way, they can eventually add up to an intolerable burden. Performance generally increases with the onset of stress, peaks, and then begins to fall off rapidly as stress levels exceed a person's ability to cope. The ability to make effective decisions during flight can be impaired by stress. There are two categories of stress — acute and chronic.

Factors referred to as stressors can increase a pilot's risk of error in the flight deck. Remember the cabin door that suddenly opened in flight on the Mooney climbing through 1,500 feet on a clear sunny day? It may startle the pilot, but the stress would wane when it became apparent the situation was not a serious hazard. Yet, if the cabin door opened in IMC conditions, the stress level makes significant impact on the pilot's ability to cope with simple tasks. The key to stress management is to stop, think, and analyze before jumping to a conclusion. There is usually time to think before drawing unnecessary conclusions.

There are several techniques to help manage the accumulation of life stresses and prevent stress overload. For example, to help reduce stress levels, set aside time for relaxation each day or maintain a program of physical fitness. To prevent stress overload, learn to manage time more effectively to avoid pressures imposed by getting behind schedule and not meeting deadlines.

Use of Resources

To make informed decisions during flight operations, a pilot must also become aware of the resources found inside and outside the flight deck. Since useful tools and sources of information may not always be readily apparent, learning to recognize these resources is an essential part of ADM training. Resources must not only be identified, but a pilot must also develop the skills to evaluate whether there is time to use a particular resource and the impact its use will have upon the safety of flight. For example, the assistance of ATC may be very useful if a pilot becomes lost, but in an emergency situation, there may be no time available to contact ATC.

Internal Resources

One of the most underutilized resources may be the person in the right seat, even if the passenger has no flying experience. When appropriate, the PIC can ask passengers to assist with certain tasks, such as watching for traffic or reading checklist items. The following are some other ways a passenger can assist:

1. Provide information in an irregular situation, especially if familiar with flying. A strange smell or sound may alert a passenger to a potential problem.
2. Confirm after the pilot that the landing gear is down.
3. Learn to look at the altimeter for a given altitude in a descent.
4. Listen to logic or lack of logic.

Also, the process of a verbal briefing (which can happen whether or not passengers are aboard) can help the PIC in the decision-making process. For example, assume a pilot provides a lone passenger a briefing of the forecast landing weather before departure. When the Automatic Terminal Information Service (ATIS) is picked up, the weather has significantly changed. The discussion of this forecast change can lead the pilot to reexamine his or her activities and decision-making. [Figure 2-17] Other valuable internal resources include ingenuity, aviation knowledge, and flying skill. Pilots can increase flight deck resources by improving these characteristics.

When flying alone, another internal resource is verbal communication. It has been established that verbal communication reinforces an activity; touching an object while communicating further enhances the probability an activity has been accomplished. For this reason, many solo pilots read the checklist out loud; when they reach critical items, they touch the switch or control. For example, to ascertain the landing gear is down, the pilot can read the checklist. But, if he or she touches the gear handle during the process, a safe extension of the landing gear is confirmed.

It is necessary for a pilot to have a thorough understanding of all the equipment and systems in the aircraft being flown. Lack of knowledge, such as knowing if the oil pressure gauge is direct reading or uses a sensor, is the difference between making a wise decision or poor one that leads to a tragic error.

Checklists are essential flight deck internal resources. They are used to verify the aircraft instruments and systems are checked, set, and operating properly, as well as ensuring the proper procedures are performed if there is a system malfunction or in-flight emergency. Students reluctant to use checklists can be reminded that pilots at all levels of experience refer to checklists, and that the more advanced the aircraft is, the more crucial checklists become. In addition, the pilot's operating handbook (POH) is required to be carried on board the aircraft and is essential for accurate flight planning and resolving in-flight equipment malfunctions. However, the most valuable resource a pilot has is the ability to manage workload whether alone or with others.

External Resources

ATC and flight service specialists are the best external resources during flight. In order to promote the safe, orderly flow of air traffic around airports and, along flight routes, the ATC provides pilots with traffic advisories, radar vectors, and assistance in emergency situations. Although it is the PIC's responsibility to make the flight as safe as possible, a pilot with a problem can request assistance from ATC. For example, if a pilot needs to level off, be given a vector, or decrease speed, ATC assists and becomes integrated as part of the crew. The services provided by ATC can not only decrease pilot workload, but also help pilots make informed in-flight decisions.

The Flight Service Stations (FSSs) are air traffic facilities that provide pilot briefing, enroute communications, VFR search and rescue services, assist lost aircraft and aircraft in emergency situations, relay ATC clearances, originate Notices to Airmen (NOTAM), broadcast aviation weather and National Airspace System (NAS) information, receive and process IFR flight plans, and monitor navigational aids (NAVAIDs). In addition, at selected locations, FSSs provide EnRoute Flight Advisory Service (Flight Watch), issue airport advisories, and advise Customs and Immigration of transborder flights. Selected FSSs in Alaska also provide TWEB recordings and take weather observations.

Situational Awareness

Situational awareness is the accurate perception and understanding of all the factors and conditions within the five fundamental risk elements (flight, pilot, aircraft, environment, and type of operation that comprise any given aviation situation) that affect safety before, during, and after the flight. Monitoring radio communications for traffic, weather discussion, and ATC communication can enhance situational awareness by helping the pilot develop a mental picture of what is happening.

Maintaining situational awareness requires an understanding of the relative significance of all flight related factors and their future impact on the flight. When a pilot understands what is going on and has an overview of the total operation, he or she is not fixated on one perceived significant factor. Not only is it important for a pilot to know the aircraft's geographical location, it is also important he or she understand what is happening. For instance, while flying above Richmond, Virginia, toward Dulles Airport or Leesburg, the pilot should know why he or she is being vectored and be able to anticipate spatial location. A pilot who is simply making turns without understanding why has added an additional burden to his or her management in the event of an emergency. To maintain situational awareness, all of the skills involved in ADM are used.

Obstacles to Maintaining Situational Awareness

Fatigue, stress, and work overload can cause a pilot to fixate on a single perceived important item and reduce an overall situational awareness of the flight. A contributing factor in many accidents is a distraction that diverts the pilot's attention from monitoring the instruments or scanning outside the aircraft. Many flight deck distractions begin as a minor problem, such as a gauge that is not reading correctly, but result in accidents as the pilot diverts attention to the perceived problem and neglects proper control of the aircraft.

Workload Management

Effective workload management ensures essential operations are accomplished by planning, prioritizing, and sequencing tasks to avoid work overload. As experience is gained, a pilot learns to recognize future workload requirements and can prepare for high workload periods during times of low workload. Reviewing the appropriate chart and setting radio frequencies well in advance of when they are needed helps reduce workload as the flight nears the airport. In addition, a pilot should listen to ATIS, Automated Surface Observing System (ASOS), or Automated Weather Observing System (AWOS), if available, and then monitor the tower frequency or Common Traffic Advisory Frequency (CTAF) to get a good idea of what traffic conditions to expect. Checklists should be performed well in advance so there is time to focus on traffic and ATC instructions. These procedures are especially important prior to entering a high- density traffic area, such as Class B airspace.

Recognizing a work overload situation is also an important component of managing workload. The first effect of high workload is that the pilot may be working harder but accomplishing less. As workload increases, attention cannot be devoted to several tasks at one time, and the pilot may begin to focus on one item. When a pilot becomes task saturated, there is no awareness of input from various sources, so decisions may be made on incomplete information and the possibility of error increases.

When a work overload situation exists, a pilot needs to stop, think, slow down, and prioritize. It is important to understand how to decrease workload. For example, in the case of the cabin door that opened in VFR flight, the impact on workload should be insignificant. If the cabin door opens under IFR different conditions, its impact on workload changes. Therefore, placing a situation in the proper perspective.

Risk Management

Risk management is the last of the three flight management skills needed for mastery of the glass flight deck aircraft. The enhanced situational awareness and automation capabilities offered by a glass flight deck airplane vastly expand its safety and utility, especially for personal transportation use. At the same time, there is some risk that lighter workloads could lead to complacency.

Humans are characteristically poor monitors of automated systems. When asked to passively monitor an automated system for faults, abnormalities, or other infrequent events, humans perform poorly. The more reliable the system, the poorer the human performance. For example, the pilot only monitors a backup alert system, rather than the situation that the alert system is designed to safeguard. It is a paradox of automation that technically advanced avionics can both increase and decrease pilot awareness.

It is important to remember that EFDs do not replace basic flight knowledge and skills. They are a tool for improving flight safety. Risk increases when the pilot believes the gadgets compensate for lack of skill and knowledge. It is especially important to recognize there are limits to what the electronic systems in any light GA aircraft can do. Being PIC requires sound ADM, which sometimes means saying “no” to a flight.

Risk is also increased when the pilot fails to monitor the systems. By failing to monitor the systems and failing to check the results of the processes, the pilot becomes detached from the aircraft operation and slides into the complacent role of passenger in command. Complacency led to tragedy in a 1999 aircraft accident.

In Colombia, a multi-engine aircraft crewed with two pilots struck the face of the Andes Mountains. Examination of their FMS revealed they entered a waypoint into the FMS incorrectly by one degree resulting in a flight path taking them to a point 60 NM off their intended course. The pilots were equipped with the proper charts, their route was posted on the charts, and they had a paper navigation log indicating the direction of each leg. They had all the tools to manage and monitor their flight, but instead allowed the automation to fly and manage itself. The system did exactly what it was programmed to do; it flew on a programmed course into a mountain resulting in multiple deaths. The pilots simply failed to manage the system and inherently created their own hazard. Although this hazard was self-induced, what is notable is the risk the pilots created through their own inattention. By failing to evaluate each turn made at the direction of automation, the pilots maximized risk instead of minimizing it. In this case, a totally avoidable accident become a tragedy through simple pilot error and complacency.

For the GA pilot transitioning to automated systems, it is helpful to note that all human activity involving technical devices entails some element of risk. Knowledge, experience, and mission requirements tilt the odds in favor of safe and successful flights. The advanced avionics aircraft offers many new capabilities and simplifies the basic flying tasks, but only if the pilot is properly trained and all the equipment is working as advertised.

Chapter Summary

This chapter focused on helping the pilot improve his or her ADM skills with the goal of mitigating the risk factors associated with flight in both classic and automated aircraft. In the end, the discussion is not so much about aircraft, but about the people who fly them.

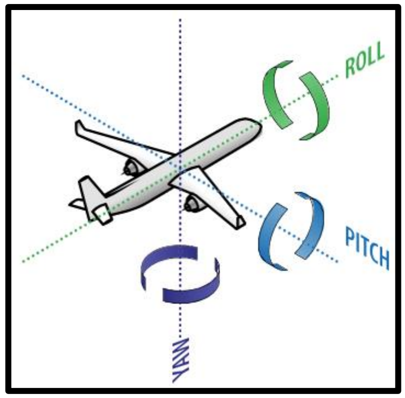
CHAPTER 11.
UAS Glossary

Autonomous Flight:	A drone's ability to fly by itself without direct pilot control.
Agisoft:	Software used to create 3D spatial data from photogrammetric processing of data.
AgVault™ Desktop:	Sentera's precision ag desktop platform that assigns imagery to the correct field, by time + type of image (RGB, NIR, NDVI, or NDRE) moments after your drone lands. Create QuickTile™ crop health maps in seconds, or order fully stitched orthomosaics directly through AgVault™ desktop. Integrate AgVault™ with your existing tools and push shapefiles directly to your equipment.
AgVault™ Mobile:	Sentera's mobile platform that tracks crop growth stages, weeds, compaction, storm damage and more. Snap a photo with your mobile device and it automatically syncs with your desktop, catalogued by location, time, and type. It also allows you to autonomously fly any DJI Mavic, Phantom 4, Phantom 3, or Inspire UAV using your iOS mobile device.
AgVault™ Web:	Sentera's online data management platform that handles all of your aerial RGB, NIR, NDVI or NDRE data for easy access through any connected, browser-equipped device.
AgVault™:	Sentera's precision ag data management platform for desktop, web and mobile devices.
Autopano Giga:	Image-stitching software.
Double 4K Sensor:	Sentera's rugged dual sensor that captures two sets of imagery simultaneously, and comes in four different variations.
Fly-Away Protection System:	Delay until morning; reschedule meeting; drive.
Gimbal:	A device used to hold and stabilize a camera to a drone. Gimbals enable crisp imagery.
Global Shutter:	Let's all light into a sensor simultaneously, allowing it to capture the most accurate representation of motion.
Graphic Processing Unit (GPU):	A graphic processing unit renders visual information such as video, images, and animations for your monitor.

Ground Effect:	Increasing air pressure on the lower wing surface as an aircraft approaches the ground.
Ground Sampling Distance (GSD):	The distance between pixel centers measured on the ground. The lower the GSD, the higher the image's spatial resolution. The result is more visible detail in images.
Gyroscope (Gyro):	The gyroscope helps keep the drone balanced (with respect to yaw, pitch and roll) by measuring the rate of rotation.
Hexicopter:	A vertical takeoff and landing drone with six rotors (propellers).
High-Precision Single Sensor:	Sentera's precise scouting sensor is available in two variants depending on which type of crop health data you'd like to collect: NDVI or NDRE.
Hobby Grade:	Mid-sized drones, typically equipped with a camera. Hobby-grade drones are perfect for moderate use.
Hyperspectral Imagery (HSI):	HSI collects and processes information from across the electromagnetic spectrum and subdivides spectrums into extremely narrow bandwidths.
Incident Light Sensor:	Sentera's color-correcting sensor.
Indago:	The Lockheed Martin Indago is an industrial-grade quadcopter. It is compatible with the Sentera High-Precision Single NDVI or NDRE sensor, the Sentera Double 4K sensors, and the Sentera Q sensor.
Inspire 1:	The DJI Inspire 1 is a prosumer grade quadcopter that allows for unobstructed 360° view. It is compatible with the Sentera High-Precision Single NDVI or NDRE sensor, the Sentera Double 4K sensors, as well as the DJI Z3, X5 or Thermal XT sensors.
JPEG:	A common image file format, able to be compressed at user discretion.
Lateral Axis, Transverse Axis, or Pitch Axis:	An axis parallel to the wings of a winged aircraft.

LiDAR:	Stands for light detection and ranging. LiDAR is a method of using a pulsed laser to measure distances.
Longitudinal Axis, or Roll Axis:	An axis drawn through the body of the aircraft from tail to nose in the normal direction of flight, or the direction the pilot faces.
Mavic:	The DJI Mavic is a consumer-grade compact quadcopter that can fold up to fit in the palm of your hand. It is compatible with Sentera's High-Precision Single NDVI or NDRE sensor.
Multi-Copter:	The generic name for a drone with multiple rotors (propellers), usually facing upwards.
Multi-Spectral Imagery (MSI):	Captures image data within specific wavelength ranges across the electromagnetic spectrum.
Near-Infrared (NIR):	Light reflected in this band correlates to the bands of light needed to view biological processes in plant material.
Normal Axis or Yaw Axis:	An axis drawn from top to bottom, and perpendicular to the other two axes (lateral axis and longitudinal axis).
Normalized Difference Red Edge (NDRE):	A measurement very similar to NDVI, but that is more useful for mature plants. NDRE can be useful for assessing plant vigor, plant stress, presence of chlorophyll in plant leaves, nitrogen uptake, and fertilizer needs.
Normalized Difference Vegetation Index (NDVI):	In simple terms, NDVI is a measurement of plant health based on how a plant reflects light at specific frequencies. Healthy plants *reflect* a large amount of near-infrared (NIR) light, while unhealthy plants *absorb* more NIR light. NDVI data is helpful for analyzing plant vigor and yield potential.
Octocopter:	A drone with eight rotors (propellers).
Omni:	The Sentera Omni is an industrial quadcopter that comes equipped with a gimballed Sentera Double 4K sensor. With the ability to capture imagery from virtually any angle, it enables you to collect inspection and / or scouting data not previously possible. It is compatible with the Sentera High-Precision Single NDVI or NDRE sensor, DJI Z3, and DJI Thermal XT sensor.

OnTop™:	Sentera inspection software that captures when and where you took a photo. Then it automatically assigns it to a site on your map and captures the type of asset in the photo. Photos are ready for analysis the moment they are captured onsite.
Orthomosaic:	These maps are created using many overlapping images taken from your UAV, to create a true-to-scale high-resolution map. The data from this type of map allows you to produce volumetrics, NDVI, 3D tours, and more.
Overlap:	The overlapping of successive photos (front to back) along a flight path.
Part 107:	United States government regulations for commercial operation of remote-operated aircraft under 55 pounds.
Payload Capacity:	How much weight a drone is able to carry (sensors, cameras, gimbal, batteries, etc.).
Payload:	Non-aircraft sensors or equipment.
Phantom 4 Pro:	DJI's robust and affordable consumer-grade quadcopter, compatible with Sentera's High- Precision Single NDVI or NDRE sensor and Double 4K Ag or Multispectral sensor.
PHX:	Maximize your acres per hour with the professional-grade Sentera PHX fixed-wing drone. Available in in three different variants: the Pro, LE, and MS, there's a PHX perfect for any industry. Equipped with the Sentera Double 4K sensor, it is also compatible with Sentera's entire line of precision sensors.
Pitch:	The movement of the nose of an aircraft up or down. A positive pitching motion raises the nose of the aircraft and lowers the tail.
Pix4D:	Software that allows you to create 2D maps and 3D models from flight imagery.
Professional Grade:	High-end drones, typically equipped with high-definition cameras and better features such as longer flight times.
Quad Multi-Spectral:	The Sentera Quad is a multispectral sensor with four customizable imagers.

Quadcopter (Quad, Quadricopter, Quadrocopter):	A drone with four rotors (propellers).
QuickTile™:	Functional stitched field map created by rapidly stitching together images from a drone flight at the field's edge, no internet required.
Radio Controller:	A device used to control a drone. 
Raw Imagery:	An image file with no compression and no processing. This is the highest quality and most easily edited format of imagery that can be collected, but also results in the largest files.
RGB:	RGB stands for Red, Green, Blue. These colors, when mixed together, create color in digital imagery. This is the standard format for digital color images.
Roll:	Rotation of an aircraft about an axis running from nose to tail.
Rolling Shutter:	Captures light using a method similar to pulling up blinds on a window.
Sentera Q:	An advanced camera capable of 10x zoom color imagery and 18MP capture that can be used to produce 3D models.
Shapefile (.SHP):	Method of storing geometric locations and their respective attributes. This information can be sent to your existing devices to be used in the field.
Sidelap:	The lateral overlapping photos taken adjacent to each other (left and right).

TIFF:	TIFF stands for "tagged image file format" and is a larger image file format with no compression.
Toy Grade:	Smaller drones, often quadcopters, that are inexpensive and great for beginners.
Waypoints:	Coordinates used to map autonomous flight missions.
Yaw:	The clockwise or counterclockwise movement of the drone from a top-down view. Characterized by left or right movement of the nose of an aircraft.

CHAPTER 12.
General Glossary

Term	Definition
2.4 Ghz:	The frequency used by digital (spread spectrum) radio communications in our applications, included 2.4Ghz RC, Bluetooth, and some video transmission equipment. This is a different band than the older 72 Mhz band that is used for analog TC communications. To avoid radio frequency conflict, it is often a good idea to use 72 Mhz radio equipment when you are using 2.4 Ghz onboard video transmitters, or use 900 Mhz video when using 2.4 Ghz RC equipment.
Accelerometer:	A device that measures the acceleration forces in a certain direction and helpful in maintaining the drone's orientation. These devices are used to stabilize quadcopters.
Aerial Photography:	Capturing images and video while in the air with a camera mounted to your drone.
AGL:	Altitude above ground level.
AHRS (Altitude Heading Reference System):	An IMU (see below) plus the code to interpret the output from its sensors to establish a plane's XYZ and heading orientation.
Altitude Hold (ALT Hold):	Allows pilot to focus on the camera while the drone hovers steadily in air by itself at a set height.
AMA (Academy of Model Aeronautics):	The main U.S. model aircraft association. The AMA works closely with the Federal Aviation Administration (FAA) to establish reasonable rules for the use of amateur UAVs. Each AMA chapter and field may have slightly different policies, but it is possible to fly and test air frames and some technology on AMA fields without violating the association's (or FAA / NAS) rules.
Arduino:	An open-source embedded processor project. Includes a hardware standard currently based on the Atmel Atmega168 microprocessor and necessary supporting hardware, and a software-programming environment based on the C-like Processing language.
AGL:	Altitude Ground Level
ARF:	Almost Ready to Fly
ATC:	Air Traffic Control
Autopilot:	A capability of a drone to conduct a flight without real-time human control. For example, following preset GPS coordinates.
Autonomous Flight:	There are some SUAVs that are managed by internal programming that have instructions on where to fly as guided by an onboard GPS system. This is in opposition to steering mechanisms that are operated by radio control from the ground.

Term	Definition
Axis:	One plane of potential flight. Most quadcopters have at least four axis controls, with six+ being preferred.
Balanced Battery Charger:	This is a charger or an internal system for LIPO batteries (or different chemistries) which uses smart technology to charge multiple cells property that are located within the battery and balances them.
Barometric Pressure Sensor:	This device used barometric readings to determine the altitude of the aircraft. It can help drones to be able to calculate their height above the ground, along with using combinations of other sensors (enables Altitude Hold feature).
Bind:	The process of making the controller (Transmitter) communicate with the quadcopter or the drone.
BNF (Bind N Fly):	The unit is ready to bind to your transmitter and fly.
BLOS:	Beyond Line of Sight
Brushless Motor:	These motors have permanent magnets that rotate around a fixed armature, which eliminates any problems that could be associated with connecting current regarding a moving part. The brushless motors are much more efficient and hardier than brushed motors.
BVLOS:	Beyond Visual Line of Sight
Camera Gimbal:	The holder of the camera used on drones. It can tilt and swerve, thanks to the servos that power it.
CMOS:	Complementary Metal-Oxide Semiconductor
COA (Certificate of Authorization):	A FAA approval for a UAV flight. See the faa.gov website for more details.
Commercial Flight:	Flying a drone for money-making purposes.
Controller:	The handheld device that is used by the drone pilot that is used to control the drone and the quadcopter. Controllers are also called transmitters.
Drone:	UAV capable of autonomous flight.
DSM:	Digital Surface Model:

Term	Definition
ESC (Electronic Speed Control):	Device to control the motor in an electric aircraft. Serves as the connection between the main battery and the RC receiver. Usually includes a BEC, or Battery Elimination Circuit, which provides power for the RC system and other onboard electronics, such as an autopilot.
FAA (Federal Aviation Administration):	A United States Department of Transportation Agency, with the authority to regulate and oversee all aspects of American civil aviation.
Firmware:	The software or sketch that is loaded into the non-volatile memory of microprocessor-based products. It is called “firmware” because it stays in the non-volatile memory even if power is removed, thus non-volatile. In the case of the autopilots, it is the “program” or application (app to smartphone users) that determines what the autopilot does, and how.
Fly Away:	Unintended flight outside of operation boundaries (altitude / airspeed / lateral), as the result of a failure of the control element or onboard systems, or both.
FPS:	Frames per Second
FPV (First-Person View):	A technique that uses an onboard video camera and wireless connection to the ground allow a pilot on the ground with video goggles to fly with a cockpit view.
GCS (Ground Control Station):	Software running on a computer on the ground that receives telemetry information from an airborne UAV and displays its progress and status, often including video and other sensor data. Can also be used to transmit inflight commands to the UAV.
GIS:	Geographical Information System
GPS (Global Position System):	Is used to track the position of an object in relation to the global spatial plan, track movement, or cause an airborne vehicle, such as a quadcopter to hold position.
Gyroscope:	A gyroscope, or gyro, measures the rate of rotation of the UAV and helps keep the craft balanced correctly with respect to yaw, pitch and roll. Helps to maintain the orientation of the quadcopter while in flight. In most cases, quadcopters use a triple axis gyroscope.

Term	Definition
IMU (Inertial Measurement Unit):	Usually has at least three accelerometers (measuring the gravity vector in the X, Y and Z dimensions) and two gyros (measuring rotation around the tile and pitch axis). Neither are sufficient by themselves, since accelerometers are thrown off by movement (i.e., they are “noisy” over short periods of time), while gyros drift over time. The data from both types of sensors must be combined in software to determine true aircraft attitude and movement to create an AHRS (see above).
INS (Inertial Navigation System):	A way to calculate position based on initial GPS reading followed buy readings from motion and speed sensors using dead reckoning. Useful when GPS is not available or has temporaily lost its signal.
IOC (Intelligent Orientation Control):	Usually, the forward direction of a flying multi-rotor is the same as the nose direction. By using Intelligent Orientation Control (IOC), wherever the nose points, the forward direction has nothing to do with nose directions.
Kalman Filter:	A relatively complicated algorithm that, in our applications, is primarily used to combine accelerometer and gyro data to provide an accurate description of aircraft attitude and movement in real-time.
LiDAR:	Light Detection and Ranging
LIPO (Lithium Polymer Battery, aka LiPoly):	Variants include Lithium Ion (Li-Ion) battery. This battery chemistry offers more power and lighter weight than NiMh and NiCad batteries.
LOS (Line of Sight):	Refers to being able to see your drone from your operating position with your naked eye. Your drone should always be within your line of sight.
MAVLink:	The Micro Air Vehicle communications protocol used by the copter and plane line of autopilots.
MAV (Micro Air Vehicle):	A small UAV.
MP:	Megapixel
NFZ:	No Fly Zone
No Fly Zone:	Areas where flying a drone is restricted by government regulations. Areas where a drone could interfere with an airplane or record sensitive information make up most of these areas.
OEM:	Original Equipment Manufacturer

Term	Definition
OSD (On-Screen Display):	A way to integrate data (often telemetry information) into the real-time video stream the aircraft is sending to the ground.
Payload:	The amount of additional weight a drone is able to lift, in addition to its own weight and batteries. If you attach a camera and gimbal to your drone, the combined weight is the payload.
PCB (Printed Circuit Board):	In our use, a specialized board designed and “fabbed” for a dedicated purpose, as opposed to a breadboard or prototype board, which can be used and reused for many projects.
PDB (Power Distribution Board):	A board used in multi-copters to distribute power to multiple ESCs.
PIC (Pilot in Command):	Refers to a FAA requirement the UAVs stay under a pilot’s direct control if they are flying under the recreational exemptions to COA approval.
Pitch:	A measure which describes the flight angle along one axis, usually measured from level in case of aerial vehicles.
POI (Point of Interest):	Designates a spot that a UAV should keep a camera pointed towards.
Pre-Flight Planning:	The activities conducted by the pilot and flight crew prior to takeoff to ensure that the flight will be conducted safely and in accordance with all applicable standards and regulations. The activity includes, but is not limited to, such things as checking weather, route of flight, airspace, equipment configuration, support personnel, terrain, and communication requirements.
PWM (Pulse Width Modulation):	The square-wave signals used in RC control to drive servos and speed controllers. There is one PWM signal for each channel. The width varies from 1,000 to 2,000 microseconds, depending on the RC manufacturer.
RC (Radio Controlled):	Control of a drone via radio waves.
RPAS:	Remotely Piloted Aircraft System
RPV:	Remote Person View
RTF:	Ready to Fly
RTL (Return to Launch):	Fly back to the “home” location where the aircraft took off.

Term	Definition
Sense and Avoid:	The capability of a UAS to remain well clear from and avoid collisions with other airborne traffic. Sense and Avoid provides the functions of self-separation and collision avoidance.
Servo (Servomotor or Servomechanism):	Aerial vehicles use servomotors for various functions, such as pan cameras and wing flaps adjustments, which can be controlled from the ground.
sUAS:	Small Unmanned Aircraft System
Telemetry System:	A two-way radio system to allow flight data to be sent from your aircraft and also to allow control or adjustment information to be sent back to it from a “ground station,” commonly a laptop computer.
Throttle:	Control that influences the RPM or the speed of electric motors.
TX:	Transmitter or transmit.
UAS	Unmanned Aerial System
UAS Incursion:	A non-participating UAS operating over or near a wildfire that: 1. Intrudes into a Temporary Flight Restriction (TFR). 2. Interferes with fire management efforts and the interference is documented through the appropriate reporting system. An example of appropriate reporting systems would include SAFECOM, SAFENET, or a reporting system used by one of the states.
UAV (Unmanned Aerial Vehicle):	In the military, these are increasingly called Unmanned Aerial Systems (UAS), to reflect that the aircraft is just part of a complex system in the air and on the ground.
Visual Observer:	A crewmember that assists the UAS pilot in the duties associated with collision avoidance. This includes, but is not limited to, avoidance of other traffic, airborne objects, clouds, obstructions, and terrain.
VLOS (Visual Line of Sight):	The pilot’s ability to see an aircraft from the ground well enough to control it, without the use of artificial visual aids (aside from glasses).
VTOL:	Vertical Takeoff and Landing

Term	Definition
WAAS (Wide Area Augmentation System):	A system of satellites and ground stations that provide GPS signal corrections, giving up to five times better position accuracy than uncorrected GPS.
Waypoint:	A set of coordinates, which define a point in space. Waypoints are useful in designing various autonomous missions for quadcopters. Mapping out would be impossible without a possibility to define these physical locations.
YAW:	Quadcopter rotation around its center axis on a level plane.