# A.1 Certification Test Case to Validate sUAS Industry Consensus Standards

A.1 Final Report

30 September 2016

Final Report

# NOTICE

**Legal Disclaimer:** The FAA has sponsored this project through the Center of Excellence for Unmanned Aircraft Systems. However, the agency neither endorses nor rejects the findings of this research. The presentation of this information is in the interest of invoking technical comment on the results and conclusions of the research.

## Technical Report Documentation Page

**Title**: A.1 Certification Test case to Validate sUAS Industry Consensus Standards: Final Report

**Report Date:** 30 September 2016

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*Appendix C is not included in the publicly releasable version of this report due to copyright of ASTM F38 standards.

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| | |
|---|---|
| AFM | Aircraft Flight Manual |
| AW | Airworthiness |
| BVLOS | Beyond Visual Line of Sight |
| C2 | Command and Control |
| CONOPS | Concept of Operations |
| CoW | Certificate of Waiver |
| DAA | Detect and Avoid |
| D&C | Design and Construction |
| FAA | Federal Aviation Administration |
| FT | Flight Test |
| KSU | Kansas State University |
| LSA | Light Sport Aircraft |
| MOC | Method of Compliance |
| NAS | National Airspace System |
| NIAR | National Institute for Aviation Research |
| ORA | Operational Risk Assessment |
| QA | Quality Assurance |
| SOW | Statement of Work |
| sUAS | Small Unmanned Aircraft System |
| SVP | Standards Validation Project |
| TC | Type Certificate |
| TIM | Technical Interchange Meeting |
| UA | Unmanned Aircraft |
| VLOS | Visual Line of Sight |

## EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) tasked Kansas State University (KSU), in partnership with Wichita State University's (WSU) National Institute for Aviation Research (NIAR), to evaluate the ASTM F38 Standards as a certification basis for small unmanned aircraft systems (sUAS). Throughout this project, referred to as ASSURE A1, the research team analyzed the ASTM F38 standards to identify gaps in the standards as well as compliance issues that manufacturers and operators may encounter when using the standards as a basis for certification through 14 CFR 21.17(b).

One of the gaps identified in previous research was the lack of flight test requirements for sUAS. As part of Task 1 of the ASSURE A1 statement of work, the research team created an F38-based Flight Test Framework. The resulting framework was deemed insufficient for use, so a gap analysis was conducted to identify areas where the F38 standards were lacking. A significantly more comprehensive flight test framework was then compiled and delivered as an extension of the original statement of work.

This report provides a summary of the gaps and issues that were identified as part of ASSURE A1 research, shows where the ASTM F38 standards do not adequately address certification flight testing, and describes the steps taken by the research team to fill in flight test gaps in the ASTM standards. Additionally, this report recommends that the ASTM F38 standards be revised to take certification flight testing into account, adapting the design and construction (D&C) standards to account for flight testing as a primary method of compliance. Additional recommendations are documented in the form of a compliance checklist.

Compliance findings were shared throughout the research project with both the FAA Small Airplane Directorate and the ASTM F38 Committees. In response to this ongoing collaboration, the F38 community is already making improvements to the standards. Most notably, the Flight Test Framework recommendations have been directly implemented by the D&C group, which is working to create an updated design, construction, and testing standard.

# 1 INTRODUCTION

This research effort, "Certification Test Case to Validate sUAS Industry Consensus Standards," referred to as ASSURE A1, was undertaken in response to a research requirement provided by the AFS-88 research sponsor through ASSURE, the FAA's Center of Excellence for UAS research. It is part of a coordinated effort to further the FAA's goal of determining acceptable criteria for sUAS type certification and establishing a clear path for OEMs to follow.

The following sections describe the objectives and outcomes of this FAA-sponsored research conducted by Kansas State University (KSU) and the National Institute for Aviation Research (NIAR). Previous research related to this project is also described in the background section as this project's deliverables build upon this previous work.

## 1.1 PURPOSE

This project supports ASTM F38 standards development by theoretically validating certification strategies for a fixed-wing sUAS (weighing less than 55 pounds) for operations conducted within visual-line-of-sight (VLOS). It aims to identify airworthiness (AW) gaps and compliance issues. This research also provides recommendations for a flight test (FT) program for sUAS certification. The following questions were provided by the sponsor to be answered through this research:

a. Are the ASTM F38 standards suitable for use as a certification basis for sUAS?
b. With which ASTM F38 standard requirements are compliance difficult or overly burdensome?
c. What are the gaps in the ASTM F38 standards with regards to assuring airworthiness and safe integration of sUAS into the National Airspace System (NAS)? Are safety-of-flight-critical hazards adequately addressed by the standard requirements?
d. Is a flight test program feasible using the ASTM requirements as a framework?

These research questions stem from the increasing demand for sUAS certification, for which a high percentage of applicants are new to the aircraft certification process; a need has been identified for explicit flight test requirements in the ASTM F38 standards. Existing FAA flight test requirements for manned aircraft are, in many cases, overly stringent or not directly applicable to sUAS which drives the need for sUAS-specific flight test requirements.

## 1.2 OUTCOMES

The research task plan and outcomes requested by the sponsor are detailed in the following table. During the first task, it became apparent that an F38-based Flight Test Framework was insufficient; therefore, the research team decided to provide tasks that go beyond the statement of work (SOW). The research team conducted a gap analysis to highlight gaps and created a thorough list of sUAS flight test requirements. For the second task, compliance issues and gaps were reviewed and the Compliance Checklist was updated. Table 1 outlines the project tasks and associated deliverables.

*Table 1 - Research Outcomes*

| Task | Outcomes | Deliverable |
|---|---|---|
| 1. Flight Test Program Development | Flight Test Report documenting the proposed F38-based flight test program | **Deliverable 1:** Flight Test Framework Portfolio (28 Dec 2015) |
| | Gap Analysis showing a comparison of flight test requirements (additional to SOW) | **Deliverable 2:** Comprehensive FT Framework and Report (31 March 2016) |
| | Recommended comprehensive flight test framework and Issues Paper documenting issues with difficulty of showing compliance (additional to SOW) | |
| 2. Compliance Findings | Compliance Findings Report | **Deliverable 3:** Compliance Findings Report Portfolio (30 June 2016) |
| | Issues Paper documenting issues with difficulty of showing compliance | |
| 3. Final Report | FY16 report documenting data, analysis, findings of the project, recommendations and lessons learned. | **Deliverable 4:** A1 Certification Test Case to Validate sUAS Industry Consensus Standards: Final Report (30 Sept 2016) |
| 4. Technical Interchange Meetings (TIMs) | Meeting notes capturing the discussions and action items from each TIM. | Monthly presentations |
| | Monthly Status Reports | |

## 1.3 BACKGROUND

This research builds upon a prior KSU/NIAR research project, the Standards Validation Project (SVP). The SVP was an FAA sponsored research effort conducted September 2013 to September 2015, prior to the UAS COE award to ASSURE. The primary goal of the SVP was to identify areas where the standards could be improved by evaluating how they could be applied to a specific aircraft. The SVP utilized a mock certification process to identify general compliance issues and gaps as well as provide standard revision suggestions. The major deliverable for the SVP project was a Compliance Checklist, which is a spreadsheet containing all the requirements (line items) in each F38 standard. The results of the SVP research stimulated discussion amongst the FAA and F38 Committees, culminating in initiatives to revise the F38 standards. The second phase of the A1 ASSURE research involved revising and updating the Compliance Checklist initially developed in the SVP.

# 2 METHODS

ASSURE A1 research was broken into two primary tasks. Task 1 focused on flight testing which plays a key role in sUAS certification. The primary objective of Task 1 was to assess flight test requirements in the ASTM F38 standards, identify issues and gaps related to flight test requirements, and provide recommendations to better define sUAS flight testing. Task 2 consisted of evaluating the standards for compliance issues and updating the Compliance Checklist from the SVP. This task also involved reviewing the Comprehensive Flight Test Framework for anticipated compliance issues.

The following sections describe the methods used to evaluate flight test requirements, first by searching within the F38 standards, then through a gap analysis and evaluation of commuter and light sport aircraft (LSA) flight test requirements. It also covers the methodology used for the Compliance Checklist review in Task 2.

Table 2 lists the standards evaluated this year, and Table 3 lists the unpublished ASTM working documents currently in development which were not evaluated during this research.

*Table 2 - ASTM F38 Standards Evaluated*

| Designation | Abbrev. | Title |
|---|---|---|
| ASTM F2908-14 | AFM | Standard Specification for Aircraft Flight Manual (AFM) for a Small Unmanned Aircraft System |
| ASTM F2909-14 | Maint. & AW | Standard Practice for Maintenance and Continued Airworthiness of Small Unmanned Aircraft Systems |
| ASTM F2910-14 | D&C | Standard Specification for Design and Construction of a Small Unmanned Aircraft System |
| ASTM F2911-14e1 | Prod. Accept. | Standard Practice for Production Acceptance of Small Unmanned Aircraft System |
| ASTM F3002-14a | C2 | Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems |
| ASTM F3005-14a | Batt. | Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems |

*Table 3 - ASTM F38 Standards Currently in Work*

| Designation | Title |
|---|---|
| WK31391 | New Specification for Testing of Small Unmanned Aircraft System (sUAS) |
| WK50655 | Practice for Software Dependability for sUAS |
| WK52059 | Specification for Extended/Beyond Visual Line of Sight Small Unmanned Aircraft System (sUAS) Operations |
| WK52089 | Specification for Operation Over People |
| WK53403 | Methods to Safely Bound Flight Behavior of UAS Containing Adaptive Algorithms |

## 2.1 TASK 1A - F38 BASED FLIGHT TEST FRAMEWORK

For the first subtask, an F38-Based Flight Test Framework was compiled by reviewing the ASTM F38 standards and identifying requirements that could and would likely use flight test as a method of compliance (MOC), specifically focused on certification-type requirements. In practice, manufacturers may choose to flight test instead of or in support of ground test, simulation, or analysis, but the scope of this effort focused on minimum flight test requirements rather than the full realm of flight test possibilities. Findings from this effort are discussed in Section 3.1.

## 2.2 TASK 1B - GAP ANALYSIS OF FLIGHT TEST REQUIREMENTS

For the second subtask, existing flight test requirements from the resources listed in Table 4 were compiled into a single document for side-by-side comparison. To enable comparison of standards with a broad range of rigor, requirements for commuter aircraft, LSA, and UAS were considered. The organizational structure of the Part 23 standard was used to outline the document. Applicable ASTM F37 (LSA) and F38 (sUAS) requirements were sorted and grouped with associated Part 23 requirements to help identify gaps in the F38 standards and support the development of a Comprehensive Flight Test Framework.

*Table 4 - Resources for Flight Test Requirements*

| Document | Title |
|---|---|
| *ASTM F38 Standards* | |
| ASTM F2910-14 | Standard Specification for Design and Construction of a Small Unmanned Aircraft System |
| ASTM F3002-14a | Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems |
| ASTM F2908-14 | Standard Specification for Aircraft Flight Manual for a Small Unmanned Aircraft System |
| *ASTM F37 Standards* | |
| ASTM F2245-15 | Standard Specification for Design and Performance of a Light Sport Aircraft |
| Draft AC 20-XX-XX | Design Standards and Assumptions for Type Design Approval Under 14 CFR 21.17(b) of Fixed Wing Unmanned Aircraft Systems (UAS) |
| AC 23-8C | Flight Test Guide for Certification of Part 23 Airplanes |

## 2.3 TASK 1C - COMPREHENSIVE FLIGHT TEST FRAMEWORK

For the third subtask, the ASSURE A1 team developed a more comprehensive framework and report to capture traditional flight test requirements and address items noted within the gap analysis. To develop the framework, the research team reviewed each Part 23 Subpart B requirement and the related ASTM requirements to determine if and how they applied to fixed-wing sUAS. There were some manned aircraft requirements that were relevant to unmanned aircraft (UA) but required modification to accommodate the unique nature of unmanned systems. In these scenarios, a flight test requirement specifically for fixed-wing sUAS was developed collaboratively among the team. This method allowed accepted organizational structure, verbiage, practices, procedures, and performance benchmarks (if applicable) from the manned aircraft to be maintained.

For unique sUAS areas that are not addressed in manned aircraft, new requirements were created specifically for sUAS. Elements of the 14 CFR Part 23, ASTM F37 LSA, and the ASTM F38 sUAS standards were utilized, and together allowed for the creation of a comprehensive set of flight test recommendations. This framework of recommendations acts as a hybrid between all of the applicable standards and is intended as a reference for flight testing of sUAS.

Regular reviews were held with FAA flight testing subject matter experts at the Small Airplane Directorate in Kansas City throughout the development of the Flight Test Framework. The intent was to create a comprehensive set of sUAS requirements that reference well-established flight test practices. It is anticipated that certification applicants will use a subset of these flight test requirements as needed to mitigate the risks associated with a specific aircraft and Concept of Operations (CONOPS).

## 2.4 TASK 2 - COMPLIANCE FINDINGS

Task 2 of the ASSURE A1 research project focused on identifying requirements in the F38 standards for which compliance is difficult or overly burdensome (referred to as "compliance issues"), as well as identifying gaps in the standards with regards to assuring airworthiness and safe integration into the NAS. Task 2 utilized a methodology similar to the SVP project and builds upon previous research findings. A graphical depiction of this process is reflected in Figure 1.

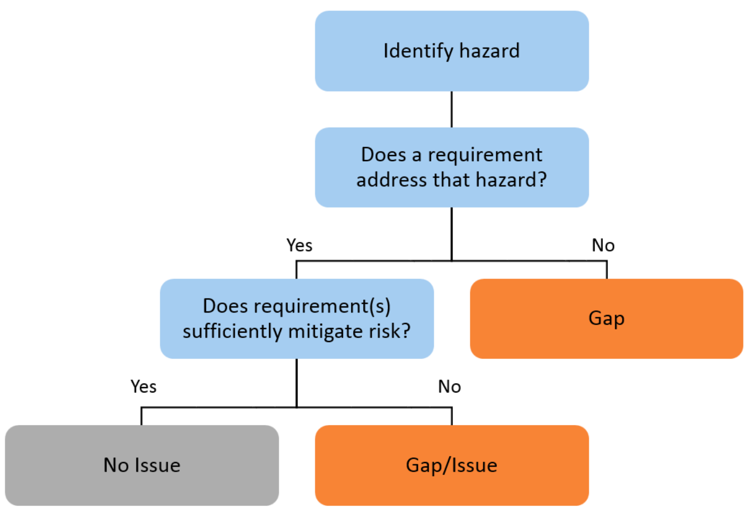


*Figure 1 - Risk and Gap Analysis Flow Chart*

Generally, a compliance checklist is part of a Certification Plan – a starting point for establishing the certification basis. This document typically defines the requirements to which compliance will be shown, as well as the methods that the applicant intends to use to show compliance. As part of the SVP, a comprehensive Compliance Checklist was generated that includes all requirements from each F38 standard. This was used to track compliance remarks, including issues and suggested line-by-line revisions. During the SVP, a thorough review of the requirements in each standard was conducted to identify specific compliance issues as well as general gaps in the standards. First, a high level operational risk assessment (ORA) was conducted to identify safety-of-flight critical hazards. This ORA was based upon KSU's typical CONOPS for the Penguin B sUAS, a 47-pound aircraft, and assumed that operations were conducted in a remote area within VLOS. The risk assessment listed the fundamental hazards associated with the CONOP and estimated the risk for each hazard. Next, hazards were matched with requirements and when no requirement was found to mitigate the hazard, a gap in the standards was documented. This gap analysis process initiated a list of gaps and served as a starting point for generating the issues list and associated issue codes within the Compliance Checklist.

A sample of the Compliance Checklist is shown in Figure 2. Each row contains a section/line from a given standard. The columns indicate the standard, section number, section text, method(s) of compliance (MOC), compliance remarks indicating potential issues, suggested revisions, issue codes, and whether or not the candidate sUAS was expected to comply with the requirement. The Compliance Checklist serves as the primary source of guidance for revisions to the standards and has demonstrated to be a valuable tool for the FAA when guiding applicants through the 14 CFR Part 21.17(b) certification process. It is currently being used to inform the certification process for sUAS, and is also being used to inform revisions to the standards.

| STANDARD | PARAGRAPH # | TESTED FOR COMPLIANCE | DESCRIPTION | MOC | OEM MOC | COMPLIANCE REMARKS | SUGGESTED REVISIONS | REFERENCED REPORT | ISSUE CATEGORY | EXPECTED TO COMPLY (PASS, FAIL, UNKNOWN, or N/A) |
|---|---|---|---|---|---|---|---|---|---|---|
| F2910-14 (D&C) | 5.1.8.2 | | REDACTED | FT, AN, DE, GT | FT, DE | Demonstrating compliance withthis requirement would pose a significant risk to the aircraft. Compliance does not seem feasible for an entity other than a manufacturer unless multiple airframes are available for testing. | This seems overly burdensome for an sUA. For many sUA, this would likely result in a crash, but may not pose a safety risk, if not operating over people. Recommend scrapping this requirement for general operations in remote locations and making this a requirement for operations over people and/or BLOS operations. | | NI | FAIL |
| F2910-14 (D&C) | 5.1.9 | | | AN, DE | DE | Demonstration of fastener integrity across all operational and environmental ranges might require a substantial test regime, unless we can use previous research/testing on similar fasteners. | Complying with "remain secure" is not measureable. Recommend rewording "shall" with "should," or listing suggested fasteners like lock nuts, thread-lock, rivets, etc. | | BU, NM | UNKNOWN |
| F2910-14 (D&C) | 5.1.10 | | | DE | DE | Panels and components that may be quickly removed or opened will be identified and a determination made if there are improvements necessary to highlight their status. | Recommend removing the word, "Quickly." Instead, add a requirement that it should be possible to determine hatch status visually.<br><br>"The sUAS should be designed and constructed so that it is possible to visually determine that all doors, panels, and hatches that can be opened are secured before takeoff." | | RW | UNKNOWN |
| F2910-14 (D&C) | 5.1.11 | | | | | | | | - | - |
| F2910-14 (D&C) | 5.1.11.1 | | | AN, DE | GT, DE | All materials incorporated in the design will be cataloged and their properties identified as suitable or not suitable for the expected operational use.<br><br>Make a list of parts and materials. Comment on each. | Reword or delete this requirement. It seems redundant with other strength/structural requirements within this standard. | | RD, RW | UNKNOWN |
| F2910-14 (D&C) | 5.1.11.2 | | | GT, AN, DE | DE, AN | Structure will be reviewed to determine areas that use, or could use, energy absorbing configurations. | This requirement is ambiguous. Recommend removing this requirement altogether. It is difficult to demonstrate compliance.<br>OR<br>Reword to: "Energy absorbing structure should be used where practical to do so, such as nose cones, leading edges, or parts of the aircraft that are most likely to impact an object in the event of an accident or mishap." | | NM, RW | UNKNOWN |

*Figure 2 - SVP Compliance Checklist Sample*

During Task 2 of the A1 research, the research team updated the Compliance Checklist to improve both its usability and effectiveness as a compliance tool. The following activities and changes were made to the Compliance Checklist and are discussed in greater detail in subsequent sections of this paper:

- Incorporation of the Comprehensive Flight Test Framework through the addition of a new spreadsheet tab
- Classification of requirement types to emphasize distinctions through the addition of a "Requirement Type" column

- Review of MOCs and notation of requirements for which flight testing could serve as the primary MOC through the addition of a "FT" column
- Review of Compliance Checklist for compliance issues and gaps

### 2.4.1 Incorporation of the Flight Test Framework

The Comprehensive Flight Test Framework was added as a separate tab within the Compliance Checklist spreadsheet. Adding flight test requirements to the Compliance Checklist is a natural extension of the work that incorporates the results from Task 1. Compliance remarks were added to the Flight Test Framework during its incorporation into the Compliance Checklist.

### 2.4.2 Classification of Requirements

The ASTM F38 standards include different types of requirements, ranging from less stringent general design guidelines to certification requirements, and sUAS certification applicants are not required to show compliance to every requirement for certification. This is because the standards were not originally written with certification as the main objective and the standards have evolved for a range of CONOPS and sUAS equipage.

For certification, applicants select appropriate ASTM F38 requirements to mitigate risks. In this process, requirements deemed important by aviation authorities could be overlooked due to the lack of distinction between certification requirements and general design guidance. Furthermore, critical safety concerns may not be sufficiently addressed if established baselines are not well defined for all users. The objective of this research subtask was to highlight a potential baseline set of requirements for applicants to use during sUAS certification.

To distinguish between certification requirements and general guidance, the ASTM F38 requirements were labeled with the classifications defined in Table 5. It should be noted that the classification of requirements and guidance was not as simple as distinguishing between "shall," "should," or "may" within each requirement. Statements that described a best practice or general methodology were labeled as design or operational guidance, regardless of whether it contained a "shall" or "should." Statements that are designated as guidance (design or operational guidance) are important, but compliance to these may not be required for certification; in fact, it may not be possible to demonstrate compliance because these items are appropriately vague. As shown in Figure 3, a new column has been added to the Compliance Checklist to label different types of requirements/guidance.

*Table 5 - Classification of Requirements and Guidance*

| Classification | Intent |
|---|---|
| Certification Requirement | Compliance may be needed for sUAS type certification, as deemed necessary by a risk assessment. |
| Design Guidance | Compliance to these statements is not deemed mandatory; they provide best practices for design and construction of a sUAS. |
| Operational Requirement | Compliance with these statements is necessary for safe sUAS operation within a certification effort. These requirements are focused on operational limitations, rather than design assurances. |

| | |
|---|---|
| Operational Guidance | These statements are focused on best-practices for operation and should be utilized when operating a certified aircraft. These items are not relevant to the design process. |

| PARAGRAPH # | DESCRIPTION | REQUIREMENT TYPE | OEM MOC | FT* | COMPLIANCE REMARKS | SUGGESTED REVISIONS | ISSUE CATEGORY |
|---|---|---|---|---|---|---|---|
| 5.1.1 | REDACTED | Certification Requirement | T, GT, DE, R/OP | X | FAA regulates that sUAS be less than 55 lbs. and that operators notify ATC when operating within 5 miles of an airport (FAA Modernization and Reform Act of 2012). Their airspeed is limited to 100 mph. Compliance with these three items would satisfy this requirement. | This requirement is broad. The terms "Performance" and "Limitations" are both vague and undefined. Does this requirement refer to operational limitations?<br><br>If there are any limitations/performance capabilities (other than weight and distance from airport) intended to be covered by this requirement, then there is a gap here. This requirement should | NM |
| 5.1.2 | | Certification Requirement | T, DE | X | Per the draft Part 107 NPRM, the max. airspeed of sUAS must not exceed 100 mph (87 kts). | It does not make sense to specify a max speed based on an unknown operational area (infinite possibilities). Turning radius is affected by airspeed, pilot skill, wind, and to an extent, structural limitations. The pilot should be responsible for remaining in a designated operating area, not the manufacturer.<br><br>Recommend removing "In addition, maximum level flight airspeed should not exceed an airspeed that | BU, RW |
| 5.1.3 | | Design Guidance | R/OP | X | General requirement, reflected in documentation required for demonstrating compliance with other standards. Strict compliance with this requirement is very difficult to demonstrate as a non-OEM. | This requirement is vague. Compliance is very flexible and the intent may not be achieved in practice. | NM |

*Figure 3 - Sample from the Compliance Checklist (Requirements Classification)*

### 2.4.3 Review of Methods of Compliance

Each requirement in the Compliance Checklist has an associated method of compliance. While developing the Flight Test Framework, it was noted that flight testing could be used in lieu of other MOCs to accelerate testing and potentially reduce costs. MOCs for all requirements within the Compliance Checklist were reviewed, and as shown in Figure 4, items were highlighted by means of an "X" in the "FT" column when flight testing might be chosen as a simpler alternative.

| PARAGRAPH # | DESCRIPTION | REQUIREMENT TYPE | OEM MOC | FT* | COMPLIANCE REMARKS | SUGGESTED REVISIONS | ISSUE CATEGORY |
|---|---|---|---|---|---|---|---|
| 5.1.1 | REDACTED | Certification Requirement | FT, GT DE, PR/O | X | FAA regulates that sUAS be less than 55 lbs. and that operators notify ATC when operating within 5 miles of an airport (FAA Modernization and Reform Act of 2012). Their airspeed is limited to 100 mph. Compliance with these three items would satisfy this requirement. | This requirement is broad. The terms "Performance" and "Limitations" are both vague and undefined. Does this requirement refer to operational limitations?<br><br>If there are any limitations/performance capabilities (other than weight and distance from airport) intended to be covered by this requirement, then there is a gap here. This requirement should | NM |
| 5.1.2 | | Certification Requirement | FT, DE | X | Per the draft Part 107 NPRM, the max. airspeed of sUAS must not exceed 100 mph (87 kts). | It does not make sense to specify a max speed based on an unknown operational area (infinite possibilities). Turning radius is affected by airspeed, pilot skill, wind, and to an extent, structural limitations. The pilot should be responsible for remaining in a designated operating area, not the manufacturer.<br><br>Recommend removing "In addition, maximum level flight airspeed should not exceed an airspeed that | BU, RW |
| 5.1.3 | | Design Guidance | PR/O | X | General requirement, reflected in documentation required for demonstrating compliance with other standards. Strict compliance with this requirement is very difficult to demonstrate as a non-OEM. | This requirement is vague. Compliance is very flexible and the intent may not be achieved in practice. | NM |

*Figure 4 - Sample from the Compliance Checklist (Flight Testing MOC)*

#### 2.4.4 Review of Compliance Issues and Gaps

Compliance issues and gaps that were identified during the SVP were reviewed to ensure that they were still relevant. The SVP analysis process was used to identify other issues or gaps in light of Task 1 flight testing findings. Any changes in the issues or gaps found were adjusted in the Compliance Checklist. This is discussed further in Sections 3.4.3 and 3.4.4.

#### 2.4.5 Industry Feedback

Lastly, to ensure that the ASSURE A1 research is relevant to industry, a short summary of this research was shared with a small, approved subset of F38 working group members and Type Certificate (TC) applicants so that feedback on current work and findings could be incorporated into this final report. This industry feedback solicitation paper was reviewed by the Small Airplane Directorate and forwarded to TC applicants and Pathfinder experimental certification applicants. The industry feedback is summarized in Section 3.4.5.

Gathering industry perspective for this report provided two beneficial outcomes. First, the A1 team gained a better understanding of the challenges that applicants face while pursuing a TC, and second, it provided better context for A1 research. This approach allowed assumptions, issues, and gaps that were identified in A1 to be compared with the most current issues that industry is facing. The A1 findings were also weighed against current industry concerns which helped to identify areas where future work is needed.

## 3 RESULTS AND DISCUSSION

The following sections summarize the findings and recommendations generated by the ASSURE A1 research. These sections are intended to relate key findings from each task and provide supporting information. This includes an overview of the F38 Based Flight Test Framework, Flight Test Gap Analysis, Comprehensive Flight Test Framework, and Compliance Findings.

Each of these outcomes was delivered to the FAA and is being utilized by both the FAA and the ASTM F38 committee. The Flight Test Gap Analysis and the Comprehensive Flight Test Framework served as a starting point for discussion about flight test requirements and support the revision of ASTM F2910-14, which defines design, construction, and testing of sUAS.

### 3.1 TASK 1A - F38 BASED FLIGHT TEST FRAMEWORK

One of the research questions in this project was to determine if a flight test program is feasible using the ASTM requirements as a framework. In short, the research findings indicate that revisions are required to make the current F38 standards suitable for a flight test framework. This became evident in the first phase of research when the F38 standards were reviewed for flight test requirements.

This review did not find any explicit flight test requirements. Some F38 requirements imply flight testing as a MOC, but none explicitly state that compliance must be shown through flight testing.

Nonetheless, these implicit flight test requirements were compiled into an ASTM F38-Based Flight Test Framework. This framework, in Appendix A, contains a total of 33 requirements. Nineteen of these were extracted from F2910-14a, which provides practices for the design and construction of sUAS. The remaining fourteen were extracted from F3002-14a, which specifies practices for the design of sUAS command and control (C2) systems.

## 3.2 TASK 1B - GAP ANALYSIS OF FLIGHT TEST REQUIREMENTS

Figure 5 displays a sample of the Flight Test Requirement Gap Analysis deliverable, which was used to compile and compare the flight testing requirements found within the F38 sUAS standards to the F37 LSA standards and the Part 23 commuter aircraft regulations. The organizational structure of Part 23 was used to outline the document; each set of requirements (Part 23, F38, and F37) was given its own column for quick visual comparisons.

In addition to the three columns containing requirements, three more columns are included to act as visual cues. They denoted when a requirement was deemed "Not applicable to sUAS per the ASSURE A1 Team," "Not applicable to sUAS per Draft AC-20-XX," or a "Gap in F38". The flight test requirement gap analysis can be found in Appendix B.

| Line No. | 14 CFR Part 23 - Commuter | F38 - sUAS | F37 - LSA | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|
| 1 | **Subpart B - Flight** | | | | | | |
| 2 | **General** | | | | | | |
| 3 | **§23.21 Proof of compliance.** | | **4.1 Proof of Compliance:** | - | - | X | - |
| 4 | (a) Each requirement of this subpart must be met at each appropriate combination of weight and center of gravity within the range of loading conditions for which certification is requested. This must be shown—<br>(1) By tests upon an airplane of the type for which certification is requested, or by calculations based on, and equal in accuracy to, the results of testing; and<br>(2) By systematic investigation of each probable combination of weight and center of gravity, if compliance cannot be reasonably inferred from combinations investigated. | | [redacted] | - | - | X | - |
| 5 | (b) The following general tolerances are allowed during flight testing. However, greater tolerances may be allowed in particular tests:<br>Item: Tolerance<br>Weight: + 5%, -10%.<br>Critical items affected by weight: + 5%, -1%.<br>C.G: ±7% total travel | | | - | - | X | - |

*Figure 5 - Sample of Flight Test Requirement Gap Analysis*

Table 6 is a tool that quickly shows a high-level review of how the different flight test references compare. The Part 23 Subpart B sections are listed on the left. The ASTM F38 and F37 columns, to the right, indicate if there is an ASTM requirement associated with each section. The Draft AC 20-XX-XX column shows which of the sections were designated as being relevant to sUAS per Appendix A of Draft AC 20-XX-XX. The Recommended Flight Test column indicates if the A1 team determined the section to be relevant to fixed-wing sUAS flight test certification.

Many of the sections contain multiple requirements (subsections), however, each individual requirement is not shown in this consolidated table. To indicate completeness, an "x" is used when all of the requirements within a section have been individually addressed in some form, and a blank indicates none of the requirements in a section have been addressed. A "/" is used when some of the section requirements were addressed, but other requirements in the section were not considered relevant to fixed-wing sUAS. For example, §23.25 Weight Limits has two subsections, (a) Maximum Weight and (b) Minimum Weight. Requirements related to both maximum and minimum weight are included in the F38 standards; therefore, the F38 column contains an "x". The F37 standards address minimum weight but not maximum weight. Therefore, the F37 column contains a "/" to indicate that some subsections were addressed.

*Table 6 - Summary of the Flight Test Comparison*

| Sections of Requirements | F38 - sUAS | F37 - LSA | Draft AC -XX-XX | Recommended FT |
|---|---|---|---|---|
| Part 23 - Subpart B Flight | | | | |
| General | | | | |
| §23.21 Proof of compliance. | | x | x | x |
| §23.23 Load distribution limits. | / | / | x | / |
| §23.25 Weight limits. | x | / | x | x |
| §23.29 Empty weight and corresponding center of gravity. | | / | x | / |
| §23.31 Removable ballast. | x | / | x | x |
| §23.33 Propeller speed and pitch limits. | / | / | / | / |
| Performance | | | | |
| §23.45 General. | | / | / | / |
| §23.49 Stalling speed. | | / | x | / |
| §23.51 Takeoff speeds. | | / | / | x |
| §23.53 Takeoff performance. | | / | / | / |
| §23.55 Accelerate-stop distance. | | / | x | / |
| §23.57 Takeoff path. | | | | |
| §23.59 Takeoff distance and takeoff run. | | | | / |
| §23.61 Takeoff flight path. | | | | |
| §23.63 Climb: General. | | / | / | / |
| §23.65 Climb: All engines operating. | | / | x | x |
| §23.66 Takeoff climb: One-engine inoperative. | / | | x | x |
| §23.67 Climb: One engine inoperative. | / | | x | / |
| §23.69 Enroute climb/descent. | / | | x | x |

| | | | | |
|---|---|---|---|---|
| §23.71 Glide: Single-engine airplanes. | / | | x | x |
| §23.73 Reference landing approach speed. | | | | / |
| §23.75 Landing distance. | | / | | / |
| §23.77 Balked landing. | | / | | / |
| Flight Characteristics | | | | |
| §23.141 General. | | | x | x |
| Controllability and Maneuverability | | | | |
| §23.143 General. | | / | x | x |
| §23.145 Longitudinal control. | | / | | / |
| §23.147 Directional and lateral control. | | / | | x |
| §23.149 Minimum control speed. | | | | / |
| §23.151 Acrobatic maneuvers. | | | | x |
| §23.153 Control during landings. | | | | / |
| §23.155 Elevator control force in maneuvers. | | | | |
| §23.157 Rate of roll. | | | / | / |
| Trim | | | | |
| §23.161 Trim. | | | | / |
| Stability | | | | |
| §23.171 General. | | | | x |
| §23.173 Static longitudinal stability. | / | / | | / |
| §23.175 Demonstration of static longitudinal stability. | / | | | / |
| §23.177 Static directional and lateral stability. | | / | | / |
| §23.181 Dynamic stability. | | / | x | x |
| Stalls | | | | |
| §23.201 Wings level stall. | / | / | / | / |
| §23.203 Turning flight and accelerated turning stalls. | | / | | x |
| §23.207 Stall warning. | / | | / | / |
| Spinning | | | | |
| §23.221 Spinning. | | / | / | / |
| Ground and Water Handling Characteristics | | | | |
| §23.231 Longitudinal stability and control. | / | / | x | x |
| §23.233 Directional stability and control. | | | x | x |
| §23.235 Operation on unpaved surfaces. | | | | x |
| §23.237 Operation on water. | | | | x |
| §23.239 Spray characteristics. | | / | | x |
| Miscellaneous Flight Requirements | | | | |
| §23.251 Vibration and buffeting. | | / | | / |
| §23.253 High speed characteristics. | | | / | / |
| §23.255 Out of trim characteristics. | | | x | / |
| Specific UAS requirements | | | | |
| Command and Control | | | | |
| Ground Control Station | x | | | x |
| Lost Link | x | | | x |
| Fly-Away Prevention | x | | | x |
| Detect and Avoid Systems | | | | |
| TBD | | | | x |
| Safety Equipment | | | | |
| Aircraft Recovery Systems | | | | x |

***ASTM F38 Observations***

Comparing the F38 and Recommended FT columns of Table 6 quickly reveals that the F38 standards do not cover many traditional flight test certification requirements that were deemed necessary in this study. Gaps in the F38 standards exist within performance, controllability and maneuverability, stability, trim, spinning, and ground handling. These gaps reflect an absence of requirements for tests such as takeoff, climb, cruise, flight envelope definition, controllability in different phases of flight, static stability thresholds, allowable oscillations, spin recovery, and envelope protection.

Conversely, there are some UAS-specific areas that are not included in Part 23 Subpart B but are covered by ASTM F38 standards. For example, the ASTM F3002-14a, related to command and control of sUAS, contains requirements for the ground control station, lost link, and fly away protection which were determined to be important requirements for flight test certification of sUAS and were included in the Comprehensive Framework.

***ASTM F37 Observations***

Throughout the development of the Flight Test Framework, ASTM F38 standards were compared to ASTM F37 standards which paved the way for the use of consensus standards for light sport aircraft. This comparison activity focused on ASTM F2245-15, "Standard Specification for Design and Performance of a Light Sport Aircraft" and ASTM F2910-14, "Standard Specification for Design and Construction of a Small Unmanned Aircraft System." One of the major differences between these two standards is their organizational structure. The LSA standard closely mimics the organization of Part 23; titles for the sections and subsections, as well as the order in which they are presented, mirror Part 23. This structure is not used in the sUAS standard; keeping the organizational structure established within Part 23 is recommended to ensure that key aspects of flight testing are addressed.

***Draft AC 20-xx-xx Observations***

Requirements deemed applicable to sUAS per Appendix A of Draft AC 20-XX-XX are listed in Table 6. The Draft AC was included as a reference. However, it was not consulted during the development of the recommended flight test requirements. A high-level comparison of the Draft AC and the recommended requirements shows that the two are fairly similar within the following: general, performance, flight characteristics, stalls, spinning, and miscellaneous flight requirements. Differences are more apparent within controllability and maneuverability, trim, stability, and ground and water handling.

## 3.3 TASK 1C - COMPREHENSIVE FLIGHT TEST FRAMEWORK

The Comprehensive Flight Test Framework contains requirements compiled specifically to aid in flight test certification of fixed-wing sUAS and was developed for a range of aircraft and CONOPS. It also contains comments related to each requirement as well as compliance remarks. A sample of the Comprehensive Flight Test Framework is shown in Figure 6 and the full Comprehensive Flight Test Framework is provided in Appendix C.10 (Redacted).

| Line No.** | Recommended FT | Comments | Compliance Remarks | N/A to sUAS per ASSURE A1 | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or |
|---|---|---|---|---|---|---|---|
| 1 | **Flight Test** | | | | | | |
| 28 | **PERFORMANCE** | | | | | | |
| 29 | **General** | | | - | - | x | - |
| 30 | (a) Test environment shall be standard ICAO atmosphere in still air conditions at sea level. Speeds shall be given in indicated (IAS) and calibrated (CAS) airspeeds. | This is a reasonable carry over from Part 23 and F37. | No Issue | - | (a)(2) | x | - |
| 31 | (b) Performance data must be determined over not less than the following ranges of conditions— (1) Airport altitudes from sea level to 10,000 feet; and (2) Temperature from standard to 30 °C above standard; or (3) The maximum ambient atmospheric temperature at which compliance with the cooling requirements are shown. | The requirement to determine performance numbers for sUAS at altitudes from sea level to 10,000 feet is indicative of the notion that sUAS may be employed from high altitude locations, such as mountain peaks or high deserts on hot days. This may be scaled to CONOPS based upon how and where the sUAS is to be operated. For aircraft that are intended for a fixed remote environment (not over people), this level or rigor may not be needed. However, if an aircraft is intended to be operated in a high-altitude environment, and/or over people, this requirement becomes more important. | This may be overly burdensome for simple CONOPs at low altitudes. | - | - | x | x |
| 32 | (c) Performance data must be determined with the power plant's cooling system operating in the same manner that would be utilized for evaluating its performance. | | No Issue | - | - | x | - |

*Figure 6 - Sample of the Comprehensive Flight Test Framework*

Within the framework, a column titled "Scalable to CONOPS and Equipage" is included to identify requirements that may be scaled. Incorporating scalability helps ensure that requirements maintain an appropriate level of rigor since operational risk of sUAS varies according to CONOPS and system size, complexity, and safety features. For example, operations over people and beyond line of sight are associated with more risk than operations in remote locations or within VLOS. Furthermore, a sUAS may be equipped with built-in systems, such as detect and avoid (DAA) systems, parachutes, or novel features to mitigate risk. Requirements that were deemed less applicable or that may potentially be eliminated for low risk operations were marked with an "X" in this "Scalable to CONOPS and Equipage" column. These requirements need further discussion to determine if and how they may be scaled. With a broad range of sUAS and possible CONOPS, there is no simple way to identify whether a given flight test requirement is scalable in every scenario. Future research and discussion should focus on determining to what degree characteristics of sUAS equipment, safety systems, and CONOPS warrant scaling of individual flight test requirements.

In addition to scaling requirements, selecting a set of requirements that is appropriate for a specific sUAS and CONOPS is recommended. Requiring applicants to comply with the full version of the Comprehensive Flight Test Framework would be overly burdensome. Furthermore, current industry practices, at least for the smaller end of the sUAS spectrum, are not necessarily compatible with some of the recommended procedures that are specified within the framework.

### 3.3.1 Next Steps for the Framework

The Comprehensive Framework is intended to serve as a foundation upon which to develop flight test requirements. Future discussions will be required to establish specific and measureable requirements as well as guidelines for safe procedures for sUAS flight testing. The following highlights some areas to expand and improve the Framework.

#### *3.3.1.1 Beyond Subpart B - Flight*

Part 23 subparts other than Subpart B, such as Subpart C - Structure, Subpart D - Design and Construction, Subpart E - Powerplant, Subpart F - Equipment, and Subpart G - Operating Limitations and Information, have flight test certification requirements which may be applicable to fixed-wing sUAS. Additional work is required to review requirements in these subparts and develop specific flight test recommendations for sUAS. Specifically, Subpart C - Structure will require further discussion to determine if flight testing can be used to meet structural testing requirements. Beyond Part 23, requirements in Part 36 - Noise Standards and Part 91 - General Operating and Flight Rules may also require flight testing and are noted for future research.

#### *3.3.1.2 Multirotor Flight Test*

The Flight Test Framework presented in this document applies only to fixed wing sUAS. Multirotors are an entirely different category of aircraft, and as such, will likely require flight test requirements that are vastly different from those governing both traditional fixed-wing aircraft and helicopters. Concepts such as stability and control, degraded flight modes, and aircraft performance must be evaluated using different criteria. Future research into the development of a separate multirotor flight test framework should focus on identifying key aspects of multirotor flight performance and additional characteristics of multirotor aircraft that lend themselves to flight testing.

#### *3.3.1.3 Additional development of sUAS-specific flight test requirements*

UAS-specific systems or systems which vary from manned aircraft demand the establishment of new flight test requirements. Such items were encountered throughout the research effort. Due to the limited timeframe and scope of this research effort, these items were not fully investigated but were noted for additional discussion, review, and/or research. The following describes the topics requiring further study to support the development of sUAS specific flight test requirements.

***Trim***

In manned aircraft, trim requirements are for relieving stick forces that the pilot must overcome in order to achieve a steady state for cruise. In unmanned aircraft, trim serves the sole purpose of rendering the sUAS in a state of static equilibrium and is often a side effect of an autopilot or flight controller making adjustments as necessary to achieve steady state cruise conditions at a given power setting. Instead of constant manual adjustments by the pilot, sUAS adjustments are made through accelerometer and gyro data interpreted by flight computers. Accordingly, trim requirements were adjusted to be appropriate for sUAS and can be referenced in line 257 of the Flight Test Framework, Appendix C.10 (Redacted).

***Stick control forces***

Stick control forces are addressed in 14 CFR §23.143(c) and ASTM F2245-15: 4.5.1.2, which outline allowable forces for both temporary and prolonged forces on aircraft controls. Unlike manned aircraft, sUAS do not have control sticks with forces that scale to control surface forces, but many sUAS still have a means for manual pilot inputs. The F38 sUAS standards do not address stick forces for sUAS controls or provide a baseline for what would constitute acceptable control forces. Since sUAS may utilize a variety of control devices that range from traditional RC controls to joysticks, joysticks with haptic feedback, keyboards, mice, and track balls, further exploration into the impact of human interaction with these devices for the purpose of sUAS control is required.

***Lateral and directional oscillations***

Additional discussion is required with respect to allowable lateral and directional oscillations, their impact on dynamic stability, the extent to which they should be dampened, and the role autopilots and flight controllers play in both creating and dampening oscillations. An appropriate level of rigor needs to be determined for these sUAS requirements.

***GCS backup power supplies and sUAS endurance***

GCS backup power supplies and sUAS endurance require more investigation to ascertain how requirements and/or flight test guidelines can be derived. It may be necessary to explore different GCS types, power sources, and sUAS with varying capabilities.

***Detect and avoid systems***

Testing of detect and avoid systems was not adequately addressed in the source material, and more research is needed to establish appropriate requirements. Given that such systems are unique to UAS, there are not requirements that address such systems within Part 23 Subpart B or the ASTM F37 light sport standards. Furthermore, F38 standards do not cover detect and avoid systems. Given that the technology is developing and not widely deployed on sUAS at this time, more research is required to determine the extent of flight testing that should be employed to verify and validate the correct function of detect and avoid systems.

***Static stability***

As noted in longitudinal control section of the Comprehensive Flight Test Framework (reference lines 166 through 171 of Appendix C.10 (Redacted)), the recommended flight test states that static stability is to be demonstrated at "low, medium, and high speeds as calculated by a percentage of the maximum airspeed for each aircraft." Further study is required to determine what that percentage should be and whether it will remain a static value or be scalable for aircraft of varying capabilities. Research should focus on basic elements of static stability and establishing guidelines that are scalable to all sUAS, regardless of weight, propulsion system, and platform/configuration.

***High-speed sUAS***

Per 14 CFR Part 107, the maximum ground speed of 87 knots (100 mph) is established for sUAS, however, it is anticipated that sUAS manufacturers may request approval for operations beyond this limitation via a type certificate (TC). Additional research is required to define "high-speed" sUAS, establish general characteristics of these aircraft, and develop flight testing requirements if appropriate. Flight test requirements for high- speed sUAS should emphasize the reduction of risk to people and property on the ground and in the air. The exact method(s) for doing so has yet to be determined. For further commentary, see line 43 of the Flight Test Framework (Appendix C.10 (Redacted)).

## 3.4 TASK 2 - COMPLIANCE FINDINGS

During Task 2, the Compliance Checklist was reviewed and updated. This effort involved incorporating the Comprehensive Flight Test Framework into the Compliance Checklist as well as modifying the Compliance Checklist to improve both its usability and effectiveness as a compliance tool.

### 3.4.1 Classification of Requirements

The classification of requirements in the F38 standards was an exercise performed during this research for two reasons. First, due to the risk-based nature of the certification process in which applicants identify requirements that mitigate risks identified by an ORA, there is potential for important requirements to be overlooked. Highlighting certification-type requirements within the standards may help applicants define a certification plan, and assist regulators by creating commonality among applications.

Secondly, there is a need for balance between prescriptive and non-prescriptive requirements, as evidenced by discussions within ASTM meetings. Because the standards were not originally written with certification as the main objective, there are many requirements that provide design guidelines but are too vague to demonstrate compliance within a certification plan. There are also many operational requirements and limitations that are irrelevant to product design assurances. This activity helps to illustrate the distribution of these different types of requirements to aid future revisions of the standards.

Each line in the Compliance Checklist was categorized as a 1) Certification requirement, 2) Design guidance, 3) Operational requirement, or 4) Operational guidance. The revised Compliance Checklist with the new requirement type column is in Appendix C (Redacted). Figure 7 shows the distribution of these different types of requirements/guidance within each ASTM F38 standard and highlights the prevalence of certification requirements. Some of the ASTM line items were considered design guidance rather than certification requirements, and compliance to these items may not be required for certification.

There are a total of 307 certification requirements, which are 77% of the line items. It is unlikely that an applicant would comply with all of these requirements for certification. Establishing sets of requirements for certain risks or CONOPS would reduce the potential to overlook appropriate requirements, Since waivers are commonly sought for operations such as beyond visual line of sight (BVLOS), operations over people, and night operations, establishing guidance material to direct applicants to specific requirements for each of these operations may be beneficial.

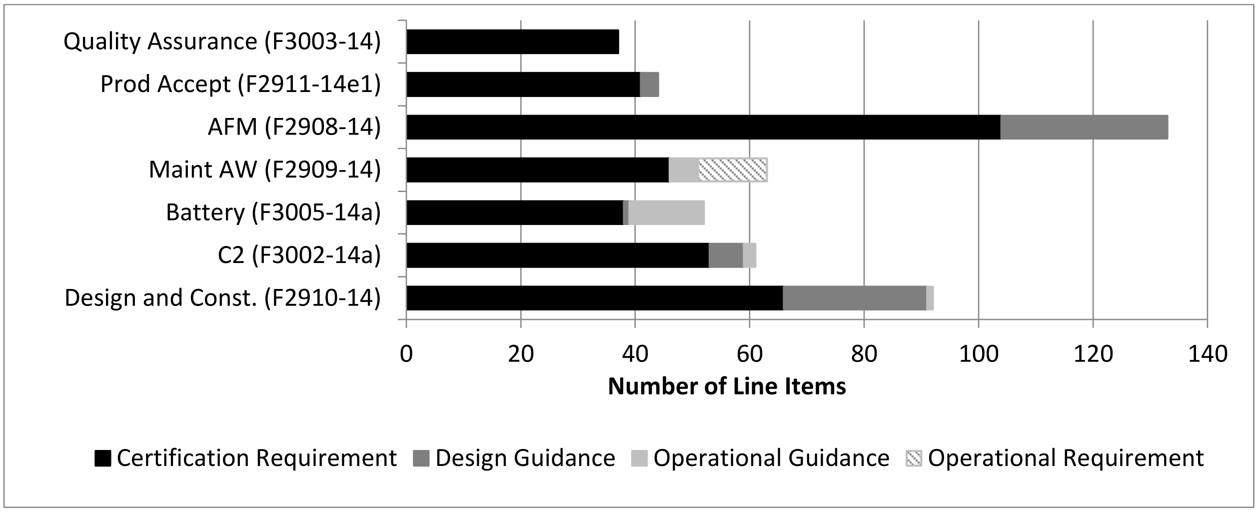


*Figure 7 - Distribution of F38 Requirements and Guidance*

### 3.4.2 Review of Methods of Compliance

Each line item within the Compliance Checklist was also reviewed to determine if compliance could be shown with flight testing in place of alternate MOCs. As shown in Table 7, applicable line items were found in the Design and Construction, Command and Control, and AFM standards. The large percentage of requirements that could utilize flight testing highlights the potential for an increased emphasis on flight testing as part of sUAS certification. Since TC applicants may rely heavily on flight testing to demonstrate compliance, it is recommended that flight testing best practices be established to promote safe, efficient, and uniform procedures.

*Table 7 - Flight Testing in Place of Alternate MOCs*

| F38 Standard | Number of line items | Percentage of the standard |
|---|---|---|
| Design and Construction (F2910-14) | 58 | 61% |
| Command and Control (F3002-14a) | 50 | 81% |
| Battery (F3005-14a) | - | 0% |
| Maintenance and AW (F2909-14) | - | 0% |
| AFM (F2908-14) | 48 | 36% |
| Production Accept (F2911-14e1) | - | 0% |
| Quality Assurance (F3003-14) | - | 0% |

### 3.4.3 Compliance Issues

Compliance issues identified during the SVP were reviewed in light of Task 2 findings and to determine if they are still relevant. Every F38 requirement was evaluated and major and minor compliance issues were identified. Minor issues related to a need for reorganization or rewording of a requirement were previously provided to the F38 Committee for revisions of the standards and are not discussed in this report. However, a list of more significant “major” issues requiring consensus amongst industry stakeholders are provided in Appendix D – Compliance Issues. Table 8 contains a sample of these issues.

The ASTM F38 committee addressed 40% of the major compliance issues noted during the SVP. To indicate which entries have been addressed during the last year, the entry is crossed out (reference Appendix D (Redacted)).

*Table 8 - Sample of Compliance Issues*

| STANDARD | PARA. NO. | PARAPHRASED REQUIREMENT | COMMENTS / REVISIONS |
|---|---|---|---|
| Prod. Accept. F2911-14e1 | 5.1.3.3 | Propeller and rotor balancing | Dynamic balancing is excessive for a small fixed-wing UAS propellers. However, it is recommended that both static and dynamic balancing be required for conventional rotorcraft that utilize rigid, semi-rigid, and/or fully-articulated rotor systems, as well as larger aircraft that are closer to the 55 lb weight limit of sUAS and are powered by internal combustion engines. |
| C2 F3002-14a | 8.2.1 | Undetected bit error rate | Recommend reword to explicitly allow alternate methods for reducing error such as cyclic redundancy check, parity bits, etc. This may require additional study to determine methods. |
| D&C F2910-14 | 5.2.1.3 | Withstanding launch and recovery loads | Recommend specifying how many cycles and clarifying which structures this refers to. This overlaps with 5.2.1.1. |
| C2 F3002-14a | 9.2.6 | Downlink bit-error rate alert | Terminology is inconsistent with previous paragraphs when relating "message error rate" and "bit error rate." Recommend making references to error rate generic so that multiple forms of error detection and preventions may be used. |

### 3.4.4 Gaps within ASTM F38 Standards

One of the research questions and an objective of this research project was to identify gaps in the standards. A list of high-level gaps in the standards was first drafted during the SVP project and reviewed again during the A1 project. Table 9 is a sample from the full list of gaps in Appendix E. Gaps range from the lack of requirements for defining software reliability to the need to define structural load cases and make provisions to allow the standards to address the full range of sUAS from less than 4.4 lbs up to 55 lbs. Some of the gaps have recently been addressed in draft ASTM standards; these are noted by strikethrough in the full table.

*Table 9 - List of Gaps*

| Gap | Comments and Recommendations |
|---|---|
| Insufficient flight test requirements | Production flight test requirements are provided in the standards, but are insufficient to address full type certification flight testing. This overlooks key elements of aircraft performance. |
| No requirements exist for the design and construction of autopilot or flight control systems. | Include specific autopilot requirements in the F3002 standard or develop a new standard to cover the design and construction of autopilot systems. Include requirements for components, critical functions, quality assurance procedures, etc. This overlaps with software verification and validation. |
| No requirements for the design, construction, or production of | Recovery equipment such as parachutes, air bags, nets, traps, and arresting cables are not covered by the standards in their current form. Recommend |

| | |
|---|---|
| complex recovery equipment such as parachutes, air bags, nets, cable recovery systems, etc. | further discussions or research to investigate the necessity of recovery equipment requirements with regards to airworthiness and certification. |
| No requirements for design, construction, and QA of ground control stations beyond simple laptops. | Define requirements for design and construction of complex ground control stations (other than laptops) to include independent design, construction, and production requirements. Focus on functional requirements whenever possible. |

### 3.4.5 Industry Feedback

When the list of compliance issues identified through the research was shared with industry, there was agreement that two of the most significant gaps are the verification of software and autopilot systems. During this research timeframe, the Design and Construction and Command and Control standards did not provide a benchmark or means for verifying the function of components that require rigorous software validation, some of which are safety of flight critical. At the end of September 2016, ASTM published a new software reliability standard. It is unknown whether this new standard "Practice for Software Dependability for sUAS" addresses this gap.

The Flight Test Gap Analysis and Comprehensive Flight Test Framework were also shared with industry TC applicants to solicit feedback on this list of flight test requirements. The Comprehensive Flight Test Framework created in this research was developed to encompass the full spectrum of sUAS and CONOPS, especially beyond Part 107 operations, which are the expected TC applicants. It is anticipated that most OEMs will not seek to comply with the Comprehensive Flight Test Framework, which, in its entirety, could be overly burdensome for small UAS. There are many examples of requirements in the Comprehensive Flight Test Framework that would be unnecessary for sUAS operating in remote environments. For example, an industry representative commented that it is not necessary to determine all V-speeds through flight test for a particular small UAS and relatively low-risk CONOP. Performance testing may not be needed by certain aircraft and CONOPs, and this highlights the need for scalable and selectable requirements driven by the ORA-based process in which requirements are selected in order to mitigate an identified hazard.

Another topic that was brought up in industry discussions and was discussed on several occasions throughout the project was the challenge of striking a balance between non-prescriptive and prescriptive requirements. On one hand, industry members indicated a preference in compliance with open-ended requirements. This allows a broad G-1 certification basis and more specific and proprietary methods of compliance in the G-2 issue paper. On the other hand, requirements that are not measurable, vague, and ambiguous may decrease product safety. In the near-term, it is recommended that a balance of both types of requirements be provided in each ASTM F38 standard, and that stakeholders be aware of the delineation between general design guidance and measurable certification requirements, as discussed in 3.4.1. In the Compliance Checklist, the research team provided recommendations on many line items that can be improved by specifying limits and benchmarks. It is also recommended that the FAA and ASTM discuss a path forward in which a standard(s) is targeted primarily towards certification applicants and potentially establishes a minimum set of requirements or design guidelines that all TC applicants need to comply with regardless of CONOP.

## 4 FUTURE WORK

A1 research highlights gaps that represent opportunities for future work. These gaps need to be addressed in order to improve system safety, airworthiness, and the certification process. A primary area of focus should include software validation, specifically in the areas of detect and avoid systems, autopilots, and geofences. Further research should also focus on refining the recommended flight test framework, best practices for flight testing, and expanding flight test practices by including procedures for multirotor aircraft.

One of the significant gaps that remains largely unaddressed is the lack of guidelines for sUAS software development and validation. Future work should explore the extent and level of rigor required to validate safety-critical software and systems. This includes autopilot systems, geofences, and detect and avoid algorithms.

This research project emphasized the need for best practices that can be used by industry to develop standardized methods for implementing flight test programs. The development of best practices for flight testing sUAS will ensure that industry is able to approach flight test in a manner that is efficient, safe, and uniform throughout. Best practices will establish a foundation for flight test guidance that can be referenced by those who may not be entirely familiar with common methodology or safety.

In addition to requirements for software and best practices for sUAS flight testing, there is a need to further develop and refine the Comprehensive Flight Test Framework. For example, the Flight Test Framework only addresses fixed-wing sUAS; a framework for multirotor flight testing should be developed. Furthermore, the requirement marked as being scalable need to be adjusted to be appropriate for a range of sUAS.

## 5 CONCLUSION

As the UAS industry grows and capabilities of sUAS continue to improve, there is an increased desire to operate beyond the constraints imposed by Part 107. Due to the increased risk associated with these operations, OEMs will be required to demonstrate to the FAA that their systems are capable of conducting these operations while minimizing risk. The ASTM F38 industry consensus standards for sUAS may be used to demonstrate risk mitigation for operations beyond Part 107.

This research project was conducted with the goal of examining the current industry consensus standards for sUAS, determining if they are suitable for use as a certification basis, and attempting to provide detailed feedback for ways in which they could be improved. Specifically, this research sought to address questions regarding the F38 standards. These questions and the research responses follow.

a. Are the ASTM F38 standards suitable for use as a certification basis for sUAS?

   Additional improvements are needed to use the F38 standards more effectively as a certification basis. There are still compliance issues and gaps within the F38 standards, but the F38 members are taking action to improve the standards, and it is anticipated that their efforts will address many of the gaps noted during this research.

b. With which ASTM F38 standard requirements is compliance difficult or overly burdensome?
Appendix D contains a list of noteworthy compliance issues, which includes requirements that are overly burdensome, not measurable, insufficient, or technically challenging. Over the past year, the F38 committee addressed 40% of these compliance issues.

c. What are the gaps in the ASTM F38 standards with regards to assuring airworthiness and safe integration of sUAS into the NAS? Are safety-of-flight-critical hazards adequately addressed by the standard requirements?
Appendix E contains a list of gaps. ASTM working documents have been initiated to address gaps such as those related to software dependability. With their continued efforts, the F38 committee already addressed 20% of these gaps during the past year.

d. Is a flight test program feasible using the ASTM requirements as a framework?
The F38 standards currently lack a set of flight test requirements for certification testing. To support the F38 committee, a Comprehensive Flight Test Framework containing a thorough set of flight test requirements was developed. The Flight Test Framework serves as a working document for future discussion as it draws upon accepted flight test material and adapts it as necessary to suit the unique needs of sUAS.

In addition to answering these questions, the research highlights the need for scalable flight test requirements, sets of requirements for certain CONOPS, and continuity with manned aircraft requirements when applicable. The research team recommends incorporating scalable requirements to maintain an appropriate level of rigor since operational risk of sUAS varies according to CONOPS and system size, complexity, and safety features. In addition to scalable requirements, establishing sets of requirements appropriate for certain sUAS and CONOPS is recommended. Since certification applicants will use a subset of requirements as needed to mitigate the risks associated with a specific aircraft and CONOPS, having subsets would help applicants define a certification plan and assist regulators by creating commonality among applicants. Additionally, the team recommends maintaining the established organizational structure, verbiage, practices, procedures, and performance benchmarks from manned aircraft requirements when applicable.

The F38 committee is continuously working to improve the sUAS standards; their efforts already resolved some of the previously identified compliance issues and gaps. It is anticipated that revisions currently in progress and working documents being developed will address the majority of the compliance issues and gaps.

# 6 ACKNOWLEDGMENTS

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Wes Ryan, FAA Small Airplane Directorate – Sponsor Subject Matter Expert/Task Monitor
Ross Schaller, FAA Small Airplane Directorate – Flight Test Subject Matter Expert
ASTM F38 Members – Industry Feedback
Andy Thurling, AeroVironment – Industry Feedback

# 7 REFERENCES


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# APPENDIX A – F38 BASED FLIGHT TEST FRAMEWORK

| | | | | Flight / Aircraft Configuration | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Para. #** | **Requirement** | **Test Objective** | **Notes** | **Max Forward CG (1)** | **Max Aft CG (2)** | **Min Weight (3)** | **Max Weight (4)** | **Standard Configuration* (5)** | **Disabled Flight Controls** (6)** | **[Insert more configurations]** |
| **Design & Construction (F2910-14)** | | | | | | | | | | |
| **General Requirements** | | | | | | | | | | |
| 5.1.1 | REDACTED | Verify that the aircraft does not exceed performance limitations set by the FAA (i.e. airspeed, altitude) | | | | x | | | | |
| 5.1.2 | REDACTED | Determine maximum level flight speed. | | | | x | | | | |
| 5.1.8.2 | REDACTED | Demonstrate control with asymmetric control surface deployment. | | | | | | | x | |
| **Structural Requirements** | | | | | | | | | | |
| 5.2.1.3 | REDACTED | Demonstrate ability to withstand launch and recovery loads. | | | | x | x | | | |
| 5.2.2 | REDACTED | Demonstrate system operation throughout flight envelope defined by the manufacturer; includes atmospheric gust loads and evasive maneuvering loads. | | | | x | | | | |
| 5.2.3 | REDACTED | Demonstrate ability to withstand landing loads. | | | | | x | | | |
| **Propulsion Requirements** | | | | | | | | | | |
| 5.3.1.1 | REDACTED | Demonstrate operation of the aircraft throughout the flight envelope. | | | | | x | | | |
| 5.3.3.3 | REDACTED | Demonstrate that the engine/propeller combination will not exceed manufacturer-specified limitations. | | | | x | | | | |
| 5.3.5.1 | REDACTED | Demonstrate ability of the fuel system to supply fuel throughout the entire flight envelope. | | | | | | x | | |
| 5.3.6.1 | REDACTED | Demonstrate adequate engine cooling. | Hot weather test | | | | x | | | |
| 5.3.6.3 | REDACTED | Verify that the engine is adequately cooled in flight. | | | | | x | | | |

| | | | | Flight / Aircraft Configuration | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Para. #** | **Requirement** | **Test Objective** | **Notes** | **Max Forward CG (1)** | **Max Aft CG (2)** | **Min Weight (3)** | **Max Weight (4)** | **Standard Configuration* (5)** | **Disabled Flight Controls** (6)** | **[Insert more configurations]** |
| **Systems & Equipment Requirements** | | | | | | | | | | |
| 5.6.7 | REDACTED | Demonstrate that the autopilot can be interrupted for manual reversion in flight. | | | | | | x | | |
| 5.6.10.1 | REDACTED | Demonstrate the ability of the landing gear to withstand landing impact loads without causing damage to the structure. | | | | | x | | | |
| **System Requirements** | | | | | | | | | | |
| 5.10.1.1 | REDACTED | Demonstrate the function of the stall warning system. | | x | | | | | | |
| 5.10.1.2 | REDACTED | Demonstrate stall recovery command. | | | x | | | | | |
| 5.10.3.1 | REDACTED | (Multi-engine aircraft only) Demonstrate that the aircraft can be controlled and defaults to a safe state in the event of a power plant failure. | Test plan dependent on aircraft configuration | | | | x | | | |
| 5.10.3.2 | REDACTED | Demonstrate controlled decent or automated recovery during power plant failure. | | | | | x | | | |
| 5.10.4 | REDACTED | Demonstrate longitudinal, lateral, and directional stability for all weights and CG positions. | | x | x | | | | | |
| 5.10.5 | REDACTED | Demonstrate warning system for departure from controlled flight. | May be demonstrated with 5.10.1.1. | | | | | x | | |
| **Command and Control (F3002-14a)** | | | | | | | | | | |
| **Ground Control Station Requirements** | | | | | | | | | | |
| *Functional Requirements* | | | | | | | | | | |
| 9.2.9 | REDACTED | Demonstrate capability of the backup power supply. | | | | | x | | | |
| *Design Requirements* | | | | | | | | | | |
| 9.4.5 | REDACTED | Demonstrate that the aircraft is prevented from launching with the reduced range attenuator attached. | | | | | | x | | |
| **Unmanned Aircraft Requirements** | | | | | | | | | | |
| *Operational Requirements* | | | | | | | | | | |
| 10.1.1 | REDACTED | Demonstrate one or a combination of lost-link responses. | | | | | | x | | |
| 10.1.1.1 | REDACTED | If applicable: Demonstrate execution of automated landing upon occurrence of lost-link. | | | | | | x | | |
| 10.1.1.2 | REDACTED | If applicable: Demonstrate that the aircraft returns to a predetermined location upon occurrence of lost-link. | | | | | | x | | |
| 10.1.1.3 | REDACTED | If applicable: Demonstrate the termination of flight upon occurrence of lost-link. | | | | | | x | | |
| 10.1.1.4 | REDACTED | If applicable: Demonstrate that the aircraft can loiter upon occurrence of lost-link. | | | | | | x | | |
| *Functional Requirements* | | | | | | | | | | |
| 10.2.3 | REDACTED | Demonstrate execution of lost-link logic upon a lost-link occurrence. | | | | | | x | | |
| *Performance Requirements* | | | | | | | | | | |

| Para. # | Requirement | Test Objective | Notes | Flight / Aircraft Configuration: Max Forward CG (1) | Max Aft CG (2) | Min Weight (3) | Max Weight (4) | Standard Configuration* (5) | Disabled Flight Controls** (6) | [Insert more configurations] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10.3.1 | REDACTED | Demonstrate integrity of geo-fencing capability. | | | | | | x | | |
| *Interoperability Requirements* | | | | | | | | | | |
| 10.4.1 | REDACTED | Demonstrate UA system function with C2 lost link. | | | | | | x | | |
| 10.4.2 | REDACTED | Demonstrate execution of lost-link function when uplink fails. | | | | | | x | | |
| 10.4.3 | REDACTED | Demonstrate execution of lost-link function when downlink fails. | | | | | | x | | |
| **Fly-Away Functionality** | | | | | | | | | | |
| *Performance Requirements* | | | | | | | | | | |
| 11.2.1 | REDACTED | Demonstrate fly-away prevention when the C2 uplink fails. | | | | | | x | | |
| 11.2.2 | REDACTED | Demonstrate fly-away prevention when the C2 downlink fails. | | | | | | x | | |

* Standard configuration refers to a configuration that represents the normal expected configuration in terms of aircraft weight and CG position with a specific payload.
** Disabled flight controls refers to a method of disabling specific flight control surfaces such that the failure of individual control surfaces may be simulated in flight.

# APPENDIX B – FLIGHT TEST REQUIREMENTS GAP ANALYSIS

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-XX | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **Subpart B - Flight** | | | | | | | | |
| 2 | **General** | | | | | | | | |
| 3 | **§23.21 Proof of compliance.** | | **4.1 Proof of Compliance:** | **Proof of compliance** | | - | - | X | - |
| 4 | (a) Each requirement of this subpart must be met at each appropriate combination of weight and center of gravity within the range of loading conditions for which certification is requested. This must be shown—<br>(1) By tests upon an airplane of the type for which certification is requested, or by calculations based on, and equal in accuracy to, the results of testing; and<br>(2) By systematic investigation of each probable combination of weight and center of gravity, if compliance cannot be reasonably inferred from combinations investigated. | | REDACTED – F2245-15 [4.1.1] | (a) Conduct flight testing at most critical weight and CG configurations and any other configurations that are required to satisfy the requirements of flight test procedures. | The manufacturer will designate and justify critical aircraft configurations. | - | - | X | - |
| 5 | (b) The following general tolerances are allowed during flight testing. However, greater tolerances may be allowed in particular tests:<br>Item – Tolerance<br>Weight – + 5%, -10%.<br>Critical items affected by weight – + 5%, -1%.<br>C.G – ±7% total travel | | REDACTED – F2245-15 [4.1.2] | REDACTED – F2245-15 [4.1.2] | These tolerances were carried over from both Part 23 and F37. It is possible that these requirements may not translate directly, but they serve as an excellent starting point. | - | - | X | - |
| 6 | **§23.23 Load distribution limits.** | | **4.2 Load Distribution Limits:** | **Load distribution limits** | | - | - | - | - |
| 7 | (a) Ranges of weights and centers of gravity within which the airplane may be safely operated must be established. If a weight and center of gravity combination is allowable only within certain lateral load distribution limits that could be inadvertently exceeded, these limits must be established for the corresponding weight and center of gravity combinations. | REDACTED – F2910-14 [5.1.6] | REDACTED – F2245-15: [4.2.1, 4.2.1.1, 4.2.1.2] | The permissible range of weight and CG of the sUAS should be established prior to testing. The maximum and minimums shall be demonstrated when establishing the flight envelope. | Flight testing must utilize a “build-up” approach. Testing must not begin at extreme configurations. The extreme configurations will ultimately need to be tested for the purpose of demonstrating compliance, but they will only be tested after more conservative combinations of weight and CG have been evaluated. | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 8 | (b) The load distribution limits may not exceed any of the following:<br>(1) The selected limits;<br>(2) The limits at which the structure is proven;<br>or<br>(3) The limits at which compliance with each applicable flight requirement of this subpart is shown. | | | N/A | Questions remain with respect to the extent to which structural testing should be carried out through flight testing. It is assumed that due to the relatively small size of sUAS, it is often more desirable to perform required structural testing on the ground wherever possible. | X | - | - | - |
| 9 | [Doc. No. 26269, 58 FR 42156, Aug. 6, 1993] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 10 | **§23.25 Weight limits.** | | | **Weight limits** | | - | - | - | - |
| 11 | (a) *Maximum weight.* The maximum weight is the highest weight at which compliance with each applicable requirement of this part (other than those complied with at the design landing weight) is shown. The maximum weight must be established so that it is—<br>(1) Not more than the least of—<br>(i) The highest weight selected by the applicant; or<br>(ii) The design maximum weight, which is the highest weight at which compliance with each applicable structural loading condition of this part (other than those complied with at the design landing weight) is shown; or<br>(iii) The highest weight at which compliance with each applicable flight requirement is shown, and<br>(2) Not less than the weight with—<br>(i) Each seat occupied, assuming a weight of 170 pounds for each occupant for normal and commuter category airplanes, and 190 pounds for utility and acrobatic category airplanes, except that seats other than pilot seats may be placarded for a lesser weight; and<br>(A) Oil at full capacity, and<br>(B) At least enough fuel for maximum continuous power operation of at least 30 minutes for day-VFR approved airplanes and at least 45 minutes for night-VFR and IFR approved airplanes; or<br>(ii) The required minimum crew, and fuel and oil to full tank capacity. | REDACTED – F2910-14 [5.1.7] | | (a) The maximum weight and corresponding center of gravity must be determined by weighing the sUA with—<br>(1) Fixed ballast (if required);<br>(2) Full fuel and/or batteries installed;<br>(3) Full operating fluids, including oil, hydraulic fluid; and other fluids required for normal operation; and<br>(4) Heaviest standard payload | The term "standard payload" can best be defined as:<br>*The intended payload(s) for which the sUA was designed to carry as designated by the UAS manufacturer.*<br>It is entirely possible for a payload to be nonstandard and it is also possible for a series of payloads to be carried by one aircraft. In this case, it was decided that for the purpose of weight limits, the heaviest of the intended payloads be considered. | - | - | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 12 | (b) *Minimum weight.* The minimum weight (the lowest weight at which compliance with each applicable requirement of this part is shown) must be established so that it is not more than the sum of—<br>(1) The empty weight determined under §23.29;<br>(2) The weight of the required minimum crew (assuming a weight of 170 pounds for each crewmember); and<br>(3) The weight of—<br>(i) For turbojet powered airplanes, 5 percent of the total fuel capacity of that particular fuel tank arrangement under investigation, and<br>(ii) For other airplanes, the fuel necessary for one-half hour of operation at maximum continuous power. | REDACTED – F2910-14 [5.1.7] | REDACTED – F2245-15 [4.2.2] | (b) The minimum weight and corresponding center of gravity must be determined by weighing the sUAS with—<br>(1) Fixed ballast (if required);<br>(2) Minimum amount of fuel and/or batteries installed;<br>(3) Full operating fluids, including oil, hydraulic fluid; and other fluids required for normal operation; and<br>(4) No payload installed. | The minimum weight assumes that the aircraft is able to be flown, but with the minimum possible fuel and payload.<br>Since minimum fuel requirements have not been established for sUAS in terms of required reserves, it is not possible to specify exactly how much fuel can be classified as a "minimum amount." | - | - | - | - |
| 13 | [Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23-7, 34 FR 13086, Aug. 13, 1969; Amdt. 23-21, 43 FR 2317, Jan. 16, 1978; Amdt. 23-34, 52 FR 1825, Jan. 15, 1987; Amdt. 23-45, 58 FR 42156, Aug. 6, 1993; Amdt. 23-50, 61 FR 5183, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 14 | **§23.29 Empty weight and corresponding center of gravity.** | | | **Empty weight and corresponding center of gravity** | | - | - | - | - |
| 15 | (a) The empty weight and corresponding center of gravity must be determined by weighing the airplane with—<br>(1) Fixed ballast;<br>(2) Unusable fuel determined under §23.959; and<br>(3) Full operating fluids, including—<br>(i) Oil;<br>(ii) Hydraulic fluid; and<br>(iii) Other fluids required for normal operation of airplane systems, except potable water, lavatory precharge water, and water intended for injection in the engines. | | REDACTED – F2245-15 [4.2.3] | (a) The empty weight and corresponding center of gravity must be determined by weighing the sUAS with—<br>(1) No fixed ballast;<br>(2) Unusable fuel and/or no battery installed;<br>(3) Full operating fluids, including oil, hydraulic fluid; and other fluids required for normal operation; and<br>(4) No payload installed. | The recommended method for determining the empty weight is hinged upon the assumption that the aircraft may not be flyable in the "empty" state. Ballast is considered to be a balancing factor only, and is added to either a.) Make up for required moments needed to balance the aircraft with a payload installed, or b.) To allow the aircraft to be flown without a payload by ensuring that the CG is located at an acceptable location. | - | - | - | - |
| 16 | (b) The condition of the airplane at the time of determining empty weight must be one that is well defined and can be easily repeated. | | | -------- | Covered by description of empty weight determination | - | - | - | - |
| 17 | [Doc. No. 4080, 29 FR 17955, Dec. 18, 1964; 30 FR 258, Jan. 9, 1965, as amended by Amdt. 23-21, 43 FR 2317, Jan. 16, 1978] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 18 | **§23.31 Removable ballast.** | | | **Removable ballast** | | - | - | - | - |
| 19 | Removable ballast may be used in showing compliance with the flight requirements of this subpart, if—<br>(a) The place for carrying ballast is properly designed and installed, and is marked under §23.1557; and | REDACTED – F2910-14 [5.1.6] | REDACTED – F2245-15 [4.2.4, 4.2.5] | REDACTED – F2245-15 [4.2.4]<br>Batteries may also fill the role of ballast if properly placarded and installed. | The intent of this Part 23 requirement is captured in ASTM F2910-14 [5.1.6] and is referenced in line 20. | - | - | - | - |
| 20 | (b) Instructions are included in the airplane flight manual, approved manual material, or markings and placards, for the proper placement of the removable ballast under each loading condition for which removable ballast is necessary. | Reference line 19 | | Compliance with ASTM F2910-14 [5.1.6] is required when removing and adding ballast. | F38 captures the intent of Part 23, requiring ballast installation areas to be properly marked and documented within the aircraft's AFM. | - | - | - | - |
| 21 | [Doc. No. 4080, 29 FR 17955, Dec. 18, 1964; 30 FR 258, Jan. 9, 1965, as amended by Amdt. 23-13, 37 FR 20023, Sept. 23, 1972] | -------- | -------- | -------- | -------- | - | - | - | - |
| 22 | **§23.33 Propeller speed and pitch limits.** | | | **Propeller speed and pitch limits** | | - | - | - | - |
| 23 | (a) *General.* The propeller speed and pitch must be limited to values that will assure safe operation under normal operating conditions. | REDACTED – F2910-14 [5.3.3.3] | REDACTED – F2245-15 [4.3] | REDACTED – F2910-14 [5.3.3.3] | Reference recommendation for 23.33(b); Line 24.<br>Direct compliance with ASTM F2910-14 [5.3.3.3] is not recommended in this case due to the requirement being burdensome if interpreted to mean that all sUAS would require some sort of governing device. | - | - | - | - |
| 24 | (b) *Propellers not controllable in flight.* For each propeller whose pitch cannot be controlled in flight—<br>(1) During takeoff and initial climb at the all engine(s) operating climb speed specified in §23.65, the propeller must limit the engine r.p.m., at full throttle or at maximum allowable takeoff manifold pressure, to a speed not greater than the maximum allowable takeoff r.p.m.; and<br>(2) During a closed throttle glide, at $V_{NE}$, the propeller may not cause an engine speed above 110 percent of maximum continuous speed. | | REDACTED – F2245-15 [4.3.1] | Demonstrate that the maximum allowable RPM for the powerplant or propeller, whichever is less, is not exceeded during takeoff, climb, flight at $0.9V_H$, and a glide at $V_{NE}$. | 23.33 (b) is listed as N/A in Draft AC 20-xx-xx Appendix A, however it is applicable to fixed pitch propellers.<br>F37 seems more applicable as the requirements are simplified, referencing a percentage of maximum level flight speed and $V_{NE}$. | - | X | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 25 | (c) *Controllable pitch propellers without constant speed controls.* Each propeller that can be controlled in flight, but that does not have constant speed controls, must have a means to limit the pitch range so that—<br>(1) The lowest possible pitch allows compliance with paragraph (b)(1) of this section; and<br>(2) The highest possible pitch allows compliance with paragraph (b)(2) of this section. | | | For variable pitch propellers, both lowest and highest pitch must be demonstrated to comply with recommendation in line 24. | 23.33 (c) is listed as N/A in Draft AC 20-xx-xx Appendix A, but variable pitch propellers may be applicable to sUAS. It should be noted that while variable pitch propellers do exist for aircraft of this size, it is not anticipated that they will be common. | - | X | X | - |
| 26 | (d) *Controllable pitch propellers with constant speed controls.* Each controllable pitch propeller with constant speed controls must have—<br>(1) With the governor in operation, a means at the governor to limit the maximum engine speed to the maximum allowable takeoff r.p.m.; and<br>(2) With the governor inoperative, the propeller blades at the lowest possible pitch, with takeoff power, the airplane stationary, and no wind, either—<br>(i) A means to limit the maximum engine speed to 103 percent of the maximum allowable takeoff r.p.m., or<br>(ii) For an engine with an approved overspeed, a means to limit the maximum engine and propeller speed to not more than the maximum approved overspeed. | | | N/A | Requirements in lines 24 and 25 already set limitations for propeller and powerplant RPM. | X | X | - | - |
| 27 | [Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23-45, 58 FR 42156, Aug. 6, 1993; Amdt. 23-50, 61 FR 5183, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 28 | **PERFORMANCE** | | | | | | - | | |
| 29 | **§23.45 General.** | | | **General** | | - | - | x | - |
| 30 | (a) Unless otherwise prescribed, the performance requirements of this part must be met for—<br>(1) Still air and standard atmosphere; and<br>(2) Ambient atmospheric conditions, for commuter category airplanes, for reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight, and for turbine engine-powered airplanes. | | REDACTED – F2245-15 [4.4] | REDACTED – F2245-15 [4.4]; Revised to refer to “Test environment” instead of “All performance requirements…” | This is a reasonable carry over from Part 23 and F37. | - | (a)(2) | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 31 | (b) Performance data must be determined over not less than the following ranges of conditions—<br>(1) Airport altitudes from sea level to 10,000 feet; and<br>(2) For reciprocating engine-powered airplanes of 6,000 pounds, or less, maximum weight, temperature from standard to 30 °C above standard; or<br>(3) For reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight and turbine engine-powered airplanes, temperature from standard to 30 °C above standard, or the maximum ambient atmospheric temperature at which compliance with the cooling provisions of §23.1041 to §23.1047 is shown, if lower. | | | (b) Performance data must be determined over not less than the following ranges of conditions—<br>(1) Airport altitudes from sea level to 10,000 feet; and<br>(2) Temperature from standard to 30 °C above standard; or<br>(3) The maximum ambient atmospheric temperature at which compliance with the cooling requirements are shown. | The requirement to determine performance numbers for sUAS at altitudes from sea level to 10,000 feet is indicative of the notion that sUAS may be employed from high altitude locations, such as mountain peaks or high deserts on hot days.<br>This may be scaled to CONOPS based upon how and where the sUAS is to be operated. For aircraft that are intended for a fixed remote environment (not over people), this level or rigor may not be needed. However, if an aircraft is intended to be operated in a high-altitude environment, and/or over people, this requirement becomes more important. | - | - | X | X |
| 32 | (c) Performance data must be determined with the cowl flaps or other means for controlling the engine cooling air supply in the position used in the cooling tests required by §§23.1041 to 23.1047. | | | (c) Performance data must be determined with the powerplant's cooling system operating in the same manner that would be utilized for evaluating its performance. | | - | - | X | - |
| 33 | (d) The available propulsive thrust must correspond to engine power, not exceeding the approved power, less—<br>(1) Installation losses; and<br>(2) The power absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition. | | | (d) The available propulsive thrust must correspond to engine power, not exceeding the approved power, less—<br>(1) Installation losses; and<br>(2) The power absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition. | For very small simple sUAS that are not operated over people, this may be overkill. However, if the aircraft is to be operated in a BVLOS environment and/or over people, it becomes more important as available and power required will play into the aircraft's climb and overall performance. | - | - | X | X |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
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| 34 | (e) The performance, as affected by engine power or thrust, must be based on a relative humidity:<br>(1) Of 80 percent at and below standard temperature; and<br>(2) From 80 percent, at the standard temperature, varying linearly down to 34 percent at the standard temperature plus 50 °F. | | | (e) For sUAS that utilize internal combustion engines, the performance, as affected by engine power or thrust, must be based on a relative humidity:<br>(1) Of 80 percent at and below standard temperature; and<br>(2) From 80 percent, at the standard temperature, varying linearly down to 34 percent at the standard temperature plus 50 °F. | There is a gap here. For sUAS that utilize electric propulsion, humidity and air density will not have a direct effect on the function of the powerplant itself.<br>It is recommended that this requirement be simplified or scaled for less complex aircraft that operate in environments that keep them away from people and structures. Performance requirements for small engines in varying conditions will need to be investigated. | - | - | X | X |
| 35 | (f) Unless otherwise prescribed, in determining the takeoff and landing distances, changes in the airplane's configuration, speed, and power must be made in accordance with procedures established by the applicant for operation in service. These procedures must be able to be executed consistently by pilots of average skill in atmospheric conditions reasonably expected to be encountered in service. | | | (f) Unless otherwise prescribed, in determining the takeoff and landing distances/areas, changes in the airplane's configuration, speed, and power must be made in accordance with procedures established by the applicant for operation in service. These procedures must be able to be executed consistently by operators of average skill in conditions reasonably expected to be encountered during operation. | It seems entirely reasonable that the manufacturer/applicant should specify procedures for aircraft configuration changes (flaps, gear, spoilers, recovery chutes, etc.) in flight and that those procedures must produce consistent results and not rely on above-average pilot skill. | - | - | X | - |
| 36 | (g) The following, as applicable, must be determined on a smooth, dry, hard-surfaced runway—<br>(1) Takeoff distance of §23.53(b);<br>(2) Accelerate-stop distance of §23.55;<br>(3) Takeoff distance and takeoff run of §23.59; and<br>(4) Landing distance of §23.75.<br>Note: The effect on these distances of operation on other types of surfaces (for example, grass, gravel) when dry, may be determined or derived and these surfaces listed in the Airplane Flight Manual in accordance with §23.1583(p). | | | (g) The following, as applicable, must be determined on a runway surface that the sUAS will most commonly encounter in operation—<br>(1) Takeoff distance;<br>(2) Takeoff distance and takeoff run; and<br>(3) Landing distance.<br>If the sUAS has traditional landing gear, the above must also be demonstrated on a smooth, dry hard-surfaced runway. | It is not terribly common for a sUAS to operate off of a traditional paved runway. These aircraft are often launched by hand or by some sort of mechanical device. Takeoffs and landings are commonly performed on grass, gravel, or other unprepared surfaces. | - | - | X | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
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| 37 | (h) For multiengine jets weighing over 6,000 pounds in the normal, utility, and acrobatic category and commuter category airplanes, the following also apply:<br>(1) Unless otherwise prescribed, the applicant must select the takeoff, enroute, approach, and landing configurations for the airplane.<br>(2) The airplane configuration may vary with weight, altitude, and temperature, to the extent that they are compatible with the operating procedures required by paragraph (h)(3) of this section.<br>(3) Unless otherwise prescribed, in determining the critical-engine-inoperative takeoff performance, takeoff flight path, and accelerate-stop distance, changes in the airplane's configuration, speed, and power must be made in accordance with procedures established by the applicant for operation in service.<br>(4) Procedures for the execution of discontinued approaches and balked landings associated with the conditions prescribed in §23.67(c)(4) and §23.77(c) must be established.<br>(5) The procedures established under paragraphs (h)(3) and (h)(4) of this section must—<br>(i) Be able to be consistently executed by a crew of average skill in atmospheric conditions reasonably expected to be encountered in service;<br>(ii) Use methods or devices that are safe and reliable; and<br>(iii) Include allowance for any reasonably expected time delays in the execution of the procedures. | | | N/A | | X | X | - | - |
| 38 | [Doc. No. 27807, 61 FR 5184, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 39 | **§23.49 Stalling speed.** | | | **Stalling speed** | | - | - | x | - |
| 40 | (a) $V_{SO}$ (maximum landing flap configuration) and $V_{S1}$ are the stalling speeds or the minimum steady flight speeds, in knots (CAS), at which the airplane is controllable with—<br>(1) For reciprocating engine-powered airplanes, the engine(s) idling, the throttle(s) closed or at not more than the power necessary for zero thrust at a speed not more than 110 percent of the stalling speed;<br>(2) For turbine engine-powered airplanes, the propulsive thrust not greater than zero at the stalling speed, or, if the resultant thrust has no appreciable effect on the stalling speed, with engine(s) idling and throttle(s) closed;<br>(3) The propeller(s) in the takeoff position;<br>(4) The airplane in the condition existing in the test, in which $V_{SO}$ and $V_{S1}$ are being used;<br>(5) The center of gravity in the position that results in the highest value of $V_{SO}$ and $V_{S1}$; and<br>(6) The weight used when $V_{SO}$ and $V_{S1}$ are being used as a factor to determine compliance with a required performance standard. | | REDACTED – F2245-15 [4.4.1] | $V_{SO}$ (maximum landing flap configuration; for sUAS equipped with flaps) and $V_{S1}$ are the stalling speeds or the minimum steady flight speeds, in knots (CAS), at which the sUA is controllable with—<br>(1) powerplant(s) idling<br>(2) throttle closed<br>(3) Zero thrust<br>(4) Maximum takeoff weight<br>(5) A CG position that results in the highest values of $V_{SO}$ and $V_{S1}$. | | - | - | X | - |
| 41 | (b) $V_{SO}$ and $V_{S1}$ must be determined by flight tests, using the procedure and meeting the flight characteristics specified in §23.201. | | | (b) $V_{SO}$ and $V_{S1}$ must be determined by flight tests, using common procedures that meet the flight characteristics specified in lines 314-321. | | - | - | X | - |
| 42 | (c) Except as provided in paragraph (d) of this section, $V_{SO}$ at maximum weight may not exceed 61 knots for—<br>(1) Single-engine airplanes; and<br>(2) Multiengine airplanes of 6,000 pounds or less maximum weight that cannot meet the minimum rate of climb specified in §23.67(a) (1) with the critical engine inoperative. | | | N/A | Stall speeds in excess of 61 knots are addressed in line 43. | X | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 43 | (d) All single-engine airplanes, and those multiengine airplanes of 6,000 pounds or less maximum weight with a $V_{SO}$ of more than 61 knots that do not meet the requirements of §23.67(a)(1), must comply with §23.562(d). | | | All sUAS must have a $V_{SO}$ at maximum takeoff weight below 61 knots unless:<br>(1) The aircraft is multi powerplant powered and is equipped with a recovery system with the ability to arrest the aircraft's descent and forward velocity; or<br>(2) The aircraft utilizes a single powerplant, non-propeller driven propulsion system and is additionally equipped with a recovery system with the ability to arrest the aircraft's descent and forward velocity. | The recommended flight test requirements listed here are intended to be a sort of "catch all" for novel aircraft that may utilize EDF or turbine propulsion and are generally higher performance. While this is not expected to be common, the use of these propulsion methods, while not always practical, is possible and should be accounted for.<br><br>Further definition is needed when defining what a high speed sUAS is. In this case, it seemed reasonable to use stall speeds > 61 knots as it seemed a reasonable threshold for serious injury or damage to property on the ground.<br><br>The use of the 61 knot airspeed is indicative of the intent inherent to the corresponding Part 23 requirement that the risk of injury to people on the ground or damage to property should be minimized. If the stall speed of a sUAS is higher than 61 knots, additional safety measures may be needed. | - | - | X | - |
| 44 | [Doc. No. 27807, 61 FR 5184, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 45 | **§23.51 Takeoff speeds.** | | | **Takeoff speeds** | | - | - | x | - |
| 46 | (a) For normal, utility, and acrobatic category airplanes, rotation speed, $V_R$, is the speed at which the pilot makes a control input, with the intention of lifting the airplane out of contact with the runway or water surface.<br>(1) For multiengine landplanes, $V_R$, must not be less than the greater of 1.05 $V_{MC}$; or 1.10 $V_{S1}$;<br>(2) For single-engine landplanes, $V_R$, must not be less than $V_{S1}$; and<br>(3) For seaplanes and amphibians taking off from water, $V_R$, may be any speed that is shown to be safe under all reasonably expected conditions, including turbulence and complete failure of the critical engine. | | | (a) Rotation speed, $V_R$, is the speed at which the operator, autopilot, or flight control system makes a control input, with the intention of lifting the sUA out of contact with the runway, launch apparatus, or water surface.<br>(1) $V_R$ must not be less than the greater of 1.05 $V_{MIN}$ or 1.10 $V_{s1}$ and must not be less than $V_{S1}$.<br>(2) $V_R$ must be a speed that is shown to be safe under all reasonably expected conditions, including turbulence, failure of the critical engine, and failed launch scenarios.<br>(3) For hand launched sUAS, $V_R$ is defined as the speed at which the aircraft must be travelling prior to the moment of launch that will result in a smooth climb out to altitude upon being thrown.<br>(4) For sUAS that rely on mechanical means for launch, $V_R$ must be defined as the speed at which the aircraft leaves the catapult or launch apparatus and is able to achieve a steady climb out. | $V_R$ can take on different meanings as it can be used to define speeds at which the aircraft lifts off of the ground or water. It can also define a speed at which the aircraft leaves the launch apparatus, whatever that may be. For hand launched aircraft, $V_R$ may be more difficult to measure as it will rely on measures of human performance and skill at throwing a specific airplane. | - | - | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 47 | (b) For normal, utility, and acrobatic category airplanes, the speed at 50 feet above the takeoff surface level must not be less than:<br>(1) For multiengine airplanes, the highest of—<br>(i) A speed that is shown to be safe for continued flight (or emergency landing, if applicable) under all reasonably expected conditions, including turbulence and complete failure of the critical engine;<br>(ii) 1.10 $V_{MC}$; or<br>(iii) 1.20 $V_{S1}$.<br>(2) For single-engine airplanes, the higher of—<br>(i) A speed that is shown to be safe under all reasonably expected conditions, including turbulence and complete engine failure; or<br>(ii) 1.20 $V_{S1}$. | | REDACTED – F2245-15 [4.4.2.2] | (b) The speed of the sUAS at 50 feet above the takeoff surface or highest point on the launch apparatus must not be less than:<br>(1) A speed that is shown to be safe for continued flight or abort procedures under all reasonably expected conditions, including the failure of powerplant(s), flight critical systems, and/or the primary command link;<br>(2) 1.10 $V_{MIN}$; or<br>(3) 1.2 $V_{S1}$. | Paragraph (1) was added to exempt sUAS from the minimum airspeed requirements if it can be demonstrated that they can be safely operated at lower speeds during climb out. | - | - | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 48 thru 56 | (c) For normal, utility, and acrobatic category multiengine jets of more than 6,000 pounds maximum weight and commuter category airplanes, the following apply:<br>(l) $V_1$ must be established in relation to $V_{EF}$ as follows:<br>(i) $V_{EF}$ is the calibrated airspeed at which the critical engine is assumed to fail. $V_{EF}$ must be selected by the applicant but must not be less than 1.05 $V_{MC}$ determined under §23.149(b) or, at the option of the applicant, not less than $V_{MCG}$ determined under §23.149(f).<br>(ii) The takeoff decision speed, $V_1$, is the calibrated airspeed on the ground at which, as a result of engine failure or other reasons, the pilot is assumed to have made a decision to continue or discontinue the takeoff. The takeoff decision speed, $V_1$, must be selected by the applicant but must not be less than $V_{EF}$ plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed and the instant at which the pilot recognizes and reacts to the engine failure, as indicated by the pilot's application of the first retarding means during the accelerate-stop determination of §23.55. | | | For sUAS that utilize more than one powerplant, the following apply:<br>For multi-powerplant sUAS, $V_1$ must be established in relation to $V_{EF}$ as follows:<br>$V_{EF}$ is the calibrated airspeed at which the critical engine, if applicable, is assumed to fail. $V_{EF}$ must be established at an airspeed that allows for positive control of the aircraft.<br>For multi-powerplant sUAS, the takeoff decision speed, $V_1$, is the calibrated airspeed on the ground at which the decision to either continue or abort the flight is assumed to have been made should a powerplant fail at takeoff. | Multi-engine/motor fixed-wing sUAS need to be taken into consideration. While they are not as common as single powerplant sUAS, benchmarks for takeoff performance with a powerplant inoperative need to be considered so that the operator can react accordingly should an emergency arise.<br>For sUAS with more than one powerplant, the establishment of a $V_1$ airspeed is a reasonable approach to addressing the need for a point at which an abort or continue decision must be made in the event of the failure of a powerplant at launch.<br>This established requirement for $V_{EF}$ seemed reasonable at first glance, and appears to provide a scalable means for determining the required airspeed based upon established aircraft performance figures. However, this requirement becomes less relevant for aircraft that may utilize an automated flight termination system with a parachute or may not be affected by a powerplant failure in the same way as a manned aircraft. | - | X | X | X |

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| 57 | (2) The rotation speed, $V_R$, in terms of calibrated airspeed, must be selected by the applicant and must not be less than the greatest of the following:<br>(i) $V_1$;<br>(ii) 1.05 $V_{MC}$ determined under §23.149(b);<br>(iii) 1.10 $V_{S1}$; or<br>(iv) The speed that allows attaining the initial climb-out speed, $V_2$, before reaching a height of 35 feet above the takeoff surface in accordance with §23.57(c)(2).<br>(3) For any given set of conditions, such as weight, altitude, temperature, and configuration, a single value of $V_R$ must be used to show compliance with both the one-engine-inoperative takeoff and all-engines-operating takeoff requirements.<br>(4) The takeoff safety speed, $V_2$, in terms of calibrated airspeed, must be selected by the applicant so as to allow the gradient of climb required in §23.67 (c)(1) and (c)(2) but must not be less than 1.10 $V_{MC}$ or less than 1.20 $V_{S1}$.<br>(5) The one-engine-inoperative takeoff distance, using a normal rotation rate at a speed 5 knots less than $V_R$, established in accordance with paragraph (c)(2) of this section, must be shown not to exceed the corresponding one-engine-inoperative takeoff distance, determined in accordance with §23.57 and §23.59(a)(1), using the established $V_R$. The takeoff, otherwise performed in accordance with §23.57, must be continued safely from the point at which the airplane is 35 feet above the takeoff surface and at a speed not less than the established $V_2$ minus 5 knots.<br>(6) The applicant must show, with all engines operating, that marked increases in the scheduled takeoff distances, determined in accordance with §23.59(a)(2), do not result from over-rotation of the airplane or out-of-trim conditions. | | | $V_R$ must not be less than the initial climb out speed, $V_2$ that allows a safe climb out in the event of an engine failure.<br>The value for $V_R$ must take into account all possible operating conditions such as weight, altitude, and temperature to allow the sUA to perform a safe takeoff.<br>The takeoff safety speed, $V_2$, in terms of calibrated airspeed must be selected and demonstrated to allow for a safe climb gradient and not less than 1.10 $V_{MIN}$ or 1.2 $V_{S1}$.<br>The one powerplant inoperative takeoff distance, using a normal rotation rate for the aircraft at a speed of 5 knots less than $V_R$ must be shown not to exceed established powerplant inoperative takeoff distance.<br>It must be demonstrated that increases in takeoff distance with all powerplants operating does not result from over rotation of an out of trim aircraft. | The presence of an autopilot adds a layer of complexity to the problem as the option of both an automated and manual procedure becomes available in the event of a powerplant failure. The response to a powerplant failure upon launch may vary from aircraft to aircraft, depending on its capabilities and equipage. It is expected that “engine out” procedures will range from aborting the flight at the cost of the aircraft, to the use of specialized recovery systems, to continuing the takeoff and returning to land/recover if the aircraft is able to do so with a failed power plant.<br>Acceptable climb gradients for sUAS are not established. Aircraft performance will vary based upon weight, powerplant, and how the aircraft is loaded. It is not possible to know what a “safe” climb gradient is without more data.<br>This level of rigor may not be required for all aircraft in all operational scenarios. This is especially true for aircraft that are on the lighter end of the sUAS spectrum that are operated manually within VLOS. | - | X | X | X |
| 58 | [Doc. No. 27807, 61 FR 5184, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |
| 59 | **§23.53 Takeoff performance.** | | | **Takeoff performance** | | - | - | x | - |
| 60 | (a) For normal, utility, and acrobatic category airplanes, the takeoff distance must be determined in | | REDACTED – F2245-15 [4.4.2, 4.4.2.1] | Demonstrate ground roll distance (if applicable) and distance to clear a | The concept of takeoff ground roll may not translate to sUAS in all | - | - | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| | accordance with paragraph (b) of this section, using speeds determined in accordance with §23.51 (a) and (b). | | | 50ft obstacle at critical weights and ambient temperatures expected during normal operation.<br>For sUAS that utilize a launch apparatus or are hand launched, the distance traveled along the launch apparatus or the average distance the aircraft must travel at a reasonable speed in order to become airborne may be substituted for ground roll distance. | possible scenarios. For aircraft that are hand launched, the “ground roll” will likely vary a great deal depending on the person launching the aircraft, wind speed, and the weight of the airplane compared to the strength of the person launching it.<br>The ground roll for a hand launched airplane will likely end up expressed as an average distance while the takeoff distance for a sUAS that uses a launch apparatus is able to be expressed as an exact distance that should not vary. | | | | |
| 61 | (b) For normal, utility, and acrobatic category airplanes, the distance required to takeoff and climb to a height of 50 feet above the takeoff surface must be determined for each weight, altitude, and temperature within the operational limits established for takeoff with—<br>(1) Takeoff power on each engine;<br>(2) Wing flaps in the takeoff position(s); and<br>(3) Landing gear extended. | | REDACTED – F2245-15 [4.4.2.2] | The distance required to takeoff and climb to a height of 50 feet above the takeoff surface, or the highest point on the launch apparatus, must be determined for each weight, altitude, and temperature within the operational limits established for takeoff with—<br>(1) Takeoff power;<br>(2) Wing flaps in the takeoff position(s) (if applicable); and<br>(3) Landing gear extended (if applicable). | For sUAS that have a fixed weight, carry one payload, are on the lighter end of the sUAS spectrum, or are operated under a CONOPs that does not have them operating over people or property, this flight test requirement may be scaled to suit the perceived level of risk associated with the operation of the aircraft. | - | - | X | X |
| 62 | (c) For normal, utility, and acrobatic category multiengine jets of more than 6,000 pounds maximum weight and commuter category airplanes, takeoff performance, as required by §§23.55 through 23.59, must be determined with the operating engine(s) within approved operating limitations. | | | N/A | This is implied by propeller and powerplant rotational speed limitations. | X | X | - | - |
| 63 | [Doc. No. 27807, 61 FR 5185, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
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| 64 | **§23.55 Accelerate-stop distance.** | | | **Use of brakes** | | - | - | x | - |
| 65 | For normal, utility, and acrobatic category multiengine jets of more than 6,000 pounds maximum weight and commuter category airplanes, the accelerate-stop distance must be determined as follows: | | | N/A | Assuming risk to property and persons is minimized by having a clear takeoff site, this requirement does not increase the level of safety. | X | - | - | - |
| 66 | (a) The accelerate-stop distance is the sum of the distances necessary to—<br>(1) Accelerate the airplane from a standing start to $V_{EF}$ with all engines operating;<br>(2) Accelerate the airplane from $V_{EF}$ to $V_1$, assuming the critical engine fails at $V_{EF}$; and<br>(3) Come to a full stop from the point at which $V_1$ is reached. | | | N/A | Accelerate-stop distances are not seen as being relevant to the vast majority of sUAS. | X | - | - | - |
| 67 | (b) Means other than wheel brakes may be used to determine the accelerate-stop distances if that means—<br>(1) Is safe and reliable;<br>(2) Is used so that consistent results can be expected under normal operating conditions; and<br>(3) Is such that exceptional skill is not required to control the airplane. | | REDACTED – F2245-15 [4.7.2] | If the sUAS is equipped with wheel brakes, the use of wheel brakes must not result in unpredictable performance, a reduction in controllability, or damage to the sUA. | Brakes are not common on sUAS, but it is possible that they may be present on more sophisticated aircraft. | - | - | X | - |
| 68 | [Amdt. 23-34, 52 FR 1826, Jan. 15, 1987, as amended by Amdt. 23-50, 61 FR 5185, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |
| 69 | **§23.57 Takeoff path.** | | | **Takeoff path** | | x | X | - | - |
| 70 | For normal, utility, and acrobatic category multiengine jets of more than 6,000 pounds maximum weight and commuter category airplanes, the takeoff path is as follows: | | | N/A | Takeoff paths will vary greatly between sUAS of varying sizes, weights, propulsion methods, launch methods, and performance characteristics. It is for this reason that takeoff paths were not considered, instead relying on basic requirements for takeoff areas to dictate takeoff performance. | X | X | - | - |

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|---|---|---|---|---|---|---|---|---|---|
| 71 | (a) The takeoff path extends from a standing start to a point in the takeoff at which the airplane is 1500 feet above the takeoff surface at or below which height the transition from the takeoff to the enroute configuration must be completed; and<br>(1) The takeoff path must be based on the procedures prescribed in §23.45;<br>(2) The airplane must be accelerated on the ground to $V_{EF}$ at which point the critical engine must be made inoperative and remain inoperative for the rest of the takeoff; and<br>(3) After reaching $V_{EF}$, the airplane must be accelerated to $V_2$. | | | N/A | Takeoff paths will vary greatly between sUAS of varying sizes, weights, propulsion methods, launch methods, and performance characteristics. It is for this reason that takeoff paths were not considered, instead relying on basic requirements for takeoff areas to dictate takeoff performance. | X | X | - | - |
| 72 | (b) During the acceleration to speed $V_2$, the nose gear may be raised off the ground at a speed not less than $V_R$. However, landing gear retraction must not be initiated until the airplane is airborne. | | | N/A | Takeoff paths will vary greatly between sUAS of varying sizes, weights, propulsion methods, launch methods, and performance characteristics. It is for this reason that takeoff paths were not considered, instead relying on basic requirements for takeoff areas to dictate takeoff performance. | X | X | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 73 | (c) During the takeoff path determination, in accordance with paragraphs (a) and (b) of this section—<br>(1) The slope of the airborne part of the takeoff path must not be negative at any point;<br>(2) The airplane must reach $V_2$ before it is 35 feet above the takeoff surface, and must continue at a speed as close as practical to, but not less than $V_2$, until it is 400 feet above the takeoff surface;<br>(3) At each point along the takeoff path, starting at the point at which the airplane reaches 400 feet above the takeoff surface, the available gradient of climb must not be less than—<br>(i) 1.2 percent for two-engine airplanes;<br>(ii) 1.5 percent for three-engine airplanes;<br>(iii) 1.7 percent for four-engine airplanes; and<br>(4) Except for gear retraction and automatic propeller feathering, the airplane configuration must not be changed, and no change in power that requires action by the pilot may be made, until the airplane is 400 feet above the takeoff surface. | | | N/A | Overly burdensome/not applicable to sUAS | X | X | - | - |
| 74 | (d) The takeoff path to 35 feet above the takeoff surface must be determined by a continuous demonstrated takeoff. | | | N/A | Overly burdensome/not applicable to sUAS | X | X | - | - |
| 75 | (e) The takeoff path to 35 feet above the takeoff surface must be determined by synthesis from segments; and<br>(1) The segments must be clearly defined and must be related to distinct changes in configuration, power, and speed;<br>(2) The weight of the airplane, the configuration, and the power must be assumed constant throughout each segment and must correspond to the most critical condition prevailing in the segment; and<br>(3) The takeoff flight path must be based on the airplane's performance without utilizing ground effect. | | | N/A | Overly burdensome/not applicable to sUAS | X | X | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 76 | [Amdt. 23-34, 52 FR 1827, Jan. 15, 1987, as amended by Amdt. 23-50, 61 FR 5185, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |
| 77 | **§23.59 Takeoff distance and takeoff run.** | | | **Takeoff area and takeoff run** | | - | X | x | - |
| 78 | For normal, utility, and acrobatic category multiengine jets of more than 6,000 pounds maximum weight and commuter category airplanes, the takeoff distance and, at the option of the applicant, the takeoff run, must be determined. | | | For sUAS, the takeoff area will be defined as follows: | Given that sUAS takeoff performance characteristics may vary significantly between sUAS of different sizes and types, it was decided to fall back on simplified ASTM requirements to define a takeoff area given constraints of a normal takeoff. This also takes CONOPs into account as given operational environment may not have prepared surfaces for use during takeoff. | - | X | X | - |
| 79 | (a) Takeoff distance is the greater of—<br>(1) The horizontal distance along the takeoff path from the start of the takeoff to the point at which the airplane is 35 feet above the takeoff surface as determined under §23.57; or<br>(2) With all engines operating, 115 percent of the horizontal distance from the start of the takeoff to the point at which the airplane is 35 feet above the takeoff surface, determined by a procedure consistent with §23.57. | | | The takeoff area required for the sUAS to takeoff under normal operating conditions is defined by the product of—<br>(1) The forward distance required for the aircraft to accelerate, become airborne, and climb to an altitude of 50 feet above the takeoff surface or highest point of the launch apparatus;<br>(2) A lateral distance that is not less than 3 times the aircraft's wingspan.<br>The takeoff area will be determined by flight test, taking into account temperature, altitude, and all aircraft weights and configurations. | A normal takeoff area is defined as:<br>- The forward distance required for the aircraft to accelerate, lift off, and climb to an altitude of 50 feet above the takeoff surface or the highest point of the launch apparatus.<br>- The lateral distance equal to at least three times the aircraft's wing span.<br>These constraints seemed reasonable and leave room for manufacturers to specify reasonable takeoff areas as appropriate to a given aircraft. They also take into account the fact that these aircraft may not always be operated from prepared surfaces and provide guidance as to the minimum required area needed for a safe takeoff. | - | X | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 80 | (b) If the takeoff distance includes a clearway, the takeoff run is the greater of—<br>(1) The horizontal distance along the takeoff path from the start of the takeoff to a point equidistant between the liftoff point and the point at which the airplane is 35 feet above the takeoff surface as determined under §23.57; or<br>(2) With all engines operating, 115 percent of the horizontal distance from the start of the takeoff to a point equidistant between the liftoff point and the point at which the airplane is 35 feet above the takeoff surface, determined by a procedure consistent with §23.57. | | | N/A | It is not anticipated that a clearway will be required for sUAS operations. | X | X | - | - |
| 81 | [Amdt. 23-34, 52 FR 1827, Jan. 15, 1987, as amended by Amdt. 23-50, 61 FR 5185, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 82 | **§23.61 Takeoff flight path.** | | | **Takeoff flight path** | | x | X | - | - |
| 83 thru 85 | For normal, utility, and acrobatic category multiengine jets of more than 6,000 pounds maximum weight and commuter category airplanes, the takeoff flight path must be determined as follows:<br>(a) The takeoff flight path begins 35 feet above the takeoff surface at the end of the takeoff distance determined in accordance with §23.59.<br>(b) The net takeoff flight path data must be determined so that they represent the actual takeoff flight paths, as determined in accordance with §23.57 and with paragraph (a) of this section, reduced at each point by a gradient of climb equal to—<br>(1) 0.8 percent for two-engine airplanes;<br>(2) 0.9 percent for three-engine airplanes; and<br>(3) 1.0 percent for four-engine airplanes.<br>(c) The prescribed reduction in climb gradient may be applied as an equivalent reduction in acceleration along that part of the takeoff flight path at which the airplane is accelerated in level flight. | | | N/A | Takeoff flight paths will vary greatly between sUAS of varying sizes, weights, propulsion methods, launch methods, and performance characteristics. Takeoff flight paths are loosely established in requirements for takeoff area which dictate that the aircraft must simply reach an altitude of at least 50 feet above the takeoff surface or the highest point on the launch apparatus. | X | X | - | - |
| 86 | [Amdt. 23-34, 52 FR 1827, Jan. 15, 1987, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 87 | **§23.63 Climb: General.** | | | **Climb: General** | | - | - | x | - |
| 88 | (a) Compliance with the requirements of §§23.65, 23.66, 23.67, 23.69, and 23.77 must be shown—<br>(1) Out of ground effect; and<br>(2) At speeds that are not less than those at which compliance with the powerplant cooling requirements of §§23.1041 to 23.1047 has been demonstrated; and<br>(3) Unless otherwise specified, with one engine inoperative, at a bank angle not exceeding 5 degrees. | | REDACTED – F2245-15 [4.4.3, 4.4.3.1, 4.4.3.2] | Determine rates of climb, $V_X$ and $V_Y$ through flight test at maximum takeoff weight. | $V_X$ and $V_Y$ are relevant to the extent that these values can be used to establish climb parameters for automated flight. They may also be used when addressing questions with regard to Part 36. | - | - | X | - |
| 89 | (b) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of 6,000 pounds or less maximum weight, compliance must be shown with §23.65(a), §23.67(a), where appropriate, and §23.77(a) at maximum takeoff or landing weight, as appropriate, in a standard atmosphere. | | | Climb performance with all powerplants operating and with one powerplant inoperative, must be demonstrated at the maximum aircraft takeoff weight in a standard atmosphere. | Climb performance with an inoperative powerplant may not be applicable to all sUAS under given CONOPs. It may also be acceptable to terminate the flight or initiate a controlled descent in the event of a powerplant failure if the sUAS is intended to operate in remote areas. | - | - | X | X |
| 90 | (c) For reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight, single-engine turbines, and multiengine turbine airplanes of 6,000 pounds or less maximum weight in the normal, utility, and acrobatic category, compliance must be shown at weights as a function of airport altitude and ambient temperature, within the operational limits established for takeoff and landing, respectively, with—<br>(1) Sections 23.65(b) and 23.67(b) (1) and (2), where appropriate, for takeoff, and<br>(2) Section 23.67(b)(2), where appropriate, and §23.77(b), for landing. | | | Climb performance must be shown at critical aircraft weights as a function of altitude, ambient temperature, and operational limits established for takeoff and landing. | | - | - | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 91 | (d) For multiengine turbine airplanes over 6,000 pounds maximum weight in the normal, utility, and acrobatic category and commuter category airplanes, compliance must be shown at weights as a function of airport altitude and ambient temperature within the operational limits established for takeoff and landing, respectively, with—<br>(1) Sections 23.67(c)(1), 23.67(c)(2), and 23.67(c)(3) for takeoff; and<br>(2) Sections 23.67(c)(3), 23.67(c)(4), and 23.77(c) for landing. | | | N/A | | X | X | - | - |
| 92 | [Doc. No. 27807, 61 FR 5186, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |
| 93 | **§23.65 Climb: All engines operating.** | | | **Climb: All engines operating** | | - | - | x | - |
| 94 | (a) Each normal, utility, and acrobatic category reciprocating engine-powered airplane of 6,000 pounds or less maximum weight must have a steady climb gradient at sea level of at least 8.3 percent for landplanes or 6.7 percent for seaplanes and amphibians with—<br>(1) Not more than maximum continuous power on each engine;<br>(2) The landing gear retracted;<br>(3) The wing flaps in the takeoff position(s); and<br>(4) A climb speed not less than the greater of 1.1 $V_{MC}$ and 1.2 $V_{S1}$ for multiengine airplanes and not less than 1.2 $V_{S1}$for single—engine airplanes. | | REDACTED – F2245-15 [4.4.3, 4.4.3.1, 4.4.3.2] | (a) sUAS at maximum weight must be able to establish and hold a steady climb gradient at sea level of at least 8.3 percent with—<br>(1) Not more than maximum continuous power (on each powerplant if applicable);<br>(2) The landing gear retracted (if applicable); and<br>(3) The wing flaps in the takeoff position(s) (if applicable); | The climb gradient referenced here was carried over from Part 23 as it seemed reasonable.<br>In the case of an aircraft that is not intended to be operated over people, it would be sufficient to demonstrate a climb gradient that allows a safe transition from the takeoff surface or the highest point on the launch apparatus. Specifying a specific climb gradient may not be necessary if an aircraft is to be operated BVLOS in a remote area, at low altitude, and away from people or structures. | - | - | X | X |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 95 | (b) Each normal, utility, and acrobatic category reciprocating engine-powered airplane of more than 6,000 pounds maximum weight, single-engine turbine, and multiengine turbine airplanes of 6,000 pounds or less maximum weight in the normal, utility, and acrobatic category must have a steady gradient of climb after takeoff of at least 4 percent with<br>(1) Take off power on each engine;<br>(2) The landing gear extended, except that if the landing gear can be retracted in not more than seven seconds, the test may be conducted with the gear retracted;<br>(3) The wing flaps in the takeoff position(s); and<br>(4) A climb speed as specified in §23.65(a)(4). | | | (b) Each sUAS must demonstrate a minimum climb gradient of at least 4 percent after takeoff/launch with—<br>(1) Takeoff power to both powerplants (if applicable);<br>(2) Landing gear retracted (if applicable);<br>(3) Wing flaps in the takeoff position; and | The climb gradient of 4 percent seemed entirely reasonable. However, it may be scaled in instances where CONOPs permits a shallower climb gradient. It is not anticipated that many fixed-wing sUAS will have problems achieving a climb gradient of 4 percent. | - | - | X | X |
| 96 | [Doc. No. 27807, 61 FR 5186, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75753, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 97 | **§23.66 Takeoff climb: One-engine inoperative.** | | | **Takeoff climb: One-engine inoperative** | | - | - | x | - |
| 98 | For normal, utility, and acrobatic category reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight, and turbine engine-powered airplanes in the normal, utility, and acrobatic category, the steady gradient of climb or descent must be determined at each weight, altitude, and ambient temperature within the operational limits established by the applicant with— | REDACTED – F2910-14 [5.10.3, 5.10.3.1] | | For sUAS, with more than one powerplant, determine the rate of climb or descent at each weight, altitude, and ambient temperature within the operational limits of the aircraft's design with— | The F38 standards do not take a climb with one powerplant inoperative into account.<br>This Part 23 requirement, although applicable to aircraft > 6,000 lbs, was adapted due to the fact that it outlines important criteria for demonstrating a takeoff climb with one powerplant inoperative.<br>It is generally assumed that a sUAS flight would be aborted in the event of a flight-critical system failure during takeoff. However, it is not unreasonable to expect a sUAS that is intended for flight in environments where a higher level of safety is required to be able to demonstrate a takeoff climb with a powerplant inoperative for the purpose of clearing an obstacle and maintaining control. This is a case where CONOPS would drive flight test requirements. This is reflected in lines 99-104 by the "scalable to CONOPS" selection. | - | - | - | X |
| 99 | (a) The critical engine inoperative and its propeller in the position it rapidly and automatically assumes; | | | (a) The critical powerplant inoperative and its propeller in the position it rapidly and automatically assumes; | The critical powerplant may be determined in the same manner as with manned aircraft. However, with electric motors, a simple rearranging of wires will allow a motor to spin in a different direction, rendering an aircraft without a critical powerplant or even changing which powerplant is critical based upon wiring. | - | - | - | X |
| 100 | (b) The remaining engine(s) at takeoff power; | | | (b) The remaining powerplant at takeoff power; | | - | - | - | X |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 101 | (c) The landing gear extended, except that if the landing gear can be retracted in not more than seven seconds, the test may be conducted with the gear retracted; | | | (c) The landing gear extended, except when retractable gear are installed and extended/retracted using servos; | This was modified to allow for landing gear with servos to be retracted. The retraction mechanisms typically perform a full retract in much less than seven seconds. | - | - | X | X |
| 102 | (d) The wing flaps in the takeoff position(s): | | | (d) The wing flaps in the takeoff position(s) (if applicable); | | - | - | X | X |
| 103 | (e) The wings level; and | | | (e) The wings level; and | | - | - | X | X |
| 104 | (f) A climb speed equal to that achieved at 50 feet in the demonstration of §23.53. | | | (f) A climb speed that is achieved at 50 feet that will allow for a safe recovery of the aircraft if flight cannot be sustained. | | - | - | X | - |
| 105 | [Doc. No. 27807, 61 FR 5186, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 106 | **§23.67 Climb: One engine inoperative.** | | | **Climb: One engine inoperative** | | - | - | x | - |
| 107 | (a) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of 6,000 pounds or less maximum weight, the following apply:<br>(1) Except for those airplanes that meet the requirements prescribed in §23.562(d), each airplane with a $V_{SO}$ of more than 61 knots must be able to maintain a steady climb gradient of at least 1.5 percent at a pressure altitude of 5,000 feet with the—<br>(i) Critical engine inoperative and its propeller in the minimum drag position;<br>(ii) Remaining engine(s) at not more than maximum continuous power;<br>(iii) Landing gear retracted;<br>(iv) Wing flaps retracted; and<br>(v) Climb speed not less than 1.2 $V_{S1}$.<br>(2) For each airplane that meets the requirements prescribed in §23.562(d), or that has a $V_{SO}$ of 61 knots or less, the steady gradient of climb or descent at a pressure altitude of 5,000 feet must be determined with the—<br>(i) Critical engine inoperative and its propeller in the minimum drag position;<br>(ii) Remaining engine(s) at not more than maximum continuous power;<br>(iii) Landing gear retracted;<br>(iv) Wing flaps retracted; and<br>(v) Climb speed not less than 1.2$V_{S1}$. | REDACTED – F2910-14 [5.10.3, 5.10.3.1] | | (a) For sUAS with more than one powerplant, the following apply:<br>(1) The sUAS must be able to maintain a steady climb gradient of a least 1.5 percent at a pressure altitude of no more than 5,000 feet with the—<br>(2) Critical powerplant inoperative;<br>(3) If the sUAS is equipped with a variable pitch propeller, the propeller must be in its minimum drag position.<br>(4) Remaining powerplant(s) at no more than maximum continuous power.<br>(5) landing gear extended (if applicable); and<br>(6) Climb speed not less than 1.2 $V_{S1}$.<br>(b) If flight cannot be maintained with one powerplant inoperative, the aircraft must comply with the requirements of ASTM F2910-14 [5.10.3.1]. | The F38 standards do not take a climb with one powerplant inoperative into account.<br>Climb gradient is a direct carry-over from Part 23. It seems reasonable as it is quite small.<br>It is specified that the landing gear remain extended due to the fact that most sUAS will likely have fixed gear, if they have gear at all.<br>For simple low weight aircraft that are not intended to operate over people, less rigorous flight test requirements are acceptable here. However, Paragraph (b) should apply regardless. | - | - | X | X |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 108 | (b) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight, and turbopropeller-powered airplanes in the normal, utility, and acrobatic category—<br>(1) The steady gradient of climb at an altitude of 400 feet above the takeoff must be no less than 1 percent with the—<br>(i) Critical engine inoperative and its propeller in the minimum drag position;<br>(ii) Remaining engine(s) at takeoff power;<br>(iii) Landing gear retracted;<br>(iv) Wing flaps in the takeoff position(s); and<br>(v) Climb speed equal to that achieved at 50 feet in the demonstration of §23.53.<br>(2) The steady gradient of climb must not be less than 0.75 percent at an altitude of 1,500 feet above the takeoff surface, or landing surface, as appropriate, with the—<br>(i) Critical engine inoperative and its propeller in the minimum drag position;<br>(ii) Remaining engine(s) at not more than maximum continuous power;<br>(iii) Landing gear retracted;<br>(iv) Wing flaps retracted; and<br>(v) Climb speed not less than 1.2 $V_{S1}$. | | | N/A | Not applicable as the Part 23 regulation is intended to apply to larger aircraft > 6,000 lbs. Equivalent regulations exist elsewhere. | X | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 109 | (c) For normal, utility, and acrobatic category jets of 6,000 pounds or less maximum weight—<br>(1) The steady gradient of climb at an altitude of 400 feet above the takeoff must be no less than 1.2 percent with the—<br>(i) Critical engine inoperative;<br>(ii) Remaining engine(s) at takeoff power;<br>(iii) Landing gear retracted;<br>(iv) Wing flaps in the takeoff position(s); and<br>(v) Climb speed equal to that achieved at 50 feet in the demonstration of §23.53.<br>(2) The steady gradient of climb may not be less than 0.75 percent at an altitude of 1,500 above the takeoff surface, or landing surface, as appropriate, with the—<br>(i) Critical engine inoperative;<br>(ii) Remaining engine(s) at not more than maximum continuous power;<br>(iii) Landing gear retracted;<br>(iv) Wing flaps retracted; and<br>(v) Climb speed not less than 1.2 $V_{S1}$. | | | N/A | Not applicable as the Part 23 regulation is intended to apply to jet aircraft < 6,000 lbs. Equivalent regulations exist elsewhere. | X | - | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO SUAS PER ASSURE A1 TEAM | N/A TO SUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 110 | (d) For jets over 6,000 pounds maximum weight in the normal, utility and acrobatic category and commuter category airplanes, the following apply:<br>(1) *Takeoff; landing gear extended.* The steady gradient of climb at the altitude of the takeoff surface must be measurably positive for two-engine airplanes, not less than 0.3 percent for three-engine airplanes, or 0.5 percent for four-engine airplanes with— (i) The critical engine inoperative and its propeller in the position it rapidly and automatically assumes; (ii) The remaining engine(s) at takeoff power; (iii) The landing gear extended, and all landing gear doors open; (iv) The wing flaps in the takeoff position(s); (v) The wings level; and (vi) A climb speed equal to $V_2$.<br>(2) *Takeoff; landing gear retracted.* The steady gradient of climb at an altitude of 400 feet above the takeoff surface must be not less than 2.0 percent of two-engine airplanes, 2.3 percent for three-engine airplanes, and 2.6 percent for four-engine airplanes with— (i) The critical engine inoperative and its propeller in the position it rapidly and automatically assumes; (ii) The remaining engine(s) at takeoff power; (iii) The landing gear retracted; (iv) The wing flaps in the takeoff position(s); (v) A climb speed equal to $V_2$.<br>(3) *Enroute.* The steady gradient of climb at an altitude of 1,500 feet above the takeoff or landing surface, as appropriate, must be not less than 1.2 percent for two-engine airplanes, 1.5 percent for three-engine airplanes, and 1.7 percent for four-engine airplanes with— (i) The critical engine inoperative and its propeller in the minimum drag position; (ii) The remaining engine(s) at not more than maximum continuous power; (iii) The landing gear retracted; (iv) The wing flaps retracted; and (v) A climb speed not less than 1.2 $V_{S1}$.<br>(4) *Discontinued approach.* The steady gradient of climb at an altitude of 400 feet above the landing surface must be not less than 2.1 percent for two-engine airplanes, 2.4 percent for three-engine airplanes, and 2.7 percent for four-engine airplanes, with— (i) The critical engine inoperative and its propeller in the minimum drag position; (ii) The remaining engine(s) at takeoff power; (iii) Landing gear retracted; (iv) Wing flaps in the approach position(s) in which $V_{S1}$ for these position(s) does not exceed 110 percent of the $V_{S1}$for the related all-engines-operated landing position(s); and (v) A climb speed established in connection with normal landing procedures but not exceeding 1.5 $V_{S1}$. | | | N/A | Not applicable as the Part 23 regulation is intended to apply to jet aircraft > 6,000 lbs. Equivalent regulations exist elsewhere. | X | - | - | - |
| 111 | [Doc. No. 27807, 61 FR 5186, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75754, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 112 | **§23.69 Enroute climb/descent.** | | | **Enroute climb/descent** | | - | - | x | - |
| 113 | (a) *All engines operating.* The steady gradient and rate of climb must be determined at each weight, altitude, and ambient temperature within the operational limits established by the applicant with—<br>(1) Not more than maximum continuous power on each engine;<br>(2) The landing gear retracted;<br>(3) The wing flaps retracted; and<br>(4) A climb speed not less than 1.3 $V_{S1}$. | | | (a) *All powerplants operating*. The climb gradient of the sUAS must be determined at each weight, altitude, and ambient temperature within the operational limits of the aircraft's design with—<br>(1) Not more than maximum continuous power on each powerplant;<br>(2) The landing gear retracted (if possible).<br>(3) The wing flaps retracted; and<br>(4) A climb speed of not less than 1.3 $V_{S1}$. | This requirement may be scaled to suit CONOPs and equipage as well as the aircraft itself. For operations in remote locations at low altitudes that do not occur over people, this information is less important. In instances where a sUAS is intended to be operated at higher altitudes, over people, BVLOS, and in close proximity to manned aircraft, this requirement is far more important.<br>In instances where a sUAS does not require such a thorough definition of allowable climb gradients, general climb characteristics under prescribed conditions may be enough, especially for very simple low risk aircraft. | - | - | X | X |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 114 | (b) *One engine inoperative.* The steady gradient and rate of climb/descent must be determined at each weight, altitude, and ambient temperature within the operational limits established by the applicant with—<br>(1) The critical engine inoperative and its propeller in the minimum drag position;<br>(2) The remaining engine(s) at not more than maximum continuous power;<br>(3) The landing gear retracted;<br>(4) The wing flaps retracted; and<br>(5) A climb speed not less than 1.2 $V_{S1}$. | REDACTED – F2910-14 [5.10.3, 5.10.3.1] | | (b) *Climb with one powerplant inoperative.* The steady gradient and/or rate of climb must be determined for the sUAS at each weight, altitude, and ambient temperature within the operational limits of the aircraft's design with—<br>(1) The critical powerplant inoperative and, if variable pitch propellers are used, its propeller in the minimum drag position;<br>(2) The remaining powerplants at not more than maximum continuous power;<br>(3) The landing gear retracted (if applicable);<br>(4) The wing flaps retracted; and<br>(5) A climb speed of not less than 1.2 $V_{S1}$.<br>(c) If flight cannot be sustained with one powerplant inoperative, then the sUAS must be shown to comply with F2910-14 [5.10.3.1] | The F38 standards do not take a climb with one powerplant inoperative into account.<br>It is important to demonstrate that a sUAS is still capable of climbing in the event that a power plant becomes inoperative. In a situation where the aircraft is being operated beyond line of sight over people, the aircraft would still be required to perform the most basic of maneuvers in the event of a powerplant failure. However, in given operational scenarios, such as in remote locations or where flights do not occur over people, it is also acceptable to terminate the flight in the event of a powerplant failure.<br>For electric aircraft, there may be no "critical engine", if the powerplants are wired to be counter-rotating. | - | - | - | X |
| 115 | [Doc. No. 27807, 61 FR 5187, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 116 | **§23.71 Glide: Single-engine airplanes.** | | | **Glide: Single-engine airplanes** | | - | - | x | - |
| 117 | The maximum horizontal distance traveled in still air, in nautical miles, per 1,000 feet of altitude lost in a glide, and the speed necessary to achieve this must be determined with the engine inoperative, its propeller in the minimum drag position, and landing gear and wing flaps in the most favorable available position. | REDACTED – F2910-14 [5.10.3.2] | | Determine the horizontal distance traveled and altitude lost in still air of the sUAS at its calculated best glide speed with the powerplant inoperative, the propeller in its minimum drag position (if equipped with variable pitch propeller(s)), and the landing gear and wing flaps in the most favorable position. The sUAS must also be shown to comply with ASTM F2910-14 [5.10.3.2]. | This is also an example of how CONOPS would help to frame flight testing. For operations over people, knowing the distance that can be traveled per a given loss of altitude at some best glide speed would allow an operator to know how far they can get in the event of an emergency. This would allow the operator to plan “outs” in their flight plan to ensure they are always within gliding distance of a safe ditching point.<br>For operations in remote areas, ASTM F2910-14 [5.10.3.2] would probably be sufficient on its own.<br>For the sake of certification, the more stringent proposed flight test recommendation(s) are listed. | - | - | X | X |
| 118 | [Doc. No. 27807, 61 FR 5187, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 119 | **§23.73 Reference landing approach speed.** | | | **Reference landing approach speed** | | - | X | x | - |
| 120 | (a) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of 6,000 pounds or less maximum weight, the reference landing approach speed, $V_{REF}$, may not be less than the greater of $V_{MC}$, determined in §23.149(b) with the wing flaps in the most extended takeoff position, and 1.3 $V_{S1}$. | | | For sUAS, the reference landing approach speed must not be less than the greater of $V_{MIN}$ with the wing flaps in the takeoff position (if applicable) and 1.3 $V_{S1}$. | An established recommended reference landing speed that is a factor of stall speed or minimum approach speed is helpful for establishing limitations for aircraft that use automated landing functions. This was added for the purpose of providing guidance when tuning an autopilot for performing automated landings. | - | X | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 121 | (b) For normal, utility, and acrobatic category turbine powered airplanes of 6,000 pounds or less maximum weight, turboprops of more than 6,000 pounds maximum weight, and reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight, the reference landing approach speed, $V_{REF}$, may not be less than the greater of $V_{MC}$, determined in §23.149(c), and 1.3 $V_{S1}$. | | | N/A | | X | X | - | - |
| 122 | (c) For normal, utility, and acrobatic category jets of more than 6,000 pounds maximum weight and commuter category airplanes, the reference landing approach speed, $V_{REF}$, may not be less than the greater of 1.05 $V_{MC}$, determined in §23.149(c), and 1.3 $V_{S1}$. | | | N/A | | X | X | - | - |
| 123 | [Amdt. 23-62, 76 FR 75754, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 124 | **§23.75 Landing distance.** | | | **Landing area** | | - | X | x | - |
| 125 | The horizontal distance necessary to land and come to a complete stop from a point 50 feet above the landing surface must be determined, for standard temperatures at each weight and altitude within the operational limits established for landing, as follows: | | REDACTED – F2245-15 [4.4.4, 4.4.4.1, 4.4.4.2] | Determine the required landing area by flight test:<br>The landing area is defined as the landing distance multiplied by 3 times the aircraft's wing span.<br>The landing distance is determined from a point at which the sUA is 50 feet above the landing surface or for all weights, ambient temperatures, and altitudes with—<br>(1) Wing flaps in the landing position (if applicable);<br>(2) The landing gear extended (if applicable); and<br>(3) Throttle in the closed position or open to the extent of allowing the aircraft to maintain a steady approach speed.<br>If the sUAS utilizes a capture system, such as a net, cable, or other system for landing/recovery then—<br>(1) The landing distance will be measured starting from 50ft above the landing surface or the highest point of any required recovery equipment.<br>(2) The stop distance will be measured at the maximum possible deflection of the net, cable, or other arresting device. | Again, it is beneficial to think of sUAS landings in terms of area. This takes into account the varied performance characteristics, sizes, and recovery methods as well as the fact that sUAS are often not operated on prepared surfaces.<br>Recommended approach parameters for each aircraft would also need to be detailed when average landing distances are determined. | - | X | X | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 126 thru 128 | (a) A steady approach at not less than $V_{REF}$, determined in accordance with §23.73 (a), (b), or (c), as appropriate, must be maintained down to the 50 foot height and—<br>(1) The steady approach must be at a gradient of descent not greater than 5.2 percent (3 degrees) down to the 50-foot height.<br>(2) In addition, an applicant may demonstrate by tests that a maximum steady approach gradient steeper than 5.2 percent, down to the 50-foot height, is safe. The gradient must be established as an operating limitation and the information necessary to display the gradient must be available to the pilot by an appropriate instrument. | | | N/A | | X | X | - | - |
| 129 | (b) A constant configuration must be maintained throughout the maneuver. | | | N/A | | X | X | - | - |
| 130 | (c) The landing must be made without excessive vertical acceleration or tendency to bounce, nose over, ground loop, porpoise, or water loop. | | | The landing must be made without excessive vertical acceleration or tendency to bounce, nose over, ground loop, porpoise, or water loop. | | - | X | X | - |
| 131 | (d) It must be shown that a safe transition to the balked landing conditions of §23.77 can be made from the conditions that exist at the 50 foot height, at maximum landing weight, or at the maximum landing weight for altitude and temperature of §23.63 (c)(2) or (d)(2), as appropriate. | | | A safe transition to balked landing flight configuration at a 50 foot height above the landing surface or highest point on the recovery apparatus at the maximum landing weight for altitude and temperature must be shown by flight test. | | - | X | X | - |
| 132 | (e) The brakes must be used so as to not cause excessive wear of brakes or tires. | | | N/A | | X | X | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 133 thru 135 | (f) Retardation means other than wheel brakes may be used if that means—<br>(1) Is safe and reliable; and<br>(2) Is used so that consistent results can be expected in service. | | | Means other than wheel brakes may be used to stop the sUAS if they are—<br>(1) Safe and reliable; and<br>(2) Used so that consistent results can be expected in service. | Requirements related to wheel braking is addressed in line 67. | - | X | X | - |
| 136 | (g) If any device is used that depends on the operation of any engine, and the landing distance would be increased when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative unless the use of other compensating means will result in a landing distance not more than that with each engine operating. | | | N/A | | X | X | - | - |
| 137 | [Amdt. 23-21, 43 FR 2318, Jan. 16, 1978, as amended by Amdt. 23-34, 52 FR 1828, Jan. 15, 1987; Amdt. 23-42, 56 FR 351, Jan. 3, 1991; Amdt. 23-50, 61 FR 5187, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 138 | **§23.77 Balked landing.** | | | **Balked landing** | | - | X | x | - |
| 139 thru 143 | (a) Each normal, utility, and acrobatic category reciprocating engine-powered airplane at 6,000 pounds or less maximum weight must be able to maintain a steady gradient of climb at sea level of at least 3.3 percent with—<br>(1) Takeoff power on each engine;<br>(2) The landing gear extended;<br>(3) The wing flaps in the landing position, except that if the flaps may safely be retracted in two seconds or less without loss of altitude and without sudden changes of angle of attack, they may be retracted; and<br>(4) A climb speed equal to $V_{REF}$, as defined in §23.73(a). | | REDACTED – F2245-15 [4.4.5, 4.4.5.1] | The sUAS must demonstrate a balked landing with—<br>(1) Takeoff power not to exceed maximum continuous power;<br>(2) If equipped with landing gear, landing gear extended;<br>(3) If equipped with wing flaps, they must be in the landing position, except when they may be safely retracted without loss of altitude and without sudden changes in angle of attack;<br>(4) Climb speed sufficient for a safe climb out to pattern altitude; and<br>(5) A climb gradient that allows for a safe transition to pattern altitude. | Balked landings are still important for sUAS and can even be automated. Demonstrating a balked landing for the purpose of certification is valuable as it ensures that an automated off-site landing, should one occur, will be more likely to be controlled as the aircraft would have demonstrated the ability to perform a go-around in the event of an unfavorable approach.<br>Given the diverse range of sUAS performance characteristics, it is not useful to set a climb speed. Demonstrating that the aircraft can safely climb is sufficient. | - | X | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 144 thru 148 | (b) Each normal, utility, and acrobatic category reciprocating engine-powered and single engine turbine powered airplane of more than 6,000 pounds maximum weight, and multiengine turbine engine-powered airplane of 6,000 pounds or less maximum weight in the normal, utility, and acrobatic category must be able to maintain a steady gradient of climb of at least 2.5 percent with—<br>(1) Not more than the power that is available on each engine eight seconds after initiation of movement of the power controls from minimum flight-idle position;<br>(2) The landing gear extended;<br>(3) The wing flaps in the landing position; and<br>(4) A climb speed equal to $V_{REF}$, as defined in §23.73(b). | | | N/A | Requirements were combined with row 139-143 requirements<br>----<br>As stated above, the climb characteristics of sUAS will vary a great deal. A generic condition that the aircraft must climb at a climb gradient that allows for a safe transition to pattern altitude is sufficient here.<br>If the functional requirements of Lines 139 through 143 are met, then the requirement(s) listed here are not necessary to ensure safe operation. | X | X | - | - |
| 149 thru 153 | (c) Each normal, utility, and acrobatic multiengine turbine powered airplane over 6,000 pounds maximum weight and each commuter category airplane must be able to maintain a steady gradient of climb of at least 3.2 percent with—<br>(1) Not more than the power that is available on each engine eight seconds after initiation of movement of the power controls from the minimum flight idle position;<br>(2) Landing gear extended;<br>(3) Wing flaps in the landing position; and<br>(4) A climb speed equal to $V_{REF}$, as defined in §23.73(c). | | | N/A | If the functional requirements of Lines 139 through 143 are met, then the requirement(s) listed here are not necessary to ensure safe operation. | X | X | - | - |
| 154 | [Doc. No. 27807, 61 FR 5187, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75754, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 155 | **Flight Characteristics** | | | | | | | | |
| 156 | **§23.141 General.** | | | **General** | | - | - | x | - |
| 157 | The airplane must meet the requirements of §§23.143 through 23.253 at all practical loading conditions and operating altitudes for which certification has been requested, not exceeding the maximum operating altitude established under §23.1527, and without requiring exceptional piloting skill, alertness, or strength. | | | The sUAS must be shown to meet all practical loading conditions and operational constraints for which certification has been requested, and must not require exceptional piloting skill or alertness to operate. | This was re-written from Part 23 as it is implied that the aircraft must behave as intended and comply with all operational constraints based upon the basis for certification. This is a common sense measure. | - | - | X | - |
| 158 | [Doc. No. 26269, 58 FR 42156, Aug. 6, 1993] | -------- | -------- | -------- | -------- | - | - | - | - |
| 159 | **Controllability and Maneuverability** | | | | | | | | |
| 101 | **§23.143 General.** | | **4.5.1 General:** | **General** | | - | - | x | - |
| 161 | (a) The airplane must be safely controllable and maneuverable during all flight phases including—<br>(1) Takeoff;<br>(2) Climb;<br>(3) Level flight;<br>(4) Descent;<br>(5) Go-around; and<br>(6) Landing (power on and power off) with the wing flaps extended and retracted. | | REDACTED – F2245-15 [4.5.1.1, 4.5.1.3, 4.5.1.4] | Demonstrate controllability and maneuverability during critical phases of flight—<br>(1) Takeoff;<br>(2) Climb;<br>(3) Level flight;<br>(4) Descent;<br>(5) Go-around; and<br>(6) Landing (power on and power off) with the wing flaps extended and retracted. | | - | - | X | - |
| 162 | (b) It must be possible to make a smooth transition from one flight condition to another (including turns and slips) without danger of exceeding the limit load factor, under any probable operating condition (including, for multiengine airplanes, those conditions normally encountered in the sudden failure of any engine). | | | Demonstrate smooth transitions from each flight condition to all other flight conditions. Ensure that limit load factors are not exceeded during flight transitions. | | - | - | X | - |

<table>
<tr><th>LINE NO.</th><th>14 CFR PART 23 - COMMUTER</th><th>F38 – sUAS[2]</th><th>F37 – LSA[3]</th><th>RECOMMENDED FT</th><th>COMMENTS</th><th>N/A TO sUAS PER ASSURE A1 TEAM</th><th>N/A TO sUAS PER DRAFT AC 20-XX</th><th>GAP IN F38</th><th>SCALABLE TO CONOPS OR EQUIPAGE</th></tr>
<tr><td>163</td><td>(c) If marginal conditions exist with regard to required pilot strength, the control forces necessary must be determined by quantitative tests. In no case may the control forces under the conditions specified in paragraphs (a) and (b) of this section exceed those prescribed in the following table:
<table>
<tr><th>Values in pounds force applied to the relevant control</th><th>Pitch</th><th>Roll</th><th>Yaw</th></tr>
<tr><td>(a) For temporary application:</td><td></td><td></td><td></td></tr>
<tr><td>Stick</td><td>60</td><td>30</td><td></td></tr>
<tr><td>Wheel (Two hands on rim)</td><td>75</td><td>50</td><td></td></tr>
<tr><td>Wheel (One hand on rim)</td><td>50</td><td>25</td><td></td></tr>
<tr><td>Rudder Pedal</td><td></td><td></td><td>150</td></tr>
<tr><td>(b) For prolonged application</td><td>10</td><td>5</td><td>20</td></tr>
</table></td><td></td><td>REDACTED – F2245-15 [4.5.1.2]</td><td>(c) Control forces for manual flight controls must not require exceptional strength on the part of the operator to manipulate.</td><td>Determination of stick control forces is considered a human factors issue and will need to be addressed by further research.<br><br>As reference points, force limits for controls could be near the force required to move:<br><br>a) The control sticks on an RC transmitter through their full range of motion.<br><br>b) The amount of force required to move a typical PC joystick that may be used as a control input device. This is something that may need to be determined through basic tests.<br><br>When addressing haptic feedback control devices, it may be prudent to scale back the forces listed in the LSA table. Exact scaling values are not yet known. However, forces would likely be measured in ounces rather than pounds when addressing traditional RC transmitter controls.</td><td>-</td><td>-</td><td>X</td><td>-</td></tr>
<tr><td>164</td><td>[Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23-14, 38 FR 31819, Nov. 19, 1973; Amdt. 23-17, 41 FR 55464, Dec. 20, 1976; Amdt. 23-45, 58 FR 42156, Aug. 6, 1993; Amdt. 23-50, 61 FR 5188, Feb. 9, 1996]</td><td>--------</td><td>--------</td><td>--------</td><td>--------</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 165 | **§23.145 Longitudinal control.** | | **4.5.2 Longitudinal Control** | **Longitudinal control** | | - | X | x | - |
| 166 thru 171 | (a) With the airplane as nearly as possible in trim at 1.3 $V_{S1}$, it must be possible, at speeds below the trim speed, to pitch the nose downward so that the rate of increase in airspeed allows prompt acceleration to the trim speed with—<br>(1) Maximum continuous power on each engine;<br>(2) Power off; and<br>(3) Wing flap and landing gear—<br>(i) retracted, and<br>(ii) extended. | | REDACTED – F2245-15 [4.5.2.1] | Starting from a trim condition at 1.3 $V_{S1}$, demonstrate in the flight configurations listed below it is possible from airspeeds below 1.3 $V_{S1}$ to pitch the nose downward so that the increase in airspeed allows prompt acceleration to a trim speed of 1.3 $V_{S1}$ with—<br>(1) Maximum continuous power (on each powerplant if multi powerplant);<br>(2) Power off;<br>(3) Wing flap and landing gear (if applicable)<br>(i) retracted, and<br>(ii) extended | Gap in ASTM standards. Longitudinal stability is considered, but control is not addressed directly.<br>This should be tested at low, medium, and high speeds, as calculated by a percentage of max airspeed for each aircraft. However, it is not yet certain what percentage should be used when determining thresholds for testing static stability or whether these thresholds should scale with airplane performance or remain static themselves. | - | X | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 172 thru 183 | (b) Unless otherwise required, it must be possible to carry out the following maneuvers without requiring the application of single-handed control forces exceeding those specified in §23.143(c). The trimming controls must not be adjusted during the maneuvers:<br>(1) With the landing gear extended, the flaps retracted, and the airplanes as nearly as possible in trim at 1.4 $V_{S1}$, extend the flaps as rapidly as possible and allow the airspeed to transition from 1.4$V_{S1}$ to 1.4 $V_{SO}$: (i) With power off; and (ii) With the power necessary to maintain level flight in the initial condition.<br>(2) With landing gear and flaps extended, power off, and the airplane as nearly as possible in trim at 1.3 $V_{SO}$: quickly apply takeoff power and retract the flaps as rapidly as possible to the recommended go around setting and allow the airspeed to transition from 1.3 $V_{SO}$ to 1.3 $V_{S1}$. Retract the gear when a positive rate of climb is established.<br>(3) With landing gear and flaps extended, in level flight, power necessary to attain level flight at 1.1 $V_{SO}$, and the airplane as nearly as possible in trim, it must be possible to maintain approximately level flight while retracting the flaps as rapidly as possible with simultaneous application of not more than maximum continuous power. If gated flat positions are provided, the flap retraction may be demonstrated in stages with power and trim reset for level flight at 1.1 $V_{S1}$, in the initial configuration for each stage— (i) From the fully extended position to the most extended gated position; (ii) Between intermediate gated positions, if applicable; and (iii) From the least extended gated position to the fully retracted position.<br>(4) With power off, flaps and landing gear retracted and the airplane as nearly as possible in trim at 1.4 $V_{S1}$, apply takeoff power rapidly while maintaining the same airspeed.<br>(5) With power off, landing gear and flaps extended, and the airplane as nearly as possible in trim at $V_{REF}$, obtain and maintain airspeeds between 1.1 $V_{SO}$, and either 1.7 $V_{SO}$ or $V_{FE}$, whichever is lower without requiring the application of two-handed control forces exceeding those specified in §23.143(c).<br>(6) With maximum takeoff power, landing gear retracted, flaps in the takeoff position, and the airplane as nearly as possible in trim at $V_{FE}$ appropriate to the takeoff flap position, retract the flaps as rapidly as possible while maintaining constant speed. | | REDACTED – F2245-15 [4.5.2.2, 4.5.2.3] | N/A | The functional requirements listed in Lines 166 through 171 satisfy basic longitudinal stability requirements above and beyond those that were originally outlined. | X | X | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 184 | (c) At speeds above $V_{MO}/M_{MO}$, and up to the maximum speed shown under §23.251, a maneuvering capability of 1.5 g must be demonstrated to provide a margin to recover from upset or inadvertent speed increase. | | | N/A | Other structural requirements should sufficiently cover the 1.5 g requirement | X | X | - | - |
| 185 | (d) It must be possible, with a pilot control force of not more than 10 pounds, to maintain a speed of not more than $V_{REF}$ during a power-off glide with landing gear and wing flaps extended, for any weight of the airplane, up to and including the maximum weight. | | | N/A | Control forces do not apply in the same manner for sUAS. In the case of an automated landing, no control forces will be needed on the part of the pilot. If landing manually, control forces will be much less, measured in ounces. | X | X | - | - |
| 186 thru 190 | (e) By using normal flight and power controls, except as otherwise noted in paragraphs (e)(1) and (e)(2) of this section, it must be possible to establish a zero rate of descent at an attitude suitable for a controlled landing without exceeding the operational and structural limitations of the airplane, as follows:<br>(1) For single-engine and multiengine airplanes, without the use of the primary longitudinal control system.<br>(2) For multiengine airplanes—<br>(i) Without the use of the primary directional control; and<br>(ii) If a single failure of any one connecting or transmitting link would affect both the longitudinal and directional primary control system, without the primary longitudinal and directional control system. | | | N/A | | X | X | - | - |
| 191 | [Doc. No. 26269, 58 FR 42157, Aug. 6, 1993; Amdt. 23-45, 58 FR 51970, Oct. 5, 1993, as amended by Amdt. 23-50, 61 FR 5188, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 192 | **§23.147 Directional and lateral control.** | | **4.5.3 Directional and Lateral Control** | **Directional and lateral control** | | - | X | x | - |
| 193 thru 199 | (a) For each multiengine airplane, it must be possible, while holding the wings level within five degrees, to make sudden changes in heading safely in both directions. This ability must be shown at 1.4 $V_{S1}$ with heading changes up to 15 degrees, except that the heading change at which the rudder force corresponds to the limits specified in §23.143 need not be exceeded, with the—<br>(1) Critical engine inoperative and its propeller in the minimum drag position;<br>(2) Remaining engines at maximum continuous power;<br>(3) Landing gear—<br>(i) Retracted; and<br>(ii) Extended; and<br>(4) Flaps retracted. | | REDACTED – F2245-15 [4.5.3.1, 4.5.3.2, 4.5.3.3] | For a multi powerplant sUAS, demonstrate that it is possible to reverse a 30 degree coordinated turn in all configurations, enter into and recover from a slip without negatively impacting flight characteristics, and demonstrate that lateral and directional control forces do not reverse with increased deflection. Compliance will be determined with the—<br>(1) Critical engine inoperative and the propeller in the minimum drag position;<br>(2) remaining engines at maximum continuous power;<br>(3) Landing gear extended and retracted; and<br>(4) Flaps retracted. | Multi powerplant sUAS are not immune from the directional and lateral control problems that are inherent to a manned aircraft in the event of an engine failure. They do, however, often have the advantage of having a flight controller or autopilot that is able to make quick corrections to ensure that as much control is maintained as possible in the event of a failure.<br>Demonstrating the ability to maintain directional control in the event of a powerplant failure is important as it will determine how the aircraft will have to correct to maintain a course while navigating. If an aircraft can't hold a course with a powerplant failed, it creates new problems when attempting to send to a given destination or execute a safety critical maneuver. This is especially true in a beyond visual line of sight scenario. | - | X | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 200 thru 205 | (b) For each multiengine airplane, it must be possible to regain full control of the airplane without exceeding a bank angle of 45 degrees, reaching a dangerous attitude or encountering dangerous characteristics, in the event of a sudden and complete failure of the critical engine, making allowance for a delay of two seconds in the initiation of recovery action appropriate to the situation, with the airplane initially in trim, in the following condition:<br>(1) Maximum continuous power on each engine;<br>(2) The wing flaps retracted;<br>(3) The landing gear retracted;<br>(4) A speed equal to that at which compliance with §23.69(a) has been shown; and<br>(5) All propeller controls in the position at which compliance with §23.69(a) has been shown. | | | For multi powerplant sUAS, it must be possible to regain full control of the aircraft or initiate a safe automated recovery procedure without reaching a dangerous altitude or attitude in the event of a sudden failure of the critical powerplant with the airplane initially in trim, in the following condition:<br>(1) Maximum continuous power on each powerplant;<br>(2) If equipped with wing flaps, the wing flaps retracted;<br>(3) If equipped with retractable landing gear, the landing gear retracted;<br>(4) A speed equal to not less than 1.3 VS1; and<br>(5) If equipped with a variable pitch propeller, propeller controls in the position for maximum thrust. | In the event of a powerplant failure on a multi powerplant sUAS that is operated manually, the reaction time of a human operator may not be fast enough to counter the roll and yaw that results from the failure of the critical powerplant in time return to level flight. This is compounded by the lack of visual references while operating near the limits of visual line of sight. However, automated systems are far more likely to adapt to the new flight mode and return to level flight more quickly and reliably. This is important to take into account when approaching the problems of a critical powerplant failure in a beyond visual line of sight scenario. | - | X | X | - |
| 206 | (c) For all airplanes, it must be shown that the airplane is safely controllable without the use of the primary lateral control system in any all-engine configuration(s) and at any speed or altitude within the approved operating envelope. It must also be shown that the airplane's flight characteristics are not impaired below a level needed to permit continued safe flight and the ability to maintain attitudes suitable for a controlled landing without exceeding the operational and structural limitations of the airplane. If a single failure of any one connecting or transmitting link in the lateral control system would also cause the loss of additional control system(s), compliance with the above requirement must be shown with those additional systems also assumed to be inoperative. | | | For all sUAS, it must be shown that the aircraft is controllable or capable of initiating a recovery procedure without the use of the primary lateral control system throughout the approved operating envelope. | In a visual line of sight operation, this requirement would be less important as the aircraft would likely be able to be manually controlled. However, in a beyond visual line of sight scenario, some assurance is needed that the aircraft can either be controlled or initiate a recovery procedure. | - | X | X | X |
| 207 | [Doc. No. 27807, 61 FR 5188, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 208 | **§23.149 Minimum control speed.** | | | **Minimum control speed** | | - | X | x | - |
| 209 | (a) $V_{MC}$ is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane with that engine still inoperative, and thereafter maintain straight flight at the same speed with an angle of bank of not more than 5 degrees. The method used to simulate critical engine failure must represent the most critical mode of powerplant failure expected in service with respect to controllability. | | | $V_{MIN}$, which must be shown by flight test, is the calibrated airspeed at which the sUAS will be limited for the purpose of maintaining positive control in all flight configurations and degraded flight modes.<br>For sUAS with envelope protection systems, $V_{MIN}$ will be shown to be at least $1.2V_{S1}$ at maximum takeoff weight. | Minimum control speed was instead expressed as a minimum flight speed ($V_{MIN}$) to simplify the flight test process, and account for the ability of an envelope protection system to operate based upon airspeeds that will restrict the aircraft's flight envelope. | - | X | X | - |
| 210 thru 215 | (b) $V_{MC}$ for takeoff must not exceed 1.2 $V_{S1}$, where $V_{S1}$ is determined at the maximum takeoff weight. $V_{MC}$ must be determined with the most unfavorable weight and center of gravity position and with the airplane airborne and the ground effect negligible, for the takeoff configuration(s) with—<br>(1) Maximum available takeoff power initially on each engine;<br>(2) The airplane trimmed for takeoff;<br>(3) Flaps in the takeoff position(s);<br>(4) Landing gear retracted; and<br>(5) All propeller controls in the recommended takeoff position throughout. | | | N/A | A simplified requirement was devised to determine $V_{MIN}$. This Part 23 requirement was considered not to be applicable. | X | X | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 216 thru 221 | (c) For all airplanes except reciprocating engine-powered airplanes of 6,000 pounds or less maximum weight, the conditions of paragraph (a) of this section must also be met for the landing configuration with— (1) Maximum available takeoff power initially on each engine; (2) The airplane trimmed for an approach, with all engines operating, at $V_{REF}$, at an approach gradient equal to the steepest used in the landing distance demonstration of §23.75; (3) Flaps in the landing position; (4) Landing gear extended; and (5) All propeller controls in the position recommended for approach with all engines operating. | | | N/A | A simplified requirement was devised to determine $V_{MIN}$. This Part 23 requirement was considered not to be applicable. | X | X | - | - |
| 222 | (d) A minimum speed to intentionally render the critical engine inoperative must be established and designated as the safe, intentional, one-engine-inoperative speed, $V_{SSE}$. | | | N/A | A simplified requirement was devised to determine $V_{MIN}$. This Part 23 requirement was considered not to be applicable. | X | X | - | - |
| 223 | (e) At $V_{MC}$, the rudder pedal force required to maintain control must not exceed 150 pounds and it must not be necessary to reduce power of the operative engine(s). During the maneuver, the airplane must not assume any dangerous attitude and it must be possible to prevent a heading change of more than 20 degrees. | | | N/A | A simplified requirement was devised to determine $V_{MIN}$. This Part 23 requirement was considered not to be applicable. | X | X | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 224 thru 229 | (f) At the option of the applicant, to comply with the requirements of §23.51(c)(1), $V_{MCG}$ may be determined. $V_{MCG}$ is the minimum control speed on the ground, and is the calibrated airspeed during the takeoff run at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane using the rudder control alone (without the use of nosewheel steering), as limited by 150 pounds of force, and using the lateral control to the extent of keeping the wings level to enable the takeoff to be safely continued. In the determination of $V_{MCG}$, assuming that the path of the airplane accelerating with all engines operating is along the centerline of the runway, its path from the point at which the critical engine is made inoperative to the point at which recovery to a direction parallel to the centerline is completed may not deviate more than 30 feet laterally from the centerline at any point. $V_{MCG}$ must be established with—<br>(1) The airplane in each takeoff configuration or, at the option of the applicant, in the most critical takeoff configuration;<br>(2) Maximum available takeoff power on the operating engines;<br>(3) The most unfavorable center of gravity;<br>(4) The airplane trimmed for takeoff; and<br>(5) The most unfavorable weight in the range of takeoff weights. | | | N/A | A simplified requirement was devised to determine $V_{MIN}$. This Part 23 requirement was considered not to be applicable. | X | X | - | - |
| 230 | [Doc. No. 27807, 61 FR 5189, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 231 | **§23.151 Acrobatic maneuvers.** | | | **Evasive maneuvers** | | - | X | x | - |
| 232 | Each acrobatic and utility category airplane must be able to perform safely the acrobatic maneuvers for which certification is requested. Safe entry speeds for these maneuvers must be determined. | | | sUAS are required to demonstrate the ability to perform evasive maneuvers for the purpose of avoiding collisions with manned aircraft. A design maneuvering speed ($V_A$) must be established such that full application of flight controls may be applied for the purpose of aggressive maneuvering without causing structural damage to the aircraft. | Acrobatic maneuvers are relevant to the extent that they represent collision avoidance maneuvers.<br>In this case, $V_A$ is established such that full, abrupt control inputs may be applied for the purpose of aggressive maneuvering.<br>This requirement is also scalable to CONOPS as aircraft that are operated at low altitudes (100 feet to 200 feet AGL), in remote areas, and not over people are less likely to require aggressive maneuvering. This requirement is more applicable to aircraft that would operate in navigable airspace (outside of Part 107 limitations), and within line of sight of an operator that would make the control inputs to prevent a collision. | - | X | X | X |
| 233 | **§23.153 Control during landings.** | | | **Control during landings** | | - | X | x | - |
| 234 | It must be possible, while in the landing configuration, to safely complete a landing without exceeding the one-hand control force limits specified in §23.143(c) following an approach to land— | | | The sUAS must be able to safely complete a landing— | Landing requirements are desirable, but may not be necessary for manual control as there is often no source of attitude, airspeed, or altitude data available to the operator during manual flight. However, having requirements in place for automated systems allows a benchmark for determining performance. | - | X | X | - |
| 235 | (a) At a speed of $V_{REF}$ minus 5 knots; | | | (1) At a speed that allows the aircraft to land without damage and within the landing area allotted by line 125. | | - | X | X | - |
| 236 | (b) With the airplane in trim, or as nearly as possible in trim and without the trimming control being moved throughout the maneuver; | | | N/A | Trim is generally different in sUAS as many aircraft do not utilize trim tabs or rarely require trim to be adjusted in flight. | X | X | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 237 | (c) At an approach gradient equal to the steepest used in the landing distance demonstration of §23.75; and | | | (2) At an approach gradient that allows for reasonable obstacle clearance at an airspeed that will satisfy the requirements of line 235; and | This requirement was written as it was to reference the fact that the approach gradient should allow for the aircraft to maintain both an acceptable airspeed and clear obstacles if necessary. | - | X | X | - |
| 238 | (d) With only those power changes, if any, that would be made when landing normally from an approach at $V_{REF}$. | | | (3) With power changes necessary to maintain a stable approach speed and gradient. | | - | X | X | - |
| 239 | [Doc. No. 27807, 61 FR 5189, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 240 | **§23.155 Elevator control force in maneuvers.** | | | **Elevator control force in maneuvers** | | X | X | - | - |
| 241 thru 243 | (a) The elevator control force needed to achieve the positive limit maneuvering load factor may not be less than:<br>(1) For wheel controls, W/100 (where W is the maximum weight) or 20 pounds, whichever is greater, except that it need not be greater than 50 pounds; or<br>(2) For stick controls, W/140 (where W is the maximum weight) or 15 pounds, whichever is greater, except that it need not be greater than 35 pounds. | | | N/A | Control servos and other types of actuators apply force to the aircraft controls. Their limits are determined through the design process and do not require feedback to the pilot.<br>There are no control wheels or control sticks present on sUAS that require the pilot to experience stick forces relative to the control surface force. | X | X | - | - |
| 244 thru 246 | (b) The requirement of paragraph (a) of this section must be met at 75 percent of maximum continuous power for reciprocating engines, or the maximum continuous power for turbine engines, and with the wing flaps and landing gear retracted—<br>(1) In a turn, with the trim setting used for wings level flight at $V_O$; and<br>(2) In a turn with the trim setting used for the maximum wings level flight speed, except that the speed may not exceed $V_{NE}$ or $V_{MO}/M_{MO}$, whichever is appropriate. | | | N/A | Control servos and other types of actuators apply force to the aircraft controls. Their limits are determined through the design process and do not require feedback to the pilot. | X | X | - | - |
| 247 | (c) There must be no excessive decrease in the gradient of the curve of stick force versus maneuvering load factor with increasing load factor. | | | N/A | Control servos and other types of actuators apply force to the aircraft controls. Their limits are determined through the design process and do not require feedback to the pilot. | X | X | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-XX | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 248 | [Amdt. 23-14, 38 FR 31819, Nov. 19, 1973; 38 FR 32784, Nov. 28, 1973, as amended by Amdt. 23-45, 58 FR 42158, Aug. 6, 1993; Amdt. 23-50, 61 FR 5189 Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 249 | **§23.157 Rate of roll.** | | | **Rate of roll** | | - | - | X | - |
| 250 | (a) *Takeoff.* It must be possible, using a favorable combination of controls, to roll the airplane from a steady 30-degree banked turn through an angle of 60 degrees, so as to reverse the direction of the turn within:<br>(1) For an airplane of 6,000 pounds or less maximum weight, 5 seconds from initiation of roll; and<br>(2) For an airplane of over 6,000 pounds maximum weight,<br>(W + 500)/1,300<br>seconds, but not more than 10 seconds, where W is the weight in pounds. | | | (a) *Takeoff.* Demonstrate that it is possible, using a favorable combination of manual controls and/or command inputs, to roll the sUA from a steady 30-degree banked turn through an angle of 60 degrees, so as to reverse the direction of the turn at a rate that will not allow for design limit loads to be exceeded or require exceptional skill on the part of the operator. | Since roll rates are often able to be set through flight autopilots and flight controllers, it is possible to achieve roll rates that may result in structural damage or be beyond the ability of a manual operator to control. The requirement was written specifically to limit roll rates to those that will maintain the aircraft's structural integrity and allow for a manual pilot to intervene if the need were to arise. | - | - | X | - |
| 251 | (b) The requirement of paragraph (a) of this section must be met when rolling the airplane in each direction with—<br>(1) Flaps in the takeoff position;<br>(2) Landing gear retracted;<br>(3) For a single-engine airplane, at maximum takeoff power; and for a multiengine airplane with the critical engine inoperative and the propeller in the minimum drag position, and the other engines at maximum takeoff power; and<br>(4) The airplane trimmed at a speed equal to the greater of 1.2 $V_{S1}$ or 1.1 $V_{MC}$, or as nearly as possible in trim for straight flight. | | | (b) The requirement in line 250 of this section must be met when rolling the sUA in each direction with—<br>(1) Wing flaps in the takeoff position if the sUA is equipped with wing flaps;<br>(2) Landing gear retracted, if the sUA has retractable landing gear;<br>(3) For single-powerplant sUA, at maximum takeoff power; and for a multi-powerplant sUA with the critical powerplant inoperative and, if equipped with a variable pitch propeller, the propeller in the minimum drag position, and the other powerplant(s) at maximum takeoff power; and<br>(4) The sUA trimmed as closely as possible for level flight. | Roll rate and roll authority are important considerations when evaluating how a sUAS will perform. From a manual flight perspective, roll rates are a factor in determining how the aircraft handles when it is operated directly through manual controls. From the standpoint of automation, roll rate plays a role in determining how the aircraft will maneuver to seek out waypoints. | - | - | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 252 | (c) *Approach.* It must be possible, using a favorable combination of controls, to roll the airplane from a steady 30-degree banked turn through an angle of 60 degrees, so as to reverse the direction of the turn within:<br>(1) For an airplane of 6,000 pounds or less maximum weight, 4 seconds from initiation of roll; and<br>(2) For an airplane of over 6,000 pounds maximum weight,<br>(W + 2,800)/2,200<br>seconds, but not more than 7 seconds, where W is the weight in pounds. | | | Using a favorable combination of controls or command inputs, it must be possible to roll the airplane from a steady 30-degree banked turn through an angle of 60 degrees so as to reverse the turn within a maximum of 4 seconds from the initiation of the roll. | Given that roll rates may be set to given values within flight controllers and autopilots, a minimum roll rate is required to allow for an acceptable level of aircraft performance to be evaluated. This value is thought to be quite generous as sUAS are often capable of greater roll rates than manned aircraft. | - | - | X | - |
| 253 | (d) The requirement of paragraph (c) of this section must be met when rolling the airplane in each direction in the following conditions—<br>(1) Flaps in the landing position(s);<br>(2) Landing gear extended;<br>(3) All engines operating at the power for a 3 degree approach; and<br>(4) The airplane trimmed at $V_{REF}$. | | | Demonstrate paragraph (b) above, but with—<br>(1) Wing flaps in the landing position, if the sUAS is equipped with wing flaps;<br>(2) Landing gear extended; and<br>(3) Powerplant(s) operating at the power necessary to maintain a stable approach. | | - | X | X | - |
| 254 | [Amdt. 23-14, 38 FR 31819, Nov. 19, 1973, as amended by Amdt. 23-45, 58 FR 42158, Aug. 6, 1993; Amdt. 23-50, 61 FR 5189, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 255 | **TRIM** | | | | | | | | |
| 256 | **§23.161 Trim.** | | | **Trim** | | - | X | x | - |
| 257 | (a) *General.* Each airplane must meet the trim requirements of this section after being trimmed and without further pressure upon, or movement of, the primary controls or their corresponding trim controls by the pilot or the automatic pilot. In addition, it must be possible, in other conditions of loading, configuration, speed and power to ensure that the pilot will not be unduly fatigued or distracted by the need to apply residual control forces exceeding those for prolonged application of §23.143(c). This applies in normal operation of the airplane and, if applicable, to those conditions associated with the failure of one engine for which performance characteristics are established. | | | Flight tests must be conducted to demonstrate that—<br>(1) The aircraft's trim may be adjusted through manual control as well as at a ground control station; and<br>(2) The aircraft's trim state can be corroborated by onboard sensors and verified at a ground station.<br>Each sUAS must meet trim requirements established in this section. For sUAS, trim defines a state in which all forces acting through the three primary axes, pitch, roll, and yaw, are in a state of static equilibrium. Trim states are described as follows:<br>The aircraft, while at an airspeed not less than the aircraft's design cruise speed must—<br>(1) Be capable of maintaining a wings level attitude without a tendency to roll left or right;<br>(2) Maintain a desired altitude with minimal tendency to climb or descend;<br>(3) Maintain a constant heading with minimal tendency drift from a desired heading. | For sUAS, there are no control forces for the pilot to overcome, so trim is instead focused on establishing a state of equilibrium to reduce the tendency of the aircraft to "wander" from straight and level flight.<br>It is common for sUAS to approach trim through servo adjustments that move the zero position of control surfaces without the use of trim tabs. It is also common to trim the aircraft at a desired cruise speed and leave it there.<br>The requirements listed here are vague for a reason. They rely on manual trimming at a desired airspeed and verification of that trim state by onboard sensors, such as accelerometers that are commonplace in autopilots and flight control computers. | - | X | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 258 thru 260 | (b) *Lateral and directional trim.* The airplane must maintain lateral and directional trim in level flight with the landing gear and wing flaps retracted as follows:<br>(1) For normal, utility, and acrobatic category airplanes, at a speed of 0.9 $V_H$, $V_C$, or $V_{MO}/M_O$, whichever is lowest; and<br>(2) For commuter category airplanes, at all speeds from 1.4 $V_{S1}$ to the lesser of $V_H$ or $V_{MO}/M_{MO}$. | | | N/A | | X | X | - | - |
| 261 thru 270 | (c) *Longitudinal trim.* The airplane must maintain longitudinal trim under each of the following conditions:<br>(1) A climb with—<br>(i) Takeoff power, landing gear retracted, wing flaps in the takeoff position(s), at the speeds used in determining the climb performance required by §23.65; and<br>(ii) Maximum continuous power at the speeds and in the configuration used in determining the climb performance required by §23.69(a).<br>(2) Level flight at all speeds from the lesser of $V_H$ and either $V_{NO}$ or $V_{MO}/M_{MO}$ (as appropriate), to 1.4 $V_{S1}$, with the landing gear and flaps retracted.<br>(3) A descent at $V_{NO}$ or $V_{MO}/M_{MO}$, whichever is applicable, with power off and with the landing gear and flaps retracted.<br>(4) Approach with landing gear extended and with—<br>(i) A 3 degree angle of descent, with flaps retracted and at a speed of 1.4 $V_{S1}$;<br>(ii) A 3 degree angle of descent, flaps in the landing position(s) at $V_{REF}$; and<br>(iii) An approach gradient equal to the steepest used in the landing distance demonstrations of §23.75, flaps in the landing position(s) at $V_{REF}$. | | | N/A | | X | X | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 271 thru 276 | (d) In addition, each multiple airplane must maintain longitudinal and directional trim, and the lateral control force must not exceed 5 pounds at the speed used in complying with §23.67(a), (b)(2), or (c)(3), as appropriate, with—<br>(1) The critical engine inoperative, and if applicable, its propeller in the minimum drag position;<br>(2) The remaining engines at maximum continuous power;<br>(3) The landing gear retracted;<br>(4) Wing flaps retracted; and<br>(5) An angle of bank of not more than five degrees. | | | N/A | | X | X | - | - |
| 277 thru 282 | (e) In addition, each commuter category airplane for which, in the determination of the takeoff path in accordance with §23.57, the climb in the takeoff configuration at $V_2$ extends beyond 400 feet above the takeoff surface, it must be possible to reduce the longitudinal and lateral control forces to 10 pounds and 5 pounds, respectively, and the directional control force must not exceed 50 pounds at $V_2$ with—<br>(1) The critical engine inoperative and its propeller in the minimum drag position;<br>(2) The remaining engine(s) at takeoff power;<br>(3) Landing gear retracted;<br>(4) Wing flaps in the takeoff position(s); and<br>(5) An angle of bank not exceeding 5 degrees. | | | N/A | | X | X | - | - |
| 283 | [Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23-21, 43 FR 2318, Jan. 16, 1978; Amdt. 23-34, 52 FR 1828, Jan. 15, 1987; Amdt. 23-42, 56 FR 351, Jan. 3, 1991; 56 FR 5455, Feb. 11, 1991; Amdt. 23-50, 61 FR 5189, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 284 | **Stability** | | | | | | | | |
| 285 | **§23.171 General.** | | | **General** | | - | X | x | - |
| 286 | The airplane must be longitudinally, directionally, and laterally stable under §§23.173 through 23.181. In addition, the airplane must show suitable stability and control "feel" (static stability) in any condition normally encountered in service, if flight tests show it is necessary for safe operation. | REDACTED – F2910-14 [5.10.4] | | The aircraft shall be demonstrated to be in compliance with ASTM F2910-14 [5.10.4]. | Stability is still important when considering sUAS flight characteristics. However, given the unique nature of sUAS and the lack of a pilot or passengers onboard, it is likely to carry less emphasis. The fundamentals are the same, but the level of rigor will differ. This is especially true given that autopilot systems and flight control algorithms can augment the stability of an otherwise unstable aircraft and make it flyable. Since control forces are out of the picture and there is no person onboard, demonstration of stability would seem to be a simpler process. | - | X | - | - |
| 287 | **§23.173 Static longitudinal stability.** | | **4.5.4 Static Longitudinal Stability:** | **Static longitudinal stability** | | - | X | x | - |
| 288 | Under the conditions specified in §23.175 and with the airplane trimmed as indicated, the characteristics of the elevator control forces and the friction within the control system must be as follows: | REDACTED – F2910-14 [5.10.4] | REDACTED – F2245-15 [4.5.4.1, 4.5.4.2, 4.5.4.4] | The sUAS must be shown to be longitudinally statically stable in all configurations and at critical weights and CG positions.<br>With the airplane trimmed as closely as possible for level flight, accelerations experienced along the longitudinal axis must be as follows: | | - | X | - | - |
| 289 | (a) A pull must be required to obtain and maintain speeds below the specified trim speed and a push required to obtain and maintain speeds above the specified trim speed. This must be shown at any speed that can be obtained, except that speeds requiring a control force in excess of 40 pounds or speeds above the maximum allowable speed or below the minimum speed for steady unstalled flight, need not be considered. | | REDACTED – F2245-15 [4.5.4.3] | (1) Pitching the nose of the aircraft down results in a positive acceleration and an increase in airspeed from the original trimmed state.<br>(2) Pitching the nose of the aircraft up results in a negative acceleration and a decrease in airspeed from the original trimmed state. | | - | X | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 290 thru 292 | (b) The airspeed must return to within the tolerances specified for applicable categories of airplanes when the control force is slowly released at any speed within the speed range specified in paragraph (a) of this section. The applicable tolerances are—<br>(1) The airspeed must return to within plus or minus 10 percent of the original trim airspeed; and<br>(2) For commuter category airplanes, the airspeed must return to within plus or minus 7.5 percent of the original trim airspeed for the cruising condition specified in §23.175(b). | | REDACTED – F2245-15 [4.5.4.5] | The airspeed must return to within tolerances specified for the airspeed sensor(s) employed on the aircraft for a trimmed state when the controls are neutralized and/or level flight is commanded. | The tolerances with which given autopilots or flight control algorithms can return an aircraft to equilibrium are not necessarily set in stone. The ability to precisely return to a trim state at a given airspeed is largely dependent on how the autopilot is “tuned” to fly the aircraft.<br>The tolerances for airspeed will be based largely upon the tolerances of the airspeed sensor used. These may vary by manufacturer unless a standard tolerance for airspeed sensors (pressure transducers) sensors is set. | - | X | X | - |
| 293 | (c) The stick force must vary with speed so that any substantial speed change results in a stick force clearly perceptible to the pilot. | | | Changes in acceleration along the longitudinal axis should be consistent with changes in airspeed. | Airspeed – measurement external to aircraft<br>Acceleration – measurement internal to aircraft<br>This demonstration confirms that both are in accordance with one another. | - | X | X | - |
| 294 | [Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23-14, 38 FR 31820 Nov. 19, 1973; Amdt. 23-34, 52 FR 1828, Jan. 15, 1987] | -------- | -------- | -------- | -------- | - | - | - | - |
| 295 | **§23.175 Demonstration of static longitudinal stability.** | | | **Demonstration of static longitudinal stability** | | - | X | x | - |
| 296 | Static longitudinal stability must be shown as follows: | REDACTED – F2910-14 [5.10.4] | | Static longitudinal stability must be shown as follows: | | - | X | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 297 | (a) *Climb.* The stick force curve must have a stable slope at speeds between 85 and 115 percent of the trim speed, with—<br>(1) Flaps retracted;<br>(2) Landing gear retracted;<br>(3) Maximum continuous power; and<br>(4) The airplane trimmed at the speed used in determining the climb performance required by §23.69(a). | | | *Climb.* The accelerations experienced by the aircraft must have a stable slope at airspeeds between 85 and 115 percent of the trim speed, with—<br>(1) Wing flaps retracted, if the sUAS is equipped with wing flaps;<br>(2) Landing gear retracted if the sUAS is equipped with retractable landing gear; and<br>(3) Maximum continuous power. | The provision for using a trim speed that is used in determining climb performance was omitted due to the differences in how sUAS are trimmed. | - | X | X | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
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| 298 | (b) *Cruise.* With flaps and landing gear retracted and the airplane in trim with power for level flight at representative cruising speeds at high and low altitudes, including speeds up to $V_{NO}$ or $V_{MO}/M_{MO}$, as appropriate, except that the speed need not exceed $V_H$—<br>(1) For normal, utility, and acrobatic category airplanes, the stick force curve must have a stable slope at all speeds within a range that is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 40 knots plus the resulting free return speed range, above and below the trim speed, except that the slope need not be stable—<br>(i) At speeds less than 1.3 $V_{S1}$; or<br>(ii) For airplanes with $V_{NE}$ established under §23.1505(a), at speeds greater than $V_{NE}$; or<br>(iii) For airplanes with $V_{MO}/M_{MO}$ established under §23.1505(c), at speeds greater than $V_{FC}/M_{FC}$.<br>(2) For commuter category airplanes, the stick force curve must have a stable slope at all speeds within a range of 50 knots plus the resulting free return speed range, above and below the trim speed, except that the slope need not be stable—<br>(i) At speeds less than 1.4 $V_{S1}$; or<br>(ii) At speeds greater than $V_{FC}/M_{FC}$; or<br>(iii) At speeds that require a stick force greater than 50 pounds. | | | *Cruise.* With wing flaps and landing gear retracted, as applicable, and the sUA trimmed as closely as possible for level flight at cruise speed, Demonstrate the following:<br>(1) Airspeed decreases when the nose of the aircraft is pitched up and returns to the original trim speed when the controls are released; and<br>(2) Airspeed increases when the nose of the aircraft is pitched down and returns to the original trim speed when the controls are released. | Stability tests would best be done in manual flight modes as autopilot or some other means of augmentation would not produce a true representation of aircraft stability. However, there is also a case to be made for aircraft that depend on augmented stability to fly. In the case that stability augmentation is required per the aircraft's design, stability tests with that stability augmentation system should be conducted and the reliability of that system should be shown.<br>In this case, the aircraft's trim state would have to be estimated as closely as possible based upon downlinked data. This is feasible, but it is not always practical. | - | X | X | - |
| 299 | (c) *Landing.* The stick force curve must have a stable slope at speeds between 1.1 $V_{S1}$ and 1.8 $V_{S1}$ with—<br>(1) Flaps in the landing position;<br>(2) Landing gear extended; and<br>(3) The airplane trimmed at—<br>(i) $V_{REF}$, or the minimum trim speed if higher, with power off; and<br>(ii) $V_{REF}$ with enough power to maintain a 3 degree angle of descent. | | | N/A | Stick control forces are not considered here as they do not correlate with an airspeed as they do in manned aviation. | X | X | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 300 | [Doc. No. 27807, 61 FR 5190, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 301 | **§23.177 Static directional and lateral stability.** | | **4.5.5 Static Directional and Lateral Stability:** | **Static directional and lateral stability** | | - | X | x | - |
| 302 | (a)(1) The static directional stability, as shown by the tendency to recover from a wings level sideslip with the rudder free, must be positive for any landing gear and flap position appropriate to the takeoff, climb, cruise, approach, and landing configurations. This must be shown with symmetrical power up to maximum continuous power, and at speeds from 1.2 $V_{S1}$ up to $V_{FE}$, $V_{LE}$, $V_{NO}$, $V_{FC}/M_{FC}$, whichever is appropriate.<br>(2) The angle of sideslip for these tests must be appropriate to the type of airplane. The rudder pedal force must not reverse at larger angles of sideslip, up to that at which full rudder is used or a control force limit in §23.143 is reached, whichever occurs first, and at speeds from 1.2 $V_{S1}$ to $V_O$. | | REDACTED – F2245-15 [4.5.5.1, 4.5.5.2, 4.5.5.3] | Demonstrate that the aircraft will return to trimmed, level flight after a lateral and directional upset. This shall be demonstrated through—<br>(1) Demonstrating recovery from a wings level side slip upon releasing the controls or commanding the sUAS to recover from the side slip;<br>(2) Demonstrating recovery from a constant heading side slip upon releasing the controls or commanding the sUAS to recover from the side slip; and<br>(3) Demonstrating that the aircraft can recover from a skid when the yaw controls are released or the sUAS is commanded to recover from the skid.<br>In the event that an aircraft is not equipped with a directional control surface, the aircraft must demonstrate positive directional and lateral control characteristics, such as the ability to “weathervane” into the wind and the ability to maintain both level flight and remain controllable and predictable in banking maneuvers. | | - | X | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 303 | (b)(1) The static lateral stability, as shown by the tendency to raise the low wing in a sideslip with the aileron controls free, may not be negative for any landing gear and flap position appropriate to the takeoff, climb, cruise, approach, and landing configurations. This must be shown with symmetrical power from idle up to 75 percent of maximum continuous power at speeds from 1.2 $V_{S1}$ in the takeoff configuration(s) and at speeds from 1.3 $V_{S1}$ in other configurations, up to the maximum allowable airspeed for the configuration being investigated ($V_{FE}$, $V_{LE}$, $V_{NO}$, $V_{FC}/M_{FC}$, whichever is appropriate) in the takeoff, climb, cruise, descent, and approach configurations. For the landing configuration, the power must be that necessary to maintain a 3-degree angle of descent in coordinated flight.<br>(2) The static lateral stability may not be negative at 1.2 $V_{S1}$ in the takeoff configuration, or at 1.3 $V_{S1}$ in other configurations.<br>(3) The angel of sideslip for these tests must be appropriate to the type of airplane, but in no case may the constant heading sideslip angle be less than that obtainable with a 10 degree bank or, if less, the maximum bank angle obtainable with full rudder deflection or 150 pound rudder force. | | REDACTED – F2245-15 [4.5.5.4, 4.5.5.5] | N/A | | X | X | - | - |
| 304 | (c) Paragraph (b) of this section does not apply to acrobatic category airplanes certificated for inverted flight. | | | N/A | | X | X | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 305 | (d)(1) In straight, steady slips at 1.2 $V_{S1}$ for any landing gear and flap position appropriate to the takeoff, climb, cruise, approach, and landing configurations, and for any symmetrical power conditions up to 50 percent of maximum continuous power, the aileron and rudder control movements and forces must increase steadily, but not necessarily in constant proportion, as the angle of sideslip is increased up to the maximum appropriate to the type of airplane.<br>(2) At larger slip angles, up to the angle at which the full rudder or aileron control is used or a control force limit contained in §23.143 is reached, the aileron and rudder control movements and forces may not reverse as the angle of sideslip is increased.<br>(3) Rapid entry into, and recovery from, a maximum sideslip considered appropriate for the airplane may not result in uncontrollable flight characteristics. | | | N/A | Control forces do not directly translate to manual controls in sUAS. | X | X | - | - |
| 306 | [Doc. No. 27807, 61 FR 5190, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75754, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |
| 307 | **§23.181 Dynamic stability.** | | | **Dynamic stability** | | - | - | x | - |
| 308 | (a) Any short period oscillation not including combined lateral-directional oscillations occurring between the stalling speed and the maximum allowable speed appropriate to the configuration of the airplane must be heavily damped with the primary controls—<br>(1) Free; and<br>(2) In a fixed position. | | REDACTED – F2245-15 [4.5.6] | Demonstrate that oscillations resulting from upsets dampen over time. Oscillations must dampen with manual controls in the neutral position and without input from the pilot. | The ASTM F38 requirements do not address dynamic stability. It can be argued that this is more important for a sUAS since the aircraft does not have a pilot onboard and oscillations may not be able to be observed if the aircraft is operation BLOS and experiences a command link fault. | - | - | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 309 | (b) Any combined lateral-directional oscillations (Dutch roll) occurring between the stalling speed and the maximum allowable speed ($V_{FE}$, $V_{LE}$, $V_{N0}$, $V_{FC}/M_{FC}$) appropriate to the configuration of the airplane with the primary controls in both free and fixed position, must be damped to $\frac{1}{10}$ amplitude in:<br>(1) Seven (7) cycles below 18,000 feet and<br>(2) Thirteen (13) cycles from 18,000 feet to the certified maximum altitude. | | | TBD | This requirement needs further discussion. The potential FT recommendation below is almost directly from Part 23, but it is unknown whether it is overly-restrictive or too lenient.<br>*Potential FT Recommendation:*<br>Combined lateral-directional oscillations must be damped to 1/10 amplitude in 7 cycles at all airspeeds between $V_{S1}$ and $V_{NE}$. | - | - | X | TBD |
| 310 | (c) If it is determined that the function of a stability augmentation system, reference §23.672, is needed to meet the flight characteristic requirements of this part, the primary control requirements of paragraphs (a)(2) and (b)(2) of this section are not applicable to the tests needed to verify the acceptability of that system. | | | Stability augmentation systems such as autopilots and flight control systems may be used to meet stability requirements if the stability augmentation system or flight control system can be shown to have appropriate reliability. | It is common for flight controllers and autopilots to supplement aircraft stability and control. There are lingering questions here with respect to reliability and redundancy that point to the need for a standard that addresses autopilots and flight controllers in and of themselves. The ASTM F38 requirements do not address them with the necessary depth. | - | - | X | - |
| 311 | (d) During the conditions as specified in §23.175, when the longitudinal control force required to maintain speeds differing from the trim speed by at least plus and minus 15 percent is suddenly released, the response of the airplane must not exhibit any dangerous characteristics nor be excessive in relation to the magnitude of the control force released. Any long-period oscillation of flight path, phugoid oscillation, that results must not be so unstable as to increase the pilot's workload or otherwise endanger the airplane. | | | Long-period oscillations or phugoid oscillations must not be so unstable so as to prevent positive manual control of the aircraft or be uncorrectable by an autopilot or flight control algorithm. | There are instances where autopilots and flight controllers can induce oscillations. These instances usually occur with improper or over calibration. | - | - | X | - |
| 312 | [Amdt. 23-21, 43 FR 2318, Jan. 16, 1978, as amended by Amdt. 23-45, 58 FR 42158, Aug. 6, 1993; Amdt. 23-62, 76 FR 75755, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 313 | **STALLS** | | | | | | | | |
| 314 | **§23.201 Wings level stall.** | | | **Wings level stall** | | - | - | x | - |
| 315 | (a) It must be possible to produce and to correct roll by unreversed use of the rolling control and to produce and to correct yaw by unreversed use of the directional control, up to the time the airplane stalls. | | REDACTED – F2245-15 [4.5.7] | It shall be possible to prevent excessive roll or yaw during the stall and subsequent recovery from the stall for all weight and CG combinations. | In many cases, a stall may be prevented altogether through the use of autopilots and flight control algorithms that are able to recognize the onset of stall conditions and make corrections in order to prevent the sUAS from reaching a full stall. However, these algorithms will still need to be tuned and verified, so there is merit in having a sUAS demonstrate a stall recovery either through manual or computer control, regardless of the computer systems onboard.<br>However, it should be noted that some aircraft, such as flying wings, may not have the ability to recover should a spin be encountered, and stalls should be avoided. In these cases, demonstration of robust stall prevention algorithms and flight control systems should take the place of stall testing. In other cases, it may be reasonable to substitute a recovery device such as a parachute as a means of stall recovery.<br>Flying wings and more novel designs may require special considerations for stall testing due to possibility of spin. | - | - | X | - |

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| 316 | (b) The wings level stall characteristics must be demonstrated in flight as follows. Starting from a speed at least 10 knots above the stall speed, the elevator control must be pulled back so that the rate of speed reduction will not exceed one knot per second until a stall is produced, as shown by either:<br>(1) An uncontrollable downward pitching motion of the airplane;<br>(2) A downward pitching motion of the airplane that results from the activation of a stall avoidance device (for example, stick pusher); or<br>(3) The control reaching the stop. | | | The wings level stall characteristics must be demonstrated from a speed at least 10 knots above the stall speed with a smooth speed reduction that:<br>(1) Does not result in an inability to control the aircraft;<br>(2) Utilizes the full deflection of pitch control surface(s); or<br>(3) Results in a stall characterized by an uncontrollable downward pitching motion of the airplane;<br>If the sUAS utilizes an envelope protection system, then—<br>(1) The envelope protection system must activate prior to the onset of stall at no less than 5% above the stall speed; and<br>(2) Initiate corrective action to prevent the sUAS from stalling. | The procedure from Part 23 was simplified and adapted to suit the unique nature of sUAS. The threshold for the envelope protection system was devised from ASTM F2910-14 [5.10.1.1]. ASTM F2910-14 [5.10.1.1] requires a stall warning activate at not less than 10% of the stall speed. The 5% threshold allows a margin between the warning and the activation of envelope protection protocols. | - | - | X | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 317 | (c) Normal use of elevator control for recovery is allowed after the downward pitching motion of paragraphs (b)(1) or (b)(2) of this section has unmistakably been produced, or after the control has been held against the stop for not less than the longer of two seconds or the time employed in the minimum steady flight speed determination of §23.49. | REDACTED – F2910-14 [5.10.1, 5.10.1.2] | | Normal use of elevator controls is allowed after the downward pitching motion that is characteristic of a full stall has been observed, or after no less than two seconds of maximum elevator deflection at the aircraft's stall speed. | It is assumed that ASTM F2910-14 [5.10.1.2] refers to a system that can prevent departure from safe flight and prevent/recover from stalls and spins. However, it may not always be realistic to expect a single action to return the aircraft to safe flight. It is more useful to either prevent a stall altogether through the use of established limitations within the autopilot or flight control, or demonstrate that an aircraft can be recovered either through an automated process or manual control.<br>It is assumed that an automated procedure that is executed by an autopilot satisfies the "single specific action" portion of ASTM F2910-14 [5.10.1.2]. | - | - | - | - |
| 318 | (d) During the entry into and the recovery from the maneuver, it must be possible to prevent more than 15 degrees of roll or yaw by the normal use of controls except as provided for in paragraph (e) of this section. | | REDACTED – F2245-15 [4.5.7] | During entry into and recovery from the stall, it must be possible to prevent more than 15 degrees of roll or yaw through some manual or automated means. | The wording of the recommended FT requirement is contingent upon the fact that a pilot that is operating the aircraft manually has access to telemetry data that allows them to view aircraft attitude information while performing the maneuver. | - | - | X | - |
| 319 | (e) For airplanes approved with a maximum operating altitude at or above 25,000 feet during the entry into and the recovery from stalls performed at or above 25,000 feet, it must be possible to prevent more than 25 degrees of roll or yaw by the normal use of controls. | | | N/A | It is not anticipated that it will be common for sUAS to be operating at the altitudes in excess of 25,000 feet MSL. | X | - | - | - |

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|---|---|---|---|---|---|---|---|---|---|
| 320 | (f) Compliance with the requirements of this section must be shown under the following conditions:<br>(1) *Wing flaps:* Retracted, fully extended, and each intermediate normal operating position, as appropriate for the phase of flight.<br>(2) *Landing gear:* Retracted and extended as appropriate for the altitude.<br>(3) *Cowl flaps:* Appropriate to configuration.<br>(4) *Spoilers/speedbrakes:* Retracted and extended unless they have no measureable effect at low speeds.<br>(5) *Power:*<br>(i) Power/Thrust off; and<br>(ii) For reciprocating engine powered airplanes: 75 percent of maximum continuous power. However, if the power-to-weight ratio at 75 percent of maximum continuous power results in nose-high attitudes exceeding 30 degrees, the test may be carried out with the power required for level flight in the landing configuration at maximum landing weight and a speed of 1.4 $V_{SO}$, except that the power may not be less than 50 percent of maximum continuous power; or<br>(iii) For turbine engine powered airplanes: The maximum engine thrust, except that it need not exceed the thrust necessary to maintain level flight at 1.5 $V_{S1}$ (where $V_{S1}$ corresponds to the stalling speed with flaps in the approach position, the landing gear retracted, and maximum landing weight).<br>(6) *Trim:* At 1.5 $V_{S1}$ or the minimum trim speed, whichever is higher.<br>(7) *Propeller:* Full increase r.p.m. position for the power off condition. | | | If the sUAS is required to demonstrate a full wings level stall, Compliance with wings level stall requirements must be shown under the following conditions:<br>(1) Throughout the full range of flap positions, if the sUA is equipped with flaps;<br>(2) With the landing gear extended and retracted, as applicable to the aircraft;<br>(3) Spoilers/speedbrakes extended and retracted if the sUA is equipped with these devices;<br>(4) At a power setting of 75 percent of maximum continuous power, at the power setting required to maintain level flight in the landing configuration, at maximum landing weight, and an airspeed of 1.4 $V_{SO}$, but not less than 50 percent of maximum continuous power; and<br>(5) The propeller in the takeoff position, if applicable; and<br>If the sUA relies on an envelope protection system that system must be demonstrated to function under the same conditions as those listed above in lieu of demonstrating a full stall. | Note: It's more likely for a sUAS to have a higher power to weight ratio when compared to a manned aircraft.<br>The presence of an envelope protection system on sUAS, in some cases, may negate the requirement to demonstrate a full stall. In such instances, it is desirable to demonstrate that the envelope protection system will function in all common stall scenarios. | - | X | X | - |
| 321 | [Doc. No. 27807, 61 FR 5191, Feb. 9, 1996, as amended by Amdt. 23-62, 76 FR 75755, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
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| 322 | **§23.203 Turning flight and accelerated turning stalls.** | | **4.5.8 Turning Flight and Accelerated Turning Stalls:** | **Turning flight and accelerated turning stalls** | | - | - | x | - |
| 323 | Turning flight and accelerated turning stalls must be demonstrated in tests as follows: | | | If the sUA relies on an envelope protection system, that system must be demonstrated to function in lieu of demonstrating a full stall in accordance with provision for envelope protection systems outlined in line 316. Otherwise, demonstrate accelerated turning stalls as follows: | A provision for an envelope protection system was added here as well. If it can be demonstrated that the aircraft will not allow itself to stall under normal conditions, substitution of envelope protection for stall testing should be considered. However, this may ultimately depend upon the aircraft's design and CONOPs. For operations that take place beyond visual line of sight, an envelope protection system would be desirable in aircraft that otherwise would have poor stall/spin recovery characteristics, such as flying wings. | - | - | X | X |
| 324 | (a) Establish and maintain a coordinated turn in a 30 degree bank. Reduce speed by steadily and progressively tightening the turn with the elevator until the airplane is stalled, as defined in §23.201(b). The rate of speed reduction must be constant, and—<br>(1) For a turning flight stall, may not exceed one knot per second; and<br>(2) For an accelerated turning stall, be 3 to 5 knots per second with steadily increasing normal acceleration. | | REDACTED – F2245-15 [4.5.8.1] | Maintain a coordinated turn in a 30 degree bank. Reduce speed by tightening the turn with the elevator until the airplane is stalled.<br>For both turning flight and accelerated turning stalls, changes in airspeed and acceleration must be constant and smooth. | Where an envelope protection system is able to prevent an accelerated stall condition, this requirement does not need to be demonstrated. Instead, demonstration of the function and reliability of the envelope protection system will suffice. | - | - | X | X |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 325 | (b) After the airplane has stalled, as defined in §23.201(b), it must be possible to regain wings level flight by normal use of the flight controls, but without increasing power and without—<br>(1) Excessive loss of altitude;<br>(2) Undue pitchup;<br>(3) Uncontrollable tendency to spin;<br>(4) Exceeding a bank angle of 60 degrees in the original direction of the turn or 30 degrees in the opposite direction in the case of turning flight stalls;<br>(5) Exceeding a bank angle of 90 degrees in the original direction of the turn or 60 degrees in the opposite direction in the case of accelerated turning stalls; and<br>(6) Exceeding the maximum permissible speed or allowable limit load factor. | | REDACTED – F2245-15 [4.5.8.2] | After the airplane has stalled, it must be possible to regain wings level flight by normal use of manual or commanded control inputs, but without increasing power and without—<br>(1) Excessive loss of altitude;<br>(2) Undue pitchup;<br>(3) Uncontrollable tendency to spin;<br>(4) Exceeding the maximum permissible speed or allowable limit load factor. | Aircraft that utilize an envelope protection system should not be required to demonstrate a full stall. Instead, the envelope protection system and/or recovery system must be able to prevent stall conditions with a high degree of reliability. | - | - | X | X |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 326 | (c) Compliance with the requirements of this section must be shown under the following conditions:<br>(1) *Wings flaps:* Retracted, fully extended, and each intermediate normal operating position as appropriate for the phase of flight.<br>(2) *Landing gear:* Retracted and extended as appropriate for the altitude.<br>(3) *Cowl flaps:* Appropriate to configuration.<br>(4) *Spoilers/speedbrakes:* Retracted and extended unless they have no measureable effect at low speeds.<br>(5) *Power:*<br>(i) Power/Thrust off; and<br>(ii) For reciprocating engine powered airplanes: 75 percent of maximum continuous power. However, if the power-to-weight ratio at 75 percent of maximum continuous power results in nose-high attitudes exceeding 30 degrees, the test may be carried out with the power required for level flight in the landing configuration at maximum landing weight and a speed of 1.4 $V_{SO}$, except that the power may not be less than 50 percent of maximum continuous power; or<br>(iii) For turbine engine powered airplanes: The maximum engine thrust, except that it need not exceed the thrust necessary to maintain level flight at 1.5 $V_{S1}$ (where $V_{S1}$ corresponds to the stalling speed with flaps in the approach position, the landing gear retracted, and maximum landing weight).<br>(6) *Trim:* The airplane trimmed at 1.5 $V_{S1}$.<br>(7) *Propeller:* Full increase rpm position for the power off condition. | | | Compliance with turning and accelerated turning stalls must be shown under takeoff, landing, and cruise conditions in each appropriate aircraft configuration. The aircraft should be trimmed at 1.5 $V_{S1.}$<br>Turning and accelerated turning stalls must be demonstrated with power off and at least 75% maximum continuous power. If the aircraft has a high power to weight ratio, then a lower power setting may be used, but it may not be at less than 50% max continuous power. | Some sUAS may have must higher power to weight ratios than manned aircraft. It is important to take this into account when considering stall demonstrations. This is especially true for sUAS that fall into the smaller, lighter segments of the sUAS spectrum. Such aircraft may be made out of foam and be powered by electric motors that produce power in excess of what is required to fly. | - | - | X | X |
| 327 | [Amdt. 23-14, 38 FR 31820, Nov. 19, 1973, as amended by Amdt. 23-45, 58 FR 42159, Aug. 6, 1993; Amdt. 23-50, 61 FR 5191, Feb. 9, 1996; Amdt. 23-62, 76 FR 75755, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |
| 328 | **§23.207 Stall warning.** | | | **Stall warning** | | - | - | - | - |
| 329 | (a) There must be a clear and distinctive stall warning, with the flaps and landing gear in any normal position, in straight and turning flight. | REDACTED – F2910-14 [5.10.1.1] | | Stall warnings must be in compliance with ASTM F2910-14 [5.10.1.1]. | | - | - | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
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| 330 | (b) The stall warning may be furnished either through the inherent aerodynamic qualities of the airplane or by a device that will give clearly distinguishable indications under expected conditions of flight. However, a visual stall warning device that requires the attention of the crew within the cockpit is not acceptable by itself. | | | A stall warning device with multiple means of indicating a stall to the operator is required. | This recommended requirement is intended to re-enforce the idea that stall warnings should consist of both visual and auditory cues. | - | - | - | - |
| 331 | (c) During the stall tests required by §23.201(b) and §23.203(a)(1), the stall warning must begin at a speed exceeding the stalling speed by a margin of not less than 5 knots and must continue until the stall occurs. | | | N/A | This is redundant when compared against line 329. | X | - | - | - |
| 332 | (d) When following procedures furnished in accordance with §23.1585, the stall warning must not occur during a takeoff with all engines operating, a takeoff continued with one engine inoperative, or during an approach to landing. | | | Stall warning should not activate unless the aircraft is in danger of entering a stall condition. | | - | - | - | - |
| 333 | (e) During the stall tests required by §23.203(a)(2), the stall warning must begin sufficiently in advance of the stall for the stall to be averted by pilot action taken after the stall warning first occurs. | | | The stall warning must give adequate time for the pilot or the flight control system to respond to the stall and must comply with ASTM F2910-14 [5.10.1.1]. | Reference line 329 for ASTM F2910-14 [5.10.1.1]. | - | - | - | - |
| 334 | (f) For acrobatic category airplanes, an artificial stall warning may be mutable, provided that it is armed automatically during takeoff and rearmed automatically in the approach configuration. | | | N/A | Previous functional requirements are sufficient; Aerobatic aircraft are not within the scope of normal sUAS operations. | X | X | - | - |
| 335 | [Amdt. 23-7, 34 FR 13087, Aug. 13, 1969, as amended by Amdt. 23-45, 58 FR 42159, Aug. 6, 1993; Amdt. 23-50, 61 FR 5191, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

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|---|---|---|---|---|---|---|---|---|---|
| 336 | **Spinning** | | | | | | | | |
| 337 | **§23.221 Spinning.** | | **4.5.9 Spinning:** | **Spinning** | | - | - | x | - |
| 338 | (a) *Normal category airplanes.* A single-engine, normal category airplane must be able to recover from a one-turn spin or a three-second spin, whichever takes longer, in not more than one additional turn after initiation of the first control action for recovery, or demonstrate compliance with the optional spin resistant requirements of this section.<br>(1) The following apply to one turn or three second spins:<br>(i) For both the flaps-retracted and flaps-extended conditions, the applicable airspeed limit and positive limit maneuvering load factor must not be exceeded;<br>(ii) No control forces or characteristic encountered during the spin or recovery may adversely affect prompt recovery;<br>(iii) It must be impossible to obtain unrecoverable spins with any use of the flight or engine power controls either at the entry into or during the spin; and<br>(iv) For the flaps-extended condition, the flaps may be retracted during the recovery but not before rotation has ceased. | | REDACTED – F2245-15 [4.5.9.1, 4.5.9.2, 4.5.9.3] | Demonstrate a spin recovery if no envelope protection system is present on the aircraft. Recovery from a spin must take place within one-turn or 3 seconds, whichever is greater. Spin recovery demonstration is not required for aircraft that have an envelope protection system that has been demonstrated to function in all aircraft configurations. Airspeed and flight loads are not to be exceeded.<br>Spin recovery may be demonstrated in manual flight, automated flight, or both.<br>Spin recovery must—<br>(1) Be demonstrated in all aircraft configurations at the most critical weight;<br>(1) Not exceed structural limit loads or limiting airspeeds of the sUAS; or<br>(2) Not Render the sUAS uncontrollable; | Spin demonstration branches off into several categories depending on recovery method(s) and method(s) of aircraft control. There are multiple aspects to consider such as aircraft design, controls, manual or automated flight modes, and the presence of an envelope protection system. Recovery and prevention methods will differ based upon equipage, flight modes, and elements of the aircraft's design. | - | - | X | X |

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| 338 cont | (2) At the applicant's option, the airplane may be demonstrated to be spin resistant by the following:<br>(i) During the stall maneuver contained in §23.201, the pitch control must be pulled back and held against the stop. Then, using ailerons and rudders in the proper direction, it must be possible to maintain wings-level flight within 15 degrees of bank and to roll the airplane from a 30 degree bank in one direction to a 30 degree bank in the other direction;<br>(ii) Reduce the airplane speed using pitch control at a rate of approximately one knot per second until the pitch control reaches the stop; then, with the pitch control pulled back and held against the stop, apply full rudder control in a manner to promote spin entry for a period of seven seconds or through a 360 degree heading change, whichever occurs first. If the 360 degree heading change is reached first, it must have taken no fewer than four seconds. This maneuver must be performed first with the ailerons in the neutral position, and then with the ailerons deflected opposite the direction of turn in the most adverse manner. Power and airplane configuration must be set in accordance with §23.201(e) without change during the maneuver. At the end of seven seconds or a 360 degree heading change, the airplane must respond immediately and normally to primary flight controls applied to regain coordinated, unstalled flight without reversal of control effect and without exceeding the temporary control forces specified by §23.143(c); and<br>(iii) Compliance with §§23.201 and 23.203 must be demonstrated with the airplane in uncoordinated flight, corresponding to one ball width displacement on a slip-skid indicator, unless one ball width displacement cannot be obtained with full rudder, in which case the demonstration must be with full rudder applied. | | REDACTED – F2245-15 [4.5.9.4] | For sUAS with inherently poor spin characteristics, a recovery system such as a parachute, airbag, or some other means of recovering from the spin and arresting the aircraft's descent may be substituted for spin recovery demonstrations if—<br>(1) The recovery system is shown to be reliable;<br>(2) Can be activated as appropriate to allow for a safe recovery from the spin;<br>(3) Does not result in irreparable damage to the sUAS; and<br>(4) Provides satisfactory protection for persons and property on the ground from harm as a result of the aircraft's descent. | | - | - | X | - |
| 339 | (b) *Utility category airplanes.* A utility category airplane must meet the requirements of paragraph (a) of this section. In addition, the requirements of paragraph (c) of this section and §23.807(b)(7) must be met if approval for spinning is requested. | | | N/A | | X | X | - | - |

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| 340 | (c) *Acrobatic category airplanes.* An acrobatic category airplane must meet the spin requirements of paragraph (a) of this section and §23.807(b)(6). In addition, the following requirements must be met in each configuration for which approval for spinning is requested:<br>(1) The airplane must recover from any point in a spin up to and including six turns, or any greater number of turns for which certification is requested, in not more than one and one-half additional turns after initiation of the first control action for recovery. However, beyond three turns, the spin may be discontinued if spiral characteristics appear.<br>(2) The applicable airspeed limits and limit maneuvering load factors must not be exceeded. For flaps-extended configurations for which approval is requested, the flaps must not be retracted during the recovery.<br>(3) It must be impossible to obtain unrecoverable spins with any use of the flight or engine power controls either at the entry into or during the spin.<br>(4) There must be no characteristics during the spin (such as excessive rates of rotation or extreme oscillatory motion) that might prevent a successful recovery due to disorientation or incapacitation of the pilot. | | | N/A | Given the general operational profile of sUAS, it is not anticipated that acrobatic flight will be a driving factor in their design or operation.<br>The risks associated with spins may also be mitigated through the use of a recovery system, such as a parachute, airbag, or other system that is designed to arrest the aircraft's descent. | X | X | - | - |
| 341 | [Doc. No. 27807, 61 FR 5191, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 342 | **GROUND AND WATER HANDLING CHARACTERISTICS** | | | | | | - | | |
| 343 | **§23.231 Longitudinal stability and control.** | | **4.7 Ground and Water Control and Stability** | **Longitudinal stability and control** | | - | - | x | - |
| 344 | (a) A landplane may have no uncontrollable tendency to nose over in any reasonably expected operating condition, including rebound during landing or takeoff. Wheel brakes must operate smoothly and may not induce any undue tendency to nose over. | REDACTED – F2910-14 [5.11.3.8] | REDACTED – F2245-15 [4.7.1, 4.7.2, 4.7.3] | If the sUAS is capable of taxiing, demonstrate safe taxi, takeoff, and landing with stable ground handling characteristics and correct brake function, as applicable. The aircraft should not display a tendency to nose over or assume an undesirable attitude during taxi or ground handling. | | - | - | - | - |

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| 345 | (b) A seaplane or amphibian may not have dangerous or uncontrollable porpoising characteristics at any normal operating speed on the water. | | | A seaplane or amphibious sUAS may not have dangerous or uncontrollable water handling characteristics. | | - | - | X | - |
| 346 | **§23.233 Directional stability and control.** | | | **Directional stability and control** | | - | - | x | - |
| 347 | (a) A 90 degree cross-component of wind velocity, demonstrated to be safe for taxiing, takeoff, and landing must be established and must be not less than 0.2 $V_{SO}$. | | | Demonstrate a safe taxi, takeoff, and landing during a 90 degree cross-component wind velocity, at a speed of the greater of 0.2 $V_{SO}$ or 5 knots. | 5 knots is up for debate and is somewhat arbitrary.<br>Any airplane with a stall speed of less than 25 knots would need to show takeoff at 5 knot crosswind – baseline. | - | - | X | - |
| 348 | (b) The airplane must be satisfactorily controllable in power-off landings at normal landing speed, without using brakes or engine power to maintain a straight path until the speed has decreased to at least 50 percent of the speed at touchdown. | | | The sUAS must be controllable in power-off landings at landing speed. | | - | - | X | - |
| 349 | (c) The airplane must have adequate directional control during taxiing. | | | The sUAS must have adequate directional control during taxiing. | This was a direct carry-over from Part 23. It is simple enough to apply to an aircraft of any size. | - | - | X | - |
| 350 | (d) Seaplanes must demonstrate satisfactory directional stability and control for water operations up to the maximum wind velocity specified in paragraph (a) of this section. | | | sUAS that are equipped for operation on water must demonstrate satisfactory directional stability and control for water operations up to the maximum allowable cross wind component. | Carried over and simplified from Part 23. | - | - | X | - |
| 351 | [Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23-45, 58 FR 42159, Aug. 6, 1993; Amdt. 23-50, 61 FR 5192, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 352 | **§23.235 Operation on unpaved surfaces.** | | | **Operation on unpaved surfaces** | | - | X | x | - |
| 353 | The airplane must be demonstrated to have satisfactory characteristics and the shock-absorbing mechanism must not damage the structure of the airplane when the airplane is taxied on the roughest ground that may reasonably be expected in normal operation and when takeoffs and landings are performed on unpaved runways having the roughest surface that may reasonably be expected in normal operation. | | | If equipped with landing gear, the sUAS must be demonstrated to have satisfactory handling characteristics on unprepared surfaces, and show that it will not be damaged as a result of normal ground operations. | | - | X | X | - |
| 354 | [Doc. No. 27807, 61 FR 5192, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |

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| 355 | **§23.237 Operation on water.** | | | **Operation on water** | | - | X | | - |
| 356 | A wave height, demonstrated to be safe for operation, and any necessary water handling procedures for seaplanes and amphibians must be established. | | | A wave height, demonstrated to be safe for operation, must be determined. | This is important to ensure that the aircraft is not damaged by partial immersion or capsized during takeoff. Damage that occurs while operating on water could potentially lead to in-flight failures. | - | X | X | - |
| 357 | [Doc. No. 27807, 61 FR 5192, Feb. 9, 1996] | -------- | -------- | -------- | -------- | - | - | - | - |
| 358 | **§23.239 Spray characteristics.** | | | **Spray characteristics** | | - | X | x | - |
| 359 | Spray may not dangerously obscure the vision of the pilots or damage the propellers or other parts of a seaplane or amphibian at any time during taxiing, takeoff, and landing. | | REDACTED – F2245-15 [4.8] | Demonstrate that spray from water taxi, takeoff, and landing does not inhibit proper function of critical aircraft electronic systems (if specifically designed for water takeoff/landing), or otherwise disrupt the function of the aircraft during takeoff, landing, taxi, or other phases of flight. | | - | X | X | - |
| 360 | **Miscellaneous Flight Requirements** | | | | | | | | |
| 361 | **§23.251 Vibration and buffeting.** | | | **Vibration and buffeting** | | - | X | x | - |
| 362 | (a) There must be no vibration or buffeting severe enough to result in structural damage, and each part of the airplane must be free from excessive vibration, under any appropriate speed and power conditions up to $V_D/M_D$, or $V_{DF}/M_{DF}$ for turbojets. In addition, there must be no buffeting in any normal flight condition, including configuration changes during cruise, severe enough to interfere with the satisfactory control of the airplane or cause excessive fatigue to the flight crew. Stall warning buffeting within these limits is allowable. | | REDACTED – F2245-15 [4.6] | Demonstrate that no heavy vibrations, buffeting, flutter, or control divergence occur throughout the flight envelope. | | - | X | X | - |

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| 363 | (b) There must be no perceptible buffeting condition in the cruise configuration in straight flight at any speed up to $V_{MO}/M_{MO}$, except stall buffeting, which is allowable. | | | There must be no buffeting during cruise that will disrupt aircraft functions or cause erratic behavior. All critical electronics must be isolated from vibrations that will negatively impact their operation. | This requirement stems from the fact that sUAS are often more susceptible to vibration than manned aircraft. Vibration is a norm, but provisions should be made to ensure that any vibration that is present in the system at cruise does not disrupt critical aircraft functions. For example, if an autopilot is not properly isolated from vibrations that occur in flight, erroneous information may be fed to onboard accelerometers, and the net result is unpredictable aircraft behavior up to and including a crash. | - | X | X | - |
| 364 | (c) For airplanes with $M_D$ greater than M 0.6 or a maximum operating altitude greater than 25,000 feet, the positive maneuvering load factors at which the onset of perceptible buffeting occurs must be determined with the airplane in the cruise configuration for the ranges of airspeed or Mach number, weight, and altitude for which the airplane is to be certificated. The envelopes of load factor, speed, altitude, and weight must provide a sufficient range of speeds and load factors for normal operations. Probable inadvertent excursions beyond the boundaries of the buffet onset envelopes may not result in unsafe conditions. | | | N/A | This requirement is outside of the scope of sUAS operations. | X | X | - | - |
| 365 | [Amdt. 23-62, 76 FR 75755, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | |
| 366 | **§23.253 High speed characteristics.** | | | **High speed characteristics** | | - | - | x | - |
| 367 | If a maximum operating speed $V_{MO}/M_{MO}$ is established under §23.1505(c), the following speed increase and recovery characteristics must be met: | | | If a maximum operating speed is established, the following speed increase and recovery characteristics must be met: | | - | - | X | - |

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|---|---|---|---|---|---|---|---|---|---|
| 368 | (a) Operating conditions and characteristics likely to cause inadvertent speed increases (including upsets in pitch and roll) must be simulated with the airplane trimmed at any likely speed up to $V_{MO}/M_{MO}$. These conditions and characteristics include gust upsets, inadvertent control movements, low stick force gradients in relation to control friction, passenger movement, leveling off from climb, and descent from Mach to airspeed limit altitude. | | | Upsets in pitch and roll must be shown to be controllable throughout the flight envelope at speeds up to $V_{MO}$. This includes gust upsets and inadvertent control movements. | | - | - | X | - |
| 369 | (b) Allowing for pilot reaction time after occurrence of the effective inherent or artificial speed warning specified in §23.1303, it must be shown that the airplane can be recovered to a normal attitude and its speed reduced to $V_{MO}/M_{MO}$, without—<br>(1) Exceptional piloting strength or skill;<br>(2) Exceeding $V_D/M_D$, or $V_{DF}/M_{DF}$ for turbojets, the maximum speed shown under §23.251, or the structural limitations; and<br>(3) Buffeting that would impair the pilot's ability to read the instruments or to control the airplane for recovery. | | | Upon occurrence of an over speed condition and accompanying warning, the aircraft speed should be able to return to a normal attitude and reduce its airspeed, without --<br>(1) Exceptional pilot skill,<br>(2) Exceeding structural limitations, or<br>(3) Buffeting that would impair the ability to control the aircraft. | | - | - | X | - |
| 370 | (c) There may be no control reversal about any axis at any speed up to the maximum speed shown under §23.251. Any reversal of elevator control force or tendency of the airplane to pitch, roll, or yaw must be mild and readily controllable, using normal piloting techniques. | | | There may be no control reversal about any axis at any speed up to the maximum operating airspeed ($V_{MO}$) as defined in the aircraft's flight envelope. If a flight controller, autopilot, or other stability augmentation system is utilized, it must be shown that it will not cause any control oscillations up to $V_{MO}$. | It is not unheard of for stability augmentation systems to induce oscillations in control surfaces that may result in control reversal if the system is not properly tuned. | - | - | X | - |
| 371 | (d) *Maximum speed for stability characteristics, $V_{FC}/M_{FC}$*. $V_{FC}/M_{FC}$ may not be less than a speed midway between $V_{MO}/M_{MO}$ and $V_{DF}/M_{DF}$ except that, for altitudes where Mach number is the limiting factor, $M_{FC}$ need not exceed the Mach number at which effective speed warning occurs. | | | N/A | | X | X | - | - |
| 372 | [Amdt. 23-7, 34 FR 13087, Aug. 13, 1969, as amended by Amdt. 23-26, 45 FR 60170, Sept. 11, 1980; Amdt. 23-45, 58 FR 42160, Aug. 6, 1993; Amdt. 23-50, 61 FR 5192, Feb. 9, 1996; Amdt. 23-62, 76 FR 75755, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

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|---|---|---|---|---|---|---|---|---|---|
| 373 | **§23.255 Out of trim characteristics.** | | | **Out of trim characteristics** | | - | - | x | - |
| 374 | For airplanes with an $M_D$ greater than M 0.6 and that incorporate a trimmable horizontal stabilizer, the following requirements for out-of-trim characteristics apply: | | | N/A | Similar requirements are already addressed previously for sUAS relevant speeds and flight conditions | X | - | - | - |
| 375 | (a) From an initial condition with the airplane trimmed at cruise speeds up to $V_{MO}/M_{MO}$, the airplane must have satisfactory maneuvering stability and controllability with the degree of out-of-trim in both the airplane nose-up and nose-down directions, which results from the greater of the following:<br>(1) A three-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load (or an equivalent degree of trim for airplanes that do not have a power-operated trim system), except as limited by stops in the trim system, including those required by §23.655(b) for adjustable stabilizers; or<br>(2) The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition. | | | From an initial condition with the sUAS trimmed at cruise speeds up to $V_{MO}$, the aircraft must have satisfactory stability and maneuvering, stability, and controllability with the degree of out-of-trim in both the nose-up and nose-down directions that result from the greater of the following:<br>(1) Misaligned control surfaces that result from imperfections in control surface rigging and installation of control actuators; or<br>(2) The maximum miss-trim for which the autopilot or flight controller can compensate while maintaining level flight at cruise conditions up to $V_{MO}$. | Out-of-trim conditions are most likely to result from errors in control actuator installation and rigging or a control actuator failure. After initial flights and adjustments, out of trim conditions are likely to be minimized. Trim changes will still occur with changes in airspeed, but they can be compensated for with either manual or automated control inputs from flight control actuators since sUAS are not likely to utilize trim tabs. | - | - | X | - |
| 376 | (b) In the out-of-trim condition specified in paragraph (a) of this section, when the normal acceleration is varied from + l g to the positive and negative values specified in paragraph (c) of this section, the following apply:<br>(1) The stick force versus g curve must have a positive slope at any speed up to and including $V_{FC}/M_{FC}$; and<br>(2) At speeds between $V_{FC}/M_{FC}$ and $V_{DF}/M_{DF}$, the direction of the primary longitudinal control force may not reverse. | | | In out-of-trim conditions when the normal acceleration is varied between the aircraft's established positive and negative g limits, the sUAS must not experience—<br>(1) Reversal of the longitudinal controls;<br>(2) Loads in excess of established limit loads and airspeeds in greater than $V_{MO}$; and<br>(3) Buffeting that reduces the effectiveness of longitudinal controls. | | - | - | X | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 377 | (c) Except as provided in paragraphs (d) and (e) of this section, compliance with the provisions of paragraph (a) of this section must be demonstrated in flight over the acceleration range as follows:<br>(1) −1 g to + 2.5 g; or<br>(2) 0 g to 2.0 g, and extrapolating by an acceptable method to −1 g and + 2.5 g. | | | N/A | Simplified compliance cases address the requirements here. | X | - | - | - |
| 378 | (d) If the procedure set forth in paragraph (c)(2) of this section is used to demonstrate compliance and marginal conditions exist during flight test with regard to reversal of primary longitudinal control force, flight tests must be accomplished from the normal acceleration at which a marginal condition is found to exist to the applicable limit specified in paragraph (b)(1) of this section. | | | N/A | Simplified compliance cases address the requirements here. | X | - | - | - |
| 379 | (e) During flight tests required by paragraph (a) of this section, the limit maneuvering load factors, prescribed in §§23.333(b) and 23.337, need not be exceeded. In addition, the entry speeds for flight test demonstrations at normal acceleration values less than 1 g must be limited to the extent necessary to accomplish a recovery without exceeding $V_{DF}/M_{DF}$. | | | N/A | Simplified compliance cases address the requirements here. | X | - | - | - |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 380 | (f) In the out-of-trim condition specified in paragraph (a) of this section, it must be possible from an overspeed condition at $V_{DF}/M_{DF}$ to produce at least 1.5 g for recovery by applying not more than 125 pounds of longitudinal control force using either the primary longitudinal control alone or the primary longitudinal control and the longitudinal trim system. If the longitudinal trim is used to assist in producing the required load factor, it must be shown at $V_{DF}/M_{DF}$ that the longitudinal trim can be actuated in the airplane nose-up direction with the primary surface loaded to correspond to the least of the following airplane nose-up control forces:<br>(1) The maximum control forces expected in service, as specified in §§23.301 and 23.397.<br>(2) The control force required to produce 1.5 g.<br>(3) The control force corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force. | | | N/A | Simplified compliance cases address the requirements here. | X | - | - | - |
| 381 | [Doc. No. FAA-2009-0738, 76 FR 75755, Dec. 2, 2011] | -------- | -------- | -------- | -------- | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 382 | **SPECIFIC UAS REQUIREMENTS** | | | | | | | | |
| 383 | **COMMAND AND CONTROL** | | | | | | | | |
| 384 | **Ground Control Station** | | | **Ground Control Station** | | - | - | - | - |
| 385 | | REDACTED – F3002-14a [9.2.9] | | TBD | This requirement may be scaled to fit different systems if the required runtime for backup power is based upon a percentage of aircraft endurance. However, more information is needed with respect to the limitations of battery backup devices.<br>*Potential FT Recommendation:*<br>Demonstrate that the backup power supply that powers the ground station is able to supply power to the system for at least ___ minutes or ___ percent of the aircraft's endurance, whichever is greater. | - | - | - | TBD |
| 386 | | REDACTED – F3002-14a [9.4.5] | | The GCS shall be demonstrated to be in compliance with ASTM F3002-14a [9.4.5]. | Compliance with this requirement will require attenuator devices to be made specifically for a given system or with the ability to interface with some element of the system as a whole, be it the ground station or the aircraft. | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 387 | **Lost Link** | | | **Lost Link** | | - | - | - | - |
| 388 | | REDACTED – F3002-14a [10.1.1] | | If a command and control link is utilized, the response to lost-link conditions must be demonstrated to be in compliance with F3002-14a [10.1.1.1], [10.1.1.2], [10.1.1.3], [10.1.1.4], [10.2.3], [10.3.1], [10.4.1], [10.4.2], and [10.4.3]. | This statement is intended to be a blanket statement that ties in the functional requirements to dictate that they must function when called upon. This is not so much flight test as it is a requirement for proper responses to be demonstrated per the ASTM F38 requirements.<br>It should be noted that many autopilot and flight controller systems are capable of being set to perform various lost-link algorithms, and it is possible that a given system may be able to comply with all of the functional requirements listed below.<br><br>The chosen lost-link response will be dependent upon a given CONOPs. Naturally, aerodynamic flight termination is not an option over a populated area. Conversely, it may not be desirable to loiter in given circumstances either. | - | - | - | X |
| 389 | | REDACTED – F3002-14a [10.1.1.1] | | The sUAS must be shown to be in compliance with ASTM F3002-14a [10.1.1.1].<br>Demonstrate that the sUA is capable of executing an auto-land procedure by severing the link and recording the behavior of the aircraft. If possible, a secondary data link may be employed to record telemetry data for the purpose of verifying lost-link function. During testing, a means of reverting the aircraft to manual control must be provided in order to ensure that the aircraft remains under control for the entire duration of the lost-link scenario. | Demonstration of all lost-link requirements hinge upon the assumption that there is a safe way to sever the command link and observe the aircraft's operation through some means other than built-in telemetry. This may require an auxiliary data link or some means of simulating a command link failure that results in the aircraft executing its assigned lost-link protocol with the ability to monitor aircraft status. | - | - | - | X |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 390 | | REDACTED – F3002-14a [10.1.1.2] | | The sUAS must be shown to be in compliance with ASTM F3002-14a [10.1.1.2].<br>If applicable, demonstrate that the sUAS will return to a predetermined launch or recovery point upon the loss of the command and control link. This may be demonstrated by severing the link and recording aircraft behavior. If possible, a secondary data link may be employed to record telemetry data for the purpose of verifying lost-link function. During testing, a means of reverting the aircraft to manual control must be provided in order to ensure that the aircraft remains under control for the entire duration of the lost-link scenario. | | - | - | - | X |

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| 391 | | REDACTED – F3002-14a [10.1.1.3] | | If the sUAS is capable of flight termination, aerodynamic or otherwise, the system must be shown to be in compliance with ASTM F3002-14a [10.1.1.3].<br><br>When demonstrating the function of flight termination algorithms in flight, the sUA must—<br><br>(1) Be equipped with a recovery device such as a parachute, airbag, or some other device that is capable of arresting the aircraft's descent and bringing it down in a controlled manner;<br><br>(2) Deploy the airframe recovery device upon execution of flight termination; and<br><br>(3) Remain in airworthy condition upon recovery and reset of the flight termination system.<br><br>For aircraft that rely on aerodynamic termination to terminate a flight, the system may be shown to function through hardware simulation or some other means that will not pose a risk to the aircraft. | Flight termination consists of two different classifications: aerodynamic flight termination and all other methods. Other methods may consist of flight termination methods that may or may not damage the aircraft upon execution of the flight termination protocol. These may consist of deploying a parachute, airbag, or some other device that is intended to stop the flight and arrest the aircraft's descent. It is also assumed that the sUA will not impact any objects during its descent.<br><br>Aerodynamic termination is a process in which the flight is terminated by inducing a spin through some automated process. Aerodynamic flight termination will almost always result in a complete hull loss. This may be desirable in given circumstances. However, in instances where the demonstration of the flight termination system is required for certification, methodology should be established that allows for the functionality of these systems to be demonstrated while minimizing the risk to the aircraft. Systems that rely on a parachute or some other recovery system capable of slowing descent will be exposed to less risk than those that utilize aerodynamic termination.<br><br>Some autopilot systems are capable of selecting between aerodynamic termination routines and flight termination routines that are less likely to harm the aircraft, such as parachute deployment. | - | - | - | X |
| 392 | | REDACTED – F3002-14a [10.1.1.4] | | If applicable, demonstrate that the aircraft is able to loiter at a specified point within the operation area for a specified period of time when the command link is severed. Demonstration must consist of | | - | - | - | X |

| LINE No. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| | | | | severing the command link and recording aircraft behavior. During testing, a means of reverting the aircraft to manual control must be provided in order to ensure that the aircraft remains under control for the entire duration of the lost-link scenario. | | | | | |
| 393 | | REDACTED – F3002-14a [10.2.3] | | Demonstrating that the UA executes lost-link logic when a lost-link condition occurs may be satisfied by demonstrating compliance with applicable requirements from ASTM F3002-14a [10.1.1] that require specific lost-link functions to be executed when the command link is severed. | This ASTM requirement is somewhat redundant, and compliance with this requirement can be accomplished by demonstrating compliance with ASTM lost-link function requirements. | - | - | - | - |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 394 | | REDACTED – F3002-14a [10.3.1] | | If applicable, demonstrate that the aircraft's autopilot or flight control system responds correctly to a geofence.<br>Geofences must prevent the sUA from exiting a predetermined operation area, and are defined as:<br>(a) A geo-referenced polygon with a defined ceiling and floor that defines an operational boundary. Geofences must—<br>(1) Prevent the operator from commanding the sUA outside of the geofenced area in an automated or augmented flight mode; and<br>(2) Alter the flight path of the sUA such that the sUA will not violate a specified boundary;<br>(b) If a geofence is established, responses to imminent violations of geofence boundaries must consist of at least one of the following—<br>(1) Initiating a flight termination protocol such that the sUA will terminate its flight prior to violating a specified boundary;<br>(2) Returning to a predefined point within the bounded operation area and loitering for a specified period of time;<br>(3) Initiating an automated landing procedure at a point within the bounded operation area; or<br>(4) A unique maneuver or operation performed by the sUA that results in the aircraft remaining within specified boundaries. | It is assumed that specifying a contained area refers to a geofence program onboard the sUAS.<br>A geofence is something that will be defined largely by CONOPS. For operations in remote areas, a geofence may not be necessary. However for operations over people or near populated areas, such features allow for an automated system to know where it can and cannot go. It is important to stress that responses to geofence violations may vary based upon CONOPS. The term "augmented flight mode" refers to manual control with autopilot or flight controller assist. It is important for an operator to maintain full control of the aircraft in the event that a geofence is violated, especially in full manual control. This ensures that there is still a way to influence the aircraft's flight path in the event of a failure outside of a geofenced area.<br>Compliance with ASTM F3002-14a [10.3.1] is assumed through the recommended flight test procedure. However, the recommended procedure was written with the assumption that geofences will be the preferred way of containing a sUAS. | - | - | - | X |

| LINE NO. | 14 CFR PART 23 - COMMUTER | F38 – sUAS[2] | F37 – LSA[3] | RECOMMENDED FT | COMMENTS | N/A TO sUAS PER ASSURE A1 TEAM | N/A TO sUAS PER DRAFT AC 20-XX | GAP IN F38 | SCALABLE TO CONOPS OR EQUIPAGE |
|---|---|---|---|---|---|---|---|---|---|
| 395 | | REDACTED – F3002-14a [10.4.1] | | The sUA must comply with ASTM F3002-14a [10.4.1] with the following exceptions—<br>(1) Reversion to standard GPS accuracy upon lost-link is acceptable if the sUA is equipped with RTK or DGPS; and<br>(2) Failure of the primary command and control link may last no longer than the duration of the lost link event if the link-loss is due to external factors. | It is assumed to be normal that a GPS system that relies on a ground based reference station would lose its enhanced accuracy if communication with the ground station is severed. Overall, this would not have a significant impact on aircraft performance except that it would make automated landings far more challenging.<br>It is also assumed that a failure of the primary command and control link is allowable as it is the reason for the lost-link scenario in the first place. It should be kept in mind that this failure is only allowed to the extent that aircraft can initiate lost-link logic and/or maintain the ability to be reverted to manual control, if possible. | - | - | - | - |
| 396 | | REDACTED – F3002-14a [10.4.2] | | Compliance with ASTM F3002-14a [10.4.2] must be demonstrated in parallel with demonstration of lost-link functions. | | - | - | - | - |
| 397 | | REDACTED – F3002-14a [10.4.3] | | Compliance with ASTM F3002-14a [10.4.3] must be demonstrated in parallel with demonstration of lost-link functions. | | - | - | - | - |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 398 | **Fly-Away Prevention** | | | **Fly-Away Prevention** | | - | - | - | - |
| 399 | | REDACTED – F3002-14a [11.2.1] | | The sUAS must be shown to be in compliance with ASTM F3002-14a [11.2.1].<br>Demonstrate the function of fly-away prevention functionality through hardware in the loop, software in the loop, or some alternative method that demonstrates the system's function and reliability in a way that can be documented. | Demonstrating the function of fly-away prevention poses a safety risk as it would imply that a fly-away scenario would have to be created intentionally by disabling other safety systems. It is recommended that any fly-away prevention function be wrapped up in flight testing, but instead be demonstrated in a software/hardware-in-the-loop environment rather than through live flight. | - | - | - | - |
| 400 | | REDACTED – F3002-14a [11.2.2] | | The sUAS must be shown to be in compliance with ASTM F3002-14a [11.2.2].<br>Demonstrate the function of fly-away prevention functionality through hardware in the loop, software in the loop, or some alternative method that demonstrates the system's function and reliability in a way that can be documented. | Demonstrating the function of fly-away prevention poses a safety risk as it would imply that a fly-away scenario would have to be created intentionally by disabling other safety systems. It is recommended that any fly-away prevention function be wrapped up in flight testing, but instead be demonstrated in a software/hardware-in-the-loop environment rather than through live flight. | - | - | - | - |
| 401 | **Detect and Avoid Systems** | | | | | | | | |
| 402 | | | | TBD | ASTM F2411-07 Standard Specification for Airborne Sense-and-Avoid System was withdrawn in 2014. Applicable requirements are TBD. | - | - | x | TBD |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 403 | **Safety Equipment** | | | | | | | | |
| 404 | **Aircraft Recovery Systems** | | | **Aircraft Recovery Systems** | | - | - | - | - |
| 405 | | | | If equipped with a recovery system, such as a parachute, airbag, or other device that is intended to arrest the aircraft's descent, it must be shown to be reliable and functional—<br>(1) In all aircraft configurations;<br>(2) Throughout the flight envelope except at airspeeds and g loadings that would render such a system ineffective;<br>(3) In all flight modes to include manual, augmented, and automated operation;<br>and<br>(4) In degraded flight modes. | | - | - | - | - |
| 406 | **Subpart C—Structure** | | | | | | | | |
| 407 | | | | TBD | Structural integrity may be evaluated with flight testing. Requirements for such testing are TBD. | | | | TBD |
| 408 | **Subpart D—Design and Construction** | | | | | | | | |
| 409 | §23.601 General. | | | | This section has not been reviewed for sUAS applicability and/or scalability. Draft AC-20-xx-xx references and associated F38 and/or F37 requirements are TBD. | | | | |
| 410 | §23.629 Flutter. | | | | See note in line 409 | | | | |
| 411 | **Control Systems** | | | | See note in line 409 | | | | |
| 412 | §23.671 General. | | | | See note in line 409 | | | | |
| 413 | §23.672 Stability augmentation and automatic and power-operated systems. | | | | See note in line 409 | | | | |
| 414 | §23.677 Trim systems. | | | | See note in line 409 | | | | |
| 415 | §23.679 Control system locks. | | | | See note in line 409 | | | | |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 416 | §23.689 Cable systems. | | | | See note in line 409 | | | | |
| 417 | §23.691 Artificial stall barrier system. | REDACTED – F2910-14 [5.10.2] | | | See note in line 409 | | | | |
| 418 | §23.697 Wing flap controls. | | | | See note in line 409 | | | | |
| 419 | §23.699 Wing flap position indicator. | | | | See note in line 409 | | | | |
| 420 | §23.701 Flap interconnection. | | | | See note in line 409 | | | | |
| 421 | **Landing Gear** | | | | See note in line 409 | | | | |
| 422 | §23.729 Landing gear extension and retraction system. | | | | See note in line 409 | | | | |
| 423 | §23.735 Brakes. | | | | See note in line 409 | | | | |
| 424 | **Personnel and Cargo Accommodations** | | | | See note in line 409 | | | | |
| 425 | §23.771 Pilot compartment. | | | | See note in line 409 | | | | |
| 426 | §23.773 Pilot compartment view. | | | | See note in line 409 | | | | |
| 427 | §23.775 Windshields and windows. | | | | See note in line 409 | | | | |
| 428 | §23.777 Cockpit controls. | | | | See note in line 409 | | | | |
| 429 | §23.785 Seats, berths, litters, safety belts, and shoulder harnesses. | | | | See note in line 409 | | | | |
| 430 | §23.803 Emergency evacuation. | | | | See note in line 409 | | | | |
| 431 | §23.807 Emergency exits. | | | | See note in line 409 | | | | |
| 432 | §23.831 Ventilation. | | | | See note in line 409 | | | | |
| 433 | **Pressurization** | | | | See note in line 409 | | | | |
| 434 | §23.841 Pressurized cabins. | | | | See note in line 409 | | | | |
| 435 | §23.843 Pressurization tests. | | | | See note in line 409 | | | | |
| 436 | **Subpart E—Powerplant** | | | | See note in line 409 | | | | |
| 437 | **General** | | | | See note in line 409 | | | | |
| 438 | §23.901 Installation. | | | | See note in line 409 | | | | |
| 439 | §23.903 Engines. | | | | See note in line 409 | | | | |
| 440 | §23.905 Propellers. | | | | See note in line 409 | | | | |
| 441 | §23.909 Turbocharger systems. | | | | See note in line 409 | | | | |
| 442 | §23.925 Propeller clearance. | | | | See note in line 409 | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 443 | §23.929 Engine installation ice protection. | | | | See note in line 409 | | | | |
| 444 | §23.933 Reversing systems. | | | | See note in line 409 | | | | |
| 445 | §23.939 Powerplant operating characteristics. | | | | See note in line 409 | | | | |
| 446 | §23.943 Negative acceleration. | | | | See note in line 409 | | | | |
| 447 | **Fuel System** | | | | See note in line 409 | | | | |
| 448 | §23.959 Unusable fuel supply. | | | | See note in line 409 | | | | |
| 449 | §23.961 Fuel system hot weather operation. | | | | See note in line 409 | | | | |
| 450 | **Fuel System Components** | | | | See note in line 409 | | | | |
| 451 | §23.1001 Fuel jettisoning system. | | | | See note in line 409 | | | | |
| 452 | **Oil System** | | | | See note in line 409 | | | | |
| 453 | §23.1027 Propeller feathering system. | | | | See note in line 409 | | | | |
| 454 | **Cooling** | | | | See note in line 409 | | | | |
| 455 | §23.1041 General. | | | | See note in line 409 | | | | |
| 456 | §23.1043 Cooling tests. | | | | See note in line 409 | | | | |
| 457 | §23.1045 Cooling test procedures for turbine engine powered airplanes. | | | | See note in line 409 | | | | |
| 458 | §23.1047 Cooling test procedures for reciprocating engine powered airplanes. | | | | See note in line 409 | | | | |
| 459 | **Induction System** | | | | See note in line 409 | | | | |
| 460 | §23.1091 Air induction system. | | | | See note in line 409 | | | | |
| 461 | §23.1093 Induction system icing protection. | | | | See note in line 409 | | | | |
| 462 | **Powerplant Controls and Accessories** | | | | See note in line 409 | | | | |
| 463 | §23.1141 Powerplant controls: General. | | | | See note in line 409 | | | | |
| 464 | §23.1145 Ignition switches. | | | | See note in line 409 | | | | |
| 465 | §23.1153 Propeller feathering controls. | | | | See note in line 409 | | | | |
| 466 | **Powerplant Fire Protection** | | | | See note in line 409 | | | | |
| 467 | §23.1189 Shutoff means. | | | | See note in line 409 | | | | |
| 468 | **Subpart F—Equipment** | | | | See note in line 409 | | | | |
| 469 | **General** | | | | See note in line 409 | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| 470 | §23.1301 Function and installation. | | | | See note in line 409 | | | | |
| 471 | §23.1303 Flight and navigation instruments. | | | | See note in line 409 | | | | |
| 472 | §23.1305 Powerplant instruments. | | | | See note in line 409 | | | | |
| 473 | §23.1307 Miscellaneous equipment. | | | | See note in line 409 | | | | |
| 474 | §23.1309 Equipment, systems, and installations. | | | | See note in line 409 | | | | |
| 475 | **Instruments: Installation** | | | | See note in line 409 | | | | |
| 476 | §23.1311 Electronic display instrument systems. | | | | See note in line 409 | | | | |
| 477 | §23.1321 Arrangement and visibility. | | | | See note in line 409 | | | | |
| 478 | §23.1322 Warning, caution, and advisory lights. | | | | See note in line 409 | | | | |
| 479 | §23.1323 Airspeed indicating system. | | | | See note in line 409 | | | | |
| 480 | §23.1325 Static pressure system. | | | | See note in line 409 | | | | |
| 481 | §23.1326 Pitot heat indication systems. | | | | See note in line 409 | | | | |
| 482 | §23.1327 Magnetic direction indicator. | | | | See note in line 409 | | | | |
| 483 | §23.1329 Automatic pilot system. | | | | See note in line 409 | | | | |
| 484 | §23.1331 Instruments using a power source. | | | | See note in line 409 | | | | |
| 485 | §23.1335 Flight director systems. | | | | See note in line 409 | | | | |
| 486 | §23.1337 Powerplant instruments installation. | | | | See note in line 409 | | | | |
| 487 | **Electrical Systems and Equipment** | | | | See note in line 409 | | | | |
| 488 | §23.1351 General. | | | | See note in line 409 | | | | |
| 489 | §23.1353 Storage battery design and installation. | | | | See note in line 409 | | | | |
| 490 | §23.1357 Circuit protective devices. | | | | See note in line 409 | | | | |
| 491 | §23.1361 Master switch arrangement. | | | | See note in line 409 | | | | |
| 492 | §23.1367 Switches. | | | | See note in line 409 | | | | |
| 493 | **Lights** | | | | See note in line 409 | | | | |
| 494 | §23.1381 Instrument lights. | | | | See note in line 409 | | | | |
| 495 | §23.1383 Taxi and landing lights. | | | | See note in line 409 | | | | |
| 496 | **Safety Equipment** | | | | See note in line 409 | | | | |
| 497 | §23.1411 General. | | | | See note in line 409 | | | | |
| 498 | §23.1415 Ditching equipment. | | | | See note in line 409 | | | | |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-XX | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 499 | §23.1416 Pneumatic de-icer boot system. | | | | See note in line 409 | | | | |
| 500 | §23.1419 Ice protection. | | | | See note in line 409 | | | | |
| 501 | **Miscellaneous Equipment** | | | | See note in line 409 | | | | |
| 502 | §23.1431 Electronic equipment. | | | | See note in line 409 | | | | |
| 503 | §23.1435 Hydraulic systems. | | | | See note in line 409 | | | | |
| 504 | §23.1441 Oxygen equipment and supply. | | | | See note in line 409 | | | | |
| 505 | §23.1447 Equipment standards for oxygen dispensing units. | | | | See note in line 409 | | | | |
| 506 | §23.1449 Means for determining use of oxygen. | | | | See note in line 409 | | | | |
| 507 | §23.1457 Cockpit voice recorders. | | | | See note in line 409 | | | | |
| 508 | §23.1459 Flight data recorders. | | | | See note in line 409 | | | | |
| 509 | **Subpart G—Operating Limitations and Information** | | | | See note in line 409 | | | | |
| 510 | §23.1501 General. | | | | See note in line 409 | | | | |
| 511 | §23.1505 Airspeed limitations. | REDACTED – F2908-14 [7.6.8, 7.6.18] | | | See note in line 409 | | | | |
| 512 | §23.1507 Operating maneuvering speed. | REDACTED – F2908-14 [7.6.17] | | | See note in line 409 | | | | |
| 513 | §23.1511 Flap extended speed. | REDACTED – F2908-14 [7.6.16] | | | See note in line 409 | | | | |
| 514 | §23.1513 Minimum control speed. | | | | See note in line 409 | | | | |
| 515 | §23.1519 Weight and center of gravity. | REDACTED – F2908-14 [7.6.1, 7.6.11] | | | See note in line 409 | | | | |
| 516 | §23.1521 Powerplant limitations. | REDACTED – F2908-14 [7.6.5, 7.6.9, 7.6.20] | | | See note in line 409 | | | | |
| 517 | §23.1523 Minimum flight crew. | | | | See note in line 409 | | | | |
| 518 | §23.1524 Maximum passenger seating configuration. | | | | See note in line 409 | | | | |
| 519 | §23.1525 Kinds of operation. | | | | See note in line 409 | | | | |
| 520 | §23.1527 Maximum operating altitude. | REDACTED – F2908-14 [7.6.12] | | | See note in line 409 | | | | |
| 521 | **Markings And Placards** | | | | See note in line 409 | | | | |
| 522 | §23.1541 General. | | | | See note in line 409 | | | | |

| Line No. | 14 CFR Part 23 - Commuter | F38 – sUAS[2] | F37 – LSA[3] | Recommended FT | Comments | N/A to sUAS per ASSURE A1 Team | N/A to sUAS per Draft AC 20-xx | Gap in F38 | Scalable to CONOPS or Equipage |
|---|---|---|---|---|---|---|---|---|---|
| 523 | §23.1543 Instrument markings: General. | | | | See note in line 409 | | | | |
| 524 | §23.1545 Airspeed indicator. | REDACTED – F2908-14 [7.6.14] | | | See note in line 409 | | | | |
| 525 | §23.1547 Magnetic direction indicator. | | | | See note in line 409 | | | | |
| 526 | §23.1549 Powerplant and auxiliary power unit instruments. | | | | See note in line 409 | | | | |
| 527 | §23.1551 Oil quantity indicator. | | | | See note in line 409 | | | | |
| 528 | §23.1553 Fuel quantity indicator. | | | | See note in line 409 | | | | |
| 529 | §23.1555 Control markings. | | | | See note in line 409 | | | | |
| 530 | §23.1557 Miscellaneous markings and placards. | | | | See note in line 409 | | | | |
| 531 | §23.1559 Operating limitations placard. | | | | See note in line 409 | | | | |
| 532 | §23.1561 Safety equipment. | | | | See note in line 409 | | | | |
| 533 | §23.1563 Airspeed placards. | | | | See note in line 409 | | | | |
| 534 | §23.1567 Flight maneuver placard. | | | | See note in line 409 | | | | |
| 535 | **Airplane Flight Manual and Approved Manual Material** | | | | See note in line 409 | | | | |
| 536 | §23.1581 General. | | | | See note in line 409 | | | | |
| 537 | §23.1583 Operating limitations. | REDACTED – F2908-14 [7.6.21, 7.6.22, 7.6.23] | | | See note in line 409 | | | | |
| 538 | §23.1585 Operating procedures. | REDACTED – F2908-14 [7.6.6, 7.6.7] | | | See note in line 409 | | | | |
| 539 | §23.1587 Performance information. | REDACTED – F2908-14 [4.3, 7.6.2, 7.6.3, 7.6.4, 7.6.15, 7.6.24, 7.6.25] | | | See note in line 409 | | | | |
| 540 | §23.1589 Loading information. | | | | See note in line 409 | | | | |
| 541 | **14 CFR Part 36** | | | | Applicability to sUAS has not been fully explored. Questions remain as to how it can be applied and whether there are challenges associated with determining compliance and/or applying for an exemption. | | | | |
| 542 | **14 CFR Part 91 Section 151** | | | | See note in line 541. | | | | |
| 543 | **14 CFR Part 91 Section 167** | | | | See note in line 541. | | | | |

Notes:

1) This document was developed for Fixed Wing sUAS that are operated outside of the restrictions of the proposed Part 107.

2) Extracted, with permission, from

   ASTM F2910-14 Standard Specification for Design and Construction of a Small Unmanned Aircraft System
   ASTM F3002-14a Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems
   ASTM F2908-14 Standard Specification for Aircraft Flight Manual (AFM) for a Small Unmanned Aircraft System

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# APPENDIX D – COMPLIANCE ISSUES

| STANDARD | PARA. NO. | COMMENTS / REVISIONS |
|---|---|---|
| Prod. Accept. F2911-14e1 | 5.1.3.3 | Dynamic balancing is excessive for a small fixed-wing UAS propellers. However, it is recommended that both static and dynamic balancing be required for conventional rotorcraft that utilize rigid, semi-rigid, and/or fully-articulated rotor systems, as well as larger aircraft that are closer to the 55 lb weight limit of sUAS and are powered by internal combustion engines. |
| D&C F2910-14 | 5.6.8.1 | Recommend specifying hard limits when speaking of "adequate" capacity. |
| D&C F2910-14 | 5.3.3.2 | Define "Adequate structural strength." How much engineering is expected to go in to propeller design? This may be a scalable requirement. |
| AFM F2908-14 | 7.6.12 | Recommend making this mandatory. sUAS may be operated in places where their performance is affected by high density altitudes. The owner/operator should be aware of the system's altitude limitations at all times. |
| AFM F2908-14 | 7.6.21 | Recommend making this mandatory. All sUAS, regardless of weight and/or configuration have environmental limitations of some kind. |
| AFM F2908-14 | 7.6.22 | Recommend making this mandatory. All environmental limitations including weather, RF environment, and other limitations should be listed and made known to the owner/operator. |
| Prod. Accept. F2911-14e1 | 5.1.6.1 | Recommend scaling this requirement to suit ground control stations of varying size and complexity, especially COTS components. It should also be noted that updating the associated software could potentially introduce errors or undesired performance in certain scenarios. This paragraph should be focused such that it captures the software aspect of GCS systems while still covering all possible hardware configurations. |
| Prod. Accept. F2911-14e1 | 5.1.6.2 | The existing standard does not address non-pneumatic-hydraulic launchers. A gap exists with respect to other launcher types. |
| Prod. Accept. F2911-14e1 | 5.1.7.1 | Recommend specifying software and firmware requirements for system configuration in addition to physical aspects. |

| STANDARD | PARA. NO. | COMMENTS / REVISIONS |
|---|---|---|
| Prod. Accept. F2911-14e1 | 5.1.7.3 | Recommend adding a requirement for software verification. |
| Prod. Accept. F2911-14e1 | 5.4.1.3 | F2909 does not specify maintenance and airworthiness documentation content or layout. Recommend drafting a maintenance manual standard or including requirements for maintenance manuals in F2909. |
| D&C F2910-14 | 5.1.4 | "Safe state," requires more definition. This could be interpreted as the aircraft powering on with the power plant defaulting to a low idle. Or it could be interpreted as the aircraft powering on while the power plant remains disarmed. Recommended wording: "A state in which the sUA's systems are powered on and a discreet arming command or ignition sequence is required to enable function of the propulsion system." |
| D&C F2910-14 | 5.1.9 | Complying with "remain secure" is not measureable. Recommend rewording "shall" with "should," or listing suggested fasteners like lock nuts, thread-lock, rivets, etc. |
| D&C F2910-14 | 5.3.4 | This is not a testable requirement. |
| C2 F3002-14a | 8.2.1 | Recommend reword to explicitly allow alternate methods for reducing error such as cyclic redundancy check, parity bits, etc. This may require additional study to determine methods. |
| C2 F3002-14a | 8.2.2 | The minimum required data has not been defined by ASTM or FAA at this time. |
| C2 F3002-14a | 8.2.3 | The minimum required data has not been defined by ASTM or FAA at this time. |
| AFM F2908-14 | 5.2 | Compliance with this paragraph is contingent upon compliance with other standards. It is also very difficult, if not impossible to measure compliance. Consider removing this requirement. |
| Prod. Accept. F2911-14e1 | 5.1.7.2 | Specify examples of which characteristics to document. This paragraph may be vague for a reason, but an example or two of required information should be included for clarity. |

| STANDARD | PARA. NO. | COMMENTS / REVISIONS |
|---|---|---|
| D&C F2910-14 | 5.2.1.1 | “Limit loads" needs clarification. It could be defined as “highest expected load” which could be a flight load, launch load, recovery load, ground/transport load, etc. Additional research is recommended to provide more specific definition to limit loads. |
| D&C F2910-14 | 5.2.1.2 | Recommend rewording to specify limit load threshold and more specific structure(s)/control actuator(s) in question. |
| D&C F2910-14 | 5.2.1.3 | Recommend specifying how many cycles and clarifying which structures this refers to. This overlaps with 5.2.1.1. |
| C2 F3002-14a | 9.2.6 | Terminology is inconsistent with previous paragraphs when relating "message error rate" and "bit error rate." Recommend making references to error rate generic so that multiple forms of error detection and preventions may be used. |
| Prod. Accept. F2911-14e1 | 5.1.6.1 | Recommend scaling this requirement to suit ground control stations of varying size and complexity, especially COTS components. It should also be noted that updating the associated software could potentially introduce errors or undesired performance in certain scenarios. This paragraph should be focused such that it captures the software aspect of GCS systems while still covering all possible hardware configurations. |
| Prod. Accept. F2911-14e1 | 5.1.7.1 | Recommend specifying both physical aspects of system configuration as well as software and firmware for the purpose of further exploring the impact of software changes on configuration. These impacts are not fully understood. |
| ~~Batt. F3005-14a~~ | ~~8.1.4~~ | ~~Specify which repairs may be carried out by both the pack assembler and/or the end user.~~ |
| ~~D&C F2910-14~~ | ~~5.1.1~~ | ~~This requirement is broad. The terms "Performance" and "Limitations" are both vague and undefined. Does this requirement refer to operational limitations? If there are any limitations/performance capabilities (other than weight and distance from airport) intended to be covered by this requirement, then there is a gap here. This requirement should reference specific limitations and performance characteristics such as weight, size, required functionalities...~~ |

| STANDARD | PARA. NO. | COMMENTS / REVISIONS |
|---|---|---|
| ~~D&C F2910-14~~ | ~~5.1.2~~ | ~~Turning radius is affected by airspeed, pilot skill, wind, and to an extent, structural limitations. The pilot must be responsible for remaining in a designated operating area, not the manufacturer. Recommend removing "In addition, maximum level flight airspeed … pilot skill."~~ |
| ~~D&C F2910-14~~ | ~~5.1.3~~ | ~~This requirement is vague. Compliance is very flexible and the intent may not be achieved in practice.~~ |
| ~~D&C F2910-14~~ | ~~5.1.5~~ | ~~The efficacy and feasibility of fire suppression systems on sUAS should be studied. This requirement could be made scalable.~~ |
| ~~D&C F2910-14~~ | ~~5.1.9~~ | ~~Recommend rewording "shall" with "should," or listing suggested fasteners like lock nuts, rivets, etc. Or provide more specific means of complying with this requirement such as using thread locking compound, torque seal, safety wire, etc.~~ |
| ~~D&C F2910-14~~ | ~~5.1.11.2~~ | ~~This requirement is ambiguous. Recommend removing this requirement altogether. It is difficult to demonstrate compliance. …OR…Reword to state "... where practical..." [REDACTED]~~ |
| ~~D&C F2910-14~~ | ~~5.3.3.3~~ | ~~Recommend restating this paragraph as requiring an alert to the pilot of an over-speed condition or specifying some means other than mechanical of preventing an over-speed condition.~~<br>~~Manned aircraft can over-speed propellers and engines in specific conditions and often rely on a marked "redline" on the tachometer to alert the pilot of an over-speed condition.~~ |
| ~~D&C F2910-14~~ | ~~5.6.1.1~~ | ~~This requirement is difficult to measure.~~ |
| ~~D&C F2910-14~~ | ~~5.6.1.2~~ | ~~This requirement would be better worded to state that "...*safety critical* components shall..."~~ |
| ~~D&C F2910-14~~ | ~~5.6.8.2~~ | ~~Recommend specifying hard limits when speaking of "adequate" capacity.~~ |

| STANDARD | PARA. NO. | COMMENTS / REVISIONS |
|---|---|---|
| ~~D&C F2910-14~~ | ~~5.9~~ | ~~Functional requirements are needed to address launch systems other than pneumatic-hydraulic launchers. Recovery systems are not covered by any existing standard.~~ |
| ~~D&C F2910-14~~ | ~~5.10.1.2~~ | ~~This may require significant design changes to satisfy the "single specification" requirement. Some aircraft designs may not allow the aircraft to return to controlled flight if a full stall occurs and results in a spin. Recommend rewording to state, [REDACTED]~~ |
| ~~D&C F2910-14~~ | ~~5.10.2~~ | ~~A definition for, "Automatic departure prevention," is needed. These systems are often intrinsic properties of autopilot or flight control computers where a minimum airspeed can be specified. If a redundant system is required, this is overly burdensome as stall prevention may be accomplished through basic features present in many autopilot systems without the need for additional components or subsystems. This is an example of a requirement that may be scaled.~~ |
| ~~D&C F2910-14~~ | ~~5.1.11.2~~ | ~~This requirement is ambiguous. Recommend removing this requirement altogether. It is difficult to demonstrate compliance. …OR…Reword to: "...should be used where practical..." [REDACTED]~~ |
| ~~D&C F2910-14~~ | ~~5.11.1~~ | ~~Suggest removing this requirement. Complying with individual requirements already requires testing/analysis/etc. This requirement essentially states that a sUAS must comply with this standard. That is already understood.~~ |
| ~~Batt. F3005-14a~~ | ~~8.1.2.2~~ | ~~Define how often the pack must meet this requirement in order to be considered "high utilization." The term "regularly" is not descriptive enough. Recommend specifying a minimum number of cycles in which the battery must exceed 80% depth of discharge to be considered high utilization.~~ |

NOTE: Entries with crossed out text indicate that the item has been addressed by the F38 committee.

# APPENDIX E – COMPLIANCE GAPS

| Gap | Comments and Recommendations |
|---|---|
| Insufficient flight test requirements | Production flight test requirements are provided in the standards, but are insufficient to address full type certification flight testing. This overlooks key elements of aircraft performance. |
| No requirements exist for the design and construction of autopilot or flight control systems. | Include specific autopilot requirements in the F3002 standard or develop a new standard to cover the design and construction of autopilot systems. Include requirements for components, critical functions, quality assurance procedures, etc. This overlaps with software verification and validation. |
| Reliance on non-existent complimentary regulation from the FAA. | Some paragraphs within the standards refer to regulations that have not yet been established by a governing aviation authority (GAA). In these cases, it is recommended that reasonable limitations pertaining to safe flight and design assurances be prescribed independently of a regulating entity. |
| The layout and content for maintenance manuals is not defined. | Define the content and layout of sUAS maintenance manuals in a separate standard or within F2908. If a separate standard is drafted, utilize a format similar to F2908. |
| The design, construction, and production for complex launch systems other than pneumatic-hydraulic systems are not defined. | Whether this gap needs to be filled for airworthiness certification is debatable. Regardless, F2910-14: 5.9 [REDACTED]. F2585-08 currently addresses pneumatic-hydraulic launchers only. |
| No requirements exist for the design, construction, or production of complex recovery equipment such as parachutes, air bags, nets, cable recovery systems, or other arresting gear. | Recovery equipment such as parachutes, air bags, nets, traps, and arresting cables are not covered by the standards in their current form. Recommend further discussions or research to investigate the necessity of recovery equipment requirements with regards to airworthiness and certification. |
| Aeroelasticity and aeroservoelasticity is not mentioned within the scope of current structural requirements found within F2910-14. | Aeroelasticity and aeroservoelasticity are important aspects of aircraft structural requirements that are left unaddressed by the standards. Add requirements within F2910 that address the structural flutter and control surface flutter. Requirements for flutter should state that the aircraft should be free from flutter up to $V_{NE}$. This is potentially a scalable requirement. |

| Gap | Comments and Recommendations |
|---|---|
| There is a lack of delineation between the smaller and larger ends of the sUAS spectrum. | A distinction should be made between the smaller (>4.4 lbs) and larger ends of the sUAS spectrum (< 55 lbs). However, this is a multi-faceted determination that would require input from many research areas. A common issue that was raised throughout the SVP was that requirements that made sense for large, fixed-wing sUAS did not always make sense for small sUAS closer to the 4.4 lb end of the spectrum.<br>It is recommended that requirements be reviewed for scalability and revised to account for the distinct differences in system design and complexity that exists between the broad spectrum of sUAS. Some examples of potentially scalable requirements include:<br>- F2911-14e1: 5.1.3.3 – Dynamic balancing of propellers<br>- F2910: 5.3.3.2 – Propeller Structural Properties |
| Material requirements are not defined. | Recommend adding requirements for material property testing in F2911-14e1. This is to ensure that properties remain consistent over time, with regards to production and quality control of certified aircraft. |
| Load cases for structural testing are not defined. | Recommend prescription of load cases within the structural requirements that are listed in F2910-14. Future research is recommended to define appropriate load cases for sUAS. This research should also explore prescribed safety factors to see if they are realistic. |
| No requirements for design, construction, and QA of ground control stations beyond simple laptops. | Define requirements for design and construction of complex ground control stations (other than laptops) to include independent design, construction, and production requirements. Focus on functional requirements whenever possible. |
| No requirements for carburetor de-icing and/or carburetor anti-icing equipment. | Add requirements for carburetor anti-ice and/or carburetor de-icing equipment, if required by the operational environment. |
| ~~No requirements are specified for the design of sUAS software.~~ | ~~It is recommended that software design, verification, validation, and configuration control be addressed within the standards. Software verification for UAS presents unique challenges because many OEMs utilize open-source software.~~<br><br>~~NOTE: There is currently an ASTM F38 working group that is drafting a standard to address software of unknown pedigree (SOUP).~~ |

| Gap | Comments and Recommendations |
|---|---|
| ~~Definition of acceptable levels of C2 link~~ | ~~Future research is recommended to determine the appropriate level of performance criteria for C2 links. However, redundant and fall-back systems may be the focus of requirements instead. Protected spectrum also factors into the requirements for a safe, reliable C2 link.~~ |
| ~~Propulsion methods other than propellers and rotors are not considered.~~ | ~~Add provisions within the existing standards to address other methods of propulsion. Turbines, ducted fans, fuel cells, and other novel propulsions methods may not be covered in the existing requirements.~~ |

NOTE: Entries with crossed out text indicate that the item has been addressed by the F38 committee.