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Atlantic City International Airport
New Jersey 08405

Recommended FAA Rules for a Generic, Remotely Piloted, Powered-Lift Vehicle Using Two Levels of Automation

January 2026

Final report

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16. Abstract

With growing industry interest in new aircraft technologies, such as unmanned aircraft systems and vertical takeoff and landing vehicles, the FAA determined that current regulations for aircraft/ground station and pilot/operator certification should be examined. Researchers determined that given the current technology capabilities that the current and proposed rules are inadequate for the long term (more than 10 years out) – especially when powered-lift aircraft were considered.

The researchers hypothesized that some of the current pilot/operator certification requirements used today are irrelevant to real world operations, such as calculating weight and balance using pencil and paper and a four-function calculator. Another requirement regarding realistic aircraft failures may also be outdated.

Researchers developed two levels of automation for a simulation study. One automation level was intended to simplify vertical flight for existing pilots and was modeled after a current production G1000® avionics suite but with a Unified flight control system (like an F-35B). The other level used an EZ-Fly flight control system where the inceptor always controlled the flight path vector (not attitude), addressed systems failures automatically, and had a flight path centric display.

An identical flight profile with failures was flown by three licensed pilots using the first level of automation and by three people with no flight experience using the second level of automation. The non-pilots using the second level of automation flew safer and more precisely than the pilot group.

Recommended aircraft/ground station and pilot/operator rule changes to accommodate these automation levels was proposed.

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Acronyms

Acronym	**Definition**
AC	Advisory Circular
ACS	Airman Certification Standards
ADS-B	Automatic dependent surveillance-broadcast
AFM	Aircraft flight manual
AGL	Above ground level
AMEL	Airplane multi-engine—land
AMES	Airplane multi-engine—sea
AOA	Angle of attack
AP	autopilot
APU	Auxilary power unit
ARC	Aviation Rulemaking Committee
ASEL	Airplane single-engine—land
ASES	Airplane single-engine—sea
ASOS	Automated surface observing system
AWOS	Automated weather observing system
ATC	Air traffic control
ATIS	Automatic terminal information service
ATP	Airline transport pilot
Automatic GCAS	Automatic ground collision avoidance system
BVLOS	Beyond visual line of sight
CAS	Crew alerting system
CCD	Climb, cruise, descent
CFI	Certified flight instructor
CFII	Certified flight instructor—instrument
CFIT	Controlled flight into terrain
CFR	Code of Federal Regulations
CG	Center of gravity
CPDLC	Controller-pilot, data link communication
CPL	Commercial pilot license
CTOL	Conventional takeoff and landing
eCTOL	Electrical conventional takeoff and landing
EMI	Electromagnetic interference

eVTOL	Electrical vertical takeoff and landing
FAA	Federal Aviation Administration
FADEC	Full-authority digital engine control
FAR	Federal Aviation Regulations
FBW	Fly-by-wire
FCC	Federal Communications Commission
FMS	Flight management system
FTE	Flight technical error
GCS	Ground control stations
GPS	Global positioning system
GUI	Graphical user interface
HIRF	High-intensity radiated fields
KCAS	Knots calibrated air speed
KIAS	Knots indicated air speed
IAF	Initial approach fix
IFR	Instrument Flight Rules
IR	Instrument rating
IMC	Instrument meteorological conditions
ISA	International standard atmosphere
LOC	Instrument landing system localizer
LOTC	Loss of thrust control
LOPC	Loss of power control
LRU	Line replaceable unit
LSA	Light sport aircraft
MAP	Missed approach point
MD	Design limit Mach number
ME	Multi-engine
MFD	Multifunction display
MMO	Maximum Mach operating
N1	Rotational speed of the low-speed spool
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Airmen
OPA	Optionally piloted aircraft
RAT	Ram air turbine
PFD	Primary flight display

PIC	Pilot in command
PIREP	Pilot report
RPA	Remotely piloted aircrafts
RPM	Revolutions per minute
RPV	Remotely piloted vehicle
SOW	Statement of work
SVO	Simplified vehicle operation
TAA	Technically advanced aircraft
TFR	Temporary flight restriction
W&B	Weight and balance
WPT	Waypoint
UA	Unmanned aircraft or uncrewed aircraft
UAS	Unmanned aircraft systems
UAV	Unmanned aerial vehicle
UCS	Unified control system
UPS	Uninterruptable power supplies
U.S.	United States
USAF	United States Air Force
VD	Design limit speed
VFR	Visual Flight Rules
VMC	Visual meteorological conditions
Vmc	Minimum control speeds
Vmin	Minimum speed
VMO	Maximum operating airspeed
VNAV	Vertical navigation
VNE	Never exceed speed
VNO	Normal operating speed
VOR	Very high-frequency omnidirectional range station
Vref	Reference speed
VTOL	Vertical takeoff and landing
Vx	Airspeed for best angle of climb

Executive summary

With growing industry interest in new aircraft technologies, such as unmanned aircraft systems (UAS) and vertical takeoff and landing (VTOL) vehicles, the Federal Aviation Administration (FAA) determined that current regulations for aircraft/ground station and pilot/operator certification should be examined, especially as they pertain to increasing automation. A research effort that included a simulation study was initiated to review the current FAA rules for pilot certification, aircraft certification, and operations as they apply to a generic, remotely piloted powered-lift vehicle with the size and performance characteristics of a Cessna Caravan aircraft and a Bell 206 helicopter. Based on this review, researchers made recommendations to update relevant regulations, certification requirements, and training procedures.

Because remotely piloted vehicles (RPVs) will most likely have advanced levels of automation, two automation levels were chosen to conduct the simulation study. The first automation level was representative of the technology available today in new airplanes but with a flight control system like the Lockheed Martin F-35B, a stealth strike fighter aircraft with short takeoff and vertical landing capabilities. The second automation level was representative of small flight vehicles that are very easy to fly and require very little training, including hobby drones and some ultralight aircraft.

Although the current private pilot and instrument rating (IR) knowledge and skills were appropriate starting points, it was found that some areas needed to be eliminated or added for an RPV pilot—especially as automation levels increase. Changes to Title 14 Code of Federal Regulations Part 61 and the relevant Airman Certification Standards (ACSs) were recommended to reflect these findings. It was also found that aircraft certification regulations also need to change to address increased automation. Suggested changes were consolidated into a single set of recommendations to cover powered-lift vehicles by combining the intent of Part 23 (airplanes) and Part 27 (helicopters). The FAA has also made a set of proposed regulations for RPVs. These were also examined in this research effort, and recommendations were made based on current and foreseen technology.

It was determined that the recommended changes for pilot certification and aircraft certification need to be developed concurrently, since one affects the other as automation levels increase. Similarly, certain operating rules also need to be changed concurrently with the aircraft and pilot certification regulations to be relevant to both new technology levels and RPVs.

Simulation studies of an RPV were conducted using an instrument departure and approach with defined failures to test the validity of the recommendations. Pilots with at least an IR but no

previous RPV or powered-lift experience were chosen to fly the first automation level . People with no aviation experience other than being a passenger on an airliner were chosen to fly the second automation level . In some cases, an assumption exists that many current pilots of general aviation aircraft currently use automation today and cannot accomplish required FAA tasks without it. In the more regulated environments (Parts 135 and 121), automated tools are used and documented but not certified, for example executing an instrument approach and calculating weight and balance. For this research, the weight and balance task was tested, but the manual instrument approach task was not . In this evaluation, 100 percent of the licensed pilots failed to calculate weight and balance correctly without automation. It was also found that non-pilots had a higher success rate when dealing with emergencies and level two automation than the pilots using level one automation.

1 Introduction

With growing industry interest in new aircraft technologies, such as unmanned aircraft systems (UAS) and vertical takeoff and landing (VTOL) vehicles, the Federal Aviation Administration (FAA) determined that current regulations for aircraft/ground station and pilot/operator certification should be examined, especially as they pertain to increasing automation. A research effort that included a simulation study was initiated to review the current FAA rules for pilot certification, aircraft certification, and operations as they apply to a generic, remotely piloted powered-lift vehicle with the size and performance characteristics of a Cessna Caravan aircraft and a Bell 206 helicopter. Based on this review, researchers made recommendations to update relevant regulations, certification requirements, and training procedures.

1.1 Purpose

This research was intended to investigate optionally piloted aircraft and large unmanned aerial systems with highly automated systems using a tiered and scaled level of ground control system (GCS) technical capability and automation. The term remotely piloted vehicle (RPV) is used in this report, but terms like unmanned aircraft systems (UAS), unmanned aerial vehicle (UAV), optionally piloted vehicle (OPV), and others are also used depending on their definition.

This research was intended to provide the FAA with recommendations concerning long-term aircraft/ground station certification requirements and pilot/operator certification requirements. The FAA has provided a framework for both aircraft and pilot certification that can accommodate the new urban mobility vertical takeoff and landing (VTOL) aircraft. The FAA also recognizes that these are temporary solutions that may not be workable in the long term. This research was specifically related to long-term, permanent solutions and not to existing certification applicants.

1.2 Background

While there are subtle differences between remotely piloted aircraft systems (for example, an aircraft system is often used to include the ground station, but an aircraft does not include the ground station), the term RPV refers to an aircraft that has no pilot on board controlling the aircraft, but is piloted from a remote location, typically on the ground.

One study (Duerksen & Martos, 2021)concluded that the pilot error accident rate for single-pilot aircraft has stabilized despite advances in training. However, it is evident that if the Urban Air Mobility industry becomes successful, the current pilot pool is not large enough to support it.

This is largely due to the expense of training to the level of commercial pilot. Recognizing the pilot error accident rate, the training expense and the (currently not certified) automation capabilities available today, this work (Duerksen & Martos, 2021) recommends including advanced automation to reduce both the accident rate and training.

1.2.1 Military large unmanned aircraft systems

The United States (U.S.) military has been operating remotely piloted aircraft (RPA) since the 1960s. These aircraft were flown like radio-controlled airplanes, which relied on a radio link from the ground to the aircraft that transmitted control inputs from the pilot to the aircraft's actuators. Then, another radio link transmitted instrumentation data from the aircraft to the ground-based pilot. The instrumentation was like that of a manned airplane, and the position of the control stick controlled the position of the flying surfaces or throttle. Thus, flying a RPA was very much like flying an instrument simulator of an airplane. This paradigm has continued mostly unchanged to the present day in that current military RPA also use conventional airplane controls and instrument displays.

The United States Air Force (USAF) training and remote pilot qualification for large RPA also reflects this. The official USAF training for RPA is divided into four major groups with the first two being very similar to the civilian private pilot airplane and instrument airplane training. The third considers training specific to remote pilots and their mission.The fourth is in-depth airplane-specific training for the RPA, including systems and operations. This fourth stage is like a type rating combined with a Part 135 operations specification, or "OpSpec" training.

1.2.2 Civilian unmanned aircraft systems

Radio-controlled aircraft have also been operating in the U.S. since the 1960s. The majority have typically been small, privately owned aircraft with maximum weights of less than 10 lb and maximum speeds of less than 100 mph. These aircraft were relatively expensive and took considerable training and practice to learn to fly. This tended to limit the number of aircraft being flown. Operation of these aircraft for private use was largely unregulated. In the last 10 years, the automation level of the flight control systems and the cost of these aircraft have decreased significantly as the cost of computers and sensors has gone down. As a result, the number of radio-controlled aircraft (now called drones) has increased dramatically. This prompted the FAA to adopt rules to regulate their use. In 2016, the FAA issued new rules, 14 CFR Part 107 (Operation and certification of small unmanned aircraft systems, 2016).

Part 107 generally limits UASs to

1. Aircraft less than 55 lb
1. Less than 100 mph ground speed
2. Line of sight operations
3. Operations in class G airspace (except with special permission)
4. Less than 400′ above ground level (AGL)
5. More than 400′ from any buildings or structures
6. Pilots must have a remote pilot certificate

1.2.3 Aviation Rulemaking Committee

The FAA has no rules governing UASs that are larger, faster, or have more capabilities. Instead of issuing regulations for these vehicles, the FAA has decided to allow operations using the exemption process to gather more data. FAA Aviation Rulemaking Committee (ARC) recommendations

Recognizing the need to expand UAS operations beyond the limitations of Part 107, on June 24, 2021, the ARC for Unmanned Aircraft Systems Beyond Visual the Line of Sight (BVLOS) was formed. The purpose of this committee was to "make recommendations to the FAA for performance-based regulatory requirements to normalize safe, scalable, economically viable, and environmentally advantageous UAS BVLOS operations that are not under positive air traffic control (ATC)". This committee released its report with final recommendations on March 10, 2022 (Aviation Rulemaking Committee, 2022).

In part, the ARC's conclusions were

1. Change 91.113 to
    a. Allow automatic detect and avoid.
    b. Give UAs right-of-way within 100 ft of structures.
    c. Give UAs right-of-way over non-automatic dependent surveillance broadcast (non-ADS-B) crewed aircraft below 400 ft.
    d. Give ADS-B-crewed aircraft right-of-way.
    e. Propose a set of right-of-way rules for low-altitude operations.
2. Create a new Part 108 that would

   a. Have an energy limit of 800,000 ft-lb (typical of a light-sport aircraft (LSA) – weight limit of 1320 lb and speed limit of 138 mph). Part 107 limits weight to 55 lb and speed to 100 mph.
   b. Keep the 400-ft maximum altitude limit.
   c. Allow BVLOS operations.
3. Extend Part 107 pilot certification rules to include BVLOS operations.
4. Provide a path to allow larger faster UAS than the proposed Part 108 rules.
5. Consider the role of automation for pilot certificates. The ARC identified four levels of automation broadly defined as:
   a. Level 1 – The operator directly controls the aerodynamic surfaces. There may be some level of automation, including an auto-hover mode and a return-to-home mode.
   b. Level 2 – The flight is mostly automated, but a human is expected to directly monitor the flight and direct route, altitude, and contingencies though a software interface.
   c. Level 3 – The flight does not require human involvement, but the human may intervene to direct operational level changes. These operations typically have one human supervising many flights simultaneously.
   d. Level 4 – Completely automated operations where a human generally cannot intervene in an individual flight. These operations typically involve many aircraft operating simultaneously and are too complex for a human to maintain situational awareness.

Because of the ARC restrictions on size and speed requirements corresponding to LSA, and the requirement to remain below 400 ft above ground level (AGL), the ARC proposal is unacceptable for this research. However, it is useful as background. (This research assumes BVLOS operations for UA in the National Airspace System (NAS) with the same size and performance characteristics of manned aircraft.)

The ARC also conducted a detailed review of Title 14 Code of Federal Regulations (14 CFR) Parts 61, 91, 107, 119, 121, and 135. They found that Part 91 alone contained over 3,200 items, with most of the other parts having substantial volume as well. They recommended a new set of rules similar to the Part 107 rules.

Because of the size of the task, an extensive examination of all operating rules will not be conducted for this research. However, an overview of some of the rules most pertinent to UAS operations will be examined, particularly Part 91.

1.2.4 Minimum Operational Performance Standards for Detect and Avoid Systems, DO-365

Radio Technical Commission for Aeronautics (RTCA) DO-365 (Minimum operational performance standards (MOPS) for detect and avoid (DAA) systems, 2021) is being proposed for beyond-line-of-sight (RPA operations that are under ATC control through a remote pilot.

This proposal assumes operation of larger and faster aircraft and at altitudes typical of general aviation aircraft. However, DO-365 is very restrictive and has not been adopted by any operators. For instance, it requires all RPA operations to be conducted on instrument flight rules (IFR) clearance and then to only use published instrument approaches when approaching an airport. No visual approaches or standard visual flight rules (VFR) traffic patterns are allowed. In addition, if a traffic conflict that produces a potential threat of a collision is detected on the approach, the only option is to execute a missed approach.

This is considered too restrictive for the emerging RPA industry. This research will go beyond the DO-365 limitations and assume RPA operations occurring in visual meteorological conditions (VMC) without an IFR clearance, operating with and without ATC communications, allowing the ability to execute standard VFR traffic patterns, and avoiding traffic by modifying a visual approach in real time to fit with manned aircraft using the same airport. Therefore, the recommended training and certification requirements for RPAs will reflect the same operations allowed for manned aircraft.

1.2.5 Applicability to pilot in aircraft operations

Although this research is directed specifically towards RPA, many of the principles apply to aircraft with the pilot inside the aircraft. This is especially true as the automation levels increase. Whether the pilot is flying the aircraft from the cockpit or the ground, the pilot is required to have very little training and the automation handles nearly all aspects of controlling the fight—including malfunctions and emergencies. In essence, the pilot of an aircraft with the highest level of automation is really a passenger with the ability to change the destination or flight path within prescribed limits in real time. At this level of automation, a ground pilot also can change only the destination or flight path within prescribed limits in real time. The controls and displays can be identical for the remote pilot or the onboard pilot.

1.3 Technical capability and automation levels

Given the current state of technology, there is a nearly infinite combination of potential technical capabilities and automation levels in any given aircraft/ground control station. The level of automation has a significant effect on the amount and type of training required of a pilot/ground station operator. Because of this, it was required to define and address some automation level options. Although particular functions and features described may not be present in every aircraft/ground stations, the automation options defined below were determined to be representative of realistic products. These were chosen primarily because the features are already in certified products, or there has been significant research to develop the concept.

1. Radio-controlled airplane-type controls with round dials.
2. A Garmin G1000-like cockpit with an autopilot (AP), auto throttle, and flight management system (FMS) for all phases of flight, and F-35-like controls.
3. A path centric control system like EZ-Fly but with a Garmin G1000-like cockpit (attitude based) (Stewart E. C., 1994).
4. A path-centric control system like EZ-Fly but with integrated path-centric display and navigation system.
5. A path-centric control system like EZ-Fly but with integrated path-centric display and navigation system and the ability for the aircraft to modify its own flight path.

1.3.1 Option 1: Radio-controlled airplane controls and round dials

This aircraft/ground station operates like a legacy radio-controlled airplane or V-22 Osprey in which a remote control sends radio signals from the ground station to a receiver in the plane. The receiver translates these signals into electric commands that control the various parts of the plane, such as the motor, wings, and tail. It has legacy controls that operate the same way as airplanes do today but expanded to include expanded controls for VTOL and short vertical takeoff and landing (SVTOL) flight operations, like the V-22. It has round dials on the cockpit display that show (analog) altitude, airspeed, and attitude readings. The round dials may be displayed on glass or liquid crystal. The cockpit display may include a rudimentary glass primary flight display with vertical scrolling tapes instead of round dials, or it may have an electronic display with vertical tapes instead of round dials. The cockpit is like a 2003 Cirrus SR22, which had an Avidyne primary flight display (PFD) and multifunction display (MFD), a Garmin® 430 navigator and an S-Tec AP. This level of automation was recommended by the FAA. This level of automation roughly correlates with Level 1, as identified by the ARC (Aviation Rulemaking Committee, 2022).

> *Level 1 – The operator directly controls the aerodynamic surfaces. There may be some level of automation including an auto hover mode and a return to home mode.*

1.3.2 Option 2: G1000® with F-35 controls

This option is representative of an integrated Garmin G1000 NXi cockpit from 2020. The cockpit includes F-35-like controls, AP with envelope protection, full vertical navigation (VNAV) capability with auto throttle integrated, and a navigation system that can be programmed before the flight. This system allows the pilot to engage the AP just after takeoff and not touch the controls again until landing. Except for the F-35-like controls, this is the current level of technology certified in modern cockpits. This is the system that several group members flew in the National Aeronautics and Space Administration (NASA) Langley simulator, although the AP was not used in the Langley demonstrations. This configuration was also subject of a NASA study done by the authors. This level roughly correlates with Level 2, as identified by the ARC (Aviation Rulemaking Committee, 2022).

> *Level 2 – The flight is mostly automated, but a human is expected to directly monitor the flight and direct route, altitude and contingencies though a software interface.*

1.3.3 Option 3: G1000 with path-centric controls (attitude-centric displays)

This option is like the Option 2system, the Garmin G1000 NXi cockpit with F-35 controls. The cockpit employs the G1000 attitude-centric display, but the control scheme is replaced with an EZ-Fly system that is path centric instead of attitude centric. This combination was recommended by the FAA. This level roughly correlates with Level 2, as identified by the ARC (Aviation Rulemaking Committee, 2022).

> *Level 2 – The flight is mostly automated, but a human is expected to directly monitor the flight and direct route, altitude, and contingencies though a software interface.*

1.3.4 Option 4: Path-centric controls with path-centric displays and integrated navigation

This option employs an EZ-Fly control system that is path centric instead of attitude centric with a path-centric display. The flight controls, display, and navigation system are all integrated. This includes full protection for systems and the flight envelope. This is the configuration flown by the FAA in the Navion aircraft and was the subject of a NASA study done by the authors (Duerksen & Martos, 2021). This level correlates to Level 3, as identified by the ARC (Aviation

Rulemaking Committee, 2022); however, Level 3 as written does not suggest a one-to-many pilot-to-aircraft ratio, but it could be expanded to include this.

> *Level 3 – The flight does not require human involvement, but the human may intervene to direct operational level changes. These operations typically have one human supervising many flights simultaneously.*

1.3.5 Option 5: Path-centric controls with integrated navigation and the ability for the aircraft to change its path

This option's configuration is the same as Option 4, i.e., EZ-Fly control system with integrated display and navigation but adds the ability of the aircraft to modify its path without human intervention. This could be to avoid traffic, reroute or divert due to unexpected weather, or deal with onboard failures and emergencies. Human intervention is still possible but only by uploading a new or modified flight plan. This level roughly correlates with Level 4 identified by the ARC (Aviation Rulemaking Committee, 2022).

> *Level 4 – Completely automated operations where a human generally cannot intervene in an individual flight. These operations typically involve many aircraft operating simultaneously and are too complex for a human to maintain situational awareness.*

1.4 The effect of automation on training requirements

The effect of automation on training requirements is complex and can have significant impact on time, cost, and benefit. For example, if the automation is supplemental and is not certified as the primary system, then the pilot must learn the primary system as well as the automation. In this situation, the burden of increased training may offset the automation effects of reduced pilot workload and increased safety. This is the case with most automation today.

On the other hand, if the automation is certified to a reliability level that it can be the primary or only system, then it can have the effect of dramatically reducing the training requirements.

Additionally, when automation that is (or could be) reliable enough to be certified as the primary or only system but pilot licensing or aircraft certification requirements are prohibitive, a legacy system is retained. This then goes back to the first type of system that increases training.

An example of this is a fly-by-wire (FBW) airplane flying an instrument approach. The current requirement for an FBW aircraft is to have

1. a flight-critical control system that maps control movements by the pilot into flight path changes.
2. flight-critical aircraft state sensors (e.g., airspeed, attitude, and attitude).

3. a flight-critical navigation system that receives electronic guidance signals.
4. a flight-critical display system that displays aircraft state and navigation guidance.

There is also typically an AP that can couple the navigation guidance to the flight control system. The pilot is required to learn how to interpret the aircraft state and guidance information provided by the display and then manipulate the controls so that the aircraft state and navigation follow the prescribed path. The guidance and the controls are connected through the pilot. If an AP is installed, the pilot is also required to learn how to couple the AP to the controls and recognize AP malfunctions (the AP is not flight critical). In this case, automation increases the pilot training requirements.

Since the FBW aircraft has a flight-critical control system, flight-critical state sensors, and a flight-critical navigation system, the navigation system can be automatically connected to the flight control system and have the same reliability but without the AP (the navigation system to flight control connection is functionally the same as the AP). This negates the need for the navigation guidance display since it does not add to reliability or safety (in essence, the AP is an integral part of the flight control system, and the AP malfunctioning is the same as the flight control system malfunctioning—which is catastrophic). Since there is no need to display guidance, there is no reason to provide it—and without a display, the pilot cannot manually fly the approach. Therefore, the pilot does not need to learn how to do this. In this case, automation reduces the pilot training requirements in some areas but increases it in others, with the overall effect of dramatically reducing total training requirements. In fact, with an FBW aircraft that has the navigation system integrated with its flight controls, the only effect of allowing the pilot to manually fly in an instrument approach is that it introduces the potential for human error and increases the chance of flight technical error.

Automation can be applied to many areas of flight operations and can be implemented at various levels from assisting the pilot with a task to doing the task for the pilot. The area of automation and the level of automation can make a significant difference in the training requirements and therefore the pilot evaluation requirements as well.

In addition to the first level of automation, which represents a radio-control type of control system combined with conventional round-dial flight and navigation instruments, this research effort examined two levels of automation.Control systems

Sections 1.5.1 through 1.5.3 will discuss control and display systems in detail because they are fundamental to training and pilot evaluations..

1.4.1 Airplane control systems

Conventional airplane control systems use mechanical linkage to translate the pilot's control movements to movements of aerodynamic surfaces, which in turn change the airplane's flight path. The relationship between pilot inputs and the aircraft motion is described in the V-22 airplane mode in Section 1.5.3.2.

The first level of automation discussed here is like that used by European FBW aircraft (e.g., Airbus and Falcon). This is similar enough to the conventional mechanical system that experienced pilots adapt very quickly to the differences. The relationship between pilot inputs and aircraft motion is described in the F-35B airplane in Section 1.5.3.3. .

The second level of automation was developed by NASA and was intended to start with basic information and develop a human-centric control system that is easy for non-pilots to fly safely (Stewart, 1994). This system, called EZ-Fly, has been refined and tested in both simulation and actual flight tests with the results showing that it is much easier to fly than conventional controls. It has not been produced because in part, there is no way to get a pilot's license to fly it. Since there is no way to get a license to fly it, there is no market for it outside of Part 103 aircraft (i.e., ultralights, which do not require a license) and hobby drones, which have nearly universally adopted a version of it. The relationship between pilot inputs and aircraft motion is described in the EZ-Fly Section 1.5.3.5.

1.4.2 Vertical flight control systems

Conventional helicopter control systems use mechanical linkage to translate the pilot's control movements to changes in the pitch of the rotors. This in turn changes the helicopter's flight path. The relationship between pilot inputs and the aircraft motion is described in the V-22 helicopter mode, Section 1.5.3.2.

The first level of automation is like that used by the F-35B Joint Strike Fighter. It is much easier to fly in hover than a helicopter because it has a single control rather than both cyclic and collective, and a computer system handles stabilization. It is designed to merge with the type of airplane control at speed as the European FBW airplanes. The relationship between pilot inputs and aircraft motion is described in the F-35B airplane Section 1.5.3.3.

The second level of automation is an extension of the EZ-Fly system that includes vertical flight. It is easy to fly in hover for non-pilots and is designed to operate the consistently independent of the aircraft's speed. Most hobby drones use a version of this.

1.4.3 Evolution of powered-lift control systems

The above levels of automation reflect the development of powered-lift control systems. Sections 1.5.3.1–1.5.3.5give a brief history that illustrates this progression and informs future developments.

1.4.3.1 Hawker Harrier

The Hawker Harrier was developed prior to the V-22 and uses thrust vectoring from its jet engine. The pilot's controls and responses are similar to the V-22, although the mechanics are different because it uses thrust vectoring, which directs thrust from the engine to control the aircraft's movements, instead of rotor feathering and flapping, in which the movement of rotor blades are manipulated to affect airspeed and lift.

1.4.3.2 V-22

The V-22 was developed as a high-speed helicopter. It uses rotor lift and flies like a helicopter when in hover; but at high speed, its nacelles change from pointing up to pointing forward, and it flies using a wing and tail like an airplane.

The V-22 flies like an airplane when the nacelles are tilted forward.

1. The throttle controls the thrust of the rotors (propellor pitch, like a constant-speed propeller).
2. Longitudinal stick controls the elevator position.
3. Lateral stick controls the aileron (flaperon) position.
4. Pedals control the rudder position.

When the nacelles are tilted up, the controls change.

1. The throttle controls the thrust of the rotors (rotor pitch is like collective control).
2. Longitudinal stick controls the swashplate angle (longitudinal cyclic – longitudinal flapping).
3. Lateral stick controls the swash plate angle (lateral cyclic – lateral flapping).
4. Pedals control differential longitudinal cyclic (like tail rotor pitch).

A computer mixes the inputs when the nacelles are between the forward and vertical positions. Thus, from the pilot's perspective, the V-22 flies like an airplane with the nacelles forward and like a helicopter with the nacelles vertical, except that the collective is controlled by a "throttle" instead of a collective lever.

1.4.3.3 F-35B Joint Strike Fighter

The mission requirements of the F-35B (VTOL version) were similar to that of the Hawker Harrier. During the development of the F-35B Joint Strike Fighter with vertical capability, it was determined that the Harrier required too much training and had an unacceptable safety record. Therefore, a new control system was developed for the F-35B to reduce pilot training and improve safety over the V-22 and Harrier control systems. The biggest changes were made to the hovering mode.

The F-35 has FBW control systems such that mechanical mixing of the pilot's inputs is not required.

The F-35B flies like an airplane in cruise mode.

1. The throttle position controls the longitudinal acceleration.
2. Zero position commands speed hold.
3. Forward part of throttle movement is reserved for airplane mode control.
4. Longitudinal stick controls the G loading.
5. This is actually vertical flight path rate with zero commanding flightpath hold.
6. Lateral stick controls roll rate.
7. Zero position commands bank hold.
8. Pedals control the sideslip angle.

When hovering, the F-35B is very different than a helicopter or a V-22.

1. The throttle controls longitudinal speed.
2. Aft part of throttle movement is reserved for hover mode control.
3. Longitudinal stick commands vertical speed.
4. Centered commands altitude hold.
5. Lateral stick commands lateral speed.
6. Centered commands zero lateral ground speed.

7. In a crosswind, zero ground speed does not equate to level bank.
8. Pedals command turn rate.
9. Centered commands heading hold.

The F-35B system and similar systems have been called unified. Research assessing aircraft with a speed range similar to a general aviation aircraft found that using the speed control as a speed command lever instead of an acceleration lever in airplane mode was effective (Scott, 2020). In the F-35, the speed range is too large for this to be practical.

1.4.3.4 Hobby drones

There are many variations of hobby drones, but many of the most popular have control systems that are easy enough to fly that consumers with no previous training or experience can successfully fly them right out of the box. A representative example of such a control system follows.

1. Moving the left joystick fore and aft commands vertical rate.
2. Centering the left joystick holds altitude.
3. Moving the left joystick laterally commands turn rate.
4. Centering the left joystick holds current heading.
5. Moving the right joystick fore and aft commands speed.
6. Centering the right joystick commands zero speed.
7. Moving the right joystick laterally commands sideways speed relative to heading.
8. Centering the right joystick commands zero side speed.
9. A separate takeoff button causes the aircraft to rise from the ground to a predetermined hover height.
10. A separate land button causes the aircraft to descend and land.

These aircraft only fly at slow speeds (near hover speeds) and lack efficient wings for forward flight. However, it can be said that the requirements of controlling the flight path of a hobby drone is not much different than controlling the flight path of an RPA. Thus, it follows to look to this development as guidance for RPA manufacturers if pilot licensing regulations allow it.

1.4.3.5 EZ-Fly

The EZ-Fly system is very similar to the hobby drone concept in that it is easy to fly with little training and can be extended to high speed flight such as jet aircraft with an integrated navigation system.

There has been considerable research performed in flight and simulators since the 1980s concerning a new control system that starts from a basic concept is developed with the assumption that no mechanical backup is needed, and therefore all control is augmented by computers. The control design is human-centric instead of having the constraints of mechanical system capabilities and existing pilot skill sets. This system has been called EZ-Fly when applied to manned aircraft. Many hobby drones have independently developed a similar control system. It should be noted that several developers of Part 103 VTOL aircraft have also adopted variations of this type of control system. (Part 103 governs small, single-seat aircraft that do not require a pilot's license – commonly called ultralights (Part 103—Ultralight Vehicles, 1982).)

A key aspect of this control system is that the aircraft response to control inputs is independent of speed or whether the aircraft is flying on rotors, a wing, vectored thrust, or any combination of these.

The system can employ joysticks, steering wheels, or other types of input devices, but this discussion will focus on an implementation that is like that of a car, since most people have experience driving a car.

1. Rotating the steering wheel left or right causes the aircraft to turn left or right.
    a. Centering the steering wheel holds the current heading if hovering or tracking at higher speed.
    b. In hover mode, this results in a zero-bank rotation.
    c. In forward flight, this results in a banked turn like a bicycle.
2. Moving the steering wheel in or out causes the aircraft to climb or descend.
    a. Centering the steering wheel holds altitude.
    b. Moving a small joystick laterally causes the aircraft to move sideways relative to its heading when hovering and its nominal track at higher speeds.
    c. Centering the small joystick commands zero sideways travel.

    d. A thumb wheel changes the desired speed—much like changing the set speed of a cruise control.

3. Acceleration is based on the difference between commanded speed and current speed. It can be adjusted using the fore and aft joystick.
    a. Moving the joystick fore and aft temporarily adjusts the speed command. Because the acceleration rate is based on the difference between the current and commanded speed, moving this stick has the effect of modifying the acceleration rate when the commanded speed is not near zero, and temporarily commanding a speed when near zero.
    b. This is mostly used for fine maneuvering when hovering.
4. There are no pedals.
5. The flight controls and navigation system are integrated such that the normal mode of flying is through the navigation system—not the control inputs described above. The above mode is intended mostly for free-form flying (e.g., sight-seeing and quick deviations from the planned path). The EZ-Fly pilot typically controls the aircraft by entering waypoints with altitude and speed restrictions. This can be done before the flight starts or during the flight. In addition, waypoints can be added, deleted, or modified in real time. This is very similar to the way that modern jet aircraft are flown today.

RPA developers are proposing variations of all the control systems described above. Because of the need for many of the new aircraft to be computer controlled, back-to-basic or raw-mode control system operation are no longer options. In fact, forcing a raw mode as a standard (like the Airbus FBW system) would require developing an entirely new control system for many of these aircraft. The result would not be any more reliable, would be more difficult to fly and therefore would be more dangerous than a system that does not provide a basic or raw mode. Therefore, having a common basic control system (raw mode) to start from and then having transition training for different types of control systems does not make sense.

In addition, many of the new designs are battery powered with very limited energy capability. Sincehovering takes much more power than operating in airplane mode, new designs are intended to use the VTOL capability only during short, transient flights so that they can use very small landing zones—and not have to maneuver while hovering like a helicopter. Because of this and the wide variation of automation, there is no standard emerging or likely to emerge soon for these aircraft.

1.5 Automation levels

1. Radio-controlled airplane-type controls with round dials.
2. A Garmin G1000-like cockpit with an AP, auto throttle, an FMS for all phases of flight, and F-35-like controls.
3. A path-centric control system like EZ-Fly but with a Garmin G1000-like cockpit (attitude based).
4. A path-centric control system like EZ-Fly but with integrated path-centric display and navigation system.
5. A path-centric control system like EZ-Fly but with integrated path-centric display and navigation system and the ability for the aircraft to modify its own flight path.

1.6 Automation levels examined

The assumed level of automation has a very significant impact on training and by extension pilot certification requirements. The five levels of technical capabilities as discussed in Sections 1.3.1 – 1.3.5 were considered.

Although many combinations of automation features are possible, it was impractical to examine more than a few as part of this study. To develop potential plot certification standards, a minimum standard must be chosen for one or more levels of pilot certification. . As a result, it was decided to use the FAA ARC as a guide. Note that these levels were also independently developed during the NASA-funded simplified vehicle operations (SVO) training and certification study done by Flight Level Engineering (Duerksen & Martos, 2021).

After reviewing all options, the FAA chose options 2 and 4 for detailed work. The following is a discussion of each option and why each was accepted or rejected.

1.6.1 Proposed option 1 (ARC Level 1)

This option is a radio-controlled airplane control system with conventional displays. It is a rudimentary system and has been overtaken in the hobby drone market by more advanced control concepts. This is because these more advanced control concepts are much easier to fly, prevent many crashes, and are cheap and easy to implement given today's computing power.

It is expected that for the same reason, manufacturers of larger drones will continue to use more advanced control schemes without providing backup pilot control schemes going forward if pilot certification and aircraft certification requirements allow them to do so. It should be noted that several manufacturers of Part 103 manned aircraft that do not require aircraft or pilot certification are already doing this.

Since the purpose of this research is to be forward-thinking and to recognize that proposed level 1 of automation is behind even current technology, this proposal was rejected for this research.

1.6.2 Proposed option 2 (ARC level 2 and SVO-A1)

This option is basically a Garmin G1000 cockpit, as represented by a 2020 Cirrus SR22 with F-35 (Unified) controls. For airplanes that do not have vertical flight capability, the controls are very similar to Airbus FBW controls. While there are differences between these and mechanical controls, pilots find the transition between the two to be easy. The F-35 control system in vertical flight is much different, and easier to fly than a helicopter's control system. It provides stability and remaps the control input to aircraft response to be more like an airplane. This system is easy for novices to learn to fly in hover, but since it transitions to a control scheme like mechanical controls for airplanes, its mapping of pilot input to aircraft output changes with speed. Although this is not ideal for novices, it has been demonstrated that pilots with airplane experience can transition quickly.

The avionics (display, navigator, AP) are very similar to a 2020 vintage G1000 NXi system with auto throttle. This includes a climb, cruise, descent (CCD) VNAV system that can be programmed before takeoff with speeds and altitudes. Once programmed, the AP can be engaged immediately after takeoff, and the pilot does not need to touch the controls again until just before landing.

Other automated features may also be part of this package. The complete list of the minimum set of assumed features is:

1. Highly augmented VTOL control system (Unified)
2. Envelope protection
3. Mandatory coupled instrument approaches
4. Automatic level flight (Level BUTTON)
5. Automated flight planning
6. Automated weight and balance
7. Automatic systems limit control (torque, temperature, revolutions per minute (RPM), current, etc.)

8. Airport navigation and operations assistance
9. Automatic ground collision avoidance system (Auto-GCAS)
10. Synthetic vision
11. Integrated CCD VNAV
12. Moving map

Each of these features is currently available today with operational history, although not all have been certified. No new technology needs to be developed. However, recognition of these features along with reliability requirements needs to occur for them to receive credit towards pilot certification. This allows pilot certification to take advantage of their capabilities and therefore eliminates the need to test pilots on obsolete procedures (such as calculating weight and balance using only a pencil, paper, and a four-function calculator).

This option was chosen because it represents the current technology level but puts available automation features together as a minimum equipage package that can be used as a baseline for pilot certification at a specific automation level. It is also a feature set that was developed by a NASA research project that examined whether automation can be used to reduce the training and pilot certification burden (Duerksen & Martos, 2021).

The term SVO-A1 (simplified vehicle operations -the "A" used to differentiate from the generic SVO term) will be used in this report to identify an aircraft with this minimum set of automation features.Eagleworks.

1.6.3 Proposed option 3 (ARC level 2)

This option retains the display, navigation, AP, and other features of option 2, but replaces the F-35-type control system with a path-centric control system.

This is the EZ-Fly control system. With a path-centric control system, the pilot commands the flight path directly, and the aircraft determines what attitude (pitch and roll) is required to fly that path. The EZ-Fly system also has consistent control input mapping to aircraft motion output from hover to high-speed flight. It has been demonstrated in fixed-wing flight that this type of control system is very easy for non-pilots to learn. It has also been demonstrated in simulator studies that non-pilots learn to master this control system very quickly—including hover, high-speed flight, and transitions (Scott, 2020).

While it has been demonstrated that the EZ-Fly control system (flight-path centric) works well with a G1000 display (attitude centric), this has been done only for maneuvering flight. While this level of automation may be better than option 2, it mismatches the control (flight- path centric) with the display (attitude centric). As such, the pilot of the EZ-Fly system leans heavily on the synthetic vision aspects of the display, and the attitude and airspeed aspects become irrelevant clutter. Flying complex navigation tasks work well with a flight-path-centric control system, but if it is tied to a display/navigation/AP system that has evolved to work best with an attitude-centric control system, its capabilities are limited. Since this option is just a variation of option 2, it represents the same level of automation as option 2 and does not make the step to the next level of automation. Because of this, this proposal was rejected for this research.

1.6.4 Proposed option 4 (ARC level 3 and SVO-A2)

This option replaces the F-35 control system of option 2 with a path-centric control system (EZ-Fly). It also replaces the display/navigation/control system of option 2 with an integrated navigation/display/control system that is path centric and completely integrated such that the control system commands a navigation path (flight plan)—not just an instantaneous path. It also includes additional features that are a minimum feature set for this automation level.

The minimum features that define this level of automation level are:

1. Human-centric integrated control, display, and navigation (EZ-Fly VTOL)
2. Complete automation of preflight planning and in-flight re-planning due to internal and external factors
3. Automated ATC communications
4. Automated takeoff and landing for conventional and vertical takeoff and landing (CTOL and VTOL, respectively) operations
5. Automatic barometric pressure setting
6. Automated aircraft collision avoidance system
7. Automatic failure protection (engine out, comm failure, system failures, etc.)

This option was chosen because it represents a step to the next level of automation. It also includes additional features that when combined define a minimum feature set for pilot certification at this level of automation. It is also a feature set that was developed by a NASA research project done by Flight Level Engineering that examined automation that can be used to reduce the training and pilot certification burden.

The term SVO-A2 will be used in this report to identify an aircraft with this minimum set of automation features. EagleworksProposed option 5 (ARC level 4)

Although not an inherent characteristic of this automation level, this option allows for one pilot operating many aircraft simultaneously. It was concluded by the FAA and the researchers that this goes beyond the scope of this effort and should be the subject of a follow-on project.

1.6.5 Choice of options to examine

For this study, the FAA and the researchers agreed to select options 2 and 4 above for further examination. These options were named SVO-A1 and SVO-A2 respectively. The reason for the naming is that they represent functionality that is envisioned in SVO (Simplified Vehicle) aircraft. The -A1 and -A2 designations are intended to be unique to differentiate them from all other combinations of SVO functions that may be proposed.

2 Task 1: Review pilot certification requirements

The first task of this research effort involved reviewing the necessary knowledge and skills for pilot certification of optionally piloted aircraft (OPA) and large unmanned aircraft systems (UAS). This review included an assessment of relevant certification categories and classes, the appropriate level of pilot certification, and the potential need for model-specific training and type ratings. Proposed certification requirements were also evaluated with consideration given to current regulations and any proposed changes. Sections 2.1 through 2.9 provide details of this review and evaluation effort.

2.1 United States Air Force remotely piloted aircraft training

The USAF uses the following sequence to train its RPA pilots.

1. Initial flight training
    a. Flight lessons performed in a Diamond DA20 airplane
    b. Similar training for Pilots, Navigators, and RPA pilots
    c. Training is similar to civilian private pilot training
2. RPA instrument qualification training
    a. Instrument training lessons using conventional airplane controls and a glass cockpit
    b. Flight simulation using a Beechcraft T-6 Texan II airplane simulator

   c. Specific RPA operational rules

3. RPA Fundamentals
   a. General aircraft training for Global Hawk and Reaper
   b. General RPA mission requirements
4. Airplane specific training for Global Hawk or Reaper
   a. Aircraft systems
   b. Weapons systems
   c. Operational tactics for specific missions

2.2 Current FAA training for remotely piloted aircraft pilots

There are currently no FAA training and licensing requirements for RPA other than Part 107, which governs small aircraft less than 55 lb with a maximum speed of 100 mph that are flown below 400-ft AGL with visual contact by the pilot. Therefore, there is a need for pilot training and certification requirements for civilian RPAs.

2.2.1 Remotely piloted aircraft training for airplanes

Given the history of RPA and the fact that the military has been operating them successfully for decades, and has basically followed the same training path as a private pilot followed by an instrument rating (IR), it is appropriate to use the current FAA private pilot – airplane, and IR – airplane training and licensing requirements (Certification: Pilots, flight instructors, and ground instructors, 1997) as a starting point for RPAs without vertical flight capability.

2.2.2 Remotely piloted aircraft training for powered lift

Many of the new civilian designs have VTOL capability and are considered powered-lift aircraft according to the FAA definition found in 14 CFR Part 61 (Definitions and abbreviation, 2025).

Part 61 (Certification: Pilots, flight instructors, and ground instructors, 1997) has a set of requirements for a private pilot and an IR for a powered-lift aircraft.

The current Part 61 powered-lift license requirements were developed just after the V-22 became operational, and there was a civilian version being proposed by the companies that developed the V-22. Therefore, it was assumed that the first civilian powered-lift aircraft would operate like a V-22. A discussion of the V-22 control system is provided in Section 1.5.

Given the current variety of aerodynamic, propulsion, and pilot interface designs, the existing Part 61 pilot qualification rules may introduce gaps in safety. As a result, the FAA developed a special rule that allows the FAA up to 10 years to revise the basic rules to match current designs (FAA, 2024). This special rule basically requires a pilot license as defined by the existing Part 61, but in addition requires a type rating for each aircraft make and model.

Examination of the current Part 61 powered-lift requirements shows that they are the same as the helicopter requirements but with the addition of airplane section requirements that do not apply in the helicopter section (such as stalls, slow flight, etc.).

Current aircraft designs have several types of controls systems for vertical flight. These are discussed in detail in Section 1.5. Because the current Part 61 powered-lift requirements only envisioned V-22 type controls, they do not address advanced automation or different control types. The CFR is not specific regarding any knowledge or skill requirements and is general enough to cover any possible automation and control types through the requirement of a type rating. In the following sections, the researchers will reviewthe Part 61 powered-lift requirements and recommend changes concerning control types and automation levels.

2.3 Recommended remotely piloted aircraft pilot training and certification requirements

This section addresses RPA operations using aircraft of the size, speed, and altitude performance capabilities that are typical of Part 23 airplanes. It also is intended to address operations in VFR, IFR, with and without ATC control and at airports with and without towers. It is assumed that these RPAs will mix seamlessly with manned operations.

Because of the success of the USAF training for RPA pilots, it is recommended that the same general approach be used for civilian RPA training and pilot certification. The key elements of the USAF training are:

1. It recognizes the value of personal experience flying as a pilot onboard the aircraft in real-world scenarios. Simulations and piloting RPA aircraft are not sufficient to provide a new pilot with the required flight experience.
2. An IR or equivalent is required to operate the RPA. This is reasonable because the RPA pilot flies the RPA without visual reference to the ground. The RPA pilot uses instruments to fly the RPA. These may or may not include synthetic depictions of the ground, video images of the ground, or traditional flight instrument gauges (six pack with round dials).

3. USAF RPA training focuses on RPA missions, RPA operations, and other aspects unique to RPAs.
4. Aircraft- and mission-specific training are included. This is roughly equivalent to an aircraft make- and model-type rating and a Part 135 Operations Specification.

Therefore, it is recommended that the private pilot and IR requirements of Part 61 be used as the baseline requirements, and deviations as appropriate be developed from the baseline.

Even though the student, private, and instrument requirements are separate in Part 61, for the RPA pilot certificate, it is recommended that these are combined into a single certificate. In essence, an RPA private pilot license cannot occur without an IR.

Because of the differences between operating an aircraft while inside of it and operating an aircraft while controlling it from the ground without visual contact, various additions and deletions must be applied to Part 61 to make it relevant to RPAs.

Since some RPAs are airplanes, some are powered-lift vehicles, and others are helicopters by the definition of these terms in Part 1, and the powered-lift requirements are generally a union of the airplane and helicopter requirements, the powered-lift requirements are used here as the starting point.

2.4 Additional required knowledge and skills for a remote pilot

In addition to the knowledge and skills required for a private and commercial license with an IR, knowledge and skills specific to remotely piloting an aircraft are required. The following is a list of recommended additional requirements specifically as applied to RPAs.

Recommended knowledge and skill requirements for an RPA in addition to existing Part 61 requirements:

1. Traffic avoidance, as is unique to RPAs
    a. Instrument meteorological conditions (IMC) but with intermittent VMC
    b. VMC
    c. With ATC traffic calls under IFR and VFR rules
        i. Planning deviations
        ii. Executing deviations
        iii. Coordinating deviations with ATC

d. Without ATC traffic calls
    i. Planning deviations
    ii. Executing deviations
e. In the airport traffic pattern with a tower
    i. Planning deviations
    ii. Executing deviations
    iii. Coordinating deviations with ATC
f. In the airport traffic pattern without a tower
    i. Determining likely paths of potential traffic in the pattern
    ii. Planning deviations
    iii. Executing deviations
    iv. Communicating with aircraft in the pattern
    v. Coordinating deviations with other aircraft
g. Wake turbulence avoidance
h. Determining clearance from clouds for VFR compliance

2. Lost communication link
    a. Remote pilot to ATC
        i. Alternative methods of communication (e.g., phone)
    b. Remote pilot to aircraft
        i. Backup links
        ii. Understanding the aircraft's behavior if the link cannot be established
        iii. Required actions to take when the link is lost (i.e., who to notify)
3. Onboard failures
    a. Degraded modes of operation
    b. Procedures to regain lost functionality

c. Rerouting to a different airport

d. Emergency descents to an appropriate off airport landing area

    i. Choosing an appropriate area

    ii. Managing the aircraft's energy to safely land at the chosen area (safe refers to people and property as well as the aircraft)

e. Loss of traffic detection sensors

    i. ADS-B in

    ii. Optical sensors

    iii. Onboard radar

    iv. Other

f. Fire

    i. Propulsion system fire

    ii. Electrical fire

    iii. Systems fire (e.g., hydraulic)

    iv. Cargo area fire

4. Ground station failures

    a. Instrumentation display failures

        i. Primary flight instruments

        ii. Propulsion system instrumentation

        iii. System health instrumentation

    b. Navigation display failures

    c. Loss of weather information

    d. Loss of traffic information

5. Weather changes

    a. Unexpected VMC to IMC

        i. Recognizing the transition from VMC to IMC (e.g., visibility and cloud clearance)
        ii. Maneuver to exit IMC or obtain an IFR clearance while in flight
    b. Wind changes at the destination airport
        i. Determining the preferred runway at towered airports
        ii. Determining the preferred runway at non-towered airports
    c. Wind shear and microbursts
        i. Predicting wind shear and microbursts
        ii. Avoiding wind shear and microbursts
        iii. Recovering from wind shear and microburst encounters close to the ground
6. Coordinating with ground crew
    a. Parking directions
    b. Clearance around the aircraft to start
    c. Handoff to or from another remote pilot at the airport for takeoff or landing
7. Loss of control due to hazardous flight conditions such as stalls, settling with power, low rotor RPM, overbank, flying on the back side of the power curve, takeoff from a hover with tailwind, etc.
    a. Recognition of hazardous flight conditions
    b. Recovery from hazardous flight conditions

2.5 Deleted Part 61 requirements

Just as there are additional knowledge and skill requirements for RPA pilots, there are also current Part 61 requirements that are not appropriate for RPA pilots.

Part 61 was written with the assumption that the pilot is inside the aircraft and therefore experiences the motions, sounds, and vibrations of the aircraft. It also assumes that the pilot's viewpoint is centered on the aircraft and can see the surrounding traffic, runways, taxiways, in a natural three-dimensional way. The pilot of an RPA is assumed to be on the ground and does not have direct visual contact with the aircraft.

Note that the assumption is that the RPA pilot requires first-hand knowledge and experience in a real aircraft to qualify for an RPA license. Therefore, the student and private pilot requirements require that the training and experience are conducted in a pilot-on-board aircraft although the final evaluation may be conducted in a simulator or using an RPA. However, if the license obtained is for RPA only, then there are some requirements that need not be fulfilled.

Sections 2.6 and 2.7 discuss the recommended deletions from Part 61 for an RPA pilot.

2.6 Student pilot deleted requirements

Nothing is deleted from this section since it is assumed that the student pilot will be operating a pilot-on-board aircraft.

2.7 Private pilot deleted requirements

A major difference between student pilots and private pilots is that student pilots must operate under the supervision of an instructor or under the restrictions placed on them by the instructor. Private pilots do not require the instructor's direct guidance. It is assumed that the RPA-only pilot will not fly a pilot-on-board aircraft as a private pilot. Therefore, the additional requirements for an RPA pilot are substituted for some of the private pilot requirements. It is recommended that the actual flight experience required for an RPA pilot is the same as for a private pilot license and is conducted in a pilot-on-board aircraft, but the actual evaluation may be done in a simulator or using an RPA.

Recommended deletions/replacements are:

1. Replace the requirement to recognize critical weather conditions in flight per 61.105(b)(6) with the additional weather requirements listed above in Section 2.4.
2. Delete the requirement for spin entry and recovery per 61.105(b)(11) and replace with the RPA loss of control requirement (section 2.4, item 7)
3. Delete the requirement for performance and ground reference maneuvers per 61.107(b)(vi) and 61.107(b)(vii). These are steep turns, a rectangular track, S-turns, and turns about a point. The visual cues for these maneuvers are completely different for an RPA pilot than for a pilot of a pilot-on-board aircraft. Demonstration of loss of control and traffic pattern maneuvering covers these for an RPA pilot.

4. Replace the slow flight and stalls requirement of 61.107(b)(ix) with the loss of control requirement (section 2.4, item 7)

2.8 Instrument rating deletions and changes

For this research, it is assumed that the ground station is not equipped with high-resolution virtual reality that includes side windows such that the pilot can see what a pilot on board would see out the window with 20/20 vision. Therefore, RPA flights are done with the pilot essentially flying in instrument conditions all the time. This is true even when the aircraft is in visual conditions. Because of this, an IR is an integral part of an RPA pilot's training, and no RPA license will be provided that does not include an IR. All instrument training can be done in a simulator or using an RPA. No flight experience in a pilot-on-board aircraft is required for an RPA IR. However, the cross-country requirements must be met using an RPA actually flying a mission or flying a pilot-on-board aircraft.

Recommended deletions are:

1. Delete the optional requirement to hold at least a private pilot certificate as required by 61.65(a)(1). This is because as recommended, the RPA private pilot must also have an IR. Therefore, there is no need to have a private pilot certificate, and there is no RPA certificate without an IR. The RPA pilot applicant may have a certificate of completion of the training and experience requirements of a private pilot RPA (this is not a private pilot certificate) or may apply for a private pilot and IR concurrently. However, a private pilot with an airplane, powered-lift, or rotorcraft rating is assumed to meet the private pilot requirements of the RPA license.
2. References to instructors with appropriate aircraft ratings (airplane, powered-lift, helicopter) ratings are changed to instructors with an appropriate RPA rating.
3. All flight experience may be obtained in an approved simulator.
4. All cross-country experience must be obtained by performing the duties of the pilot in command (PIC) with one-on-one supervision by an authorized instructor or in a pilot-on-board aircraft.
5. Due to the nature of most civilian RPA missions, the cross-country time may need to be reduced. Consider reducing it to that required for a helicopter rating.

Appendix D provides details for recommended Part 61 changes and example Airman Certification Standards (ACSs) for the two automation levels examined in this report, as well as recommended additional ACS tasks for RPA pilots.

2.9 New license category and class for advanced automation

The recommended path for remote pilot certification of large UAS being flown in public airspace beyond line of slight is to basically follow the pilot certification path for manned aircraft. This includes the current pilot category, class, and type ratings. The current classifications are characterized by the method used to generate lift. For example, the airplane category applies to aircraft that generate lift using fixed wings, and the rotorcraft category applies to aircraft that produce lift using rotating blades.

Historically this has been reasonable because the skills required to control a rotorcraft have been very similar for all rotorcraft, and the skills required to control an airplane have been very similar for all airplanes; but the skills required to control a rotorcraft are very different than the skills required to control an airplane. These differences regarding rotorcraft and airplanes, and similarities between all rotorcraft and all airplanes have been the result of the mechanical control systems used to control them. However, with the advent of FBW control systems, it is possible to change the way the pilot controls the aircraft such that the skills required to control the aircraft do not need to be related to the method of producing lift.

For example, the F-35B control system flies like an airplane when the speed is above about 30 knots. The aircraft does not produce enough lift from its fixed wing to lift the aircraft at this speed. And at hover, F-35B controls are much different than those of a helicopter. So, for an aircraft with control system like an F-35B, would a pilot need an airplane license with an F-35B-type control endorsement? Or a powered-lift license? However, the powered-lift license does not fit either because it also assumes control characteristics of a helicopter at low speed. These automated aircraft also typically have envelope protection systems that prevent stalls and eliminate other typical pilot skills and tasks. So, if a pilot gets a license in an advanced airplane with F-35B-type controls, does the resulting certificate prevent flying in one without these advanced features?

This is similar to the debate whether technically advanced aircraft (TAA) need a type rating or similar. A TAA is defined by the FAA (Technically Advanced Airplane, 2025) as an aircraft with a minimum of an IFR-certified global positioning system (GPS) navigation equipment [navigator] with moving map; or an MFD with weather, traffic or terrain graphics; and an integrated AP. The result was that a type rating or logbook endorsement was not required and this has worked well. However, the advanced flight controls are much different in that they fundamentally change the way a pilot controls the aircraft.

It is possible that the current category and class licensing system could be applied to these new aircraft by requiring a type rating for them. While this is probably the best short-term solution (and is the temporary solution the FAA has taken), this does not apply long term. This is because a type rating builds on the knowledge of the basic class rating such that the pilot must acquire the skills for the class rating and then add the knowledge and skills required for the type. One of the major purposes of advanced automation is to reduce the required pilot knowledge and skill. Adding a type rating to an existing category and class rating defeats the purpose of the automation.

This leads to the conclusion that for advanced automation (ARC levels 2, 3, and 4), there needs to be a license based on the pilot interface—not the method of producing lift. Thus, it is recommended that an SVO-A category license be developed with classes corresponding generally with automation levels 2, 3, and 4 as identified in the ARC for UAS Beyond the Line of Sight with an additional subcategory for manned aircraft and RPA. This is much like the breakout for landplanes and seaplanes. They are very similar, but each has unique characteristics that need to be addressed for pilot training and certification.

In summary, the recommendation is to create a new aircraft certification part, modify the existing Part 61, and modify existing operation rules, as shown in Figure 1.

- New aircraft certification part that
    - Borrows heavily from Parts 23 and 27.
    - Requires specific automation features and their associated reliability and availability level that together define an SVO-A1, SVO-A2, or SVO-A3 aircraft.
- Add to Part 61:
    - Create an SVO-A category with SVO-A1, SVO-A2, and SVO-A3 classes.
    - Each class maps to an automation level as defined by the new aircraft certification part.
    - Each class has specific knowledge and skill requirements appropriate for that class only.
- Modify the operating rules (Parts 91, 121, 133, 135, and 137) as appropriate for the technology level and aircraft capabilities.

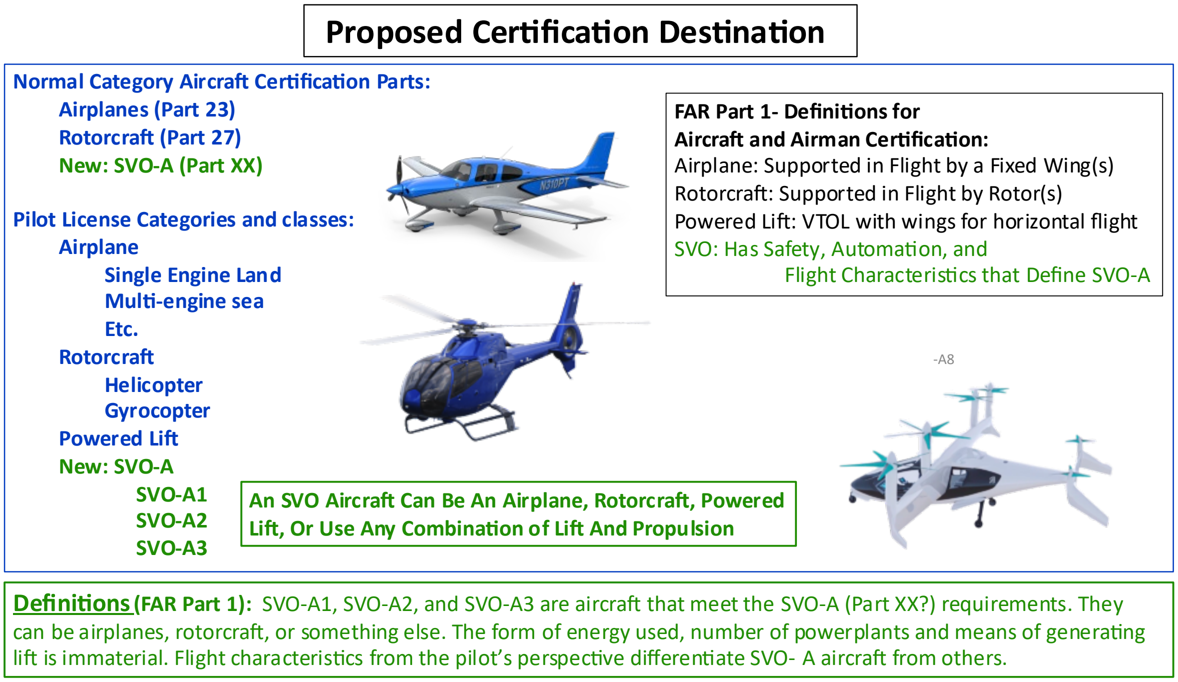

Figure 1. Long-term automation driven aircraft and pilot certification recommendation

3 Task 2: Review operating rules

In the next phase of this research effort, a thorough examination of the operating rules defined in 14 CFR Parts 91, 121, 133, 135, and 137 was conducted to determine their relevance to large UAS operations and pilot certification for OPA or large UAS. This review also involved comparing these regulations with the latest updates or any proposed changes.

There are currently many operating rules that apply to various operations for the same aircraft. For instance, currently the same airplane can be operated under Parts 91, 121, or 135. Under Part 135 and Part 121 rules, individual operators have different operating rules specific to their operations. As such, it is impossible to develop a comprehensive set of recommendations for operating rules that might apply to UAVs, particularly with different levels of automation. However, there are some operating rules that are clearly intended to apply to pilot-in-the-aircraft with minimal automation. The most obvious ones are identified and discussed in Appendix E.Recommended changes to those identified are also discussed.

4 Task 3: Develop airman certification standards for remotely piloted vehicles

For the third task of this effort, researchers developed a draft outline for the ACS, created a curriculum for OPA and large UAS pilot certification informed by prior reviews, and designed the experiment in close collaboration with the FAA. This work includes determining which data to record, how much data to collect per subject, and the approach for analyzing data to achieve the experiment's objectives.

The researchers developed two parts to the ACS task. The first part was specific to RPVs. Because of advanced automation, the researchers felt compelled to extend the ACS to include advanced automation. Since there are an infinite combination of automated features, the researchers focused on the two sets of automation features defined as examples for this research. These two sets of features are identified as SVO-A1 and SVO-A2 to differentiate them from other sets of automation. For more detail about automation levels and the selection process, see Section 1.7 and Appendix A..

The researchers recommend that the curriculum and ACS for an RPV pilot start with the private, commercial, instrument and airline transport pilot (ATP) ACSs already in use. Specific changes to these ACSs for an RVP are listed in ACS format in Appendix D.

The RPV and automation ACSs are intended to work together with the current aircraft ACS as follows. Starting with the appropriate ACS or PTS as appropriate for the aircraft category, class, and type, the RPV ACS is then applied to add and remove tasks as required by the proposed RPV ACS; finally, the SVO-A1 or SVO-A2 ACSs are applied as appropriate for the automation level.

It is beyond the scope of this research to develop a comprehensive curriculum for an RPV with any possible automation level. Therefore, two partial curricula were developed specifically for an RPV with SVO-A1 and one for the same tasks specifically for an RPV with SVO-A2. The tasks were weight and balance, instrument approaches, emergency, and emergency procedures related to an all-electric aircraft for a powered lift vehicle.

Details of this curricula are provided in Section 9.

5 Task 4: Review relevant Federal Aviation Regulations Parts to identify necessary revisions for a conventional takeoff and landing / vertical and/or short take-off and landing for optionally piloted aircraft or large unmanned aircraft system

For Task 4, aircraft certification rules as they pertain to OPVs and large UASs were reviewed, with particular attention to the knowledge and skills required of pilots operating these platforms. This review included a comparison with the most current regulations and any proposed regulatory changes.

As with the ACS task, the aircraft certification task was comprised of two parts. The first part included recommending changes to the aircraft ground station system as it relates to advanced automation levels. The researchers found that as the automation level increases, the difference in tasking between the pilot in the aircraft and the pilot on the ground is reduced. That is to say, at high automation levels, the pilot task is reduced to the point where very little training is required, and the aircraft takes care of itself without pilot intervention. This requires significantly different regulations than those existing in Parts 23, 27, and 33. Therefore, recommended changes to Parts 23, 17, and 33 are proposed (see in Appendix B for details). These recommendations are intended to be performance-based rules that apply to all automation levels.

The FAA also proposed a set of rules for RPVs. These proposed rules are mostly design based and therefore may or may not apply to advanced technology. The researchers reviewed the proposed rules, captured the safety intent, and made recommendations to convert them to performance-based rules. These recommendations are also outlined in Appendix B.

When converting design rules to performance-based rules, the concept of converting design requirements to design assurance requirements often becomes a key concept. Because of this, it is appropriate to discuss the required level of design assurance and the reasons behind the recommended levels. This discussion and recommendations are included in Appendix C.

In addition to the recommendations for changes to Parts 23, 27, and 33 along with the FAA proposed UAV rules, the researchers concluded that it is important that a human operator, either onboard the aircraft or on the ground, approve the aircraft to land in all cases—including when the aircraft normally lands autonomously. This is because databases and remote sensing may not always detect hazards in the landing zone. Therefore, the researchers recommend that for all operations, a means for a human to view the landing zone in real time is required and the human (normally the pilot, but could be a ground observer) is required to authorize the landing at an altitude of about 50 ft. This view can be provided by a window aligned with the direction of flight for aircraft with a pilot or trained passenger on board, or a camera pointing in the direction of flight viewable by the pilot for operations without a ground observer at the landing site. While this requirement often maps to an aircraft requirement (window or camera), in general it becomes an operational requirement because it may be met by a ground observer. Therefore, this recommendation is part of 91.205 (Powered civil aircraft with standard U.S. airworthiness certificates: Instrument and equipment requirements, 2025) (the rule that specifies required equipment for kinds of operations).

6 Task 5: Modify existing simulators

For Task 5, the objective was to enhance existing software simulations to accommodate a conventional takeoff and landing (CTOL) or vertical and/or short take-off and landing (VSTOL) OPA or large UAS with energy levels exceeding 3,000,000 joules—comparable in size and performance to a blend of a Cessna Caravan and a Bell 206. Additionally, adjustments to the ground simulator hardware and software must be updated as necessary to accurately represent the ground station in each scenario. This includes developing a ground station interface, like a G1000 cockpit, featuring a moving map and autopilot, and integrating a conventional airplane control system with simplified controls for VTOL operations, inspired by platforms such as the F-35. Automation should also be added to the ground control system, enabling point-and-click functionality without traditional flight control inceptors, and allowing operators to select various phases of flight such as takeoff, climb, level flight, turns, descent, and landing. Advanced automation should be implemented that permits the entire flight profile to be defined on the ground and transmitted to the aircraft's flight management system, with the capability for the aircraft to autonomously adjust its flight path in response to real-time traffic detection, while the pilot monitors the vehicle's adherence to its defined flight profile.

The existing simulators previously targeted an electrical vertical takeoff and landing (eVTOL) vehicle simulation instead of a ground control station (GCS). The existing eVTOL vehicle simulators represented SVO-A1 automation with the unified control system (UCS) and SVO-A2 automation with the EZ-Fly control system (details of both control systems are provided in Appendix A) except for the inceptors; both simulators included outside view display(s), a PFD, and an MFD. The unified simulator inceptor implementation included a right-hand control-loaded sidestick, a control-loaded pedal, and a left-hand control-loaded speed/acceleration inceptor. The EZ-Fly simulator inceptor implementation included a control-loaded steering wheel, a speed wheel, and a hover joystick controller. Both simulators were rebuilt and combined into one GCS simulation cabin such that the center steering wheel could be easily stowed during the EZ-Fly part of the experiment. During discussions with the FAA (prior to the experiment execution), an additional display, which was the same size as PFD and MFD, was added to the GCS. This display replaced the outside view display, which previously was a large television monitor and was not as representative of a typical GCS. The Unified GCS had a traditional G1000-like display, while the EZ-Fly system had a custom display. The general layout of these displays was unchanged, but additional features were added. The MFD had a map or ground view with additional features added.

The existing lift + cruise aircraft had a similar weight compared to a Bell 206. Figure 2 shows the configuration used in this work.

Figure 2. Representative configuration used in this work

Representative battery and cooling systems were modelled for the experiments. The battery system was divided into 10 packs, each with individual modelling for voltage, state of charge, and temperature. The power usage of the rotor and pusher system was mapped to battery current and voltage usage, and the thermal increase due to the battery usage was also modelled. The maximum power available was also modelled in the new power system such that a reduction in the battery voltage would cause a reduction in rotor and pusher performance. The battery package capacity was also defined based on the maximum length of the flight using full power in the rotor system. Basic thermal dynamics of the battery and cooling system were also added, in which, when the cooling system failed, the battery temperature would rise. The battery temperature would rise even under idle usage of the power system. The battery temperature would also increase when full power was used, such as transition during the departure phase of the flight. Additionally, a temperature and battery warning system were added to the GCS so that crew alerting system (CAS) messages could be displayed or used by the automation based on the current battery condition.

The automation mapping in the Unified GCS pitch and yaw axes remained the same under a system failure but with significant performance impacts. The speed/acceleration command inceptor was changed for this experiment: from the prior experiment, it was found that this inceptor was the most difficult control inceptor to train because it included different mappings in hover (speed command only) versus forward-flight (acceleration command) from the original F-35 setup. This also included a mixed control between the two ranges. In this experiment, because of the limited flight envelope in speed, the speed-acceleration inceptor was remapped to be a speed-only inceptor. Then each individual position of the inceptor represented one speed command. In addition to the inceptor change, the PFD for the Unified GCS was changed so that the control mode was also indicated on the top of the display. This depicted flight information including speed, pitch (flight path command or attitude hold), and bank commands. These indicators would also display AP modes when they were engaged, like a traditional Garmin AP display. During the initial testing, it was found that the operator wanted to use the heading or altitude bug as a reference. This was subsequently added to the PFD so that the desired heading and altitude could be manually set by the pilot. The Unified GCS AP was also overhauled so that a flexible flight plan could be loaded by the operator during different phases of the flight. A level mode was added to the AP, which would trigger a level command in both the bank and flight path. A weight-and-balance (W&B) page was also added to the MFD with manual inputs for the weights at each defined loading position. This allowed the center of gravity (CG) location in the X and Y axes to be displayed automatically after each weight entry.

The EZ-Fly GCS had no changes in the information displayed, but additional flight path features were added. The original flight plan for this simulator only allowed maximum performance in the flight path, which was no longer suitable for the instrument approach needed for this experiment. The additional flight plan definitions were added to the current FMS for the EZ-Fly to accomplish this feature, which allows both the EZ-Fly and the Unified GCS to be operated using the same flight plan, resulting in similar flight characteristics. This feature was critical for the instrument approach analysis. In addition, because of the nature of the EZ-fly GCS, which provided auto-land during an emergency, a feature to override flight plan and display was added to this GCS so that the vehicle could decide and choose a preset flight plan based on the nature of the emergency. A W&B page was added to the MFD with modifiable weights at each predefined loading position. The CG location in the X and Y axes would be displayed after pressing the ‘recalibration’ button to represent the automatic W&B feature onboard an SVO2 vehicle or its GCS. The EZ-fly GCS also locked out the pilot command when the W&B was not within the vehicle nominal range, this prevented takeoff.

The flight plan used in the previous experiments was also modified and separated into different departure and approach procedures. An additional approach used for CTOL landings was also developed. Subsequently, IFR charts presenting all these departure and arrival procedures were made for ground school training.

7 Task 6: Test functionalality of existing simulators

For this Task, each GCS was simulated to test functionality and ensure that each GCS implementation satisfied the experiment design requirements. The existing Unified and EZ-Fly simulators were tested under different scenarios and failure modes. To satisfy research requirements of testing operator performance under emergency conditions, the GCS was tested first with the existing performance under different failures. In past research, no failures were examined or used by the researchers. This required additional aircraft modeling design, test, and analysis before designing the current research experiment.

The basic functionality for Unified GCS tests included but was not limited to direct control (e.g., roll rate command with bank angle hold, and gamma dot command), flight envelope protections (e.g., overspeed and under-speed protection, bank angle protection, and vortex ring state protection), automatic ground collision surveillance system (Automatic GCAS), AP, and related display elements. The basic functionality for the EZ-Fly GCS tested included but was not limited to direct control (e.g., speed knob, speed command joystick inceptor, and steering wheel command), AP engagement, flight envelope protections, Automatic GCAS protection, etc.

In addition to testing the existing features used in past experiments, analyzing the system performance under various external environments was accomplished. This included rotor failures, e.g., complete rotor failure, pulsate, stuck, and control system behavior under turbulence—such as gust, wind shear, and Dryden turbulence models. The interaction between the different scenarios and the current envelope protection systems was recorded. The rotor failure cases were further investigated as they can be tied to common system failures for eVTOL vehicles, such as battery failure, and would ultimately be used for the experiment after discussions with the FAA. The system control limitations and operational impacts were determined, and it was found that both GCSs have limited glide capabilities under a complete rotor failure. This directly impacts the outcomes of the flight during an emergency, which can then be used to analyze if the operator reacted according to the emergency procedure. The original GCS did not include a detailed display and modelling of the battery system. As this information is needed for the operator to understand the system status under the battery failure scenarios in the experiment, the new basic battery pack modelling and display were further tuned based on the new cooling systems design. This ensured a limited and defined time frame in the experiment for when the CAS message appears and for when the rotor system enters a complete failure under the battery cooling system failure scenario. The tuning also estimated a pilot reaction time of 30 seconds after the first CAS message appeared. The results of both the operator reaction and landings in and outside the given time windows (in this case, 4-5 minutes) were tested to make sure the operator had a high probability of not being able to reach the landing site if the operator reaction was inappropriate. This proved to be especially valuable for the unified GCS. The system was also tested to ensure that a catastrophic event would not occur if the pilot failed to recognize the need to avoid transitioning from the wing to the rotors after the cooling system failure. Similar testing was also conducted for the battery pack failure case, in which the operator had to land without re-transitioning to the rotors. The EZ-Fly GCS testing for these scenarios was relatively simple and only involved ensuring that the automation could bring the vehicle safely to the test site. However, additional testing was done to ensure that no operator action would impact the system performance, and the displays for the automation that was handling the emergency were displayed clearly to the operator. Furthermore, testing was done to determine the best location for triggering the cooling system failure, as the experiments required the failure CAS message to appear at a similar location.

For instrument approach analysis, since the Unified GCS requires a coupled instrument approach, additional approach statuses, such as vertical and lateral derivation indications, were tested to ensure they were displayed properly. Additional AP and automation messages were added and tested. The previous experiments showed this area could be improved so that the experiment could focus on the emergency procedure analysis with a good assumption that it is easy for the operator to understand the automation and react to the emergency accordingly based on their best knowledge of the automation. Additional augmentation, such as a Level button and a more flexible FMS for flight plans in the Unified GCS, were added and tested. This allowed the experiment to better represent a GCS with current automation technologies. These results were then reported to the FAA to obtain a consensus on experiment design, system performance, and operational impacts. Additional changes to the GCS control system and displays were made based on feedback from the FAA.

To satisfy the W&B scenario, a W&B calculator was added to the MFD of both GCSs. For EZ-Fly GCS, there was no entry for the calculator, and it could only be changed by the simulation operator, thus simulating a system that automatically weighs either the whole aircraft or the people and baggage and does the required calculations automatically. For the Unified GCS, only manual entries for the weight for each payload location were allowed. Various payload loading scenarios were tested, including several in CG limit and several out of CG limit. Both calculators were checked for accuracy.

8 Task 7: Perform initial experiment testing

For Task 7, initial experiment testing was performed including tests on one non-pilot and one experienced pilot to evaluate the experiment design. Following these initial tests, the collected data was analyzed corresponding to the established design. After the experiment design was decided (see Appendix K), initial experiment testing was conducted. Initial testing included one operator per GCS. For the Unified GCS, a person Eagleworkswith an existing IR was selected. For the EZ-fly GCS, Eagleworksa person with limited to no experience in the design and operation of this research was selected. The ground school training was conducted for each operator to provide an overview of the system operation and proper procedure under different emergency scenarios. The operators experienced the same scenarios as the final experiment, and afterward their performance was analyzed. The data for the experiment was recorded, but more importantly, feedback was collected on the ground school, system response, and display setup. The results were mostly analyzed qualitatively with a focus on operators' comments on issues and feedback from the system's operational and training standpoint. For example, the Unified GCS operator showed insufficient understanding of the system control layout, such as the left speed command inceptor and the lateral stick command mapping, which impacted their performance during an emergency in the experiment. This feedback resulted in some augmentations of the experiment setup to allow more GCS practice in a standard pattern and additional ATC commands to ensure the operators had a better understanding of the system and system setup when an emergency was triggered. Moreover, there were comments regarding inconsistent performance between the GCS vehicle response and a traditional fixed-wing aircraft, such as poor glide characteristics under a complete engine failure. This made it difficult for an existing fixed-wing operator to transition to a vehicle capable of VTOL operations. In the end, all comments were considered in the development of ground school training. This helped standardize operators so that a fair analysis could be made based on their performance in different scenarios. The use of different system indications, system operations, and abnormal conditions including but not limited to the battery and power cooling systems, was also analyzed and understood to ensure that the current system layout provides sufficient data for the operator to monitor the system performance.

EZ-Fly testing focused on the robustness of the automation during normal and emergency operations to make sure the system responded correctly under all scenarios. The difference between the focus of the two GCSs during the initial experiment testing was expected as the Unified system has more operator involvement, in which the interaction between the operators and the automation needs to be measured and analyzed; the EZ-Fly GCS has a higher automation level, which resulted in more testing and analysis on the automation system performance and robustness. The initial testing results were reported to the FAA, and additional experiment design elements were adjusted based on the feedback from both test operators. The data recording and analysis tools were also developed and tested after the initial experiment test and before conducting the final experiment. Some minor but important changes, such as adding traffic on the runway, were requested and added to the experiment after the initial experiment testing discussions. In addition, a third screen, which is the same size as the PFD and MFD, was requested per FAA discussion and added to the GCS to serve as an outside view screen for the GCS.

9 Task 8: Perform experiment testing

Task 8 was intended to. train several non-pilots and existing pilots against the scenario(s) and GCS version using the draft ACS, curriculum, and supporting proposals to aircraft certification, pilot certification, and operating rules.

The experiment was conducted in the same time frame for both GCSs. The operator selections for both GCSs were as diverse as possible, especially for the Unified GCS operators. This group had more limited but more diverse operators in their operational background, which could impact the results for the aircraft certification, pilot certification, and operation rules. The background and experience of the Unified group are listed in Table 1.

Table 1. Unified GCS operators' experience

Operator Nr	**Total flight time (approx. hrs)**	**Multi-engine flight time (approx. hrs)**	**Rating**	**FBW** Experience
1	7,600	5,500	ATP, CFI, CFII, CPL, IR, ME	Yes
2	315	0	IR, PPL	No
3	4,000	3,200	ATP, CFI, CFII, CPL, IR, ME	No

ATP = Airline Transport Pilot
CFII = Certified flight instructor—instrument
CFI = Certified flight instructor
CPL = Commercial pilot's license
ME = Multi-engine
PPL = Private pilot's license

None of the operators had previous experience in VTOL or rotorcraft simulations or operational experience (see Appendix I and Appendix J for questionnaire details). None of the EZ-fly operators had remote-control aircraft or drone/UAV experience, experience with a flight simulator, or experience manipulating the flight controls of an aircraft. All operators had ground school training before the start of the experiment. The ground school covered the controls in the GCS, general system knowledge, and general emergency procedures training (see Appendix L for additional details).

The experiment contained four scenarios (See Appendix K for additional details) in the following order:

1. Weight and balance (W&B) calculation
2. Instrument approach
    a. Traffic on the runway was presented during the final approach and was removed after reported by the operator.
3. Battery cooling system failure
4. Battery pack system failure

For the Unified GCS operators, a W&B calculation was tested using only pencil, paper, and four-function calculator because this calculation method is included on every FAA written test for a pilot's license. It was expected that this W&B knowledge would be retained due to previous pilot licenses ratings . If the operator could obtain a final W&B value, the built-in calculator at the GCS would be used to verify the results. This portion of the experiment was not included on the EZ-Fly GCS ground school because that knowledge is not expected for operators and was designed as part of the automation. No prior notice of W&B expectations was given to either group before the start of this experiment. However, before the start of the simulation experiment, an unbalanced aircraft was presented to the operators, in which the operator responses and actions were recorded.

All parts of the simulation experiment were recorded including the operators' behavior for each scenario were recorded, and several post-scenario questions were presented to the operators and answered. All operators practiced a standard pattern around the VTOL test site multiple times. The flight pattern is shown in Figure 3. Several ATC commands, such as heading, altitude, and speed changes, were given to the operator between waypoint (WPT)4 and the Flatwoods WPTs to practice control of the vehicle. All operators were given as much practice as needed before they felt comfortable operating the vehicle for the various scenarios. An additional ATC command was also added if the operator had trouble maintaining the previous command to ensure performance was standardized.

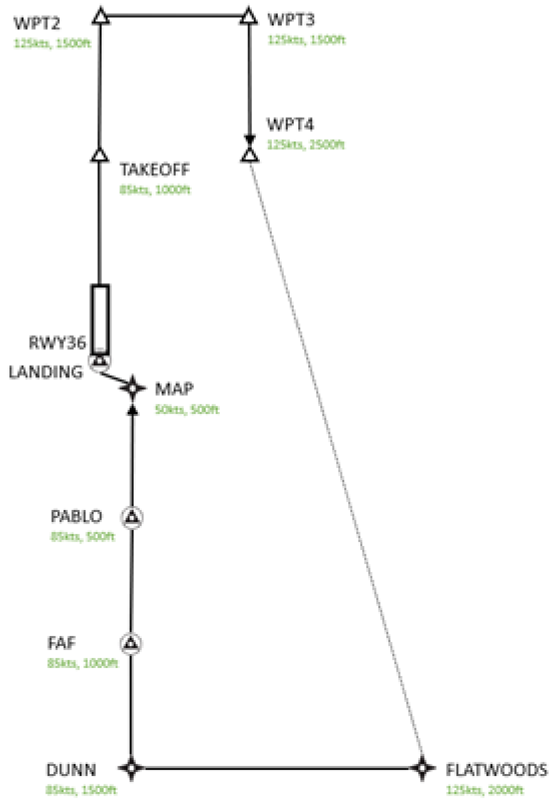

Figure 3. Pattern used by the experiment for practice

The first recorded experiment was the instrument approach, in which runway traffic, a Dassault Mirage, was placed on the runway post departure. A heading change, an altitude change, and a speed change were commanded by ATC after WPT4, and the operator was cleared for landing using the standard terminal arrival route (STAR) landing procedure. The flight path after the missed approach point (MAP) was analyzed for each operator, as the approach prior to the MAP was done by automation for both GCSs. The operator usage of each screen was closely monitored, and the reaction to the traffic on the runway by the operator, if observed, was recorded. The final landing position and performance were also used for hover performance analysis. The runway number was listed as the termination point and hover point target for each operator. The operator was asked to maintain 30 seconds on the runway heading at the hover point for stabilized hover analysis. For all operators, the simulator-operator requested the GSC operators to stabilize the approach and maintain at 10 ft before reaching the hover point target.

The simulation was then reset, and the cooling system failure test was conducted. Pilot reaction to different CAS messages was closely monitored, especially for the Unified GCS operator, as the reaction time and action were closely linked to whether the proper emergency procedure was performed. For the EZ-Fly GCS operator, the action was minimal. The simulation was reset, and the battery failure case was conducted. A similar analysis was done for this scenario compared to the cooling failure analysis. The whole scenario was recorded, but no quantitative analysis was done.

10 Task 9: Analyze test results

In Task 9, the data collected from the experiment testing was analyzed according to the experiment design.

10.1 Ground control system flight control practice results

Most of the Unified GCS operators were successful in adopting the Unified GCS flight control system. However, difficulties were initially observed for operator 2 using the automation, such as control system mapping, auto-transition, stall protection, and backup power. IFR instrument fixation was observed when changing the altitude, heading, and airspeed. Some impact was observed on performance during the experiment, especially under an emergency. Overall, whether the operators had FBW aircraft experience or not did not appear to be a factor in the adaptation of the Unified GCS in this limited operator pool. All EZ-Fly operators were able to adopt the control scheme in a short time without difficulty.

10.2 Weight and balance calculation

All the Unified GCS operators failed to calculate the final CG position of the vehicle with the given payload and position data using the manual method of a pencil, paper, and four-function calculator (see Appendix H for details). All the operators noted that they had done these calculations in the past as they obtained their licenses, they all said that they now used existing electronic applications, such as ForeFlight and others, for these calculations. None of the operators mentioned using an aircraft flight manual (AFM) or indicated that they could have done the calculations for an airplane they recently flew without using an electronic application. As a result, none of the operators used the built-in W&B calculator as there was no solution provided by them to be verified.

For EZ-Fly GCS, all the operators were able to observe the unbalanced vehicle on the W&B display page and were able to obtain a properly balanced vehicle by telling the simulator operator how to adjust the payload on their own.

10.3 Instrument approach

The results for both unified and EZ-Fly GCS operators showed that most of their time was spent on the PFD, with significantly less time on the MFD and outside view, during the final approach. All operators noted spending more than half of their time monitoring the PFD, with . some operators estimating close to 90% of their time spent monitoring the PFD. All operators noted that the PFD was the most useful display for the final approach for both GCSs. Two experienced Unified GCS operators noted that they used the PFD for primary indication, the MFD for brief situation awareness updates, and outside view for outside awareness and obstacle avoidance. All EZ-Fly GCS operators noticed the traffic on the runway. Two Unified GCS operators noticed the traffic on the runway, and the remaining operator noticed the traffic on the runway on the MFD as they flew over it (the MFD had transitioned to a downward camera at this time).

Data was collected for this scenario for all Unified operators and two of the three EZ-Fly operators. The remaining EZ-Fly operator discontinued the flight plan after seeing traffic on the runway and before the simulator operator was able to remove the traffic. For performance analysis, the previous practice run final approach was used for this operator. Data from the other operators was successfully recorded during this scenario.

The overall track of all operators is plotted in Figure 4. The results showed consistent results between the departure and most of the instrument approach, as they were operated by the AP or flight plan mode in both GCS. Closer results were observed between the operators under the same GCS type. The path between WPT4 and Flatwoods WPTs varied based on each operator per ATC command and was not part of the analysis for this experiment. Figure 5 shows a detailed 3D view of all the operators after passing the MAP, in which the Unified GCS operators were required to disengage the AP and manually land the vehicle, while the EZ-Fly GCS operators landed the vehicle under the flight plan mode with no manual control. Because of a lack of outside environmental change during the simulation, all the EZ-Fly results were consistent and closely matched with each other, as no flight plans were changed, and there were no external factors caused by different operators. All operators showed a steady converging path toward the flight path between the MAP and termination point (runway number), as shown in Figure 4. The altitude performance varied based on operators, especially for Unified GCS operators, as shown in Figure 9. This section of the approach wasalso analyzed per FAA-S-ACS-16 Commercial Pilot for Rotorcraft Category Helicopter Rating ACS (FAA, 2023) provided in Appendix F for Takeoffs, Landings, and Go-Arounds (CH.V.) Task B (Normal and Crosswind Approach)-Skills (S) and Appendix G for hovering maneuvers (CH.IV.), Task A—Vertical Takeoff and Landing.

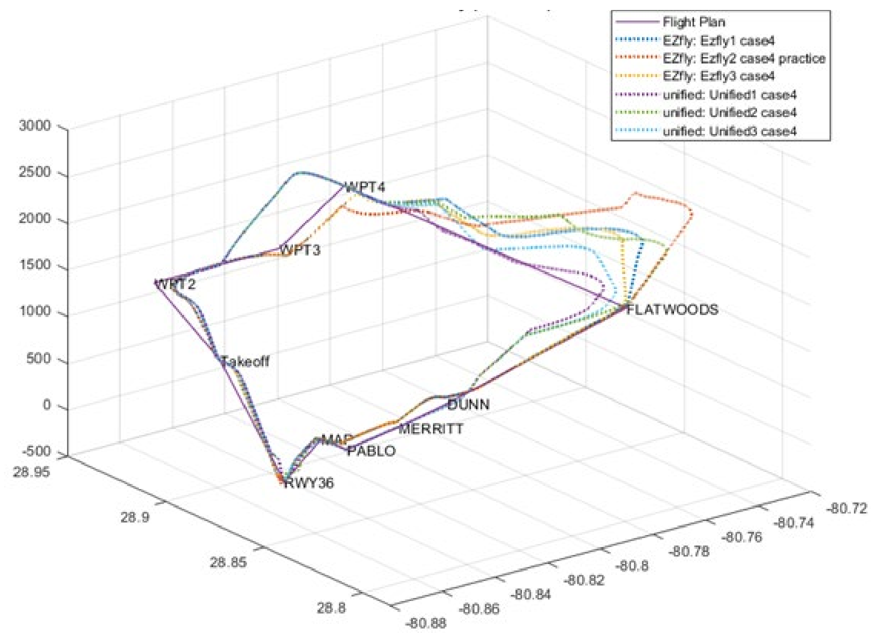

Figure 4. Instrument approach scenario total track history in 3D

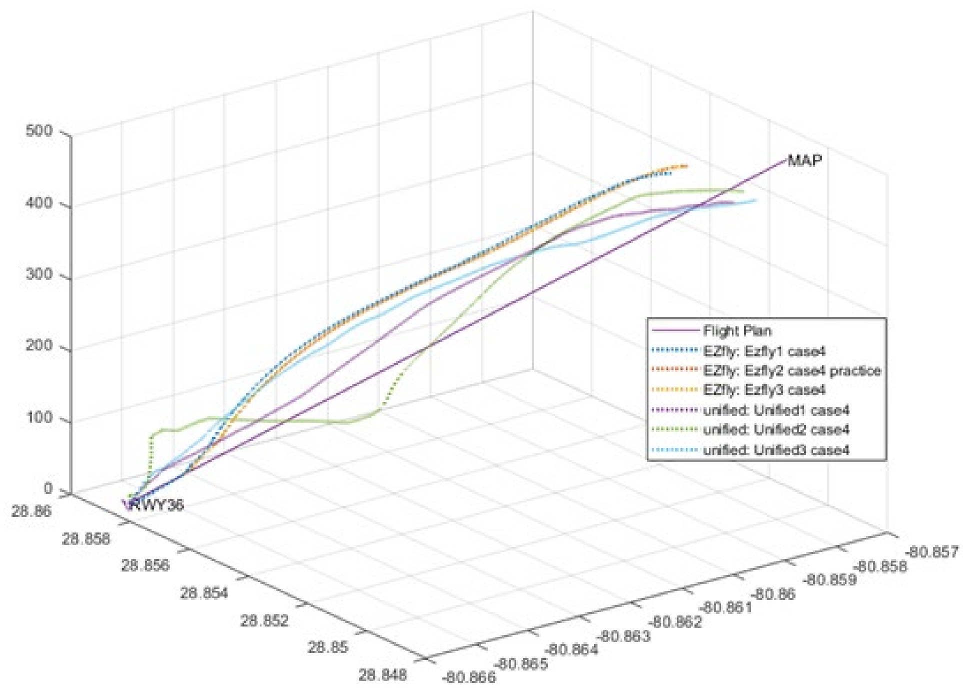

Figure 5. Instrument approach scenario history after MAP in 3D

10.3.1 Takeoffs, landings, and go-arounds—Task B: normal and crosswind approach skills (CH.V.B.S)

CH.V.B.S1-S3, S8, and S10 (Chapter 5, Task B, Skills 3, 8, and 10) of FAA-S-ACS-16 (FAA, 2023) were not applicable to the GCS setups in this experiment. All operators satisfied CH.V.B.S4, as shown in Figure 6 , because all the operators' paths showed a converging path in heading compared to the reference flight plan path at the end of the final approach. All operators were observed scanning the landing area and touchdown point during the final approach as per CH.V.B.S5. Only one unified GCS operator failed to notice the traffic on the runway until they were over the traffic as viewed through the downward-pointing ground-view camera. All other operators noticed the traffic, which satisfied the ACS requirement.

It is also notable that operators, especially unified GCS operators, spent most of their time on the PFD, which contained most of the information for the flight but did not contain the traffic information. this is why an outside-view camera is needed under the current GCS. .

CH.V.B.S6 was analyzed with no crosswind simulation during the experiment, which would increase the workload of the automation or the operator and negatively impact their performance. Figure 7 and Figure 8 shows those results. As shown in Figure 7, the EZ-Fly GCS results show a lower lateral position error and standard deviation from the direct flight path, which means the EZ-Fly automation and its operators could maintain closer to the direct flight path throughout the final approach. The lower standard deviation also represented a steady position error, which presents a more stable approach in the position and heading, as large heading changes would cause more fluctuation in the position error.

As shown in Figure 8, the EZ-Fly operators also had a longer after-convergency time than the Unified GCS operators, which presents a faster convergence during the approach. However, both GCS operators show a low error and standard deviation after convergence, which means all operators were likely able to maintain the ground track after the approach was stabilized.

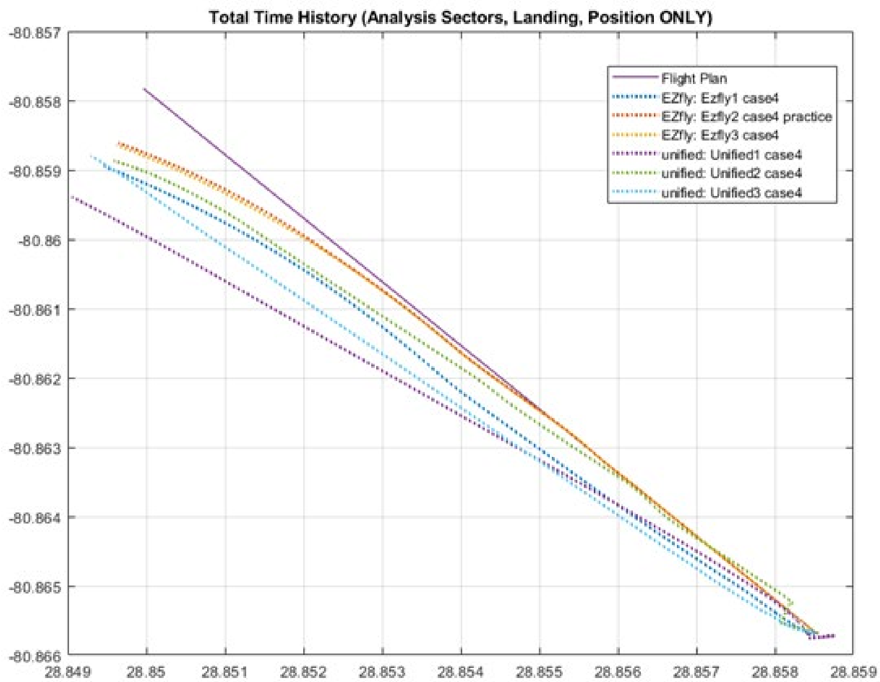

Figure 6. Instrument approach scenario position history after MAP

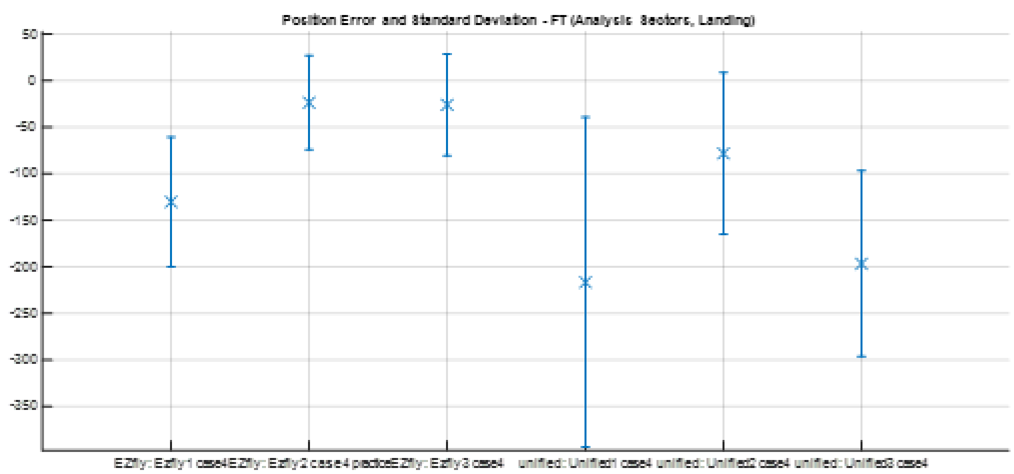

Figure 7. Instrument approach scenario total lateral position error and standard deviation from desired flight path after MAP to the termination point

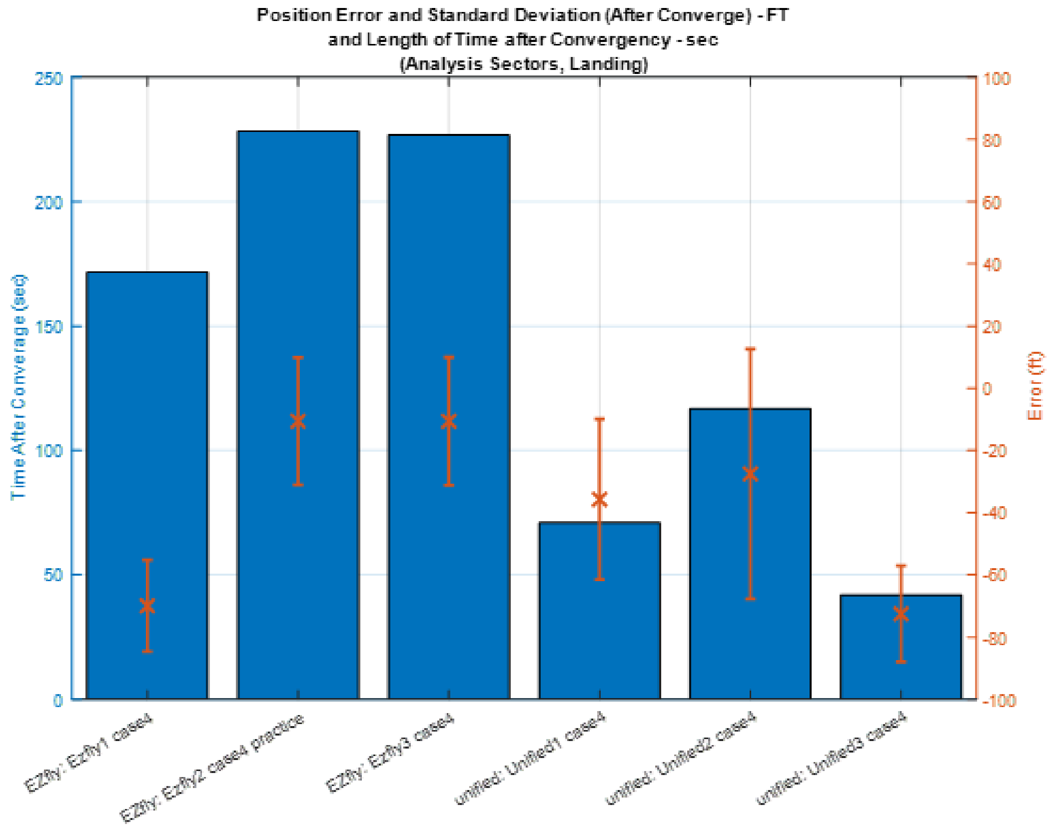

Figure 8. Instrument approach scenario total lateral position error and standard deviation after converging within 100 feet from approach flight path (right axes) and the length in seconds after convergence and before reaching the termination point (left axes)

Figure 9 and Figure 10 show the analysis for the CH.V.B.S7 requirement. Figure 9 contains both a dashed reference line that is plotted directly between the point where the operator started the descent to the end of the approach (termination point), and a dotted line, which is the actual path. The end of approach or termination point is defined as the point when the vehicle enters 5 feet from the hover point altitude or below 5 knots. and a dotted line, which is the actual path. It is noted that in Figure 9, because the figure normalized to the end of the approach, the operator preferred a gradual descent approach when approaching the hover point, regardless of the time it took to approach the target. The EZ-Fly GCS results showed a similar trend between the operators, while the Unified GCS results showed a varied trend between each operator based on the adjustments of the operator over time. All the Unified GCS operators used the flight path marker on the PFD as the reference to the termination point, as defined as the runway number prior to the scenario, and then switched to visual reference as the target approached. The trend observed was an approach that started with a stable path, but with a greater variation in the rate of descent toward the end. The second Unified GCS operator switched to visual reference much earlier—during the last 40% of the approach—compared to about 25% for the other two operators, and also had a significantly worse rate of closure.. In general, most of the operators in both GCSs were able to maintain a normal approach and rate of closure. Figure 10 shows the instrument approach scenario altitude error and standard deviation.

Figure 11 shows the analysis for the CH.V.B.S9 requirement. All EZ-Fly GCS operators were able to achieve exactly 10 ft using automation, while only one Unified GCS operator was able to achieve the same performance. However, the simulation did not contain a reference mark on the boundary termination point, which would probably be needed if the data is analyzed in a quantitative way, as is commonly done in military standard MIL-DTL-32742 (U.S. Department of Defense, 2023), *Mission Task Elements* evaluations, especially for setups that require manual adjustments. However, this result might also represent the operators' lack of awareness of the exact position of the vehicle under the same GCS setup used for this experiment. It is also noted that neither GCS would start their descent at the MAP nor achieve zero errors in position, as the MAP was flown as a fly-by WPT for both systems.

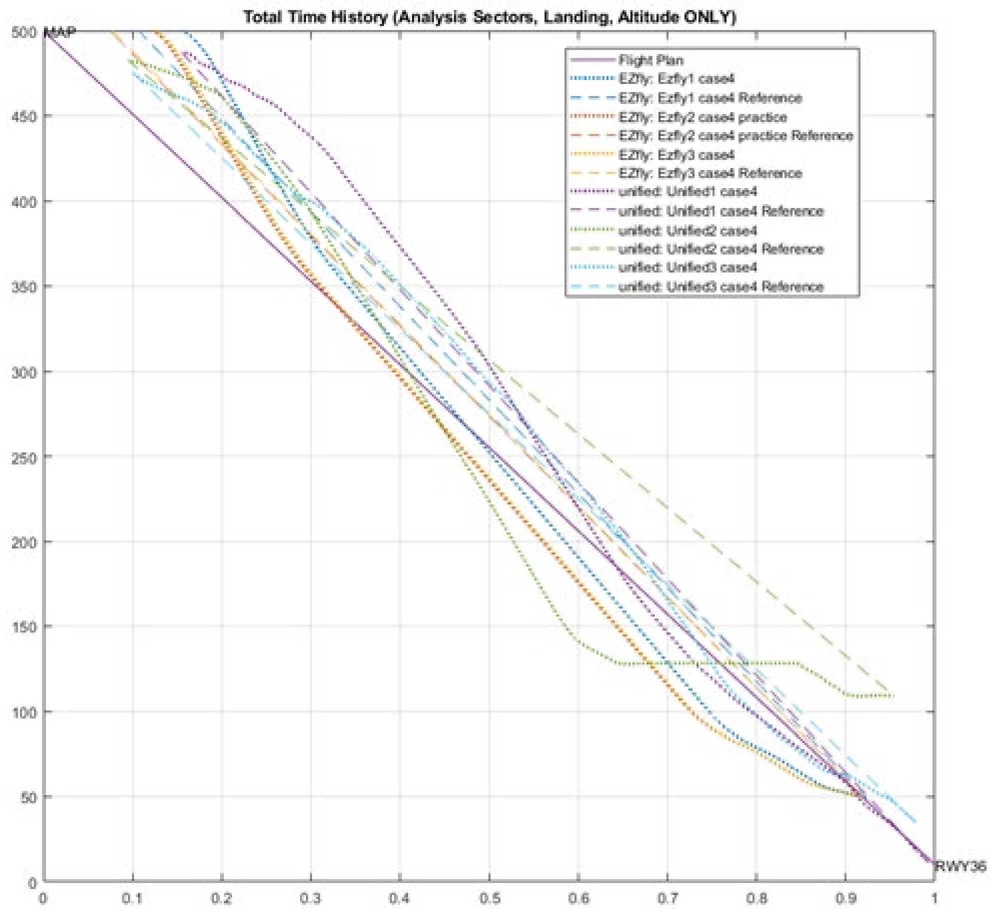

Figure 9. Instrument approach scenario altitude history after MAP, normalized based on distance to the hover point (runway number)

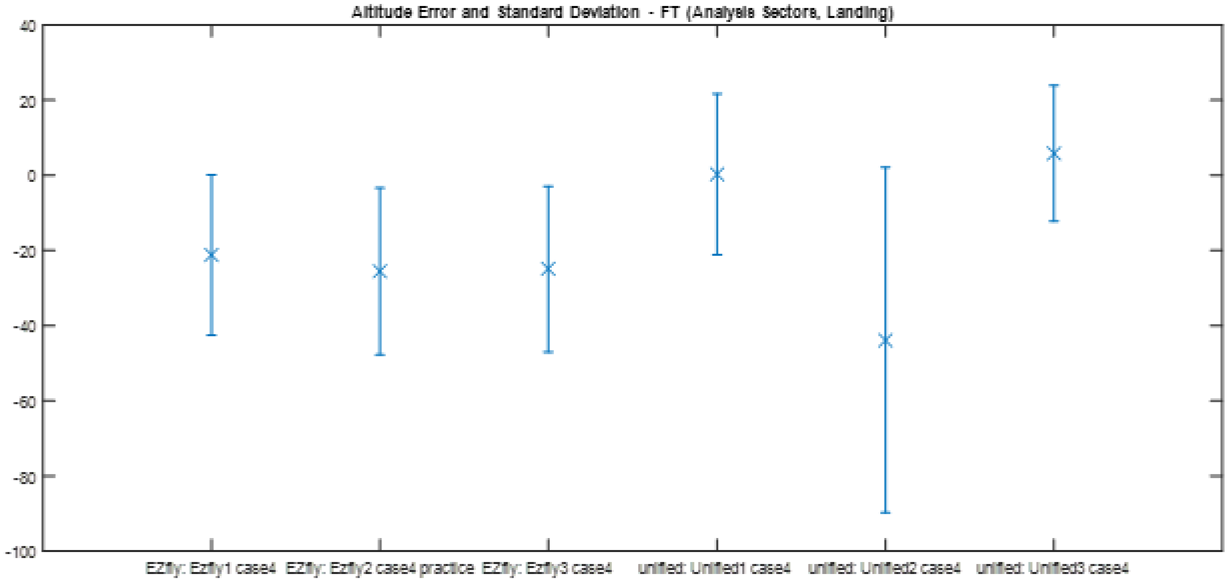

Figure 10. Instrument approach scenario altitude error and standard deviation

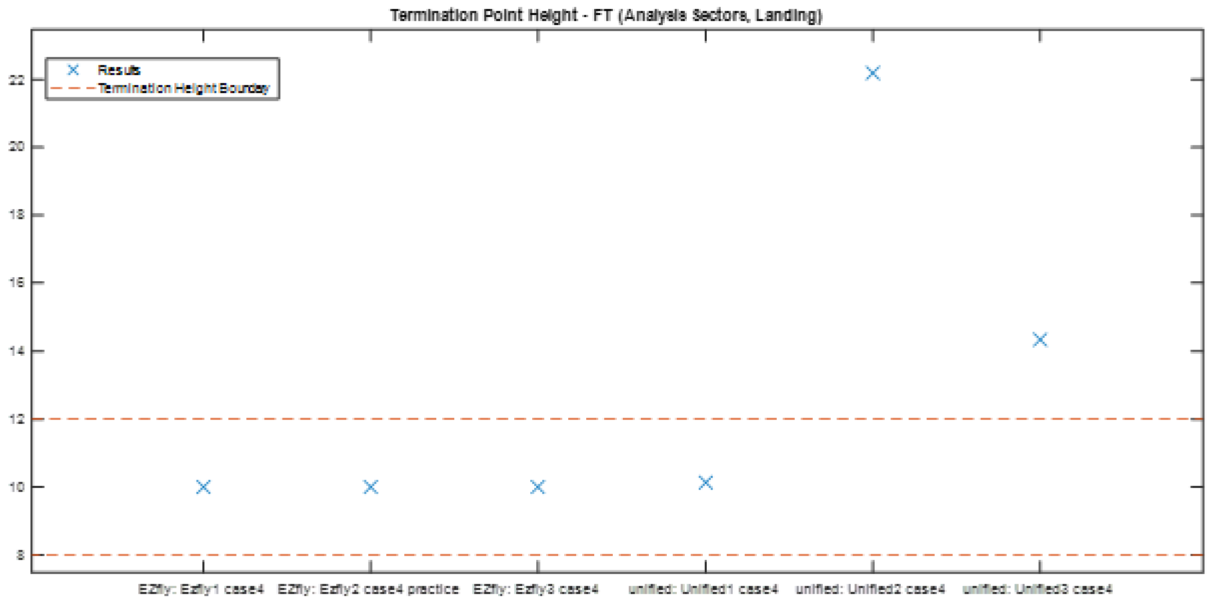

Figure 11. Instrument approach scenario termination point height

10.3.2 Hovering maneuvers—Task A: vertical takeoff and landing skills (CH.IV.A.S)

The hovering performance was also analyzed per FAA-S-ACS-16 Commercial Pilot for Rotorcraft Category Helicopter Rating ACS (FAA, 2023), Hovering Maneuvers, Task A, Vertical Takeoff and Landing (CH.IV.A.) Skills (S), provided in Appendix G. The analysis began when the operator reached the end point of the final approach. For the heading analysis, however, it started when the final hovering turn reached the target heading, which was defined as 360 degrees within a 5-degree margin. CH.IV.A.S1-4 and S7 were not applicable to this experiment. Because of the lack of reference to the exact location of the hover point, some analysis included both the performance during the whole hovering task and the performance when the vehicle was within a 25-ft circle from the hover point target. It was noted earlier that the setup of the experiment could cause a deficiency for all the GCS operators as the target and its boundary were not clearly marked or defined during the experiment. For the CH.IV.A.S5 requirement, the analysis used data starting when the vehicle first entered the 25-foot circle around the hover point after the approach. It continued until the vehicle exited that 25-ft circle for the last time. The minimum, maximum, mean and error values are plotted in Figure 12. Two Unified GCS operators had the same maximum value as the termination point height in the previous analysis, which means that the excursion only happened at the beginning. This event also caused an increase in standard deviation and average height during the analysis. There was no observable difference between the two sets of data. The results of the 25-ft circle data results showed an overall low standard deviation, indicating that altitude control was consistent and not difficult throughout the analysis. This result is reasonable based on the GCS setup, as both systems have altitude hold features under the hover phase of flight.

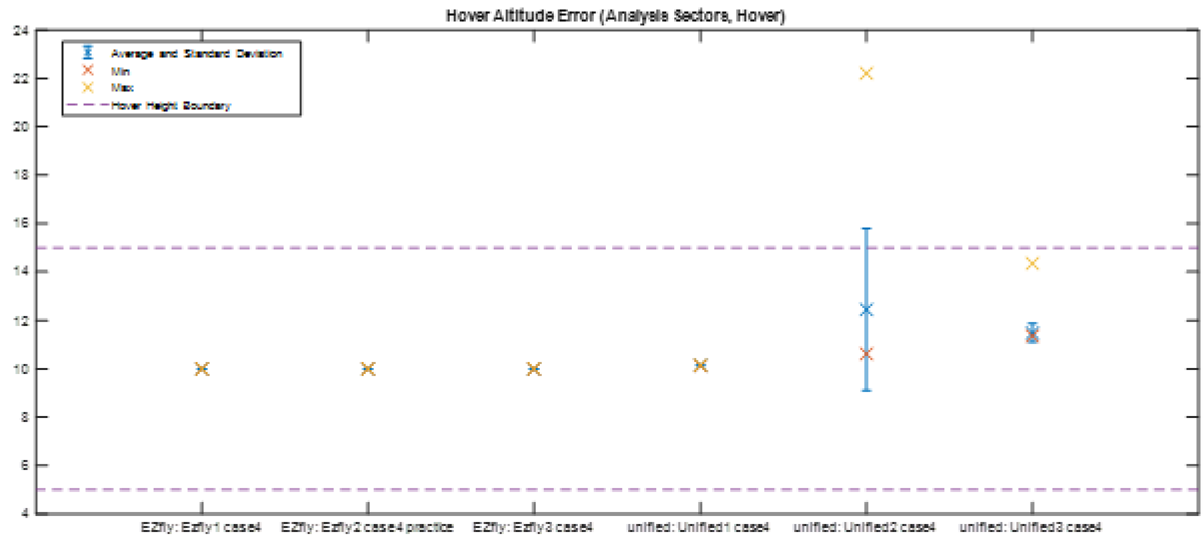

Figure 12. Instrument approach scenario hovering task altitude error, entire hovering maneuver

For the CH.IV.A.S6 requirement, the position of the vehicle was reviewed and analyzed . Figure 13 shows the data that was plotted from when the vehicle first entered the 15-ft circle from the hover point and stopped if the vehicle exited the 25-ft circle. The analysis relaxed the 2-ft requirement because none of the operators met this standard. The EZ-Fly GCS operators' results are generally concentrated at the same locationbecause the flight plan controlled the hover point, which generated a more consistent result. With further tuning of the automation software, the results could be improved. The Unified GCS results showed a more diverse time history, as it was controlled by each operator. Since there was no excursion from the 15-ft circle after the first entry, this result was likely caused by the lack of reference position instead of the lack of controllability of the vehicle. While it is likely that more pilot experience (i.e. more hours flying and more training time) would have produced better results, the point of the research was to determine if the subjects could produce adequate performance with very little training. CH.IV.A.S7 was skipped in this experience as the vertical controllability was analyzed during the final approach phase, and there was no task designed for this analysis during the hover phase of flight.

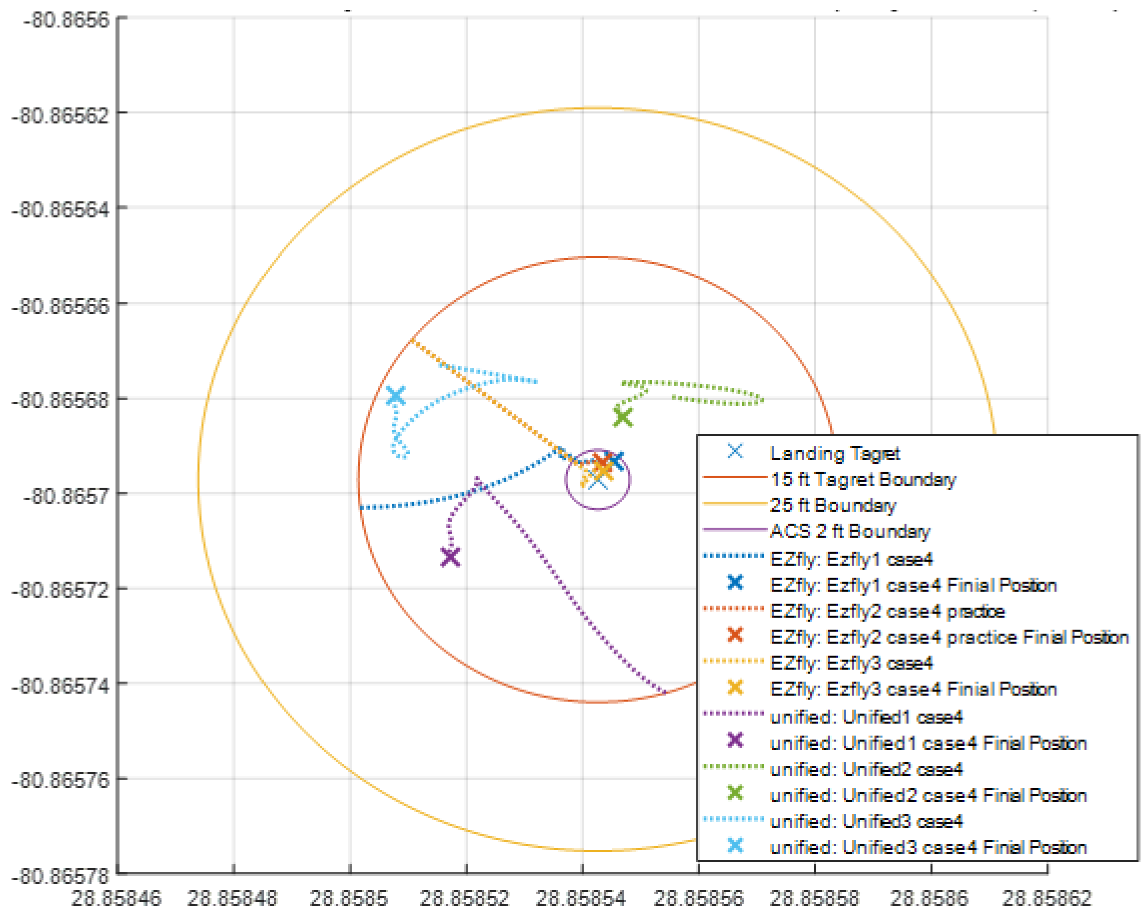

Figure 13. Instrument approach scenario hovering task position history

Figure 14 and Figure 15 show the analysis ofthe heading controllability during the hover under CH.IV.A.S8. Both plots consider the data when the operator captures the heading after entering the 5-degree heading boundary while maintaining a close to zero yaw rate. All operators required manual control to capture and hold the heading, and all operators were able to maintain the heading boundary with a noticeable amount of time. Thus, the heading standard deviation is shown to be low. Because the first and third Unified GCS operators chose to line up with the runway heading when approaching the termination point, the heading boundary entry was not recorded for their flights , which is shown as the minimum heading value for the other operators. The third Unified GCS operator had an additional heading change with overshoot after the start of the analysis for this task, but they never exceeded the required 10-degree window, as defined by ACS. Therefore, it is reasonable to conclude the controllability of the heading under hover for both GCSs satisfied the airmen certification requirements.

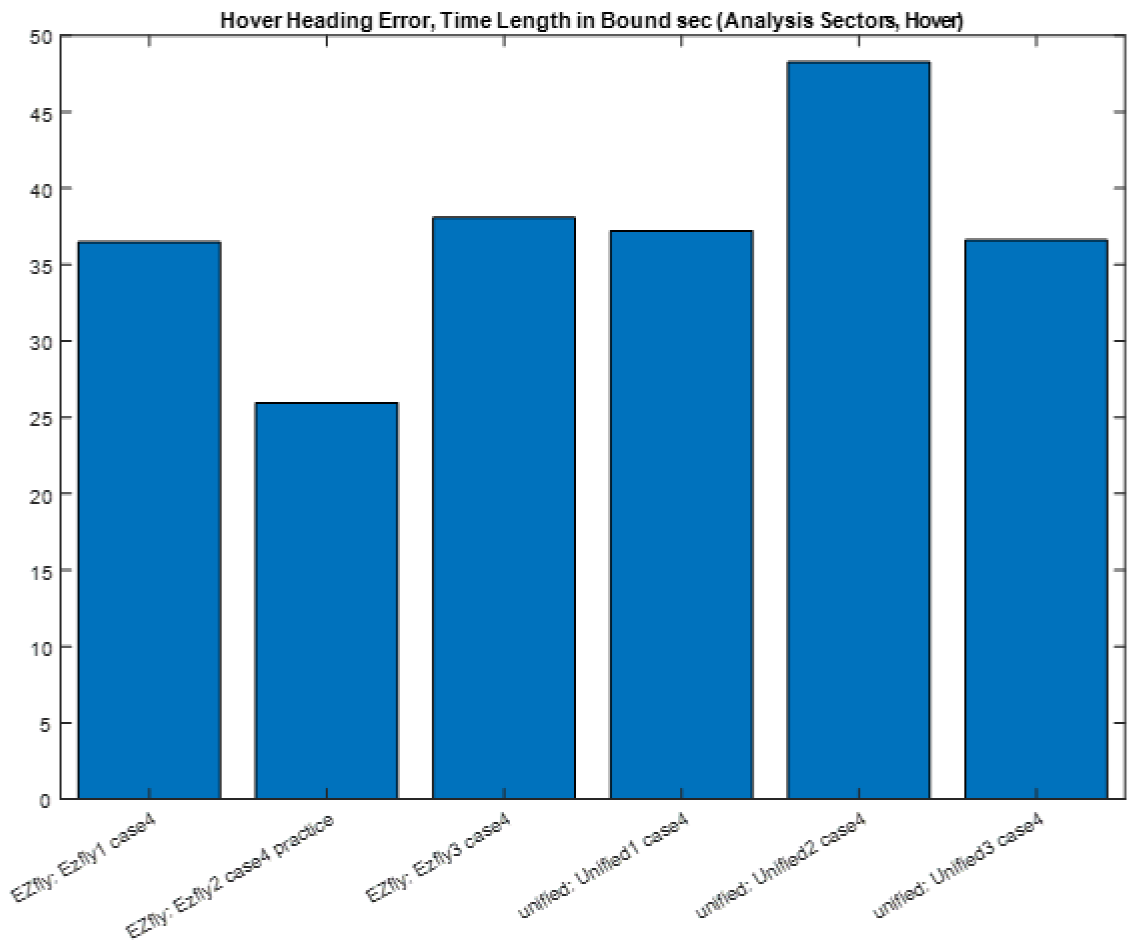

Figure 14. Instrument approach scenario hovering task—time spent inside the permissible heading error while maintaining heading

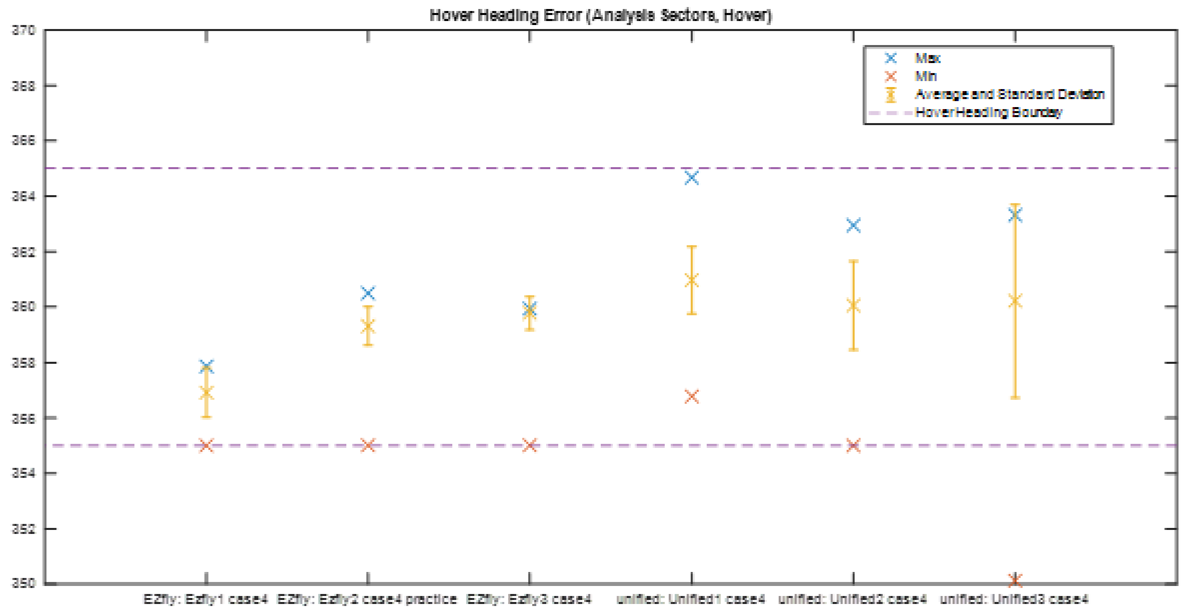

Figure 15. Instrument approach scenario hovering task: hold heading

10.4 Battery cooling failure

After the cooling system failure was triggered, every Unified GCS operator failed to land at the VTOL test site. It was observed that the current GCS failed to indicate the trend of the failure and when the system would fail completely. All operators acknowledged the yellow "Battery Temp" message and chose to turn toward the VTOL test site after they decided that the battery temperature situation would not improve. One operator actively communicated with the ATC and tried to quicken the approach as the temperature warning remained unfavorable. However, the decision-making time frame was beyond the 30-second window, and one operator clearly noted that they were expecting more time to return to the test site than they had. The results suggest that the Unified GCS operators were likely able to make proper aviation decisions during this emergency. However, the current setup for the warning system setup and system information, which were also critical for this emergency, might have negatively contributed to their failure in response—especially since the eVTOL vehicles included unfamiliar components like the battery system. None of the operators intentionally transitioned to hover during the emergency. Additionally, the operators did not fully anticipate and understand that the rotors had failed completely when the battery temperature reached 70 degrees Celsius. Here, the system automatically shuts off all the rotors to avoid a battery fire. In this case, a understanding of the system design and failure modes was lacking.

It may be important to note that two of the three Unified GCS operators had significant experience flying airliners that are certified under Part 25. For Part 25 aircraft, an amber indication is considered a caution, and a red indication is considered a warning. For these airplanes, a caution is defined as an abnormal situation that does not require immediate action but may need action in the future or may affect aircraft performance or safety margins. A warning is defined as an abnormal situation that requires immediate pilot action. Part 23 airplanes do not always follow this convention. For this experiment, the cooling failure indication started as a temperature trend that was not indicated in red until it was at a critical temperature. By the time the temperature was in the red, it was too late to successfully complete the flight.

All EZ-Fly GCS operators were able to return to the VTOL landing site without issue. The workload for the operator was observed to be low, and some of the operators actively made suggestions regarding the warning display during the emergency return conducted by the automation.

10.5 Battery pack failure

All the Unified and EZ-Fly GCS operators were able to return to the VTOL test site after noticing the battery failure. The Unified GCS operators acknowledged the red "Battery Fail" message, returned to the test site immediately, and landed in a CTOL configuration. Most operators noted that after reviewing the emergency time sequence and trend after the landing, they could probably select a longer CTOL approach so that they could conduct a more stabilized approach. It is probable that the decision-making process was impacted by the previous failed attempt during the battery cooling failure scenario. Some operators also noted that the GCS did not show the total time available under CTOL operation, which could also be applied to the battery cooling failure scenario. No action was needed for the EZ-Fly operators as the system conducted the emergency return, and all the EZ-Fly operators were able to return to the VTOL test site safely. One operator noted that they would like to know the nature of the cause of the emergency during the process, in addition to the emergency return message provided by the automation.

11 Task 10: Report findings

To ensure consistent communication and transparency throughout the project, findings were shared with the FAA through a structured reporting process. This includes biweekly telecom meetings to provide updates and address any emerging issues, quarterly reports summarizing accomplishments, upcoming plans, challenges, financial details, and revisions to the Project Plan, and technical or final reports prepared according to FAA-provided templates and timelines.

12 Conclusions

Based on research and experiments, the following conclusions were made:

1. The current private and instrument Part 61 and ACS or PTS should be used for core training for RPV pilots. The military has a successful history of training RPV pilots using this approach.
2. Skills and knowledge areas specific to RPV pilots discovered during this research should be added to current regulations. Additionally, skills and knowledge areas that do not apply to RPVs should be deleted from the current Part 61 and ACS or PTS for RPV pilots.
3. Automation levels have a significant effect on the required training. As automation takes over manual pilot tasks, it can significantly decrease the amount of training required. This change in training should be acknowledged in Part 61 and the ACS.
4. Aircraft and ground station certification rules should be adjusted to reflect advanced automation.
5. Operating rules should be adjusted to reflect RPV and advanced automation operations.
6. If changed, pilot certification, aircraft and ground station certification, and operating rules must be changed together. Changing one certification or rule to reflect automation levels will be ineffective if the other areas are not changed to reflect the same automation effects at the same time.
7. Any rules that apply to advanced automation or technology must be written to be performance based (only the desired outcome is specified), not design based (current solutions being codified) to avoid limiting technology development. Because of this, most rules identify a function and specify a design-assurance level driven by a hazard level associated with a failure of that function.
8. Current technology has already surpassed current pilot certification rules. For example, current rules require calculating weight and balance via the widespread use of W&B calculators and manually executing instrument approaches although there areAPs that are more reliable than humans.

9. Current technology can provide a level of automation that allows pilots to be trained in significantly less time than current traditional training. Safety considerations for pilots can be improved during normal and emergency operations if the technology levels and proper design assurance levels are provided.
10. As the automation level increases, the roles and training for remote and onboard pilots become nearly identical. Eventually, a passenger-carrying aircraft could be operated by someone with only basic ground instruction—whether they are in the cockpit or controlling it remotely.

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A Selection of features for simplified vehicle operations-A1 and -A2

This appendix provides discussion of the feature selection and the subject areas for instruction for simplified vehicle operation (SVO)-A1 and SVO-A2. Using data from Embry Riddle University (n.d.), Table A-1 shows a compilation of the subject areas that take the most instruction time.

Table A-1. Selection of features for SVO-A1 and SVO-A2

Ground:	**Legacy Hours**
Principles of aerodynamics, powerplants, and systems	17
Use of IFR en route and instrument procedure charts	6.5
IFR navigation and approaches	6
Recognition of critical weather situations from the ground and in flight, windshear avoidance, and the procurement and use of aeronautical weather reports and forecasts	5
Air traffic control system and procedures for instrument flight operations	5
Safe and efficient operation of aircraft, including collision avoidance, and recognition and avoidance of wake turbulence	4.5
Energy management, mast bumping, low rotor RPM, Low G hazards, and rotor RPM decay	2
Weight and balance computations	2
Most Burdensome Items Total: Ground	**48**

Flight:	Legacy Hours
Instrument approach procedures	25.5
Takeoff, landing, go-around	15
Performance and ground reference maneuvers	11.5
Flight by reference to instruments	10.5
Navigation	8
Hovering maneuvers	6.5
Navigation systems	3
Most burdensome items total: Flight	**80**
Ground and flight time of most burdensome items	**120**

IFR = Instrument flight rules
RPM = Revolutions per minute

A.1 Selection of SVO-A1 automation features

Subjects that require the most training timewere examined to determine if the current technology could be used to reduce the training time for these subject areas. Because the FAA needs operational data to move to a new level of automation to ensure that the new automation functions as intended over a range of conditions, only currently available technology was considered. In this context, currently available technology means that it is widely available commercially and is used routinely or that it is standard equipment on the entire fleet of at least one military aircraft. While commercial availability and routine use or experience in military aircraft provides the operational data needed, reliability and overall availability still need to be evaluated to make these technology levels certifiable and capable for pilot credit.

Reliability and availability are addressed in Appendix C.

Given the current availability and its potential effect on the training burden, the following were chosen as a minimum set of functions and features required for an automation SVO-A1 aircraft.

The expected effect on the training burden for each feature is summarized in Section A.12, Combined effects on training and training burden of SVO-A1 features.

1. Highly augmented vertical takeoff and landing (VTOL) control system (Unified)

    A Unified control system (UCS) mimics the Airbus or Falcon fly-by-wire (FBW) control system at airplane speed, but in VTOL flight it simplifies the control system significantly form that of a helicopter. The F-35B uses this control system.

2. Envelope protection

   All new aircraft currently delivered with a Garmin G1000® and a Garmin integrated autopilot (AP) have envelope protection.

3. Mandatory coupled instrument approaches

   Nearly all APs today have the capability to fly all published instrument procedures.

4. Automatic level flight (Level button)

   All new aircraft currently delivered with a Garmin G1000 and a Garmin integrated AP have a level button.

5. Automated flight planning

   Automatic flight plan generating programs are widely available on the internet and available for Electronic Flight Bags (EFBs). Nearly all pilots today use one or more of these tools to make flight plans. Most of them also file the flight plan when it has been created.

6. Automated weight and balance

   Automated weight and balance (W&B) calculators are available on the internet and available for EFBs. Nearly all pilots today use one of these to calculate W&B. Many new airplanes also have a W&B program built into the avionics.

7. Automatic systems limit control (i.e., torque, temperature, RPM, and air current

   While many older designs still require the pilot to control the engine or systems to stay within their limits, newer designs typically control these limits automatically (for instance on turbines, the pilot would control to a maximum temperature, rotational speed of the low-speed spool (N1), etc., but newer full-authority digital engine control (FADEC) engines control to these limits automatically.

8. Airport navigation and operations assistance

   All new aircraft currently delivered with a Garmin G1000® have Garmin SafeTaxi, which provides a moving map of the airport and the aircraft's location on it. Many other avionics manufacturers also have a similar feature.

9. Automatic Ground Collision Avoidance System (Automatic GCAS)

   Automatic GCAS is employed on all United States Air Force (USAF) F-16 aircraft with a proven record of preventing controlled flight into terrain.

10. Integrated synthetic vision, climb, cruise, descent (CCD) vertical navigation (VNAV) moving map and flight controls

    Synthetic vision along with a moving map and a navigator that is capable of lateral and vertical navigation (CCD VNAV) from just after takeoff to just before landing is standard in all new aircraft equipped with a G1000, Garmin AP, and Garmin auto throttle.

Note: the reference to Garmin equipment is not intended to be an endorsement of Garmin. It is referenced only to show that the functions are readily available for the target size and performance class of aircraft.

If this set of functions is made to be a part of an aircraft so that the availability and reliability is guaranteed to an appropriate certification level, then pilots would not need to learn the manual equivalent to these functions. The expected reduction in pilot training for these subjects that are the most burdensome would be as reflected in Table A-2.

Table A-2. Simplified vehicle operation-A1 automation features

Ground:	**Legacy Hours**	**Reduction**	**SVO-A1 Hours**
Principles of aerodynamics, powerplants, and aircraft systems	17	10	7
Use of IFR en route and instrument approach procedure charts	6.5	3	3.5
IFR navigation and approaches by use of navigation systems	6	3	3
Recognition of critical weather situations from the ground and in flight, windshear avoidance, and the procurement and use of aeronautical weather reports and forecasts	5	3	2
Air traffic control system and procedures for instrument flight operations	5		5
Safe and efficient operation of aircraft, including collision avoidance, and recognition and avoidance of wake turbulence	4.5		4.5
Energy management, mast bumping, low rotor RPM, Low G hazards, and rotor RPM decay	2	1	1
Weight and balance computations	2	1.5	.5
Most burdensome items total: Ground	**48**	**16.5**	**26.5**
Flight:	**Hours**		
Instrument approach procedures	25.5	6	19.5
Takeoff, landing, go-around	15	6	9
Performance and ground reference maneuvers	11.5	3	8.5
Flight by reference to instruments	10.5	1.5	9
Navigation	8	2	6
Hovering maneuvers	6.5	5	1.5
Navigation systems	3	2	1
Most Burdensome Items Total: Flight	80	25.5	54.5
Ground and flight time of most burdensome items	**120**	**42**	**81**

IFR = Instrument flight rules

Section A.2, Detailed SVO-A1 Automation Design Features provides a more detailed description and justification for each of the SVO-A1 automation functions.

A.2 Detailed SVO-A1 Automation Design Features

1. Highly augmented VTOL control system (Unified)
2. Envelope protection
3. Mandatory coupled instrument approaches
4. Automatic level flight (Level button)
5. Automated flight planning
6. Automated weight and balance
7. Automatic systems limit control (i.e., torque, temperature, RPM, and air current)
8. Airport navigation and operations assistance
9. Automatic Ground Collision Avoidance System (Automatic GCAS)
10. Synthetic vision with integrated CCD VNAV and a moving map

This section summarizes and discusses the major features of a level 2 automation aircraft. The control and display system are a significant part of the required standardization. Because of this, an aircraft certification requirement is recommended that defines an SVO-A1 aircraft as one that has at least the automation functions listed above.

A.3 Summary of SVO-A1 Feature 1: Highly augmented VTOL control system (Unified)

The SVO-A1 aircraft will have a flight control system modeled after the F-35B system. This system is commonly referred to as Unified. Its primary flight controls are arranged like those of a conventional airplane with a stick or wheel, throttle, and rudder pedals. In cruise flight, it is remarkably like a conventional airplane; in vertical flight, the controls operate more like an airplane than a helicopter. This is an FBW control system that is certified as flight critical. There is no manual backup mode.

In cruise flight:

- Longitudinal stick (wheel) position commands rate of change of vertical flight path.
- Lateral stick (wheel) position commands roll rate.
- Throttle position commands acceleration.
- Pedal position commands sideslip angle.

In vertical flight:

- Longitudinal stick (wheel) position commands vertical speed.
- Lateral stick (wheel) position commands lateral speed.
- Throttle position commands longitudinal speed.
- Pedal position commands turn rate.

Justification and background

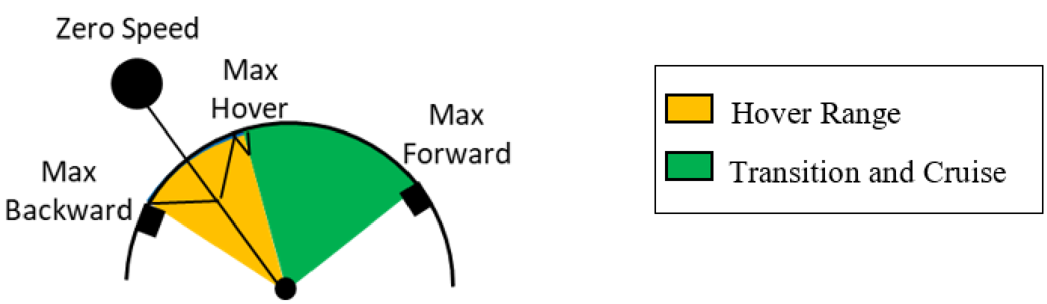
The physics of VTOL vehicles indicate that without augmentation, an aircraft is neutrally stable to unstable in hover. This means that if it is disturbed, it will continue the disturbed path without a tendency to return to the original condition or will diverge exponentially. These disturbances come from wind gusts and sometimes from the aircraft's own wake. Thus, to hover a VTOL aircraft, the pilot must make continuous corrections to maintain both attitude and position. Hovering a helicopter is one of the most difficult tasks to learn. To significantly reduce training burden for the SVO-A1 aircraft, a highly augmented control system is required. Since the SVO-A1 aircraft is intended for pilots who already know how to fly mechanically controlled airplanes, the highly augmented vertical flight control system should transition to a control system familiar to existing airplane pilots. The military faced this problem with the Harrier as they recognized that the Harrier had an unacceptable accident rate due to VTOL operations and that it was difficult to learn to fly the Harrier in VTOL operations. To solve this problem, the military developed a control system that is commonly referred to as Unified. The UCS was adopted for the F-35B Joint Strike Fighter. The UCS operates in a manner that is like a mechanically controlled aircraft that is always in trim while in forward flight but transitions to VTOL operations using a scheme much different than a conventional helicopter. The UCS is summarized below. Note the unique left-hand inceptor (throttle) positioning and detents.

The flight control system for vertical flight is much different than for a conventional helicopter, but it is patterned after the flight characteristics of a fixed-wing airplane. Therefore, airplane flight training provides skills to help pilots transition to an SVO-A1 VTOL pilot. The flight control system for fast-forward flight is similar but not identical to a conventional airplane. The differences are intended to allow a smooth transition from VTOL operations to fast-forward flight operations. Note that there is no longitudinal trim. This is because speed stability is throttle based (like an airplane with auto throttle), not elevator based. Thus, the aircraft is always in trim longitudinally (releasing the stick results in one G flight, and the aircraft holding the current flight path angle). Table A-3 and Figure A-1 illustrates the control inceptor mapping.

Table A-3. Unified input/output mapping

	Hover	**Transition**	**Fast Forward**
Stick (control wheel) fore and aft	Rate of climb, centered holds altitude	Blends from hover commands to fast-forward commands	Flight path rate (G loading), centered holds one G and current vertical path
Stick (control wheel) left and right	Lateral speed relative to earth, centered holds position laterally	Transitions from lateral speed command to bank angle command then transitions to roll rate command as the aircraft accelerates past Vref for a run-on landing	Roll rate, centered holds current bank angle
Speed Command Lever	Longitudinal speed relative to earth, spring loaded to zero speed	Blends from ground speed commands to airspeed commands	Airspeed, friction hold
Pedals	Yaw rate centered holds heading	Blends from hover commands to fast forward commands	Sideslip centered commands zero body axis lateral acceleration

Vref = Reference speed



- Lever is spring loaded to zero speed when below max hover speed

Figure A-1. Unified input/output mapping

Discussion

The driving principles for an SVO-A1 control system are to:

1. Dramatically simplify vertical operations by using fixed-wing pilot skills.
2. Control the aircraft in a way familiar to fixed-wing pilots during fast-forward flight.
3. Dramatically simplify hovering operations as compared to a helicopter.
4. Transition from hovering operations to and from fast-forward flight in an intuitive manner.

<u>Fore and aft motion of the stick (wheel)</u>

In a conventional airplane, moving the stick fore and aft directly changes the elevator position, which in turn changes the angle of attack of the airplane. In fast-forward flight, this movement changes the G loading, which in turn changes the vertical flight path. Therefore, fore and aft positioning of the stick commands G loading. Since the rate of change of flight path angle times true airspeed equals G loading, this control can also be considered as commanding the rate of change of the vertical flight path. Centering the stick commands one G or no flight path change. When the commanded flight path is near zero and the stick is centered, the SVO-A1 system assumes the intent is to hold altitude. Therefore, when the stick is centered and commanding near level flight, the SVO-A1 system holds the current altitude. In fast-forward flight, the SVO-A1 control system works like a conventional airplane for longitudinal movements.

If power is held constantly, an increase in the vertical flight path causes the airplane to slow down, and a decrease in the vertical flight path causes the airplane to speed up. As it does this, the weathervane tendency of the elevator of a conventional airplane causes a change in the elevator hinge moment which is felt in the stick as a force due to speed change. This is known as static longitudinal stability and is the source of trim changes with airspeed. Thus, a conventional airplane has speed stability provided through the elevator weathervane tendency. This couples the flight path and speed together. However, at high speed, small changes in elevator surface produce large changes in G loading so that at high speed, flight path can be controlled mostly through the stick and speed mostly through the throttle. The SVO-A1 control system provides speed stability through the throttle (see throttle below), so the speed does not change due to changes in flight path. Therefore, there is no need for trim changes, because this system remains in trim.

During slow flight in a conventional airplane (such as during final approach), changing the elevator changes the angle of attack, resulting in only a small change in G loading. As a result, the flight path and airspeed become more closely aligned. Pilots learn to control speed through the elevator, and flight path through the throttle. Thus, for a conventional airplane at high speed, the stick primarily controls flight path while the throttle primarily controls speed; but at low airspeed, the roles of the stick and throttle are reversed. The SVO-A1 control system decouples flight path from speed and preserves this decoupling at all speeds. Although this is not the same as in a conventional airplane, training experience in Airbus airliners and F-35B have shown that experienced pilots adapt well to this change.

As the aircraft slows to zero speed, the flight path angle no longer applies or becomes meaningless. However, vertical speed is very similar to flight path angle so as the aircraft slows, the longitudinal stick position changes from commanding a change in flight path angle (same as rate of climb at a constant airspeed) to rate of climb. This makes transitioning from a conventional airplane to a VTOL capable aircraft easy for fixed-wing pilots.

Left and right motion of the stick (wheel)

In a conventional airplane, moving the stick left and right directly changes the aileron position, which causes a roll rate. Centering the stick results in nearly zero roll rate. There is no bank stability—the pilot must continuously make corrections to keep from banking. The SVO-A1 control system preserves the characteristic of moving the stick causing a roll rate, and centering the stick reduces the rate to near zero, except that the SVO-A1 system provides bank stability by controlling to the current bank angle when the stick is centered. Thus, the airplane pilot should not notice any difference between the conventional airplane and the SVO-A1 aircraft in roll; however, the SVO-A1 aircraft remains at the pilot-commanded bank angle when the stick is centered instead of wandering as a conventional airplane does.

In hover, a conventional helicopter's lateral stick position commands roll rate. This integrates to bank angle, which causes a tilt in the lift vector; this creates a lateral acceleration, which then integrates into lateral speed and then position. These steps create a significant lag between the stick position and the change in position. One of the most time-consuming tasks in learning to fly a helicopter is learning to hover. Part of this is caused by this control lag. Another part is caused by the fact that all the axes are coupled in a conventional helicopter. The SVO-A1 control system decouples all axes and changes the roll rate command into a transitional speed command (TRC), with centered stick holding lateral position relative to the ground—thus significantly simplifying the control in hover.

Given that in hover, the lateral stick commands lateral speed, and in fast-forward flight it commands roll rate, there needs to be a transition path. The transition path is that as the aircraft accelerates, it changes from commanding lateral speed to commanding bank angle and then finally commanding roll rate. The bank command stage should only last a few seconds. The intermediate bank angle stage is needed because if the pilot is holding lateral position during hover before a takeoff in a crosswind, the stick will be centered, and the aircraft will be banked into the wind to hold that position. As the aircraft accelerates, if it transitions directly to roll rate command, then it will hold the hovering bank angle through and after the acceleration since the stick would be centered through the acceleration. The result would be a turn with the stick centered as the aircraft accelerates. With the bank command transition stage, as the aircraft accelerates, with the stick centered, it goes to bank command mode, which reduces the bank to zero then to roll rate command. The roll rate command holds the bank at zero, and the result is a straight takeoff. The reverse occurs on landing. Assume that the aircraft is doing a vertical landing with a crosswind. On the approach, it is crabbing into the wind to hold the desired track relative to the ground. The pilot is holding the stick in the center laterally since there is no roll rate. As the aircraft transitions to the bank command phase, the centered stick still commands zero bank; but as the aircraft slows to transition to the hover mode, the aircraft banks into the wind automatically to continue the ground track as the aircraft slows to zero forward speed.

Speed command lever

In a conventional airplane, the throttle controls power or thrust. From a stabilized condition, moving the throttle forward a set amount causes the airplane to accelerate until it reaches a new stabilized speed. In the SVO-A1 aircraft, the position of the speed command lever commands only speed, not power, thrust, or acceleration. At the aft stop, the lever commands the maximum rearward speed. There is a detent at the maximum forward speed at which the control system is fully in hover mode. The zero-speed command position is between the aft stop and the detent. The lever is spring loaded between the aft stop and the detent to the zero-speed position. Forward of the detent, the lever has friction to hold it in position. The forward stop commands maximum speed.

In the hover range, the lever commands ground speed. As the lever is moved forward of the detent, the position of the lever commands airspeed. The lever position vs. commanded speed is scaled so that at the high speed end, the minimum speed increments are 5 kt when above 250 kt and 2 kt above 200 kt. This allows more precision at low speeds while still commanding a large speed range for aircraft capable of large speed ranges.

When there is wind, blending of airspeed and ground speed must occur when in the transition region (the lever position just forward of the detent). The transition must occur based on groundspeed to prevent getting stuck in airspeed mode when in high winds.

The speed command lever is back driven like a current auto throttle so that when the flight plan changes speed, the throttle position matches the flight plan speed. If it is not back driven, the following situation can occur:

1. The pilot engages the AP at cruise, the AP executes an approach and is at approach speed.
2. The throttle lever is commanding high speed, but the aircraft is at low speed.
3. The pilot disengages the AP to execute a slow circle-to-land maneuver, but the throttle immediately goes to full power to try to accelerate the aircraft to the commanded speed.

Pedals

In a conventional airplane, the rudder pedals command sideslip angle in flight. The SVO-A1 control system does this just like a conventional airplane. However, many airplanes with more sophisticated yaw-damping systems coordinate turns, damp Dutch roll, and automatically trim the airplane due to power effects (torque and P-factor). The SVO-A1 control system will do these things, too. Therefore, the aircraft generally flies with the pedals centered. Sideslip is desired for crosswind takeoff and landing flare. This is accommodated through the pedals by producing the required sideslip. Another way to think of the operation of the SVO-A1 pedals in fast-forward flight is that they are a lateral acceleration command. Normally, the system works to zero the lateral acceleration, but the pilot can intentionally create a lateral acceleration by moving the pedals out of the centered position. Note that a sideslip creates a lateral acceleration.

During taxi in a conventional airplane, the pedals are used to steer (command a turn radius and turn radius times speed equals turn rate). In the SVO-A1 control system hover mode, the position of the pedals commands the turn rate. This should be familiar to fixed-wing airplane pilots, since it is like taxiing an airplane—except that in hover, the SVO-A1 aircraft can turn without moving. A helicopter also uses the pedals to turn in hover, but a helicopter is unstable in this axis and is very susceptible to small changes in wind. Also, in a helicopter, all the axes are coupled so that any change in one control causes the helicopter to turn. The SVO-A1 aircraft is stabilized with respect to the ground such that if the pedals are centered the aircraft holds the current heading.

Display and avionics system

The display and avionics are similar to today's glass cockpits. A G1000 NXi or similar avionics system with these capabilities meets the requirements of an SVO-A1 aircraft.

Making the SVO-A1 display and avionics interface similar to today's glass cockpits is to reduce the training transition burden for current fixed wing pilots. In addition, a system like the Garmin

G1000 NXi has all the capabilities required for SVO-A1. However, the reliability may need to be upgraded – especially the AP actuator system since the current designs typically have a single actuator per axis and the requirement to have all published instrument procedures done by coupling to the AP will likely require dual actuators.

A.4 Summary of SVO-A1 Feature 2: Envelope protection

SVO-A1 aircraft will have, as a minimum, protection against:

- Stalls
- Departure from controlled flight including spins
- Overbank
- Overspeed
- Under-speed
- Settling with power
- G loading
- Flight conditions where a failure would result in a catastrophic event
- Powerplant or systems exceedances
- Excessive sideways and rearward speeds for VTOL operations
- Sudden or extreme control inputs.

Justification and background

Loss of control is the single largest cause of accidents. Loss of control typically occurs because of a stall, disorientation due to inadvertent flight into instrument conditions, loss of airspeed awareness, and high workload that results in excessive bank. The disorientation and overbank also often result in the pilot pulling too many Gs at high speed, which then results in structural damage. For vertical flight, settling with power is also a cause of accidents while conducting landings to confined areas.

While these are primarily safety features, they each represent a hazard for which the pilot must be trained. Training includes recognition of the factors that lead to a hazardous situation, proper procedures to avoid the hazard, and recovery from the onset of the hazard. In most cases, the pilot is required to demonstrate recognition and recovery of the hazard during the flight check. Thus, together they represent a significant training burden.

Discussion

Existing envelope protection is often implemented as a barrier, such as a pusher or bank limiter with a stop. These kinds of protections require training so that the pilot recognizes the barrier and responds correctly to it. SVO-A aircraft need envelope protections that are integrated into the flight controls so that they limit aircraft motion smoothly and in a way that does not create a control discontinuity.

In addition, the envelop protections in SVO-A aircraft need to be prioritized so that they work together. This is especially true when two or more protections are active at the same time and may prompt conflicting control input. An example of this is when an overspeed condition occurs at high speed while in a bank. The aircraft may pull up to prevent the overspeed and the G protection may push down to limit G loading. But the best response may be to reduce the bank and then pull up.

A.5 Summary of SVO-A1 feature 3: Coupled instrument approaches

All published instrument departures, arrivals, and approaches will be executed coupled to an automatic flight control system. This includes instrument landing system localizer (LOC), very high-frequency omnidirectional range station (VOR), and area navigation (RNAV) approaches with or without vertical guidance. When the published procedure does not include vertical guidance, the automation will generate it. For approaches with step-down fixes, the automation will generate a continuously descending vertical path that honors the step-down fixes. Aircraft certification credit for the pilot flying the approach will not be allowed for SVO-A1 aircraft. If the pilot takes no action during the approach, the automation will execute a missed approach at the missed approach fix and fly the published missed approach (or as directed by the flight plan).

Justification and background

As shown by Table A-1 learning to fly instrument procedures is by far the costliest items (14 CFR §61.65 (b)(4) (Instrument rating requirements, 2025) and Airplane Instrument ACS item VI and Helicopter Instrument PTS Item VI (FAA, 2023)). These items require approximately 10 hours of ground training and 18.5 hours of flight training out of a total of 40 required hours of flight training for the airplane. In addition, the helicopter addition requires 5 hours of ground training and 10 hours out of a total of 15 required hours of flight training for the helicopter add-on. This is also consistent with the instrument knowledge requirements for both airplane and helicopter.

Current technology has already provided the functionality for this. Nearly all current production Federal Aviation Regulations (FAR) Part 23 airplanes have an AP capable of coupling to any approach procedure or other published procedure with a lateral path as standard equipment. However, the man/machine interface to correctly couple to a procedure may be different between aircraft and may not be as intuitive as needed. To reduce the training burden and reduce the potential for pilot error, it is recommended that SVO-A1 aircraft be required to automatically execute all published procedures that contain a lateral path and those that use global positioning system (GPS), VOR, or localizer as the primary navigation source. This includes approaches with step-down fixes and approaches that require an outer marker. It does not include approaches that require an automatic direction finder (ADF). The pilot of an SVO-A1 is still required to take off and land.

Discussion

The flight controls are certified to a level appropriate for a catastrophic event. The navigation receiving system is the same regardless of whether the pilot can control the aircraft. For the pilot to control the aircraft, there must be a mechanism to convert navigation signals to a display; the pilot must interpret the display and make control inputs to follow the information on the display. For the coupled system, there must only be a mechanism to convert the navigation signals to flight control commands. This mechanism bypasses the display, pilot, and inceptor. Therefore, it improves reliability by eliminating the potential failures of the display and the pilot (the inceptor may still be required to allow an intuitive mechanism to abandon the approach). Also, history has shown that the pilot is the least reliable link in this system and eliminating pilot control therefore eliminates the risk of pilot error. Also, to significantly reduce the training burden for instrument approaches, pilots must not be required to learn to fly instrument approaches manually. Thus, for SVO-A1 aircraft, aircraft certification credit for a pilot manually flying the approach after a failure is not allowed.

A.6 Summary of SVO-A1 feature 4: Automatic level flight (Level button)

When disoriented, the pilot can take a single action, such as pressing a button, and the aircraft will go to straight-and-level flight at the current airspeed (or position if near hover) and stay there until the pilot commands a change.

Justification and background

One of the leading causes of loss of control accidents is pilot disorientation—especially in instrument conditions and in turbulence. While unusual attitude training is typically not one of the more difficult or time-consuming tasks to learn, basic attitude flying in instrument conditions (and by extension, unusual attitude recovery) is a skill that seems to deteriorate rapidly when not practiced. It is also a skill that when needed must be done quickly and correctly the first time. The envelope protection systems prevent the aircraft from having an accident, but the level button can reduce workload, increase confidence, and generally allow the pilot to conduct the flight in a safer way.

Discussion

This feature has been certified in several aircraft already and has proven effective. However, it is not required in any aircraft and there is no requirement associated with its reliability today.

A.7 Summary of SVO-A1 feature 5: Automated flight planning

Given the departure and destination, the automatic flight planning feature SEARCHES appropriate weather information and plans the flight. The output will be:

- Suggested routing
- Distance to the destination
- Time to the destination given likely winds
- Suggested altitude
- Forecast weather at the departure for the proposed time of departure
- Forecast weather at the destination for the time of arrival
- A suggested alternate if one is required
- Forecast weather at the alternate for the time of arrival
- Fuel/energy reserve
- Notices to Airmen (NOTAMs) that may affect the flight
- Output in a format suitable for filing a flight plan

The system includes takeoff and landing performance compared to airfield characteristics, the effect on energy reserves of an attempted VTOL landing and go-around at the destination (if a conventional landing is possible given the aircraft and destination), as well as a VTOL landing at the alternate. If there are insufficient energy reserves, the system splits the flight into legs as appropriate for refueling stops.

This system is built into the aircraft and available on portable devices that need not be co-located with the aircraft.

Justification and background

Preflight planning is one of the areas that takes the most ground training time. Experienced pilots generally use various electronic flight planning programs to calculate the time, fuel, and distance of flight, including the effect of winds. Many of these same programs also connect to online weather reporting and forecast sources to obtain current and forecast weather, then use this information to suggest alternates. Some of these programs also look at historical air traffic control (ATC) clearances and predict a likely routing if not direct. These programs or services are not standardized nor controlled or monitored by the FAA, and therefore, the FAA cannot assume that they will be available or contain specific functionality. Because of this, the pilot trainee must learn to gather the required information from FAA-approved sources and calculate the time fuel and distance with likely winds, then determine if an alternate is required, and if so select an appropriate one.

Ironically, the student pilot must spend significant time and effort to learn how to obtain the appropriate information and then plan a flight, but the experienced pilot rarely uses the same skills again.

The technology exists today to plan a flight automatically as described above. Fuel starvation and inadvertent flight into bad weather are significant causes of accidents. These accidents are typically the result of inadequate preflight planning.

Discussion

The purpose of automated flight planning is to standardize the automated functions that are currently available in various forms and formats in current flight planning software. This will enable the FAA to take credit for the use of these features in determining that the pilot (or the aircraft) considered all appropriate flight planning information. If it is automated, the pilot does not need to learn how to obtain aeronautical weather information, learn its symbology and abbreviations, learn how to interpret it, and then learn to use this weather information to make flight planning decisions. The information is all available online and a set of rules for making aeronautical decisions can be reduced to algorithms (these decision-making rules are already taught to student pilots).

Pilot advisories can also be presented to the pilot in a human-centric form as opposed to raw data form. For instance, obtaining pilot reports (PIREPs) from FAA sources results in a series of cryptic abbreviations—many of which are not relevant to the flight. The automation can filter the PIREPs to those appropriate for the flight and decode them into pain text.

Additionally, weather information that may be marginal for the pilot's experience or aircraft equipment can be identified using plain text.

A.8 Summary of SVO-A1 feature 6: Automated weight and balance

The aircraft will have some means of calculating weight and balance (W&B) before takeoff and landing. This functionality must be a part of the aircraft but may also be housed in a remote device. At a minimum, this feature may require the pilot to enter the weights of passengers and baggage and assign them specific locations such as a seat location or baggage compartments. It is recommended that the W&B be done automatically without pilot action. Examples include fitting load cells to the landing gear and installing a load cell(s) on a boarding step that is used as passengers board the aircraft. The aircraft will not take off without a satisfactory W&B check.

Justification and background

Calculating W&B is one of the preflight preparation items that cause problems for new pilot — especially pilots who are not strong in math. The current procedure is for the pilot to calculate moments, add the weights and moments to get a total of each of these, and then either look up the moment on a graph or use the total moment and total weight to calculate a center of gravity (CG). The calculated center gravity is checked against a graph or table of CG limits. There are many tools available to automate this, but since none are mandated to be available to the pilot, the pilot must learn to do the calculations manually.

This feature is required to reduce the training burden and to reduce errors in W&B calculations.

Discussion

Many avionics systems delivered in today's general aviation aircraft include this feature. There are also many applications on the internet and various in-flight planning software packages that contain this feature that are widely accepted and used by pilots today. By requiring this feature in SVO-A1 aircraft, it becomes a standard capability, allowing the FAA to remove the need for pilots to learn and be tested on manual W&B calculations using traditional methods.

A.9 Summary of SVO-A1 feature 7: Automatic systems limit control

Automatic systems limit control provides automatic control over an aircraft's systems to prevent exceeding component and system limits. This includes environmental, propulsion, control, power generation, and any other system or component. With automatic systems limit control, the pilot does not have to monitor and provide control for critical systems, such as temperature, pressure, and rpm, to prevent components or systems from exceeding their limits.

Justification and background

Today, the largest ground training burden for pilots is learning aerodynamics, powerplant, and systems operation. A reason for requiring knowledge of powerplant and system operations is that today, the pilot can operate an aircraft in such a way as to exceed the aircraft's limitations and therefore, the pilot becomes an integral part of the control system that prevents damage to the aircraft. If the systems and components protect themselves, then the pilot is no longer part of the control loop and does not need to understand system limitations or how the system works. is the automated systems limit control also provides a system safety aspect because the system cannot be damaged by pilot error or neglect.

Discussion

Current aircraft often require the pilot to manually control the powerplant to prevent exceeding system limits. For example, in jet engine operations, there are N1 limits. A pilot must manually control the engine speed to prevent exceeding this limit. In fixed-pitch propeller airplanes, a pilot must reduce power in a descent to avoid exceeding the engine speed limit. In helicopter autorotation, the pilot is required to manage rotor RPM while descending to a landing spot. In turboprops, the pilot is required to control engine torque to prevent exceeding a limit and finally in turbocharged airplanes the pilot must manage mixture or power to avoid exceeding the turbine inlet temperature. Many other examples exist.

Although there are many possible SVO-A1 aircraft configurations, all are expected to operate in a similar manner from the pilot's perspective. To both reduce the training burden and to standardize operations, it is highly desirable to not have the pilot as part of the control loop for the purpose of managing its systems—especially because of the variety of aircraft with different types of systems.

Current aircraft under development use batteries, fuel cells, piston or turbine engines to drive generators, and other means to produce electricity. This electricity powers electric motors using various techniques that drive fixed pitch, variable pitch, rotors, lift fans, or a combination of those elements. If a pilot is expected to be able to fly an aircraft with any of these systems and be part of the control loop for the system, then the training burden becomes large (as it is currently). However, if the power generation and propulsion/lift systems all manage themselves with limits, then the pilot need not understand how they work. This will reduce the training burden and eliminate pilot error. This is not a new principle. A modern automobile provides a good example of this principle. The driver does not need to know about the engine, transmission, or any other system to drive the car. This is because in today's cars these systems take care of themselves.

In SVO-A1 aircraft, an override switch may be needed for abnormal operations that change the limits. There may also be dynamic limits based on time or other parameters. In some cases, the aircraft may allow a limit exceedance and then require maintenance because of the exceedance.

A.10 Summary of SVO-A1 feature 8: Airport navigation and operations assistance

Airport navigational and operations assistance tools are electronic systems that assist pilots by providing real-time information about their aircraft's position, route, and surrounding environment, helping to reduce workload, improve situational awareness, and enhance flight safety. For example, a moving map is a type of automated navigational aid that displays the aircraft's current location on a digital map, updating continuously to show the aircraft's progress and relevant geographic features. When operating on an airport or helipad, the moving map automatically changes to ground mode (it can be manually switched to flight mode temporarily). In ground mode, the map depicts the aircraft and its heading on a map that is optimized to show ground features such as taxiways, runways, landing zones, parking areas, preferred routes, obstacles, passenger loading/unloading areas, and refueling/charging stations.

Also, the moving map highlights areas of high-traffic density, areas where traffic converges at angles that may not be obvious, and areas where transitions from ground to flight operations occur (including runways). When there are places that require a clearance to enter that area (such as a runway), a conspicuous indication of this taxi limit is displayed. The indication is removed when the pilot acknowledges that a clearance to enter this area has been received.

At the pilot's discretion, a magenta line may be used to indicate the taxi route. The taxi route may be generated by entering the taxiways from a taxi clearance, or the system may automatically generate a route at the pilot's request. The second option is particularly useful during night operations when the tower is closed or there is no tower.

The system detects and alerts the pilot when the aircraft is preparing to land and is approaching a spot other than a normal landing spot. The system also detects and alerts the pilot when beginning a takeoff from an inappropriate location.

Justification and background

Airport and ground operations are one of the more confusing types of operations to learn. There are many signs and rules to learn. Runway incursion is also one of the areas that is constantly on the FAA accident/incident list, which can be mitigated via a moving map that raises a pilot's situational awareness.

Discussion of SVO-A1 feature (8)

This functionality is currently provided by most major avionics companies today.

A.11 Summary of SVO-A1 feature (9): Automatic ground collision avoidance system

An Automatic Ground Collision Avoidance System (Automatic GCAS) is a function built into the flight control system that monitors the aircraft's flight path relative to the ground and calculates escape paths to avoid hitting the ground. When the last available escape path has a minimum ground clearance pad, the Automatic GCAS system takes control of the aircraft and prevents a crash.

Justification and background

Controlled flight into terrain (CFIT) is the second highest cause of accidents in general aviation. This system will prevent most if not all these accidents.

Discussion

Unlike the other SVO-A1 features (except for the control system), Automatic GCAS is not widely available in the current market. However, Automatic GCAS is a significant safety feature and as such is required for SVO-A1 as an advisory feature. Because it is an advisory feature, the pilot is allowed to override this function. Including Automatic GCAS in SVO-A1 is expected to generate enough operational data such that it can be included in SVO-A2 as a required feature without pilot backup.

Automatic GCAS has been deployed on the entire USAF F-16 fleet and has been credited with several saves where system took over at the last second and saved the airplane from flying into the ground. It has been developed by NASA for retrofit onto general aviation aircraft, but this requires integration into the flight control system and thus far has not been integrated into any production general aviation systems.

A.11 Summary of SVO-A1 feature 10: Synthetic vision and a moving map

Synthetic vision is a stylized, forward-looking picture of what the pilot would see out the windshield. It is styled to eliminate ground features that are not of interest to the pilot (e.g., vegetation and houses) but emphasize those that are (e.g., obstacles and runways).

Moving map refers to a map that depicts the aircraft along with surrounding aviation-related features to scale in relation to the aircraft. The aircraft symbol remains relatively fixed while the map moves relative to the aircraft. The view is from the top.

This refers to synthetic vision and moving map displays as installed on most glass cockpit airplanes currently delivered. The Garmin G1000 and similar systems are examples of this.

Justification and background

Synthetic vision and moving maps have both demonstrated a significant reduction in pilot workload for navigation and terrain avoidance—especially in instrument conditions.

Discussion

Currently, these systems are certified as advisory only with no certification credit given for their use. Thus, these systems cannot be used legally for primary guidance by the pilot. The pilot must use other certified means of navigation (usually centering needles that indicate deviation from the intended path) for primary navigation. This requirement ensures that synthetic vision and a moving map are certified for use as primary guidance systems. This eliminates the need to use deviation needles for navigation and the need to learn how to interpret them.

A.12 Combined effects on training and training burden of SVO-A1 features

See Appendix D for the combined effect of these features on Part 61 and the Airman Certification Standards (ACS).

Expected effects on the training burden for SVO-A1 (1 through 10)

Table A-4 shows the estimated training reduction for the private pilot, instrument, helicopter, and helicopter instrument add-on ratings that require the most training time. The legacy training time values come from Appendix D. The estimated reduction in training time for the SVO-A1 aircraft comes from personal experience by the authors who are both flight instructors and the results of experiments conducted in flying aircraft and simulators with pilots and non-pilots using the

SVO-A features (see Appendix I). Only the items with the highest training burden are considered here. There are many other areas that take less training time and are not considered here but would also benefit from SVO-A1 features. Note that the total times listed are only those associated with the items that have the highest burden, they do not represent the total training burden.

Table A-4. The expected effect of SVO-A1 automation features on training burdens

Ground	**Legacy Hours**	**Reduction**	**SVO-A1 Hours**
Principles of aerodynamics, powerplants, and aircraft systems	17	10	7
Use of IFR en route and instrument approach procedure charts	6.5	3	3.5
IFR navigation and approaches by use of navigation systems	6	3	3
Recognition of critical weather situations from the ground and in flight, windshear avoidance, and the procurement and use of aeronautical weather reports and forecasts	5	3	2
Air traffic control system and procedures for instrument flight operations	5		5
Safe and efficient operation of aircraft, including collision avoidance, and recognition and avoidance of wake turbulence	4.5		4.5
Energy management, mast bumping, low rotor RPM, Low G hazards, and rotor RPM decay	2	1	1
Weight and balance computations	2	1.5	.5
Most burdensome items total: Ground	**48**	**16.5**	**26.5**
Flight:			
Instrument approach procedures	25.5	6	19.5
Takeoff, landing, go-around	15	6	9
Performance and ground reference maneuvers	11.5	3	8.5
Flight by reference to instruments	10.5	1.5	9
Navigation	8	2	6
Hovering maneuvers	6.5	5	1.5
Navigation systems	3	2	1
Most burdensome items total: Flight	**80**	**25.5**	**54.5**
Ground and flight time of most burdensome items	**120**	**42**	**81**

A.13 Selection of SVO-A2 automation features

Most SVO-A1 automation features are currently already in use by pilots, and those that are not, such as Unified controls and Automatic GCAS, have been readily accepted by pilots transitioning to them. This combination of automation features is intended as an incremental step, allowing pilots to maintain the skills needed for mechanically controlled airplanes and traditional six-pack flight instrumentation.

The SVO-A2 automation features are intended to build on the SVO-A1 functions but move beyond the limitations of mechanical controls and six-pack flight instruments to a human-centric design that is not encumbered by these features.

Given the data about training burdens presented in Tables A-1 and A-2, the following were chosen as a minimum set of functions and features required for an SVO-A2 aircraft, in addition to the SVO-A1 functions. .

1. Human-centric integrated control, display, and navigation (EZ-Fly VTOL)

    This is a control system in which the pilot commands the flight path and speed. There are no attitude or engine power displays since they provide no value and would clutter the controls. The controls command the same thing no matter what the speed.

2. Complete automation of preflight planning and in-flight replanning due to internal and external factors

    The aircraft controls preflight and in-flight planning, and the pilot inputs only the destination. If there is an in-flight emergency or weather change that requires a change in routing or destination, the aircraft automatically reworks the flight plan.

3. Automated ATC communications

    ATC communications are done via text-to-speech and speech-to-text. The pilot does not talk to or listen to ATC. The pilot may initiate communications via text or graphics. A voice link is available for emergencies or off-nominal communication. ATC operations are unchanged from current procedures.

4. Automated takeoff and landing for commercial and vertical takeoff and landing (CTOL and VTOL, respectively) operations

    Takeoff and landing skills are difficult to learn and are the cause of most loss-of-control accidents. Automating these procedures reduces the training burden and improves safety.

5. Automatic barometric pressure setting

    This is related to the automated flight planning and replanning function. Automated weather, including the barometric pressure setting, is required for the planning function; but in some instances, it is provided by ATC via voice. Automatic barometric setting was not included in the SVO-A1 functions.

6. Automated Aircraft Collision System

    This is like the Automatic GCAS function in the SVO-A1 function set but includes traffic as well as terrain and obstacles. It requires sensors to reliably sense other aircraft.

7. Automatic failure protection (e.g., engine out, communications failure, system failures)

    This function automatically executes emergency or abnormal procedures for all emergencies and abnormal conditions that are normally identified in the Flight Manual. It also identifies the nearest safe landing zone as appropriate and flies the aircraft to that place if that is part of the emergency procedure.

8. All flights are done under Instrument Flight Rules (IFR) on a valid flight plan with a clearance

    Many of the more difficult regulations that a pilot must learn have to do with operations under Visual Flight Rules (VFR) (e.g., airspace and cloud clearance). When operating under IFR many of these more complex rules are not applicable.

A.14 Detailed SVO-A2 aircraft design features

SVO-A2 (1): Human-centric integrated control, display, and navigation (EZ-Fly VTOL)

SVO-A2 (2): Complete automation of preflight planning and in-flight replanning due to internal and external factors

SVO-A2 (3): Automated ATC communications

SVO-A2 (4): Automated takeoff and landing for CTOL and VTOL operations

SVO-A2 (5): Automatic barometric pressure setting

SVO-A2 (6): Automated Aircraft Collision System

SVO-A2 (7): Automatic failure protection (e.g., engine out, communications failure, and system failures)

SVO-A2 (8): All flights are done IFR on a valid flight plan with a clearance

A.15 Simplified vehicle operation-A2 control concepts considerations

SVO-A1 is intended for pilots of airplanes with conventional controls and conventional instrumentation (either round dials or tapes). Therefore, when operating in forward flight at speeds similar to airplanes, the displays and control responses for SVO-A1 are nearly identical to that of conventional airplanes. SVO-A2 is not constrained by conventional control or display paradigms. It takes advantage of the capabilities allowed by FBW and computer graphics to create a human-centric integrated cockpit. Many concepts have been studied to simplify flight vehicle operations. The EZ-Fly concept is noteworthy has a history of NASA human factors design as well as multiple flight test program.

In the 1980s, NASA developed a control system for general aviation airplanes called EZ-Fly that commands the flight path vector directly. The simulator studies of this system showed that even with no training, people with no flight experience could maneuver and fly a simulated airplane using this system to Airline Transport Pilot (ATP) performance standards in instrument conditions—including on an instrument approach (Stewart, 1994). In the 1990s, this system was flight tested and demonstrated the same results as the simulation studies (Duerksen, 2003).

These experiments verified that when manually controlling an aircraft, inexperienced pilots want to control where the aircraft goes along with its speed, not its attitude, attitude rate, or acceleration. Based on these experiments, it was determined that the SVO-A2 flight control system would map the inceptor position to the vehicle's flight path vector, not attitude or attitude rate in fast-forward flight.

Although not originally developed for VTOL aircraft, the EZ-Fly concept has been expanded to include VTOL and short vertical takeoff and landing (SVTOL) operations.

The inceptor motion to vehicle motion mapping remains constant throughout the entire flight envelope. Since the pilot commands the flight path vector instead of aircraft attitude, the EZ-Fly VTOL control concept is the same for all aircraft types and is therefore applicable to all types independent of the physical means of lift or control. For example, a multi-copter may accelerate from hover by pitching forward to tilt the lift vector so that the aircraft accelerates forward; on the other hand, a lift-plus-cruise aircraft may remain level, and a separate propeller may provide thrust to accelerate forward. From a hover, the pilot commands either vehicle to accelerate; however, the multi-copter pitches forward to accelerate, while the lift-plus-cruise vehicle accelerates in a level attitude. In both cases, the pilot input is the same, and the effect on the aircraft's long-term velocity vector is the same even though the attitude time history of the two aircraft is different. The EZ-Fly VTOL concept is independent of aircraft design and configuration.

It is recognized that the primary purpose of an SVO-A2 aircraft is transportation. When used as a transportation machine, cruise flight and approaches are typically done coupled to a navigator. Thus, the most common manual control task for the SVO-A2 aircraft is preparing for takeoff, after landing, and positioning on (or near) the ground. Therefore, emphasis is given to control during these operations.

Using lessons from EZ-Fly leads to a control system with the following general characteristics for a powered-lift aircraft.

- A steering wheel commands turn rate. At speed, a turn naturally results in a bank, much like a bicycle.
- Moving the wheel in or out commands climb or descent rate. Alternatively, or in parallel, this function can be through a thumb switch or thumb wheel on the steering wheel.
- A joystick commands lateral speed.
- The same joystick commands longitudinal speed. The longitudinal position behaves like a power control, like the gas pedal on a car. It momentarily adjusts speed relative to the commanded speed when near the commanded speed. This also has the effect of increasing or decreasing acceleration.
- Primary speed control is via a knob or wheel—or though the navigator. The commanded speed is always displayed.

Previous work done by the authors indicates that conventional flight instruments are not needed with an EZ-Fly control system, and learning to interpret conventional flight instrumentation is therefore also not needed (Duerksen & Martos, n.d.). For instance, there is no need for an attitude indicator nor is there a need for the pilot to learn to interpret an attitude indicator since the control system controls attitude—not the pilot as is the case with a conventional control system (or an SVO-A1 control system). Thus, a display designed to work with the EZ-Fly control system is appropriate.

Previous work by the authors also indicates that integrating the navigation system with the controls and display makes a better overall system for new pilots to learn when navigation is recognized as a primary task, as opposed to an afterthought. Therefore, the SVO-A2 aircraft will have an integrated navigation, display, and flight control system as opposed to traditional and SVO-A1 aircraft where these three parts are separate functions with their own pilot interfaces.

A.16 Summary of SVO-A2 feature 1: Human-centric integrated control, display, and navigation (EZ-Fly VTOL)

The SVO-A2 aircraft has an integrated navigation, display, and control system. Since the primary function of the SVO-A2 aircraft is transportation, controlling the aircraft along a flight plan is the primary means of control. Takeoff and landing are automated and are therefore part of the integrated system. The aircraft is required to have a valid flight plan (as described by the automated flight planning function for the SVO-A1 aircraft and contains a landing with appropriate reserves) before it will allow a takeoff. The pilot may change the flight plan (either before or after takeoff) but may not change it to one that is not valid.

Some SVO-A2 aircraft may be VTOL only and may not have the ability to taxi on the surface. For these aircraft, hover taxiing is used to maneuver on the ground. Thus, the SVO-A2 aircraft control system has a means to hover taxi by directing the velocity vector and speed of the aircraft relative to the ground directly. In some instances, the navigation system may become unavailable during flight. When this occurs, the pilot may control the velocity vector directly. The pilot also can take over control of the velocity vector for evasive maneuvers, but the flight plan is still active and before the point where the aircraft cannot land at a valid landing zone, the automation takes over and lands on a landing zone.

The display contains two parts—a forward-looking synthetic vision display with real time obstacles blended with the synthetic features and a moving map display. The synthetic vision display is flight path centric (except at very low speed when it is heading centric) and contains a flight path marker along with elements of the flight plan including relevant waypoints (WPTs). It also includes commanded airspeed and altitude. The moving map display includes a horizontal and vertical depiction of the flight plan with speeds as well as a present position and direction symbol (typically a plan view of the aircraft).

The aircraft is coupled to the flight plan at takeoff. The pilot may take direct control of the flight path by moving the steering wheel. The pilot may recouple to the original flight plan by maneuvering such that the flight path marker is on an element of the flight plan in the forward-looking synthetic vision display and centering the steering wheel.

The pilot must always (except in an emergency) indicate that the landing zone is suitable for landing. If the pilot does not indicate this, the aircraft will execute a missed approach and suggest alternate landing zones (including the original one first).

In the event of an emergency, the pilot may manually control the aircraft to a landing that may not be at a landing zone recognized by the aircraft (via directing the velocity vector and speed). However, the aircraft will still protect against a hard landing that may injure the occupants.

All flights will be conducted under IFR. This eliminates the need for the pilot to learn and understand the restrictions associated with the various airspace classes and VFR. Because of the features of the SVO-A2 aircraft, the SVO-A2 pilot does not need instrument flying skills to fly in instrument meteorological conditions (IMC). Therefore, there is no need for the SVO-A2 pilot to avoid IMC. Because of this, the SVO-A2 pilot rating is also an SVO-A2 instrument rating (IR)—a VFR-only SVO-A2 pilot does not exist.

Justification and background

The Harrier and the F-35B have similar configurations and use similar powered-lift technology. Based on the experience of the Harrier, the military determined that for safety and pilot training purposes, a new and simplified flight control scheme was required for the F-35B. The result was the UCS. The development of UCS clearly showed the effect on safety and training requirements that an advanced control system can provide. The NASA-funded EZ-Fly experiments went further with control system augmentation designed for people with no previous piloting experience. These systems have not been placed in production aircraft in part because a different set of skills is required to fly aircraft with these systems, and there is no path to gain these skills and obtain a pilot license appropriate to these skills (unlike the military that develops and operates its own training and pilot qualification programs).

Historically, aircraft control systems were developed based on what could be done mechanically to control the aircraft. Pilots then adapted to the control system to fly the aircraft. Given the capability of FBW control systems to create nearly any imaginable control system, this historical paradigm is turned around and starts with what the human wants to control and then adapts the aircraft to the human.

Primary flight instrumentation also evolved based on the information the pilot needed to control the aircraft based on the historical control system. Navigation systems have historically been separated from the controls and primary flight instrumentation – and the human interface to the navigation systems has evolved with the evolution of electronic screens, making navigation systems developed a few years apart very different regarding their man/machine interface.

Since the SVO-A2 aircraft can start from basics and use FBW and computer graphics technology, the best known human-centric control system for airplanes was chosen (EZ-Fly). That system was then modified using concepts from the myCopter project (École Polytechnique

Fédérale de Lausanne (EPFL)) for VTOL aircraft, an integrated navigation system, and a display system to create the EZ-Fly VTOL concept.

The intent was to create a control/navigation/display system that makes it as easy as possible for a pilot with no previous piloting experience to learn to operate a CTOL and/or VTOL aircraft as a transportation machine in near all weather conditions.

Discussion

The driving principles for the SVO-A2 control/navigation/display system are

1. Start with human control objectives and adapt the aircraft to them.
2. Integrate navigation into the control system since navigation is the primary objective of control.
3. Integrate pilot displays to provide the information needed given these objectives.

Discussion of SVO-A2 navigation system

Navigation is the primary purpose of controlling the aircraft from the pilot's perspective (the FBW system controls the attitude and stabilizes the aircraft). Therefore, navigation is central to the control scheme. It is expected that most flights will be conducted while coupled to the navigation system. The only part of the flight that is normally not coupled to the navigation system is repositioning on the ground, primarily before takeoff and after landing.

Like with the SVO-A1 navigation system, the SVO-A2 system can couple to any published procedure. The SVO-A2 navigation system also can create approaches in real time considering terrain, weather, local routing preferences and traffic constraints. These approaches may be used initially in visual flight conditions where the pilot can see obstacles and take evasive action manually. As experience is gained with these systems, these aircraft-created approaches may be used in IMC to increase traffic flow to equal traffic volume in VFR conditions.

The navigation system also can follow another aircraft.

The navigation system has the required leg types to follow any reasonable ATC clearance, both vertically and laterally.

The accuracy is consistent with fully automatic landings as normal operations.

The navigation system and the control system are integrated so that following the flight plan is the default mode of operation, and it takes a conscious pilot action to manually command the flight path vector.

Discussion of SVO-A2 control system

The control system is integrated with the navigation and display systems. The aircraft must have a valid flight plan and IFR clearance to fly that flight plan before it will take off. When the pilot authorizes takeoff, the aircraft automatically couples to the flight plan. Thus, the default control mode is coupled.

The pilot must take action to uncouple or deviate from the flight plan. The pilot does this by manually commanding the flight path vector through the manual control system. While commanding the flight path, the pilot may recouple to the flight plan by putting the flight path marker that is on the synthetic vision display on an element of the flight plan, which is also displayed on the synthetic vision display and releasing the controls.

On landing, the controls automatically slow the aircraft to taxi speed or hover just above the landing spot and pauses a few seconds for the pilot to take over manual control (by moving one or more controls). If the pilot does not take over manual control to maneuver off the runway or landing zone the aircraft stops on the runway or sets down on the landing zone.

When operating on the ground (either hover taxiing or taxiing on wheels), the control mapping to vehicle motion is the same except that some axes may be constrained (for instance, a wheeled machine may be constrained to not being able to translate sideways or turn with zero speed).

The manual control system consists of:

- A steering wheel that turns.
- The steering wheel moves in and out, or there is a thumb wheel or switch on the steering wheel.
- A climb/descent hold button if the wheel moves in and out.
- A joystick commands longitudinal and lateral speed.
- A primary speed control knob or wheel.

These vehicle responses are the same independent of speed. Table A-5 shows the control mapping for the SVO-A2 system.

Table A-5. Control mapping for SVO-A2

Vehicle Motion	**Pilot Control**	**Comments**

Turn	Steering wheel rotation	Spring loaded to center. Centered holds track above about 25 kt ground speed and heading less than about 15 kt ground speed.
Climb/descend	Steering wheel fore/aft or thumb wheel or up/down switch on wheel Climb/descent hold button if no up/down wheel or switch	Spring loaded to center. Centered holds altitude. Pressing the thumb wheel or switch commands altitude hold. Pressing the climb/descent hold button locks the wheel climb/descent position. Pressing it again releases it. Moving the wheel in or out releases it.
Longitudinal speed target	Knob or wheel	First motion syncs to the current speed.
Longitudinal speed adjustment	Longitudinal movement of joystick	Momentarily modifies the speed target which also affects the acceleration rate. Centered does not modify the speed command and uses the default acceleration rate which is proportional to speed error.
Lateral speed	Lateral movement of joystick	Commands lateral speed. Centered commands coordinated flight and zero lateral speed.

In normal conditions, takeoffs and landings are done automatically. However, the automation may not be able to identify all potential hazards or obstacles related to takeoff and landing. Therefore, the pilot is required to provide final approval for takeoff and landing using a button or other means for authorization. This button will be conspicuous when authorization is required.

<u>Discussion of SVO-A2 display system</u>

The display system is integrated with the navigation and control systems. Since the primary purpose of the SVO-A2 aircraft is navigation and the only means of manual control is by controlling the flight path directly, the display is flight plan and flight path centric. It consists of two screens:

1. Forward-looking synthetic vision/enhanced vision display
2. Moving map display

Note that there are no attitude indicator, airspeed or altitude tape, vertical speed indicator, magnetic compass, or course deviation indications. Also, there are no powerplant displays as a part of the basic SVO-A2 aircraft since the aircraft is required to manage all powerplant related functions automatically. However, this does not prevent the addition of any displays that the manufacturer deems appropriate if they do not interfere with the forward-looking synthetic vision and moving map displays.

Forward-looking synthetic vision/enhanced vision display

The forward-looking synthetic vision display is flight path centric—meaning that the flight path marker is always in the center of the screen. The exception is at very low speeds.

The background of the screen is a synthetic depiction of the terrain and obstacles. Enhanced vision is incorporated into the background and displays real-time obstacles at short range for takeoff, landing, and ground operations in limited visibility. Since takeoff and landings are done automatically, very low visibility minima can be used. However, the system needs to know if the landing area is clear of other aircraft, vehicles, people, and other obstacles that are not part of the obstacle database. The pilot makes this determination on landing by authorizing the system to land. The pilot uses the enhanced vision part of the display or actual visual contact with the landing area before making this authorization. The presence or quality of the enhanced vision system combined with the landing and takeoff speed and profile will determine visibility minima.

The flight plan are shown as a series of hoops and if needed, translucent connecting corridors. The hoops have appropriate information, such as altitude, speed, and name of waypoint.

The commanded airspeed and commanded altitude are displayed digitally. The actual airspeed and altitude are displayed next to the commanded airspeed and altitude when the airspeed and altitude are not within control tolerances. There is also an indication next to these displays to indicate whether the commanded parameter is from the flight plan or from direct pilot input. Touching either of these opens a keypad that the pilot can use to enter a new commanded value.

The top of the display contains a status bar that indicates the control mode (e.g., manual, coupled to the flight plan)

Moving map display

The moving map display has two parts—the plan view and the profile view. Both views are displayed continuously and show the present position in relation to the flight plan.

The plan view has a compass ring around the present position symbol. The pilot may touch this ring at any heading and after acknowledgment, the aircraft will turn to and hold that heading.

The moving map is oriented track-up, which orients the map to how the ground appears beneath the aircraft, as a power on default. It may be changed to other orientations though manual selection or application of a pilot profile.

The profile view displays terrain and obstacles along the flight plan when coupled to the flight plan (the path may curve) and along the current flight path when not coupled (always straight ahead). A clear indication is shown to differentiate between coupled and uncoupled display modes.

Both views clearly display terrain and obstacles that are near or intersect the flight path.

There is always a means available to open the flight plan with a single pilot action. When the pilot opens the flight plan, any entry can be changed by touching it and entering new information, using a cursor control device, or other interface.

Effect on certification requirements of SVO-A2 feature (1)

See recommended Special Condition Unmanned Aerial Vehicle (UAV) 23.2730 in Appendix B for details concerning the EZ-Fly VTOL control system.

Effect on training (Part 61 and ACS/PTS) of SVO-A2 feature (1)

See Appendix E for the effect of the flight control system on the on Part 61 and the Airman Certification Standards (ACS).

Expected effect on training burden of SVO-A2 feature (1)

Simulator experiments conducted by NASA showed that when using the EZ-Fly control system and a synthetic vision display with a pathway that non-pilots with very little or no training could fly an airplane in simulated instrument conditions including an ILS approach to a level similar to an ATP using conventional controls and flight instruments (Stewart, 1994).

Demonstrations of the EZ-Fly system in a Beech Bonanza with conventional instrumentation and a moving map display showed that non-pilots with no training could fly an actual airplane through aggressive maneuvers including steep turns, maximum performance climbs and descents and then self-vector onto a circling approach with step-down altitudes and maneuver to a runway 90 degrees to the approach path at the minimum descent altitude (Duerksen, 2003).

Further flight experiments and demonstrations in a Ryan Navion equipped with the EZ-Fly system and a display/navigation system optimized for the EZ-Fly control system showed that non-pilots with no training could fly the airplane through aggressive maneuvering as demonstrated in the Bonanza. The non-pilots were also able to easily navigate and couple to a flight plan leg (Duerksen & Martos, n.d.).

The EZ-Fly control system was expanded to include vertical flight, called EZ-Fly VTOL. It was coupled to a simulation of a flight vehicle with airplane characteristics in forward flight and helicopter characteristics in vertical flight. In addition, simulator studies with non-pilots found that in the span of a few minutes, the non-pilots could hover, takeoff transition to airplane mode, navigate, transition back to vertical mode and then back to a hover over a spot and land (Duerksen & Martos, n.d.). .

Effects on operations (Parts 91 and 135)

Since the SVO-A2 aircraft takes-off and lands automatically, the traditional ceiling and visibility requirements for instrument approaches may be reduced significantly without the need for special training or currency.

A.17 Summary of SVO-A2 feature 2: Complete automation of preflight planning and in-flight re-planning

The SVO-A2 aircraft have a built-in function that works like today's automotive navigation functions. This function can identify the current location, and the pilot can enter the destination via text, voice, or identifying a location on a map. The system uses the functionality developed for the SVO-A1 flight planning feature to create a flight plan. The flight plan is transmitted to ATC when appropriate. During the startup procedure, the system automatically requests an ATC clearance. This may be via text-to-speech if required. When a clearance is delivered, the aircraft enters that clearance as a flight plan. When required, the clearance is received via voice and converted to a digital format. The pilot is not normally involved in this conversation. However, the pilot retains the ability to communicate with ATC via voice if needed.

If a change to the flight plan is required in flight, either due to a pilot action, such as changing the destination, or a system-detected change, such as weather or a malfunction, the aircraft re-plans the flight, notifies the pilot of the proposed change, and displays the change graphically. After pilot approval, the aircraft requests the change from ATC and implements the ATC-approved change to the clearance. The pilot may also communicate with ATC directly via voice if required. If the automated flight planning system cannot provide an appropriate clearance, the pilot may deviate from the clearance in the flight plan by directly commanding the flight path as described in the control section.

Since SVO-A2 aircraft normally operate under IFR, the flight plan generated by the SVO-A2 flight planning application, contains a suffix appended to the aircraft model identifier that indicates this flight is an IFR-only flight. See UAV 23.2730 in Appendix B for more details.

Justification and background

Flight planning has one of the largest time requirements in the current training curriculum. This is an extension of the SVO-A1 automated flight plan feature. It is intended to further reduce the pilot training burden by further automating the flight planning task.

Discussion

The SVO-A1 automated flight planning feature is intended as a work reduction tool for the flight planning task. For SVO-A1, the pilot is still actively involved in the details of the flight plan. Using the experience for SVO-A1, the SVO-A2 automated flight planning feature moves to the next step and does the actual flight planning. The only function required of the pilot is final approval. Because the pilot does not do the actual work to develop the flight plan, there is no need for the flight planning feature to have a remote component.

This feature is intended to work like automotive GPS navigation—the driver gets in the car and tells the navigator where they want to go, and the navigator determines a route while considering traffic, road construction, toll roads, and other hazards. To ensure that the navigation device is always available, it is built into the aircraft. A mobile device that can do the flight planning is not prohibited; however, it is not required.

This feature also adds ATC communication (see Section A.18) to the flight planning feature. Understanding ATC clearances is an area that requires training and practice. Mistakes are often made because it involves two-way radio connection with considerable background noise.

Pilots are taught about aeronautical decision-making, including risks as conditions change—particularly weather conditions. Pilots are usually trained to develop personal minimums that are more conservative than published minimums based on their skill and currency. However, there is no standard about how to determine these. The accident database has many examples of pilots exceeding their personal capabilities in weather that should have been avoided. The re-planning part of this feature constantly monitors weather and aircraft condition, and suggests a change based on rules consistent with the aircraft's capabilities. Since there is little pilot skill required, the aircraft capabilities are the driving factor and can be determined in advance, thus making in-flight decision making a fact-based exercise.

Expected effect on training burden of SVO-A2 automated flight planning

Automated preflight reduces the required training to near zero. The pilot goes to the application and enters the departure and destination airports. The application calculates an appropriate route given weather, terrain, and airspace. The time energy and distance required are then calculated and compared to the aircraft's capabilities and performance. The application does the required aircraft performance calculations and files the flight plan. W&B is calculated when the pilot enters the weights in the appropriate locations using the aircraft specific application.

There is no need for the pilot to know about aviation weather products, and how to decode them. There is also no need for the pilot to know about NOTAMs or PIREPs since these are automatically retrieved and incorporated into the flight planning process automatically.

<u>Effect on operations (Parts 91 and 135) of SVO-A2 automated flight planning</u>

This feature has no effect on operations.

A.18 Summary of SVO-A2 feature 3: Automated air traffic control communications

The SVO-A2 aircraft will automate nearly all ATC communications. Initial clearance requests and requested clearance changes are completed automatically . Frequency changes are also done automatically so that the aircraft is always on the appropriate ATC frequency.

Text-to-speech and speech-to-text will be used as needed when direct digital communication – (Controller-Pilot, Data Link Communication [CPDLC]) is not sufficient.

The ability for the pilot to communicate directly with ATC via voice is retained.

<u>Justification and background</u>

For new pilots, communication with ATC is difficult, time consuming to learn, and intimidating. The pilot must learn the phonetic alphabet along with new aeronautical terms. Waypoint names are often not pronounced like they are spelled. Radio sound quality can be challenging—especially when near the edges of reception— and noise in an aircraft can be high. These barriers to effective communication cause miscommunications, especially among new pilots.

<u>Discussion</u>

For this research, it is assumed that ATC-to-pilot communication will remain as is—i.e., using radios that are manually tuned to different frequencies and voice-based communications.

Communication from ATC is very structured and uses very standard phraseology, which makes translating ATC speech to text a plausible technology for aircraft. Once in textual (electronic) form, the aircraft's systems can decode it and propose an action to the pilot for approval. When approved, the aircraft can formulate an appropriate textual response back to ATC and then convert that text-to-speech and transmit it to ATC. Of course, where there is CPDLC available, this technology can be used instead of converting speech-to-text and text-to-speech.

Some routine ATC communications, such as frequency changes, may be conducted in a completely automated manner without pilot involvement. Other communications like clearances may be completely graphical from the pilot's perspective.

Because unforeseen events sometimes occur, there is a means by which the pilot can talk directly to ATC in English (or an appropriate other language).

Effect on certification requirements of SVO-A2 automated ATC communications

Although there is no recommended regulation concerning automated ATC communication, this feature is required of the SVO-A2 aircraft.

The SVO-A2 aircraft has speech-to-text and text-to-speech integrated into the communication radios such that frequency changes are handled seamlessly for the pilot without pilot action. Clearances are proposed to the pilot in graphical form. The pilot may approve them or modify them graphically. If approved, the system generates a speech string and transmits that to ATC. If modified, the system creates a speech string and transmits that to ATC as a request. Generally, the pilot does not communicate verbally with ATC. However, a provision is made for a free-form conversation if needed.

Expected effect on training burden of SVO-A2 automated ATC communications

With automated ATC communications, pilots do not need to learn the phonetic alphabet and many phrases that are unique to aviation. This not only reduces ground training time but also reduces flight training time spent on other tasks, because the pilot is interrupted less often by ATC communications.

Notably, because pilots may not need to talk to ATC for normal operations, the requirement to understand and speak English may be deleted. They must only be able to understand and speak the local language where they fly and understand and speak English when flying outside of the area where their local language is spoken. This significantly reduces training for pilots who do not know English. ATC controllers would still need to understand, read, and speak English so that they can communicate with pilots from outside the local area.

Effect on operations (Parts 91 and 135) of SVO-A2 automated ATC communications

The details of the effect on operations of automated ATC communications is yet to be determined.

A.19 Summary of SVO-a2 feature 4: Automated takeoff and landing for conventional and vertical operations

In normal operations for SVO-A2 aircraft, takeoffs and landings are done automatically. This includes VTOL and CTOL operations.

Typically, the pilot maneuvers the aircraft into position to takeoff and to authorize takeoff. The aircraft will couple to the flight plan, takeoff, and follow the flight plan.

Approaches are conducted automatically—including visual approaches—and the landing done automatically. As the aircraft approaches the landing zone, a window of time opens in which the pilot must approve the landing. If the pilot does not approve the landing, a missed approach is executed at the missed approach point (MAP). Note that for the SVO-A2 aircraft, the MAP may be significantly closer to the ground than a published procedure MAP. This is because the MAP for an SVO-A2 aircraft is based on the final approach speed and the aircraft's ability to transition to a missed approach. Since the landing is accomplished automatically, there is no need for the pilot to acquire visual references and then transition from flying by reference to instruments to flying by reference to visual cues. However, it is recognized that the landing zone may be contaminated in such a way that the aircraft cannot detect the contamination. The pilot is required to visually acquire the landing zone and verify it is clear before landing. For some operations, a ground observer can verify that the landing zone is clear and communicate that to the pilot who then authorizes the aircraft to land without seeing the ground—thus providing for landings with zero visibility.

For VTOL operations, the aircraft hovers over the intended spot and pauses. If the pilot does not take over control during a short pause, it will land. The pilot may take manual control and taxi away from the landing spot as required. For CTOL landings, the automatic system will bring the aircraft to taxi speed at a deceleration rate consistent with the runway length and desired taxiway intersections. The pilot may take control at taxi speed or if the pilot takes no action the aircraft will stop on the runway.

The pilot may take over control and direct the aircraft path to a landing spot in an emergency; however, the actual landing is automated, which is considered an abnormal condition.

Justification and background

Landing is one of the most difficult tasks for pilots to learn. It is also the task that is most often involved in loss of control accidents. Loss of control accidents are the most common type and are usually the result of pilot error. Controlled flight into terrain (CFIT) is the second most common type of accidents. To prevent these accident types and reduce the training burden, automated landings are a feature of SVO-A2 aircraft. Many SVO-A2 aircraft will have VTOL capability, and many will also conventional take off and land capability. Even for VTOL-capability aircraft, when a runway is available, it may be preferable to take-off or land conventionally to reduce energy consumption. Therefore, to bring the benefits of automated landings to SVO-A2 aircraft, both VTOL and CTOL landings will be automated. Since landings are automated, and the flight is also flown coupled to the automated navigation system, it only makes sense to automate takeoffs as well.

A manually flown landing is considered an abnormal procedure for the purpose of pilot training and aircraft certification. Therefore, for pilot certification purposes, minor damage to the aircraft during a manually flown landing is acceptable. This means that for training and testing purposes, the pilot need only demonstrate the ability to manually fly the aircraft on a suitable approach to a position close to the ground and at an attitude and speed from which an acceptable landing could be made. This is analogous to the current flight training situation with helicopter autorotations. For the private and commercial helicopter rating, the pilot is only trained to do an autorotation to about 5 ft above the ground and then add power to recover before touching down. During manual landing, all envelope protection features assist the pilot.

Discussion

Category (CAT) III landings (automatic landings) and reduced visibility takeoffs (takeoffs with less than normal visibility requirements) are currently allowed, but carry with them significant training and recurrent training requirements. The reason for the current training requirement is that it is assumed that the pilot is still required as a backup for these systems. Therefore, if the system fails while close to the ground, the pilot has very little time to react to the failed system and prevent an accident. Note that for these systems, the actual reliability of the system does not determine whether the training is required. Regardless of the reliability of the system, Part 61 requires this training.

Because the SVO-A2 aircraft always land automatically in normal operations, it is assumed that the SVO-A2 pilot has not learned to land the aircraft without the automated system. This requires that the landing system reliability be at the appropriate level to support not using the pilot as a backup in the system safety analysis.

An interesting aspect of the aircraft always landing itself is that the quality of the landing becomes a marketing distinction. Therefore, the performance characteristics of normal landings are not addressed in regulation.

For failure conditions and other abnormal situations, an imperfect landing is allowed. There are two different types of abnormal conditions to consider. One is a failure that affects the landing system (e.g., lift production and controllability). The other is a condition that does not affect the landing system (ee.g., a fire on board that does not affect the landing system).

Failures that affect the landing system are governed by the hazard generated by the failure. In essence, the failure creates a hazard (likely aircraft damage or occupant injury) and the likely outcome then determines the minimum probability allowed for this failure.

Conditions that do not affect the landing system may require that the aircraft land in conditions that are not envisioned by the system designers and therefore may not have all the sensor or algorithm capability to make an optimum landing. An example of this may be a fire in flight over rugged terrain with no landing sites available (as determined by the landing system). In this case, the pilot would choose a landing location, and by using the "manual" flight control system (EZ-Fly VTOL) would direct the flight path to that location—and into the ground. The Automatic GCAS would need a means to be over-ridden so that the aircraft could land at other than landing zones in these emergency conditions. For VTOL/STOL aircraft, this may be a speed limit imposed by the flight controls when below a specified height. The flight controls may also limit vertical descent and forward speed when close to the ground to limit the speed at which ground contact is made. This can intentionally be designed so that the aircraft sustains damage through crumple zones and other safety features to prevent or minimize injury in emergency conditions. A parachute may be a viable option for these kinds of emergencies for aircraft that cannot slow to speeds that prevent or minimize injury.

The recommended regulation UAV 23.2150 discussed in Appendix B requires that the aircraft be able to accelerate vertically such that it can prevent ground contact with any combination of height and rate of descent allowed by the flight controls (note that this requires the flight controls to limit descent rate as a function of height when close to the ground). For conditions where the navigation component of the automatic approach and landing system have failed, but the flight conditions are such that the pilot can see the landing zone, the pilot can put the flight path marker on the landing zone and the aircraft will arrive there. The pilot would adjust speed as required to slow down as the aircraft approaches the landing zone (like stopping a car at a stop sign). The flight control provision to limit the rate of descent as a function of height reduces the descent rate to provide a safe touchdown if the pilot does not slow the descent rate; or in the case of a VTOL aircraft, the pilot can simply reduce the rate of descent to zero a short distance above the landing zone and transition to ground maneuvering.

It is expected that for most operations, the aircraft will be coupled to the flight plan before takeoff. in the event it is is not coupled, it will takeoff automatically. This is to reduce pilot error accidents (loss of control accidents) during takeoff. It also reduces the training requirements for the pilot to learn to takeoff. However, it would be possible using the "manual" control (EZ-Fly VTOL system) to manually takeoff if desired. This is done for a CTOL takeoff by setting the desired speed (recall that the minimum commandable speed is reference speed [Vref]), commanding a climb as speed develops, and commanding the flight path marker along the runway. For VTOL takeoffs this is done by commanding a climb.

While the requirement for the pilot to authorize a takeoff when coupled may not be technically required (it could be provided by ATC), an SVO-A2 pilot is still considered to be in the loop and monitor flight operations even when coupled for the entire flight. Therefore, it is appropriate for the aircraft to receive final confirmation that the pilot is ready to monitor operations and take corrective action if needed. This feature also prevents inadvertent takeoff by an unoccupied aircraft.

<u>Effects on certification requirements of SVO-A2 automated takeoff and landing for CTOL and VTOL capability</u>

For an SVO-A2 aircraft, the approach and landing are automatic, but the pilot is required to approve the landing. If there is no approval, the aircraft automatically executes a missed approach.

This is an area where the aircraft requirements and the operational requirements affect each other. It is recommended that the applicant develop the ceiling/visibility requirements (operational rules) for the aircraft as a function of landing speed/descent rate and publish this in the Flight Manual. It is recommended that the applicant use the following rules and assumptions to determine the ceiling/visibility requirements.

At the minimum approved ceiling/visibility, it is assumed that the pilot takes 3 seconds to acquire the entire landing zone including the rollout area if needed (note that the visibility requirement includes being able to see the path to the touchdown point as well as the rollout distance), and an additional 3 seconds to evaluate it and provide approval. Thus, there is at least a 6-second time frame from breaking out to approving a landing. It is assumed that there is a 7-ft obstacle on the landing zone (this covers a tall person or a tall vehicle like a passenger van), and the aircraft needs to clear the obstacle by at least 3 ft. Thus, the missed approach path needs to descend to no less than 10 ft above the ground. The recommended SVO-A 23.2150 rule specifies a minimum vertical acceleration capability of 0.2 G in the up direction while descending. Therefore, 0.2 G shall be used for the vertical acceleration in these calculations. The descent rate and forward velocity of the aircraft will then determine the minimum ceiling/visibility requirements.

Note that since the purpose of the ceiling/visibility minima are intended to allow the pilot the ability to assess the landing zone, if there is an alternate means of doing this, such as the use of a ground observer that communicates the state of the landing zone to the pilot, then the ceiling/visibility requirements may be lowered as appropriate commensurate with the alternative means of determining the landing zone is clear.

Effect on training (Part 61 and ACS/PTS) of SVO-A2 automated takeoff and landing

See Appendix E for the effect of the SVO-A2 system on the on Part 61 and the Airman Certification Standards (ACS).

Expected effect on training burden of SVO-A2 automated takeoff and landing

The pilot licensing requirements for SVO-A2 must require the pilot to be able to select the appropriate approach and couple the aircraft to it, recognize a clear landing zone, and authorize the aircraft to land; but they do not require the pilot to fly the approach or landing.

Also, the pilot must be able to select appropriate landing areas in the event of an emergency that requires an off-site landing and to direct the aircraft to that location. Operational knowledge of special features such as a parachute may also be required. The ability to visually identify a landing zone and manually fly to it with a failed navigation system may be required.

Note that there is no classification for VFR-only SVO-A2 pilot. This implies that the pilot need not learn VFR-specific rules such as airspace and cloud clearances. ATC keeps the pilot out of inappropriate airspace (including temporary flight restrictions [TFRs]). However, there may be an add-on VFR rating for SVO-A2 pilots that includes training concerning airspace, cloud clearances, and allows a pilot to fly without an IFR clearance (more freedom requires more responsibility and training).

Effect on operations (Parts 91 and 135) of SVO-A2 automated takeoff and landing

Automated takeoff and landing can have a significant effect on the ceiling and visibility requirements as discussed. The proposal is that the applicant certify the ceiling and visibility requirements appropriate for the aircraft given the performance capabilities of the aircraft and publish those minima in the flight manual. This is similar to the concept of having different minima based on the approach speed of the aircraft, except that instead of a approach speed alone determining the minima, the applicant uses both approach speed and descent rate to determine ceiling and visibility minima. The minima are then published in the aircraft flight manual (AFM) instead of the approach procedure. However, these lower minima can only be used when obstacle clearance allows them. This means that the approach must be approved for SVO-A2 minima when minima less than the published minima are used. This is similar to a helicopter that can use half the published approach minima unless the approach prohibits it.

The SVO-A2 concept also allows for true zero-zero takeoffs without specific training. It also allows for zero-zero landings without specific training if there is a means other than the pilot to ensure that the landing zone is clear.

A.20 Summary of SVO-A2 feature 5: Automatic barometric pressure setting

The aircraft automatically sets and adjusts the barometric pressure is as required in flight.

Justification and background

Aircraft systems is an area that consumes significant training time, especially the altimeter system and in particular the barometric adjustment.. Including this automated feature is expected to reduce training time and reduce errors associated with the pilot entering the wrong barometric setting.

Discussion

When on the ground, the aircraft automatically sets the local barometric setting. Priority is given to local sources providing this information, including automatic terminal information service (ATIS), automated weather observing system (AWOS), or automated surface observing system (ASOS). If these sources are not available, the aircraft calculates the barometric pressure using the field elevation and the aircraft’s altimeter.

When in the air, and within 30 miles of the destination airport, the aircraft uses the destination airport ATIS, AWOS, or ASOS to set the barometric pressure. If these sources are not available at the destination airport, the aircraft will use ATIS, AWOS, or ASOS from the airport closest to the destination. Enroute below 18,000 ft, the aircraft automatically updates the barometric pressure from ATIS, AWOS, or ASOS based on its current location. When above 18,000 ft the aircraft sets the barometric pressure to 29.92.

Error checking is required to ensure a single erroneous report does not cause the aircraft to sense a hazardously misleading barometric altitude. This error checking can be done using surrounding readings, GPS altitude, height measurements, ATC reports, and other means.

Expected effect on training burden of SVO-A2 automated barometric pressure setting

It is assumed that the pilot does not have a means to directly set the barometric pressure. Therefore, the pilot need not learn the atmospheric theory behind why it needs to be set, the difference between pressure altitude and barometric altitude, or how to obtain the barometric setting.

Effect on operations (Parts 91 and 135) of SVO-A2 automated barometric pressure setting

This feature has no effect on operations.

A.21 Summary of SVO-A2 feature 6: Automated aircraft collision system

The automated aircraft collision system is intended to operate in the same way as the Automatic GCAS.

Justification and background

The SVO-A2 pilot is expected to be much less engaged in the real-time operation of the aircraft. This often results in the pilot missing information that would otherwise be noticed, such as the detection of other airborne traffic. Because of this, assistance and active avoidance (if needed) is required for SVO-A2 aircraft.

Discussion

Although the details of this function are the subject of many research and development projects, they are outside the scope of this document.

Effect on certification requirements of SVO-A2 automated aircraft collision avoidance

While automated aircraft collision avoidance is currently the subject of considerable research, there is no specific requirement in this document other than that the SVO-A2 aircraft shall have the feature.

Expected effect on training burden of SVO-A2 automated aircraft collision avoidance

Although collision avoidance is automated, it is still recommended to teach pilots about the concept. It is also valuable in spotting traffic that is called out by ATC.

Effect on operations (Parts 91 and 135) of SVO-A2 automated aircraft collision avoidance

This feature has no effect on operations.

A.22 Summary of SVO-A2 feature 7: Automatic failure protection (engine out, communications failure, and other system failures)

Automatic failure protection in an SVO-A2 aircraft ensures that for any failure or combination of failures with a probability of greater than is allowed for a catastrophic event, the aircraft continues to operate normally without any pilot action except replanning the flight. A reduction in performance or capability is allowed. The aircraft's new state and capabilities (if appropriate) are displayed to the pilot. First failures and combination of failures can produce minor hazards as defined by Advisory Circular (AC) 23-1309 (FAA, 2011).

A reduction in performance or capability may mean that the range is reduced such that the aircraft cannot reach the original destination with appropriate reserves. It may mean that the aircraft is not capable of vertical flight and therefore must perform a conventional landing. With automated failure protection, the aircraft identifies its new state and immediately replans the flight and recommends one or more amended flight plan(s) to the pilot. The amended flight plan may be to a different landing zone or to a runway at the same facility or a runway at a different facility. The pilot approves the amended plan, and the aircraft transmits that plan as a requested clearance change to ATC along with the reason for the change (e.g., power failure, unable to conduct vertical flight, need a runway of at least 2,000 ft). When ATC provides a new clearance, the flight management system (FMS) replaces the current flight plan with the new clearance. If the pilot does not approve a recommended flight plan at the point where the current one is not compatible with the aircraft's capabilities, then the amended flight plan is adopted without approval, an emergency is declared by the aircraft, and the aircraft communicates its destination to ATC (like the current certified Garmin emergency Autoland system).

Some additional examples of failures and their effects are described below.

- A primary navigation sensor fails:
    - The aircraft automatically switches to the backup navigation sensor.
    - The flight control system and AP remain operational in the same mode through the switch.
    - An annunciation is displayed indicating which navigation sensor failed.
- Communication radio #1 fails:

    - If the aircraft was set to transmit on comm 1, it switches comm 2 to the frequency that comm 1 was using.
    - Comm 2 is set as the active communications radio.
    - An annunciation displays that indicates comm 1 is inoperative
- A power distribution circuit breaker trips that takes out the forward flight display, and flight control computer #1:
    - The aircraft automatically switches to flight control computer #2.
    - If the AP is engaged, it remains engaged in the same mode it was in before the failure.
    - The system attempts to reset the breaker once to bring the failed components back online.
    - An annunciation is provided to the pilot indicating the circuit breaker trip.
    - If the circuit breaker trips a second time, the state of the aircraft is displayed.
    - If the forward display remains inoperative, the moving map display automatically switches to a composite of the forward display and a moving map.

Justification and background

Accident data indicates that pilots can become engrossed in a non-critical failure and then lose control of the aircraft or take an inappropriate action that causes the accident. The purpose of automated failure protection is to significantly reduce these accidents by training the pilot that they do not need to do anything other than approve a new flight plan when a failure occurs, and to reduce the training time devoted to learning aircraft systems.

Discussion

Training pilots in aircraft systems operation is a time-consuming effort. The main purpose of this training is to teach the pilot to recognize failures and take the appropriate action when they occur. When failures occur, they are often accompanied by other events that may or may not be related to the failure, such that the pilot's workload is high (an example of this might be a failed AP on approach that unexpectedly puts the aircraft in an unusual attitude). Since the failed state is unfamiliar to the pilot, the combination of unfamiliar operating characteristics and high workload can often lead to an unsafe condition.

The solution to the safety problem is to make the aircraft operate normally after a failure, and if pilot action is required, to do so in a way that is not time critical .

The normal-operation, non-time-critical solution eliminates (or significantly reduces) the pilot's need to understand how the aircraft systems work, what are the potential failure modes, how to recognize the failure, and what to do about it.

After a failure, the pilot may be able to reconfigure their aircraft to regain lost capability, but this is never required to make a safe landing. More importantly, there is not a time-critical aspect to any failure. Generally, for any failure, the best action is to do nothing or simply approve the recommended flight plan when it appears.

Effect on certification requirements of SVO-A2 automated failure protection

Although there is no recommended regulation concerning automatic failure protection, this feature is required of the SVO-A2 aircraft. The intent is for all foreseen failures (at least all of those that would normally appear in the flight manual) to be managed by the aircraft's systems. This means that for any first failure, the pilot is not required to take any action other than potentially replanning the flight.

Expected effect on training burden of SVO-A2 automated failure protection

Because there is nothing the pilot needs to do to monitor or control the internal workings of a system, there is no need for them to learn about how they work.

Effect on operations (Parts 91 and 135) of SVO-A2 automated failure protection

There is no effect on operations from this feature.

A.23 Summary of SVO-A2 (8): All Flights flown underInstrument Flight Rules on a valid flight plan with a clearance

The SVO-A2 aircraft usually operates using IFR, meaning that it must have a valid IFR flight plan and clearance before automatic takeoff. (Note that manual takeoff can be accomplished but is not normal for SVO-A2 operations, and manual takeoffs are not a part of the SVO-A2 training requirements.) See UAV 23.2730 in Appendix B for details concerning IFR enforcement and VFR flights in SVO-A2 aircraft.

Once in flight, the pilot may deviate from the flight plan or clearance by controlling the flight path directly. This can be done in the same manner as today, i.e., when ATC clears an IFR flight into a block of airspace, or in an emergency, when ATC clears the path.

Justification and background

Learning VFR flight rules is a major part of the ground training burden. Much of this burden consists of the VFR operating rules such as cloud clearances, equipage requirements and the like in the different classes of airspace. On an IFR flight, ATC directs the aircraft to comply with restricted airspace requirements, TFRs and directs flights to preferred routes designed for efficient traffic flow, to avoid noise sensitive areas, etc.

In essence, flying IFR is easier than flight VFR because ATC is responsible for traffic separation, clearances into airspaces when required, etc. Also, the IFR pilot need not be concerned with avoiding clouds and cloud clearance requirements.

Also, because the SVO-A2 aircraft has automatic takeoff and landing capability, the weather minima can be significantly lower than with aircraft that require the pilot to take off and land. (See Appendix F)

Discussion

The SVO-A2 aircraft has an integrated navigation/display/control system, takeoffs are automatic, and it has ATC speech-to-text, which is translated into clearances and flight plan changes, therefore the parts needed to force IFR-only flight are in place. In addition, since all aircraft are required to have automatic dependent surveillance broadcast (ADS-B), which includes the aircraft identification, An SVO-A2 aircraft that is flown without an IFR clearance is easily identified, and the pilot can expect to be contacted regarding the flight by the FAA.

Expected effect on training burden of SVO-A2 IFR-only flight requirement

Because all flights are done under IFR and ATC directs all IFR flights, much of the responsibility for knowing the definition of the various airspaces and the various rules that apply to each is eliminated. This is responsible for a large reduction in the training burden.

Effect on operations (Parts 91and 135) of SVO-A2 IFR-only flight requirement

This feature eliminates VFR operations for most SVO-A2 aircraft. Therefore, the sections of Parts 91 and 135 that deal with VFR operations become irrelevant. The parts that do not deal specifically with VFR operations are not affected by this feature.

A.23 Combined effects of SVO-A2 features on the training burden

In addition to the individual features, all the required features combine to reduce the proficiency requirement, as recommended in Recommended Changes to Part 61 and ACS/PTS. Specifically, the recommended change to § 61.57 (Recent flight exerience: Pilot in command, 2025).

61.57 (c) contains a significant reduction in the instrument proficiency requirements. Since all flights are conducted using IFR and are on a flight plan with a clearance, the pilot only needs proficiency in executing a flight instead of executing instrument approaches.

Expected effect on the training burden SVO-A2 features 1 through 10

Table A-6 shows the estimated training reduction for the private pilot, instrument, helicopter and helicopter instrument add-on ratings that require the most training time. The legacy training time values come from Embry-Riddle Aeronautical University (Embry Riddle Aeronautical University, n.d.). The estimated reduction in training time for the SVO-A2 aircraft comes from personal experience by the authors, who are both flight instructors, and the results of experiments conducted in flying aircraft and simulators with pilots and non-pilots using the SVO-A features. Only the items with the highest training burden are considered here. There are many other areas that take less training time and are not considered here but which would also benefit from SVO-A2 features. Note that the total times listed are only those associated with the items that have the highest burden. They do not represent the total training burden.

Table A-6. The expected effect of SVO-A2 automation features

Ground:	**Legacy Hours**	**Reduction**	**SVO-A2 Hours**
Principles of aerodynamics, powerplants, and aircraft systems	17	15	2
Use of IFR en route and instrument approach procedure charts	6.5	4	2.5
IFR navigation and approaches by use of navigation systems	6	3	3
Recognition of critical weather situations from the ground and in flight, windshear avoidance, and the procurement and use of aeronautical weather reports and forecasts	5	4	1
Air traffic control system and procedures for instrument flight operations	5	3	2
Safe and efficient operation of aircraft, including collision avoidance, and recognition and avoidance of wake turbulence	4.5	2.5	2
Energy management, mast bumping, low rotor RPM, low G hazards, and rotor RPM decay	2	2	0
Weight and balance computations	2	1.5	.5
Most burdensome items total: Ground	**48**	**35**	**13**

Ground:	Legacy Hours	Reduction	SVO-A2 Hours
Flight:	**Hours**		
Instrument approach procedures	25.5	23.5	2
Takeoff, landing, go-around	15	10	5
Performance and ground reference maneuvers	11.5	9.5	2
Flight by reference to instruments	10.5	10.5	0
Navigation	8	7	1
Hovering maneuvers	6.5	5.5	1
Navigation systems	3	3	0
Most burdensome items total: Flight	**80**	**69**	**11**
Total ground and flight time of most burdensome items	**120**	**104**	**24**

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B Recommended aircraft certification rules for unmanned aerial vehicles

This appendix consists of two parts. The first part addresses existing aircraft certification rules and provides recommendations to make them applicable to aircraft with advanced automation systems such as those identified in this report as simplified vehicle operation (SVO)-A1 and SVO-A2. The recommendations also recognize that some of the designs being proposed by industry are in fact powered lift designs. It is understood that these designs will be certified under Title 14 Code of Federal Regulations (14 CFR) Part 23 with additional requirements appropriate to the design (Airworthiness Standards: Normal Category Airplanes, 2016). The intent of this first section is to make recommendations for Part 23 to accommodate the advanced automation features and vertical takeoff and landing (VTOL) aircraft. As such, the recommendations are not appropriate for fixed-wing aircraft without the SVO-A1 or SVO-A2 automation packages. The recommended Part 23 rules will be referred to as unmanned aerial vehicle (UAV) 23.XX to differentiate them from the existing Part 23 rules.

The second part of this appendix is a response to a set of regulations proposed by the FAA for unmanned aircraft systems (UASs). The recommendations are intended to make these proposed rules performance based and independent of any technology level while allowing industry to meet the safety goals with innovative technology. The proposed FAA UAS rules will be referred to as UAS.XX because this is the name given by the FAA to these proposed rules.

B.1 Part 23 recommendations relating to automation, electric propulsion, and advanced features

To ensure safe operations, aircraft with the pilot not on board, or ground pilot, may need different requirements than aircraft with the pilot on board. Although some requirements need to be considered for addition to Part 23, some of the current Part 23 requirements can be eliminated without adversely affecting safety. Other Part 23 requirements are generally appropriate but need modification to be relevant to unmanned vehicles.

As more automation is added to an aircraft, the distinctions between a pilot on board and a ground pilot are reduced. As the current aircraft certification regulations were examined in the light of the proposed SVO-A1 and SVO-A2 features sets (these sets were agreed to for the purpose of this research), it became clear that the same recommended changes generally apply equally to UAVs and manned aircraft. Because of this and the need to identify each regulation examined in this research, this appendix is organized and labeled according to the Part 23 regulation being addressed. The regulation with the recommended changes is identified by the UAV prefix to clearly differential it from the actual regulation.

Historically, propulsion and flight control systems were nearly entirely mechanical. Part 23 regulations reflect this by treating these systems differentlybased on their reliability and how failures are addressed. For instance, flight control systems are considered more like structural components than aircraft systems, and it is assumed that engines can fail. To ensure safety, the aircraft is required to remain controllable after a failure—for example, requiring single-engine airplanes to have a slow stall speed and multi-engine (ME) airplanes to be controllable after an engine failure).

Because the flight control systems of UAVs do not have a mechanical link to the pilot, it is recommended that the flight control systems of UAVs be governed by the more generic guidance of Advisory Circular (AC) 23.1309 (which is the same guidance that covers the effects of failures in electronic systems) (FAA, 2011).

Because propulsion control is essential to propulsion reliability—and since there is no mechanical link from the pilot to the powerplant, especially with the advent of electric-powered aircraft,—it is recommended that propulsion also be governed by the more generic guidance of Advisory Circular (AC) 23.1309 (FAA, 2011),which is also applies to electronic systems failures.

The major changes for UAVs reflect the following characteristics:

1. Propulsion and control may be integrated such that a failure of a propulsion component can have a major effect on aircraft control . Parts 23 and 27 assume the propulsion and control systems are independent of each other or can be made independent for emergency purposes. Historically, propulsion systems, control systems, and other systems have been treated separately for reliability purposes. The recommended special conditions treat failures in any system the same as failures in any other system. In essence, all failures have a hazard classification and that hazard classification determines the design assurance level required independent of the system or component.

2. The recommended changes recognize the aircraft may have the ability to takeoff or land vertically and to hover, or hover taxi. Part 27 concepts were incorporated into these recommendations to cover these capabilities.

These recommended UAV regulations are intended to preserve the intent of Part 23 but apply to UAVs, including those with VTOL capabilities, electric propulsion, and advanced automation features.

Because Part 23 is the basis for these recommendations , only the regulations of Amendment 23-64 (FAA, 2022) that change are listed here. Since these recommendations are intended to apply to VTOL aircraft as well as airplanes, concepts from Part 27 are included as appropriate. When a concept from Part 27 is included, this fact is identified in the discussion section.

Many of these recommendations convert current design-based regulations into performance-based regulations. Doing this in a way that applies to future unknown technology levels requires identifying desired safety functions and then specifying the level of design assurance that is appropriate for that function. Appendix C provides recommended design assurance levels and a discussion of how they were developed.

For this Appendix, FAA rules and FAA proposed rules are in *italics*. The authors' response and recommended changes are in normal, **bolded** text.

B.2 UAV 23.2000: Applicability and definitions

Current FAA rule:

23.2000 Applicability and definitions

(a) This part prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for airplanes in the normal category.

(b) For the purposes of this part, the following definition applies:

***Continued safe flight and landing** means an airplane is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some airplane damage may occur as a result of a failure condition.*

Recommended rule

(a) This part prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for **aircraft in the normal category that comply with the functions, features and characteristics of this UAV part**.

(b) For the purposes of this part, the following definition applies:
Continued safe flight and landing means an **aircraft** is capable of continued controlled flight and

landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some **aircraft** damage may occur as a result of a failure condition.

Discussion

The current Part 23 rule specifically applies only to normal category airplanes. Part UAV 23.2000applies to any aircraft that meet the requirements of this UAV part including airplanes, rotorcraft, or a combination of airplane and rotorcraft configuration that complies with the recommended requirements of UAV 23.2000.

B.3 UAV 23.2005: Certification of normal category aircraft

Current FAA rule:

23.2005 Certification of normal category airplanes

(a) Certification in the normal category applies to airplanes with a passenger-seating configuration of 19 or less and a maximum certificated takeoff weight of 19,000 pounds or less.

(b) Airplane certification levels are:

(1) Level 1 – for airplanes with a maximum seating configuration of 0 to 1 passengers.

(2) Level 2 – for airplanes with a maximum seating configuration of 2 to 6 passengers.

(3) Level 3 – for airplanes with a maximum seating configuration of 7 to 9 passengers.

(4) Level 4 – for airplanes with a maximum seating configuration of 10 to 19 passengers.

(c) Airplane performance levels are:

(1) Low speed – for airplanes with a normal operating speed (VNO) and maximum operating airspeed (VMO) ≤ 250 Knots Calibrated Airspeed (KCAS) and a maximum Mach operating (MMO) ≤ 0.6.

(2) High speed – for airplanes with a VNO or VMO > 250 KCAS or a MMO > 0.6.

(d) Airplanes not certified for aerobatics may be used to perform any maneuver incident to normal flying, including—

(1) Stalls (except whip stalls); and

(2) Lazy eights, chandelles, and steep turns, in which the angle of bank is not more than 60 degrees.

(e) Airplanes certified for aerobatics may be used to perform maneuvers without limitations, other than those limitations established under subpart G of this part.

Recommended rule

(a) Certification in the normal category applies to aircraft with a passenger-seating configuration of 19 or less and a maximum certificated takeoff weight of 19,000 pounds or less.

(b) **Aircraft certification levels are:**

> **(1) UAV Level 1 – for UAV aircraft with a maximum weight of 1,320 lb and a maximum speed in level flight of 120 KCAS.**
>
> **(2) UAV Level 2 – for UAV aircraft with a maximum weight of 6,000 lb and a maximum speed in level flight of 170 KCAS.**
>
> **(3) UAV Level 3 – for UAV aircraft with a maximum weight of 12,500 and a maximum speed in level flight of 250 KCAS.**
>
> **(4) UAV Level 4 – for UAV aircraft up to 19,000 lb**
>
> **(5) If a UAV carries people, then the higher of the UAV level or the level from part 23 based on seating capacity is used.**

(c) Airplane performance levels are:

> (1) Low speed – for airplanes with a VNO and VMO $\leq$ 250 KCAS and a MMO $\leq$ 0.6.
>
> (2) High speed – for airplanes with a VNO or VMO > 250 KCAS or a MMO > 0.6.

(d) Airplanes not certified for aerobatics may be used to perform any maneuver incident to normal flying, including—

> (1) Stalls (except whip stalls); and
>
> (2) Lazy eights, chandelles, and steep turns, in which the angle of bank is not more than 60 degrees.

(e) Airplanes certified for aerobatics may be used to perform maneuvers without limitations, other than those limitations established under subpart G of this part.

Discussion

This recommended UAV rule has been changed to reflect that UAVs may not carry people. The levels for UAVs generally reflect the kinetic energy the corresponding Part 23 aircraft of the same level. For instance, the UAV level 1 weight and speed limits are the same as the light-sport aircraft (LSA) limits since LSAs are the most prominent class of aircraft with 1 passenger. The top of UAV level 2 generally represents piston twins. The UAV level 3 represents turboprops and level 4 represents commuter category airplanes. If the UAV carries passengers, then the higher of the normal Part 23 levels (based on seating capacity) or the UAV levels (based on kinetic energy) are used.

B.4 UAV 23.2100: Weight and center of gravity

Current FAA rule:

23.2100 Weight and center of gravity

(a) The applicant must determine limits for weights and centers of gravity that provide for the safe operation of the airplane.

(b) The applicant must comply with each requirement of this subpart at critical combinations of weight and center of gravity within the airplane's range of loading conditions using tolerances acceptable to the Administrator.

(c) The condition of the airplane at the time of determining its empty weight and center of gravity must be well defined and easily repeatable

Recommended rule:

(a) The applicant must determine limits for weights and centers of gravity that provide for the safe operation of the **aircraft**.

(b) The applicant must comply with each requirement of this subpart at critical combinations of weight **and longitudinal and lateral** center of gravity within the **aircraft**'s range of loading conditions using tolerances acceptable to the Administrator.

(c) The condition of the **aircraft** at the time of determining its empty weight and center of gravity must be well defined and easily repeatable.

<u>Discussion</u>

Section 27.27 specifically mentions both longitudinal and lateral center of gravity. Part 23 does not mention either specifically. This change adds clarification. Guidance in AC 23-8C specifies some tests being performed using the maximum fuel imbalance. This is a form of specifying the maximum lateral center of gravity (CG) location, and if the aircraft's lateral CG location is

dominated by fuel imbalance, is an acceptable means for specifying lateral CG location. It is recognized that a UAV may be designed such that it can be loaded asymmetrically.

B.5 UAV 23.2105: Performance data

Current FAA rule:

23.2105 Performance Data

(a) Unless otherwise prescribed, an airplane must meet the performance requirements of this subpart in—

(1) Still air and standard atmospheric conditions at sea level for all airplanes; and

(2) Ambient atmospheric conditions within the operating envelope for levels 1 and 2 high-speed and levels 3 and 4 airplanes.

(b) Unless otherwise prescribed, the applicant must develop the performance data required by this subpart for the following conditions:

(1) Airport altitudes from sea level to 10,000 feet (3,048 meters); and

(2) Temperatures above and below standard day temperature that are within the range of operating limitations, if those temperatures could have a negative effect on performance.

(c) The procedures used for determining takeoff and landing distances must be executable consistently by pilots of average skill in atmospheric conditions expected to be encountered in service.

*(d) Performance data determined in accordance with paragraph (b) of this section must account for losses due to atmospheric conditions, cooling needs, and other demands on power sources.*Recommended rule:

(a) Unless otherwise prescribed, an **aircraft** must meet the performance requirements of this subpart in—

(1) Still air and standard atmospheric conditions at sea level for all **aircraft**; and

(2) Ambient atmospheric conditions within the operating envelope for levels 1 and 2 high-speed and levels 3 and 4 **aircraft**.

(b) Unless otherwise prescribed, the applicant must develop the performance data required by this subpart for the following conditions:

(1) Airport altitudes from sea level to 10,000 feet (3,048 meters); and

(2) Temperatures above and below standard day temperature that are within the range of operating limitations, if those temperatures could have a negative effect on performance.

(3) If humidity affects performance, the data must consider these effects. A minimum relative humidity of 80% below international standard atmosphere (ISA) and varying linearly to 34% at ISA + 28C should be considered.

(c) The procedures used for determining takeoff and landing distances must be executable consistently by pilots of average skill in atmospheric conditions expected to be encountered in service.

(d) Performance data determined in accordance with paragraph (b) of this section must account for losses due to atmospheric conditions, cooling needs, **previous use** and other demands on power sources.

(e) If the aircraft is capable of vertical flight, the maximum weight as a function of atmospheric conditions and wind for vertical takeoff and landing must be included. Also, for aircraft capable of vertical flight, the maximum service ceiling for hovering out of ground effect as a function of temperature and weight must be included. (The out of ground effect hovering service ceiling is the maximum altitude at which the aircraft can sustain a steady climb rate of at least 50 ft. per minute.)

(1) For aircraft that can takeoff or land vertically as well as using free stream velocity to generate lift, both methods must be included.

<u>Discussion</u>

14 CFR § 27.45 includes the effects of humidity if high humidity has an adverse effect on performance (General, 2025). The recommended rule wording brings this concept to Part 23. It is assumed that humidity generally does not affect wing-borne flight.

The original Part 23 text did not adequately cover vertical flight or electric battery-powered propulsion. Battery deterioration with use and taking off with partial charge needs to be considered.

For aircraft that use power to improve field performance (such as blown flaps, energized boundary layer, etc.) but also allow takeoff or landing without these power-enhanced features, the unpowered state must also be considered.

B.5 UAV 23.2110: Minimum flight speed

Current FAA rule:

23.2110 Stall Speed

The applicant must determine the airplane stall speed or the minimum steady flight speed for each flight configuration used in normal operations, including takeoff, climb, cruise, descent, approach, and landing. The stall speed or minimum steady flight speed determination must account for the most adverse conditions for each flight configuration with power set at—

(a) Idle or zero thrust for propulsion systems that are used primarily for thrust; and

(b) A nominal thrust for propulsion systems that are used for thrust, flight control, and/or high-lift systems.

*thrustthrust*Recommended rule:

The applicant must determine **the minimum steady flight speed** for each flight configuration used in normal operations, including takeoff, climb, cruise, descent, approach, and landing. The **minimum steady flight speed** determination must account for the most adverse conditions for each flight configuration.

(a) A minimum achievable speed must be determined for each configuration. The minimum achievable speed is the minimum speed at which the aircraft can maintain level flight.

(b) For configurations that rely on free stream velocity for all or part of their lift, reference speed (Vref) will be 1.3 times the minimum achievable speed unless Vref is greater than 100 kt, for these aircraft Vref may be 1.23 times the minimum achievable speed.

(c) For aircraft configurations or control modes the minimum commandable air speed when not less than 50′ above ground level (AGL) during takeoff or landing or at climb power or above is Vref for that configuration.

(d) The aircraft may fly slower than Vref at climb power and above if the air speed for best angle of climb (Vx) is slower than Vref. However, aircraft configured to rely on free stream velocity for all or part of their lift may not be allowed to fly slower than Vx (speed for best angle of climb) plus a maneuver margin. Vx must consider maneuver margin and gusts. Vx for the purpose of this regulation may be faster than the aerodynamic Vx.

Discussion

This regulation applies as written. All references to stall speed and power are deleted.

The title of this regulation is “Stall Speed.” A more appropriate title as applied here would be “Minimum Flight Speed.”

Because a human pilot is not onboard the aircraft and therefore does not experience some of the cues related to an approaching stall, this regulation effectively requires a control system so that the pilot cannot command a speed that allows the aircraft to stall.

(a) The minimum achievable speed needs to be determined in each configuration and flight condition. The minimum achievable speed may be zero for some configurations.
(b) The minimum achievable speed (Vmin) is used like stall speed for other regulations.

Except for maximum climbs, there is never a need to fly below Vref. History shows that Vref generally produces adequate maneuver margins and gust margins while allowing slow landing speeds. Therefore, the commandable speed is limited to more than Vref; or if the control mode commands acceleration, the aircraft will not command deceleration to speeds less than Vref. When Vmin is very low, the gust margins described in the stall characteristics regulation (14 CFR §23.2150 Stall characteristics, stall warning, and spins) may require Vref to be higher than is specified by this (stall speed) regulation.

Limiting the speed at full power to no less than Vx can be done by limiting angle of attack (AOA).

For most Part 23 airplanes, Vref is 1.3 times stall speed. This has been proven to provide a satisfactory maneuver and turbulence margin. Many Part 25 and high-end Part 23 airplanes with approach speeds of more than 100 knots set Vref at 1.23 times stall speed. Experience has shown thisto also be satisfactory. Although the reasoning for using 1.23 instead of 1.3 as the stall speed multiplier is not due to the higher speeds—however in practice, it has worked out that way. Therefore, the 1.23 factor is allowed for configurations with high minimum achievable speeds. For configurations where Vref is greater than 100 kt when using 1.3 and less than 100 kt when using 1.23, Vref of 100 kt is appropriate.

An adequate maneuvering margin and gust margin must also be provided at Vref and Vx.In Part 25 aircraft that require display of the maneuvering margin, an acceptable maneuvering margin is 1.1 times stall warning speed where stall warning speed is 5 – 10 KCAS above stall speed. The 10% increase comes from the ability to generate 0.2 G in addition to the commanded G level. In level flight, this equates to the ability to bank to 35 degrees and hold altitude. Mathematically, approximately the same AOA is obtained in level flight at 1.0 G and in 1.2 G accelerated flight when the airspeed is about 10% higher than the unaccelerated level flight speed.

For configurations that use free-stream velocity for part or all their lift, Vref is the greater of:

- 1.3 times Vmin or 1.23 times Vmin if Vref is greater than 100 KCAS (the 1.23 factor applies when Vmin > 77 KCAS)
- Vmin plus 10 KCAS if Vmin < 33 KCAS

The minimum allowable speed (Vx) is the is the greater of:

- Aerodynamic best angle of climb speed
- 1.1 times Vmin + 5 KCAS
- A speed determined by the applicant

Vref may not be less than the minimum allowable speed or the low-speed warning speed (see UAV 23.2150).

Vref and/or Vx may be conservatively set for some configurations/flight conditions to simplify operations and/or certification.

The gust and maneuvering margin requirements must also be satisfied at Vx. Since the aircraft is climbing at Vx, the minimum speed may be lower than Vref. For Vx, the aircraft can be considered to meet the requirement if the aircraft is holding altitude at the maximum bank allowed at the minimum speed, and a 20-kt longitudinal or lateral gust lasting 2 seconds is experienced, or a 10-kt vertical gust lasting 2 seconds is experienced, and the aircraft returns to the commanded flight condition without loss of control. Note that these gust levels are different than the gust levels specified for structural integrity regulations. This is because the critical case for structural-related gusts is high frequency and high gust level, where upsets and aerodynamic stalls are critical for lower-frequency gusts (for a high-frequency gust, the aircraft may experience a stall for a very short time and then normal flow is re-established causing no upset, but a bump).

For simplicity, the gust levels specified for Vx can be flight tested by overriding the flight control protections and pulling a G level that produces the AOA equivalent to the AOA produced by the gust for 2 seconds and demonstrating that the aircraft will recover immediately.

For aircraft that transition from one type of lift to another, the more conservative speed can be used for the entire transition, or the transition can be broken up into segments and the more conservative speed for each segment used for that segment.

B.6 UAV 23.2115: Takeoff performance

Current FAA rule:

23.2115 Takeoff Performance

(a) The applicant must determine airplane takeoff performance accounting for—

(1) Stall speed safety margins;

(2) Minimum control speeds; and

(3) Climb gradients.

(b) For single engine airplanes and levels 1, 2, and 3 low-speed multiengine airplanes, takeoff performance includes the determination of ground roll and initial climb distance to 50 feet (15 meters) above the takeoff surface.

(c) For levels 1, 2, and 3 high-speed multiengine airplanes, and level 4 multiengine airplanes, takeoff performance includes a determination the following distances after a sudden critical loss of thrust—

(1) An aborted takeoff at critical speed;

(2) Ground roll and initial climb to 35 feet (11 meters) above the takeoff surface; and

*(3) Net takeoff flight path.*Recommended rule:

(a) The applicant must determine takeoff performance accounting for—

(1) Minimum flight speed margins for aircraft that use free stream velocity for all or part of their lift;

(2) Component or system failures during takeoff and;

(3) Climb gradients.

(b**) For UAV aircraft that carry people and meet the emergency landing requirements (UAV 23.2270) when landing on an unprepared surface, takeoff performance** includes the determination of ground roll and initial climb distance to 50 feet (15 meters) above the takeoff surface **for all approved takeoff configurations that require a ground roll.**

(c) **For UAV aircraft that carry people and do not meet the emergency landing requirements (UAV 23.2270) when landing on an unprepared surface,** takeoff performance includes **the** determination of the following distances after **the most critical failure or combination of failures that do not meet the reliability requirement for a catastrophic event at the critical speed for all approved takeoff configurations that require a ground roll.**

(1) An aborted takeoff at critical speed;

(2) Ground roll and initial climb to 35 feet (11 meters) above the takeoff surface; and

(3) Net takeoff flight path.

(d) If there is a speed/height envelope where continued safe flight cannot be maintained after sudden critical loss of power or thrust, it must be determined.

(e) For UAV aircraft that do not carry people, (c) applies.

(Note: see Design Requirements for Category A Aircraft (Airworthiness Standards: Normal Category Airplanes, 2016) for additional modification to this paragraph for Category A certification. Category A certification is required for UAVs that operate primarily over urban areas.)

<u>Discussion</u>

<u>(1) Stall speed</u>

Minimum flight speed replaces stall speed since stall speed does not exist for aircraft with smooth AOA protection.

The "free stream" clause is added to avoid an unnecessary burden for VTOL only aircraft.

<u>(2) Minimum control speed</u>

The minimum control speed (Vmc) in Part 23 aircraft has a specific meaning and is related to loss of the critical engine in multi-engine airplanes. It is a fixed speed, which is marked on the airspeed indicator (with a blue radial). The other requirements of this Part (one of which is that no single failure combined with no pilot action other than controlling the flight path shall cause a catastrophic event) make the Vmc requirement redundant. For the designs covered by this Part, there may be failures that affect takeoff performance other than an engine failure. The intent is to include these failures along with engine failures.

For aircraft where a component failure results in longer takeoff distances, the effect of this must be determined as well as the accelerate-stop distance. The effect of all failures need not be considered—only the effect of the most critical one needs to be determined.

Also, if a single component failure occurs in the propulsion system that prevents the aircraft from climbing, then the aircraft must be able to land safely in that failed configuration.

(b) and (c):

The rewritten (b) and (c) sections separate aircraft based on their ability to meet the crashworthiness requirements (independent of the number of powerplants) instead of the number of engines and/or passenger seats. Aircraft that meet crashworthiness requirements do not experience a catastrophic event when a failure prevents continued flight, while it is assumed that aircraft that do not meet the crashworthiness requirements do experience a catastrophic event after a critical failure or combination of failures. Therefore, a failure or combination of failures must not be more probable than is allowed for a catastrophic event.

The distances specified in (b) and (c) shall be determined for all approved takeoff configurations that require a ground roll.

The eVTOL designs may have multiple motors but still have a single failure that prevents continued flight (like a single-engine airplane). This change from Part 23 was made to accommodate these aircraft. It is assumed that eVTOL aircraft can glide, autorotate, or provide some other means of arresting the descent after a failure just after takeoff.

(d):

Height-velocity envelope, 14 CFR §27.87 (Height-velocity envelope, 2025), requires that if there is any combination of height and forward speed (including hover) under which a safe landing cannot be made after a power failure, a limiting height-speed envelope must be established. Paragraph (d) brings this concept to these special conditions.

Aircraft may rely on autorotation, gliding, a parachute, backup temporary power source, rocket motor, or other means to accomplish a safe landing after failure of a powerplant. There may be a speed/height envelope from which a safe landing cannot be made after a sudden failure of the powerplant. The existence of this envelope may drive control-system design to prevent flight within this envelope. The use of non-normal devices or operations (e.g., autorotation, parachute, rockets, and emergency power from auxiliary power sources) may reduce the size of this envelope or eliminate it.

Paragraphs (b), (c), and (e) reflect that when people are carried in a UAV, the safety level must reflect the safety level that is required of crewed aircraft.

B.7 UAV 23.2120: Climb requirements

Current FAA rule:

23.2120 Climb Requirements

The design must comply with the following minimum climb performance out of ground effect:

(a) With all engines operating and in the initial climb configuration—

> *(1) For levels 1 and 2 low-speed airplanes, a climb gradient of 8.3 percent for landplanes and 6.7 percent for seaplanes and amphibians; and*
>
> *(2) For levels 1 and 2 high-speed airplanes, all level 3 airplanes, and level 4 single-engines a climb gradient after takeoff of 4 percent.*

(b) After a critical loss of thrust on multiengine airplanes—

> *(1) For levels 1 and 2 low-speed airplanes that do not meet single-engine crashworthiness requirements, a climb gradient of 1.5 percent at a pressure altitude of 5,000 feet (1,524 meters) in the cruise configuration(s);*
>
> *(2) For levels 1 and 2 high-speed airplanes, and level 3 low-speed airplanes, a 1 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the takeoff configuration(s); and*
>
> *(3) For level 3 high-speed airplanes and all level 4 airplanes, a 2 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the approach configuration(s).*

(c) For a balked landing, a climb gradient of 3 percent without creating undue pilot workload with the landing gear extended and flaps in the landing configuration(s).

Recommended rule:

The design must comply with the following minimum climb performance out of ground effect:

(a) With all engines operating and in the initial climb configuration(s)—

(1) For levels 1 and 2 low-speed aircraft, a climb gradient of 8.3 percent for landplanes and 6.7 percent for seaplanes and amphibians; and

(2) For levels 1 and 2 high-speed aircraft, all level 3 aircraft, and level 4 single-engines a climb gradient after takeoff of 4 percent.

(3) For all aircraft (including VTOL), the minimum steady state rate of climb is 500 ft/min for land planes and 400 ft/min for amphibians and sea planes. The takeoff profile must provide the specified climb rate and gradient.

(b) An event or combination of events that causes the climb performance to fall below that specified by (b)(1), (b)(2) or (b)(3) as appropriate for the aircraft is considered a catastrophic event.

(1) For levels 1 and 2 low-speed **aircraft** that do not meet **the emergency landing requirements (UAV 23.2270) when landing on an unprepared surface, a climb gradient of 1.5 percent at a pressure altitude of 5,000 feet (1,524 meters) in the cruise configuration(s). For aircraft capable of vertical takeoff, compliance with this rule may be demonstrated by a 1.5 percent climb gradient at 60 knots indicated air speed (KIAS) or greater, or a minimum climb rate of 100 ft/min at any lower speed at 5,000 ft density altitude. For all aircraft, at 5,000 ft density altitude, the aircraft must be able to climb at 100 ft/minute or a climb gradient of 1.5 percent, whichever provides a higher climb rate.**

(2) For levels 1 and 2, high-speed **aircraft**, and level 3 low-speed **aircraft**, a 1 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the takeoff configuration(s); and

(3) For level 3, high-speed **aircraft** and all level 4 **aircraft**, a 2 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the approach configuration(s).

(4) For aircraft capable of vertical takeoff, compliance with this rule may be demonstrated by the climb gradient specified in the rule at 100 KIAS or greater, or a minimum average climb rate of 200 ft/min at any lower speed from 50 ft to 400 ft AGL.

(c) For a balked landing, a climb gradient of 3 percent without creating undue pilot workload with the landing gear extended and flaps in the landing configuration(s).

(1) If the aircraft automatically reconfigures after a go-around, then the go around configuration may be used if the required climb gradient is achieved in less than 6 seconds and is maintained.

(2) In addition to the minimum climb gradient, the minimum balked landing climb rate is 200 feet per minute which is about equivalent to 3% at 60 kt.

(Note: see Design Requirements for Category A Aircraft (Airworthiness Standards: Normal Category Airplanes, 2016) for additional modification to this paragraph for Category A certification. Category A certification is required for UAVs operated primarily over urban areas.)

<u>Discussion</u>

<u>(a):</u>

A climb gradient requirement is unnecessary for an aircraft going straight up (the gradient is infinite). However, a minimum climb requirement for these operations is still needed. For CVTOL aircraft, a 60-kt climb speed with a climb gradient of 8.3 percent results in about a 500-fpm climb rate, and 6.7 percent results in about 400 ft/min. This is a reasonable minimum climb rate for VTOL operations. The words "higher of the climb rate and gradient" are included to ensure that an aircraft (such as an electric VTOL aircraft) that needs to reduce power after takeoff can still achieve an acceptable climb gradient and rate with the reduced power.

<u>(b):</u>

The amendment 64 rule (FAA, 2022) was written specifically for aircraft with two independent engines (but covers three or more) and does not consider engine reliability or potential propulsion system integration issues. The wording was changed to reflect the potential for many different propulsion configurations and bring propulsion system reliability in line with other critical system reliability.

<u>(b)(1):</u>

Part 23 references the "single-engine crashworthiness requirements." Amendment 64 does not specify any similar requirements. In the previous amendments, 23.562 specified crashworthiness requirements. For Part 23 the phrase "…*airplanes that do not meet single-engine crashworthiness requirements*" is replaced with "…aircraft that do not meet the emergency landing requirements (UAV 23.2270) when landing on an unprepared surface" so that this part is up to date.

The intent of this rule is to require aircraft to have at least a minimum climb capability up to 5,000 ft to be able to continue level flight at a reasonable altitude. The rule specifies this in the form of a 1.5 percent climb gradient. At 60 kt, a 1.5 percent climb gradient is about 100 ft/min. Thus, a 100 ft/min minimum climb rate at low speeds accomplishes the intent.

(b)(2) & (b)(3):

The intent of this rule is to ensure that after loss of an engine that the aircraft has the ability to clear reasonable obstacles along the takeoff flight path. For VTOL aircraft, a gradient requirement is not needed. However, it is still desired to require a reasonable climb capability after loss of an engine on takeoff. Requiring a maximum of two minutes to reach 400 ft at very low speeds demonstrates this capability.

(c):

If an aircraft automatically configures for go-around, then credit should be allowed for this. Part 25 field performance allows the applicant to skip first segment climb gradient calculations if the landing gear retraction time is less than 6 seconds. (The first segment climb is the takeoff segment between leaving the ground and the landing gear being fully retracted.) Therefore, a 6-second transition time for go-around seems reasonable here since go-around is less critical than takeoff.

The 200 ft/minute requirement is to account for aircraft that can fly at very low or zero-forward speed. This requirement ensures a reasonable climb rate after a go-around.B.8 UAV 23.2125: Climb information

Current FAA rule:

23.2125 Climb Information

(a) The applicant must determine climb performance at each weight, altitude, and ambient temperature within the operating limitations—

(1) For all single-engine airplanes;

(2) For levels 1 and 2 high-speed multiengine airplanes and level 3 multiengine airplanes, following a critical loss of thrust on takeoff in the initial climb configuration; and

(3) For all multiengine airplanes, during the enroute phase of flight with all engines operating and after a critical loss of thrust in the cruise configuration.

(b) The applicant must determine the glide performance for single-engine airplanes after a complete loss of thrust.

Recommended rule:

(a) The applicant must determine climb performance at each weight, altitude, and ambient temperature within the operating limitations—

(1) For normal operations;

(**2) Following a critical loss of propulsive power, lifting power or control power that is more likely than is required for a catastrophic event, in all approved initial climb configurations; and**

(3) during the enroute phase of flight in normal operations and after a critical loss of thrust in the cruise configuration.

(b) The applicant must determine the glide performance **for aircraft that have a propulsion failure more likely than is required for a catastrophic event if that failure precludes maintaining altitude.**

Discussion

Unconventional designs may use power to maintain lift in addition to providing thrust. For example, a design may use a blown flap or boundary layer control or rotor lift to supplement wing lift that uses power. Loss of this power can have a significant effect on performance.

In some designs, loss of thrust or power may result in control compensation that has a detrimental effect on performance. For example, an aircraft may have significant blowing from tractor propellers to increase lift and spoilers for roll control. If the blowing on one side fails, there may be negligible thrust loss; but the lift loss on that side would be matched by deflecting the spoiler on the other side, which would also reduce lift.

The new wording embodies the same concept as the Part 23 rule but instead of splitting aircraft out according to the number of engines, it uses the probability of a failure in the propulsion/control system and its effect on performance.B.9 UAV 23.2130: Landing

Current FAA rule:

23.2130 Landing

The applicant must determine the following, for standard temperatures at critical combinations of weight and altitude within the operational limits:

(a) The distance, starting from a height of 50 feet (15 meters) above the landing surface, required to land and come to a stop.

(b) The approach and landing speeds, configurations, and procedures, which allow a pilot of average skill to land within the published landing distance consistently and without causing damage or injury, and which allow for a safe transition to the balked landing conditions of this part accounting for:

(1) Stall speed safety margin; and

(2) Minimum control speeds.

Recommended rule:

The applicant must determine the following, for standard temperatures at critical combinations of weight and altitude within the operational limits:

(a) The distance, starting from a height of 50 feet (15 meters) above the landing surface, required to land and come to a stop.

(b) The approach and landing speeds, configurations, and procedures, which allow a pilot of average skill to land within the published landing distance **or execute a vertical landing** consistently and without causing damage or injury, and which allow for a safe transition to the balked landing conditions **starting from any height down to touchdown** of this part accounting for **minimum touchdown speed**.

Discussion

New wording in (b) require that for aircraft capable of vertical takeoff and landing, the maximum landing weight for the altitude must be calculated, and the maximum weight must include the ability to go-around. Also, the lowest point where the go-around is started is defined (touchdown).

Since the aircraft covered by this airworthiness criteria do not have a stall speed, the minimum touchdown speed is used instead of stall speed in (b)(1), and (b)(1) is incorporated into (b).

For an applicant to use this airworthiness criteria, the control system must not allow the aircraft to fly below a speed at which it is controllable. Therefore (b)(2) is covered by (b)(1).

B.10 UAV 23.2135: Controllability

Current FAA rule:

23.2135 Controllability

(a) The airplane must be controllable and maneuverable, without requiring exceptional piloting skill, alertness, or strength, within the operating envelope—

(1) At all loading conditions for which certification is requested;

(2) During all phases of flight;

(3) With likely reversible flight control or propulsion system failure; and

(4) During configuration changes.

(b) The airplane must be able to complete a landing without causing substantial damage or serious injury using the steepest approved approach gradient procedures and providing a reasonable margin below Vref or above approach angle of attack.

(c) V_{MC} *is the calibrated air speed at which, following the sudden critical loss of thrust, it is possible to maintain control of the airplane. For multiengine airplanes, the applicant must determine* V_{MC}*, if applicable, for the most critical configurations used in takeoff and landing operations.*

(d) If the applicant requests certification of an airplane for aerobatics, the applicant must demonstrate those aerobatic maneuvers for which certification is requested and determine entry speeds.

Recommended rule:

(a) The **aircraft** must be controllable and maneuverable, without requiring exceptional piloting skill, alertness, or strength, within the operating envelope—

(1) At all loading conditions for which certification is requested;

(2) During all phases of flight;

(3) With flight control or propulsion system failures that are more probable than allowed for a catastrophic event; and

(4) During configuration changes.

(b) The aircraft must be able to complete a landing without causing substantial damage or serious injury using the steepest approved approach gradient procedures and providing a reasonable margin below Vref or above approach angle of attack.

(c) For aircraft with multiple thrust, lift or power sources, the speed and configuration envelope outside of which a critical power, lift or thrust failure would result in loss of control must be determined, and if the probability of such a failure is greater than allowed for a catastrophic event, the control system must be designed to prevent flight in this envelope.

(d) UAV aircraft must have protections that prevent loss of control or exceeding the flight envelope.

(e) For aircraft with hover taxi capability, the aircraft must be controllable and maneuverable during hover taxi, without requiring exceptional piloting skill, alertness, or strength, with wind velocity of zero to 17 knots from all azimuths.

Discussion

Paragraph (a)(3) refers to reversible controls. The aircraft covered by this airworthiness criteria do not have reversible controls. However, the rewritten paragraph (a)(3) addresses the potential analogous failure for fly-by-wire (FBW).

Paragraph (c) was written in Amendment 64 with conventional twin-engine aircraft that have mechanical controls in mind. New aircraft configurations or FBW control systems may have flight envelopes in which a failure could result in loss of control (like loss of an engine below Vmc in a conventional twin can result in loss of control). This regulation is expanded to include these potential new designs. It also specifies that the control system should prevent operations within this envelope if the probability of a failure that could result in loss of control is greater than that allowed for a catastrophic event. This is because it is assumed that loss of control is catastrophic.

Paragraph (d) addresses aerobatic flight. UAVS are typically not used for aerobatic flight, but in the event they are, that option is retained. However, since there is no pilot, normal cues (e.g., buffet, G loading, and sounds) that often accompany approaching the edge of the flight envelope are not available. Envelope protections are therefore required to prevent loss of control.

Paragraph (e) is a concept from UAV 27.143(c) & (d). Part 27 requires controllability and maneuverability with winds up to 17 knots. Part 23 has no wind requirements but does require publishing a maximum demonstrated crosswind speed (not a limitation). VTOL aircraft often hover taxi, so a wind from all azimuths is appropriate. The 17-knot requirement comes directly from Part 27.

B.11 UAV 23.2140: Trim

Current FAA rule:

23.2140 Trim

(a) The airplane must maintain lateral and directional trim without further force upon, or movement of, the primary flight controls or corresponding trim controls by the pilot, or the flight control system, under the following conditions:

(1) For levels 1, 2, and 3 airplanes in cruise.

(2) For level 4 airplanes in normal operations.

(b) The airplane must maintain longitudinal trim without further force upon, or movement of, the primary flight controls or corresponding trim controls by the pilot, or the flight control system, under the following conditions:

(1) Climb.

(2) Level flight.

(3) Descent.

(4) Approach.

(c) Residual control forces must not fatigue or distract the pilot during normal operations of the airplane and likely abnormal or emergency operations, including a critical loss of thrust on multiengine airplanes.

Recommended rule:

(a) During non-hovering flight, the aircraft must require no pilot force to maintain a straight lateral and vertical path at constant speed.

(b) During hovering flight, the aircraft must require no pilot force to maintain heading and zero speed.

(c) At speeds near hover, a constant force may be allowed to command slow constant lateral or longitudinal speed.

(d) During abnormal operations, pilot control forces must not fatigue or distract the pilot, including a critical loss of thrust on aircraft with multiple power sources, thrust or lift devices.

(e) During automatic configuration changes only minor deviations in flight path are allowed with no pilot input.

Discussion

UAV aircraft provide inceptor force independent of aerodynamic or mechanical forces from the control system.

Many of the proposed control systems are always in trim during unaccelerated flight in a constant configuration. Therefore, they have control systems that do not require the pilot to trim the aircraft in any axis. The rule was rewritten to allow these new control systems but also allow conventional UAV systems where a spring is used for centering and a trim control is used to "center" the actuator.

Paragraph (a)(1) of Part 23 appears to be a concession for small airplanes that typically don't have trim in all axes. With UAVs there is no need for this concession. Paragraphs (a)(2) and (b) are covered by the new paragraphs (a), (b) and (c). The new paragraph (d) covers the intent of the original (c).

Paragraph (e) requires that if the aircraft changes configuration automatically (without pilot action) that the flight path remains substantially unchanged from the commanded flight path through the configuration change. This requirement is important when the pilot has set up a trajectory and a configuration change occurs that the pilot did not initiate. Since the pilot may not know exactly when the configuration change will occur, they may not be tightly in the loop to control the trajectory as the configuration change occurs. In this case, it is unacceptable for the aircraft to also unexpectedly change the flight path from what the pilot commanded. If the pilot commands the configuration change, then it is acceptable for the aircraft to change the commanded flight path since the pilot initiated the change. This is much like a pilot-commanded flap change in a conventional airplane, which can change the trim, and the pilot is expected to retrim if needed. However, if the flap change occurs automatically as the airplane changes speed, the change may occur at a time when the pilot is busy with other tasks and may not notice the trajectory change.

The intent of this rule is to provide a zero-force reference for the stability requirement (UAV 23.2145). Constant pilot force is specifically allowed during a turn since a turn is a temporary condition of short duration. The zero-force requirement may be met by a position hold function of the controls such as the flight path stick position lock.

Trim and stability are related. See the discussion regarding the stability rule (UAV 23.2145 Stability) for more information concerning trim and stability.

B.12 UAV 23.2145: Stability

Current FAA rule:

23.2145 Stability

(a) Airplanes not certified for aerobatics must—

> *(1) Have static longitudinal, lateral, and directional stability in normal operations;*
>
> *(2) Have dynamic short period and Dutch roll stability in normal operations; and*
>
> *(3) Provide stable control force feedback throughout the operating envelope.*

(b) No airplane may exhibit any divergent longitudinal stability characteristic so unstable as to increase the pilot's workload or otherwise endanger the airplane and its occupants.

Recommended rule:

(a) The aircraft must have static and dynamic stability about the following states for all operations.

(1) Vertical flight path, vertical speed, or vertical acceleration

(2) Altitude when zero vertical speed is commanded (altitude stability replaces vertical path or vertical speed or vertical acceleration stability)

(3) Forward speed

(4) Bank angle

(5) Lateral speed during hover (lateral speed stability replaces bank stability)

(6) Heading or track when zero bank is commanded (heading or track stability replaces bank stability)

(b) Static stability is defined as

(1) the tendency to return to a commanded state when an external disturbance causes the aircraft to deviate from the commanded state and

(2) when the pilot exerts a force on the inceptor, the inceptor is displaced proportionally to the force and

(3) the position of the inceptor generates the commanded aircraft state and

(4) the aircraft motion shall be in the same direction as the inceptor motion – it is not acceptable for the aircraft motion to reverse without a reversal of the inceptor position, except that airspeed may reverse when a climb rate is commanded that results in full power and the aircraft cannot maintain the commanded speed and climb rate (climb rate has priority over airspeed when these two commands cannot be satisfied together).

(c) The aircraft must be dynamically stable about the commanded state with heavy damping - heavy damping is defined as less than 1/10th amplitude in 3 cycles. However, Dutch roll may be damped to 1/10th amplitude in no more than 7 cycles.

(d) Dynamic preprogrammed maneuvers such as takeoff, landing, and go around may provide stability about some other state than is listed in (a). However, they must provide stability about a defined state such as pitch attitude, normal acceleration, longitudinal acceleration, etc. The state about which stability is provided may change as the preprogrammed maneuver progresses.

Discussion

The Part 23 rule specifies stability that can be achieved though unaugmented mechanical control systems. Because of the nature of mechanical control systems, axes are coupled together. FBW systems can provide stability about each axis independently and therefore decouple the axes. This makes the aircraft easier to learn to fly. The UAV rule was rewritten to require stability about each axis independently.

(a), (b):

Trim and stability requirements (UAV 23.2140 and UAV 23.2145, respectively) are intended to work together. Therefore, the discussion of trim and stability are combined in this section to provide a more comprehensive and succinct discussion than if trim and stability were discussed separately.

The listed parameters in the trim and stability requirements are intended to apply to an aircraft that has acceptable workload and meets the intent of the original regulation, but they are stated in a way that applies to FBW and UAV aircraft generically. Note that the requirements apply to all operations. This includes AP operations.

Note that a conventional mechanical control Part 23 airplane or helicopter may not meet these requirements. The original regulations made concessions in the original regulations based on historical mechanical control system/aerodynamics that allow for characteristics that have been shown to increase pilot workload or contribute to loss of control accidents. These characteristics include spiral divergence for airplanes and lack of pitch, bank, and speed stability for helicopters in hover. FBW and control systems used in UAVs are well suited to eliminate these characteristics.

Lateral stability is the ability to raise a wing using rudder, as traditionally understood for the purpose of Part 23. Bank stability is desired, but the aerodynamics of typical general aviation configurations usually do not provide it without augmentation. However, with dihedral configurations, bank, yaw and sideslip are connected. Yaw stability is provided by the vertical fin. Thus, a bank instability can be improved by providing dihedral effect. The dihedral effect combined with sideslip improves an airplane's lateral characteristics. The ability to raise a wing by producing sideslip, which is called static lateral stability for certification purposes, demonstrates that an airplane has this coupling. For UAVs, the understanding of lateral stability is replaced with bank stability.

A stable bank angle produces a stable turn rate at a constant speed. Therefore, an aircraft that commands turn rate may demonstrate turn stability in forward flight by demonstrating bank stability.

To make a helicopter safe for instrument flight, Part 27 adds appendix B, which adds specific stability requirements for a helicopter that are similar to the requirements for fixed-wing airplanes. It also implicitly recognizes that helicopters with conventional mechanical controls are not inherently stable in hover by specifically allowing a minimum instrument flight rules (IFR) speed for which a mechanical control helicopter can be made stable. It also addresses stability augmentation devices that may be required to make a helicopter stable. FBW and UAV aircraft are expected to be stable through the normal flight envelope and therefore the equivalent of Part 27 Appendix B is not required.

The following describes how the vertical and lateral trim and stability requirements apply for the traditional Radio-Controlled Airplane, Unified and EZ-Fly VTOL control systems during non-hover flight.

Radio-controlled airplane

A traditional radio-controlled airplane system uses an inceptor that is spring loaded to the center and directly controls the position of the elevator, ailerons, rudder, and throttle. The actuator on the aircraft is biased using a trim slider near the actuator. The change in bias has the effect of changing the position of the actuator when the inceptor is centered.

The longitudinal stick position controls the position of the elevator, which in turn controls the AOA. The commanded state is therefore AOA, but when the operator moves the stick, the aircraft climbs or descends. When it climbs or descends, if the throttle is not changed, the aircraft will speed up or slow down. If the operator then releases the stick, the elevator goes back to its original position, which changes the AOA and causes the aircraft to increase or decrease its flight path angle to regain the original flight path angle at the original speed. Thus, it has vertical path stability and speed stability if the thrust or power is held constant. The trim slider moves the center position of the actuator, which also changes the AOA. The aircraft then pitches up or down as commanded by the new AOA until the aircraft reaches a speed and flight path angle at which thrust and the component of gravity along the flight path match the aircraft's drag, and the airplane stabilizes at a new speed and flight path angle. Thus, a traditional radio-controlled airplane flight control system meets the (a)(1) –vertical and (a)(3) –speed but not (a)(2) –altitude hold parts of the stability requirement without an autogemination. Manually holding altitude without augmentation for long periods of time with a control system like this and without the external cues of feeling updrafts, hearing speed increases, etc. requires low effort but is an extremely repetitive task. Humans are inherently not good at performing these kinds of tasks reliably over time.

The lateral stick position directly commands the aileron position. In the short term this commands bank acceleration with stabilizes over the long term to bank rate. The aircraft typically does not have natural bank stability and in fact is typically divergent such that if the pilot does not constantly correct the bank angle, it slowly diverges to an extreme angle. This system does not meet the requirements of (a)(4) –bank stability or (a)(6) –heading or track stability when centered without augmentation. As in the unaugmented vertical stability case, the pilot of this type of system would be required to constantly make corrections to hold heading or track a navigation course but without the benefit of feeling roll accelerations and rates that an onboard pilot feels. Like the case of holding altitude with an unaugmented system, this is a low effort but extremely repetitive task that humans are not good at performing reliably over time.

However, due to the centering spring on the inceptor, this system does meet the trim requirements in non-hovering flight.

<u>Unified control systems</u>

For the unified control system (UCS), the longitudinal stick force commands vertical acceleration in cruise and vertical speed in hover, with zero force commanding zero acceleration (constant flight path) in cruise and altitude hold in hover.

For a mechanical control system, the longitudinal stick force is

$$F_s = k_1 * N_z + k_2 * \Delta V$$

where F_s is stick force,

k_1 is a constant,

N_z is vertical acceleration,

k_2 is a constant and

ΔV is the difference between the current speed and the trim speed.

The Unified system sets k_2 to zero. Therefore, there is no force due to being off trim speed, and there is no static longitudinal stability as defined by Part 23 Advisory Circular (AC-23-8) (FAA, 2011). The stick position (force) in the UCS commands vertical acceleration only in forward flight and the aircraft is always in trim. Zero force commands zero vertical acceleration. The aircraft is always “trimmed” for zero vertical acceleration at any and all speeds. An auto throttle system is required to provide the forward-speed stability.

The UCS provides vertical acceleration stability.

Lateral displacement of the stick from its centered position commands a bank rate. The centered position holds the current bank angle (provides bank angle stability) except when near-zero bank. At near-zero bank, the control law assumes the pilot intends to go straight and transitions to holding the current heading or track (depending on implementation). The UCS meets the trim and stability requirements.

<u>EZ-Fly VTOL</u>

For EZ-Fly VTOL, stick force commands flight path angle in cruise and vertical speed in hover, with zero-force commanding level at all speeds. There is no trim. There is a provision to lock the stick into a pilot selected position to command a constant flight path other than level with zero force. The speed command is required to provide the forward-speed stability.

The EZ-Fly VTOL system provides altitude stability but also provides flight path stability when the stick is locked in a non-zero position.

Lateral displacement of the stick commands turn rate. Centering the stick commands heading or track hold. EZ-Fly VTOL meets the stability and trim requirements.

(c):

1/10th amplitude is easy to determine through use of a strip chart, and 1/10th amplitude is also often considered to be zero motion when qualitatively watching a system. Damped in 3 cycles or less is often used in AP evaluations as barely acceptable. Amendment 63 of Part 23 specified seven cycles or less to damp as the minimum damping for Dutch roll at low altitude. Electronic feedback control loops with more than 1.5 cycles to damp in a conformed prototype aircraft may experience difficulty providing the required damping at less than three cycles in all production versions at all flight conditions. Therefore, applicants are encouraged to verify greater stability margin than the minimum required in their certification aircraft to prevent failure of this requirement by production aircraft.

Conventional aircraft configurations with positive lateral stability often have a lightly damped Dutch roll mode. The reduced damping ratio for the Dutch roll mode is a concession for conventional airplane configurations. Since a lightly damped Dutch roll mode is not considered unsafe but is primarily a pilot/passenger annoyance, this concession is extended to all aircraft.

Part 27 only requires that the aircraft move in the direction the stick is moved. For a mechanically controlled helicopter in hover, there is typically no stability about any axis, and all axes are coupled. This new rule requires that UAVs be stable in all axes during hover and the axes are not coupled.

(d):

This paragraph is included to allow a provision for flight modes or pilot-selected automatic modes that produce dynamic maneuvers. For instance, an automated conventional takeoff mode may command an acceleration followed by a pitch rate to a specified pitch attitude until a specific speed is reached, and then pitch to follow that speed until a height above ground is reached, then command an acceleration until another specified speed is reached, and then command a flight path angle. Each of these segments must be stable about its defined state even if the commanded state is changing.

B.13 UAV 23.2150: Low-speed characteristics, low-speed warning, and upsets

Current FAA rule:

23.2150 Stall characteristics, stall warning, and spins

(a) The airplane must have controllable stall characteristics in straight flight, turning flight, and accelerated turning flight with a clear and distinctive stall warning that provides sufficient margin to prevent inadvertent stalling.

(b) Single-engine airplanes, not certified for aerobatics, must not have a tendency to inadvertently depart controlled flight.

(c) Levels 1 and 2 multiengine airplanes, not certified for aerobatics, must not have a tendency to inadvertently depart controlled flight from thrust asymmetry after a critical loss of thrust.

(d) Airplanes certified for aerobatics that include spins must have controllable stall characteristics and the ability to recover within one and one-half additional turns after initiation of the first control action from any point in a spin, not exceeding six turns or any greater number of turns for which certification is requested, while remaining within the operating limitations of the airplane.

(e) Airplanes certified for aerobatics that include spins must have controllable stall characteristics and the ability to recover within one and one-half additional turns after initiation of the first control action from any point in a spin, not exceeding six turns or any greater number of turns for which certification is requested, while remaining within the operating limitations of the airplane.

(1) With any typical use of the flight or engine power controls; or

(2) Due to pilot disorientation or incapacitation.

Recommended rule:

(a) The aircraft must not have reversals or discontinuities of aircraft vertical motion relative to the commanded vertical motion during normal operations. For conventional landing flare, pitch can be considered as the vertical command.

(b)The aircraft must not experience control reversals or control discontinuities due to gusts of 10 kt for less than 1 second from any direction. Transient response to the gust is expected.

(c) For severe turbulence induced upsets, the aircraft shall return to controlled flight within the normal flight envelope without pilot action within 5 seconds after the turbulence has subsided for a bank upset and 10 seconds for a pitch upset.

(d) Failure to maintain continued controlled flight after a failure in continued turbulence of 20 kt gusts from any direction is considered catastrophic.

(e) Aircraft capable of vertical flight must be designed to prevent settling with power such that maximum available power does not produce less than 0.2 G of upward acceleration in any flight condition other than climbing, and can prevent ground contact with any combination of height and rate of descent allowed by the flight controls.

(f) There must be an indication to the pilot when the minimum commandable speed has been commanded. There must also be an indication to the pilot that the minimum commandable speed is being approached or has been crossed due to a vertical path command.

Discussion

The UCS and EZ-Fly VTOL control systems prevent stalls and spins, but other causes of upsets need to be addressed, such as turbulence caused by atmospheric phenomena and wake turbulence from other aircraft. This revised regulation requires that the aircraft be able to recover from these upsets and provides a performance requirement for doing so. It also addresses settling with power since this is a low-speed, loss-of-control phenomenon.

Stalls and spins are often either the cause or result of an upset. Upset recovery from any cause can be covered by the same regulation. Therefore, upset recovery is included in this rule. Paragraphs (d) and (e) of Part 23 do not apply since the envelope protections prevent aerobatic maneuvers.

Paragraph (a) prohibits vertical aircraft motion opposite of the pilot commanded motion. This applies during protections. For instance, UAV 23.2170 requires overspeed protection. One way to accomplish this is to pitch up to climb and slow down when flaps are deployed above Vfe. This would violate paragraph (a) since the pilot may be commanding down while deploying flaps. Another way to accomplish the overspeed protection would be to prevent flaps from being deployed above maximum flap speed. This would comply with paragraph (a). Maintaining a constant altitude (within a reasonable tolerance) is not considered to be vertical motion opposite of the command, regardless of the vertical command.

From the pilot's perspective, a stall occurs when the pilot commands more up until the aircraft stalls. When the stall occurs, the airplane reverses vertical direction and starts to go down with the pilot still commanding up. This is a reversal of aircraft vertical motion relative to the commanded vertical motion and violates paragraph (a) since the aircraft is going down while the pilot is commanding up. This rule is intended to prevent this situation. The required AOA protection from UAV 23.2170 may require that the throttle be integrated as part of the AOA protection system. For such an integrated system, the aircraft may slow to the minimum commandable speed as defined by UAV 23.2110 (c), at which point, if the pilot continues to command more up, the aircraft adds power so that the aircraft goes up. If the pilot continues to command up such that there is insufficient power to maintain speed, the aircraft will limit AOA to Vx, as defined in UAV 23.2110 (c). The result is the aircraft climbing at climb power and Vx (no vertical motion reversal).

During a conventional (not VTOL) landing flare, pitch may be used as the vertical command for the purpose of this regulation. This special case is allowed because during the landing flare the airspeed is decreasing, which requires AOA (and therefore pitch) to increase even though the aircraft may be descending.

For aircraft that directly command speed (EZ-Fly VTOL), a display of commanded speed and an indication when the commanded speed is at the minimum or maximum for the current configuration is considered to meet the intent of paragraph (f). For aircraft that use a throttle and require the pilot to control speed through modulation of power or acceleration (UCS), a conspicuous marking on the airspeed indicator denoting the minimum commandable airspeed combined with the automatic increase of power is considered to meet the intent of paragraph (f). In both cases, a conspicuous indication that the aircraft is slowing below the minimum commandable speed resulting from commanding a climb must be provided.

The following is an example of a way that each of the example control systems can meet this requirement. Wing-borne flight without transition to powered vertical lift is assumed for these examples.

<u>SVO-A1 (Unified)</u>

At speed, the speed command lever commands acceleration along the flight path. The flight path is nearly parallel to the body axis. Because thrust is directly proportional to acceleration for a constant mass, for UCS at speed, the speed command lever acts very similar to a conventional throttle of a jet airplane.

Assume the pilot is descending and commands a deceleration, but in this case that aircraft is not allowed to transition to hover mode as the aircraft slows. As the aircraft slows, the pilot maintains the stick position in neutral to command a constant vertical flight path. The aircraft slows due to the deceleration command but maintains the same vertical flight path. Eventually the aircraft reaches its minimum commandable airspeed for that configuration. Since in this aircraft, the pilot closes the loop on speed using the acceleration command (like a throttle), an airspeed indicator that provides trend information is required. The minimum commandable airspeed (Vref) is marked on the airspeed indicator. The pilot continues to hold the stick in the neutral position, which causes the aircraft to continue to decelerate. As the aircraft reaches the minimum commandable speed, the speed command lever (acting like a throttle) automatically moves forward to add thrust to prevent slowing below the minimum commandable speed. The aircraft stabilizes at the minimum commandable airspeed (Vref, per UAV 23.2110). If the pilot pulls back on the stick to command an up acceleration, the aircraft pitches up and thrust is added to maintain the minimum commandable speed. As the climb rate gets high enough that there is not enough thrust to maintain the vertical speed at maximum thrust, the aircraft slows below the minimum commandable speed. The aircraft continues to slow with maximum thrust until Vx (speed for maximum climb angle) is reached. At this point, the AOA system stabilizes the aircraft at the AOA that corresponds to Vx (See UAV 23.2110), which leaves the aircraft climbing at maximum thrust and Vx.

For this design example, no vertical motion reversal occurs.

<u>SVO-A2 (EZ-Fly VTOL)</u>

The aircraft is descending with the stick locked in a forward-of-neutral position. The pilot selects the minimum commandable speed by moving the speed command as far as possible in the "slower" direction. The aircraft slows to and stabilizes at the minimum commandable speed for that configuration (Vref, per UAV 23.2110). The pilot unlocks the stick and pulls back to command a climb rate then locks the stick in that position. The aircraft pitches up to achieve the commanded climb rate. Thrust is automatically increased to hold the commanded speed. The commanded climb rate is higher than the available thrust can maintain. The aircraft starts to slow below the minimum commandable speed as maximum thrust is applied. The aircraft continues to slow until Vx (speed for maximum climb angle) is reached. At this point, the AOA system stabilizes the aircraft at the AOA that corresponds to Vx (See UAV 23.2110), which leaves the aircraft climbing at maximum thrust and Vx.

For this design example, no vertical motion reversal occurs.

<u>VTOL:</u>

The requirement for vertical flight aircraft is intended to prevent designs from entering a condition, such as a settling with power or vortex ring state, where the aircraft cannot stop descending or landing safely with the pilot simply commanding more "up." This may require the flight controls to be designed to not allow speed/descent rate/power combinations that are conducive to this state.

The 0.2 G requirement comes from the concept of providing a minimum maneuvering margin. Part 25 requires that an amber band be provided on the airspeed tape indicating a maneuvering margin relative to stall warning speed. There is no specific requirement for this margin, but a common speed used by original equipment manufacturers is the minimum speed at which the aircraft can hold altitude and bank to 35 degrees without triggering stall warning. The additional G loading due to a level 35-degree bank turn is 0.22 G.

The requirement to recover from severe turbulence after the turbulence has subsided may be satisfied by showing that the flight control system will recover the aircraft from all attitudes from which it is possible to recover the aircraft. In other words, the flight control system produces the maximum control power available and in the appropriate direction to recover the aircraft.

Note that in the revised rule, actual stalls are not mentioned. The intent of the original rule was to require acceptable handling characteristics and warnings related to stalls. The rule is no intended to prevent stalls . The issue is thel ack of controllability that results from stalls in conventional mechanically controlled airplanes. The recommended rule in this section and the stability section (UAV 23.2125(b)(iv)) deals with the root issue by requiring the aircraft always goes in the direction it is commanded.

An example of appropriate airspeed markings is included in the recommended Advisory Circular (UAV 23.2150) (Stall characteristics, stall warning, and spins, 2025), as discussed in Appendix C.

B.13 UAV 23.2160: Vibration, buffeting, and high-speed characteristics

Current FAA rule:

23.2160 Vibration, buffeting, and high-speed characteristics

(a) Vibration and buffeting, for operations up to VD/MD, must not interfere with the control of the airplane or cause excessive fatigue to the flightcrew. Stall warning buffet within these limits is allowable.

(b) For high-speed airplanes and all airplanes with a maximum operating altitude greater than 25,000 feet (7,620 meters) pressure altitude, there must be no perceptible buffeting in cruise configuration at 1g and at any speed up to VMO/MMO, except stall buffeting.

(c) For high-speed airplanes, the applicant must determine the positive maneuvering load factors at which the onset of perceptible buffet occurs in the cruise configuration within the operational envelope. Likely inadvertent excursions beyond this boundary must not result in structural damage.

(d) High-speed airplanes must have recovery characteristics that do not result in structural damage or loss of control, beginning at any likely speed up to VMO/MMO, following—

(1) An inadvertent speed increase; and

(2) A high-speed trim upset for airplanes where dynamic pressure can impair the longitudinal trim system operation.

Recommended changes:

(a) Vibration and buffeting, for operations up to design limit speed (VD)/design limit Mach number (MD), must not interfere with the control of the **aircraft** or cause excessive fatigue to the flight crew. **Mild vibration and/or buffet due to separation during transition to and from vertical flight within these limits is allowable.**

(b) For high-speed **aircraft** and all **aircraft** with a maximum operating altitude greater than 25,000 feet (7,620 meters) pressure altitude, there must be no perceptible buffeting in cruise configuration at 1g and at any speed up to VMO/MMO**, Mild vibration and/or buffet due to separation during transition to and from vertical flight is allowable.**

(c) For high-speed **aircraft,** the applicant must determine the positive maneuvering load factors at which the onset of perceptible buffet occurs in the cruise configuration within the operational envelope. Likely inadvertent excursions beyond this boundary must not result in structural damage.

(d) High-speed **aircraft** must have recovery characteristics that do not result in structural damage or loss of control, beginning at any likely speed up to VMO/MMO, following—

(1) An inadvertent speed increase; and

(2) A high-speed **flight control system failure for aircraft where dynamic pressure or Mach can impair the control system operation**.

(e) for aircraft capable of vertical takeoff or landing, there must be no ground resonance that interferes with control of the aircraft.

Discussion

(a)(b):

Paragraphs (a) and (b) apply to FBW aircraft as written except that stall warning buffet should not be allowed since the minimum speed will be about where current stall warning is or higher.

They also apply to VTOL aircraft, but there may need to be a concession for buffet caused by separated airflow during transition.

(d)(2):

This rule was originally written with the assumption that aircraft had mechanical control systems but may have electric trim. FBW aircraft have electronics for all control. Therefore, considering any flight control system failure is more appropriate for FBW aircraft as opposed to only considering trim failures.

€:

Section 27.663 assumes a means to prevent ground resonance and discusses the failure of this means. This addition regulates ground resonance. The reliability of the ground resonance damping system must meet requirements for the hazard level assigned to failure of the system.

B.14 UAV 23.2165: Performance and flight characteristics requirements for flight in icing conditions

Current FAA rule:

23.2165 Performance and flight characteristics requirements for flight in icing conditions

(a) An applicant who requests certification for flight in icing conditions defined in part 1 of appendix C to part 25 of this chapter, or an applicant who requests certification for flight in these icing conditions and any additional atmospheric icing conditions, must show the following in the icing conditions for which certification is requested under normal operation of the ice protection system(s):

(1) Compliance with each requirement of this subpart, except those applicable to spins and any that must be demonstrated at speeds in excess of—

(i) 250 knots CAS;

(ii) VMO/MMO or VNE; or

(iii) A speed at which the applicant demonstrates the airframe will be free of ice accretion.

(2) The means by which stall warning is provided to the pilot for flight in icing conditions and non-icing conditions is the same.

Recommended rule:

(a) An applicant who requests certification for flight in icing conditions defined in part 1 of appendix C to part 25 of this chapter, or an applicant who requests certification for flight in these icing conditions and any additional atmospheric icing conditions, must show the following in the icing conditions for which certification is requested under normal operation of the ice protection system(s):

(1) Compliance with each requirement of this subpart, except those applicable to spins and any that must be demonstrated at speeds in excess of—

(i) 250 knots calibrated air speed (KCAS);

(ii) VMO/MMO or never exceed speed (VNE); or

(iii) A speed at which the applicant demonstrates the airframe will be free of ice accretion.

(Note: this rule applies as written except that (a)(2) should be deleted.)

Discussion

Stall warning has no real meaning for aircraft covered by this rule. See discussion concerning UAV 23.2150 Low-speed characteristics, low-speed warning, and upsets

B.14 UAV 23.2200: Structural design envelope

Current FAA rule:

23.2200 Structural Design Envelope

The applicant must determine the structural design envelope, which describes the range and limits of airplane design and operational parameters for which the applicant will show compliance with the requirements of this subpart. The applicant must account for all airplane design and operational parameters that affect structural loads, strength, durability, and aeroelasticity, including:

(a) Structural design airspeeds, landing descent speeds, and any other airspeed limitation at which the applicant must show compliance to the requirements of this subpart. The structural design airspeeds must—

(1) Be sufficiently greater than the stalling speed of the airplane to safeguard against loss of control in turbulent air; and

(2) Provide sufficient margin for the establishment of practical operational limiting airspeeds.

(b) Design maneuvering load factors not less than those, which service history shows, may occur within the structural design envelope.

(c) Inertial properties including weight, center of gravity, and mass moments of inertia, accounting for—

(1) Each critical weight from the airplane empty weight to the maximum weight; and

(2) The weight and distribution of occupants, payload, and fuel.

(d) Characteristics of airplane control systems, including range of motion and tolerances for control surfaces, high lift devices, or other moveable surfaces.

(e) Each critical altitude up to the maximum altitude

Recommended rule:

The applicant must determine the structural design envelope, which describes the range and limits of the **aircraft's** design and operational parameters for which the applicant will show compliance with the requirements of this subpart. The applicant must account for all **aircraft** design and operational parameters that affect structural loads, strength, durability, and aeroelasticity, including:

(a) Structural design airspeeds, landing descent speeds, and any other airspeed limitation at which the applicant must show compliance to the requirements of this subpart. The structural design airspeeds must—

(1) Be sufficiently greater than **the minimum speed** of the aircraft to safeguard against loss of control in turbulent air; and

(2) Provide sufficient margin for the establishment of practical operational limiting airspeeds.

(b) Design maneuvering load factors not less than those, which service history shows, may occur within the structural design envelope.

(c) Inertial properties including weight, center of gravity, and mass moments of inertia, accounting for—

(1) Each critical weight from the **aircraft** empty weight to the maximum weight; and

(2) The weight and distribution of occupants, payload, and fuel.

(d) Characteristics of **aircraft** control systems **and propulsive devices used for control**, including range of motion and tolerances for control surfaces, high-lift devices, or other moveable surfaces.

(e) Each critical altitude up to the maximum altitude

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Discussion

(a)(1):

The aircraft that use this section do not have a stall speed. They have a minimum speed instead.

(d):

This paragraph includes propulsive devices that are used to affect control of the aircraft, or that provide powered lift, or augment lift by adding energy to the airstream.B.15 UAV 23.2215: Flight load conditions

Current FAA rule:

23.2215 Flight load conditions

The applicant must determine the structural design loads resulting from the following flight conditions:

(a) Atmospheric gusts where the magnitude and gradient of these gusts are based on measured gust statistics.

(b) Symmetric and asymmetric maneuvers.

(c) Asymmetric thrust resulting from the failure of a power plant unit.

Recommended rule:

The applicant must determine the structural design loads resulting from the following flight conditions:

(a) Atmospheric gusts where the magnitude and gradient of these gusts are based on measured gust statistics.

(b) Symmetric and asymmetric maneuvers.

(c) Asymmetric thrust resulting from the failure of a power plant unit.

(d) Failure of control systems.

Discussion

Failure of the FBW system can create loads that are not seen for failures of mechanical control systems. These loads are then used to determine the criticality level of the failure which then determines the required probability associated with that failure.

B.16 UAV 23.2220: Ground and water load conditions.

Current FAA rule:

23.2220 Ground and water load conditions.

The applicant must determine the structural design loads resulting from taxi, takeoff, landing, and handling conditions on the applicable surface in normal and adverse attitudes and configurations.

Recommended rule:

The applicant must determine the structural design loads resulting from taxi, takeoff, landing, and handling conditions on the applicable surface in normal and adverse attitudes and configurations. **For aircraft capable of vertical landing, the landing tests and analysis may assume that no more than 2/3 of the aircraft's weight is supported aerodynamically throughout the landing impact.**

Discussion

The additional sentence comes from 27.427 (a) (Unsymmetrical loads, 2025). For conventional landings, the wing provides lift throughout the landing. This wing lift is easily calculated as a function of AOA in ground effect and speed. The aerodynamic lift through landing is not as obvious for VTOL aircraft. The added sentence is intended to define residual aerodynamic lift through the landing for structural load purposes.

B.17 UAV 23.2230: Limit and ultimate loads

Current FAA rule:

23.2230 Limit and ultimate loads

The applicant must determine—

(a) The limit loads, which are equal to the structural design loads unless otherwise specified elsewhere in this part; and

(b) The ultimate loads, which are equal to the limit loads multiplied by a 1.5 factor of safety unless otherwise specified elsewhere in this part.

Recommended changes:

The applicant must determine—

(a) The limit loads, which are equal to the structural design loads unless otherwise specified elsewhere in this part; and

(b) The ultimate loads, which are equal to the limit loads multiplied by a 1.5 factor of safety unless otherwise specified elsewhere in this part.

(c) The ultimate loads for lifting fans or rotors, which are equal to the limit loads times 1.5 for normal and emergency operations and 1.5 times the load resulting from a sudden stoppage due to failure of the drive mechanism. For this requirement, loads resulting from components hitting a stop during normal operations (such as ground operations) must be included.

Discussion

Section 27.361 (Engine torque, 1988) defines limit and ultimate torque loads based on the aircraft having a turbine engine or an engine with multiple cylinders. The turbine requirement is based on a sudden stoppage of the engine. The sudden stoppage requirement also meets the intent of the Part 27 requirement for piston engines.

Section 27.547 (d)(1) specifically includes the concept of blades, hubs, etc. hitting stops during ground operations.

B.18 UAV 23.2235: Structural strength

Current FAA rule:

23.2235 Structural strength

The structure must support:

(a) Limit loads without—

(1) Interference with the safe operation of the airplane; and

(2) Detrimental permanent deformation.

(b) Ultimate loads.

Recommended rule:

The structure must support:

(a) Limit loads without—

(1) Interference with the safe operation of the aircraft; and

(2) Detrimental permanent deformation.

(b) Ultimate loads.

(c) Dynamic loads of rotor systems and propellers used for lift.

Discussion

The new requirement comes from 14 CFR 27.307 (b)(1). Rotors and propellers used for lift are more critical than propellers used for thrust only. Also, propellers used for thrust only are typically mounted to an engine, which is attached to the structure through mounts that isolate dynamic loads. Rotors are often attached through bearings that transmit dynamic loads to the structure.

B.19 UAV 23.2245: Aeroelasticity

Current FAA rule:

23.2245 Aeroelasticity.

(a) The airplane must be free from flutter, control reversal, and divergence—

(1) At all speeds within and sufficiently beyond the structural design envelope;

(2) For any configuration and condition of operation;

(3) Accounting for critical degrees of freedom; and

(4) Accounting for any critical failures or malfunctions.

(b) The applicant must establish tolerances for all quantities that affect flutter.

Recommended rule:

(a) The **aircraft** must be free from flutter, control reversal **(at the inceptor – not necessarily at the control effector),** and divergence—

(1) At all speeds within and sufficiently beyond the structural design envelope;

(2) For any configuration and condition of operation;

(3) Accounting for critical degrees of freedom; and

(4) Accounting for any critical failures or malfunctions.

(b) The applicant must establish tolerances for all quantities that affect flutter.

Discussion

For FBW aircraft, the control surface (or device that provides control) may reverse as the aircraft maneuvers through a non-reversing motion. This is acceptable. It is not acceptable for the aircraft motion to reverse when the cockpit control is not reversed. Aeroelasticity, or actively controlled structural deflection, may be intentionally built into a design to improve ride quality or other flight characteristics. This may result in unconventional design analysis. This airworthiness criteria should be applied in a manner that assures safety, even if the above requirements are not met due to a design characteristic that was not envisioned by the rule.

B.20 UAV 23.2250: Design and construction principles

Current FAA rule:

23.2250 Design and construction principles

(a) The applicant must design each part, article, and assembly for the expected operating conditions of the airplane.

(b) Design data must adequately define the part, article, or assembly configuration, its design features, and any materials and processes used.

(c) The applicant must determine the suitability of each design detail and part having an important bearing on safety in operations.

(d) The control system must be free from jamming, excessive friction, and excessive deflection when the airplane is subjected to expected limit airloads.

(e) Doors, canopies, and exits must be protected against inadvertent opening in flight, unless shown to create no hazard when opened in flight.

Recommended rule:

(a) The applicant must design each part, article, and assembly for the expected operating conditions of the **aircraft**.

(b) Design data must adequately define the part, article, or assembly configuration, its design features, and any materials and processes used.

(c) The applicant must determine the suitability of each design detail and part having an important bearing on safety in operations.

(d) The control system must be free **from excessive friction at the inceptor. Friction and deflection due to air loads are allowed if they do not adversely affect stability, control, or handling qualities.**

(e) Doors, canopies, and exits must be protected against inadvertent opening in flight, unless shown to create no hazard when opened in flight.

(f) Each rotor, fan, or propeller, must be designed such that the risk of contact with persons is minimized.

<u>Discussion</u>

(d):

It should be noted that from the pilot's perspective, the aircraft performed as expected throughout the envelope. If there are significant changes in friction, highly non-linear control deflections, or excessive deflections due to air loads—and the control system can manage these characteristics so that the aircraft meets the rest of the requirements—then these characteristics are acceptable. A non-reversible control system may be intentionally designed to take advantage of deflection or friction resulting from air loads. This design concept is acceptable.

(f):

This concept comes from 14 CFR 27.1565.

B.21 UAV 23.2270: Emergency conditions

Current FAA rule:

23.2270 Emergency conditions

(a) The airplane, even when damaged in an emergency landing, must protect each occupant against injury that would preclude egress when—

> *(1) Properly using safety equipment and features provided for in the design;*
>
> *(2) The occupant experiences ultimate static inertia loads likely to occur in an emergency landing; and*
>
> *(3) Items of mass, including engines or auxiliary power units (APUs), within or aft of the cabin, that could injure an occupant, experience ultimate static inertia loads likely to occur in an emergency landing.*

(b) The emergency landing conditions specified in paragraph (a)(1) and (a)(2) of this section, must—

> *(1) Include dynamic conditions that are likely to occur in an emergency landing; and*
>
> *(2) Not generate loads experienced by the occupants, which exceed established human injury criteria for human tolerance due to restraint or contact with objects in the airplane.*

(c) The airplane must provide protection for all occupants, accounting for likely flight, ground, and emergency landing conditions.

(d) Each occupant protection system must perform its intended function and not create a hazard that could cause a secondary injury to an occupant. The occupant protection system must not prevent occupant egress or interfere with the operation of the airplane when not in use.

(e) Each baggage and cargo compartment must—

> *(1) Be designed for its maximum weight of contents and for the critical load distributions at the maximum load factors corresponding to the flight and ground load conditions determined under this part;*
>
> *(2) Have a means to prevent the contents of the compartment from becoming a hazard by impacting occupants or shifting; and*
>
> *(3) Protect any controls, wiring, lines, equipment, or accessories whose damage or failure would affect safe operations.*

Recommended rule:

(a) The **aircraft**, even when damaged in an emergency landing, must protect each occupant against injury that would preclude egress when—

> (1) Properly using safety equipment and features provided for in the design;
>
> (2) The occupant experiences ultimate static inertia loads likely to occur in an emergency landing; and
>
> (3) Items of mass, including engines or auxiliary power units (APUs), within or aft of the cabin, that could injure an occupant, experience ultimate static inertia loads likely to occur in an emergency landing.
>
> **(4) the aircraft is in water if ditching approval is requested.**

(b) The emergency landing conditions specified in paragraph (a)(1) and (a)(2) of this section, must—

> (1) Include dynamic conditions that are likely to occur in an emergency landing; and
>
> (2) Not generate loads experienced by the occupants, which exceed established human injury criteria for human tolerance due to restraint or contact with objects in the aircraft.
>
> **(3) Not inhibit egress in water if ditching approval is requested.**

(c) The aircraft must provide protection for all occupants, accounting for likely flight, ground, and emergency landing conditions.

(d) Each occupant protection system must perform its intended function and not create a hazard that could cause a secondary injury to an occupant. The occupant protection system must not prevent occupant egress or interfere with the operation of the aircraft when not in use.

(e) Each baggage and cargo compartment must—

> (1) Be designed for its maximum weight of contents and for the critical load distributions at the maximum load factors corresponding to the flight and ground load conditions determined under this part;
>
> (2) Have a means to prevent the contents of the compartment from becoming a hazard by impacting occupants or shifting; and
>
> (3) Protect any controls, wiring, lines, equipment, or accessories whose damage or failure would affect safe operations.

(f) An event that is likely to result in occupant injury more severe than specified by (a) or (b) is considered a catastrophic event for the purpose of design reliability. An event that may result in occupant injury, but that injury is less severe than specified by (a) or (b) is considered a hazardous event for the purpose of design reliability.

<u>Discussion</u>

<u>(a)(4) and (b)(3):</u>

The purpose of this addition is to bring the concept of ditching from Part 27.563 into this airworthiness criteria. While at first this may appear to be a new requirement for Part 23 aircraft that are not VTOL capable, in practice it should not be. Part 23 aircraft have naturally met the intent of the requirement by the nature of their design. However, Part 27 aircraft often have not met the intent without special design features.

<u>(f):</u>

The purpose of the addition is to bring landing under the design reliability criteria of AC 23.1309 (FAA, 2011) (or its equivalent). This becomes important as designs move toward automatic landing as a normal operation. The airworthiness criteria does not consider hard landings that do not result in injury. Normal market forces will prevent designs that do not consistently provide smooth landings.

B.22 UAV 23.2300: Flight control systems

Current FAA rule:

23.2300 Flight control systems

(a) The applicant must design airplane flight control systems to:

(1) Operate easily, smoothly, and positively enough to allow proper performance of their functions.

(2) Protect against likely hazards.

(b) The applicant must design trim systems, if installed, to:

(1) Protect against inadvertent, incorrect, or abrupt trim operation.

(2) Provide a means to indicate—

(i) The direction of trim control movement relative to airplane motion;

(ii) The trim position with respect to the trim range;

(iii) The neutral position for lateral and directional trim; and

(iv) The range for takeoff for all applicant requested center of gravity ranges and configurations.

Recommended rule:

(a) The applicant must design the flight control systems to:

(1) Operate easily, smoothly, and positively enough to allow proper performance of their functions.

(2) Protect against likely hazards.

(Note: this rule applies as written except that (b) is eliminated.)

<u>Discussion</u>

<u>(b):</u>

For all FBW aircraft, there is no mechanical connection between the cockpit control and the aircraft control devices. Trim reduces the forces felt by the pilot. Although, trim can also be used to reduce the force experienced by actuators, control linkages, etc., using trim to reduce structural loads is not what is meant by this rule.

For the Unified and EZ-Fly VTOL systems there is no trim system. Therefore (b) does not apply.

B.23 UAV 23.2305: Landing gear systems

Current FAA rule:

23.2305 Landing gear systems

(a) The landing gear must be designed to—

(1) Provide stable support and control to the airplane during surface operation; and

(2) Account for likely system failures and likely operation environments (including anticipated limitation exceedances and emergency procedures).

(b) All airplanes must have a reliable means of stopping the airplane with sufficient kinetic energy absorption to account for landing. Airplanes that are required to demonstrate aborted takeoff capability must account for this additional kinetic energy.

(c) For airplanes that have a system that actuates the landing gear, there is—

(1) A positive means to keep the landing gear in the landing position; and

(2) An alternative means available to bring the landing gear in the landing position when a non-deployed system position would be a hazard.

Recommended rule:

(a) The landing gear must be designed to—

(1) Provide stable support and control to the **aircraft** during surface operation; and

(2) Account for likely system failures and likely operation environments (including anticipated limitation exceedances and emergency procedures).

(b) All **aircraft** must have a reliable means of stopping the aircraft with sufficient kinetic energy absorption to account for landing. **Aircraft** that are required to demonstrate aborted takeoff capability must account for this additional kinetic energy. **This paragraph applies to the highest kinetic energy state for which the aircraft is approved.**

(c) For **aircraft** that have a system that actuates the landing gear, there is—

> (1) A positive means to keep the landing gear in the landing position; and
>
> (2) An alternative means available to bring the landing gear in the landing position when a non-deployed system position would be a hazard.

Discussion

The purpose of the addition in paragraph (b) is to ensure that aircraft with VTOL (or STOL) capability but are also approved for CTOL have brakes capable of stopping them in the highest kinetic energy case.

B.24 UAV 23.2320: Occupant physical environment

Current FAA rule:

(a) The applicant must design the airplane to—

> *(1) Allow clear communication between the flightcrew and passengers;*
>
> *(2) Protect the pilot and flight controls from propellers; and*
>
> *(3) Protect the occupants from serious injury due to damage to windshields, windows, and canopies.*

(b) For level 4 airplanes, each windshield and its supporting structure directly in front of the pilot must withstand, without penetration, the impact equivalent to a two-pound bird when the velocity of the airplane is equal to the airplane's maximum approach flap speed.

(c) The airplane must provide each occupant with air at a breathable pressure, free of hazardous concentrations of gases, vapors, and smoke during normal operations and likely failures.

(d) If a pressurization system is installed in the airplane, it must be designed to protect against—

> *(1) Decompression to an unsafe level; and*
>
> *(2) Excessive differential pressure.*

(e) If an oxygen system is installed in the airplane, it must—

> *(1) Effectively provide oxygen to each user to prevent the effects of hypoxia; and*
>
> *(2) Be free from hazards in itself, in its method of operation, and its effect upon other components.*

Recommended rule:

(a) The applicant must design the aircraft to—

(1) Allow clear communication between the flight crew and passengers;

(2) Protect the pilot and flight controls from propellers **and/or rotors**; and

(3) Protect the occupants from serious injury due to damage to windshields, windows, and canopies.

(b) For level 4 **aircraft**, each windshield and its supporting structure directly in front of the pilot must withstand, without penetration, the impact equivalent to a two-pound bird when the velocity of the **aircraft** is equal to the **aircraft's** maximum approach flap speed**, VNE or 200 KIAS, whichever is less.**

(c) The **aircraft** must provide each occupant with air at a breathable pressure, free of hazardous concentrations of gases, vapors, and smoke during normal operations and likely failures.

(d) If a pressurization system is installed in the aircraft, it must be designed to protect against—

(1) Decompression to an unsafe level; and

(2) Excessive differential pressure.

(e) If an oxygen system is installed in the **aircraft**, it must—

(1) Effectively provide oxygen to each user to prevent the effects of hypoxia; and

(2) Be free from hazards in itself, in its method of operation, and its effect upon other components.

<u>Discussion</u>

<u>(a)(2):</u>

Rotors are included to extend the intent of the rule to aircraft with rotors.

<u>(b):</u>

Some new configurations may have high cruise speeds but no flaps. Thus, for these aircraft approach flap speed would be VNE. For these aircraft, there needs to be a reasonable speed that meets the intent of the regulation.

B.25 UAV 23.2325: Fire Protection

See Recommended Aircraft Certification rules for UAVs for modification to this paragraph for Category A certification. See Appendix C3.

B.26 UAV 23.2400: Powerplant installation

Current FAA rule:

23.2400 Powerplant installation

(a) For the purpose of this subpart, the airplane powerplant installation must include each component necessary for propulsion, which affects propulsion safety, or provides auxiliary power to the airplane.

(b) Each airplane engine and propeller must be type certificated, except for engines and propellers installed on level 1 low-speed airplanes, which may be approved under the airplane type certificate in accordance with a standard accepted by the FAA that contains airworthiness criteria the Administrator has found appropriate and applicable to the specific design and intended use of the engine or propeller and provides a level of safety acceptable to the FAA.

(c) The applicant must construct and arrange each powerplant installation to account for—

(1) Likely operating conditions, including foreign object threats;

(2) Sufficient clearance of moving parts to other airplane parts and their surroundings;

(3) Likely hazards in operation including hazards to ground personnel; and

(4) Vibration and fatigue.

(d) Hazardous accumulations of fluids, vapors, or gases must be isolated from the airplane and personnel compartments, and be safely contained or discharged.

(e) Powerplant components must comply with their component limitations and installation instructions or be shown not to create a hazard.

Recommended rule:

(a) For the purpose of this subpart, the **aircraft** powerplant **includes all components that add energy to the air for the purpose of propulsion, lift or control. It also includes components that provide power to aircraft systems.**

(b) Each **aircraft propulsive device (engine, motor, rotor, propeller, rocket, or any other device or combination of components used to add energy to the air or vehicle) must be type certificated, or be approved under the aircraft type certificate in accordance with a standard accepted by the FAA that contains airworthiness criteria the Administrator has found appropriate and applicable to the specific design and intended use of the propulsive device and provides a level of safety acceptable to the FAA.**

(c) The applicant must construct and arrange each powerplant installation to account for—

(1) Likely operating conditions, including foreign object threats;

(2) Sufficient clearance of moving parts to other aircraft parts and their surroundings;

(3) Likely hazards in operation including hazards to ground personnel; and

(4) Vibration and fatigue.

(d) Hazardous accumulations of fluids, vapors, or gases must be isolated from the aircraft and personnel compartments, and be safely contained or discharged.

(e) Powerplant components must comply with their component limitations and installation instructions or be shown not to create a hazard.

(f) All propellers and rotors must be controlled such that they always remain within their safe operating envelope without pilot action.

Discussion

(a):

New aircraft designs may have multiple propulsive devices such that no individual device is required for propulsion (and hence, no propulsive device on that aircraft would be covered by this subpart without the new definition). New aircraft designs may also use power devices to create or enhance lift. The above definition is intended to cause the requirements of this subpart to apply to these devices.

For new aircraft design concepts, there is a need to include components that produce thrust for lift or control (see note for Subpart E).

(b):

New aircraft designs may need this change to allow new and novel propulsive systems that are not envisioned under the current certification rules for aircraft engines (Part 33). This change allows a propulsive device to be certified under the type design of the aircraft instead of under Part 33. This allows the applicant to integrate the propulsive system into the control system and have the propulsive system controlled by the flight control computer (instead of being independently controlled as Part 33 requires).

(f):

Part 27.33 covers rotor speed warnings and rotor speed limits. The requirement that an erroneous pilot action cannot cause a catastrophic event implies this, but the wording was added here to make that clear.

B.27 UAV 23.2405: Automatic power or thrust control systems

Current FAA rule:

23.2405 Automatic Power or thrust control systems

(a) An automatic power or thrust control system intended for in-flight use must be designed so no unsafe condition will result during normal operation of the system.

(b) Any single failure or likely combination of failures of an automatic power or thrust control system must not prevent continued safe flight and landing of the airplane.

(c) Inadvertent operation of an automatic power or thrust control system by the flightcrew must be prevented, or if not prevented, must not result in an unsafe condition.

(d) Unless the failure of an automatic power or thrust control system is extremely remote, the system must—

> *(1) Provide a means for the flightcrew to verify the system is in an operating condition;*
>
> *(2) Provide a means for the flightcrew to override the automatic function; and*
>
> *(3) Prevent inadvertent deactivation of the system.*

Recommended rule:

(a) **A power** or thrust control system intended for in-flight use must be designed so no unsafe condition will result during normal operation of the system.

(b) Any single failure or likely combination of failures of the automatic power or **thrust control that prevents continued safe flight and landing is considered a catastrophic event**.

(c) Inadvertent operation **of a part-time** automatic power or thrust control system by the flight crew must be prevented, or if not prevented, must not result in an unsafe condition.

(d) Unless the **reliability** of an automatic power or thrust control system **is the same or better than the primary flight control system**, the system must—

(1) Provide a means for the flight crew to verify the system is in an operating condition;

(2) Provide a means for the flight crew to override the automatic function; **or the automatic function must comply with the same reliability requirements as the rest of the FBW flight control system and**

(3) Prevent inadvertent deactivation of the system.

Discussion

$\Delta F = M a$, where ΔF is change in force, M is mass, and a is acceleration. For a jet airplane, the throttle acts like a thrust lever. Since mass is constant for the short term, the throttle also acts like an acceleration lever. The UCS has an acceleration command lever. It is expected that there may be part-time automated throttle functions in SVO-A1 aircraft that are like those in airplanes with an auto-throttle today.

The EZ-Fly VTOL control has a full-time automatic power system that is an integral part of the control system, which provides the required speed stability. An EZ-Fly VTOL aircraft does not provide the ability for the pilot to override the automatic system, and it is assumed that the pilot trained to operate an EZ-Fly VTOL system would not know how to control the aircraft by manual control. New aircraft configurations may also require full-time automatic power control to provide stability. Therefore, for these aircraft, control of the power system has the same flight criticality as any other part of the control system and is covered by the control system reliability requirements.

B.28 UAV 23.2450 (Part 33.28 Special condition for FBW aircraft)

33.28 Engine control systems.

Current FAA rule:

…

(h) Aircraft-supplied data. Single failures leading to loss, interruption or corruption of aircraft-supplied data (other than thrust or power command signals from the aircraft), or data shared between engines must:

> *(1) Not result in a hazardous engine effect for any engine; and*

> *(2) Be detected and accommodated. The accommodation strategy must not result in an unacceptable change in thrust or power or an unacceptable change in engine operating and starting characteristics. The applicant must evaluate and document in the engine installation instructions the effects of these failures on engine power or thrust, engine operability, and starting characteristics throughout the flight envelope.*

(i) Aircraft-supplied electrical power.

> *(1) The applicant must design the engine control system so that the loss, malfunction, or interruption of electrical power supplied from the aircraft to the engine control system will not result in any of the following:*

>> *(i) A hazardous engine effect, or*

>> *(ii) The unacceptable transmission of erroneous data.*

> *(2) When an engine dedicated power source is required for compliance with paragraph (i)(1) of this section, its capacity should provide sufficient margin to account for engine operation below idle where the engine control system is designed and expected to recover engine operation automatically.*

> *(3) The applicant must identify and declare the need for, and the characteristics of, any electrical power supplied from the aircraft to the engine control system for starting and operating the engine, including transient and steady state voltage limits, in the engine instructions for installation.*

> *(4) Low voltage transients outside the power supply voltage limitations declared in paragraph (i)(3) of this section must meet the requirements of paragraph (i)(1) of this section. The engine control system must be capable of resuming normal operation when aircraft-supplied power returns to within the declared limits.*

…

Recommended rule:

For FBW aircraft, the applicant may choose to replace 33.28 (h) & (i) with

(h) Aircraft-supplied data and control of the powerplant(s) may be created and distributed at the same or better reliability level as for the primary flight controls.

(i) Aircraft-supplied electrical power for propulsion or control of the powerplant(s) may be created and distributed at the same or better reliability level as for the primary flight controls.

(Note: the 33.28 rule applies as is, except that UAV 23.2450 creates an option to replace (h) and (i) in 33.28 with (h) and (i) of UAV 23.2450 for FBW aircraft.)

Discussion

Ellipses (…) are used to indicate that portions of this regulation are not included here for brevity. These excluded portions apply as written.

Part 33.28 envisioned turbine or piston engines that are hydromechanically controlled or electronically controlled via a FADEC (Full-Authority Digital Engine Control), which is part of the engine. It also assumes that these engines are installed on aircraft with mechanical controls (although it does not exclude FBW aircraft).

The intent of (h) and (i) is to provide a minimum level of integrity and reliability for aircraft-supplied signals and electrical power used for engine control to support the required reliability of the engine.

The primary flight controls of FBW aircraft have a required level of integrity and reliability at least as high as the power plants. The additions to this airworthiness criteria allow the powerplant to be included in the flight control design and reliability analysis—potentially reducing the certification burden without reducing the safety margins.

Also, some of the new configurations require control of the power plants to accomplish aircraft control. Thus, the power plants effectively become part of the flight control system. When used as part of the primary flight control system, the aircraft's flight control computers need to generate control signals to the power plants. The additions to 33.28 provide for this.

The original 33.28 implies that the power plants control themselves with their own hydromechanical or FADEC systems. The additions to 33.28 are intended to allow an aircraft computer to control the engine directly (for example, the flight control computer may use engine and flight data to directly control a fuel metering valve for a turbine engine—the engine does not have its own controls).

B.29 UAV 23.2510: Equipment, systems, and installations

Current FAA rule:

23.2510 Equipment, systems, and installations.

For any airplane system or equipment whose failure or abnormal operation has not been specifically addressed by another requirement in this part, the applicant must design and install each system and equipment, such that there is a logical and acceptable inverse relationship between the average probability and the severity of failure conditions to the extent that:

(a) Each catastrophic failure condition is extremely improbable;

(b) Each hazardous failure condition is extremely remote; and

(c) Each major failure condition is remote.

Recommended rule:

This section applies generally to installed equipment and systems unless a section of this part imposes requirements for a specific piece of equipment, system, or systems.

(a) The equipment and systems required for an aircraft to operate safely in the kinds of operations for which certification is requested (Day Visual Flight Rules [VFR], Night VFR, Instrument Flight Rules [IFR]) must be designed and installed to—

(1) Meet the level of safety applicable to the certification and performance level of the aircraft; and

(2) Perform their intended function throughout the operating and environmental limits for which the aircraft is certificated.

(b) The systems and equipment not covered by paragraph (a), considered separately and in relation to other systems, must be designed and installed so their operation does not have an adverse effect on the aircraft or its occupants.

(c) For all FBW systems, the probability of a failure of the flight control system that causes a catastrophic event shall be no more than the following.

(1) Level 1 used primarily for pleasure or recreation: $< 10^{-6}$

(2) Level 1 not used primarily for pleasure or recreation: < 10^{-7}

(3) Level 2: < 10^{-7}

(4) Level 3: < 10^{-8}

(5) Level 4: < 10^{-9}

- **The maximum probability for a hazardous event may be 10 times that of a catastrophic event.**
- **The maximum probability for a major event may be 100 times that of a catastrophic event.**
- **The maximum probability for a minor event may be 1000 times that of a catastrophic event.**
- **There is no probability requirement for events that provide no safety hazard.**
- **If the propulsion system is used to control the aircraft, provide lift, augment lift (thrust vectoring, blown flaps, etc.), or affects control of the aircraft, the propulsion system is considered part of the control system for the purposes of this part.**

For the purpose of this part, a pilot is considered to be part of the flight control system and represents a probability of failure equal to 0.7 failures per 100,000 flight hours. The pilot failure is considered to exhibit two failure modes, 1) inaction by the pilot and 2) erroneous action by the pilot. When considering pilot failures, the worst case of these two failure modes is to be considered.

No single event involving any system or component (including systems and components not associated with the control system) may cause a catastrophic event. Some examples of single events may be:

- **An undetected manufacturing flaw such that the same flaw affects multiple sensors**
- **An undetected process flaw that affects multiple rotors**
- **A single software bug**
- **An incapacitated pilot**
- **A pilot action**
- **For an aircraft certified in icing, an event that overwhelms all pitot probes**

- **Jamming or loss of GPS**

Structural fatigue and fatigue due to damage in normal operations and manufacturing flaws must be considered when calculating failure effects and probability of failures.

Discussion

To avoid confusion and ambiguity, actual probability numbers are specified for the various aircraft levels and operations in the UAV 23.2510 rule.

To provide a safety level at least as good as the current general aviation accident rate, the following maximum probabilities of a failure causing a catastrophic result are recommended. The following assumes that all instrument landing system localizer (LOC) and CFIT accidents are eliminated but about 1/10th the number of LOC/CFIT accidents occur because of flight control system failures. Thus, the overall system safety is improved by about a factor of 10.

For reference, UAV 23.2005 (and 23.2005) defines aircraft levels as follows.

- Level 1—for aircraft with a maximum seating configuration of 0 to 1 passenger.
- Level 2—for aircraft with a maximum seating configuration of 2 to 6 passengers.
- Level 3—for aircraft with a maximum seating configuration of 7 to 9 passengers.
- Level 4—for aircraft with a maximum seating configuration of 10 to 19 passengers.

Note that these probability levels are also the allowable failure probabilities specified in AC 23.1309 (FAA, 2011) for classes 1, 2, 3, and 4 respectively.

Note that flight instruction, business travel, or operations for compensation are not considered pleasure or recreation. Therefore, a two-seat aircraft that is used for flight instruction must be certified like a two- to six-passenger aircraft for reliability purposes.

The FBW control system of SVO-A aircraft is considered flight critical. If it fails catastrophically, there is no mechanical backup. Using a mechanical backup as mitigation for an FBW control system failure defeats the entire purpose of the SVO-A aircraft. This is because if credit is taken for a mechanical system, the pilot must demonstrate the ability to fly the aircraft using that mechanical system. This is in addition to the normal FBW control system. Thus, if a mechanical backup is used, the pilot must learn to operate the aircraft using two different systems, which adds to the training burden instead of reducing it.

B.30 UAV 23.2540: Flight in icing conditions

Current FAA rule:

23.2540 Flight in icing conditions

An applicant who requests certification for flight in icing conditions defined in part 1 of appendix C to part 25 of this chapter, or an applicant who requests certification for flight in these icing conditions and any additional atmospheric icing conditions, must show the following in the icing conditions for which certification is requested:

(a) The ice protection system provides for safe operation.

(b) The airplane design must provide protection from stalling when the AP is operating.

Recommended rule:

An applicant who requests certification for flight in icing conditions defined in Part 1 of Appendix C to Part 25 of this chapter, or an applicant who requests certification for flight in these icing conditions and any additional atmospheric icing conditions, must show the following in the icing conditions for which certification is requested:

(a) The ice protection system provides for safe operation.

(b) The minimum safe speeds for flight in icing conditions (Vref and Vx) must be determined using the same criteria as is used in non-icing conditions and must contain the same margins. The flight control system must prevent the aircraft from flying slower than the appropriate minimum icing speeds.

Discussion

For SVO-A aircraft, this rule prevents the aircraft from flying at a speed less than the minimum speed for icing conditions—the minimum icing speed should be determined so that it provides a similar safety margin as the non-icing minimum speed. Also, the statement about the AP should be removed for SVO-A aircraft. The control system should prevent flying too slow all the time.

B.31 UAV 23.2600: Flightcrew interface

Current FAA rule:

23.2600 Flightcrew interface

(a) The pilot compartment, its equipment, and its arrangement to include pilot view, must allow each pilot to perform his or her duties, including taxi, takeoff, climb, cruise, descent, approach, landing, and perform any maneuvers within the operating envelope of the airplane, without excessive concentration, skill, alertness, or fatigue.

(b) The applicant must install flight, navigation, surveillance, and powerplant controls and displays so qualified flightcrew can monitor and perform defined tasks associated with the intended functions of systems and equipment. The system and equipment design must minimize flightcrew errors, which could result in additional hazards.

(c) For level 4 airplanes, the flightcrew interface design must allow for continued safe flight and landing after the loss of vision through any one of the windshield panels.

(a) The pilot compartment, its equipment, and its arrangement to include pilot view, must allow each pilot to perform his or her duties, including taxi, takeoff, CCD, approach, landing, and perform any maneuvers within the operating envelope of the aircraft, without excessive concentration, skill, alertness, or fatigue.

(b)

Flight, power plant, and systems instrumentation and controls must be installed as required by the system design to allow the crew to detect failures and take appropriate action if the failure is not detected automatically and appropriate action is not taken automatically.

(c) For level 4 **aircraft**, the flight crew interface design must allow for continued safe flight and landing after the loss of vision through any one of the windshield panels.

(d) Exhaust gases may not impair pilot vision at night due to glare.

<u>Discussion</u>

<u>(b):</u>

SVO-A aircraft may not need to have the controls and displays required by the Part 23 rule for safe operation. If this is the case, then these controls and displays should not be required. This is especially true if the system monitoring is automatic and corrective action is taken by the automation in the event of abnormal operations. It is envisioned that for many vehicles, when a failure occurs, the aircraft notifies the operator that maintenance is required on landing, and no further action is required by the pilot.

(d):

Some configurations of VTOL aircraft may emit exhaust gases that cause heat mirages that can impair operation or glare at night. Section 27.1121 (e) addresses this.

Instructions for Continued Airworthiness

Appendix A of Part 23 addresses Instructions for Continued Airworthiness. Appendix A of Part 23 is used as is. Part 23 Appendix A contains many references to propellers. For SVO-A aircraft, when Part 23 Appendix A refers to propellers it also means rotors, fans, propellers, and any other device that rotates and is intended to produce lift or thrust.

Airworthiness Criteria for VTOL Instrument Flight

There are no specific requirements for instrument flight for the aircraft that meet the requirements of these special conditions. Appendix B of Part 27 contains special requirements for rotorcraft to operate in instrument conditions. Because of the significance of Part 27 Appendix B, this appendix is addressed to indicate that it was not inadvertently omitted.

UAV 23.2145 redefines stability and requires stability at all speeds including hover. Therefore, there is no need for separate criteria for SVO-A VTOL aircraft in instrument conditions.

Recommended airworthiness comments for UAS

The FAA provided the researchers with the following set of proposed rules for UAS and asked for comments and recommendations relative to these proposed rules, organized as follows.

UAS.2500	UAS Level System Requirements
UAS.2505	General Requirements on Equipment Installation
UAS.2510	Equipment, Systems and Installations
UAS.2520	High-Intensity Radiated Fields (HIRF) Protection*
UAS.2522	Cyber Security
UAS.2523	Electronic Equipment
UAS.2529	Unmanned aircraft (UA) Flight Control System
UAS.2555	Data Logging

UAS.2800 Minimum UA Crew

UAS.2805 UA Crew Work Place Lights

UAS.2810 Communication System

UAS.2815 Ucs Electrical Systems

UAS.2820 UCS Power Supply

UAS.2825 UAS Handover Between Two UCS

UAS.2830 Command and Control of Multiple UA

UAS.2835 UA Status Data

UAS.3328 Engine Control System

UAS.3353 Engine System and Component Tests

Many of these proposed rules codify best design practices given current designs. This inhibits innovative designs which can improve safety and aircraft efficiency. Therefore, many of the comments from the researchers are designed to take the safety intent of the proposed rule and rewrite it to capture the safety intent but without specifying how the safety level is achieved. As such, the principle of identifying a potential system level failure, determining its effect on safety of the aircraft and then assigning a design assurance level to the system is used extensively. Please see Appendix C for the recommended design assurance levels.

The FAA proposed rule is included in *italics* to differentiate it from the researchers' comments relative to that proposed rule.

B.33 UAS.2500: Unmanned aircraft system level system requirements

FAA-proposed rule:

(a) *Requirements UAS.2500, UAS.2505 and UAS.2510 are general requirements applicable to the systems and equipment of the UAS, and should not be used to supersede any other specific UAS requirement.*

(b) *Equipment and systems required to comply with type certification requirements, airspace requirements or operational rules, or whose improper functioning would lead to a hazard,* *must be designed and installed so that they perform their intended function throughout the operating and environmental limits for which the UAS is certified.*

No comments.

B.34 UAS.2505:General requirements on equipment installation

FAA-proposed rule:

(a) *Each item of installed equipment is installed according to limitations specified for that equipment.*

(b) *On multi-engine UAs, engine-driven accessories essential to safe operation must be distributed among multiple engines.*

Part (b) of this rule restricts design flexibility and may in fact reduce reliability. There may be different types of engines on an aircraft with different reliability characteristics. For example, a UAV may have two engines that normally operate for takeoff and climb, but one is normally shut down for cruise and descent. This rule would require engine-driven accessories to be distributed between the engine normally always operating and the engine that is normally shut down for a significant part of the flight.

It is recommended to maintain the hazard level associated with a failure and the resulting reliability level of the function, which implies eliminating part (b) from this rule. UA.2510 includes this but rule 2505(b) as written provides an exception that specifies a design requirement instead of a performance requirement, which in effect can reduce safety.

B.35 UAS.2510:Equipment, systems, and installations

FAA Proposed rule:

(a) *The equipment and systems identified in CS-UAS.2500, considered separately and in relation to other systems, must be designed and installed such that:*
   1. *each catastrophic failure condition is extremely improbable; and*
   2. *each hazardous failure condition is extremely remote; and*
   3. *each major failure condition is remote.*

(b) *The systems and equipment not covered by CS-UAS.2500 must be designed and installed so their operation does not have an adverse effect on the UAS throughout the operating and environmental limits for which the UAS is certified unless the adverse effect does not pose a risk to people on the ground or in the air*

No comments.

B.35 UAS.2522: Cyber security

FAA-proposed rule:

(a) UAS equipment, systems and networks, considered separately and in relation to other systems, must be protected from intentional unauthorized electronic interactions that may result in an adverse effect on the safety of the UAS by showing that the security risks have been identified, assessed, and mitigated as necessary. The control station, navigation system (GPS), and C2 link must be resistant to unauthorized access, intrusion, extraction, or other attacks.

(b) Any mitigations established for cybersecurity must be addressed in the instructions for continued airworthiness to ensure security protections are maintained.

No recommended changes.

B.36 UAS.2523: Electronic equipment

FAA-proposed rule:

(a) In showing compliance with UAS.2510 with respect to radio and electronic equipment and their installations, critical environmental conditions must be considered.

(b) Radio and electronic equipment, controls, and wiring must be installed so that operation of any unit or system of units will not adversely affect the simultaneous operation of any other radio or electronic unit, or system of units.

(c) Electronic payload equipment and wiring must be installed so that operation will not adversely affect the simultaneous operation of any other radio or electronic unit, or system of units.

(d) All sensitive and essential equipment as identified in (a) must be protected against internal and external sources of electromagnetic interference/compatibility (EMI/C).

This rule regarding EMI is vague. EMI in aircraft adversely affect many systemsalthough this adverse effect often has very little impact on the operations. This rule does not take that into account. The level of adverse effects needs to be defined. Connecting this to a hazard level is recommended. For instance, no adverse effect greater than a minor hazard is allowed. because paragraph (d) then becomes a design requirement rather than a performance requirement, it can be eliminated.

B.37 UAS.2529: Unmanned aircraft flight control system

FAA-proposed rule:

(a) The UA flight control system comprises sensors, actuators, computers, and all those elements of the UAS, necessary to control the attitude, speed, trajectory, and three-dimensional position of the UA and shall ensure the UA remains within the approved flight envelope, the intended flight path and within all geographical limitations in all flight phases.

(b) If the approved flight envelope, the intended flight path, or the geographical limitations no longer can be ensured, a means to transmit this information to the surrounding aviation system must be available.

(c) The UA flight control system shall be designed to ensure that the Emergency Recovery Capability and Procedures according to UAS.2570 and the Command, Control, and Communication Contingency requirements according to UAS.2575 are met.

For paragraph (a), Suggest leaving out attitude. All that really matters is the position trajectory and speed. It is irrelevant (from a regulatory perspective) where the machine is pointed.

It is recommended to delete paragraphs (b) and (c), which basically imply that the UAS must comply with UA 2570 and UA 2575, for redundancy.

Note that several elements occur on multiple occasions throughout the proposed rules without definition, e.g., What is "the surrounding aviation system"? Is this transmitting to the ground station? ATC (air traffic control)? Surrounding traffic? Etc.? These elements need more definition. For example, perhaps include the following statement: "ATC and/or CTAF (common traffic advisory frequency) as appropriate."?

B.38 UAS.2555: Data logging

FAA-proposed rule:

The UAS or control station must have the capability to store UA telemetry data as data log files. Data logger files must be retrievable. Data logger files must contain sufficient parameters to analyze system performance and potential root causes of mishaps.

This rule requires data logging. It allows data logging of telemetry data only. It is recommended to require logging of data on board the UA when telemetry fails.

B.39 UAS.2570: Emergency recovery capability

FAA-proposed rule:

(a) The UA system must integrate an emergency recovery capability that consists of:

(1) a flight termination system, procedure or function that aims to immediately end normal flight, or,

(2) an emergency recovery procedure that is implemented through UA crew command or through autonomous design means to mitigate the effects of critical failures with the intent of minimizing the risk to third parties, or,

(3) any combination of UAS.2570 (a)(1) and UAS.2570 (a)(2).

(b) The emergency recovery capability must function as desired over the whole flight envelope under the most adverse combination of environmental conditions.

(c) The emergency recovery capability must be safeguarded from interference leading to inadvertent operation.

(d) The emergency recovery capability must receive its electrical power, if needed, from the bus that provides the maximum reliability for operation. In case of complete loss of the primary electrical power generating system, it must automatically switch to the battery.

(e) Where the emergency recovery capability includes a preprogrammed course of action to reach a predefined site where it can be reasonably expected that fatality will not occur, the dimensions of such areas must be stated in the UA system Flight Manual.

Paragraph (a) allows the UA to be intentionally blown up over densely populated areas as an acceptable means of emergency recovery. The recommendation is if ending normal flight is allowed that it require a means of reducing the energy on impact (e.g., a parachute) or navigating in a way that the termination point is a non-populated area (e.g., body of water, freeway right of way, or agricultural land).

Paragraph (b) is a set of design requirements. It should be replaced by performance requirements. A battery-powered aircraft may have a ram air turbine (RAT) to power the emergency systems in the event of a failure of the main (battery) bus. This rule requires that if the main bus (battery bus) fails, the system must be powered by the battery bus that failed. This rule prevents the use of the RAT bus to power the emergency systems.

The wording of Paragraph (c) requires that the dimensions of preprogrammed recovery areas be included in the flight manual. There may be thousands of potential preprogrammed recovery areas. This raises a question whether the intent of the paragraph is to provide the dimensions of every one of them in the flight manual or to provide the minimum area required for an emergency recovery. The authors believe it is the latter. However, this may depend on weight, altitude and temperature and wind.

B.40 UAS.2575: Command, control, and communication contingency

FAA-proposed rule:

(a) Where the safe operation of the UAS requires command, control, and communication functionality, the UA must initiate adequate contingency procedures following a command, control, or communication function loss or a degraded status that no longer ensures safe operation of the UA by the crew

(b) The contingency procedures must be specified in the Flight Manual for the crew for each operational situation

There shall be a means to transmit to the surrounding aviation system the relevant information about the UA contingency procedures

No recommended changes.

B.41 UAS.2580: Geo-limitation

FAA-proposed rule:

Geo-limitation system is software and hardware to create a virtual boundary to prevent a UA from entering or exiting defined geographic areas.

(a) Load and display forbidden flight zones (e.g., restricted areas and airports) and shall be able to be updated by the operator, the remote pilot, or dynamically during a flight; and

(b) Provide a warning and/or alert notification when the UA approaches programmed boundaries.

(c) Provide an error display when setting up and uploading a route to the UA, if the flight route crosses a forbidden/restricted area or the route uploading is unsuccessful.

(d) Provide an alert with an error display when setting up and uploading a geographic limitation to the UA, if the uploading is unsuccessful.

It is recommended to replace the words “software and hardware” with a more generic phrase, such as “a system.” Also, the phrase “software is employed in the system control platform” should be replaced with “system is employed.” Again, this is more generic and streamlined. The system may be completely controlled via the hardware.

B.42 UAS.2605: Installation and operation

FAA Proposed rule:

(a) Each item of installed equipment related to the flight crew interface must be labelled, if applicable, as to its identification, function, or operating limitations, or any combination of these factors.

(b) There must be a discernible means of providing system operating parameters required to operate the airplane, including warnings, cautions, and normal indications to the responsible crewmember.

(c) Information concerning an unsafe system operating condition must be provided in a timely manner to the crewmember responsible for taking corrective action. The information must be clear enough to avoid likely crewmember errors.

Recommend changing “airplane” to “aircraft.”

B.43 UAS.2625: Systems for launch and recovery not permanently installed on the unmanned aircraft

FAA-proposed rule:

(a) If a Launch System is required for normal operation:

(1) The UA must achieve sufficient energy and controllability at the end of the launch phase to ensure safe and controllable continuation of the flight under the most adverse combination of the approved environmental and operating conditions.

(2) It must be shown that the acceleration sustained by the UA during the launch phase is within the loads for normal operation.

(3) A launch safety area must be defined as a predetermined geometrical area in which the UA remains after a failure or malfunction in the launch phase, calculated under any combination of approved environmental and operational conditions.

(4) The size and shape of the launch safety area shall be stated in the UAS Flight Manual.

(b) If a Recovery System is required for the operation of the UA:

(1) The Recovery System must safely reduce sufficient energy to ensure a controlled termination of the flight.

(2) It must be shown that the deceleration sustained by the UA during the recovery phase is within the loads for normal operation, except where the UA is not designed for multiple recovery.

(3) A recovery safety area must be defined as a predetermined geometrical area in which the UA remains after a failure or malfunction in the recovery phase, calculated under any combination of approved environmental and operational conditions.

(4) The size and shape of the recovery safety area shall be stated in the UAS Flight Manual.

The end of the launch phase and the beginning of the normal flight phase needs to be defined, for example, using 35 ft above ground level (AGL) to match programmed field performance concepts. This makes a failed launch analogous to an accelerate stop;, except in this case, the vehicle may be in the air a short time before coming to a stop.

B.44 Subpart H—Command and control data link

UAS.2700 General

FAA-proposed rule:

(a) The UAS communication system typically consists of the following subsystems:

(1) the command-and-control data link subsystem,

(2) the ATC communication subsystem, and

(3) the payload data link subsystem.

(b) A UAS must include a command-and-control data link (a radio-frequency link, for example) for control of the UAS with the following functions:

(1) transmittal of UA crew commands from the unified control system (UCS) to the UA (uplink), and

(2) transmittal of UA status data from the UA to the UCS (downlink). This status data must include, to the appropriate extent, navigational information, response to UA crew commands, and equipment operating parameters in accordance with subpart I requirements.

Paragraph (b)(1) raises to the question is a UCS an uncrewed control station?

Paragraph (b)(2)raises the question, why does the U.S. need to transmit navigational information if its position is detected by means other than the UA transmitting that data (for instance automatic dependent surveillance broadcast [ADS-B])? If more navigation data is required, it should be specified. Recommend changing the downlink to require data as appropriate to safe operation and remove any specifics that are likely to create unnecessary burdens in future designs.

UAS.2705 Command-and-control data link architecture

FAA-proposed rule:

The command-and-control data link architecture must ensure that there is no single failure that could lead to a Hazardous or more serious event.

No recommended changes.

UAS.2710 Data link electromagnetic interference and compatibility

FAA Proposed rule:

(1) The command-and-control data link must be protected against electromagnetic interference (EMI).

(2) Each command-and-control data link must be protected in such a way to prevent electromagnetic vulnerability (EMV).

(3) The command-and-control data link electromagnetic compatibility (EMC) must meet UAS.2510.

(4) The command-and-control data link, as system must comply with UAS.2510 requirement.

(5) The command-and-control data link must be designed to be protected against electrostatic, lightning and EME hazards, in accordance with UAS.2510.

Paragraphs (3), (4), and (5) basically say that the aircraft must comply with UAS.2510. This makes these rules redundant and prone to error. Suggest deleting (3), (4), and (5) since they are already covered in UAS.2510. Alternatively, UAS.2510 could be rewritten to remove these rules so that they are only addressed only here.

UAS.2715 Command-and-control data link performance and monitoring

FAA-proposed rule:

(a) The effective maximum range of each command-and-control data link must be stated in the UAS System Flight Manual, for a range of altitudes up to the maximum operating altitude, and for a range of availability levels agreed by the FAA for the uplink and for the downlink.

(b) For each command-and-control data link, the effective maximum range, which may include an acceptable safety margin, must be displayed in the UCS for a specific availability level for both uplink and downlink on request of the UAS crew. The corresponding availability level must be displayable on UAS crew request at the appropriate position on the UCS display.

(c) For each command-and-control data link, the integrity of the uplink and downlink must be continuously monitored at a refresh rate consistent with safe operation.

(d) Maximum range cues must be provided in the UCS by UAS crew request or automatically in case of a likely breakdown of the command-and-control data link.

(e) Transmission and reception information must be displayed in the UCS and warning cues provided to the UAS crew to prevent a total loss of command-and-control data link.

(f) The UAS must provide an alert to the crew following the total loss of the command-and-control function or C2 degradation to where remote active control of the UA in a timely manner is no longer ensured.

This rule does not require the aircraft to always maintain a command-and-control link but that the loss of that link due to range must be made known to the crew. Suggest adding (g) to specifically address temporary loss of link due to range or terrain. This is analogous to loss of radar and voice contact during IFR operations due to range or terrain but with the expectation that it will be regained again.

UAS.2720 Command-and-control data link latency

FAA-proposed rule:

(a) Time delays in the command and control data link (namely 'latency') shall be specified in the UAS System Flight Manual as a function of all relevant conditions.

(b) The command and control data link latency must not lead to an unsafe condition, considering all probable environmental conditions and envisaged type of operations and must be agreed by the Certifying Authority.

(c) Delays or latencies in UA control data shall be accounted for in determining the operational specifications of the UA for safety critical functions such as take-off and landing operations.

Paragraph (a) specifies latency shall be specified as a function of all relevant conditions, which requires the determination of latency in all relevant conditions. This can be an extremely time-consuming task with little actual value. Suggest specifying the maximum latency, which may be specified as a function of a few conditions such as range, or other parameters if they have a significant effect.

UAS.2725 Command-and-control data link loss strategy

FAA-proposed rule:

(a) A command-and-control data link loss strategy must be established, approved, and presented in the UAS Flight Manual considering the emergency recovery capability as defined in UAS.2570.

(b) The command-and-control data link loss strategy shall include an autonomous reacquisition process to try to re-establish in a short, reasonable time the command and control data link.

No recommended changes.

UAS.2730 Command-and-control data link antenna maskings

FAA-proposed rule:

(a) For all UAS attitudes and orientations relative to the signal source within the design envelope, the UAS antenna margin must be consistent to maintain a sufficient link budget for safe operation.

(b) The masking must be stated in the UAS System Flight Manual.

(c) Warning cues shall be provided to the UAS crew in case of approaching masking to prevent a total loss of command-and-control data link.

Some UAS may be able to operate longer periods without a link while others may require a near continuous link. The warnings for the crew should consider the UA's tolerance for masking. For instance, a UA that needs near constant control to maintain a desired flight path may need immediate warning, but a UA that is normally autonomous may only not be affected by masking of a minute or more.

UAS.2735 Command-and-control data link switchover function

FAA-proposed rule:

(a) For all UAS attitudes and orientations relative to the signal source within the design envelope, the UAS antenna margin must be consistent to maintain a sufficient link budget for safe operation.

(b) The masking must be stated in the UAS System Flight Manual.

(c) Warning cues shall be provided to the UAS crew in case of approaching masking attitudes to prevent a total loss of command-and-control data link.

Some UAS may be able to operate longer periods without a link while others may require a near continuous link. The warnings for the crew should consider the UA's tolerance for masking. For instance, a UA that needs near constant control to maintain a desired flight path may need immediate warning, but a UA that is normally autonomous may not be affected by masking of a minute or more.

UAS.2740 Flight interruption system

FAA-proposed rule:

(a) There must be a means for the flight crew to quickly and safely discontinue the UA flight.

(b) The UAS must have a means to safely discontinue the UA flight when safe operation cannot continue or be maintained.

(c) There must be means to prevent inadvertent operation of the flight interruption system.

This is the same as UAS.2570. If there are intended to be different concepts in these two, the concepts should be combined in a single rule since they are so closely related.

UAS.2745 Data link system design

FAA-proposed rule:

The overall design of UA data link shall include the following requirements:

(a) Within the regulatory constraints imposed upon operation of a data link in a specific spectrum band, the design shall mitigate co-channel and adjacent channel interference both as victim and interferer with other users of the spectrum; and

(b) Other design considerations such as multiplexing or coding gains, antenna configuration and associated gain, or dynamic adaptation to channel conditions, shall be verified for compliance with required data link performance criteria.

Paragraph (a) implies that the data link must comply with Federal Communications Commission (FCC) rules, which is redundant. If this is not the intent, is the intent to create FAA specific radio frequency rules separate from FCC rules? Suggest leaving this out unless the FAA intends to make radio frequency rules. A reference to the appropriate FCC rules may be an appropriate replacement.

Paragraph (b) lists several specific design strategies. Suggest ommitting the design strategies and stating that the data link performance must be verified over the certified operating conditions.

UAS.2750 Bandwidth and rate requirements

FAA-proposed rule:

(a) The required bandwidth and coding (including overheads of encryption, interleaving and scrambling) shall deliver a net data rate throughput, loss and delay that meets the requirements of the C2 application and any other services that use the data link for the purpose of managing the flight of the UA.

(b) The characteristics of the data link shall ensure a reliable connection and the desired data rate at the maximum operating range of the UA taking account of degradation of the signal in space in the proposed operational scenario.

This rule has been covered already by the datalink reliability requirements. It is redundant And should be deleted.

UAS.2755 Antenna module design

FAA-proposed rule:

The antenna module generally consists of an antenna, a feed line, a radome, a bracket, or an antenna base. The antenna combination design shall consider the following requirements:

(a) The same polarization of the airborne antenna and the ground terminal antenna shall be used to reduce the polarization loss;

(b) The influence of the body of the UA on the antenna pattern shall be minimized;

(c) Antenna feeders shall use low-loss lines with small electromagnetic wave losses;

(d) The mechanical and electrical properties of feeders shall meet the bending and stretching scenarios that may occur during use; and

(e) *The radome shall be made of low electromagnetic loss material that combines the entire structure and appearance of the UA.*

This rule specifies several design requirements and best practices. However, the data link reliability and performance requirements already address this. Suggest deleting this rule. This type of rule prevents the incorporation of new technological advancements that make current requirements and best practices obsolete.

UAS.2760 C2 link operation

FAA Proposed rule:

The C2 Link shall:

(a) *be able to maintain a bi-directional data transmission between the UA and the remote pilot station; and*

(b) *provide usable signal reliability between the UA and remote pilot station with the remote pilot station or relay equipment.*

(c) *have sufficient bandwidth for the remote pilot to maintain control of the UA at all times.*

(d) *prioritize transmitting flight critical data above all other data.*

(e) *transmit and receive data in all intended operating environments and conditions.*

(f) *provide for safe flight in all operating environments, conditions, and aircraft maneuvers.*

Some rules are based on specific design requirements, but the comments provided suggest replacing these with performance-based rules. Performance-based rules simply require that the communication link must be reliable and effective enough for safe operation, based on the level of risk if it fails.

If performance-based rules are used instead of design-based rules, this rule becomes redundant and can be deleted.

UAS.2765 C2 Link security

FAA-proposed rule:

(a) *The C2 Link shall be encoded in a manner to be unique between the remote pilot station and the UA.*

(b) *The C2 Link shall be resistant to spoofing/hacking attacks.*

No recommended changes.

UAS.2770 C2 Link protocol

FAA-proposed rule:

The remote pilot station to UA C2 Link protocol shall provide separation between flight critical data and non-flight critical data.

This rule requires separation between flight critical data and non-flight critical data but does not give a reason why this is necessary. The requirement here is for the crew to receive flight-critical data, which is already addressed. There is no clear reason what purpose non-flight-critical data serves and why it is needed. This rule adds complexity to the design, which may not improve reliability may even degrade it depending on the architecture of the system. Suggest deleting this rule.

UAS.2775 Reliability requirements

FAA-proposed rule:

The control data link, telemetry and payload data link shall include the ability to:

(a) identify and account for interference;

(b) expeditiously acquire and synchronize with a secondary data link in the event of a loss of a previously operational data link;

(c) ensure a safety margin is included when determining the distance and rate requirements; and

(d) mitigate co-channel and adjacent channel interference within the requirements of the applicable radio regulations.

Although the reliability of the data link is already defined, this rule lists several current design practices that provide reliability. It would be more effective to omit the design requirement and continue to focus on performance requirements. These and other design requirements and best practices described in this rule set are good to include in a means of compliance or guide of best practices, but they should not be included as rules.

UAS.2780 Security requirements

FAA-proposed rule:

The privacy and integrity requirements of the data carried by the data link shall ensure:

(a) The C2 Link is designed to prevent remote data from being intercepted or spoofed;

(b) The C2 Link is designed to prevent UA from being hijacked; and

(c) The telemetry and payload data links are encrypted and authenticated if operational requirements dictate the need for encryption.

No recommended changes.

UAS.2785 Communication

FAA-proposed rule:

(a) The applicant must define the type, methods, and operational limits of communication, including the mitigation of any hazard created by any loss of communication between the flight crew and between the flight crew and the UAS.

(b) A means must be provided to allow for all communication necessary to safely operate the UA.

(c) The UAS must provide a means to inform the crew of the C2 signal strength, quality, or status.

(d) The UAS must provide an alert to the crew upon loss of C2 link functionality or C2 degradation that prevents control of the UA in a timely manner.

(e) The aircraft flight manual (AFM) must include minimum requirements for C2 availability or quality of service, and procedures to determine if C2 availability and quality of service is adequate for planned operations. The AFM or UAS must disallow takeoff/launch when the C2 link is unavailable.

No recommended changes.

B.45 Subpart I—UAS control station

UAS.2800 Minimum UA crew

FAA-proposed rule:

The minimum UAS crew or the maximum aircraft-to-pilot ratio must be established so that it is sufficient for safe operation considering

(a) The workload on individual UAS crew members considering at least the following tasks:

(1) Operation and monitoring of all essential UAS System elements,

(2) Navigation,

(3) Flight path control,

(4) Communications,

(5) Compliance with airspace, air traffic, and air traffic control requirements,

(6) Command decisions including Crew resource management,

(7) Management of a credible worst-case number of multiple anomalies, emergencies, and off-nominal or degraded conditions,

(8) The accessibility and ease of operation of necessary controls.

Add to (a)(8), recognition of a single event that may affect multiple aircraft, such as an unexpected weather event or a security threat that requires immediate landing of all aircraft in a particular area or the unexpected closing of an airport where many aircraft were going.

UAS.2805 Unmanned aircraft crew workplace lights

FAA Proposed rule:

The UAS crew workplace lights must:

(a) Make each indicator, data display, information, markings, placard and control easily readable, and discernible;

(b) Be installed so that their direct rays, and rays reflected from any surface, are shielded from the UAS crew's eyes;

Suggest adding a paragraph (c) that addresses reflection from screens. For instance, a light that shines on a crew member's white shirt may reflect off a screen and make the symbology on that screen difficult to read.

UAS.2810 Communication system

FAA-proposed rule:

(a) For those UASs that require more than one UAS crew member in the UCS, or whose operation will require communication with more than one UAS crew member, the UCS must be evaluated to determine if the UAS crew, when at their workplaces, can converse without difficulty under the actual UCS environment. If the UCS design includes provisions for the

use of communication headsets, the evaluation must also consider conditions where headsets are being used. If the evaluation shows conditions under which it will be difficult to converse, an intercommunication system must be provided.

(b) If the communication equipment that is installed incorporates transmit switches, these switches must be such that when released, they return from the "transmit" to the "off" position.

(c) If provisions for the use of communication headsets are provided, it must be demonstrated that the UA crew will receive all aural warnings under the actual UCS noise conditions when any headset is being used.

No recommended changes.

UAS.2815 Unified control system electrical systems

FAA-proposed rule:

(a) Each electrical system in the UCS must be:

(1) free from hazards in itself, in its method of operation, and in its effects on other parts of the UCS

(2) so designed that the risk of electrical shock is reduced to a minimum.

(3) designed to be protected against electrostatic, lightning and EME hazards.

(b) The total electrical heat emission must be considered in the design of the UCS

No recommended changes.

UAS.2820 Unified control system power supply

FAA-proposed rule:

(a) Failure conditions of UCS power supply shall be assessed according to UAS.2510.

(b) The minimum UCS power supply consistent with sub-paragraph (a) must be stated in the UAS System Flight Manual.

(c) The remote pilot station power delivery system shall provide adequate power to all the remote pilot station line replaceable units (LRUs) (at max power rating) without overloading any circuit breakers.

(d) The remote pilot station should be powered by uninterruptable power supplies (UPS). An alert shall be provided to the remote pilot if the UPS system fails under otherwise normal operating conditions.

(e) Flight critical LRUs should have redundant power supplies and UPS systems.

Paragraph (c) references circuit breaker requirements for the power supply. It appears that the power supply is the local electric grid or a generator. It is assumed that the power supply is not FAA certified (likely the local power grid). It is unclear how compliance can be achieved if the power supply is not FAA certified or part of the conformed design.

UAS.2825 UAS handover between two UCS

FAA-proposed rule:

Where the UAS is designed for UA handover between two UCS:

(a) The in-control UCS must be clearly identified to all UA crew members.

(b) Positive control must be maintained during handover.

(c) The command-and-control functions that are transferred during handover must be defined in the UA System Flight Manual.

(d) Handover between two UCS must not lead to unsafe conditions.

(e) The in-control UCS must have the required functionality to accommodate emergency situations.

No recommended changes.

UAS.2830 Command and control of multiple UA

FAA-proposed rule:

Where a UCS is designed to command and control multiple UAS, the following requirements apply:

(a) The minimum UAS crew must be established so that it is sufficient for safe operation of each vehicle in compliance with UAS.2800 and emergency conditions.

(b) The UAS data shall be displayed in the UCS in a manner that prevents confusion and inadvertent operation.

(c) The UAS controls must be available to the UAS crew for each UAS of which it has command and control in a manner that prevents confusion and inadvertent operation.

(d) All indicators and warnings must be available to the UAS crew for each UAS in a manner that prevents confusion and inadvertent operation.

(e) Where the UCS is designed to monitor multiple UAS, there must be a means to clearly indicate to the UAS crew the UAS over which it has command and control.

No recommended changes.

UAS.2835 UA status data

FAA-proposed rule:

The data regarding UA status shall include:

(a) Location, including latitude and longitude and altitude (AGL, above mean sea level (AMSL), or height above take-off point);

(b) horizontal speed, vertical speed, and heading;

(c) UA attitude;

(d) the status of remaining energy or fuel; and

(e) the status of other on-board equipment deemed safety critical by the manufacturer.

This proposed rule defines status data but does not make any requirements relative to it. If this included for information purposes only, a blanket statement that any information deemed critical by the manufacturer is considered status data should be included.

The requirements of paragraphs (a) and (b) can be provided by surveillance, ADS-B, or similar elements. This rule is unclear as to whether the UA is required to transmit this too, and if so, for what purpose. Since this section is located in the ground station section of the rules, it is assumed that the intent is that the ground station has this information by some means, and transmission by the UA may or may not be required. In this instance, the orientation of the aircraft is of less concern than the trajectory is. If this rule is kept, the heading requirement to track should change.

Paragraph (c) states that the attitude may be completely irrelevant and the pilot may have no control of it anyway. In fact, for some control/display systems combined with some aircraft configurations, attitude can be very distracting. For some configurations, the same flight path and speed can be obtained with very different attitudes. In general, this rule could be deleted, but may be included for aircraft where attitude control by the pilot is important for flight path control.

UAS.3328 Engine Control System

FAA-proposed rule:

(a) Applicability. These requirements are applicable to any system or device that is part of engine type design, that controls, limits, or monitors engine operation, and is necessary for the continued airworthiness of the engine.

(b) Validation.

(1) Functional aspects. The applicant must substantiate by tests, analysis, or a combination thereof, that the engine control system performs the intended functions in a manner that

(i) enables selected values of relevant control parameters to be maintained and the engine kept within the approved operating limits over changing atmospheric conditions in the declared flight envelope;

(ii) complies with the operability requirements of Sec. 33.51, 33.65, and 33.73, as appropriate, under all likely system inputs and allowable engine power or thrust demands, unless it can be demonstrated that failure of the control function results in a non-dispatchable condition in the intended application;

(iii) allows modulation of engine power or thrust with adequate sensitivity over the declared range of engine operating conditions; and

(iv) does not create unacceptable power or thrust oscillations.

(2) Environmental limits. The applicant must demonstrate, when complying with Sec. 33.53 or 33.91, that the engine control system functionality will not be adversely affected by declared environmental conditions, including electromagnetic interference (EMI), High-Intensity Radiated Fields (HIRF), and lightning. The limits to which the system has been qualified must be documented in the engine installation instructions.

(c) Control transitions

(1) The applicant must demonstrate that, when fault or failure results in a change from one control mode to another, from one channel to another, or from the primary system to the back-up system, the change occurs so that

(i) the engine does not exceed any of its operating limitations;

(ii) the engine does not surge, stall, or experience unacceptable thrust or power changes or oscillations or other unacceptable characteristics; and

(iii) there is a means to alert the flight crew if the crew is required to initiate, respond to, or be aware of the control mode change. The means to alert the crew must be described in the engine installation instructions, and the crew action must be described in the engine operating instructions.

(2) The magnitude of any change in thrust or power and the associated transition time must be identified and described in the engine installation instructions and the engine operating instructions.

(d) Engine control system failures. The applicant must design and construct the engine control system so that

(1) the rate for Loss of Thrust (or Power) Control (LOTC/LOPC) events, consistent with the safety objective associated with the intended application can be achieved;

(2) in the full-up configuration, the system is single fault tolerant, as determined by the Administrator, for electrical or electronic failures with respect to LOTC/LOPC events;

(3) single failures of engine control system components do not result in a hazardous engine effect; and

(4) foreseeable failures or malfunctions leading to local events in the intended aircraft installation, such as fire, overheating, or failures leading to damage to engine control system components, do not result in a hazardous-engine effect due to engine control system failures or malfunctions.

(e) System safety assessment. When complying with this section and Sec. 33.75, the applicant must complete a System Safety Assessment for the engine control system. This assessment must identify faults or failures that result in a change in thrust or power, transmission of erroneous data, or an effect on engine operability producing a surge or stall together with the predicted frequency of occurrence of these faults or failures.

(f) Protection systems.

(1) The design and functioning of engine control devices and systems, together with engine instruments and operating and maintenance instructions, must provide reasonable assurance that those engine operating limitations that affect turbine, compressor, fan, and turbosupercharger rotor structural integrity will not be exceeded in service.

(2) When electronic overspeed protection systems are provided, the design must include a means for testing, at least once per engine start/stop cycle, to establish the availability of the protection function. The means must be such that a complete test of the system can be achieved in the minimum number of cycles. If the test is not fully automatic, the requirement for a manual test must be contained in the engine instructions for operation.

(3) When overspeed protection is provided through hydromechanical or mechanical means, the applicant must demonstrate by test or other acceptable means that the overspeed function remains available between inspection and maintenance periods.

(g) Software. The applicant must design, implement, and verify all associated software to minimize the existence of errors by using a method, approved by the FAA, consistent with the criticality of the performed functions.

(h) Aircraft-supplied data. Single failures leading to loss, interruption or corruption of aircraft-supplied data (other than thrust or power command signals from the aircraft), or data shared between engines must

(1) not result in a hazardous engine effect for any engine; and

(2) be detected and accommodated. The accommodation strategy must not result in an unacceptable change in thrust or power or an unacceptable change in engine operating and starting characteristics.

The applicant must evaluate and document in the engine installation instructions the effects of these failures on engine power or thrust, engine operability, and starting characteristics throughout the flight envelope.

(i) Aircraft-supplied electrical power.

(1) The applicant must design the engine control system so that the loss, malfunction, or interruption of electrical power supplied from the aircraft to the engine control system will not result in any of the following:

(i) A hazardous engine effect, or

(ii) The unacceptable transmission of erroneous data.

(2) When an engine dedicated power source is required for compliance with paragraph (i)(1) of this section, its capacity should provide sufficient margin to account for engine operation below idle where the engine control system is designed and expected to recover engine operation automatically.

(3) The applicant must identify and declare the need for, and the characteristics of, any electrical power supplied from the aircraft to the engine control system for starting and operating the engine, including transient and steady state voltage limits, in the engine instructions for installation.

(4) Low-voltage transients outside the power supply voltage limitations declared in paragraph (i)(3) of this section must meet the requirements of paragraph (i)(1) of this section. The engine control system must be capable of resuming normal operation when aircraft-supplied power returns to within the declared limits.

(j) Air pressure signal. The applicant must consider the effects of blockage or leakage of the signal lines on the engine control system as part of the System Safety Assessment of paragraph (e) of this section and must adopt the appropriate design precautions.

(k) NOT APPLICABLE TO SINGLE ENGINE AIRCRAFT.

(l) Engine shut down means. Means must be provided for shutting down the engine rapidly.

(m) Programmable logic devices. The development of programmable logic devices using digital logic or other complex design technologies must provide a level of assurance for the encoded logic commensurate with the hazard associated with the failure or malfunction of the systems in which the devices are located. The applicant must provide evidence that the development of these devices has been done by using a method, approved by the FAA, that is consistent with the criticality of the performed function.

This section is appropriate for piston and turbine engines but may not be for electric motors. This section mostly comes from Part 33. Part 33 is designed to address current technology, but also retains provisions and complexities from previous amendments. For UAS, it is recommended that propulsion systems be treated exactly like other systems on the UA. For other systems, the effect of failures determines its hazard level, which determines the reliability requirements. The rules can be simplified and streamlined by eliminating the entire UAS.3328 rule and treating propulsion systems like all the other systems with their requirements for reliability, limit protections, critical indications, etc. In fact, for some of the new designs, the propulsion system and the control system are integrated such that there is no distinction between the two. For these aircraft, it needs to be determined which set of rules apply to which component. This issue is eliminated by including propulsion with all the other systems.

The hazard associated with a propulsion or control failure should consider the effect of persons or property on the ground. For instance, a medium-sized UA operated over urban areas may be expected to cause multiple fatalities and significant property damage if it crashes at high speed, where a large UA operating over agricultural land would be expected to cause no injury and minor property damage if it crashes at high speed.

B.46 UAS.3353 Engine System and Component Tests

FAA-proposed rule:

(a) For those systems and components that cannot be adequately substantiated in accordance with endurance testing of Sec. 33.49, the applicant must conduct additional tests to demonstrate that systems or components are able to perform the intended functions in all declared environmental and operating conditions.

(b) Temperature limits must be established for each component that requires temperature controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.

No recommended changes.

B.47 Reference

FAA. (2011). System safety analysis and assessment for Part 23 airplanes (*AC 23.1309-1E*). Retrieved from https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1019681

C Recommended design assurance requirements for automation that replaces pilot tasks

C.1 The need for defined design assurance levels associated with automation

Automation has replaced many pilot tasks and will continue to replace more. If done well and with the appropriate design assurance levels not only is training reduced, but safety is improved. Two examples are presented here that were examined during the experiment described in Appendix K.

1. Computerized weight and balance.

Currently, every FAA written test has a question that requires the applicant to calculate weight and balance (W&B) using pencil, paper, and a four-function calculator. Today, nearly all pilots use some form of computerized W&B calculator. It takes much less training to learn how to use a computerized W&B calculator than it does to learn how to do the calculations with pencil and paper and a four-function calculator. Using a computerized W&B calculator also reduces the probability of human error during calculations, which improves safety.

2. Flying an instrument approach

Nearly all current production airplanes come standard with an autopilot (AP) capable of flying an instrument approach. It takes less time to train a pilot to set up the avionics to fly the approach than it does to train a pilot to manually fly the approach.

According to the National Transportation Safety Board (NTSB), loss-of-control accidents occur at a rate of about 1 in every 100,000 flight hours. If an AP is more reliable than this, then safety is improved. Because of this, Cirrus Aircraft and several major airlines recommend that all approaches be flown using the AP. The question then becomes what level of design assurance is enough to eliminate the need for a pilot to learn (and practice) manually flying instrument approaches. One answer is that it must be enough that the ability to fly the approach manually reduces safety. This occurs when the manual backup is provided "in case the automation fails." When manual backup is allowed, it is usually a requirement that the pilot know how to use the backup. Practicing this backup scenario, pilots expose themselves to a higher probability of loss of control—especially when using the manual backup in a real emergency as opposed to a training scenario. Using the backup in an emergency may have less favorable results than when a pilot demonstrates the skill in a training environment.

C.2 Recommendation: Aircraft (manned and unmanned) operated commercially over urban areas must meet Category A design requirements

It is recommended that aircraft operated commercially over urban areas must be certified as Category A aircraft. Currently, helicopters that operate commercially over urban areas in Europe are required to comply with the requirements of Category A of Part 27 or Part 29. It is expected that the public will not tolerate large unmanned aerial vehicles (UAVs) if they crash at the current general aviation accident rate. Category A rules are intended to bring the accident rate closer to that of commercial air travel.

Part 23 reliability requirements assume that the only people involved in the accident are the aircraft occupants. Category A reliability requirements assume that people on the ground will also be involved in the accident if it occurs over an urban area. Therefore, the number of seats is not the driving factor for Category A aircraft. This concept comes from Part 27, which copies the appropriate rules from Part 29 amendment 57. The recommended requirements of this appendix rely heavily on the requirements of Part 27 (and by extension, Part 29) Category A aircraft. Part 23 does not have a Category A certification path.

C.3 Category A reliability

The probability of a flight control system failure that causes a catastrophic event shall be no more than the following. For these special conditions, an event that causes an aircraft operating in an urban area to land at other than a landing zone (or an emergency landing zone) due to any failure (including propulsion failure) is considered a catastrophic event. This is due to the probability that in an urban area, that event will cause serious injury or death to people on the ground even if the occupants of the aircraft are protected.

- Level 1 used primarily for pleasure or recreation: $< 10^{-6}$
- Level 1 not used primarily for pleasure or recreation: $< 10^{-7}$
- Level 1 used for commercial operations over urban areas: $< 10^{-8}$
- Level 2: $< 10^{-7}$
- Level 2 used for commercial operations over urban areas: $< 10^{-8}$
- Level 3: $< 10^{-8}$
- Level 4: $< 10^{-9}$

The maximum probability for a hazardous event may be 10 times that of a catastrophic event.

The maximum probability for a major event may be 100 times that of a catastrophic event.

The maximum probability for a minor event may be 1000 times that of a catastrophic event.

There is no probability requirement for events that provide no safety hazard.

For aircraft not used in Urban Air Mobility, most of the flight is conducted over sparsely populated areas. Thus, if an event occurs that causes the aircraft to crash, it will most likely not injure people that are not occupants of the aircraft, and the number of affected people is therefore limited by the occupancy limit of the aircraft. However, aircraft used in Urban Air Mobility and UAVs are expected to fly over densely populated areas. Therefore, if the aircraft crashes, it is likely to cause injuries to people who are not occupants of the aircraft and the number of affected people is therefore not limited by the occupancy limit of the aircraft. Thus, the reliability requirements for Category A aircraft are the same for all aircraft smaller than level 4.

The following sections discuss the current FAA rules and the proposed changes to those regulations. Changes to the existing rule are in bold-face type, followed by a discussion of those changes.

C.4 UAV Category A 23.2000—Applicability and definitions

FAA Rule:

23.2000 Applicability and definitions

(a) This part prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for aircraft in the normal category that comply with the functions, features and characteristics of this part.

(b) For the purposes of this part, the following definition applies:

> ***Continued safe flight and landing*** *means an airplane is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some airplane damage may occur as a result of a failure condition.*

(a) This part prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for **aircraft** in the normal category.

(b) For the purposes of this part, the following definition applies:

> (1) *Continued safe flight and landing* means an **aircraft** is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring

exceptional pilot skill or strength. Upon landing, some **aircraft** damage may occur as a result of a failure condition.

(2) For aircraft in commercial use in urban areas continued safe flight and landing means:

(i) an aircraft is capable of continued controlled flight and navigating to and landing on an appropriate landing area, such as a runway or vertiport, emergency use heliport, etc., and stopping within that landing zone, or navigating outside of the urban area possibly using emergency or automated procedures, without requiring exceptional pilot skill or strength. Upon landing, some aircraft damage may occur as a result of a failure condition. A body of water may be considered an appropriate landing area if the aircraft is approved for ditching or water operations.

or

(ii) the aircraft touches down with less than 94,000 ft*lb of kinetic energy.

<u>Discussion</u>

In an urban environment, safe landing areas, i.e., large, open, and sparsely populated areas, are rare. In a non-urban area, a failure such as an engine failure in an airplane that has a stall speed of less than 61 kt is not likely to result in fatalities in most instances. However, in an urban area, this same aircraft is less likely to land without causing fatalities either to the occupants or people on the ground.

A runway or landing zone can be a private airport, emergency-use-only helipad, military base, open space in a freeway interchange, or other area that is kept available for emergency landings even if that space is not normally considered a landing zone.

A popular general aviation airplane that weighs 3,600 lb and has a parachute touches down at about 17 kt under parachute. This is a kinetic energy of 94,000 ft*lb. Experience with these aircraft that have come down under parachute in populated areas has shown that this speed and kinetic energy level is generally low enough to prevent serious injury or death for either the aircraft occupants or people on the ground.

Examples:

1. A heavy aircraft with a flight control system that does not meet the reliability requirements for operation over urban areas may have a parachute that deploys in the

event of a flight control system failure, but the resulting kinetic energy at touchdown is too high for Category A operations. This requirement is met under the following conditions:

   a. The parachute is steerable and the aircraft's navigation system reliably keeps the parachute within the gliding distance of a suitable emergency landing zone, then
   b. It is demonstrated that the aircraft under parachute can automatically maneuver to the landing zone when the parachute deploys and touchdown at a speed that prevents catastrophic injury to the occupants.

2. An aircraft has a propulsion system that does not meet the reliability requirements for urban operations but is operated in an environment and uses operating rules that ensure that it is always within gliding distance of a suitable landing zone. The aircraft has glide guidance that automatically engages when a propulsion failure occurs. If it can be shown that when the propulsion system fails that the typical pilot without special training can reliably follow the guidance and land and stop on a suitable landing zone, then this requirement is met.

3. A single-pilot aircraft may meet the "Lack of pilot action cannot result in a catastrophic event" by incorporating a feature that prevents the aircraft from taking off without identifying a valid destination, forces a valid destination to always be active, and has a feature that detects pilot incapacitation. When the aircraft detects that the pilot is incapacitated, then the aircraft goes to the destination and lands ("damage can occur as long as the result is not catastrophic"). Note that in this case the automatic features must have the appropriate reliability level.

C.5 UAV Category A 23.2115—Takeoff performance

FAA Rule:

23.2115 Takeoff Performance*(a) The applicant must determine airplane takeoff performance accounting for—*

> *(1) Minimum flight speed margins for aircraft that use free-stream velocity for all or part of their lift;*
>
> *(2) Component or system failures during takeoff and;*
>
> *(3) Climb gradients.*

(b) For aircraft that meet the emergency landing requirements (23.2270) when landing on an unprepared surface, takeoff performance includes the determination of ground roll and initial

climb distance to 50 feet (15 meters) above the takeoff surface for all approved takeoff configurations that require a ground roll.

(c) For aircraft that do not meet the emergency landing requirements (23.2270) when landing on an unprepared surface, takeoff performance includes the determination of the following distances after the most critical failure or combination of failures that do not meet the reliability requirement for a catastrophic event at the critical speed for all approved takeoff configurations that require a ground roll.

(1) An aborted takeoff at critical speed;

(2) Ground roll and initial climb to 35 feet (11 meters) above the takeoff surface; and

(3) Net takeoff flight path.

(d) If there is a speed/height envelope where continued safe flight cannot be maintained after sudden critical loss of power or thrust, it must be determined.

Recommended changes:

(a) The applicant must determine aircraft takeoff performance accounting for—

(1) Minimum flight speed margins for aircraft that use free-stream velocity for all or part of their lift;

(2) Component or system failures during takeoff and;

(3) Climb gradients.

(b) For aircraft that meet the emergency landing requirements (UAV 23.2270) when landing on an unprepared surface, takeoff performance includes the determination of ground roll and initial climb distance to 50 feet (15 meters) above the takeoff surface for all approved takeoff configurations that require a ground roll.

(c) For aircraft that do not meet the emergency landing requirements (UAV 23.2270) when landing on an unprepared surface, takeoff performance includes the determination of the following distances after the most critical failure or combination of failures that do not meet the reliability requirement for a catastrophic event at the critical speed for all approved takeoff configurations that require a ground roll.

(1) An aborted takeoff at critical speed;

(2) Ground roll and initial climb to 35 feet (11 meters) above the takeoff surface; and

(3) Net takeoff flight path.

(d) If there is a speed/height envelope where continued safe flight cannot be maintained after sudden critical loss of power or thrust, it must be determined.

(e) If a speed/height envelope exists as established in UAV 23.2115 (d), then the aircraft will not allow flight within that envelope.

C.6 UAV Category A 23.2120—Climb requirements

FAA Rule:

23.2120 Climb Requirements

The design must comply with the following minimum climb performance out of ground effect:

(a) With all engines operating and in the initial climb configuration—

(1) For levels 1 and 2 low-speed aircraft, a climb gradient of 8.3 percent for landplanes and 6.7 percent for seaplanes and amphibians; and

(2) For levels 1 and 2 high-speed aircraft, all level 3 aircraft, and level 4 single engines a climb gradient after takeoff of 4 percent.

(3) For all aircraft (including VTOL), the minimum steady state rate of climb is 500 ft/min for land planes and 400 ft/min for amphibians and sea planes. The takeoff profile must provide the specified climb rate and gradient.

(b) An event or combination of events that causes the climb performance to fall below that specified by (b)(1), (b)(2) or (b)(3) as appropriate for the aircraft is considered a catastrophic event.

(1) For levels 1 and 2 low-speed airplanes that do not meet the emergency landing requirements (23.2270) when landing on an unprepared surface, a climb gradient of 1.5 percent at a pressure altitude of 5,000 feet (1,524 meters) in the cruise configuration(s). For aircraft capable of vertical takeoff, compliance with this rule may be demonstrated by a 1.5 percent climb gradient at 60 KIAS or greater, or a minimum climb rate of 100 ft/min at any lower speed at 5,000 ft. density altitude. For all aircraft, at 5,000 ft density altitude, the aircraft must be able to climb at 100 ft/minute or a climb gradient of 1.5 percent, whichever provides a higher climb rate.

(2) For levels 1 and 2 high-speed aircrafts, and level 3 low-speed aircrafts, a 1 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the takeoff configuration(s); and

(3) For level 3 high-speed airplanes and all level 4 aircrafts, a 2 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the approach configuration(s).

(4) For aircraft capable of vertical takeoff, compliance with this rule may be demonstrated by the climb gradient specified in the rule at 100 KIAS or greater, or a minimum average climb rate of 200 ft/min at any lower speed from 50 ft to 400 ft AGL.

(c) For a balked landing, a climb gradient of 3 percent without creating undue pilot workload with the landing gear extended and flaps in the landing configuration(s).

(1) If the aircraft automatically reconfigures after a go around, then the go around configuration may be used if the required climb gradient is achieved in less than 6 seconds and is maintained.

(2) In addition to the minimum climb gradient, the minimum balked landing climb rate is 200 feet per minute which is about equivalent to 3% at 60 kt.

Recommended changes:

The design must comply with the following minimum climb performance out of ground effect:

(a) With all engines operating and in the initial climb configuration—

(1) For levels 1 and 2 low-speed aircraft, a climb gradient of 8.3 percent for landplanes and 6.7 percent for seaplanes and amphibians; and

(2) For levels 1 and 2 high-speed aircraft, all level 3 aircraft, and level 4 single engines a climb gradient after takeoff of 4 percent.

(3) For all aircraft (including VTOL), the minimum steady state rate of climb is 500 ft/min for land planes and 400 ft/min for amphibians and sea planes. The takeoff profile must provide the specified climb rate and gradient.

(b) An event or combination of events that causes the climb performance to fall below that specified by (b)(1), (b)(2) or (b)(3) as appropriate for the aircraft is considered a catastrophic event.

(1) For levels 1 and 2 low-speed aircraft that do not meet the emergency landing requirements (UAV 23.2270) when landing on an unprepared surface, a climb gradient of 1.5 percent at a pressure altitude of 5,000 ft (1,524 m) in the cruise configuration(s). For aircraft capable of vertical takeoff, compliance with this rule may be demonstrated by a 1.5 percent climb gradient at 60 KIAS or greater, or a minimum climb rate of 100 ft/min at any lower speed at 5,000 ft density altitude. For all aircraft, at 5,000 ft density altitude, the aircraft must be able to climb at 100 ft/min or a climb gradient of 1.5 percent, whichever provides a higher climb rate.

(2) For levels 1 and 2 high-speed aircraft, and level 3 low-speed aircraft, a 1 percent climb gradient at 400 ft (122 m) above the takeoff surface with the landing gear retracted and flaps in the takeoff configuration(s); and

(3) For level 3 high-speed aircraft and all level 4 aircraft, a 2 percent climb gradient at 400 ft (122 m) above the takeoff surface with the landing gear retracted and flaps in the approach configuration(s).

(4) For aircraft capable of vertical takeoff, compliance with this rule may be demonstrated by the climb gradient specified in the rule at 100 KIAS or greater, or a minimum average climb rate of 200 ft/min at any lower speed from 50 ft to 400 ft AGL.

(c) For a balked landing, a climb gradient of 3 percent without creating undue pilot workload with the landing gear extended and flaps in the landing configuration(s).

(1) If the aircraft automatically reconfigures after a go-around, then the go-around configuration may be used if the required climb gradient is achieved in less than 6 s and is maintained.

(2) In addition to the minimum climb gradient, the minimum balked landing climb rate is 200 ft/min, which is about equivalent to 3percent at 60 kt.

(d) Failure to meet the climb requirements of UAV 23.2120 (b) is considered a catastrophic event for system reliability purposes.

(e) From the takeoff point to 1000 ft above the takeoff point, the climb gradient shall always be positive or level.

(f) Failure to meet the climb requirements of UAV 23.2120 (c) is considered a catastrophic event for system reliability purposes.

Discussion:

This concept comes from the Category A requirements of Part29 (29.59 Takeoff Path: Category A, and 29.85: Balked landing: Category A) (Takeoff path: Category A., 1999). The concept is to ensure that acceptable climb performance is available after any system failure. The intent is to treat low climb capability on takeoff the same as a catastrophic event for certification purposes. System failures or combinations of system failures that result in low climb performance on takeoff are treated like any other system failure. There is nothing special about an Engine or power plant.

C.7 UAV Category A 23.2325—Fire protection

FAA Rule:

§23.2325 Fire protection.

(a) The following materials must be self-extinguishing—

(1) Insulation on electrical wire and electrical cable;

(2) For levels 1, 2, and 3 aircraft, materials in the baggage and cargo compartments inaccessible in flight; and

(3) For level 4 aircraft, materials in the cockpit, cabin, baggage, and cargo compartments.

(b) The following materials must be flame resistant—

(1) For levels 1, 2, and 3 aircraft, materials in each compartment accessible in flight; and

(2) Any equipment associated with any electrical cable installation and that would overheat in the event of circuit overload or fault.

(c) Thermal/acoustic materials in the fuselage, if installed, must not be a flame propagation hazard.

(d) Sources of heat within each baggage and cargo compartment that are capable of igniting adjacent objects must be shielded and insulated to prevent such ignition.

(e) For level 4 aircraft, each baggage and cargo compartment must—

(1) Be located where a fire would be visible to the pilots, or equipped with a fire detection system and warning system; and

(2) Be accessible for the manual extinguishing of a fire, have a built-in fire extinguishing system, or be constructed and sealed to contain any fire within the compartment.

(f) There must be a means to extinguish any fire in the cabin such that—

(1) The pilot, while seated, can easily access the fire extinguishing means; and

(2) For levels 3 and 4 aircraft, passengers have a fire extinguishing means available within the passenger compartment.

(g) Each area where flammable fluids or vapors might escape by leakage of a fluid system must—

(1) Be defined; and

(2) Have a means to minimize the probability of fluid and vapor ignition, and the resultant hazard, if ignition occurs.

(h) Combustion heater installations must be protected from uncontained fire.

Proposed changes:

(a) The following materials must be self-extinguishing—

(1) Insulation on electrical wire and electrical cable;

(2) For levels 1, 2, and 3 aircraft, materials in the baggage and cargo compartments inaccessible in flight; and

(3) For level 4 aircraft, materials in the cockpit, cabin, baggage, and cargo compartments.

(b) The following materials must be flame resistant—

(1) For levels 1, 2 and 3 aircraft, materials in each compartment accessible in flight; and

(2) Any equipment associated with any electrical cable installation and that would overheat in the event of circuit overload or fault.

(c) Thermal/acoustic materials in the fuselage, if installed, must not be a flame propagation hazard.

(d) Sources of heat within each baggage and cargo compartment that are capable of igniting adjacent objects must be shielded and insulated to prevent such ignition.

(e) For level 4 aircraft, each baggage and cargo compartment must—

(1) Be located where a fire would be visible to the pilots, or equipped with a fire detection system and warning system; and

(2) Be accessible for the manual extinguishing of a fire, have a built-in fire extinguishing system, or be constructed and sealed to contain any fire within the compartment.

(f) There must be a means to extinguish any fire in the cabin such that—

(1) The pilot, while seated, can easily access the fire extinguishing means; and

(2) For levels 3 and 4 aircraft, passengers have a fire extinguishing means available within the passenger compartment.

(g) Each area where flammable fluids or vapors might escape by leakage of a fluid system must—

(1) Be defined; and

(2) Have a means to minimize the probability of fluid and vapor ignition, and the resultant hazard, if ignition occurs.

(h) Combustion heater installations must be protected from uncontained fire.

(i) If flammable substances are contained in a compartment that has an ignition source or hot surfaces that may cause ignition of these substances, then a fire extinguishing system that extinguishes the fire fueled by that substance and prevents it from restarting must be installed in that compartment.

Discussion

This concept comes from Part 29 (section 29.1195, Fire extinguishing systems) (Fire extinguishing systems, 1978) and is intended to treat onboard fire extinguishing systems with more rigor than the non-Category A rule. Even if an aircraft can control an onboard fire long enough to execute an emergency descent and land safely, it is not acceptable for it to make an emergency landing in an urban area while still on fire, as this puts people on the ground at risk.

C.8 UAV Category A 23.2620—Aircraft flight manual

FAA Rule

§23.2620 Aircraft flight manual

The applicant must provide an Aircraft Flight Manual that must be delivered with each aircraft.

(a) The Aircraft Flight Manual must contain the following information—

(1) Aircraft operating limitations;

(2) Aircraft operating procedures;

(3) Performance information;

(4) Loading information; and

(5) Other information that is necessary for safe operation because of design, operating, or handling characteristics.

(b) The following sections of the Aircraft Flight Manual must be approved by the FAA in a manner specified by the administrator—

(1) For low-speed, level 1 and 2 airplanes, those portions of the Aircraft Flight Manual containing the information specified in paragraph (a)(1) of this section; and

(2) For high-speed level 1 and 2 airplanes and all level 3 and 4 airplanes, those portions of the Aircraft Flight Manual containing the information specified in paragraphs (a)(1) through (a)(4) of this section.

The applicant must provide an Aircraft Flight Manual (AFM) that must be delivered with each aircraft.

(a) The AFM must contain the following information—

(1) Aircraft operating limitations;

(2) Aircraft operating procedures;

(3) Performance information;

(4) Loading information; and

(5) Other information that is necessary for safe operation because of design, operating, or handling characteristics.

(b) For all Category A aircraft, sections (a)(1) through (a)(4) of the Aircraft Flight Manual must be approved by the FAA in a manner specified by the administrator.

(c) Aircraft that require electronic applications to accomplish a function listed in (a) a paper version of that function need not be included in the flight manual

Discussion

Subsection 23.2620 allows the AFM for low-speed level 1 and level 2 aircraft to only include operating limitations. This modification for Category A certification requires that flight manuals for Category A also include operating procedures, performance information, loading information, and other information that is necessary for safe operation because of design, operating, or handling characteristics. This is the same requirement §23.2630 required for all level 3 and 4 aircraft.

(c):

The intent of paragraph (c) is that electronic applications will replace paper checklists, weight and balance charts, performance charts and other items that can be done easier and with less tendencies to error electronically than by using pencil and paper.

D Recommended changes to Part 61 and airman certification standards/practical test standards

D.1 Simplified vehicle operations-A changes to Part 61

Simplified vehicle operations (SVO)-A aircraft can have characteristics of both airplanes and helicopters. Powered-lift vehicles as envisioned by the current Part 61 powered-lift rules also have characteristics of both airplanes and helicopters. Because of this, Part 61 requirements for powered lift are generally used as a starting point for the Part 61 proposed SVO-A requirements. Some items are eliminated because the technology required in SVO-A1, SVO-A2, and SVO-A3 aircraft make the requirement obsolete. Some requirements are added to ensure that the SVO-A pilot knows how to use the technology. The total hours required are also reduced because the SVO-A aircraft are easier to operate than legacy aircraft. The hours required for some specific tasks (e.g., cross country and night flight) are not reduced because the development of flight experience is important.

This appendix is organized in the numerical order of the existing Part 61 paragraphs, not the order that the pilot typically acquires the ratings.

D.2 Part 61.57—Recent flight experience: Pilot in command

The instrument proficiency requirements are:

(c) ***Instrument experience.*** *Except as provided in paragraph (e) of this section, a person may act as pilot in command under IFR or weather conditions less than the minimums prescribed for VFR only if:*

(1) ***Use of an airplane, powered-lift, helicopter, or airship for maintaining instrument experience.*** *Within the 6 calendar months preceding the month of the flight, that person performed and logged at least the following tasks and iterations in an airplane, powered-lift, helicopter, or airship, as appropriate, for the instrument rating privileges to be maintained in actual weather conditions, or under simulated conditions using a view-limiting device that involves having performed the following—*

(i) Six instrument approaches.

(ii) Holding procedures and tasks.

(iii) Intercepting and tracking courses through the use of navigational electronic systems.

(2) relates to a simulator and (3) relates to a glider

Recommended changes

Add (4) and (5) to (c):

(4) Use of an SVO-A1 aircraft in weather conditions less than visual flight rules (VFR), in actual or simulated instrument conditions:

(i) Program the navigator to execute six instrument approaches

(ii) Program the navigator to execute a holding pattern

(iii) Couple the autopilot (AP) to fly six instrument approaches

(5) Use of an SVO-A2 aircraft in weather conditions less than VFR, in actual or simulated instrument conditions:

(i) File and execute at least one instrument flight rules (IFR) flight from takeoff to landing including an instrument approach

Discussion

In the SVO-A1 aircraft, all published instrument procedures are conducted by selecting the procedure on the navigator and coupling to the procedure. Therefore, the only proficiency requirement is the ability to program the navigator and couple to the procedure.

All SVO-A2 flights are done under IFR, and the pilot does not control attitude or the navigation for instrument procedures. The pilot acts to direct the flight path and cause the flight plan to be created. Therefore, the only proficiency needed is creating a flight plan and executing a flight.

D.3 Part 61.65—Instrument rating

The IR requirements for a powered-lift aircraft are:

(a) ***General.*** *A person who applies for an instrument rating must:*

(1) Hold at least a current private pilot certificate, or be concurrently applying for a private pilot certificate, with an airplane, helicopter, or powered-lift rating appropriate to the instrument rating sought;

(2) Be able to read, speak, write, and understand the English language. If the applicant is unable to meet any of these requirements due to a medical condition, the Administrator may place such operating limitations on the applicant's pilot certificate as are necessary for the safe operation of the aircraft;

(3) Receive and log ground training from an authorized instructor or accomplish a home-study course of training on the aeronautical knowledge areas of paragraph (b) of this section that apply to the instrument rating sought;

(4) Receive a logbook or training record endorsement from an authorized instructor certifying that the person is prepared to take the required knowledge test;

(5) Receive and log training on the areas of operation of paragraph (c) of this section from an authorized instructor in an aircraft, full flight simulator, or flight training device that represents an airplane, helicopter, or powered-lift appropriate to the instrument rating sought;

(6) Receive a logbook or training record endorsement from an authorized instructor certifying that the person is prepared to take the required practical test;

(7) Pass the required knowledge test on the aeronautical knowledge areas of paragraph (b) of this section; however, an applicant is not required to take another knowledge test when that person already holds an instrument rating; and

(8) Pass the required practical test on the areas of operation in paragraph (c) of this section in—

(i) An airplane, helicopter, or powered-lift appropriate to the rating sought; or

(ii) A full flight simulator or a flight training device appropriate to the rating sought and for the specific maneuver or instrument approach procedure performed. If an approved flight training device is used for the practical test, the instrument approach procedures conducted in that flight training device are limited to one precision and one non-precision approach, provided the flight training device is approved for the procedure performed.

(b) ***Aeronautical knowledge.*** *A person who applies for an instrument rating must have received and logged ground training from an authorized instructor or accomplished a home-study course on the following aeronautical knowledge areas that apply to the instrument rating sought:*

(1) Federal Aviation Regulations of this chapter that apply to flight operations under IFR;

(2) Appropriate information that applies to flight operations under IFR in the "Aeronautical Information Manual;"

(3) Air traffic control system and procedures for instrument flight operations;

(4) IFR navigation and approaches by use of navigation systems;

(5) Use of IFR en route and instrument approach procedure charts;

(6) Procurement and use of aviation weather reports and forecasts and the elements of forecasting weather trends based on that information and personal observation of weather conditions;

(7) Safe and efficient operation of aircraft under instrument flight rules and conditions;

(8) Recognition of critical weather situations and windshear avoidance;

(9) Aeronautical decision making and judgment; and

(10) Crew resource management, including crew communication and coordination.

(c) ***Flight proficiency.*** *A person who applies for an instrument rating must receive and log training from an authorized instructor in an aircraft, or in a full flight simulator or flight training device, in accordance with paragraph (g) of this section, that includes the following areas of operation:*

(1) Preflight preparation;

(2) Preflight procedures;

(3) Air traffic control clearances and procedures;

(4) Flight by reference to instruments;

(5) Navigation systems;

(6) Instrument approach procedures;

(7) Emergency operations; and

(8) Postflight procedures.

*(f) **Aeronautical experience for the instrument-powered-lift rating**. A person who applies for an instrument-powered-lift rating must have logged:*

(1) Except as provided in paragraph (g) of this section, 50 hours of cross-country flight time as pilot in command, of which 10 hours must have been in a powered-lift; and

(2) Forty hours of actual or simulated instrument time in the areas of operation listed under paragraph (c) of this section, of which 15 hours must have been received from an authorized instructor who holds an instrument-powered-lift rating, and the instrument time includes:

(i) Three hours of instrument flight training from an authorized instructor in a powered-lift that is appropriate to the instrument-powered-lift rating within 2 calendar months before the date of the practical test; and

(ii) Instrument flight training on cross country flight procedures, including one cross country flight in a powered-lift with an authorized instructor that is performed under instrument flight rules, when a flight plan has been filed with an air traffic control facility, that involves—

(A) A flight of 250 nautical miles along airways or by directed routing from an air traffic control facility;

(B) An instrument approach at each airport; and

(C) Three different kinds of approaches with the use of navigation systems.

(g) An applicant for a combined private pilot certificate with an IR may satisfy the cross-country flight time requirements of this section by crediting:

(1) For an instrument-airplane rating or an instrument-powered-lift rating, up to 45 hours of cross-country flight time performing the duties of PIC with an authorized instructor; or

(2) For an instrument-helicopter rating, up to 47 hours of cross-country flight time performing the duties of PIC with an authorized instructor.

(h) Use of full flight simulators or flight training devices. If the instrument time was provided by an authorized instructor in a full flight simulator or flight training device—

(1) A maximum of 30 hours may be performed in that full flight simulator or flight training device if the instrument time was completed in accordance with part 142 of this chapter; or

(2) A maximum of 20 hours may be performed in that full flight simulator or flight training device if the instrument time was not completed in accordance with part 142 of this chapter.

(i) Use of an aviation training device. A maximum of 10 hours of instrument time received in a basic aviation training device or a maximum of 20 hours of instrument time received in an advanced aviation training device may be credited for the instrument time requirements of this section if—

(1) The device is approved and authorized by the FAA;

(2) An authorized instructor provides the instrument time in the device; and

(3) The FAA approved the instrument training and instrument tasks performed in the device.

(j) Except as provided in paragraph (h)(1) of this section, a person may not credit more than 20 total hours of instrument time in a full flight simulator, flight training device, aviation training device, or a combination towards the instrument time requirements of this section.

Recommended changes

For the SVO-A1 instrument rating (IR) (b)(11) and (k) are added as follows.

(b)

(11) For an SVO-A1 IR (b)(4), (b)(5), and (b)(6), are replaced with

(i) Using the flight planning application to enter and file IFR flight plans

(ii) Finding and coupling to the appropriate procedures.

(k) SVO-A aeronautical experience

(i) For SVO-A1 aircraft, the aeronautical experience requirements for powered lift (61.65(f) apply and the 40- and 15-hour requirements of (f)(2) are reduced to 30 and 10, respectively.

(ii) For SVO-A2 aircraft, there are no specific instrument flight time requirements.

Discussion

The SVO-A1 aircraft has a built-in flight planning application that can create IFR flight plans and file them. This application automatically takes weather observations and forecasts into consideration. The SVO-A1 aircraft is also required to have the ability to couple the AP to a published instrument procedure at a reliability level that does not require the pilot to be a backup. Therefore, the ability to manually fly instrument procedures or read instrument procedure charts is not needed. But the ability to identify and load the correct procedure into the navigator is required.

The hour requirements of (f)(2) are reduced to reflect the fact that the SVO-A1 pilot does not need to learn unusual attitude recoveries or how to manually fly an approach.

The SVO-A2 aircraft is always on an IFR flight plan, and therefore the required instrument skills are a part of the basic private pilot license (See the new proposed 61.109 section). There is no such thing as a VFR-only SVO-A2 pilot. Table D-1 shows a comparison of the proposed minimum time requirements for an IR for legacy, SVO-A1, and SVO-A2 aircraft.

Table D-1. Comparison of the proposed instrument rating minimum time (in hours) requirements

Minimum Aeronautical Experience for an Instrument Rating			
Task	**Powered Lift**	**SVO-A1**	**SVO-A2**
Cross country PIC	50	50	0
Cross country PIC in category	10	10	0
Instrument time	40	30	0
Instrument instruction	15	10	0

D.4 Part 61.87—Solo requirements for student pilots

Paragraphs (a), (b), and (c) are general and apply to all aircraft. Section 61.87 (h), **Maneuvers and procedures for pre-solo flight training in a powered-lift**, is used as a guide. A new section (q) is added to 61.87 for SVO-A1 and SVO-A2.

The difference between (h) powered-lift and (q) SVO-A is that (10) is removed and (h) (17) is changed to (q) (16) to include any system failure that is more probable than is allowed for a catastrophic event.

61.87 (h)(10) Stall entries from various flight attitudes and power combinations with recovery initiated at the first indication of a stall, and recovery from a full stall;

61.87(h)(17) For multiengine powered-lifts, simulated one-engine-inoperative approaches and landings.

<u>Recommended changes</u>

(q) Maneuvers and procedures for pre-solo flight training in an SVO-A1 or SVO-A2 aircraft. A student pilot who is receiving training for an SVO-A1 or SVO-A2 rating must receive and log flight training in the following maneuvers and procedures:

(1) Proper flight preparation procedures, including preflight planning and preparation, powerplant operation, and aircraft systems;

(2) Taxiing or surface operations, including runups;

(3) Takeoffs and landings, including normal and crosswind;

(4) Straight and level flight, and turns in both directions;

(5) Climbs and climbing turns;

(6) Airport traffic patterns, including entry and departure procedures;

(7) Collision avoidance, windshear avoidance, and wake turbulence avoidance;

(8) Descents with and without turns;

(9) Flight at various airspeeds from cruise to slow flight;

(10) Emergency procedures and equipment malfunctions;

(11) Ground reference maneuvers;

(12) Approaches to a landing with simulated engine malfunctions;

(13) Go-arounds;

(14) Approaches to the landing area;

(15) Hovering and hovering turns; and

(16) Approaches and landings with failures more probable than is permitted for a catastrophic event.

Discussion

Stalls are eliminated because SVO-A aircraft cannot stall.

SVO-A aircraft certification regulations treat all failures the same. Therefore, this training requirement matches this philosophy.

D.5 Part 61.93—Solo cross-country flight requirements

61.93 (i), **Maneuvers and procedures for cross-country flight training in a powered-lift**, is used as a guide. A new section (n) is added for SVO-A1 and SVO-A2.

The differences between (i) powered-lift and (n) SVO-A are (1), (2), and (3) are replaced by (1) Use of the flight plan application and (2) Navigation using the flight plan. Additionally, "VFR" is eliminated from item (8) Use of radios.

(n) **Maneuvers and procedures for cross-country flight training in an SVO-A1 and SVO-A2 aircraft.** A student pilot who is receiving training for cross-country flight training in an SVO-A1 or SVO-A2 aircraft must receive and log flight training in the following maneuvers and procedures:

(1) Use of the flight planning application to include navigation, aircraft performance and weather information.

(2) Navigation using the flight plan.

(3) Emergency procedures;

(4) Traffic pattern procedures that include area departure, area arrival, entry into the traffic pattern, and approach;

(5) Procedures and operating practices for collision avoidance, wake turbulence precautions, and windshear avoidance;

(6) Recognition, avoidance, and operational restrictions of hazardous terrain features in the geographical area where the cross-country flight will be flown;

(7) Procedures for operating the instruments and equipment installed in the aircraft to be flown, including recognition and use of the proper operational procedures and indications;

(8) Use of radios for navigation and two-way communications;

(9) Takeoff, approach, and landing procedures that include high-altitude, steep, and shallow takeoffs, approaches, and landings; and

(10) Control and maneuvering solely by reference to flight instruments, including straight and level flight, turns, descents, climbs, use of radio aids, and air traffic control (ATC) directives.

Discussion

The SVO-A aircraft are required to have a built-in flight planning application that creates a flight plan (including re-planning in the air), which calculates aircraft performance and obtains weather information.

"VFR" is removed from the use of radios item because SVO-A2 always operates on an IFR flight plan.

D.6 Part 61.105—Aeronautical knowledge – Private Pilot

Paragraphs (c) and (d) are added to 61.105. (61.105 (a) and (b) are included here for reference.)

(a) ***General.*** *A person who is applying for a private pilot certificate with an SVO-A1 or SVO-A2 rating must receive and log ground training from an authorized instructor or complete a home-study course on the aeronautical knowledge areas of paragraph (b) of this section that apply to the aircraft category and class6 rating sought.*

(b) ***Aeronautical knowledge areas****.*

(1) Applicable Federal Aviation Regulations of this chapter that relate to private pilot privileges, limitations, and flight operations;

(2) Accident reporting requirements of the National Transportation Safety Board;

(3) Use of the applicable portions of the "Aeronautical Information Manual" and FAA advisory circulars;

(4) Use of aeronautical charts for VFR navigation using pilotage, dead reckoning, and navigation systems;

(5) Radio communication procedures;

(6) Recognition of critical weather situations from the ground and in flight, wind shear avoidance, and the procurement and use of aeronautical weather reports and forecasts;

(7) Safe and efficient operation of aircraft, including collision avoidance, and recognition and avoidance of wake turbulence;

(8) Effects of density altitude on takeoff and climb performance;

(9) Weight and balance computations;

(10) Principles of aerodynamics, powerplants, and aircraft systems;

(11) Stall awareness, spin entry, spins, and spin recovery techniques for the airplane and glider category ratings;

(12) Aeronautical decision making and judgment; and

(13) Preflight action that includes—

(i) How to obtain information on runway lengths at airports of intended use, data on takeoff and landing distances, weather reports and forecasts, and fuel requirements; and

(ii) How to plan for alternatives if the planned flight cannot be completed or delays are encountered.

<u>Recommended changes</u>

Add subsections (c) and (d) to current §61.105:

(c) Applicants for a private pilot with SVO-A1 rating need to comply with (b) except (b)(6), (b)(8), (b)(9), (b)(11) and (b)(13), which are replaced with

(1) Recognition of critical weather situations from the ground and in flight, including wind shear avoidance.

(2) Using the flight planning application to determine takeoff and climb performance at high-density altitude.

(3) Using the weight and balance application to calculate weight and balance

(4) Using the flight planning application to

(i) determine runway lengths required for takeoff and landing,

(ii) runway length and width available at airports,

(iii) weather information appropriate for the flight including reports and forecasts,

(iv) energy requirements for the flight along with reserves, and

(v) alternates for unforeseen weather or aircraft emergencies.

(5) Using the flight planning application to re-plan the flight while airborne

(d) Applicants for a private pilot with SVO-A2 rating need to comply with (b) except (b)(4), (b)(5), (b)(6), (b)(8), (b)(9), (b)(10), (b)(11) and (b)(13), which are replaced with

(1) Using the flight planning application to create and file an IFR flight plan.

(2) Using the weight and balance application to calculate weight and balance.

(3) Using the flight planning application to replan the flight while airborne.

(4) Finding and coupling to the appropriate procedures.

(5) Federal Aviation Regulations of this chapter that apply to flight operations under IFR.

(6) Appropriate information that applies to flight operations under IFR in the "Aeronautical Information Manual."

(7) Safe and efficient operation of aircraft under instrument flight rules and conditions.

<u>Discussion</u>

<u>(c)—SVO-A1 knowledge requirements</u>

Section (b)(6) is replaced with (c)(1), which omits the requirement to obtain weather information because the flight planning application provides the required weather reports and forecasts.

Section (b)(8) is replaced with (c)(2) because the flight planning application that is a part of the aircraft makes all the takeoff and climb calculations automatically. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Section (b)(9) is replaced with (c)(3) because the weight and balance application that is a part of the aircraft computes weight and balance computations. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Section (b)(11) is deleted because the SVO-A1 aircraft cannot stall or spin.

Section (b)(13) is replaced with (c)(1) through (c)(3) because the flight planning application will collect the information listed in (b)(13). The pilot needs to know how to use this application but does not need to know how to obtain this information outside of the application.

<u>SVO-A2 knowledge requirements</u>

Section (b)(4) is deleted since all SVO-A2 flights will be on an IFR flight plan and will not use pilotage or dead reckoning.

Section (b)(5) is deleted because the SVO-A2 aircraft will have automated ATC communications.

Section (b)(6) is replaced with (d)(1), which leaves out the requirement to obtain weather information because the flight planning application provides the required weather reports and forecasts.

Section (b)(8) is replaced with (d)(1) because the flight planning application that is a part of the aircraft makes all the takeoff and climb calculations automatically. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Section (9) is replaced with (d)(2) because the weight and balance application that is a part of the aircraft computes weight and balance computations. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Section (b)(10) is deleted because knowledge of aerodynamics, powerplants and systems is not required of the pilot to avoid dangerous flight conditions or to deal with failures. The SVO-A2 aircraft has all the protections needed to prevent the aircraft from entering a dangerous flight condition and its powerplant and systems design is such that it will continue to operate normally (with a possible reduction in performance) after a failure (fail operational).

Section (b)(11) is deleted because the SVO-A2 aircraft cannot stall or spin.

Section (b)(13) is replaced with (c)(3) and (c)(4) because the flight planning application will collect the information listed in (b)(13). The pilot needs to know how to use this application but does not need to know how to obtain this information outside of the application.

Notice that the private pilot SVO-A2 knowledge requirements are similar to those listed for the SVO-A1 IR. This is because all SVO-A2 flights are done under Instrument Flight Rules (including training flights). Therefore, there is no such thing as a VFR only SVO-A2 pilot.

D.7 Part 61.107—Flight proficiency: Private pilot

Part 61.107 (b)(5) the powered-lift category rating is used as a guide. Paragraphs (b)(7) and (b)(8) are added for SVO-A1 and SVO-A2..

(10) Stall entries from various flight attitudes and power combinations with recovery initiated at the first indication of a stall, and recovery from a full stall;

Recommended changes:

Another difference is that (b)(8)(x) Coupling to an instrument approach is added for SVO-A2.

(b)(7) For an SVO-A category with SVO-A1 class rating:

(i) Preflight preparation;

(ii) Preflight procedures;

(iii) Airport and heliport operations;

(iv) Hovering maneuvers;

(v) Takeoffs, landings, and go-arounds;

(vi) Performance maneuvers;

(vii) Ground reference maneuvers;

(viii) Navigation;

(ix) Basic instrument maneuvers;

(x) Emergency operations;

(xi) Night operations, except as provided in §61.110 of this part; and

(xii) Postflight procedures.

(b)(8) For an SVO-A category with SVO-A2 class rating:

(i) Preflight preparation;

(ii) Preflight procedures;

(iii) Airport and heliport operations;

(iv) Hovering maneuvers;

(v) Go-arounds;

(vi) Performance maneuvers;

(vii) Ground reference maneuvers;

(viii) Navigation;

(ix) Basic instrument maneuvers;

(x) Coupling to an instrument approach

(xi) Emergency operations;

(xii) Night operations, except as provided in §61.110 of this part; and

(xiii) Postflight procedures.

Discussion

These requirements are a combination of airplane single engine and helicopter. Stalls and slow flight are removed since SVO-A aircraft are not allowed to stall. Takeoff and landing are removed from SVO-A2 requirements because takeoffs and landings are automatic in SVO-A2 aircraft. Coupling to an instrument approach is included in SVO-A2 since an SVO-A2 rating includes the equivalent of an IR.

D.8 Part 61.109—Aeronautical experience: Private pilot

Paragraphs (m) and (n) are added to §61.109

(m) For an SVO-A1 rating. Except as provided in paragraph (k) of this section, a person who applies for a private pilot certificate with an SVO-A1 category rating must log flight training in the areas of operation listed in §61.107(b)(5) of this part, and the training must include at least—

(1) 3 hours of cross-country flight training in an SVO-A1;

(2) Except as provided in §61.110 of this part, 3 hours of night flight training in an SVO-A1 that includes—

(i) One cross-country flight of over 100 nautical miles total distance; and

(ii) 10 takeoffs and 10 landings to a full stop (with each landing involving a flight in the traffic pattern) at an airport.

(3) 3 hours of flight training in a SVO-A1 on the control and maneuvering of an SVO-A1 by reference to instruments, including straight and level flight, constant airspeed climbs and descents, turns to a heading, recovery from unusual flight attitudes, radio communications, and the use of navigation systems/facilities and radar services appropriate to instrument flight;

(4) 3 hours of flight training with an authorized instructor in a SVO-A1 in preparation for the practical test, which must have been performed within the preceding 2 calendar months from the month of the test; and

(5) solo flight time in an airplane or powered-lift, rotorcraft, or SVO-A1 consisting of at least—

(i) 5 hours cross-country time;

(ii) One solo cross-country flight of 150 nautical miles total distance, with full-stop landings at three points, and one segment of the flight consisting of a straight-line distance of more than 50 nautical miles between the takeoff and landing locations; and

(iii) Three takeoffs and three landings to a full stop (with each landing involving a flight in the traffic pattern) at an airport with an operating control tower.

(n) For an SVO-A2 rating. Except as provided in paragraph (k) of this section, a person who applies for a private pilot certificate with an SVO-A2 category rating must log flight training in the areas of operation listed in §61.107(b)(5) of this part, and the training must include at least—

(1) 3 hours of cross-country flight training in an SVO-A2;

(2) Except as provided in §61.110 of this part, 3 hours of night flight training in an SVO-A2 that includes—

(i) One cross-country flight of over 100 nautical miles total distance; and

(ii) 10 takeoffs and 10 landings to a full stop (with each landing involving a flight in the traffic pattern) at an airport.

(3) 3 hours of flight training in an SVO-A2 on the control and maneuvering of an SVO-A2 by reference to instruments, including straight and level flight, constant airspeed climbs and descents, turns to a heading, recovery from unusual flight attitudes, ATC communications, and the use of navigation systems/facilities and radar services appropriate to instrument flight;

(4) 3 hours of flight training with an authorized instructor in an SVO-A2 in preparation for the practical test, which must have been performed within the preceding 2 calendar months from the month of the test; and

(5) solo flight time in an airplane or powered-lift, rotorcraft, or SVO-A1 or SVO-A2 consisting of at least—

(i) 5 hours cross-country time;

(ii) One solo cross-country flight of 150 nautical miles total distance, with full-stop landings at three points, and one segment of the flight consisting of a straight-line distance of more than 50 nautical miles between the takeoff and landing locations; and

(iii) Three takeoffs and three landings to a full stop (with each landing involving a flight in the traffic pattern) at an airport with an operating control tower.

For an SVO-A2 rating

Same as (e), powered-lift, except that the 40 hours of total flight time, 20 hours of flight training, and 10 hours of solo in (e) are eliminated, and the 10-hour requirement of (e)(5) is eliminated.

Discussion

Paragraphs (n) and (m) are the same as (e), powered-lift, except that the 40 hours of total flight time, 20 hours of flight training, and 10 hours of solo in (e) are eliminated, and the 10-hour requirement of (e)(5) is eliminated.

This reduces the training burden of flight training as listed in (e)(1) through (e)(4). All the required flight training time for individual skills including cross-country flying is adequate for the private pilot rating in both the SVO-A1 and SVO-A2 aircraft since these aircraft are simpler to operate than a legacy airplane or powered-lift vehicle. For SVO-A2, the instruction requirement also includes training to couple to an instrument approach. This is possible because SVO-A2 aircraft are simpler to operate than SVO-A1 aircraft.

The minimum time requirements for general experience (40 hours), flight training (20 hours), and solo hours (10), in the airplane, helicopter, and powered-lift categories are needed to ensure the applicant has been exposed to aspects of aeronautical decision making that are not explicitly covered in the structured training. The time requirements that are eliminated are justified by the fact that the SVO-A aircraft have significant decision-making aids built into them. The legacy requirements assumed that the pilot would navigate by pilotage (comparing landmarks to symbology on a map) and dead reckoning (flying a heading for a given amount of time). Calculating ground speed by timing the aircraft's progress along the ground was required to verify there would be enough fuel to complete the leg. The SVO-A aircraft are required to have moving maps with ground speed readouts. Thus, navigation practice is not required. The minimum time requirements for training prescribed in the SVO-A sections combined with these aids allows the elimination of this time. The specified training times are minimums. The applicant may still take longer than the minimum time to acquire the skill and knowledge. Despite the fact that there are minimum hour requirements for specific areas, the general intent is that the minimums are performance based and not time based. Today, by far, most applicants have many more hours than the minimum required. This indicates that the system is generally operating as a performance-based system already and the time requirements are not relevant.

Table D-2 shows a comparison of the proposed minimum time requirements for a private pilot license for legacy, SVO-A1, and SVO-A2 aircraft.

Table D-2. Comparison of the proposed minimum time (in hours) for the private pilot

Minimum Aeronautical Experience for a Private Pilot License			
Task	**Powered Lift**	**SVO-A1**	**SVO-A2**
Flight time	40	0	0
Flight training	20	0	0
Solo	10	5	5
Cross county instruction	3	3	3
Night instruction	3	3	3
Instrument instruction	3	3	3

D.9 Part 61.125—Aeronautical knowledge: Commercial pilot

Paragraphs (c) and (d) are added to §61.125. (61.125 (a) and (b) are included here for reference.)

(a) *General.* A person who applies for a commercial pilot certificate must receive and log ground training from an authorized instructor, or complete a home-study course, on the aeronautical knowledge areas of paragraph (b) of this section that apply to the aircraft category and class rating sought.

(b) *Aeronautical knowledge areas.*

(1) Applicable Federal Aviation Regulations of this chapter that relate to commercial pilot privileges, limitations, and flight operations;

(2) Accident reporting requirements of the National Transportation Safety Board;

(3) Basic aerodynamics and the principles of flight;

(4) Meteorology to include recognition of critical weather situations, windshear recognition and avoidance, and the use of aeronautical weather reports and forecasts;

(5) Safe and efficient operation of aircraft;

(6) Weight and balance computations;

(7) Use of performance charts;

(8) Significance and effects of exceeding aircraft performance limitations;

(9) Use of aeronautical charts and a magnetic compass for pilotage and dead reckoning;

(10) Use of air navigation facilities;

(11) Aeronautical decision making and judgment;

(12) Principles and functions of aircraft systems;

(13) Maneuvers, procedures, and emergency operations appropriate to the aircraft;

(14) Night and high-altitude operations;

(15) Procedures for operating within the National Airspace System; and

(16) Procedures for flight and ground training for lighter-than-air ratings.

(c) Applicants for a commercial pilot with SVO-A1 rating must comply with (b) except (b)(4), (B)(6), (b)(7), (b)(9), and (b)(16), which are replaced with

(1) Recognition of critical weather situations from the ground and in flight, including wind shear avoidance.

(2) Using the weight and balance application to calculate weight and balance

(3) Using the flight planning application to determine takeoff and climb performance at high density altitude.

(4) Using the flight planning application to

(i) determine runway lengths required for takeoff and landing

(ii) determine runway length and width available at airports

(iii) obtain weather information appropriate for the flight including reports and forecasts

(iv) determine energy requirements for the flight along with reserves

(v) determine alternates for unforeseen weather or aircraft emergencies

(5) Using the flight planning application to re-plan the flight while airborne

(d) Applicants for a commercial pilot with SVO-A2 rating must comply with (b) except (b)(4), (b)(6), (b)(7), (b)(8), (b)(9), (b)(10), and (b)(16), which are replaced with

(1) Using the flight planning application to create and file an IFR flight plan

(2) Using the weight and balance application to calculate weight and balance

(3) Using the flight planning application to replan the flight while airborne

(4) Finding and coupling to the appropriate procedures.

(5) Federal Aviation Regulations of this chapter that apply to flight operations under IFR;

(6) Appropriate information that applies to flight operations under IFR in the "Aeronautical Information Manual;"

(7) Safe and efficient operation of aircraft under instrument flight rules and conditions;

Discussion

(c)—SVO-A1 knowledge requirements

Paragraph (b)(4) is replaced with (c)(1), which leaves out the requirement to obtain weather information because the flight planning application provides the required weather reports and forecasts.

Paragraph (b)(6) is replaced with (c)(2) because the weight and balance application that is a part of the aircraft computes weight and balance. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Paragraph (b)(7) is replaced with (c)(3) because the flight planning application that is a part of the aircraft makes all the takeoff and climb calculations automatically. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Paragraph (b)(9) is deleted because the SVO-A1 aircraft navigate using the flight plan and moving map.

Paragraph (b)(16) refers to lighter-than-air vehicles and does not apply.

(d)—SVO-A2 knowledge requirements

Paragraph (b)(4) is deleted since all SVO-A2 flights will be on an IFR flight plan and will not use pilotage or dead reckoning.

Paragraph (b)(6) is replaced with (d)(2) because the weight and balance application that is a part of the aircraft computes weight and balance. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Paragraph (b)(7) is replaced with (d)(3) because the flight planning application that is a part of the aircraft makes all of the takeoff and climb calculations automatically. The pilot needs to know how to use this application but does not need to know how to make these calculations.

Paragraph (b)(8) is eliminated because the SVO-A2 aircraft cannot exceed its performance limitations.

Paragraph (b)(9) is deleted because the SVO-A2 aircraft navigate using the flight plan and moving map.

Paragraph (b)(10) is deleted because the SVO-A2 aircraft uses blended navigation sensors automatically and the pilot need not know what sources are being used.

Paragraph (b)(16) refers to lighter than air vehicles and does not apply.

D.10 Part 61.127—Flight proficiency – Commercial pilot

Paragraphs (b)(9) and (b)(10) are added to §61.127.

(b)(9) For SVO-A category with SVO-A1 class rating:

(i) Preflight preparation;

(ii) Preflight procedures;

(iii) Airport and heliport operations;

(iv) Hovering maneuvers;

(v) Takeoffs, landings, and go-arounds;

(vi) Performance maneuvers;

(vii) Ground reference maneuvers;

(viii) Navigation;

(ix) Emergency operations;

(x) High-altitude operations;

(xi) Special operations; and

(xii) Postflight procedures.

(b)(10) For SVO-A category with SVO-A2 class rating:

(i) Preflight preparation;

(ii) Preflight procedures;

(iii) Airport and heliport operations;

(iv) Hovering maneuvers;

(v) Takeoff and landing at locations not in the database or flight plan;

(vi) Performance maneuvers;

(vii) Ground reference maneuvers;

(viii) Navigation;

(ix) Instrument maneuvers;

(x) Coupling to instrument procedures;

(ix) Emergency operations;

(xi) High-altitude operations;

(xii) Special operations; and

(xiii) Postflight procedures.

<u>Discussion</u>

These lists are a combination of the single engine airplane and helicopter lists. Stalls and slow flight are left out since SVO-A aircraft cannot stall. Takeoffs and landings in SVO-A2 aircraft are automatic for normal operations that start and stop at locations in the database. However, a manual takeoff or landing is made when the location is not in the database. This is the purpose for item (v). Coupling to published procedures is included in SVO-A2 since the basic SVO-A2 rating includes the equivalent of an IR.

D.11 Part 61.129—Aeronautical experience: Commercial pilot

Paragraph (k) and (l) are added to 61.129.

<u>(k) For an SVO-A1 rating</u>

Except as provided in paragraph (i) of this section, a person who applies for a commercial pilot certificate with an SVO-A1 rating must log at least 125 hours of flight time as a pilot that consists of at least:

(1) 100 hours in powered aircraft.

(2) 50 hours of pilot-in-command flight time, which includes at least—

(i) 30 hours in an SVO-A1 aircraft; and

(ii) 30 hours in cross-country flight.

(3) 20 hours of training on the areas of operation listed in §61.127(b)(9) of this part that includes at least—

(i) 10 hours of instrument training using a view-limiting device including attitude instrument flying, partial panel skills, recovery from unusual flight attitudes, and intercepting and tracking navigational systems. Five hours of the 10 hours required on instrument training must be in an SVO-A1 aircraft;

(ii) One 2-hour cross country flight in an SVO-A1 aircraft in daytime conditions that consists of a total straight-line distance of more than 100 nautical miles from the original point of departure;

(iii) One 2-hour cross country flight in an SVO-A1 aircraft in nighttime conditions that consists of a total straight-line distance of more than 100 nautical miles from the original point of departure; and

(iv) 3 hours in an SVO-A1 aircraft with an authorized instructor in preparation for the practical test within the preceding 2 calendar months from the month of the test.

(4) Ten hours of solo flight time in an SVO-A1 aircraft or 10 hours of flight time performing the duties of pilot in command in a SVO-A1 aircraft with an authorized

instructor on board (either of which may be credited towards the flight time requirement under paragraph (e)(2) of this section, on the areas of operation listed in §61.127(b)(9) that includes—

(i) One cross-country flight of not less than 300 nautical miles total distance with landings at a minimum of three points, one of which is a straight-line distance of at least 250 nautical miles from the original departure point. However, if this requirement is being met in Hawaii the longest segment need only have a straight-line distance of at least 150 nautical miles; and

(ii) 5 hours in night VFR conditions with 10 takeoffs and 10 landings (with each landing involving a flight in the traffic pattern) at an airport with an operating control tower.

(l) For an SVO-A2 rating

Except as provided in paragraph (i) of this section, a person who applies for a commercial pilot certificate with an SVO-A2 rating must log at least 70 hours of flight time as a pilot that consists of at least:

(1) 60 hours in powered aircraft.

(2) 30 hours of pilot-in-command flight time, which includes at least—

(i) 20 hours in an SVO-A2 aircraft; and

(ii) 20 hours in cross-country flight.

(3) 10 hours of training on the areas of operation listed in §61.127(b)(9) of this part that includes at least—

(i) N/A

(ii) One 2-hour cross country flight in an SVO-A2 aircraft in daytime conditions that consists of a total straight-line distance of more than 100 nautical miles from the original point of departure;

(iii) One 2-hour cross country flight in an SVO-A2 aircraft in nighttime conditions that consists of a total straight-line distance of more than 100 nautical miles from the original point of departure; and

(iv) 3 hours in an SVO-A2 aircraft with an authorized instructor in preparation for the practical test within the preceding 2 calendar months from the month of the test.

(4) Ten hours of solo flight time in an SVO-A2 aircraft or 10 hours of flight time performing the duties of pilot in command in a SVO-A2 aircraft with an authorized instructor on board (either of which may be credited towards the flight time requirement under paragraph (e)(2) of this section, on the areas of operation listed in §61.127(b)(9) that includes—

(i) One cross-country flight of not less than 300 nautical miles total distance with landings at a minimum of three points, one of which is a straight-line distance of at least 250 nautical miles from the original departure point. However, if this requirement is being met in Hawaii the longest segment need only have a straight-line distance of at least 150 nautical miles; and

(ii) 5 hours in night conditions with 10 takeoffs and 10 landings (with each landing involving a flight in the traffic pattern) at an airport with an operating control tower.

Discussion

The powered-lift section (e) was used as a guide for the SVO-A sections. The SVO-A1 and SVO-A2 requirements are the same as those for powered lift except that the 50 hours in (1) is eliminated. All required cross-country time and instructional time for individual skills is considered adequate for the commercial pilot rating in both the SVO-A1 and SVO-A2 aircraft since these aircraft are simpler to operate than a typical airplane or powered-lift vehicle.

For SVO-A2, the VFR requirement of (4)(ii) is deleted since all SVO-A2 flights are done using an IFR flight plan and there is no such thing as a VFR only SVO-A2 pilot.

Since the SVO-A aircraft are easier to operate, they do not require as much experience as legacy aircraft.

Table D-3 shows a comparison of the proposed minimum time requirements for a commercial pilot license for legacy, SVO-A1, and SVO-A2 aircraft.

Table D-3. Comparison of the proposed minimum time (in hours) requirements for a commercial pilot license

Minimum aeronautical experience for a commercial license			
Task	**Powered Lift**	**SVO-A1**	**SVO-A2**
Flight time	250	125	70
PIC	100	50	30
PIC in class	50	30	20
Cross country PIC	50	30	20
Cross country PIC in class	10	10	10
Instrument instruction	10	10	0
Cross country day in class	2	2	2
Cross country night in class	2	2	2
Solo in class	10	10	10
Solo night in class	5	5	5

D.12 Part 61.155—Aeronautical knowledge: Airline transport pilot

All of §61.155 applies to SVO-A1 and SVO-A2 Airline Transport Pilots (ATPs).

SVO-A1 and SVO-A2 aircraft have simplified control systems and automated flight planning applications that obtain weather information for a flight automatically. Therefore, it could be argued that obtaining National Weather Service and FAA weather information (§61.155(c)(4)(5)) is not required for the SVO-A1 and SVO-A2 pilot. However, at the ATP level, it is appropriate for the pilot to be able to use other resources in addition to the flight planning application.

SVO-A1 and SVO-A2 aircraft have an application that does performance calculations and may not have paper charts for performance calculations. In this case, the pilot may not be able to demonstrate the use of charts, graphs and formulas for aircraft loading and performance. But the ATP should have a good understanding of the effects of altitude, temperature, weight and other factors on aircraft performance. The ATP should also be able to explain the effect of center of gravity (CG) on aircraft handling characteristics and performance.

D.13 Part 61.157—Flight proficiency: ATP

The following are added to 61.157(a)

(vi) SVO-A category SVO-A1 class rating

(vii) SVO-A category SVO-A2 class rating

The following is added to 61.157(e)

(5) For an SVO-A category rating:

(i) Preflight preparation;

(ii) Preflight procedures;

(iii) Takeoff and departure phase;

(iv) In-flight maneuvers;

(v) Instrument procedures;

(vi) Landings and approaches to landings;

(vii) Normal and abnormal procedures;

(viii) Emergency procedures; and

(ix) Postflight procedures.

Discussion

Paragraph 61.157(a) lists the various categories and class ratings. The additions add SVO-A1 and SVO-A2 to this list.

Paragraph 61.157(e) lists the areas of operation that the pilot is to be tested on. Items (1) through (4) list the various categories and classes of ratings. Item (5) is added to include SVO-A in this list. For all items, the areas of operation listed as (i) through (ix) are identical. Therefore, the (i) though (ix) areas of operation for SVO-A are also identical to the areas of operation for items (1) though (4).

D.14 Part 61.164—Aeronautical experience: SVO-A category and class ratings – Airline transport pilot

The requirements of §61.159, Aeronautical experience: Airplane category rating, are used as the basis for a new §61.164 covering SVO-A. SVO-A is the category, like airplane is the category in §61.159, and SVO-A1 and SVO-A2 are classes like single-engine land and multi-engine land are classes in §61.159.

(a) Except as provided in paragraphs (b), (c), and (d) of this section, an applicant for an airline transport pilot certificate with an SVO-A category and class rating must have at least 750 hours of total time for SVO-A1 class and 400 for SVO-A2 as a pilot that includes at least:

(1) 250 hours of cross-country flight time for SVO-A1 and 125 hours for SVO-A2.

(2) 50 hours of night flight time for SVO-A1 and 25 hours for SVO-A2.

(3) N/A

(4) 75 hours of instrument flight time, in actual or simulated instrument conditions

(5) 125 hours of flight time in an SVO-A1 or 70 hours of flight time in an SVO-A2 as a pilot in command, or when serving as a required second in command flight crew member performing the duties of pilot in command while under the supervision of a pilot in command, or any combination thereof, which includes at least—

(i) 100 hours of cross-country flight time; and

(ii) 25 hours of night flight time.

Discussion

Paragraph 61.164 is a new regulation number to include the SVO-A category. Usually, powered lift is used as a guide for SVO-A regulations. But the powered-lift category (§61.163) does not have any classes, and the airplane category (§61.159) does. Since the SVO-A category has two classes (and may develop more as the category matures), the airplane category regulation was chosen as the guide. The powered-lift category requires significantly more hours in category than the airplane category does, but since the SVO-A aircraft's handling characteristics are highly augmented and more closely related to an airplane than a powered-lift aircraft, which is assumed to have helicopter-like handling characteristics when in hover, the experience requirements for an airplane were considered to be more appropriate.

Table D-4 shows a comparison of the proposed minimum time requirements for an ATP certificate for legacy, SVO-A1, and SVO-A2 aircraft.

Table D-4. Comparison of proposed minimum time requirements (in hours) for airline transport pilot

Minimum time for an ATP certificate			
Task	**Airplane**	**SVO-A1**	**SVO-A2**
Flight time	1500	750	400

Cross country	500	250	125
Night	100	50	25
Instrument	75	40	20
PIC in class	250	125	70
Cross country PIC in class	100	50	25
Night PIC in class	25	25	10

D.15 SVO-A Airman Certification Standards

It is the researchers' opinion that the pilot training and testing for both a manned aircraft and an unmanned aerial vehicle (UAV) are the same through private and IR. However, with the advent of advanced technology, the knowledge and skills are different for higher levels of automation. Because of this, the recommended Airman Certification Standards (ACS) are written as pilot-in-the-aircraft standards, with levels of automation as defined as SVO-A1 and SVO-A2 in Appendix A. There is a section at the end of the proposed ACS with a difference table for the UAV pilot. This allows for a compact and coherent ACS that covers both traditional pilots and UAV pilots in the same document and that also covers advanced automation levels.

The typical career progression for an airplane pilot is private, instrument, commercial, multi-engine (ME), and then ATP if needed. It is assumed that the SVO-A aircraft progression is the same. However, for the SVO-A aircraft a ME rating does not exist since it is assumed that propulsion and control are integrated, and the aircraft automatically does most of the tasks required of the pilot for engine failures. Also, the SVO-A2 aircraft always flies on an IFR flight plan and clearance, therefore an IR is an integral part of all SVO-A2 ratings.

Since SVO-A aircraft may have VTOL capability, airplane and vertical flight pilot requirements are appropriate. Since the airplane ACS are more recent than the helicopter and powered-lift practical test standards (PTS), the airplane ACS are used as a starting point with the helicopter add-on tables from the PTS used as a guide to ensure that nothing is left out. Use of the powered-lift standard would be appropriate if it existed, but it only exists for the IR.

Some SVO-A aircraft may not have VTOL capability. If such an aircraft is used for the practical test, then a restriction for conventional takeoff and landing (CTOL) only should be applied to the rating. The restriction can be lifted when the pilot takes the test in an aircraft that can accomplish the VTOL tasks (tasks from the helicopter addon tables).

This section is organized in the order that would normally be taken for SVO-A1 and SVO-A2 pilots:

Note that there is no IR for the SVO-A2 pilot. Since all SVO-A2 flights are conducted under IFR, the IR is integrated into the private pilot rating.

The current master list of questions for the written tests need not be changed. However, the written test for the SVO-A pilot will not contain questions that do not relate to SVO-A aircraft or operations (such as stalls, calculating fuel required for a flight, etc.)

D.16 Private pilot ACS for SVO-A1

Table D-5 and Table D-6 contain the task list for the Private Pilot SVO-A1 ACS. Table D-7 shows the tasks from the helicopter PTS that are required for a pilot adding a helicopter rating to a private pilot airplane rating.

Table D-5. SVO-A1 private pilot ACS from airplane private pilot ACS

Item from the airplane private pilot ACS	**Changes for the SVO-A1 private pilot ACS**
I. Preflight preparation A. Pilot qualifications B. Airworthiness requirements C. Weather information D. Cross-country flight planning E. National Airspace System F. Performance and limitations G. Operation of systems H. Human factors I. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	
II. Preflight procedures A. Preflight assessment B. Flight deck management C. Engine starting D. Taxiing (ASEL, AMEL) E. Taxiing and sailing (ASES, AMES) F. Before Takeoff Check	
III. Airport and seaplane base operations A. Communications, light signals, and runway lighting systems B. Traffic patterns	

Item from the airplane private pilot ACS	**Changes for the SVO-A1 private pilot ACS**
IV. Takeoffs, landings, and go-arounds A. Normal takeoff and climb B. Normal approach and landing C. Soft-field takeoff and climb (ASEL) D. Soft-field approach and landing (ASEL) E. Short-field takeoff and maximum performance climb (ASEL, AMEL) F. Short-field approach and landing (ASEL, AMEL) G. Confined area takeoff and maximum performance climb (ASES, AMES) H. Confined area approach and landing (ASES, AMES) I. Glassy water takeoff and climb (ASES, AMES) J. Glassy water approach and landing (ASES, AMES) K. Rough water takeoff and climb (ASES, AMES) L. Rough water approach and landing (ASES, AMES) M. Forward slip to a landing (ASEL, ASES) N. Go-around/rejected landing	
V. Performance and ground reference maneuvers A. Steep turns B. Ground reference maneuvers	
VI. Navigation A. Pilotage and dead reckoning B. Navigation systems and radar services C. Diversion D. Lost procedures	Item A is deleted.
VII. Slow flight and stalls A. Maneuvering during slow flight B. Power-off stalls C. Power-on stalls D. Spin awareness	Not applicable. The SVO-A aircraft cannot stall.
VIII. Basic instrument maneuvers A. Straight-and-level flight B. Constant airspeed climbs C. Constant airspeed descents D. Turns to headings E. Recovery from unusual flight attitudes F. Radio communications, navigation systems/facilities, and radar services	No change except that item E is done only by use of the level button.

Item from the airplane private pilot ACS	Changes for the SVO-A1 private pilot ACS
IX. Emergency operations A. Emergency descent B. Emergency approach and landing (simulated) (ASEL, ASES) C. Systems and equipment malfunctions D. Emergency equipment and survival gear E. Engine failure during takeoff before VMC (Simulated) (AMEL, AMES) F. Engine failure after liftoff (simulated) (AMEL, AMES) G. Approach and landing with an inoperative engine (simulated) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
X. Multiengine Operations A. Maneuvering with one engine inoperative (AMEL, AMES) B. VMC demonstration (AMEL, AMES) C. One Engine inoperative (simulated) (solely by reference to instruments) during straight-and-level flight and turns (AMEL, AMES) D. Instrument approach and landing with an inoperative engine (simulated) (solely by reference to instruments) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
XI. Night operations A. Night preparation	
XII. Postflight procedures A. After landing, parking and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

AMES = Airplane multi-engine sea
ASEL = Airplane single-engine land
ASES = Airplane single-engine sea
VMC = Visual meteorological conditions

Table D-6. SVO-A1 private pilot ACS from helicopter private pilot ACS

Item from the helicopter private pilot add-on PTS	**Changes for the SVO-A1 private pilot ACS**
I. Preflight preparation a. N/A b. N/A c. N/A d. N/A e. National Airspace System f. Performance and limitations g. Operation of systems h. N/A	Covered above by using an SVO-A1 aircraft
II. Preflight procedures a. Preflight inspection b. Cockpit management c. Engine starting and rotor engagement d. Before takeoff check	Covered above by using an SVO-A1 aircraft
III. Airport and heliport operations a. N/A b. Traffic patterns c. Airport/heliport runway, helipad, and taxiway signs, markings, and lighting	Covered above by using an SVO-A1 aircraft
IV. Hovering maneuvers a. Vertical takeoff and landing b. Slope operations c. Surface taxi d. Hover taxi e. Air taxi	This item is added to the SVO-A1 ACS.
V. Takeoffs, landings, and go-arounds a. Normal and crosswind takeoff and climb b. Normal and crosswind approach c. Maximum performance takeoff and climb d. Steep approach e. Rolling takeoff f. Confined area operation g. Pinnacle/platform operations h. Shallow approach and running/roll-on landing i. Go-around	This item is added to the SVO-A1 ACS.

Item from the helicopter private pilot add-on PTS	**Changes for the SVO-A1 private pilot ACS**
VI. Performance maneuvers a. Rapid deceleration b. Straight in autorotation c. 180 autorotation	Item A is added to the SVO-A1 ACS. Items B and C are covered in the emergency operation section.
VII. Navigation (N/A)	
VIII. Emergency operations a. Power failure at hover b. Power failure at altitude c. Systems and equipment malfunctions d. Settling with power e. Low rotor RPM recovery f. Antitorque system failure g. Dynamic rollover h. Ground resonance i. Low G conditions j. Emergency equipment and survival gear	Covered above by using an SVO-A1 aircraft
IX. Night operation (N/A)	
X. Post-flight procedures a. After landing and securing	Covered above by using an SVO-A1 aircraft

Table D-7. Helicopter private pilot add-on task list

Addition of a Rotorcraft/Helicopter rating to an existing Private Pilot Certificate									
Area of Operation	**Required TASKS are indicated by either the TASK letter(s) that apply(s) or an indication that all or none of the TASKS must be tested.**								
	PRIVATE PILOT RATING(S) HELD								
	ASEL	**ASES**	**AMEL**	**AMES**	**RG**	**NON-POWER GLIDER**	**POWER GLIDER**	**FREE BALLOON**	**AIRSHIP**
I	E, F, G	E, F, G	E, F, G	E, F, G	E, F, G	E, F, G	E, F, G	E, F, G	E, F, G
II	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
III	B, C	B, C	B, C	B, C	ALL	ALL	ALL	ALL	B, C
IV	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
V	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
VI	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
VII	NONE	NONE	NONE	NONE	B	B, C, D	B, C, D	B, C, D	NONE
VIII	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
IX	NONE	NONE	NONE	NONE	NONE	ALL	ALL	ALL	ALL
X	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL

RG = Rotorcraft-Gyroplane

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Addition of a Rotorcraft/Helicopter rating to an existing Private Pilot Certificate									
Area of Opera-tion	Required TASKS are indicated by either the TASK letter(s) that apply(s) or an indication that all or none of the TASKS must be tested.								
	PRIVATE PILOT RATING(S) HELD								
	ASEL	ASES	AMEL	AMES	RG	Non-Power Glider	Power Glider	Free Balloon	Airship
I	E,F,G	E,F,G	E,F,G	E,F,G	E,F,G	E,F,G,	E,F,G,	E,F,G,	E,F,G
II	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
III	B,C	B,C	B,C	B,C	ALL	ALL	ALL	ALL	B,C
IV	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
V	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
VI	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
VII	NONE	NONE	NONE	NONE	B	B,C,D	B,C,D	B,C,D	NONE
VIII	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
IX	NONE	NONE	NONE	NONE	NONE	ALL	ALL	ALL	ALL
X	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL

The first column (ASEL [airplane single-engine land]) of the add-on table from the private pilot helicopter PTS indicates what tasks from the PTS need to be performed in a helicopter if the applicant already has an ASEL rating.

D.18 Instrument rating ACS for SVO-A1

The proposed instrument SVO-A1 ACS uses the airplane ACS as a starting point. The following deletions and additions to the Airplane Instrument ACS are made for the SVO-A1 aircraft.

An SVO-A1 aircraft may have VTOL capability. Therefore, the airspace and operating rules appropriate for a helicopter must be included. The main differences between a helicopter and an airplane in this regard are VFR cloud clearances, special VFR, and approach visibility minima.

All other aspects of the helicopter IR are the same as an airplane except that the test is done in an aircraft with different controls and instrumentation. Since the SVO-A1 aircraft has airplane and VTOL controls, there is no need for additional tasks. Therefore, there is no need to consider the requirements for a helicopter add-on IR for the SVO-A1 pilot. However, if an SVO-A1 rating is obtained in an aircraft without VTOL capability, then this should be noted as a restriction on the rating and the pilot must take another test in an aircraft with VTOL capability to get the restriction removed (like a multi-engine rating with a centerline thrust restriction).

For all tasks, the use of SVO-A1 required equipment is expected (e.g., weather and flight planning application). The use of equipment that is not required (e.g., manual navigation radio-tuning capability) is not to be tested even if it is installed.

Table D-8 identifies a list of the tasks in the Airplane Instrument ACS and the changes required for the SVO-A1 Instrument ACS.

Table D-8. SVO-A1 instrument ACS from airplane instrument ACS

Item from the airplane instrument ACS	**Changes for the SVO-A1 instrument ACS**
I. Preflight preparation A. Pilot qualifications B. Weather information C. Cross-country flight planning	Items B and C are to be conducted exclusively using the required flight planning application.
II. Preflight procedures A. Airplane systems related to IFR operations B. Airplane flight instruments and navigation equipment C. Instrument flight deck check	
III. Air traffic control clearances and procedures A. Compliance with air traffic control clearances B. Holding procedures	
IV. Flight by reference to instruments A. Instrument flight B. Recovery from unusual flight attitudes	Unusual attitude recovery is limited to recognition of an unusual attitude and pressing the level button.
V. Navigation systems A. Intercepting and tracking navigational systems and arcs	This is replaced by use of the required navigator and AP to program appropriate flight paths and couple to them.

Item from the airplane instrument ACS	Changes for the SVO-A1 instrument ACS
B. Departure, en route, and arrival operations	
VI. Instrument approach procedures A. Non-precision approach B. Precision approach C. Missed approach D. Circling approach E. Landing from an instrument approach	All instrument approaches will be coupled to the AP. A and B are limited to selecting the appropriate approach and coupling to it. C, D, and E shall be conducted by hand flying from the missed approach point.
VII. Emergency operations A. Loss of communication B. One engine inoperative (simulated) during straight-and-level flight and turns (AMEL, AMES) C. Instrument approach and landing with an inoperative engine (Simulated) (AMEL, AMES) D. Approach with loss of primary flight instrument indicators	This section is replaced by procedures appropriate for failures that can realistically occur on the SVO-A1 aircraft being used.
VIII. Postflight procedures A. Checking instruments and equipment	

AMES = Airplane multi-engine sea
ASEL = Airplane single-engine land
ASES = Airplane single-engine sea

D.19 Commercial Pilot airman certification standards for SVO-A1

Table D-9 and Table D-10 contain the task list for the SVO-A1 Commercial Pilot ACS. Table D-11 shows the tasks from the helicopter PTS that are required for a pilot adding a helicopter rating to a commercial pilot airplane rating.

Table D-9. SVO-A1 commercial pilot ACS from airplane commercial pilot ACS

Item from the Airplane commercial pilot ACS	**Changes for the SVO-A1 commercial pilot ACS**
I. Preflight preparation A. Pilot qualifications B. Airworthiness requirements C. Weather information D. Cross-country flight planning E. National Airspace System F. Performance and limitations G. Operation of systems H. Human factors I. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	
II. Preflight procedures A. Preflight assessment B. Flight deck management C. Engine starting D. Taxiing (ASEL, AMEL) E. Taxiing and sailing (ASES, AMES) F. Before takeoff check	
III. Airport and seaplane base operations A. Communications, light signals, and runway lighting systems B. Traffic patterns	

Item from the Airplane commercial pilot ACS	Changes for the SVO-A1 commercial pilot ACS
IV. Takeoffs, landings, and go-arounds A. Normal takeoff and climb B. Normal approach and landing C. Soft-field takeoff and climb (ASEL) D. Soft-field approach and landing (ASEL) E. Short-field takeoff and maximum performance climb (ASEL, AMEL) F. Short-field approach and landing (ASEL, AMEL) G. Confined area takeoff and maximum performance climb (ASES, AMES) H. Confined area approach and landing (ASES, AMES) I. Glassy water takeoff and climb (ASES, AMES) J. Glassy water approach and landing (ASES, AMES) K. Rough water takeoff and climb (ASES, AMES) L. Rough water approach and landing (ASES, AMES) M. Power-off 180° accuracy approach and landing (ASEL, ASES) N. Go-around/rejected landing	Item M does not apply.
V. Performance and ground reference maneuvers A. Steep turns B. Steep spiral (ASEL, ASES) C. Chandelles (ASEL, ASES) D. Lazy eights (ASEL, ASES) E. Eights on pylons (ASEL, ASES)	
VI. Navigation A. Pilotage and dead reckoning B. Navigation systems and radar services C. Diversion D. Lost procedures	Item A is deleted.
VII. Slow flight and stalls A. Maneuvering during slow flight B. Power-off stalls C. Power-on stalls D. Accelerated stalls E. Spin awareness	Not applicable. The SVO-A aircraft cannot stall.

Item from the Airplane commercial pilot ACS	Changes for the SVO-A1 commercial pilot ACS
VIII. High-altitude operations A. Supplemental oxygen B. Pressurization	
IX. Emergency operations A. Emergency descent B. Emergency approach and landing (Simulated) (ASEL, ASES) C. Systems and equipment malfunctions D. Emergency equipment and survival gear E. Engine failure during takeoff before VMC (simulated) (AMEL, AMES) F. Engine failure after liftoff (simulated) (AMEL, AMES) G. Approach and landing with an inoperative engine (simulated) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
X. Multiengine operations A. Maneuvering with one engine inoperative (AMEL, AMES) B. VMC demonstration (AMEL, AMES) C. One engine inoperative (simulated) (solely by reference to instruments) During straight-and-level flight and turns (AMEL, AMES) D. Instrument approach and landing with an inoperative engine (simulated) (solely by reference to instruments) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
I. Postflight Procedures A. After landing, parking and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

Table D-10. SVO-A1 commercial pilot ACS from helicopter commercial pilot ACS

Item from the helicopter commercial pilot add-On PTS	**Changes for the SVO-A1 commercial pilot ACS**
I. Preflight preparation Task A: N/A Task B: N/A Task C: N/A Task D: N/A Task E: N/A Task F: Performance and limitations Task G: Operation of systems Task H: N/A Task I: N/A Task J: N/A	Covered above by using an SVO-A1 aircraft
II. Preflight Procedures Task A: Preflight inspection Task B: Cockpit management Task C: Engine starting and rotor engagement Task D: Runway incursion avoidance Task E: Before takeoff check	Covered above by using an SVO-A1 aircraft
III. Airport and Heliport Operations Task A: N/A Task B: Traffic patterns Task C: Airport/heliport runway, helipad, and taxiway signs, markings, and lighting	Covered above by using an SVO-A1 aircraft
IV. Hovering Maneuvers Task A: Vertical takeoff and landing Task B: Slope operations Task C: Surface taxi Task D: Hover taxi Task E: Air taxi	This item is added to the SVO-A1 ACS.

Item from the helicopter commercial pilot add-On PTS	**Changes for the SVO-A1 commercial pilot ACS**
V. Takeoffs, landings, and go-arounds Task A: Normal and crosswind takeoff and climb Task B: Normal and crosswind approach Task C: Maximum performance takeoff and climb Task D: Steep approach Task E: Rolling takeoff Task F: Shallow approach and running/roll-on landing Task G: Go-around	This item is added to the SVO-A1 ACS.
VI. Performance maneuvers Task A: Rapid deceleration Task B: Straight in autorotation Task C: 180° autorotation Task D: Approach and landing with simulated powerplant failure – multiengine helicopter	Item A is added to the SVO-A1 ACS. Items B, C, and D are covered in the emergency operation section.
VII. Navigation (N/A)	
VIII. Emergency operations Task A: Power failure at a hover Task B: Power failure at altitude Task C: Systems and equipment malfunctions Task D: Settling-with-power Task E: Low rotor RPM recovery Task F: Dynamic rollover Task G: Ground resonance Task H: Low G conditions Task I: Emergency equipment and survival gear	Covered above by using an SVO-A1 aircraft
IX. Special Operations Task A: Confined area operation Task B: Pinnacle/platform operations	This item is added to the SVO-A1 ACS.
X. Postflight procedures Task: After landing and securing	Covered above by using an SVO-A1 aircraft

Table D-11. Helicopter commercial pilot add-on task list

Addition of a rotorcraft–Helicopter rating to an existing commercial pilot certificate									
Required Tasks are indicated by either the Task letter(s) that apply(s) or an indication that all or none of the Tasks must be tested based on the notes in each Area of Operation.									
Areas of Operation	**Commercial pilot rating(s) held**								
	ASEL	**ASES**	**AMEL**	**AMES**	**RG**	**Non-power glider**	**Power glider**	**Free balloon**	**Airship**
I	F, G	F, G	F, G	F, G	F, G	F, G, I, J	F, G, I, J	F, G, I, J	F, G
II	All	All	All	All	All	All	All	All	All
III	B, C	B, C	B, C	B, C	All	All	All	All	B, C
IV	All	All	All	All	All	All	All	All	All
V	All	All	All	All	All	All	All	All	All
VI	All	All	All	All	All	All	All	All	All
VII	None	None	None	None	B	B, C, D	B, C, D	B, C, D	None
VIII	All	All	All	All	All	All	All	All	All
IX	All	All	All	All	All	All	All	All	All
X	All	All	All	All	All	All	All	All	All

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D.20 Airline transport pilot ACS for SVO-A1

Table D-12 and Table D-13 contain the task list for the SVO-A1 ATP ACS. Unlike private, instrument, and commercial ratings, there is no task list for an add-on helicopter rating. Thus, the entire ATP helicopter task list is included. However, there is nothing in the helicopter ATP PTS that is not in the airplane ATP ACS.

Table D-12. SVO-A1 airline transport pilot ACS from airplane airline transport pilot ACS

Item from the airplane ATP ACS	Changes for the SVO-A1 ATP ACS
I. Preflight preparation A. Operation of systems B. Performance and limitations C. Weather information (ATP) D. High-altitude aerodynamics (ATP) (AMEL, AMES) E. Air carrier operations (ATP) (AMEL, AMES) F. Human factors (ATP) G. The Code of Federal Regulations (ATP) H. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	
II. Preflight procedures A. Preflight assessment B. Powerplant start C. Taxiing (ASEL, AMEL) D. Taxiing and sailing (ASES, AMES) E. Before takeoff checks	

Item from the airplane ATP ACS	Changes for the SVO-A1 ATP ACS
III. Takeoffs and landings A. Normal takeoff and climb B. Normal approach and landing C. Glassy water takeoff and climb (ASES, AMES) D. Glassy water approach and landing (ASES, AMES) E. Rough water takeoff and climb (ASES, AMES) F. Rough water approach and landing (ASES, AMES) G. Confined-area takeoff and maximum performance climb (ASES, AMES) H. Confined-area approach and landing (ASES, AMES) I. Rejected takeoff J. Go-around/rejected landing	
IV. Inflight maneuvers A. Steep turns B. Recovery from unusual flight attitudes C. Specific flight characteristics	Unusual attitude recovery is achieved using the level button.
V. Stall prevention A. Partial flap configuration stall prevention B. Clean configuration stall prevention C. Landing configuration stall prevention	Not applicable. The SVO-A aircraft cannot stall.
VI. Instrument procedures A. Instrument takeoff B. Departure procedures C. Arrival procedures D. Non-precision approaches E. Precision approaches F. Landing from a precision approach G. Circling approach H. Landing from a circling approach I. Missed approaches J. Holding procedures	All published procedures are conducted by selecting the procedure in the navigator and coupling to the AP. Holds are done by programming them into the navigator and coupling to the AP.

Item from the airplane ATP ACS	**Changes for the SVO-A1 ATP ACS**
VII. Emergency operations A. Emergency procedures B. Powerplant failure during takeoff C. Powerplant failure (Simulated) (ASEL, ASES) D. Inflight powerplant failure and restart (AMEL, AMES) E. Approach and landing with a powerplant failure (simulated) (AMEL, AMES) F. Precision approach (manually flown) with a Powerplant failure (Simulated) (AMEL, AMES) G. Landing from a no-flap or a nonstandard flap approach	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures. Abnormal procedures will be conducted as appropriate for the aircraft.
VIII. Postflight procedures A. After landing, parking, and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

AMES = Airplane multi-engine sea
ASEL = Airplane single-engine land
ASES = Airplane single-engine sea

Table D-13. SVO-A1 airline transport pilot ACS from helicopter airline transport pilot ACS

Item from the Helicopter ATP Add-On PTS	Changes for the SVO-A1 ATP ACS
I. Preflight preparation A. Equipment examination B. Performance and limitations	Covered above by using an SVO-A1 aircraft
II. Preflight procedures A. Preflight inspection B. Powerplant start C. Taxiing D. Pre-takeoff checks	Covered above by using an SVO-A1 aircraft
III. Takeoff and departure phase A. Normal and crosswind takeoff B. Instrument takeoff C. Powerplant failure during takeoff D. Rejected takeoff E. Instrument departure	Covered above by using an SVO-A1 aircraft
IV. Inflight maneuvers A. Steep turns B. Powerplant failure — multi-engine helicopter C. Powerplant Failure — single-engine helicopter D. Recovery from unusual attitudes E. Settling-with-power	Covered above by using an SVO-A1 aircraft
V. Instrument procedures A. Instrument arrival B. Holding C. Precision instrument approaches D. Non-precision instrument approaches E. Missed approach	Covered above by using an SVO-A1 aircraft
VI. Landings and approaches to landings A. Normal and crosswind approaches and landings B. Approach and landing with simulated C. Powerplant failure—multi-engine helicopter D. Rejected landing	Covered above by using an SVO-A1 aircraft
VII. Normal and abnormal procedures	Covered above by using an SVO-A1 aircraft
VIII. Emergency procedures	Covered above by using an SVO-A1 aircraft

Item from the Helicopter ATP Add-On PTS	Changes for the SVO-A1 ATP ACS
IX. Postflight procedures A. After-landing procedures B. Parking and securing	Covered above by using an SVO-A1 aircraft

D.21 Private pilot ACS for SVO-A2

SVO-A2 aircraft are always flown on an IFR flight plan and clearance. Therefore, an IR is built into the SVO-A2 Private Pilot license. The airplane private pilot ACS, helicopter private pilot add-on PTS and airplane instrument ACS are combined to create the SVO-A2 Private Pilot ACS. Table D-14, Table D-15, and Table D-16 contain the task list for the Private Pilot SVO-A2 ACS.

Table D-14. SVO-A2 private pilot ACS from the airplane private pilot ACS

Item from the Airplane Private Pilot ACS	Changes for the SVO-A2 Private Pilot ACS
I. Preflight preparation A. Pilot qualifications B. Airworthiness requirements C. Weather information D. Cross-country flight planning E. National airspace F. Performance and limitations G. Operation of systems H. Human factors I. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	Items C through I are eliminated. The required built-in flight planning application collects weather information and creates an appropriate flight plan considering airspace restrictions and aircraft performance capabilities. The envelope protection system protects the flight envelope as well as system limits.
II. Preflight procedures A. Preflight assessment B. Flight deck management C. Engine starting D. Taxiing (ASEL, AMEL) E. Taxiing and sailing (ASES, AMES) F. Before takeoff check	
III. Airport and seaplane base operations A. Communications, light signals, and Runway Lighting Systems B. Traffic patterns	

Item from the Airplane Private Pilot ACS	**Changes for the SVO-A2 Private Pilot ACS**
IV. Takeoffs, landings, and go-arounds A. Normal takeoff and climb B. Normal approach and landing C. Soft-field takeoff and climb (ASEL) D. Soft-field approach and landing (ASEL) E. Short-field takeoff and maximum performance climb (ASEL, AMEL) F. Short-field approach and landing (ASEL, AMEL) G. Confined area takeoff and maximum performance climb (ASES, AMES) H. Confined area approach and landing (ASES, AMES) I. Glassy water takeoff and climb (ASES, AMES) J. Glassy water approach and landing (ASES, AMES) K. Rough water takeoff and climb (ASES, AMES) L. Rough water approach and landing (ASES, AMES) M. Forward Slip to a Landing (ASEL, ASES) N. Go-Around/Rejected Landing	Item M does not apply.
V. Performance and ground reference maneuvers A. Steep turns B. Ground reference maneuvers	A is deleted.
VI. Navigation A. Pilotage and dead reckoning B. Navigation systems and radar services C. Diversion D. Lost procedures	A, B and D are deleted. C is replaced by demonstration of use of the built-in flight planner to replan a different destination in flight.
VII. Slow flight and stalls A. Maneuvering during slow flight B. Power-off stalls C. Power-on stalls D. Spin awareness	Not applicable. The SVO-A aircraft cannot stall.

Item from the Airplane Private Pilot ACS	Changes for the SVO-A2 Private Pilot ACS
VIII. Basic instrument maneuvers A. Straight-and-level flight B. Constant air speed climbs C. Constant air speed descents D. Turns to headings E. Recovery from unusual flight attitudes F. Radio communications, navigation systems/facilities, and radar services	E is deleted. F is retained but is changed to communicating with ATC via the on-board communication system (not voice).
IX. Emergency operations A. Emergency descent B. Emergency approach and landing (simulated) (ASEL, ASES) C. Systems and equipment malfunctions D. Emergency equipment and survival gear E. Engine failure during takeoff before VMC (simulated) (AMEL, AMES) F. Engine failure after liftoff (Simulated) (AMEL, AMES) G. Approach and landing with an inoperative engine (simulated) (AMEL, AMES)	Not applicable. The SVO-A2 automation executes the tasks done by the pilot for foreseeable failures.
X. Multiengine operations A. Maneuvering with one engine inoperative (AMEL, AMES) B. VMC demonstration (AMEL, AMES) C. One engine inoperative (simulated) (solely by reference to instruments) during straight-and-level flight and turns (AMEL, AMES) D. Instrument approach and landing with an inoperative engine (simulated) (solely by reference to instruments) (AMEL, AMES)	Not applicable. The SVO-A2 automation executes the tasks done by the pilot for foreseeable failures.
XI. Night operations A. Night preparation	
XII. Postflight procedures A. After landing, parking, and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

AMES = Airplane multi-engine sea

ASEL = Airplane single-engine land
ASES = Airplane single-engine sea
VMC = Visual meteorological conditions

Table D-15. SVO-A2 private pilot ACS from the helicopter private pilot ACS

Item from the helicopter private pilot add-on PTS	Changes for the SVO-A2 private pilot ACS
I. Preflight preparation a. N/A b. N/A c. N/A d. N/A e. National Airspace System f. Performance and limitations g. Operation of systems h. N/A	Covered above by using an SVO-A2 aircraft
II. Preflight Procedures a. Preflight inspection b. Cockpit management c. Engine starting and rotor engagement d. Before takeoff check	Covered above by using an SVO-A2 aircraft
III. Airport and heliport operations a. N/A b. Traffic patterns c. Airport/heliport runway, helipad, and taxiway signs, markings, and lighting	Covered above by using an SVO-A2 aircraft
IV. Hovering maneuvers a. Vertical takeoff and landing b. Slope operations c. Surface taxi d. Hover taxi e. Air taxi	This item is added to the SVO-A2 ACS.

Item from the helicopter private pilot add-on PTS	Changes for the SVO-A2 private pilot ACS
V. Takeoffs, landings, and go-arounds a. Normal and crosswind takeoff and climb b. Normal and crosswind approach c. Maximum performance takeoff and climb d. Steep approach e. Rolling takeoff f. Confined area operation g. Pinnacle/platform operations h. Shallow approach and running/roll-on landing i. Go-around	This item is added to the SVO-A2 ACS.
VI. Performance maneuvers a. Rapid deceleration b. Straight in autorotation c. 180 autorotation	Item A is added to the SVO-A2 ACS. Items B and C are covered in the emergency operation section.
VII. Navigation (N/A)	
VIII. Emergency operations a. Power failure at hover b. Power failure at altitude c. Systems and equipment malfunctions d. Settling with power e. Low rotor RPM recovery f. Antitorque system failure g. Dynamic rollover h. Ground resonance i. Low G conditions j. Emergency equipment and survival gear	Covered above by using an SVO-A2 aircraft
IX. Night operation (N/A)	
X. Post-flight procedures a. After landing and securing	Covered above by using an SVO-A2 aircraft

Table D-16. SVO-A2 Private pilot ACS from the airplane instrument ACS

Item from the airplane instrument ACS	**Changes for the SVO-A2 private pilot ACS**
I. Preflight preparation A. Pilot qualifications B. Weather information C. Cross-country flight planning	Covered above by using an SVO-A2 aircraft
II. Preflight procedures A. Airplane systems related to IFR operations B. Airplane flight instruments and navigation equipment C. Instrument flight deck check	Covered above by using an SVO-A2 aircraft
III. Air traffic control clearances and procedures A. Compliance with air traffic control clearances B. Holding procedures	This item is added to the SVO-A2 ACS.
IV. Flight by reference to instruments A. Instrument flight B. Recovery from unusual flight attitudes	Covered above by using an SVO-A2 aircraft
V. Navigation systems A. Intercepting and tracking navigational systems and arcs B. Departure, en route, and arrival operations	This is replaced by use of the required navigator to program appropriate flight paths and couple to them.
VI. Instrument approach procedures A. Non-precision approach B. Precision approach C. Missed approach D. Circling approach E. Landing from an instrument approach	All instrument approaches will be coupled. Therefore, A and B are limited to selecting the appropriate approach and coupling to it. C, D, and E shall be conducted by hand flying from the missed approach point.
VII. VII. Emergency operations A. Loss of communications B. One engine inoperative (simulated) during straight-and-level flight and turns (AMEL, AMES) C. Instrument approach and landing with an inoperative engine (simulated) (AMEL, AMES) D. Approach with loss of primary flight instrument indicators	This section is replaced by procedures appropriate for failures that can realistically occur on the SVO-A2 aircraft being used.
VIII. Postflight procedures A. Checking instruments and equipment	

D.22 Commercial pilot airman certification standards for SVO-A2

Table D-17 and Table D-18 contain the task list for the SVO-A2 commercial pilot ACS

The airplane commercial pilot ACS and helicopter commercial pilot add-on PTS are combined to create the SVO-A2 Private Pilot ACS.

Table D-17. SVO-A2 commercial pilot ACS from the airplane commercial pilot ACS

Item from the airplane commercial pilot ACS	**Changes for the SVO-A2 commercial pilot ACS**
I. Preflight preparation A. Pilot qualifications B. Airworthiness requirements C. Weather information D. Cross-country flight planning E. National Airspace System F. Performance and limitations G. Operation of systems H. Human factors I. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	Items C through I are eliminated. The required built-in flight planning application collects weather information and creates an appropriate flight plan considering airspace restrictions and aircraft performance capabilities. The envelope protection system protects the flight envelope as well as system limits.
II. Preflight procedures A. Preflight assessment B. Flight deck management C. Engine starting D. Taxiing (ASEL, AMEL) E. Taxiing and sailing (ASES, AMES) F. Before takeoff check	
III. Airport and seaplane base operations A. Communications, light signals, and runway lighting systems B. Traffic patterns	

Item from the airplane commercial pilot ACS	**Changes for the SVO-A2 commercial pilot ACS**
IV. Takeoffs, landings, and go-arounds A. Normal takeoff and climb B. Normal approach and landing C. Soft-field takeoff and climb (ASEL) D. Soft-field approach and landing (ASEL) E. Short-field takeoff and maximum performance climb (ASEL, AMEL) F. Short-field approach and landing (ASEL, AMEL) G. Confined area takeoff and maximum performance climb (ASES, AMES) H. Confined area approach and landing (ASES, AMES) I. Glassy water takeoff and climb (ASES, AMES) J. Glassy water approach and landing (ASES, AMES) K. Rough water takeoff and climb (ASES, AMES) L. Rough water approach and landing (ASES, AMES) M. Power-off 180° accuracy approach and landing (ASEL, ASES) N. Go-around/rejected landing	Item M does not apply.
V. Performance and ground reference maneuvers A. Steep turns B. Steep spiral (ASEL, ASES) C. Chandelles (ASEL, ASES) D. Lazy eights (ASEL, ASES) E. Eights on pylons (ASEL, ASES)	A, C and D are deleted.
VI. Navigation A. Pilotage and dead reckoning B. Navigation systems and radar services C. Diversion D. Lost procedures	A, B, and D are deleted. C is replaced by demonstration of use of the built-in flight planner to replan a different destination in flight.

Item from the airplane commercial pilot ACS	Changes for the SVO-A2 commercial pilot ACS
VII. Slow flight and stalls A. Maneuvering during slow flight B. Power-off stalls C. Power-on stalls D. Accelerated stalls E. Spin awareness	Not applicable. The SVO-A aircraft cannot stall.
VIII. High-altitude operations A. Supplemental oxygen B. Pressurization	
IX. Emergency operations A. Emergency descent B. Emergency approach and landing (simulated) (ASEL, ASES) C. Systems and equipment malfunctions D. Emergency equipment and survival gear E. Engine failure during takeoff before VMC (Simulated) (AMEL, AMES) F. Engine failure after liftoff (simulated) (AMEL, AMES) G. Approach and landing with an inoperative engine (Simulated) (AMEL, AMES)	Not applicable. The SVO-A2 automation executes the tasks done by the pilot for foreseeable failures.
X. Multiengine operations A. Maneuvering with one engine inoperative (AMEL, AMES) B. VMC demonstration (AMEL, AMES) C. One engine inoperative (simulated) (solely by reference to instruments) during straight-and-level flight and turns (AMEL, AMES) D. Instrument approach and landing with an inoperative engine (simulated) (solely by reference to instruments) (AMEL, AMES)	Not applicable. The SVO-A2 automation executes the tasks done by the pilot for foreseeable failures.
XI. Postflight procedures A. After landing, parking and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

Table D-18. SVO-A2 commercial pilot ACS from the helicopter commercial pilot ACS

Item from the helicopter commercial pilot add-on PTS	**Changes for the SVO-A1 commercial pilot ACS**
I. Preflight preparation Task A: N/A Task B: N/A Task C: N/A Task D: N/A Task E: N/A Task F: Performance and limitations Task G: Operation of systems Task H: N/A Task I: N/A Task J: N/A	Covered above by using an SVO-A2 aircraft
II. Preflight procedures Task A: Preflight inspection Task b: Cockpit management Task C: Engine starting and rotor engagement Task D: Runway incursion avoidance Task E: Before takeoff check	Covered above by using an SVO-A2 aircraft
III. Airport and heliport operations Task A: N/A Task B: Traffic patterns Task C: Airport/heliport runway, helipad, and taxiway signs, markings, and lighting	Covered above by using an SVO-A2 aircraft
IV. Hovering maneuvers Task A: Vertical takeoff and landing Task B: Slope operations Task C: Surface taxi Task D: Hover taxi Task E: Air taxi	This item is added to the SVO-A2 ACS.

Item from the helicopter commercial pilot add-on PTS	**Changes for the SVO-A1 commercial pilot ACS**
V. Takeoffs, landings, and go-arounds Task A: Normal and crosswind takeoff and climb Task B: Normal and crosswind approach Task C: Maximum performance takeoff and climb Task D: Steep approach Task E: Rolling takeoff Task F: Shallow approach and running/roll-on landing Task G: Go-around	This item is added to the SVO-A2 ACS.
VI. Performance maneuvers Task A: Rapid deceleration Task b: Straight in autorotation Task C: 180° Autorotation Task D: Approach and landing with simulated powerplant failure – multiengine helicopter	Item A is added to the SVO-A2 ACS. Items B, C and D are covered in the emergency operation section.
VII. Navigation (N/A)	
XII. Emergency operations Task A: Power failure at a hover Task B: Power failure at altitude Task C: Systems and equipment malfunctions Task D: Settling-with-power Task E: Low rotor RPM recovery Task F: Dynamic rollover Task G: Ground resonance Task H: Low G conditions Task I: Emergency equipment and survival gear	Covered above by using an SVO-A2 aircraft
XIII. Special operations Task A: Confined area operation Task b: Pinnacle/platform Operations	This item is added to the SVO-A2 ACS.
XIV. Postflight procedures Task: After landing and securing	Covered above by using an SVO-A2 aircraft

D.23 Airline transport pilot ACS for SVO-A2

Table D-19 and Table D-20 contain the task list for the SVO-A2 Airline Transport Pilot ACS. Unlike the private, instrument, and commercial ratings there is no task list for an add on helicopter rating. Thus, the entire ATP helicopter task list is included. However, the helicopter ATP PTS does not include anything that is not in the airplane ATP ACS.

Table D-19. SVO-A2 airline transport pilot ACS from the airplane airline transport pilot ACS

Item from the airplane ATP ACS	**Changes for the SVO-A2 STP ACS**
I. Preflight preparation A. Operation of systems B. Performance and limitations C. Weather information (ATP) D. High-altitude aerodynamics (ATP) (AMEL, AMES) E. Air carrier operations (ATP) (AMEL, AMES) F. Human factors (ATP) G. Code of Federal Regulations (ATP) H. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	
II. Preflight procedures A. Preflight assessment B. Powerplant start C. Taxiing (ASEL, AMEL) D. Taxiing and sailing (ASES, AMES) E. Before takeoff checks	

Item from the airplane ATP ACS	Changes for the SVO-A2 STP ACS
III. Takeoffs and landings A. Normal takeoff and climb B. Normal approach and landing C. Glassy water takeoff and climb (ASES, AMES) D. Glassy water approach and landing (ASES, AMES) E. Rough water takeoff and climb (ASES, AMES) F. Rough water approach and landing (ASES, AMES) G. Confined-area takeoff and maximum performance climb (ASES, AMES) H. Confined-area approach and landing (ASES, AMES) I. Rejected takeoff J. Go-around/rejected landing	
IV. Inflight maneuvers A. Steep turns B. Recovery from unusual flight attitudes C. Specific flight characteristics	Delete this item.
V. Stall prevention A. Partial flap configuration stall prevention B. Clean configuration stall prevention C. Landing configuration stall prevention	Not applicable. The SVO-A aircraft cannot stall.
VI. Instrument procedures A. Instrument takeoff B. Departure procedures C. Arrival procedures D. Non-precision approaches E. Precision approaches F. Landing from a precision approach G. Circling approach H. Landing from a circling approach I. Missed approaches J. Holding procedures	All published procedures are conducted by selecting the procedure in the navigator and coupling to it. Holds are done by programming them into the navigator and coupling to the path.

Item from the airplane ATP ACS	Changes for the SVO-A2 STP ACS
VII. Emergency operations A. Emergency procedures B. Powerplant failure during takeoff C. Powerplant failure (simulated) (ASEL, ASES) D. Inflight powerplant failure and restart (AMEL, AMES) E. Approach and landing with a powerplant failure (simulated) (AMEL, AMES) F. Precision approach (Manually Flown) with a powerplant failure (simulated) (AMEL, AMES) G. Landing from a no-flap or a nonstandard flap approach	Not applicable. The SVO-A2 automation executes the tasks done by the pilot for foreseeable failures. Abnormal procedures will be conducted as appropriate for the aircraft.
VIII. Postflight Procedures A. After landing, parking, and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

Table D-20. SVO-A2 ATP ACS from the helicopter ATP ACS

Item from the helicopter ATP add-on PTS	Changes for the SVO-A2 ATP ACS
I. Preflight preparation A. Equipment examination B. Performance and limitations	Covered above by using an SVO-A2 aircraft
II. Preflight procedures A. Preflight inspection B. Powerplant start C. Taxiing D. Pre-takeoff checks	Covered above by using an SVO-A2 aircraft
III. Takeoff and departure phase A. Normal and crosswind takeoff B. Instrument takeoff C. Powerplant failure during takeoff D. Rejected takeoff E. Instrument departure	Covered above by using an SVO-A2 aircraft

Item from the helicopter ATP add-on PTS	Changes for the SVO-A2 ATP ACS
IV. Inflight maneuvers A. Steep turns B. Powerplant failure—Multi-engine helicopter C. Powerplant failure—Single-engine helicopter D. Recovery from unusual attitudes E. Settling-with-power	Covered above by using an SVO-A2 aircraft
V. Instrument procedures A. Instrument arrival B. Holding C. Precision instrument approaches D. Non-precision Instrument Approaches E. Missed approach	Covered above by using an SVO-A2 aircraft
VI. Landings and approaches to landings A. Normal and crosswind approaches and landings B. Approach and landing with simulated C. Powerplant failure—Multi-engine helicopter D. Rejected landing	Covered above by using an SVO-A2 aircraft
VII. Normal and abnormal procedures	Covered above by using an SVO-A2 aircraft
VIII. Emergency procedures	Covered above by using an SVO-A2 aircraft
IX. Postflight procedures A. After-landing procedures B. Parking and securing	Covered above by using an SVO-A2 aircraft

D.24 Unmanned aircraft vehicle ACS

D.24.1 Airman certification standards for a UAV pilot

As discussed in the text of section 2, the researchers recommend that the UAV pilot license has substantially the same requirements as the pilot-in-the-aircraft license except for specific additions and a few deletions. The additions are listed in Table D-21 in the format used for an ACS. To become a UAV pilot, the applicant must pass the requirements of the existing ACS, and in addition pass the requirements for the UAV pilot. Note that Table D-21 only reflects today's automation level, not advanced automation levels. Creating the table for each automation level creates too many combinations to manage easily. Therefore, when aircraft with advanced automation levels are considered, the UAV table and the SVO-A1 or SVO-A2 tables are combined, as appropriate.

Table D-21. Added UAV specific tasks for all levels and ratings

Added UAV specific tasks for all levels and ratings
1. Traffic avoidance a. Instrument meteorological conditions (IMC) but with intermittent VMC conditions b. VMC c. With ATC traffic calls under IFR and VFR rules i. Planning deviations ii. Executing deviations iii. Coordinating deviations with ATC d. Without ATC traffic calls i. Planning deviations ii. Executing deviations e. In the airport traffic pattern with a tower i. Planning deviations ii. Executing deviations iii. Coordinating deviations with ATC f. In the airport traffic pattern without a tower i. Determining likely paths of potential traffic in the pattern ii. Planning deviations iii. Executing deviations iv. Communicating with aircraft in the pattern v. Coordinating deviations with other aircraft g. Wake turbulence avoidance h. Determining clearance from clouds for VFR compliance
2. Lost communication link a. Remote pilot to ATC i. Alternative methods of communication (phone etc.) b. Remote pilot to aircraft i. Backup links ii. Understanding the aircraft's behavior if the link cannot be established iii. Required actions to take when the link is lost (who to notify)

Added UAV specific tasks for all levels and ratings
3. On-board failures a. Degraded modes of operation b. Procedures to regain lost functionality c. Rerouting to a different airport d. Emergency descents to an appropriate off airport landing area i. Choosing an appropriate area ii. Managing the aircraft's energy to safely land at the chosen area (safe refers to people and property as well as the aircraft) e. Loss of traffic detection sensors i. Automatic dependent surveillance broadcast (ADS-B) in ii. Optical sensors iii. On-board radar iv. Other f. Fire i. Propulsion system fire ii. Electrical fire iii. Systems fire (hydraulic, etc.) iv. Cargo area fire
4. Ground station failures a. Instrumentation display failures i. Primary flight instruments ii. Propulsion system instrumentation iii. System health instrumentation b. Navigation display failures c. Loss of weather information d. Loss of traffic information

Added UAV specific tasks for all levels and ratings
5. Weather changes a. Unexpected VMC to IMC i. Recognizing the transition from VMC to IMC (visibility, cloud clearance, etc.) ii. Maneuver to exit IMC or obtain an IFR clearance while in flight b. Wind changes at the destination airport i. Determining the preferred runway at towered airports ii. Determining the preferred runway at non-towered airports c. Wind shear and microbursts i. Predicting wind shear and microbursts ii. Avoiding wind shear and microbursts iii. Recovering from wind shear and microburst encounters close to the ground
6. Coordinating with ground crew a. Parking directions b. Clearance around the aircraft to start c. Handoff to or from another remote pilot at the airport for takeoff or landing
7. Loss of control due to hazardous flight conditions such as stalls, settling with power, low rotor RPM, overbank, flying on the back side of the power curve, takeoff from a hover with tailwind, etc. a. Recognition of hazardous flight conditions b. Recovery from hazardous flight conditions

D.25 Recommended changes and deletions to Part 61 for unmanned aircraft vehicle pilots

<u>Private pilots</u>

Recommended deletions/replacements are:

1. Replace the requirement to recognize critical weather conditions in flight per §61.105(b)(6) with the additional weather requirements listed above for remotely piloted aircraft (RPA) pilots.

2. Delete the requirement for spin entry and recovery per §61.105(b)(11) and replace with the RPA loss of control requirement above.

3. Delete the requirement for performance and ground reference maneuvers per §61.107(b)(vi) and §61.107(b)(vii). These are steep turns, a rectangular track, S-turns, and turns about a point. The visual cues for these maneuvers are completely different for an RPA pilot than for a pilot of a pilot-on-board aircraft. Demonstration of loss-of-control and traffic pattern maneuvering covers these for an RPA pilot.
4. Replace the slow flight and stalls requirement of §61.107(b)(ix) with the loss-of-control requirement above.

<u>Instrument</u>

Recommended deletions are:

1. Delete the optional requirement to hold at least a private pilot certificate as required by §61.65(a)(1). This is because as recommended, the RPA private pilot must also have an IR. Therefore, there is no need to have a private pilot certificate because there is no RPA certificate without an IR. The RPA pilot applicant may have a certificate of completion of the training and experience requirements of a private pilot RPA (this is not a private pilot certificate) or may apply for a private pilot and IR concurrently. However, a private pilot with an airplane, powered-lift, or rotorcraft rating is assumed to meet the private pilot requirements of the RPA license.
2. References to instructors with appropriate aircraft ratings (i.e., airplane, powered-lift, helicopter ratings), are changed to instructors with an appropriate RPA rating.
3. All flight experience may be obtained in an approved simulator.
4. All cross-country experience must be obtained by performing the duties of PIC with one-on-one supervision by an authorized instructor or in a pilot-on-board aircraft.
5. Due to the nature of most civilian RPA missions, the cross-country time may need to be reduced. Consider reducing it to that required for a helicopter rating.

D.26 Recommended changes

Tables D-22-D-28 summarize the changes recommended for UAV private pilots ACS, SVO-A1 private pilot ACS, UAV Instrument ACS, UAV Commercial Pilot ACS, SVO-A1 commercial pilot ACS, UAV ATP ACS, and SVO-A1 ATP ACS.

Table D-22. SVO-A1 private pilot ACS from the airplane private pilot ACS

Item from the Airplane Private Pilot ACS	**Changes for the UAV Private Pilot ACS**
I. Preflight preparation A. Pilot qualifications B. Airworthiness requirements C. Weather information D. Cross-country flight planning E. National airspace F. Performance and limitations G. Operation of systems H. Human factors I. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	
II. Preflight procedures A. Preflight assessment B. Flight deck management C. Engine starting D. Taxiing (ASEL, AMEL) E. Taxiing and sailing (ASES, AMES) F. Before takeoff check	
III. Airport and seaplane base operations A. Communications, light signals, and runway lighting systems B. Traffic patterns	

Item from the Airplane Private Pilot ACS	**Changes for the UAV Private Pilot ACS**
I. Takeoffs, landings, and go-arounds A. Normal takeoff and climb B. Normal approach and landing C. Soft-field takeoff and climb (ASEL) D. Soft-field approach and landing (ASEL) E. Short-field takeoff and maximum performance climb (ASEL, AMEL) F. Short-field approach and landing (ASEL, AMEL) G. Confined area takeoff and maximum performance climb (ASES, AMES) H. Confined area approach and landing (ASES, AMES) I. Glassy water takeoff and climb (ASES, AMES) J. Glassy water approach and landing (ASES, AMES) K. Rough water takeoff and climb (ASES, AMES) L. Rough water approach and landing (ASES, AMES) M. Forward slip to a landing (ASEL, ASES) N. Go-around/rejected landing	
II. Performance and ground reference maneuvers A. Steep turns B. Ground reference maneuvers	
III. Navigation A. Pilotage and dead reckoning B. Navigation systems and radar services C. diversion D. Lost procedures	Item A is deleted.
IV. Slow flight and stalls A. Maneuvering during slow flight B. Power-off stalls C. Power-on stalls D. Spin awareness	Not applicable. The SVO-A aircraft cannot stall.

Item from the Airplane Private Pilot ACS	**Changes for the UAV Private Pilot ACS**
V. Basic instrument maneuvers A. Straight-and-level flight B. Constant airspeed climbs C. Constant airspeed descents D. Turns to headings E. Recovery from unusual flight attitudes F. Radio communications, navigation systems/facilities, and radar services	No change except that item E is done only by use of the level button.
VI. Emergency operations A. Emergency descent B. Emergency approach and landing (simulated) (ASEL, ASES) C. Systems and equipment malfunctions D. Emergency equipment and survival gear E. Engine failure during takeoff before vmc (simulated) (AMEL, AMES) F. Engine failure after liftoff (simulated) (AMEL, AMES) G. Approach and landing with an inoperative engine (simulated) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
VII. Multi-engine operations A. Maneuvering with one engine inoperative (AMEL, AMES) B. VMC demonstration (AMEL, AMES) C. One engine inoperative (simulated) (solely by reference to instruments) during straight-and-level flight and turns (AMEL, AMES) D. Instrument approach and landing with an inoperative engine (simulated) (solely by reference to instruments) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
VIII. Night operations A. Night preparation	
IX. Postflight procedures A. After landing, parking, and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

Table D-23. SVO-A1 private pilot ACS from the helicopter private pilot ACS

Item from the helicopter private pilot add-on PTS	**Changes for the SVO-A1 private pilot ACS**
I. Preflight preparation a. N/A b. N/A c. N/A d. N/A e. National Airspace System f. Performance and limitations g. Operation of systems h. N/A	Covered above by using an SVO-A1 aircraft
II. Preflight procedures a. Preflight inspection b. Cockpit management c. Engine starting and rotor engagement d. Before takeoff check	Covered above by using an SVO-A1 aircraft
III. Airport and heliport operations a. N/A b. Traffic patterns c. Airport/heliport runway, helipad, and taxiway signs, markings, and lighting	Covered above by using an SVO-A1 aircraft
IV. Hovering maneuvers a. Vertical takeoff and landing b. Slope operations c. Surface taxi d. Hover taxi e. Air taxi	This item is added to the SVO-A1 ACS.
V. Takeoffs, landings, and go-arounds a. Normal and crosswind takeoff and climb b. Normal and crosswind approach c. Maximum performance takeoff and climb d. Steep approach e. Rolling takeoff f. Confined area operation g. Pinnacle/platform operations h. Shallow approach and running/roll-on landing i. Go-around	This item is added to the SVO-A1 ACS.

Item from the helicopter private pilot add-on PTS	**Changes for the SVO-A1 private pilot ACS**
VI. Performance maneuvers a. Rapid deceleration b. Straight in autorotation c. 180 autorotation	Item A is added to the SVO-A1 ACS. Items B and C are covered in the emergency operation section.
VII. Navigation (N/A)	
VIII. Emergency operations a. Power failure at hover b. Power failure at altitude c. Systems and equipment malfunctions d. Settling with power e. Low rotor RPM recovery f. Antitorque system failure g. Dynamic rollover h. Ground resonance i. Low G conditions j. Emergency equipment and survival gear	Covered above by using an SVO-A1 aircraft
IX. Night operation (N/A)	
X. Post-flight procedures a. After landing and securing	Covered above by using an SVO-A1 aircraft

Table D-24. SVO-A1 instrument rating ACS

Item from the Airplane Instrument ACS	**Changes for the UAV Instrument ACS**
I. Preflight preparation A. Pilot qualifications B. Weather information C. Cross-country flight planning	Items B and C are to be conducted exclusively using the required flight planning application.
II. Preflight procedures A. Airplane systems related to IFR operations B. Airplane flight instruments and navigation equipment C. Instrument flight deck check	
III. Air traffic control clearances and procedures A. Compliance with air traffic control clearances B. Holding procedures	
IV. Flight by reference to instruments A. Instrument flight B. Recovery from unusual flight attitudes	Unusual attitude recovery is limited to recognition of an unusual attitude and pressing the level button.
V. Navigation systems A. Intercepting and tracking navigational systems and arcs B. Departure, en route, and arrival operations	This is replaced by use of the required navigator and AP to program appropriate flight paths and couple to them.
VI. Instrument approach procedures A. Non-precision approach B. Precision approach C. Missed approach D. Circling approach E. Landing from an instrument approach	All instrument approaches will be coupled to the AP. A and B are limited to selecting the appropriate approach and coupling to it. C, D, and E shall be conducted by hand flying from the missed approach point.
VII. Emergency operations A. Loss of communications B. One engine inoperative (simulated) during straight-and-level flight and turns (AMEL, AMES) C. Instrument approach and landing with an inoperative engine (simulated) (AMEL, AMES) D. Approach with loss of primary flight instrument indicators	This section is replaced by procedures appropriate for failures that can realistically occur on the SVO-A1 aircraft being used.
VIII. Postflight procedures	

Item from the Airplane Instrument ACS	Changes for the UAV Instrument ACS
A. Checking instruments and equipment	

Table D-25. SVO-A1 commercial pilot ACS from airplane commercial pilot ACS

Item from the Airplane Commercial Pilot ACS	Changes for the UAV Commercial Pilot ACS
I. Preflight preparation A. Pilot qualifications B. Airworthiness requirements C. Weather information D. Cross-country flight planning E. National Airspace System F. Performance and limitations G. Operation of systems H. Human factors I. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	
II. Preflight procedures A. Preflight assessment B. Flight deck management C. Engine starting D. Taxiing (ASEL, AMEL) E. Taxiing and Sailing (ASES, AMES) F. Before takeoff check	
III. Airport and seaplane base operations A. Communications, light signals, and runway lighting systems B. Traffic patterns	

Item from the Airplane Commercial Pilot ACS	**Changes for the UAV Commercial Pilot ACS**
I. Takeoffs, landings, and go-arounds A. Normal takeoff and climb B. Normal approach and landing C. Soft-field takeoff and climb (ASEL) D. Soft-field approach and landing (ASEL) E. Short-field takeoff and maximum performance climb (ASEL, AMEL) F. Short-field approach and landing (ASEL, AMEL) G. Confined area takeoff and maximum performance climb (ASES, AMES) H. Confined area approach and landing (ASES, AMES) I. Glassy water takeoff and climb (ASES, AMES) J. Glassy water approach and landing (ASES, AMES) K. Rough water takeoff and climb (ASES, AMES) L. Rough water approach and landing (ASES, AMES) M. Power-off 180° accuracy approach and landing (ASEL, ASES) N. Go-around/rejected landing	Item M does not apply.
II. Performance and ground reference maneuvers A. Steep turns B. Steep spiral (ASEL, ASES) C. Chandelles (ASEL, ASES) D. Lazy eights (ASEL, ASES) E. Eights on pylons (ASEL, ASES)	
III. Navigation A. Pilotage and dead reckoning B. Navigation systems and radar services C. Diversion D. Lost procedures	Item A is deleted.
IV. Slow flight and stalls A. Maneuvering during slow flight B. Power-off stalls C. Power-on stalls D. Accelerated stalls E. Spin awareness	Not applicable. The SVO-A aircraft cannot stall.

Item from the Airplane Commercial Pilot ACS	**Changes for the UAV Commercial Pilot ACS**
V. High-altitude operations A. Supplemental oxygen B. Pressurization	
VI. Emergency operations A. Emergency descent B. Emergency approach and landing (Simulated) (ASEL, ASES) C. Systems and equipment malfunctions D. Emergency equipment and survival gear E. Engine failure during takeoff before vmc (simulated) (AMEL, AMES) F. Engine failure after liftoff (simulated) (AMEL, AMES) G. Approach and landing with an inoperative engine (simulated) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
VII. Multi-engine operations A. Maneuvering with one engine inoperative (AMEL, AMES) B. VMC demonstration (AMEL, AMES) C. One engine inoperative (simulated) (solely by reference to instruments) during straight-and-level flight and turns (AMEL, AMES) D. Instrument approach and landing with an inoperative engine (simulated) (solely by reference to instruments) (AMEL, AMES)	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures.
VIII. Postflight procedures A. After landing, parking, and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

Table D-26. SVO-A1 commercial pilot ACS from helicopter commercial pilot ACS

Item from the helicopter commercial pilot add-on PTS	**Changes for the SVO-A1 commercial pilot ACS**
I. Preflight preparation Task A: N/A Task B: N/A Task C: N/A Task D: N/A Task E: N/A Task F: Performance and limitations Task G: Operation of systems Task H: N/A Task I: N/A Task J: N/A	Covered above by using an SVO-A1 aircraft
II. Preflight procedures Task A: Preflight inspection Task B: Cockpit management Task C: Engine starting and rotor engagement Task D: Runway incursion avoidance Task E: Before takeoff check	Covered above by using an SVO-A1 aircraft
III. Airport and heliport operations Task A: N/A Task B: Traffic patterns Task C: Airport/heliport runway, helipad, and taxiway signs, markings, and lighting	Covered above by using an SVO-A1 aircraft
IV. Hovering maneuvers Task A: Vertical takeoff and landing Task B: Slope operations Task C: Surface taxi Task D: Hover taxi Task E: Air taxi	This item is added to the SVO-A1 ACS.

Item from the helicopter commercial pilot add-on PTS	**Changes for the SVO-A1 commercial pilot ACS**
V. Takeoffs, landings, and go-arounds Task A: Normal and crosswind takeoff and climb Task B: Normal and crosswind approach Task C: Maximum performance takeoff and climb Task D: Steep approach Task E: Rolling takeoff Task F: Shallow approach and running/roll-on landing Task G: Go-around	This item is added to the SVO-A1 ACS.
VI. Performance maneuvers Task A: Rapid deceleration Task B: Straight in autorotation Task C: 180° autorotation Task D: Approach and landing with simulated powerplant failure – multi-engine helicopter	Item A is added to the SVO-A1 ACS. Items B, C and D are covered in the emergency operation section.
VII. Navigation (N/A)	
VIII. Emergency operations Task A: Power failure at a hover Task B: Power failure at altitude Task C: Systems and equipment malfunctions Task D: Settling-with-power Task E: Low rotor RPM recovery Task F: Dynamic rollover Task G: Ground resonance Task H: Low G conditions Task I: Emergency equipment and survival gear	Covered above by using an SVO-A1 aircraft
IX. Special operations Task A: Confined area operation Task B: Pinnacle/platform operations	This item is added to the SVO-A1 ACS.
X. Postflight procedures Task: After landing and securing	Covered above by using an SVO-A1 aircraft

Table D-27. SVO-A1 airline transport pilot ACS from the airplane airline transport pilot ACS

Item from the Airplane ATP ACS	Changes for the UAV ATP ACS
I. Preflight preparation A. Operation of systems B. Performance and limitations C. Weather information (ATP) D. High-altitude aerodynamics (ATP) (AMEL, AMES) E. Air carrier operations (ATP) (AMEL, AMES) F. Human factors (ATP) G. Code of Federal Regulations (ATP) H. Water and seaplane characteristics, seaplane bases, maritime rules, and aids to marine navigation (ASES, AMES)	
II. Preflight procedures A. Preflight assessment B. Powerplant start C. Taxiing (ASEL, AMEL) D. Taxiing and sailing (ASES, AMES) E. Before takeoff checks	
III. Takeoffs and landings A. Normal takeoff and climb B. Normal approach and landing C. Glassy water takeoff and climb (ASES, AMES) D. Glassy water approach and landing (ASES, AMES) E. Rough water takeoff and climb (ASES, AMES) F. Rough water approach and landing (ASES, AMES) G. Confined-area takeoff and maximum performance climb (ASES, AMES) H. Confined-area approach and landing (ASES, AMES) I. Rejected takeoff J. Go-around/rejected landing	
IV. Inflight maneuvers A. Steep turns B. Recovery from unusual flight attitudes C. Specific flight characteristics	Unusual attitude recovery is by use of the level button.

Item from the Airplane ATP ACS	Changes for the UAV ATP ACS
V. Stall prevention A. Partial flap configuration stall prevention B. Clean configuration stall prevention C. Landing configuration stall prevention	Not applicable. The SVO-A aircraft cannot stall.
VI. Instrument procedures A. Instrument takeoff B. Departure procedures C. Arrival procedures D. Non-precision approaches E. Precision approaches F. Landing from a precision approach G. Circling approach H. Landing from a circling approach I. Missed approaches J. Holding Procedures	All published procedures are conducted by selecting the procedure in the navigator and coupling to the AP. Holds are done by programming them into the navigator and coupling to the AP.
VII. Emergency operations A. Emergency procedures B. Powerplant failure during takeoff C. Powerplant failure (simulated) (ASEL, ASES) D. Inflight powerplant failure and restart (AMEL, AMES) E. Approach and landing with a powerplant failure (simulated) (AMEL, AMES) F. Precision approach (manually flown) with a powerplant failure (simulated) (AMEL, AMES) G. Landing from a no flap or a nonstandard flap approach	Not applicable. The SVO-A1 automation executes the tasks done by the pilot for foreseeable failures. Abnormal procedures will be conducted as appropriate for the aircraft.
VIII. Postflight procedures A. After landing, parking, and securing (ASEL, AMEL) B. Seaplane post-landing procedures (ASES, AMES)	

Table D-28. SVO-A1 airline transport pilot ACS from the airplane airline transport pilot ACS

Item from the helicopter ATP add-on PTS	**Changes for the SVO-A1 ATP ACS**
I. Preflight preparation A. Equipment examination B. Performance and limitations	Covered above by using an SVO-A1 aircraft
II. Preflight procedures A. Preflight inspection B. Powerplant start C. Taxiing D. Pretakeoff checks	Covered above by using an SVO-A1 aircraft
III. Takeoff and departure phase A. Normal and crosswind takeoff B. Instrument takeoff C. Powerplant failure during takeoff D. Rejected takeoff E. Instrument departure	Covered above by using an SVO-A1 aircraft
IV. Inflight maneuvers A. Steep turns B. Powerplant failure—multi-engine helicopter C. Powerplant failure—single-engine helicopter D. Recovery from unusual attitudes E. Settling-with-power	Covered above by using an SVO-A1 aircraft
V. Instrument procedures A. Instrument arrival B. Holding C. Precision instrument approaches D. Non-precision instrument approaches E. Missed approach	Covered above by using an SVO-A1 aircraft
VI. Landings and approaches to landings A. Normal and crosswind approaches and landings B. Approach and landing with simulated C. Powerplant failure— multi-engine helicopter D. Rejected landing	Covered above by using an SVO-A1 aircraft
VII. Normal and abnormal procedures	Covered above by using an SVO-A1 aircraft
VIII. Emergency procedures	Covered above by using an SVO-A1 aircraft

Item from the helicopter ATP add-on PTS	**Changes for the SVO-A1 ATP ACS**
IX. Postflight procedures A. After-landing procedures B. Parking and securing	Covered above by using an SVO-A1 aircraft

E Operating rules (Parts 91 and 135)

Appendix E considers Part 91 and Part 135 operations. Part 91 focuses on general operating and flight rules. Part 135 focuses on commuter and on demand operations and rules governing persons on board such aircraft.

E.1 Section 91.205—Powered civil aircraft with standard category U.S. airworthiness certificates: Instrument and equipment requirements.

FAA rule:

(a) General. Except as provided in paragraphs (c)(3) and (e) of this section, no person may operate a powered civil aircraft with a standard category U.S. airworthiness certificate in any operation described in paragraphs (b) through (f) of this section unless that aircraft contains the instruments and equipment specified in those paragraphs (or FAA-approved equivalents) for that type of operation, and those instruments and items of equipment are in operable condition.

(b) Visual-flight rules (day). For VFR flight during the day, the following instruments and equipment are required:

(1) Airspeed indicator.

(2) Altimeter.

(3) Magnetic direction indicator.

(4) Tachometer for each engine.

(5) Oil pressure gauge for each engine using pressure system.

(6) Temperature gauge for each liquid-cooled engine.

(7) Oil temperature gauge for each air-cooled engine.

(8) Manifold pressure gauge for each altitude engine.

(9) Fuel gauge indicating the quantity of fuel in each tank.

(10) Landing gear position indicator, if the aircraft has a retractable landing gear.

…

(c) Visual flight rules (night). For VFR flight at night, the following instruments and equipment are required:

(1) Instruments and equipment specified in paragraph (b) of this section.

(2) Approved position lights.

…

(d) Instrument flight rules. For IFR flight, the following instruments and equipment are required:

(1) Instruments and equipment specified in paragraph (b) of this section, and, for night flight, instruments and equipment specified in paragraph (c) of this section.

(2) Two-way radio communication and navigation equipment suitable for the route to be flown.

(3) Gyroscopic rate-of-turn indicator, except on the following aircraft:

(i) Airplanes with a third attitude instrument system usable through flight attitudes of 360 degrees of pitch and roll and installed in accordance with the instrument requirements prescribed in §121.305(j) of this chapter; and

(ii) Rotorcraft with a third attitude instrument system usable through flight attitudes of ±80 degrees of pitch and ±120 degrees of roll and installed in accordance with §29.1303(g) of this chapter.

(4) Slip-skid indicator.

(5) Sensitive altimeter adjustable for barometric pressure.

(6) A clock displaying hours, minutes, and seconds with a sweep-second pointer or digital presentation.

(7) Generator or alternator of adequate capacity.

(8) Gyroscopic pitch and bank indicator (artificial horizon).

(9) Gyroscopic direction indicator (directional gyro or equivalent).

…

(h) Night vision goggle operations. For night vision goggle operations, the following instruments and equipment must be installed in the aircraft, functioning in a normal manner, and approved for use by the FAA:

(1) Instruments and equipment specified in paragraph (b) of this section, instruments and equipment specified in paragraph (c) of this section;

(2) Night vision goggles;

(3) Interior and exterior aircraft lighting system required for night vision goggle operations;

(4) Two-way radio communications system;

(5) Gyroscopic pitch and bank indicator (artificial horizon);

(6) Generator or alternator of adequate capacity for the required instruments and equipment; and

(7) Radar altimeter.

…

Recommended changes:

Although Part 91.205 is an operations rule, it specifies required equipment for certain operations. The required equipment impacts the design of the aircraft and ground station and is based on obsolete technology. Therefore, the requirements of §91.205 that affect aircraft design are included in this airworthiness criteria.

This rule applies as written except that the following sections are added.

- (b)(11), (b)(12),
- (c)(3), (c)(4),
- (d)(10), (d)(11),
- (h)(8), (h)(9), and
- (j)

These additions remove and replace the sections of Part 61 that are not appropriate. This avoids the need to change existing Part 61 rules where they apply.

(b) Visual flight rules (VFR) (day). For VFR flight during the day, the following instruments and equipment are required:

(11) Except any indicator listed in (1) through (10) that may be deleted if it can be shown that the pilot does not need it to conduct safe operations including during failures and emergencies for day VFR flight.

(12) Indicators and equipment required for the pilot to conduct safe operations including during failures and emergencies that must be installed and functional for day VFR flight.

(c) VFR (night). For VFR flight at night, the following instruments and equipment are required:

(3) Except any indicator listed in (1) that may be deleted if it can be shown that the pilot does not need it to conduct safe operations including during failures and emergencies for night VFR flight.

(4) Indicators and equipment required for the pilot to conduct safe operations including during failures and emergencies that must be installed and functional for night VFR flight.

(d) Instrument flight rules (IFR). For IFR flight, the following instruments and equipment are required:

(10) Except any indicator listed in (1) through (9) that may be deleted if it can be shown that the pilot does not need it to conduct safe operations including during failures and emergencies for day or night IFR flight.

(11) Indicators and equipment required for the pilot to conduct safe operations including during failures and emergencies that must be installed and functional for day or night IFR flight.

(h) Night-vision goggle or enhanced-vision operations. For night-vision goggle operations, the following instruments and equipment must be installed in the aircraft, functioning in a normal manner, and approved for use by the FAA:

(8) Except any indicator listed in (4) through (7) that may be deleted if it can be shown that the pilot does not need it to conduct safe operations including during failures and emergencies for night-vision goggle operations.

(9) Indicators and equipment required for the pilot to conduct safe operations including during failures and emergencies that must be installed and functional for night-vision goggle operations.

(j) Remote Pilot Operations. For operations with a remote pilot, if an observer is not available at the landing site to ensure the landing zone is clear, then a means must be provided for the pilot to observe the flight path in real time using live images.

Discussion

Ellipses (…) are used to indicate that portions of this regulation are not included here for brevity. These excluded portions apply as written.

The instrument lists in this rule were developed based on technology available before computers and glass screens were in common use. Current technology provides the opportunity to provide the pilot with required information in better formats than is provided by the listed instruments. For example, engine monitoring software can track engine oil pressure as a function of engine operating conditions and when an unexpected change occurs can then post a message. This is more effective than expecting the pilot to monitor an oil pressure gauge and notice changes when the reading is still within normal limits. Another example is that since the EZ-Fly VTOL control system always controls the aircraft attitude so there is no need for the pilot to use attitude to control the aircraft. For an EZ-Fly VTOL installation, an attitude indicator only provides clutter.

The purpose of changing these rules is to allow and encourage the applicant to develop displays that are appropriate for the aircraft and reduce display clutter and pilot workload.

Note that two-way communication, navigation, and an alternator or generator are also included in the list of equipment that may be deleted. This is done to allow new technology that may emerge that is not commonly referred to as two-way radio communication, a generator or an alternator.

For the certification process, the default is to include all the items listed and then have the applicant explain why each one is not required for the specific design.

The recommended rule for remote pilot operations is based on experience of the researchers doing simulation studies These studies clearly showed the importance for a human observer to clear the aircraft to land when just above the landing zone. A tower operator does not automatically satisfy this requirement. The purpose is for the observer to see obstacles that may not be visible to the tower operator such as wildlife, trash, etc. for fixed-wing operations, and for obstacles that may be incompatible with the downwash from VTOL operations.

E.2 PART 97—STANDARD INSTRUMENT PROCEDURES

Federal Aviation Regulations (FAR) Part 97.3 contains details concerning helicopter minima and helicopter procedures (Symbols and terms used in procedures, 2007). SVO-A aircraft in VTOL mode use existing helicopter visibility minima. When in a mode that cannot land vertically, they use existing airplane minima.

SVO-A aircraft may use helicopter procedures if they fly the procedure in VTOL mode or if they can fly within the speed restrictions of helicopter procedures and can transition to VTOL mode before the missed approach point (MAP) without deviating from the lateral or vertical flight path.

SVO-A2 aircraft can take off and land automatically without pilot action (other than to approve the landing when a few feet above the ground. The instrument approach minima in Part 97 are based on a pilot transitioning from control by reference to instruments to control by visual references. Since the SVO-A2 aircraft has automatic takeoff and landing capability, there is no need for pilot transition time from instrument conditions to visual control. Therefore, approach minima can be much lower for SVO-A2 aircraft.

FAR 91.171 very high-frequency omnidirectional range station (VOR) check requires that if VOR navigation is used for IFR, the VOR receiver must be checked by comparing to another VOR receiver, a VOR test point on an airport or by flying on a published airway over a ground feature. It is recommended that in addition to the methods allowed in the regulation that an additional method be allowed that uses any IFR qualified navigation device to check the accuracy. The recommended error is 4 degrees (the same as a VOR-to-VOR check). Add global positioning system (GPS) radials or fixes, 4 degrees. This regulation was written when VOR navigation was the only IFR method of navigating for most pilots. This addition recognizes that navigation methods other than VOR are now available and can be used to check a VOR receiver for accuracy. This is particularly true for the use of GPS waypoints while doing a VOR approach, VOR intersections that are also GPS waypoints, etc. It is recommended that GPS specifically not be required. This allows any IFR approved navigation system to be used. Thus, if new navigation technology becomes available, it can be used without rewriting the rule.

Part 135 has many requirements that are based on legacy technology in aircraft. For many SVO-A aircraft these requirements are not appropriate. A complete review of Part 135 to make it compatible with SVO-A aircraft is outside the scope of this document.

However, some areas where Part 135 needs revision for SVO-A operations have been identified.

§135.93—Minimum altitudes for use of AP

§135.243—Pilot-in-command qualifications

§135.244—Operating experience

§135 subpart C—Aircraft and equipment

§135 subpart H—Training

§135 subpart M—A new section for SVO-A performance operating limitations (similar to I for airplanes and L for helicopters).

F Commercial pilot for rotorcraft category helicopter rating airman certification standards: Normal and crosswind approach

This appendix lists the requirements from the FAA Airman Certification Standard *FAA S ACS 16* (2023) for normal and crosswind approach.

F.1 Area of Operation V—Takeoffs, Landings, and Go-Arounds: Task B. Normal and Crosswind Approach

References: AIM; FAA-H-8083-2, FAA-H-8083-21, FAA-H-8083-25; POH/RFM

Objective: To determine the applicant exhibits satisfactory knowledge, risk management, and skills associated with a normal and crosswind approach.

Note: If a crosswind condition does not exist, the applicant's knowledge of crosswind elements must be evaluated through oral testing.

Knowledge: The applicant demonstrates understanding of:

CH.V.B.K1 Effects of wind, weight, altitude, and temperature on performance.

CH.V.B.K2 Wind correction techniques on approach and landing.

CH.V.B.K3 Landing surface, obstructions, and selection of a suitable touchdown point.

CH.V.B.K4 Factors affecting the profile of the height/velocity (H/V) diagram.

Risk Management: The applicant is able to identify, assess, and mitigate risk associated with:

CH.V.B.R1 Selection of approach path and landing based on aircraft performance and limitations, and wind.

CH.V.B.R2 Effects of:

CH.V.B.R2a a. Crosswind

CH.V.B.R2b b. Windshear

CH.V.B.R2c c. Tailwind

CH.V.B.R2d d. Turbulence, including wake turbulence

CH.V.B.R2e e. Vortex ring state (VRS)

CH.V.B.R2f f. Touchdown surface and condition

CH.V.B.R3 Go-around/rejected landing.

CH.V.B.R4 Collision hazards.

CH.V.B.R5 Distractions, task prioritization, loss of situational awareness, or disorientation.

CH.V.B.R6 Loss of tail rotor effectiveness (LTE).

Skills: The applicant exhibits the skill to:

CH.V.B.S1 Complete the appropriate checklist(s).

CH.V.B.S2 Make radio calls as appropriate.

CH.V.B.S3 Determine wind direction with or without visible wind direction indicators.

CH.V.B.S4 Align the helicopter with the correct/assigned runway or touchdown point.

CH.V.B.S5 Scan the landing area/touchdown point and adjoining area for traffic and obstructions.

CH.V.B.S6 Maintain proper ground track with crosswind correction, if necessary.

CH.V.B.S7 Establish and maintain a normal approach angle and rate of closure.

CH.V.B.S8 Maintain powerplant and main rotor (Nr) speed within normal limits.

CH.V.B.S9 Arrive at the termination point, on the surface or at a stabilized hover ±2 feet.

CH.V.B.S10 Use runway incursion avoidance procedures, if applicable

F.2 Reference

FAA. (2023, November). Commercial pilot for rotorcraft category helicopter rating airman certification standards (*FAA-S-ACS-16*). Retrieved from https://www.faa.gov/training_testing/testing/acs/commercial_helicopter_acs_16.pdf

G Commercial pilot for rotorcraft category helicopter rating airman certification standards: Hovering maneuvres

This appendix lists the requirements from the FAA Airman Certification Standard *FAA S ACS 16* (2023) for hovering maneuvers.

G.1 Area of Operation IV. Hovering Maneuvers

> ***Note:*** *Task D must be tested in addition to the other Tasks if the applicant supplies a helicopter with wheel-type landing gear.*

Task A. Vertical Takeoff and Landing

References: *14 CFR part 91; AC 90-95; FAA-H-8083-2, FAA-H-8083-21, FAA-H-8083-25; POH/RFM*

Objective: To determine the applicant exhibits satisfactory knowledge, risk management, and skills associated with vertical takeoff and landing from a hover.

Knowledge: The applicant demonstrates understanding of:

CH.IV.A.K1 Elements related to a vertical takeoff to a hover and landing from a hover.

CH.IV.A.K2 Effect of wind on flight control inputs.

CH.IV.A.K3 Effect of weight and balance and various centers of gravity.

CH.IV.A.K4 Ground effect.

Risk Management: The applicant is able to identify, assess, and mitigate risk associated with:

CH.IV.A.R1 Loss of tail rotor effectiveness (LTE).

CH.IV.A.R2 Dynamic rollover.

CH.IV.A.R3 Ground resonance.

CH.IV.A.R4 Powerplant failure during hover.

Skills: The applicant exhibits the skill to:

CH.IV.A.S1 Complete the appropriate checklist(s).

CH.IV.A.S2 Comply with air traffic control (ATC) or evaluator instructions and make radio calls as appropriate.

CH.IV.A.S3 Maintain powerplant and main rotor (Nr) speed within normal limits.

CH.IV.A.S4 Ascend to and maintain recommended hovering altitude, and descend from recommended hovering altitude in headwind, crosswind, and tailwind conditions, without drift.

CH.IV.A.S5 Maintain recommended hovering altitude, ±1/2 of that altitude within 10 feet of the surface, if above 10 feet, ±5 feet.

CH.IV.A.S6 Maintain position within 2 feet of a designated point with no aft movement.

CH.IV.A.S7 Descend vertically to within 2 feet of the designated touchdown point.

CH.IV.A.S8 Maintain specified heading, ± 10°.

G.2 Reference

FAA. (2023, November). Commercial pilot for rotorcraft category helicopter rating airman certification standards (*FAA-S-ACS-16*). Retrieved from https://www.faa.gov/training_testing/testing/acs/commercial_helicopter_acs_16.pdf

H Weight and balance calculation

This appendix presents a scenario used to calculate the weight and balance (W&B) of an aircraft. Figures H-1 shows the calculation form with a graph showing the relation between the center of gravity (CG) and gross weight. Figure H-2 provides a sample calculation scenario with basic instructions.

LIFT+CRUISE CONFIGURATION
WEIGHT & BALANCE

Date: / /

Item/Position	Weight	Arm		Moment
Basic Empty Wt.	______	X 95	=	______
Front L Seat	______	X 94	=	______
Front R Seat	______	X 94	=	______
Rear L Seat	______	X 105	=	______
Rear R Seat	______	X 105	=	______
Baggage Area	______	X 180	=	______
Total Weight & Moment	______			______

______ ÷ ______ = ______

Total Moment **Total Weight** **C.G.**

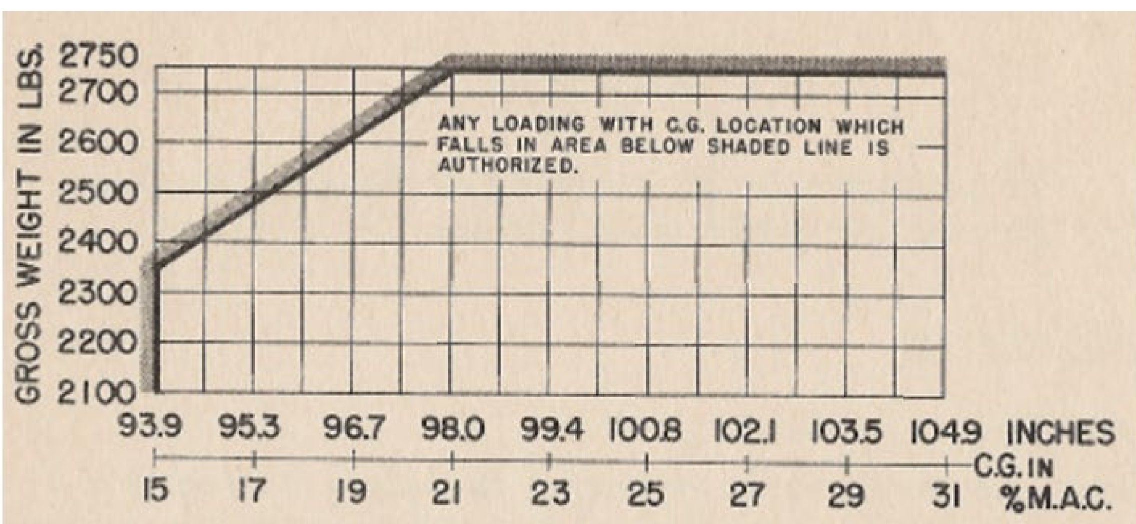

Figure H-1. Weight and balance calculation sheet with graph showing acceptable guidelines

Please fill out the W&B form on the first page using a pencil/pen and a four function calculator to calculate the weight and balance in the following scenario:

Basic Empty Weight = 2200 pounds

Front Left Seat = 215 pounds

Front Right Seat = 0 pounds

Rear Left Seat = 0 pounds

Rear Right Seat = 200 pounds

Baggage Area = 155 pounds

Figure H-2. Sample calculation scenario instructions

I EZ-FLY questionnaire

This appendix provides a copy of the questionnaire used by EZ-Fly in their pilot screening process (Figure I-1 below).

EZ-FLY Questionnaire:

____

Used for demographic purposes and potential future contact if clarification is required.

Name (optional): ________________________ Age: _________ MALE FEMALE

Contact info (e-mail or phone for text)

____

Subject number: ________________

1) Are you a remote-control aircraft pilot YES NO

2) Total Drone/UAV flight hours:

3) Do you have experience with video games YES NO

Describe:

4) Do you have experience with flight simulators YES NO

Describe:

Describe your experience (if any) flying (or flying in) a small airplane or helicopter.

Figure I- 1. EZ-Fly pilot screening questionnaire

J Unified questionnaire

This appendix provides a copy of the Unified questionnaire in their pilot screening process (Figures J-1 and J-2 below).

UNIFIED Questionnaire:

Used for demographic purposes and potential future contact if clarification is required.

Name (optional): ________________________ Age: _________ MALE FEMALE

Contact info (e-mail or phone for text)

Subject number: ________________

Total Flight Hours (approximately) ____________

Multi-Engine hours (approximately) __________

1) As a pilot, what are you licensed to operate?

   Fixed Wing

   Rotorcraft

2) Which ratings do you hold currently? [mark all that apply]
   - Airline Transport Pilot (ATP)
   - Certified Flight Instructor (CFI)
   - Certified Flight Instructor – Instrument (CFII)
   - Commercial
   - Instrument Rating
   - Multi-Engine
   - Private Pilot
   - Other (specify)

If other, please specify:

3) Please list the type of aircraft you are licensed to fly.

4) Have you flown a vertical take-off and landing (VTOL) aircraft in a simulator?

   Yes

   No

If yes, please list the type of aircraft.

Figure J-1. Unified pilot screening questionnaire, page 1

5) Have you flown a vertical take-off and landing (VTOL) aircraft (not in a simulator)?

Yes

No

If yes, please list the type of aircraft.

6) Have you flown aircraft with a fly by wire flight control system? (Yes/No)

Yes

No

If yes, please list the type of aircraft.

7) Familiarity with sidestick: None Little Limited but Comfortable Lots

8) Are you a remote-control aircraft pilot YES NO

9) Total Drone/UAV flight hours:

10) Do you have experience with video games YES NO

Describe:

11) Do you have experience with flight simulators YES NO

Describe:

Figure J-2. Unified pilot screening questionnaire, page 2

K Experiment Scenarios

This appendix describes the experimental scenarios to test pilot operators' knowledge of weight and balance (W&B) calculations.

K.1 Scenario 1 (Weight and balance calculation)

In scenario 1, two groups of participants—SVO-A1 using the Unified Control System [UCS] and SVO-A2 using EZ-Fly system—were tasked with calculating (W&B) for an aircraft. The first group, SVO-A1, pilots were assumed to know how to manually calculate and needed no additional training. The second group, SVO-A2, were assumed to have no knowledge of manual calculations. Both groups started with the same number of passengers, fuel, and baggage. The correct result for the given information would cause the vehicle to be outside the approved W&B limitations for both groups.

<u>SVO-A1 (UCSGroup)</u>

a) It was assumed that this group knew how to manually calculate W&B and no additional training was provided. This group received paper, a pencil, and a four-function calculator.
b) This group had to calculate the W&B by hand, using information consisting of "weights" and "arms" for various passengers, fuel, and baggage.
c) Help was provided when necessary to accurately calculate the W&B and enter it into the Garmin G1000® software interface.
d) Once the calculations were successfully entered into the G1000 interface, the task was concluded. Note no flying was necessary for this task.

SVO-A1 includes a mandatory graphical user interface (GUI) for calculating W&B and does not require a pencil and paper calculation. However, this setup is intended to test the pilot's ability to calculate W&B correctly by using pencil and paper and make the point that a certified version of the graphical interface is required.

SVO-A2 (EZ-Fly Group)

a) For this scenario, researchers assumed that this group was not trained to calculate W&B and was provided with the equivalent of a 5-minute W&B briefing in ground school lessons. This briefing included the importance of W&B and how to calculate it using the certified W&B program.
b) This group was not required to calculate W&B manually. The vehicle automatically sensed the weights of each passenger, fuel, baggage, etc., as shown in Figure K-1. Participants used the GUI to calculate W&B. Although the vehicle may weigh itself with no human input, this group was a good population to use to test the hypothesis that an inexperienced student can learn what is needed about W&B in a few minutes if a calculator with a GUI is provided.
c) Based on the calculation results, the vehicle would not allow the pilot to take off. The application on the screen would ask if someone wanted to get out or if a bag was removed. If the operator selected this option and the system confirmed it, the operator would be allowed to take off.

Data analysis was straightforward because the W&B calculations were graded for accuracy, and participant choices were recorded manually.

Implementation:

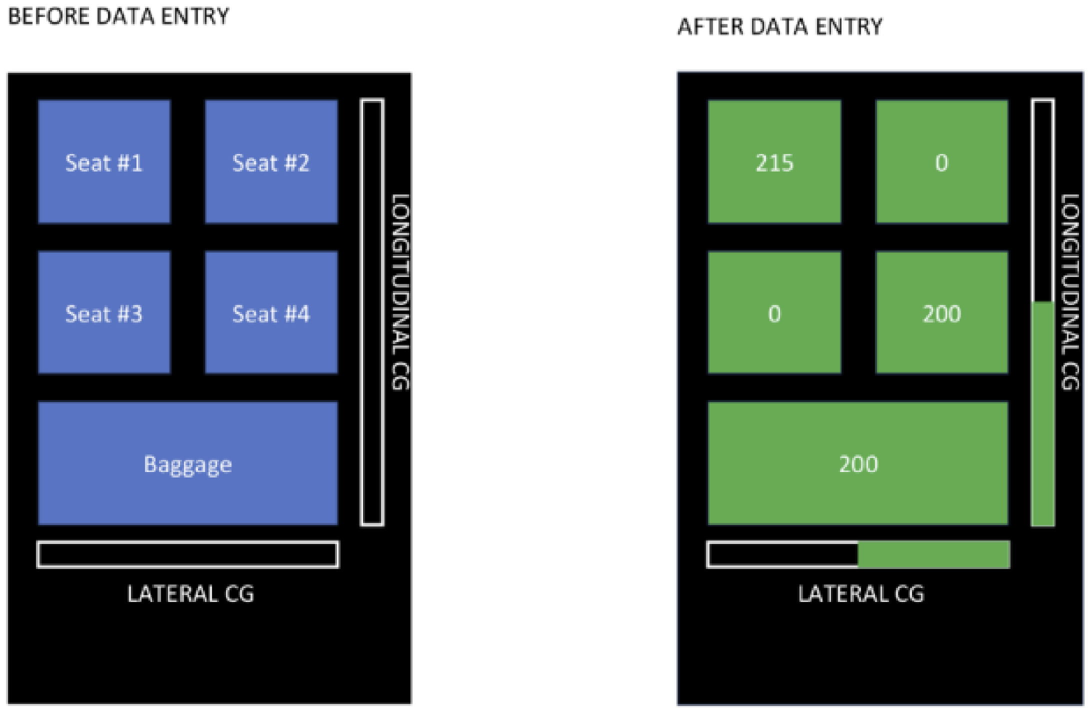

Figure K-1. Diagram of W&B before and after data entry

K.2 Scenario 2: System failure—Battery temperature caution and warning/cooling system failure)

A system monitoring function identifies an unexpected battery temperature rise in the battery packs of the eVTOL resulting in a caution message. If the pilot or the automation does not take immediate action, the aircraft will not be able to land successfully because ALL propulsion batteries will fail. If the pilot attempts to transition to the rotors enough propulsion batteries will fail to cause loss of control (huge power demand will raise the temperature and have an immediate runaway failure). The only way to make it back to the runway is to land on the wing and do it quickly before the batteries fail.

In this scenario, participants from the SVO-A1 and the SVO-A2 groups were tasked with identifying, responding, and reacting to system failures and battery temperature cautions during simulation operations.

SVO-A1 (UCS)

A system monitoring function identifies an unexpected battery temperature rise and displays it to the pilot via caution message/graph, etc. Initially, there is no warning message. However, the situation gets worse if unaddressed. If the pilot does not take immediate action, the aircraft will not be able to land safely on the wing.

a) The SVO-A1 group was provided with ground school training in various systems including but not limited to the aircraft's electrical system and battery systems. Training also included various abnormal and emergency procedures.
b) The test flight path is shown in Figure K-2. To ensure data consistency in all the runs, this scenario started after the pilot crossed waypoint (WPT)2. At this point, the battery temperature SLOWLY starts to increase, and a graph was shown to the pilot at approximately WPT3. After crossing WPT4 and after crossing abeam the runway, a caution message appears in yellow "BATT TEMP". The rate of the temperature rise was such that there is only 4 to 5 minutes of flight time available on the wing and only 15 seconds after a transition is done. The time started when the failure was introduced by the simulation operator.
c) If the pilot immediately abandons the overall approach and heads directly for the runway, the aircraft can be landed safely within the time allowed, but only on the wing—no transition. In this option, the pilot uses synthetic vision and a moving map to navigate to the runway. After the vehicle flies for 3 to 4 minutes, a warning message/light will appear "BATT TEMP." After this message appears, if the vehicle is on the wing, it has 60 seconds before the aircraft transitions into gliding flight. If the vehicle is on rotor, it has 5 seconds before losing all lift capability.

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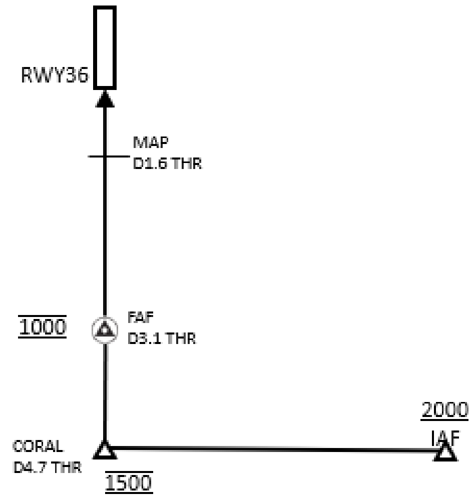

Figure K-2. Diagram of flight path for scenario 2

d) If the pilot continues flying the standard approach through the initial approach fix (IAF), then after 3 to 4 minutes a warning message will appear: "BATT TEMP." After 60 seconds from the warning message appearance, the aircraft transitions into gliding flight.

Figure K-3 shows view of the flight plan and associated cooling failure for the SVO-A1 (Unified Group), if the approach had not been abandoned and the original instrument approach procedure had been completed.

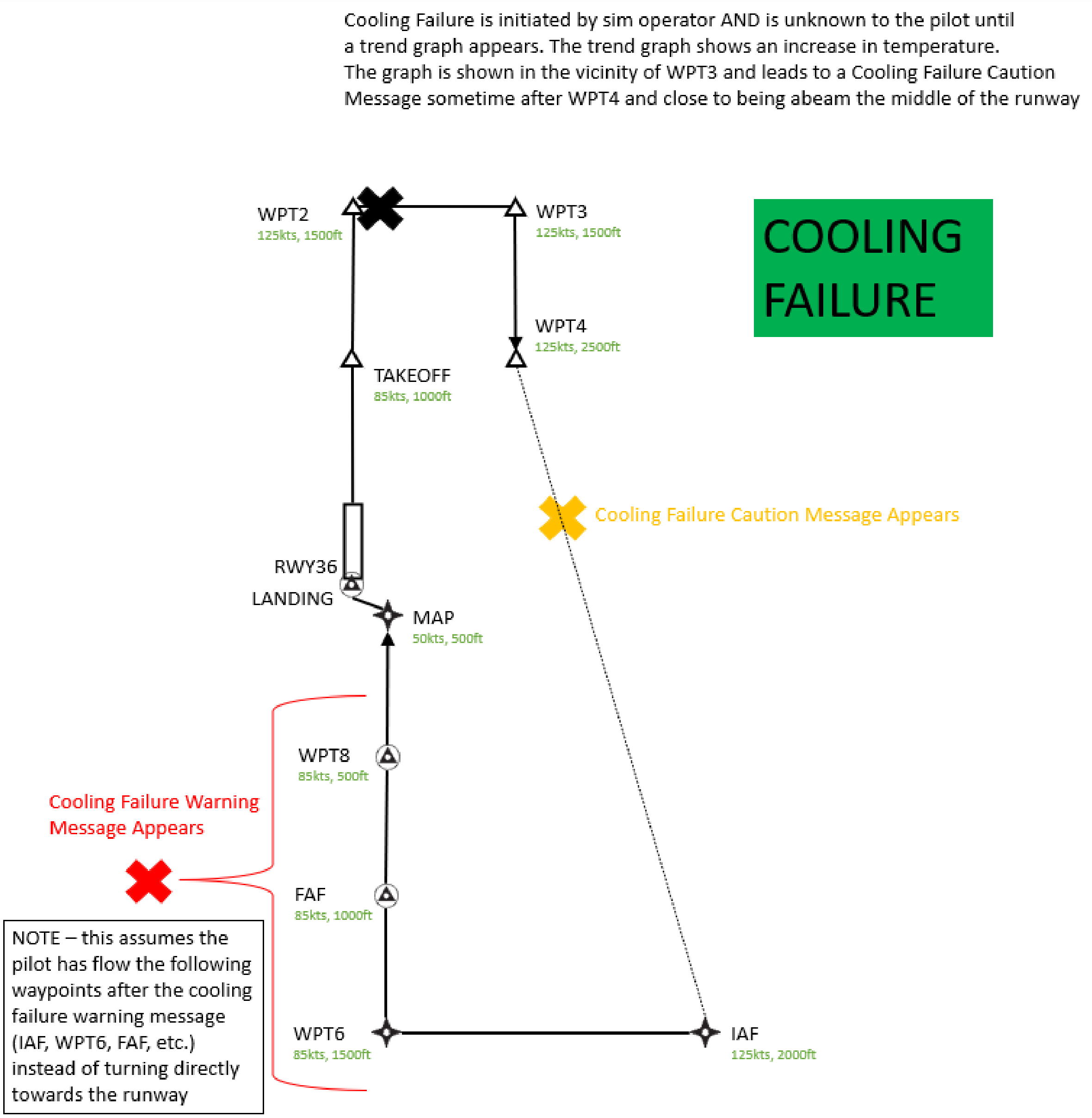

Figure K-3. Original flight plan and associated cooling failure for the SVO-A1

:

The key here is for the pilot to land on the wing without trying to transition. Additionally, landing on the wing must be performed quickly to avoid the battery temperature warning message and impending failure. The 4- to 5-minute setting was chosen so that if the pilot goes directly to the runway and remains on the wing, a landing can be made with about a minute to spare.

SVO-A2 (EZ-Fly Group)

For this group of participants, the automation loads a new flight plan, automatically engages the flight plan, and goes to the runway without pilot action.

a) This group was provided with a very basic and short ground school training about the aircraft's electrical system, battery systems, and electrical abnormal and emergency procedures.
b) To ensure data consistency in all the runs, this scenario started after the pilot was vectored by air traffic control (ATC) to a heading of 150 degrees after crossing WPT4, after crossing abeam the runway departure threshold.
c) A message appeared that the system detected an impending battery temperature failure, engaged a new flight plan (e.g., a shortened approach that includes maneuvering to intercept the vertical and lateral guidance to the runway), and locked the operator out of control unless the operator overrides the automation.
d) The system returns the vehicle safely to the runway and flies an approach on the wing and lands as an electrical conventional takeoff and landing (eCTOL).

K.3 Scenario 3 (System failure—Battery failure warning/battery system failure)

A system monitoring function identifies a battery failure resulting in a warning message. The auxiliary power unit (APU) has enough energy to run the pusher, basic avionics, and primary actuators but not the lift fans. The pilot or the automation does not need to take immediate action but cannot fly with the same endurance as before the failure. The failure forces the lift rotors to be inoperative (INOP), therefore, the pilot is locked out from transitioning to the lift rotors. Therefore, the pilot will be required to land on the wing like a fixed-wing vehicle if using UCS.

In this scenario, both groups were presented with a battery system failure for their control system to assess their responses.

SVO-A1 (UCS Group)

A system monitoring function identifies an unexpected battery failure and displays it to the pilot, i.e., warning message. The test flight plan is shown in Figure K-4.

a) This group was provided with ground school training about the aircraft's electrical system, battery systems, and electrical abnormal and emergency procedures.

b) Additional ground school training was provided on the flight control system for manual operation.
c) Flight training was provided to ensure pilots could manually fly the approach.
d) To ensure data consistency in all the runs, this scenario started after the pilot was vectored by ATC to a heading of 150 degrees after crossing WPT4, after crossing abeam the runway departure threshold. After crossing WPT4 and after crossing abeam the runway, a caution message appeared in yellow “BATT FAIL.”
e) The pilot needed to continue with the AP, disengage the AP right before landing, and manually land as a fixed-wing vehicle.

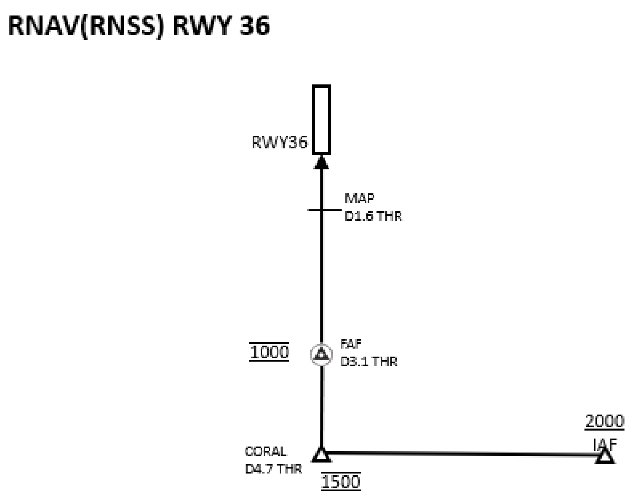

Figure K-4. Diagram of flight plan for SVO-A1, scenario 3

The key here is for the pilot to land on the wing woithout trying to transition. The approach must be flown manually. Although there is no a red/caution situation (as long as battery reserve is acceptable), it is still necessary to land as soon as practical.

SVO-A2 (EZ-Fly Group)

In this group’s simulation, the automation loads a new flight plan, automatically engages the new fixed-wing flight plan, and approaches the runway and lands without pilot action. The new flight plan looks is shown in Figure K-5.

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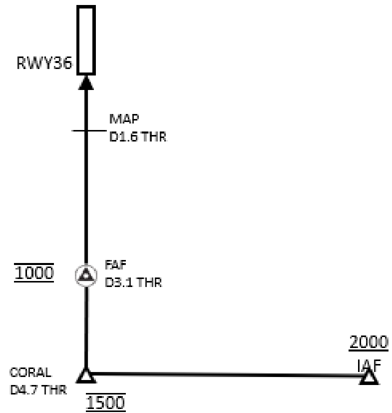


Figure K-5. Diagram of flight plan for AVO-A2, scenario 3

a) This group was provided very basic and short ground school training about the aircraft's electrical system, battery systems, and electrical abnormal and emergency procedures.
b) A message appeared that the system sensed an impending battery failure, engaged a new flight plan, and locked the operator out of control unless the operator overrides the automation.
c) The system returned the vehicle safely to the runway and flew an approach on the wing and landed as an eCTOL.

Figure K-6 shows a view of the flight plan and associated battery failure.

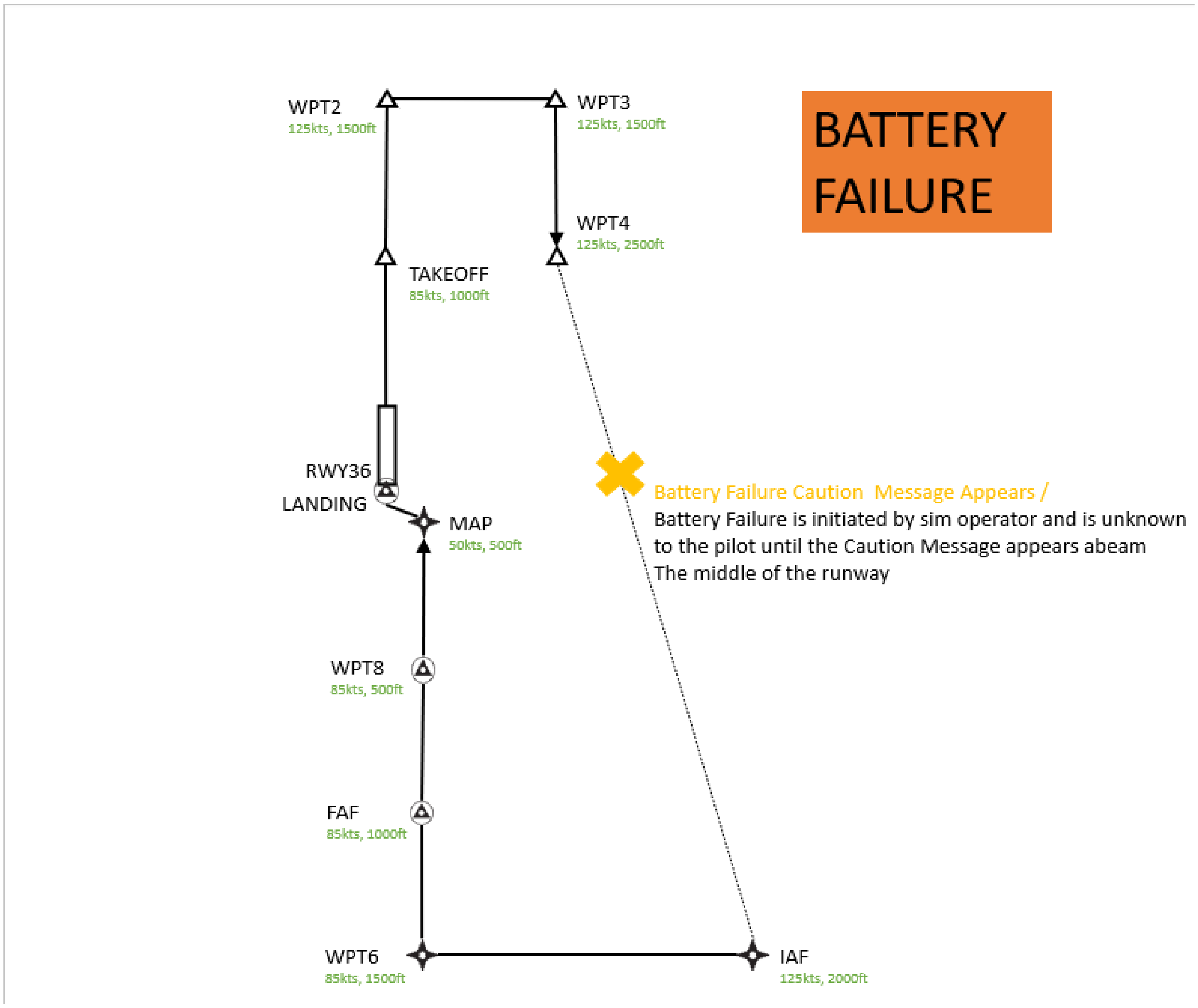


Figure K-6. View of the scenario flight plan and associated battery failure

K.4 Scenario 4 (Instrument approach—alternate)

Instrument approach procedure was performed from an IAF to the landing point on the runway and then the aircraft hovered to heliport. The purpose of this fourth scenario was to evaluate the flight technical error (FTE and the ability of both groups to fly an instrument approach to the runway under a standard approach procedure. The FTE of both groups was then compared to commercial and ATP standards.

<u>SVO-A1 (UCS Group)</u>

The operator engaged the autopilot (AP) after crossing WPT4, and the system flew the instrument approach to the missed approach point (MAP). Then, the pilot disengaged the AP and flews manually to the runaway into a 10-foot hover over the numbers, as the standard operation process. Both the AP section and the manual visual section of the approach was recorded. The manual visual section was analyzed for FTE against the FAA ACS.

a) This group was provided with ground school training about the aircraft's AP system, including transitions.
b) Additional ground school training was provided on the flight control system for manual operations.
c) Flight training was provided to ensure pilots could manually fly the approach from the MAP to landing.
d) To ensure data consistency in all runs, this scenario started after the pilots have reached the MAP.

SVO-A2 (EZ-Fly Group)

The operator engaged the IAF hoop, and the system flew the instrument approach to a 5-foot hover above the runway numbers. The system was engaged the entire time until it began to hover above the runway number as the standard operation process. The whole approach, starting from the IAF to the hover above the runway, was recorded and analyzed from the MAP to the hover above the runway.

This group was provided with a very basic and short ground school training about instrument approach procedures that focused on how to activate an approach, monitor the system, and how to disengage from an approach.

Figure K-7 shows a view of the instrument approach procedure for SVO-A1 and SVO-A2.

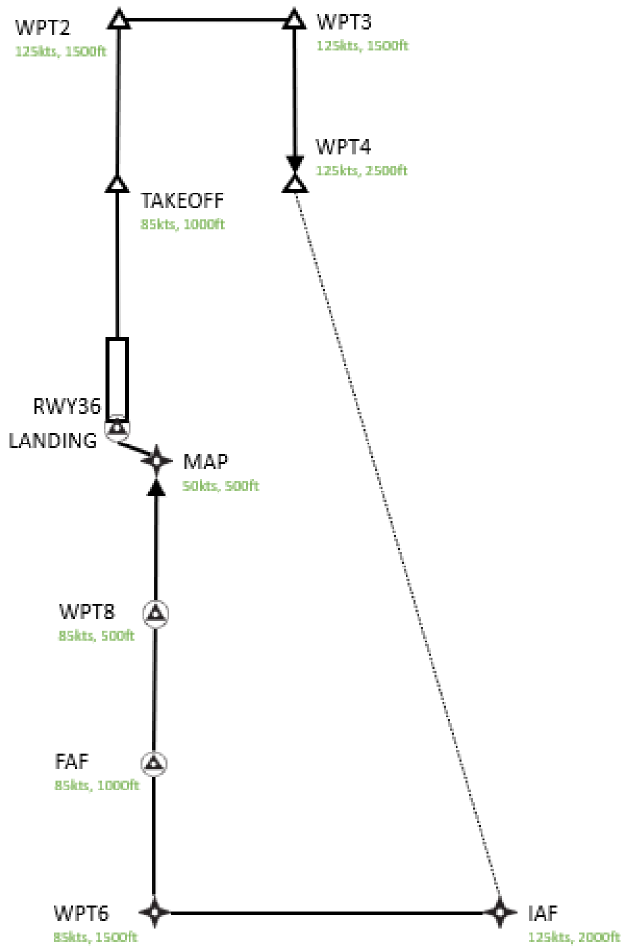


Figure K-7. View of the instrument approach procedure for SVO-A1 and SVO-A2

L Ground school checkout briefings

This appendix present literature from Eagleworks ground school briefings. The literature is unedited but formatted to comply with the FAA report guidelines.

Figure L-1. Eagleworks SVO 1 checkout brief cover page

Eagleworks SVO 1 checkout briefing

General information

- All Electric—Battery Powered
  - Lithium Iron Phosphate battery bank
  - Self protected against:
    - Fire
    - Overcharging
    - Overheating
    - Short circuits
  - Electric motors self protect against
    - Overheating
    - Overspeed
    - Vibration
- Hover time with fill charge: 80 minutes
- Flight time at speed with full charge: 170 minutes
- Cruise speed: 125 mph
- Normal range with reserve and 5-minute hover: 245 nautical miles/280 miles
- Approach speed without lift rotors: 85 mph
- Has four lift rotors, if one fails its counterpart shuts down, and it flies normally but with less maneuverability in hover
- For any electrical faults, the system shuts down the rotor associated with the failure (and its counterpart)
- If the pusher prop system experiences a fault, the aircraft can glide, and the lift rotors can be used to land

- Can take off or land using a runway without hovering, can take off or land vertically and transition to cruise
- Fly-by-wire control system is triple redundant, so that it continues to operate but may reduce manueverability

SVO1 has a typical glass PFD with synthetic vision (Figure L-2). The aircraft has Automatic GCAS which prevents the aircraft from flying into terrain or obstacles. It automatically comes on. It can be turned off by pressing the red button on the sidestick.

Figure L-2. Primary SVO1 display

The waypoints in your flight plan are also shown on the map. They are numbered as shown (Figure L-3). This gives you an overall view of where you are going and how you will get there. The blue fighter jet symbol is your location. It moves on the map to show your present position.

There is also a profile view. This view “straightens out” your path and depicts the vertical part of your path. The same waypoints from your flight plan are also depicted on the profile view.

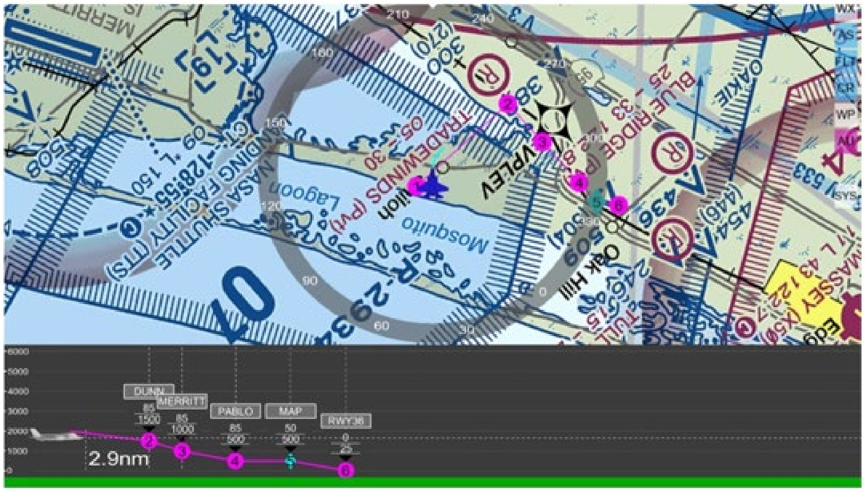


Figure L-3. Map and profile views of waypoints

Figure L-4. Pilot control setup

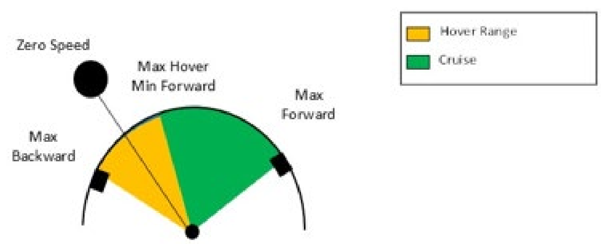


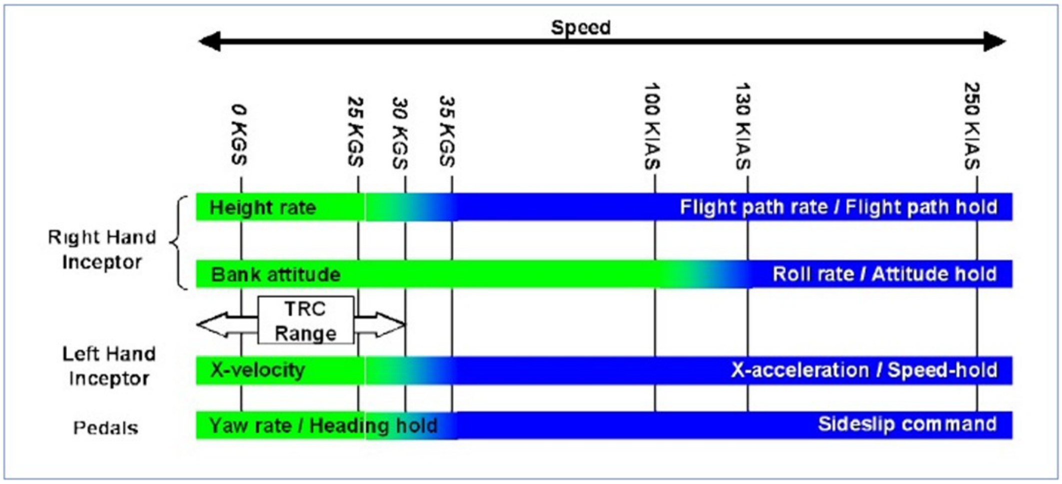
Figure L-5.Diagram of pilot command limits

Table L-1. Pilot control descriptions

	Hover	**Transition**	**Fast forward**
Stick (control wheel) fore and aft	Rate of climb, centered holds attitude	Blends from hover commands to fast-forward commands	Flight path rate (G loading), centered holds one G and current vertical paths

<table>
<tr><th></th><th>Hover</th><th>Transition</th><th>Fast forward</th></tr>
<tr><td>Stick (control wheel) left and right</td><td>Lateral speed relative to earth, centered holds position laterally</td><td>Transitions from lateral speed commands to bank angle command then transitions to roll rate command as the aircraft accelerates past Vref for a run-on landing</td><td>Roll rate, centered holds current bank angle</td></tr>
<tr><td>Speed command lever</td><td>Longitudinal speed relative to earth, spring loaded to zero speed</td><td>Blends form ground speed commands to air speed commands</td><td>Airspeed, friction hold</td></tr>
<tr><td>Pedals</td><td>Yaw rate centered holds heading</td><td>Blends from hover commands to fast-forward commands</td><td>Sideslip center commands zero body axis lateral acceleration</td></tr>
<tr><td colspan="4">
There is a detent to push through to go from Max Hover Speed to Minimum flight Speed.
There is a detent to push through to go from Minimum Flight Speed to Max Hover Speed.
There is a spring ramp starting at zero hover and going back to Maximum Backward Hover Speed.
Friction above zero up to Maximum Flight Speed.
</td></tr>
</table>

Vref = Reference speed



TRC: Translational Rate Command

Below about 30 knots ground speed you command speed of motion
The lift rotors turn on and off automatically depending on speed
Above about 120 KIAS it flies just like an airplane except that you cannot stall, overbank or overspeed

Figure L-6. Translational rate commands

Emergency and abnormal conditions unique to electric VTOL aircraft

If a lift rotor motor or its drive system fails, an amber annunciation appears on the PFD indicating this failure. The aircraft manages the failure as best it can given the operational lift rotors. The aircraft will fly normally, except that its maneuverability is not as quick as normal so care should be taken to fly as smoothly as possible.

If a second lift rotor fails, an RED warning is annunciated along with a warning horn. This indicates that vertical flight is not possible and immediate transition to wing-borne flight is required to maintain control. A normal landing as a conventional airplane can then be made. Safe autorotation is not possible.

There is also a Power Panel that shows the condition of your electrical power system. It shows the energy level in the battery bank, the power being used, the temperature of the hottest motor, the temperature of the hottest inverter, the temperature of the hottest battery cell and the battery voltage. Just like for a piston powered airplane, if any of the indications start getting outside of the normal (green) range, (like cylinder temp in a piston powered airplane), it indicates that something is not normal.

Figure L-7. Power Panel

Warning lights feature two different colors.

YELLOW LIGHT—Amber-colored warning lights indicate a moderate problem that requires timely, though not necessarily immediate, attention.

Abnormal procedures: Regardless of the system the abnormal procedure for a yellow light is stay on the wing as soon as practical. Landing on the rotors is not advised.

RED LIGHT—Red-colored warning lights indicate a serious problem that requires immediate attention.

Emergency procedures: Regardless of the system the emergency procedure for a red light is stay on the wing or transition on the wing as soon as practical. Land as soon as practical.

Figure L- 8. Eagleworks SVO 2 checkout briefing cover page

Eagleworks SVO 2 checkout briefing

General information

- All Electric—Battery Powered
    - Lithium Iron Phosphate battery bank
    - Self protected against:
        - Fire
        - Overcharging
        - Overheating
        - Short circuits
    - Electric motors self protect against
        - Overheating
        - Overspeed
        - Vibration
- Hover time with fill charge: 80 minutes
- Flight time at speed with full charge: 170 minutes
- Cruise speed: 125 mph
- Normal range with reserve and 5-minute hover: 245 nautical miles/280 miles
- Approach speed without lift rotors: 85 mph
- Has four lift rotors, if one fails its counterpart shuts down, and it flies normally but with less maneuverability in hover
- For any electrical faults, the system shuts down the rotor associated with the failure (and its counterpart)

- If the pusher prop system experiences a fault, the aircraft can glide, and the lift rotors can be used to land
- Can take off or land using a runway without hovering, can take off or land vertically and transition to cruise
- Fly-by-wire control system is triple redundant, so that it continues to operate but may reduce manueverability

Weight and balance

It is important that you load your aircraft correctly. If you put too many people on board or exceed the weight carrying capability of your aircraft the aircraft may be unsafe. If you put excessively heavy items in the baggage compartment the same is true. Your aircraft has built-in weight and balance calculator. Simply put the weight of each occupant and cargo in the right location and the system will calculate your weight and balance for you. If you are within limits, the boxes will illuminate in green. Green means GO.

The SVO2 primary display shows synthetic vision, the waypoints on the flight plan, commanded and actual air speed, commanded and actual altitude, and the flight mode (Figure L-9).

Figure L-9. Waypoint display and control panel showing green condition

Normal operating mode is the FLT PLAN mode. Its components (automatically commanded altitude, waypoints) are identified by the magenta color (Figure L-10).

Figure L-10. Primary SVO2 display

Waypoints are points in space (location and altitude) and may also have speed limits. A flight plan is made up of a series of waypoints. A flight plan is automatically created when you tell the flight planner where you are and where you want to go. This flight plan is automatically loaded into the airplane for you (Figure L-11). Simply select the flight plan and engage it.

Figure L-11. Flight plan display

Sometimes there are special instructions that Air Traffic Control want you to follow. That is what the steering wheel is for. You can manually control the direction and altitude of the aircraft by turning the wheel and pushing or pulling on it. When you do this, you go to a manual mode that is identified by green elements. To get back to FLIGHT PLAN mode, change the directionof the airplane manually towards a waypoint (magenta ring). The diamond shows the direction of the airplane. When the diamond is inside a ring let go of the steering wheel and the airplane will re-enter flight plan mode.

The waypoints in your flight plan are also shown on the map (Figure L-12). They are numbered as shown. This gives you an overall view of where you are going and how you will get there. The blue fighter jet symbol is your location. It moves on the map to show your present position.

There is also a profile view (Figure L-12). This view “straightens out” you path and depicts the vertical part of your path. The same waypoints from your flight plan are also depicted on the profile view.

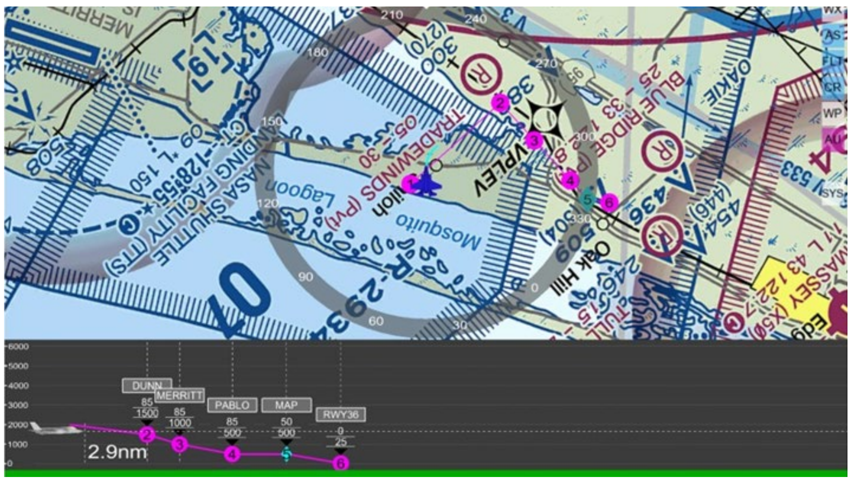


Figure L-12. Waypoint map with profile view


Figure L-13. Pilot command console

Table L-2. Pilot command controls

Vehicle motion	Pilot control	Comments
Turn	Steering wheel rotation	Spring loaded to center. Centered holds track above about 25 kt ground speed and heading less than about 15 kt ground speed
Climb/descend	Steering wheel fore/aft or thumb wheel or up/dn switch on wheel Climb/descent hold button if no up/dn wheel or switch	Spring loaded to center. Centered holds altitude. Pressing the thumb wheel or switch commands altitude hold. Pressing the climb/descent hold button locks the wheel climb/descent position. Pressing it again releases it. Moving the wheel in or out releases it.
Longitudinal speed target	Knob or wheel	First motion syncs to the current speed.
Longitudinal speed adjustment	Longitudinal movement of joystick	Momentarily modifies the speed target which also affects the acceleration rate. Centered does not modify the speed command and uses the default acceleration rate which is proportional to speed error.
Lateral speed	Lateral movement of joystick	Commands lateral speed. Centered commands coordinated flight and zero lateral speed.

Power system display and emergencies

This display is mostly intended for maintenance and troubleshooting. You need not be concerned with it. However, for owners who fly the same airplane consistently, they can monitor small changes over time which can reduce maintenance costs by fixing small issues before they become major ones.

The aircraft is designed to deal with all possible power system failures. If the aircraft is hovering, and it cannot sustain a hover, it will settle to the ground. If the aircraft is already at speed, it will prevent the aircraft from hovering and fly to a safe airport and land there (which may not be your preferred destination). In other cases, it may just turn directly towards your destination even though the flight plan shows a different route there to fit traffic better. In all cases, there is no pilot action required—the airplane will get you to the ground safely if at all possible.

If there is a failure of the power system, it will be shown on the display and owners can then describe the indications to the maintenance personnel. Air traffic control will be notified of failure without any required action.

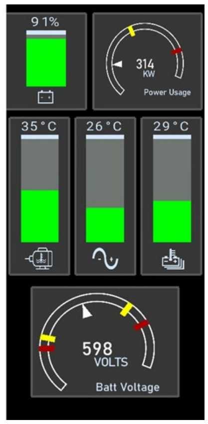


Figure L- 14. Sample display panel