NASA/CR–2019-220407

Certification Gap Analysis

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EXECUTIVE SUMMARY

None of the Federal Aviation Regulations envisioned electric propulsion when the regulations were promulgated. Further, most of the technology for spark ignition reciprocating engines had been innovated decades ago, so that subsequent certifications of newer reciprocating engines had an heritage, along with legacy means of compliance so that certification was clear-cut.

Recent technology innovations in vehicle concepts and the technology that support the vehicles have pushed the limits of their ability to be certified. The FAA's recent response to that challenge with its regulation by objective, supported by the update of FAR 23 to amendment 23-64 show a remarkable intent to adapt to the technology challenge. In particular, the ASTM committees to develop standards that support these standards are laudable.

Accordingly, there can now be made a clear mapping between the regulations and certification criteria and the X-57 Scalable Convergent Electric Propulsion Technology and Operations Research (SCEPTOR) program. The results of planning and tests from the program is able to address still-open questions and challenges in the development of the means of compliance to the ASTM standards, as well as gaps between the existing regulations and the new vehicles that are pushing innovative technologies.

This report describes a generic method for addressing any new technology to its associated set of regulations and certification criteria. The result is a framework under which a detailed assessment can be conducted.

Using just such a framework, the report maps the detailed updated regulations and evolving ASTM standards to the particular technology planning and tests.

As a result, a roadmap of NASA technology is documented that shows clear transfer of technology data to industry (standards developers, as well as technology developers) and the FAA regulatory policy and certification staff upon whom certification and policy will be data-driven.

Future work will include the development of new standards and means of compliance for new insights from the NASA flight project. To validate the approach, a new NASA vehicle concept should be examined for its certification issues. It is conceivable that the approach and framework can be used to inform the decision-making by NASA for new vehicle concepts.

INDEX

TABLE OF FIGURES AND TABLES

1. Introduction

None of the Federal Aviation Regulations envisioned electric propulsion when the regulations were promulgated. Further, most of the technology for spark ignition reciprocating engines had been innovated decades ago, so that subsequent certifications of newer reciprocating engines had an heritage, along with legacy means of compliance so that certification was clear-cut.

This report describes a generic method for addressing any new technology to its associated set of regulations and certification criteria, and assessing it with respect to a generic electric propulsion vehicle. The result is a framework under which a detailed assessment can be conducted for particular vehicle configurations.

The report then describes some of the key characteristics of the X-57 Maxwell Scalable Convergent Electric Propulsion Technology and Operations Research (SCEPTOR). In particular, the approach of taking a Tecnam P2006T aircraft, and replacing the wing and twin Rotax R912 spark ignition reciprocating engines with a high-aspect ratio wing with leading-edge distributed electric propulsion motors for high-lift climb and descent, as well as two electric propulsion units for cruise flight.

Using the generic framework and applying it to the X-57 Maxwell SCEPTOR, as an example vehicle, the report maps the detailed updated regulations and evolving ASTM standards to the particular technology planning and tests of the X-57.

As a result, a roadmap of NASA technology is documented that shows clear transfer of technology data to industry (standards developers, as well as technology developers) and the FAA regulatory policy and certification staff upon whom certification and policy will be data-driven.

Accordingly, there can now be made a clear mapping between the regulations and certification criteria and the X-57 SCEPTOR program. The results of planning and tests from the program is able to address still-open questions and challenges in the development of the means of compliance to the ASTM standards, as well as gaps between the existing regulations and the new vehicles that are pushing innovative technologies.

2. An Approach to Identify Areas to Focus Electric Propulsion Certification

This report describes the initial assessment of aircraft procedures for emerging technologies. The objective is to identify gaps that may exist due to emerging technologies in both new certification rules and existing standards used as a means of compliance to these rules for Normal Category Aircraft.

There are three tasks associated with this assessment. The first is a certification basis review. The second is the evaluation of NASA activities relevant to certification gaps. The final is the coordination between NASA, the regulators and the standards bodies.

2.1. Certification Basis Review

The approach to the certification basis review is done in three parts. First identify the appropriate engineering certification regulations for the advanced vehicle concept. Next, identify the technology innovations. Finally, select the particular vehicle concept and regulatory environment.

2.1.1. Identify the appropriate engineering certification regulations

This involves capturing the relevant aircraft and propulsion certification regulations, as well as the associated Aircraft Flight Manual and-or the Pilot Operating Handbook (while operational, these later documents contain limitations based on the engineering certification of the aircraft), and with some portions of the operational certification regulations. Figure 1 shows a list of potential concept vehicles and potential associated regulation groups.

Figure 1, Identification of Appropriate Certification-Regulations for Advanced Concept Vehicles

2.1.2. Evaluation of NASA Activities Relevant to Certification Gaps

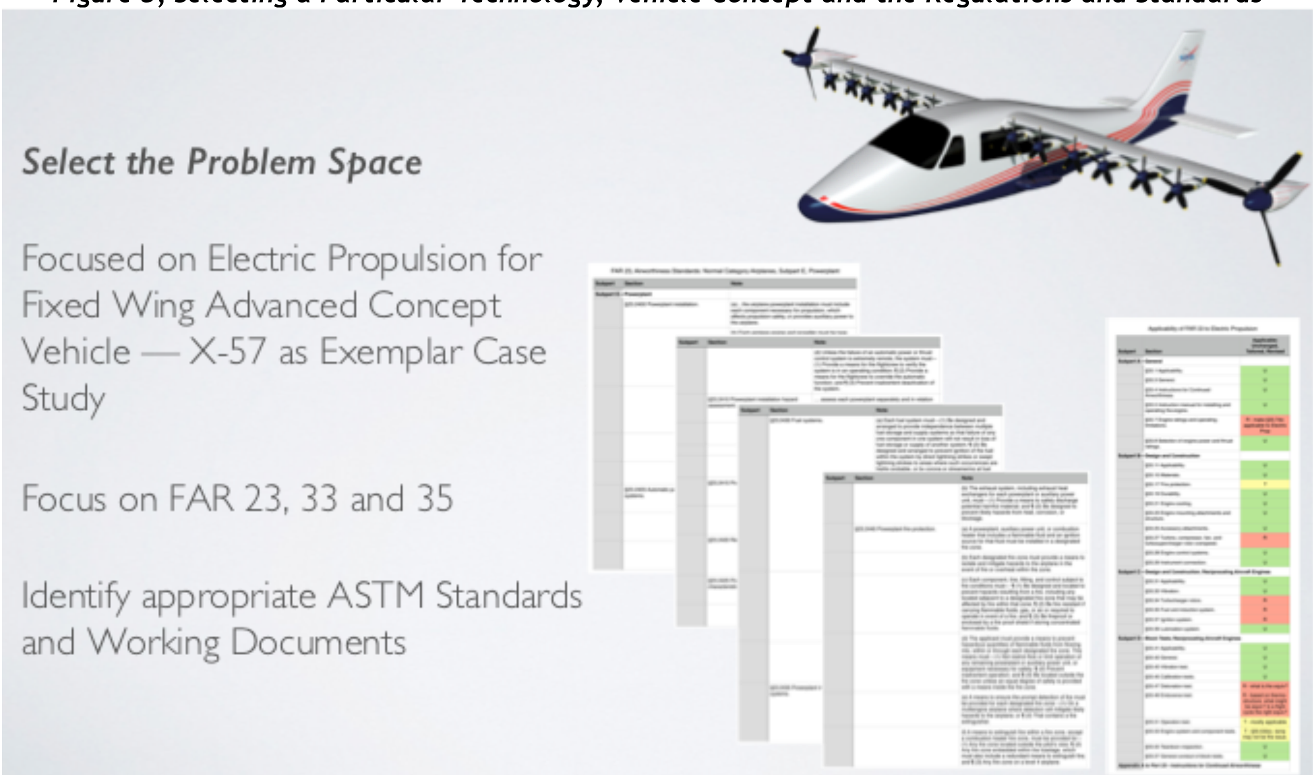
This involves capturing the relevant technology innovations to be demonstrated, as well as key vehicle concepts. For example, a vehicle concept may focus on a large, transport-category aircraft that leverages boundary layer injection. Associated with that technology is hybridized powerplants and integrated turbine engines. An electric cruise propulsion vehicle may focus on electric propulsion systems and battery management systems, while concurrently demonstrating high-lift distributed electric propulsion. Other examples are also shown and summarized in Figure 2.

Figure 2, Technology Innovation and Vehicle Concepts

2.1.3. Selecting a Vehicle Concept and Technology

The third and final part is to select a particular problem space that focuses on a vehicle concept and technology, and focuses on the appropriate engineering certification and standards. Figure 3 shows the example of focusing on electric propulsion for a fixed wing advanced concept vehicle, which further focuses on 14 CFR 23, 33 and 35, as well as appropriate ASTM standards and working documents.

Figure 3, Selecting a Particular Technology, Vehicle Concept and the Regulations and Standards



Once the problem space is defined for electric propulsion, then begins the review the current regulations that apply to small aircraft, as well as the Means of Compliance (MOC) by both FAA Advisory Circulars and Standards. A significant body of new standards are being developed by ASTM in its committees F44 and F39, based on the FAA approach of performance-based regulation, epitomized in 14 CFR 23, Amendments 62 through 64. A considerable legacy of standards are also found in SAE, RTCA and other organizations, as well.

This review of the current regulations are examined with respect to to the new concept vehicle and new technology, in this case to identify areas to focus electric propulsion certification, and to uncover elements of the applicable Federal Aviation Regulations (FAR) that suggest a need of tailoring or wholesale revision.

The approach taken to infer the need for tailoring or revision is to integrate the regulations with the vehicle concept using the system technology demonstration phases. This allows insights into the particular phase of the system technology demonstration phase, and its applicable regulation or MOC standard. This is shown in Figure 4.

At each intersection shown in Figure 4, an assessment of the effect of the advanced technology insight is conducted on the regulation and certification. The purpose is to assess the appropriateness of the regulatory criteria or conditions on the technology. This establishes a simple means of asserting that the regulation-certification is unchanged, needs tailoring or needs revision.

Figure 4, Integrating Regulations with Vehicle Concepts by System Technology Phase

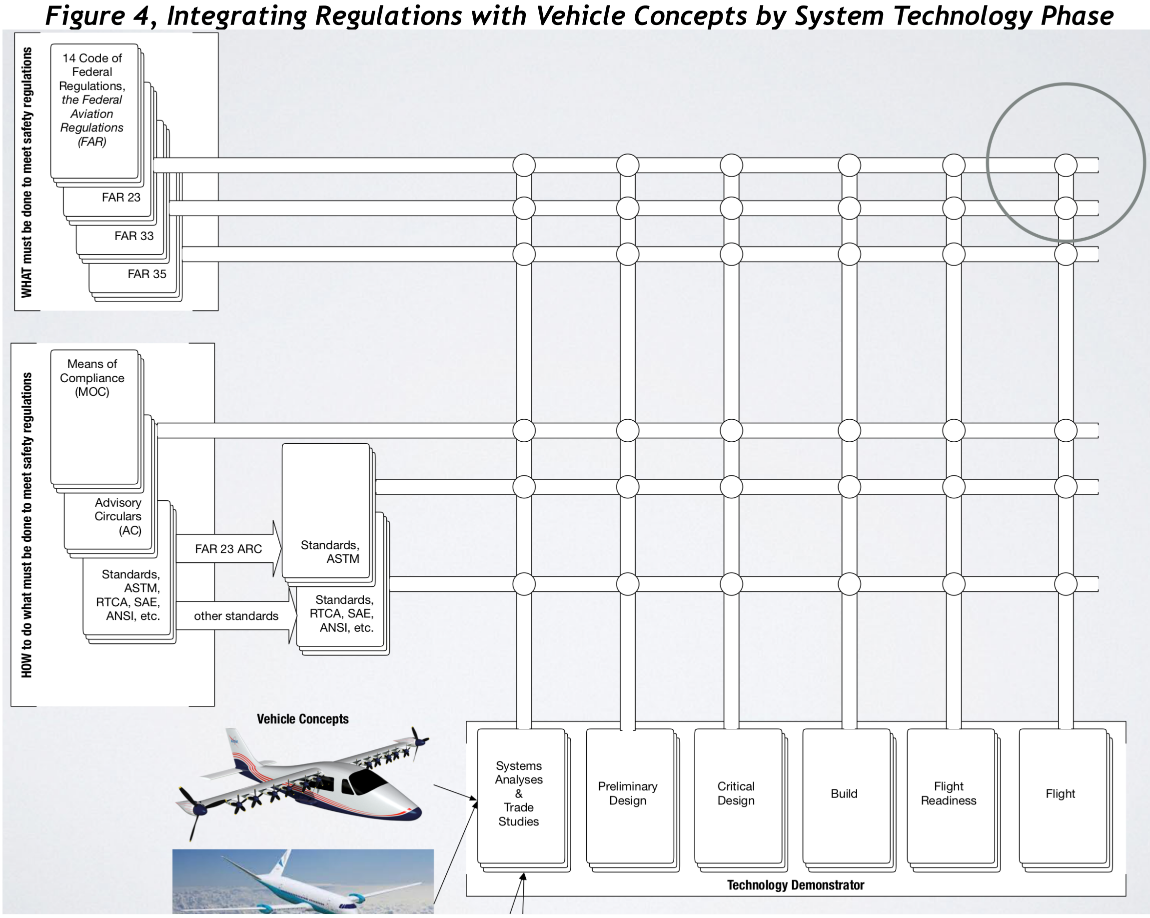
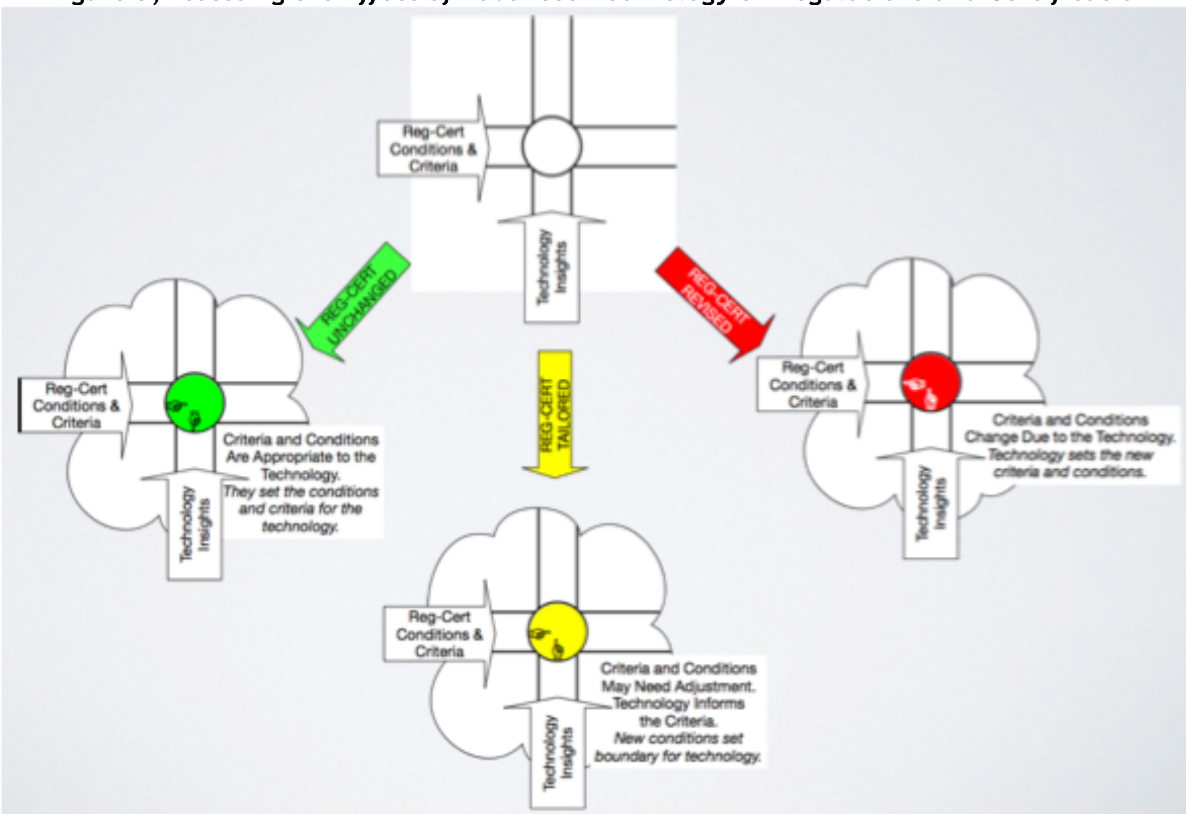


Figure 5 shows a hypothetical decomposition of an intersection and a caricature of the decision process. In one case, the criteria and conditions of the regulation-certification are appropriate to the technology, and sets the conditions and criteria for the technology. The regulation-certification, in this case, is unchanged.

The next case, the criteria and conditions may need adjustments, and the technology informs the criteria. The new conditions set the boundary for the technology, and, thus, the regulation-certification is tailored for the technology.

Finally, the criteria and conditions change due to the technology, and the technology sets new criteria and conditions. The regulation-certification need revision.

Figure 5, Assessing the Effect of Advanced Technology on Regulations and Certification



After conducting an evaluation of 14 CFR 23, Airworthiness Standards: Normal Category Airplanes[1], 33, Airworthiness Standards: Aircraft Engines[2], and 35 Airworthiness Standards: Propellers[3], for a fixed-wing electric propulsion concept vehicle, most of the regulations were found to be appropriate for electric propulsion. Of the 122 sections reviewed in FAR 35, 33 and 23, 8 were found to need revision and 20 would need tailoring for the electric propulsion technology. This provides some confidence that the regulatory process is robust in the presence of the new technology.

2.2. Evaluation of NASA activities relevant to certification gaps

This report focuses on the assessment of the NASA vehicle concept of the X-57 SCEPTOR Distributed Electric Propulsion technology and its ability to affect the relevant certification and regulatory environment. In the process, this report assesses the certification gaps.

[1] 14 CFR 23, Amendment 23-64, Dated 30 Aug 2017 (https://www.ecfr.gov/cgi-bin/retrieveECFR?pitd=20170830&n=pt14.1.23)

[2] 14 CFR 33, General, Design and Reciprocating Aircraft Engines, Dated 3 October 2018, (https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt14.1.33)

[3] 14 CFR 35, Dated 3 October 2018, (https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt14.1.35)

2.3. Coordination between NASA, the regulators and the standards bodies

The third task is to ensure that the vehicle concept and technology has the ability to be reviewed and understood by the regulators and standards bodies. While traditional engineering certification processes are proscriptive in nature (with explicit pass-fail criteria that must be demonstrated by the applicant to the certification office), the recent vehicle concepts and associated technologies have stretched this traditional model to its limits. Accordingly, a number of initiatives, which formed a new organization within the FAA certification service (AIR-600, Policy and Innovation Division, in the Aircraft Certification Service), within which new technology vehicles are being assessed for their ability to be certified using special conditions. Further, rather than an applicant entering the certification process with all documentation completed and ready to pass all of the criteria, this new service encourages new vehicle developers to enter discussions, so that the FAA better understands the technology, and can offer the new vehicle developer a potential path forward when the developer is ready to begin certification.

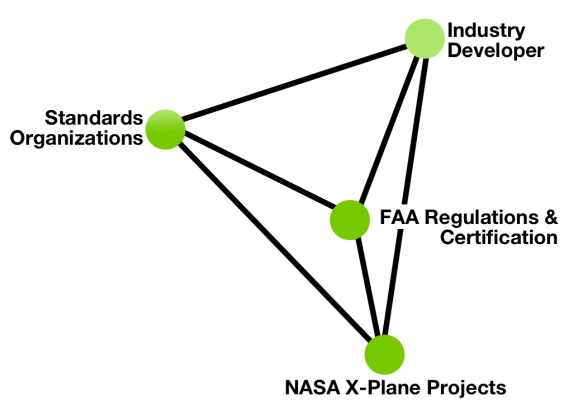
A significant portion of any certification program is a solid knowledge of the means of compliance (MOC) to each paragraph within the regulations. These MOCs are traditionally done by FAA Advisory Circulars. However, a number of MOC are better done by industry-accepted standards. Aviation standards organizations such as ASTM, RTCA, SAE (and others) build their standards, typically, through consensus of industry and Government technical specialists gathering to develop their standards.

Of particular note for general aviation is that the ASTM has built the Committee F44 on General Aviation Aircraft, and Committee F39 on Aircraft Systems. These committees are actively contributing to the standards body of knowledge on electric propulsion, in particular.

NASA involvement with the regulators and standards bodies is openly encouraged, and forms a unique ability to ensure contribution of NASA technology to the industry.

As a result, the X-57 SCEPTOR program becomes an equal contributor to the industry developer, the standards organization and the FAA regulator and certifier, as illustrated in Figure 6.

Figure 6, NASA's Role in Emerging Technology Environments



3. Overview of the X-57 Project

Based on the summary assessment of the regulations with respect to electric propulsion, an assessment was conducted with particular focus on the NASA Scalable Convergent Electric Propulsion Technology and Operations Research (SCEPTOR) X-57 project.

The SCEPTOR X-57 project addresses a NASA Aeronautics Research Mission Directorate (ARMD) goal to enable technologies that reduce fuel burn and emissions across the U.S. aviation fleet. System studies, identified in the SCEPTOR X-57 "Maxwell" Objectives and Requirements Document (ORD)[4], have shown that extremely high coupling between the aerodynamics, propulsion, control, structure, and acoustics through electric propulsion offers the most aggressive method of accomplishing a reduced fuel burn and emissions goal. The project will validate these system studies through the flight test of a human piloted all-electric GA aircraft. Performance of the conventionally powered baseline GA aircraft is compared to that of the all-electric aircraft in order to validate the performance gain. The objectives of the SCEPTOR project are shown in Table 1.

[4] SCEPTOR X-57 Maxwell Objectives and Requirements Document (ORD), ORD-CEPT-002, Release A, 8 January 2018.

Table 1, Flight and Complex Distributed Electric Propulsion (DEP) Objectives (from ORD)

Objective Number	Objectives	Precedence	Performance Measure
OBJ-1	Achieve at least a 3.0x lower energy usage compared to baseline General Aviation (GA) aircraft at high speed cruise.	Primary	Cruise energy per nm resulting from the product of aerodynamic, propulsive and structural efficiencies. Measured by collecting air data for true airspeed, GPS for distance, and power usage of the battery system.
OBJ-2	Achieve at least a 1.2x lower energy usage compared to electrified General Aviation (GA) aircraft at high speed cruise.	Secondary	Cruise energy per nm resulting from the product of aerodynamic, propulsive and structural efficiencies. Measured by collecting air data for true airspeed, GPS for distance, and power usage of the battery system.
OBJ-3	Raise the TRL from 5 to 6 of a complex, integrated DEP system on a manned aircraft	Primary	Min Success: Flight with a complex, integrated DEP system containing at least 8 motors operating at a total power level of at least 60kW during a power-idle descent Full Success: Level flight with a complex, integrated DEP system active down to at least 58 KCAS
OBJ-4	Demonstrate low-speed handling qualities, landing profile, and takeoff profile using a complex DEP system	Primary	Min Success: Cooper-Harper rating of 6 Full Success: Cooper-Harper rating of 4
OBJ-5	Demonstrate a means of compliance for certification of DEP technologies	Primary	Min Success: Publicly-available presentation or report that describes the approach that was used to address NASA airworthiness standards related to the DEP system Full Success: Incorporation of at least one NASA-developed DEP-related airworthiness procedure in a consensus standard that is accepted as a means of compliance to 14 CFR Part 23 or Part 33 (e.g., ASTM F44, ASTM F39, etc.)
OBJ-6	Generate a reference acoustic signature of a DEP configuration	Secondary	Min Success: Build an acoustic model based on collected reference data Full Success: Conduct acoustic signature characterizations acceptable to 14 CFR Part 36, Appendix G

The SCEPTOR X-57 project intends to modify an existing GA aircraft. This provides for a "re-wing" of the aircraft utilizing a wing optimally designed for electric propulsion at cruise, while reducing the risk and cost associated with a new aircraft design. Additionally, this allows for a direct comparison between performance of the GA baseline aircraft and the X-57 aircraft. The project objectives may be met with the selection of various GA aircraft that operate in the desired flight envelope and are capable of high speed cruise; a representative geometry reflecting a re-winged Tecnam P2006T is shown in Figure 6. Representative performance data are shown in Table 2. (These data may change as the vehicle configuration evolves.)

Figure 7, A Representation of the X-57 SCEPTOR as a Re-Winged Tecnam P2006T

Table 2, Electrified GA Aircraft Performance Characteristics of the X-57 SCEPTOR

Performance Characteristic	Value
Wing Area	67 sq. ft.
Wing Aspect Ratio	15
Cruise Motors (no. @ power each)	2 @ 45kW (60 kW peak)
High Lift Motors (no. @ power each)	12 @ 10kW
Aircraft Weight	3000 lb
Battery Weight	800 lb
Cruise Altitude	9000 ft
Ceiling	15000 ft
Cruise L/D	14
Cruise Speed	152 KTAS
Stall Speed	58 KCAS
Flight Time	30 min

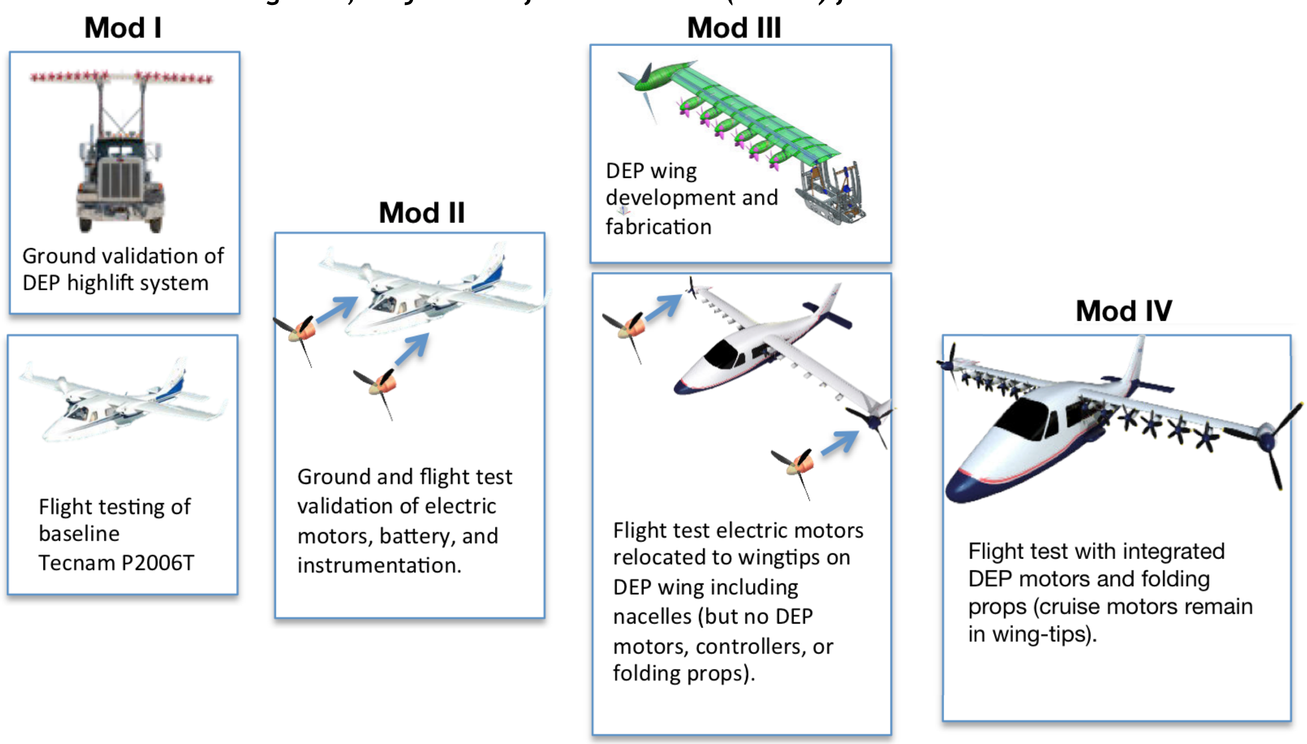
The X-57 aircraft is a human-rated, human-piloted aircraft with a conventional mechanical flight control system. A digital flight control system is not required for aircraft control, and therefore is considered an unnecessary complexity. However, a level of fault-tolerant digital control is required for operation of the electric propulsion system.

The SCEPTOR X-57 project's development approach incorporates conventional design practices, a build-up testing approach, and model validation. The development plan ensures an advanced understanding of the electrical power system, motors, wing structure, and flight controls, and demonstrates NASA airworthiness of the X-57 aircraft prior to flight.

The X-57 aircraft maintains the base GA aircraft system fuselage, empennage, landing gear, and control system for pitch and yaw. The wing structure, and consequently the roll control system and high-lift system, are a new design. The new wing structure is primarily of carbon-fiber construction. The wing provides ailerons for roll control and flaps for high-lift augmentation, plus nacelles for the wing tip and High Lift motors, and routing accommodations for the electrical power system. The wing shall be designed according to G-7123.1-001 Aircraft Structural Safety of Flight Guidelines.

The SCEPTOR X-57 project is divided into 4 primary developmental phases, referred to as modifications, and abbreviated as Mod I, II, III, and IV. Each modification results in an incremental build-up in system complexity. Mod I includes build-up of a ground test version of the primary electrical propulsion system. Additionally, flight data for simulation validation is collected from a rental aircraft during Mod I. Mod II involves the integration and flight test of the electrical propulsion system and is used for flight validation of the new propulsion system. Mod III involves development and integration of the new wing design with the propulsion system installed on the wing-tips. Mod IV adds the High Lift system, which restores the original low speed performance envelope of the aircraft. The project Mods are shown in Figure 7.

Figure 8, Project Modification Phases ("Mod") for SCEPTOR X-57



There are four flight phases to the X-57 flight testing, correlating to the three project modifications, categorized as Mod I, Mod II, Mod III, and Mod IV.

Mod I consists of test flights on a rental aircraft to develop pilot familiarization and collect flight data for simulation validation. These data support energy consumption with a representative reciprocating engine; pilot familiarization of the basic aircraft controls that remain unchanged when proceeding to Mod II; and collecting aero-model, stability and control, and flight characteristics for simulator development.

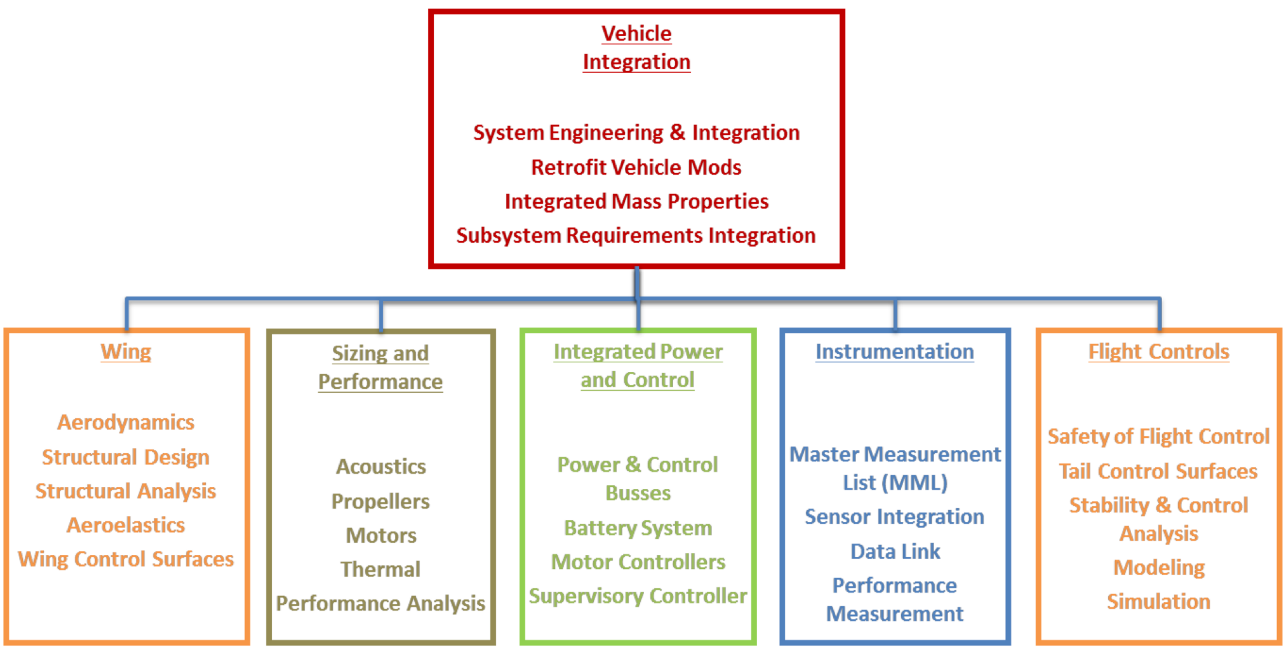
Mod II is flight testing of the base GA aircraft with the electric motor(s). The focus of Mod II is (1) to develop pilot proficiency in the operation of the electric aircraft, and (2) establish baseline performance of the aircraft with electric motors. The flight test for Mod II includes energy consumption measurements, and validation of the simulator model for operation and failure states of the electric motors.

Mod III ground and flight testing begins following integration of the new wing and wing- tip cruise motors. Ground testing including Ground Vibration Tests (GVT) conducted to validate system models prior to flight test. This Mod of flight testing requires envelope expansion as the vehicle is required to establish flutter clearance and validate motor-out performance.

Mod IV ground and flight testing follows the integration of the High Lift system and therefore expands the flight envelope accordingly. Operations of the High Lift system will occur first at altitude prior to operations during take-off and landing.

While the X-57 SCEPTOR project development is builds on progressions between each modification phase, the project structure is based on an integrated product team structure with Vehicle Integration as the integrating integrated product team, with five integrated product teams consisting of Wing, Sizing and Performance, Integrated Power and Control, Instrumentation, and Flight Controls. The disciplines and responsibilities associated with each integrated product teams is shown in Figure 8.

Figure 9, Integrated Product Team Structure of the X-57 SCEPTOR Project



Further X-57 SCEPTOR project details can be found in the ORD, as well as the six specifications: Motor and Controller Specification (SPEC-CEPT-001), Traction Battery System Specifications (SPEC-CEPT-002), Mod III/IV Wing Structural Specifications (SPEC-CEPT-003), High-Lift Motor Specification (SPEC-CEPT-004), High-Left Motor Controller (SPEC-CEPT-005), and High-Lift Propeller Specification (SPEC-CEPT-006).

There is also a public-facing document repository with technical papers, as well as the Preliminary Design Review and Critical Design Review presentations available at the NASA X-57 Technical Data Repository[5].

4. Evaluation of the Federal Aviation Regulations and the X-57 SCEPTOR

The X-57 is not bound by the Federal Aviation Regulations, and as such does not need to go through an aircraft certification process. As a NASA experimental aircraft there is a robust body of NASA safety of flight and safety-and-mission-assurance processes and practices that it must meet in order to fly. These are complemented by a robust set of NASA program and project management practices in systems engineering with oversight by Chief Engineering organizations.

This assessment was conducted of the regulations as they might be affected by the new technology in the X-57. The purpose of which is to ensure that the technology development, as well as results and insights from simulations and tests of the X-57 during its four modification phases are available for the industry and FAA, as a resource for their decision-making. It is not to conduct a certification test plan for the X-57.

The approach was to generate a “Proposed Compliance Matrix” (PCM) that mimics a traditional test matrix. While a test matrix is not needed for the X-57, this structure provides a means by which an assessment of the current regulations can be done based on the X-57 technology development. This is a similar process to that which was described in the Introduction section of this paper. The difference is that instead of using the generic system technology demonstration phases (“systems analysis”, PDR, CDR, etc.), this assessment will focus on the four development phases of the X-57 to assess the readiness of the regulations to its new technology.

A review of the Airworthiness Standards: Normal Category Airplanes (FAR 23), Aircraft Engines (FAR 33), and Propellers (FAR 35) for their robustness to electric propulsion and distributed electric propulsion follows.

4.1. Summary of Normal Category Airplanes Regulations (FAR 23) and X-57

Installation of electric propulsion units, electrical storage systems and distributed electric propulsion were not envisioned when 14 CFR part 23 was created.

Fortunately, the Federal Aviation Administration’s (FAA) Policy and Innovation Division’s Small Airplane Standards Branch (AIR-690), in the face of increasing requests to certify new aircraft with advanced technology, began the process of adjusting its practices to better accommodate new technology in certification efforts, the FAA certification office began initiatives such as the safety continuum concept, implementation of performance based regulations, reaching out within its organization to a much broader intra-agency collaboration, and the application of

[5] https://www.nasa.gov/aeroresearch/X-57/technical/index.html

risk based approach to safety analyses[6]. One of the most effective efforts that the certification service has used is an early engagement with industry (prior to application for a certificate, which is the traditional time when the industry meets with the FAA certification process). Further, the FAA certification office is continuing to re-examine the regulatory landscape, and is reviewing ways to comply with the regulations.

The FAA developed Amendment 23-64 to 14 CFR 23[7], which reflected a move to performance based rules with a Means of Compliance (MOC) within consensus standards, which is less tied to aircraft configuration, and enables flexible requirement development. This encourages industry innovation, and breaks the cycle of rule language falling behind technology. However, advanced configurations are rapidly emerging, and it is apparent that some gaps still exist in Part 23-64. The FAA Policy and Innovation Division's Small Airplane Standards Branch (AIR-690) established a team in mid-2017 to complete the gap analysis.

The scope of the FAA Future Aircraft Safety Team's (FAST) gap analysis was threefold: Aircraft that use fixed wings for horizontal flight and propulsion systems for vertical flight; Aircraft that are piloted by a person onboard; and Aircraft with the ability to fly away and-or land safely after critical power and-or thrust failures not extremely improbable. The FAST was made up of specialists from the Small Airplane Standards Branch; Rotorcraft Standards Branch; and Engine Propeller Standards Branch. The FAST strategy was three-phased: Small Airplane Standards; Small Airplane and Rotorcraft; and all three Standards from the three Branches.

The FAST used a series of questions as they developed the language of their gap analysis, such as: *Does the language accommodate a performance based philosophy? Does the language address all overall aircraft configurations? Does the language address all forms of propulsion? Are all anticipated flight characteristics accommodated? Have all anticipated structural considerations been reflected? Have all levels of systems complexity and interaction been reflected? Have all crew considerations been examined?* And finally: *Are there significant Part 27 (Normal Category Rotorcraft[8]) considerations?*

The following sections are organized by each of the Federal Aviation Regulation 23[9] subparts, and provide an overview of the detailed assessment shown in the "Proposed Compliance Matrix" (PCM). The ASTM MOCs[10] are shown for each, along with notes, as necessary.

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[6] This description of the FAA's initiatives are from a presentation made by the FAA at the ASTM F44 Committee meeting during the "Advanced Aircraft Technology Certification Workshop," 23 October 2018.

[7] 14 CFR 23, Amendment 23-64, Dated 30 Aug 2017 (https://www.ecfr.gov/cgi-bin/retrieveECFR?pitd=20170830&n=pt14.1.23)

[8] Part 27—Airworthiness Standards: Normal Category Rotorcraft, August 30, 2017, https://www.ecfr.gov/cgi-bin/text-idx?SID=d1bf1e3a146fffd61ba16f2dfa4a1e4b&pitd=20170830&tpl=/ecfrbrowse/Title14/14cfr27_main_02.tpl

[9] 14 CFR 23, Amendment 23-64, Dated 30 Aug 2017 (https://www.ecfr.gov/cgi-bin/retrieveECFR?pitd=20170830&n=pt14.1.23)

[10] Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA).

There were no issues with §23.1457 Cockpit voice recorders (CVR), §23.1459 Flight data recorders (FDR), or §23.1529 Instructions for continued airworthiness (ICA). As the X-57 is an experimental aircraft, there is no need for ICA. However, for the CVR and FDR, the mission control and data telemetry will more than accommodate any needs within the regulations.

4.1.1.Normal Category Airplanes, Subpart A, General

Revised §23.2000 with expanded applicability and definitions to account for unique powered lift characteristics. Details can be found in the PCM.

4.1.2.Normal Category Airplanes, Subpart B, Flight

Performance (§§23.2100-23.2130): Performance constitutes one of the key areas where vertical flight vehicles show their effect in FAR 23, with the incorporation of hight-lift capabilities into weight and center of gravity, performance data, stall speed, takeoff performance, climb requirements, climb information, and landing. The X-57, during Mod IV, conducts its flight test of the Distributed Electric Propulsion (DEP) system that will provide significant publicly available data to the community of the DEP regarding performance, stall speed (renamed “minimum safe speed” in the FAST white paper), takeoff performance, climb and landing.

Flight Characteristics (§§23.2135-§23.2165): Flight characteristics is also heavily affected by the FAST gap analysis. Controllability; trim; stability; stall characteristics, stall warning, and spins; ground and water handling characteristics; vibration, buffeting, and high-speed characteristics; and performance and flight characteristics requirements for flight in icing conditions are all addressed, with particular focus on controllability, stall characteristics, warning and spins, having significant opportunity for data from X-57 SCEPTOR during Mod IV. However, since the X-57 SCEPTOR is based on the Tecnam P2006T, and there are restrictions from operating in known icing conditions as part of its type certificate data sheet[11]. Accordingly, there will be no experience generated from the X-57 SCEPTOR regarding icing.

4.1.3.Normal Category Airplanes, Subpart C, Structures

For §23.2200 Structural design envelope, there were only minor edits from the FAST gap analysis to reflect the change from “stall speed” to “minimum safe speed,” as well as adding a reference to accommodate powered lift aircraft with engine-driven lifting devices. While this is typically associated with vertical flight concept vehicles, it will also be informed by the X-57 SCEPTOR.

Structural Loads (§§23.2210-23.2230): Structural loads is modestly affected by the FAST gap analysis. Some references are made to accommodate engine-driven lifting devices. As appropriate, data from the DEP Flight test during Mod IV, as well as battery installation and testing from Mod’s II and III, will be supplied to inform the regulations and ASTM MOCs.

[11] Type Certificate Data Sheet No. A62CE, Revision 5, Costruzioni Aeronautiche Tecnam srl, P2006T, October 17, 2017. http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/24e12213052297b9862581bf0052286a/$FILE/A62CE_Rev_5.pdf

Structural Performance (§§23.2235-23.2245): There are no changes from the FAST gap analysis for structural performance. As appropriate, data from the battery installation and testing from Mod's II and III, will be supplied to inform the regulations and ASTM MOCs.

Design (§§23.2250-23.2265): There are no changes from the FAST gap analysis for design. As appropriate, data from the battery installation and testing, as well as wing design, fabrication and testing from Mod's II and III, will be supplied to inform the regulations and ASTM MOCs.

Structural Occupant Protection (§§23.2270): There are no changes from the FAST gap analysis for emergency conditions. There is significant work established to ensure the safety of the flight research pilot for the X-57 for both structural occupant protection, as well as emergency conditions as part of the flight research activities in Mod's II, III and IV, and these will be supplied to inform the regulations and ASTM MOCs.

4.1.4. Normal Category Airplanes, Subpart D, Design & Construction

For §§23.2300-23.2310 (Flight control systems; Landing gear systems; and Buoyancy for seaplanes and amphibians), there are minor revisions to reflect harmonization and ensure that language reflects performance-based regulations. There was an addition that the flight control system design should include an indication when control authority is reduced from nominal to account for unique characteristics of electronic flight control systems. The control system for the X-57 SCEPTOR will provide unique insights to inform the regulations and ASTM MOCs.

Occupant System Design Protection (§§23.2315-23.2320): There are some revisions from the FAST gap analysis to reflect harmonization. That information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Fire and High Energy Protection (§§23.2325-23.2335): There are some revisions from the FAST gap analysis to reflect harmonization. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

4.1.5. Normal Category Airplanes, Subpart E, Powerplant

Powerplant installation (§23.2400): The FAST gap analysis revised §23.2400(b) to provide a path to concurrent aircraft and propulsion approval for Level 1-4 aircraft.

Automatic power or thrust control systems (§23.2405): The FAST gap analysis revised the title to "Power or thrust control systems" as well as (a), (b) and (c) to account for manual, automatic and reverse power and thrust controls systems in powered lift aircraft. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available. The X-57, during Mod IV, conducts its flight test of the Distributed Electric Propulsion (DEP) system that will provide significant publicly available data of benefit to regulations and MOCs.

Powerplant installation hazard assessment (§23.2410): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Powerplant ice protection (§23.2415): The FAST gap analysis made no revisions to this section. Since the X-57 SCEPTOR of benefit to regulations and MOCs will be made available. Since since the X-57 SCEPTOR is based on the Tecnam P2006T, and there are restrictions from operating in known icing conditions as part of its type certificate data sheet. Accordingly, there will be no experience generated from the X-57 SCEPTOR regarding powerplant icing protection.

Reversing systems (§23.2420): The FAST gap analysis recommended deleting this section, as it was incorporated in the revised 23.2405, Power or thrust control systems.

Powerplant operational characteristics (§23.2425): The FAST gap analysis: (1) revised §23.2425(b) to account for characteristics of the automatic distributed electric propulsion system on this aircraft; (2) revised §23.2430(a)(6) to include criteria from §27.952 to account for powered lift configurations; and (3) deleted §23.2430(b)(4) for consistency with §25, §27 and §29. The X-57, during Mod IV, conducts its flight test of the Distributed Electric Propulsion (DEP) system that will provide significant publicly available data of benefit to revisions reflected in (1) and (2), and MOCs.

Powerplant induction and exhaust systems (§23.2435): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit, such as the performance of the battery exhaust system, to regulations and MOCs will be made available.

Powerplant fire protection (§23.2440): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit, such as the battery containment system, to regulations and MOCs will be made available.

4.1.6.Normal Category Airplanes, F, Equipment

Airplane level systems requirements (§23.2500): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Function and installation (§23.2505): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Equipment, systems, and installations (§23.2510): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Electrical and electronic system lightning protection (§23.2515): The FAST gap analysis revised §23.2515 to account for configurations with electronic flight and propulsion control systems. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

High-intensity Radiated Fields (HIRF) protection (§23.2520): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit, such as the NASA Electric Aircraft Testbed (NEAT) electromagnetic interference tests, to regulations and MOCs will be made available.

System power generation, storage, and distribution (§23.2525): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit, such as the power architecture and integrated power and control specifications and tests, to regulations and MOCs will be made available.

External and cockpit lighting (§23.2530): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Safety equipment (§23.2535): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Flight in icing conditions (§23.2540): The FAST gap analysis revised §23.2540 to allow for future means of complying with flight in icing, and §23.2540(b) to reflect the change from stall speed to minimum flight speed. Since the X-57 SCEPTOR is based on the Tecnam P2006T, and there are restrictions from operating in known icing conditions as part of its type certificate data sheet. Accordingly, there will be no experience generated from the X-57 SCEPTOR regarding flight in icing protection.

Pressurized systems elements (§23.2545): The FAST gap analysis made no revisions to this section. The operational profile for the X-57 SCEPTOR precludes the requirement for pressurization. Accordingly, there will be no experience generated from the X-57 SCEPTOR regarding pressurized systems.

Equipment containing high-energy rotors (§23.2550): The FAST gap analysis deleted §23.2550 as its intent is covered in §23.2250(c) and for harmonization.

4.1.7.Normal Category Airplanes, G, Flightcrew Interface and Other Information

Flightcrew interface (§23.2600): The FAST gap analysis revised §23.2600(a) to reflect applicable modes and phases of flight, and §23.2600(b) to accommodate non-traditional pilot-aircraft interfaces; and deleted §23.2600(c) as it is better addressed by MOC. Information from the X-57 SCEPTOR of benefit, such as the simulation and flight test of displays, to regulations and MOCs will be made available.

Installation and operation (§23.2605): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit, such as the simulation and flight test of displays, to regulations and MOCs will be made available.

Instrument markings, control markings, and placards (§23.2610): The FAST gap analysis made no revisions to this section. Information from the X-57 SCEPTOR of benefit, such as the simulation and flight test of displays, to regulations and MOCs will be made available.

Flight, navigation, and powerplant instruments (§23.2615): The FAST gap analysis revised §23.2615(a) to reflect both phases and modes of flight, and revised §23.2615 (b)(2) to clarify applicability. Information from the X-57 SCEPTOR of benefit, such as the simulation and flight test of displays, as well as telemetered data, to regulations and MOCs will be made available.

Airplane flight manual (§23.2620): The FAST gap analysis revised §23.2620 to remove (b)(1) and (b)(2) which may be reflected in MOC. Information from the X-57 SCEPTOR of benefit, such as the operational procedures and performance to those procedures, to regulations and MOCs will be made available.

4.2. Summary of Aircraft Engines Regulations (FAR 33) and X-57

Installation of electric propulsion units, electrical storage systems and distributed electric propulsion were not envisioned when 14 CFR part 33 was created.

The aircraft engine regulations, Part 33—Airworthiness Standards: Aircraft Engines[12], was reviewed to examine how the X-57 SCEPTOR might contribute to the regulations and ASTM MOC. The review focused on FAR 33, Subpart A, General; Subpart B, Design and Construction-General; Subpart C, Design and Construction-Reciprocating Aircraft Engines; and Subpart D, Block Tests-Reciprocating Aircraft Engines.

The X-57 SCEPTOR Power and Command Integrated Product Team produced a report, "Electric Cruise Motor Testing Standards,"[13] the purpose of which was to provide testing insight for the X-57 Maxwell SCEPTOR regarding the Cruise Motor Test and any applicable aircraft engine testing requirements under the Federal Aviation Regulations (FAR) Part 33. The requirements were used as guidelines and not stringent requirements. However, as part of the X-57 Maxwell testing, new aircraft electric motor testing standards are likely to be developed. Therefore, a thorough examination of the current testing requirements will help shape the new aircraft electric motor testing regulations in the future. A matrix of proposed test methods was proposed and tabulated against the FAR 33. These items are identified in the PCM and reflected below.

A cursory review of the turbine aircraft engine Subpart E, Design and Construction-Turbine Aircraft Engines; and Subpart F, Block Tests-Turbine Aircraft Engines, revealed that to a first-order, few of the sections would be informed by the X-57 SCEPTOR technology. The sections of FAR 33, subpart E, Design and Construction-Turbine Aircraft Engines, such as §33.62, Stress analysis; §33.63, Vibration; §33.70, Engine life-limited parts; §33.71, Lubrication system; §33.73, Power or thrust response; §33.74, Continued rotation; and §33.75, Safety analysis, may benefit from the X-57 SCEPTOR technology demonstration. The sections of FAR 33, subpart F, Block Tests for Turbine Aircraft Engines, such as §33.83, Vibration test; §33.85, Calibration tests; §33.87, Endurance test; §33.89, Operation test; §33.90, Initial maintenance inspection test; §33.91, Engine system and component tests; and §33.95, Engine-propeller systems tests may benefit from the X-57 SCEPTOR technology demonstration. But the benefit assessment for both of those subparts is for a subsequent report.

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[12] 14 CFR 33, General, Design and Reciprocating Aircraft Engines, Dated 3 October 2018, (https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt14.1.33)

[13] "Electric Cruise Motor Testing Standards: FAR-Part 33: Airworthiness Standards: Aircraft Engines, Selected sections pertaining to an electric aircraft motor," NASA AFRC, 10/20/2016.

The Means of Compliance (MOC) for Electric Propulsion Units (EPU) was developed under ASTM Committee F39.05 and is a draft standard "Design of Electric Propulsion Units for General Aviation Aircraft"[14]. It is intended to contain both the regulatory and standards language, and as it evolves, the regulatory language will be excerpted for use by the FAA, and the remaining language will contain the pure standard language.

4.2.1.Aircraft Engines, Subpart A—General

Applicability (§33.1): Applicable uncharged.

General (§33.3): Applicable uncharged.

Instructions for Continued Airworthiness (§33.4): The MOC in the draft WK47374, §5.1 are applicable.

Instruction manual for installing and operating the engine (§33.5): The MOC in the draft WK47374, §5.2 are applicable. Information from the X-57 SCEPTOR of benefit, such as the power architecture and integrated power and control specifications, to regulations and MOCs will be made available.

Engine ratings and operating limitations (§33.7): The MOC in the draft WK47374, §5.3 are applicable. Information from the X-57 SCEPTOR of benefit, such as the electric motor ratings and operating limitations (identified in the ORD, for example), to regulations and MOCs will be made available.

Selection of engine power and thrust ratings (§33.8): The MOC in the draft WK47374, §5.3, in particular §5.3.3, *et sequa*, are applicable. Information from the X-57 SCEPTOR of benefit, such as the electric motor ratings and operating limitations (identified in the ORD, for example), to regulations and MOCs will be made available.

4.2.2.Aircraft Engines, Subpart B—Design and Construction

Applicability (§33.11): Applicable uncharged.

Materials (§33.15): The MOC in the draft WK47374, §5.5 are applicable. Information from the X-57 SCEPTOR of benefit, such as the electric motor materials, to regulations and MOCs will be made available.

Fire protection (§33.17): The MOC in the draft WK47374, §5.6 are applicable. Information from the X-57 SCEPTOR of benefit, such as the battery containment, to regulations and MOCs will be made available.

Durability (§33.19): The MOC in the draft WK47374, §5.7 are applicable. Information from the X-57 SCEPTOR of benefit, such as a durability test on the Airvolt, to regulations and MOCs will be made available.

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[14] ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)

Engine cooling (§33.21): The MOC in the draft WK47374, §5.8 are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Engine mounting attachments and structure (§33.23): The MOC in the draft WK47374, §5.8 are applicable. Information from the X-57 SCEPTOR of benefit, such as wingtip mounting of the engines, to regulations and MOCs will be made available.

Accessory attachments (§33.25): Applicable uncharged.

Turbine, compressor, fan, and turbosupercharger rotor overspeed (§33.27): The MOC in the draft WK47374, §5.9 are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Engine control systems (§33.28): The MOC in the draft WK47374, §5.10 are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Instrument connection (§33.29): The MOC in the draft WK47374, §5.11 are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

4.2.3.Aircraft Engines, Subpart C—Design and Construction; Reciprocating Aircraft Engines

Applicability (§33.31): Applicable uncharged.

Vibration (§33.33): The MOC in the draft WK47374, §5.12 are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Turbocharger rotors (§33.34): Not applicable.

Fuel and induction system (§33.35): Not applicable. *(This may be an area where energy storage system and distribution may be a consideration.)*

Ignition system (§33.37): Not applicable.

Lubrication system (§33.39): The MOC in the draft WK47374, §5.16 are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

4.2.4.Aircraft Engines, Subpart D—Block Tests; Reciprocating Aircraft Engines

Applicability (§33.41): Applicable uncharged.

General (§33.42): Applicable uncharged.

Vibration test (§33.43): The MOC in the draft WK47374, §5.20.3, Vibration test are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Calibration tests (§33.45): The MOC in the draft WK47374, §5.20.6, calibration test are applicable. Information from the X-57 SCEPTOR of benefit to regulations and MOCs will be made available.

Detonation test (§33.47): Not applicable.

Endurance test (§33.49): The MOC in the draft WK47473, §§5.20.2, Endurance and durability test are applicable. Information from the X-57 SCEPTOR durability test plan, and subsequent test data of benefit to regulations and MOCs will be provided.

Operation test (§33.51): The MOC in the draft WK47473, §§5.20.7, Operation test are applicable. Information from the X-57 SCEPTOR electric cruise motor test plan, and subsequent test data of benefit to regulations and MOCs will be provided.

Engine system and component tests (§33.53): The MOC in the draft WK47473, §§5.20.XXXX, YYYY test are applicable. Information from the X-57 SCEPTOR electric cruise motor test plan, and subsequent test data of benefit to regulations and MOCs will be provided.

Teardown inspection (§33.55): The MOC in the draft WK47473, §§5.22, Teardown inspection are applicable. Information from the X-57 SCEPTOR electric cruise motor test plan, and subsequent test data of benefit to regulations and MOCs will be provided.

General conduct of block tests (§33.57):

4.2.5.Aircraft Engines, Subpart F-Block Tests; Turbine Aircraft Engines

Engine overtorque test (§33.84): When approval is sought for a transient maximum EPU overtorque, the turbine engine section is appropriate, and the draft WK47374 §5.20.4 is applicable. This test will become part of endurance test procedures (WK47374, §5.20.3) if elected to be pursued. Results from the X-57 SCEPTOR endurance test as planned in “Propulsion Systems Acceptance Testing on Airvolt” will be provided as available.

Engine overtemperature test (§33.88): When approval is sought for an EPU overtemperature, the turbine engine section is appropriate, and the draft WK47374 §5.20.5 is applicable. This test will become part of endurance test procedures (WK47374, §5.20.3) if elected to be pursued. Results from the X-57 SCEPTOR endurance test as planned in “Propulsion Systems Acceptance Testing on Airvolt” will be provided as available.

4.3. Summary of Propellers Regulations (FAR 35) and X-57

Installation of electric propulsion units, electrical storage systems and distributed electric propulsion were not envisioned when 14 CFR part 33 was created.

The X-57 SCEPTOR is based on a Tecnam P2006T, and while the wing and motors have been modified, the propeller is the same propeller as approved in the Type Certificate Data Sheet, which are two MT Propeller MTV-21. The data derived from the X-57 SCEPTOR will baseline performance during Mod I and II, and during Mods III and IV will be evaluated with the electric power unit.

In addition to the “tractor motor” propellers (those used for cruise flight), the X-57 SCEPTOR has propellers designed for the Distributed Electric Propulsion demonstrations and are only used for take-off and landing, and stowed in flight. This presents a unique opportunity to inform FAR 35 with a high-lift device technology.

The regulations for FAR 35, Airworthiness Standards: Propellers[15] will be reviewed by subpart.

4.3.1.Propellers, Subpart A—General

Applicability (§35.1): Applicable uncharged.

Propeller configuration (§35.2): Applicable uncharged.

Instructions for propeller installation and operation (§35.3): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

Instructions for Continued Airworthiness (§35.4): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

Propeller ratings and operating limitations (§35.5): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

Features and characteristics (§35.7): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

4.3.2.Propellers, Subpart B—Design and Construction

Safety analysis (§35.15): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

Propeller critical parts (§35.16): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

Materials and manufacturing methods (§35.17): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

Durability (§35.19): Applicable uncharged for cruise motor propellers. Will provide unique DEP propeller data.

Variable and reversible pitch propellers (§35.21): XXXXX

Feathering propellers (§35.22): Applicable unchanged for MTV-21. Will provide unique DEP propeller data.

Propeller control system (§35.23): Applicable unchanged for MTV-21. Will provide unique DEP propeller data.

Strength (§35.24): Applicable unchanged for MTV-21. Will provide unique DEP propeller data.

4.3.3.Propellers, Subpart C—Tests and Inspections

General (§35.33): Applicable unchanged for MTV-21. Will provide unique DEP propeller data.

[15] 14 CFR 35, Dated 3 October 2018, (https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt14.1.35)

Inspections, adjustments and repairs (§35.34): Applicable unchanged for MTV-21. Will provide unique DEP propeller data.

Centrifugal load tests (§35.35): Applicable unchanged for MTV-21. Will provide unique DEP propeller data.

Bird impact (§35.36): No tests conducted.

Fatigue limits and evaluation (§35.37): Applicable unchanged for MTV-21. Will provide unique DEP propeller data.

Lightning strike (§35.38): No tests conducted.

Endurance test (§35.39): Tested with the MTV-21 attached during Airvolt electric motor durability tests.

Functional test (§35.40): No tests conducted with electric motor.

Overspeed and overtorque (§35.41): Tested as part of the overspeed and overtorque electric motor tests.

Components of the propeller control system (§35.42): No specific test conducted.

Propeller hydraulic components (§35.43): No specific test conducted.

4.4. Accounting for Electric Storage Systems in the FAR and X-57

Currently there is no reference for Electric Storage Systems (ESS, such as batteries in the case of the X-57 SCEPTOR) within the Federal Aviation Regulations. The approach is to fit ESS certification within references to fuel and-or fuel systems within FAR 23 and 33. The current means of compliance for ESS is the ASTM Committee F39.05 under the draft WK56255[16]. This draft standard is, as of this report, in flux.

There are five germane section within the current draft of WK56255. Those are: §6. Data requirements; §7. Design criteria; §8. Performance; §9. Safety requirements; and §10. Testing and qualification requirements.

The X-57 SCEPTOR program has extensive design and test data that will be provided to the ASTM committee during Mod II, as well as Mod III and IV.

5. Conclusion

None of the Federal Aviation Regulations envisioned electric propulsion when the regulations were promulgated. Further, most of the technology for spark ignition reciprocating engines had been innovated decades ago, so that subsequent certifications of newer reciprocating engines had an heritage, along with legacy means of compliance so that certification was clear-cut.

[16] ASTM F39.05, WK56255, Design of Electric Propulsion Energy Storage Systems for General Aviation Aircraft, DRAFT STANDARD, Dated 21 May 2018, "WK56255-6.docx", (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/WK56255-6.docx)

Recent technology innovations in vehicle concepts and the technology that support the vehicles have pushed the limits of their ability to be certified. The FAA's recent response to that challenge with its regulation by objective, supported by the update of FAR 23 to amendment 23-64 show a remarkable intent to adapt to the technology challenge. In particular, the ASTM committees to develop standards that support these standards are laudable.

Accordingly, there can now be made a clear mapping between the regulations and certification criteria and the X-57 SCEPTOR program. The results of planning and tests from the program is able to address still-open questions and challenges in the development of the means of compliance to the ASTM standards, as well as gaps between the existing regulations and the new vehicles that are pushing innovative technologies.

This report describes a generic method for addressing any new technology to its associated set of regulations and certification criteria. The result is a framework under which a detailed assessment can be conducted.

Using just such a framework, the report maps the detailed updated regulations and evolving ASTM standards to the particular technology planning and tests.

As a result, a roadmap of NASA technology is documented that shows clear transfer of technology data to industry (standards developers, as well as technology developers) and the FAA regulatory policy and certification staff upon whom certification and policy will be data-driven.

The framework also revealed the significant contributions that NASA X-57 SCEPTOR will make to the industry and regulatory-standards community: Distributed Electric Propulsion technology demonstration will directly affect most of the revision in the FAST Gap Analysis and provides a foundation for eVTOL technology; and the cruise motor contributes directly to WK47374 MOC.

It is important to note that the means by which the NASA X-57 SCEPTOR project contributes to the industry and regulators is through the active participation in the specific technical subcommittees of the ASTM Committee F44 on General Aviation Aircraft and Committee F39 on Aircraft Systems. Through this participation, the knowledge of the NASA X-57 SCEPTOR will make immediate and lasting contributions to the industry and regulators.

In addition to identifying contributions, the framework also exposed gaps in the technology program to standards community needs, such as the effect of icing on EPU operation.

The framework highlighted a need for some form of regulatory references for Electric Storage System regulations. While this may begin with the use of a Special Condition, and after sufficient applications and a recognized need for such, potentially the regulators may consider a regulation.

The framework identified some regulations in need of revision. For example, FAR 33.47, Detonation test, is only applicable to spark ignition, reciprocating engines, and is not applicable to electric propulsion units. Another regulation, FAR 33.49, Endurance test, Reciprocating Aircraft Engines (and, perhaps, FAR 33.87, Endurance test, Turbine Aircraft

Engines), requires some fundamental reexamination, as to its test objectives and subsequent methods, practices and means of testing.

Further, the unique approach to high-lift in the X-57 SCEPTOR project of Distributed Electric Propulsion, and in particular, the use of folding-blade propellers on the smaller motors, has no reference in FAR 33, Aircraft Engines, or FAR 35, Propellers. And while the European Aviation Safety Agency has certified a number of gliders with folding propellers, there does not appear to be any references in their regulation CS-P (equivalent to FAR 33). In this case, The NASA requirements, specifications and technical reports must contribute to the technical subcommittees in ASTM Committee F44 on General Aviation Aircraft and Committee F39 on Aircraft Systems, which are focusing on Distributed Electric Propulsion, and provide these technical subcommittees with the NASA data.

Future work should include the development of new standards and means of compliance based on the new insights from the NASA X-57 SCEPTOR flight project. Planning for and contributing to the ASTM standards process must become a key objective of the project.

Additional work should be considered to streamline the collection of the data used to implement the results of this report. Application of a formal Model-Based Systems Engineering techniques will make the application of the approach used in this report much more agile to future projects, and would provide the means to assess trades of standards versus technology versus regulatory approach, much more agile, while maintaining the integrity of the approach described in this report.

Further, this approach described within this report should be applied to future NASA projects. The concept of NASA playing a key role, not only to industry, but also to the development of new standards and the application of those new standards to the evolution of regulatory material, should be a significant consideration in the decision-making of a new project.

Appendix A, The "Proposed Compliance Matrix" (PCM) Deconstructed

The following tables reflect the Proposed Compliance Matrix, PCM, for each of the Federal Aviation Regulations, and shows the paragraph-level reference from the FAR, any notes, an assessment of the applicability to electric propulsion (unchanged, tailored or revised, from Figure 5, in section 2.2), a reference to the current Means of Compliance referencing an ASTM standard (or draft standard, as applicable), and, finally an entry reflecting the source of X-57 SCEPTOR Mod I, II, III or IV reference.

Table A-1 shows the PCM for FAR 23, while A-2 reflects FAR 33 and A-3 shows FAR 35.

Table A-1, Proposed Compliance Matrix (PCM) for 14 CFR 23 as Test Matrix for X-57

Subpart	Section	Note	FAA Future Advanced Safety Team (FAST) Gap Analysis to New Technology and FAR 23 ("FAST language recommendation rev0.docx", email from NASA to HSAC, dated 11 Sep 2018)	Associated FAST Footnote	Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA)	Citation of the Means of Compliance in relevant ASTM Standard, Combined with Changes as Noted in {braces} from FAA NOA	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
14 CFR 23, Amendment 23-64, Dated 30 Aug 2017 (https://www.ecfr.gov/cgi-bin/retrieveECFR?pitd=20170830&n=pt14.1.23)											
	§23.1457 Cockpit voice recorders.				ASTM F3264-17, section 9.12	9.12 Installation of Cockpit Recorders: 9.12.1 F3061/ F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.12.1.1 F3228 – 17 Standard Specification for Flight Data and Voice Recording in Small Aircraft	UNCHANGED	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry
		(a) Each cockpit voice recorder required by the operating rules of this chapter must be approved and must be installed so that it will record the following: ¶ (1) Voice communications transmitted from or received in the airplane by radio. ¶ (2) Voice communications of flightcrew members on the flight deck. ¶ (3) Voice communications of flightcrew members on the flight deck, using the airplane's interphone system. ¶ (4) Voice or audio signals identifying navigation or approach aids introduced into a headset or speaker. ¶ (5) Voice communications of flightcrew members using the passenger loudspeaker system, if there is such a system and if the fourth channel is available in accordance with the requirements of paragraph (c)(4)(ii) of this section. ¶ (6) If datalink communication equipment is installed, all datalink communications, using an approved data message set. Datalink messages must be recorded as the output signal from the communications unit that translates the signal into usable data.					UNCHANGED				
		(b) The recording requirements of paragraph (a)(2) of this section must be met by installing a cockpit-mounted area microphone, located in the best position for recording voice communications originating at the first and second pilot stations and voice communications of other crewmembers on the flight deck when directed to those stations. The microphone must be so located and, if necessary, the preamplifiers and filters of the recorder must be so adjusted or supplemented, so that the intelligibility of the recorded communications is as high as practicable when recorded under flight cockpit noise conditions and played back. Repeated aural or visual playback of the record may be used in evaluating intelligibility.					UNCHANGED				
		(c) Each cockpit voice recorder must be installed so that the part of the communication or audio signals specified in paragraph (a) of this section obtained from each of the following sources is recorded on a separate channel: ¶ (1) For the first channel, from each boom, mask, or handheld microphone, headset, or speaker used at the first pilot station. ¶ (2) For the second channel from each boom, mask, or handheld microphone, headset, or speaker used at the second pilot station. ¶ (3) For the third channel—from the cockpit-mounted area microphone. ¶ (4) For the fourth channel from: ¶ (i) Each boom, mask, or handheld microphone, headset, or speaker used at the station for the third and fourth crewmembers. ¶ (ii) If the stations specified in paragraph (c)(4)(i) of this section are not required or if the signal at such a station is picked up by another channel, each microphone on the flight deck that is used with the passenger loudspeaker system, if its signals are not picked up by another channel. ¶ (5) And that as far as is practicable all sounds received by the microphone listed in paragraphs (c)(1), (2), and (4) of this section must be recorded without interruption irrespective of the position of the interphone-transmitter key switch. The design shall ensure that sidetone for the flightcrew is produced only when the interphone, public address system, or radio transmitters are in use.					UNCHANGED				
		(d) Each cockpit voice recorder must be installed so that: ¶ (1) ¶ (i) It receives its electrical power from the bus that provides the maximum reliability for operation of the cockpit voice recorder without jeopardizing service to essential or emergency loads. ¶ (ii) It remains powered for as long as possible without jeopardizing emergency operation of the airplane. ¶ (2) There is an automatic means to simultaneously stop the recorder and prevent each erasure feature from functioning, within 10 minutes after crash impact. ¶ (3) There is an aural or visual means for preflight checking of the recorder for proper operation. ¶ (4) Any single electrical failure external to the recorder does not disable both the cockpit voice recorder and the flight data recorder. ¶ (5) It has an independent power source— ¶ (i) That provides 10 ±1 minutes of electrical power to operate both the cockpit voice recorder and cockpit-mounted area microphone; ¶ (ii) That is located as close as practicable to the cockpit voice recorder; and ¶ (iii) To which the cockpit voice recorder and cockpit-mounted area microphone are switched automatically in the event that all other power to the cockpit voice recorder is interrupted either by normal shutdown or by any other loss of power to the electrical power bus. ¶ (6) It is in a separate container from the flight data recorder when both are required. If used to comply with only the cockpit voice recorder requirements, a combination unit may be installed.					UNCHANGED				

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		(e) The recorder container must be located and mounted to minimize the probability of rupture of the container as a result of crash impact and consequent heat damage to the recorder from fire. ¶ (1) Except as provided in paragraph (e)(2) of this section, the recorder container must be located as far aft as practicable, but need not be outside of the pressurized compartment, and may not be located where aft-mounted engines may crush the container during impact. ¶ (2) If two separate combination digital flight data recorder and cockpit voice recorder units are installed instead of one cockpit voice recorder and one digital flight data recorder, the combination unit that is installed to comply with the cockpit voice recorder requirements may be located near the cockpit.					UNCHANGED				
		(f) If the cockpit voice recorder has a bulk erasure device, the installation must be designed to minimize the probability of inadvertent operation and actuation of the device during crash impact.					UNCHANGED				
		(g) Each recorder container must— ¶ (1) Be either bright orange or bright yellow; ¶ (2) Have reflective tape affixed to its external surface to facilitate its location under water; and ¶ (3) Have an underwater locating device, when required by the operating rules of this chapter, on or adjacent to the container, which is secured in such manner that they are not likely to be separated during crash impact.					UNCHANGED				
	§23.1459 Flight data recorders.				ASTM F3264-17, section 9.13	9.13 Installation of Flight Data Recorders: 9.13.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.13.1.1 F3228 – 17 Standard Specification for Flight Data and Voice Recording in Small Aircraft	UNCHANGED	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry	ORD §§7.3, 7.4 and 9.10, accommodated w/i the experimental data and voice telemetry
		(a) Each flight recorder required by the operating rules of this chapter must be installed so that— ¶ (1) It is supplied with airspeed, altitude, and directional data obtained from sources that meet the aircraft level system requirements and the functionality specified in §23.2500; ¶ (2) The vertical acceleration sensor is rigidly attached, and located longitudinally either within the approved center of gravity limits of the airplane, or at a distance forward or aft of these limits that does not exceed 25 percent of the airplane's mean aerodynamic chord; ¶ (3)(i) It receives its electrical power from the bus that provides the maximum reliability for operation of the flight data recorder without jeopardizing service to essential or emergency loads; ¶ (ii) It remains powered for as long as possible without jeopardizing emergency operation of the airplane; ¶ (4) There is an aural or visual means for preflight checking of the recorder for proper recording of data in the storage medium; ¶ (5) Except for recorders powered solely by the engine-driven electrical generator system, there is an automatic means to simultaneously stop a recorder that has a data erasure feature and prevent each erasure feature from functioning, within 10 minutes after crash impact; ¶ (6) Any single electrical failure external to the recorder does not disable both the cockpit voice recorder and the flight data recorder; and ¶ (7) It is in a separate container from the cockpit voice recorder when both are required. If used to comply with only the flight data recorder requirements, a combination unit may be installed. If a combination unit is installed as a cockpit voice recorder to comply with §23.1457(e)(2), a combination unit must be used to comply with this flight data recorder requirement.					UNCHANGED				
		(b) Each non-ejectable record container must be located and mounted so as to minimize the probability of container rupture resulting from crash impact and subsequent damage to the record from fire. In meeting this requirement, the record container must be located as far aft as practicable, but need not be aft of the pressurized compartment, and may not be where aft-mounted engines may crush the container upon impact.					UNCHANGED				
		(c) A correlation must be established between the flight recorder readings of airspeed, altitude, and heading and the corresponding readings (taking into account correction factors) of the first pilot's instruments. The correlation must cover the airspeed range over which the airplane is to be operated, the range of altitude to which the airplane is limited, and 360 degrees of heading. Correlation may be established on the ground as appropriate.					UNCHANGED				
		(d) Each recorder container must— ¶ (1) Be either bright orange or bright yellow; ¶ (2) Have reflective tape affixed to its external surface to facilitate its location under water; and ¶ (3) Have an underwater locating device, when required by the operating rules of this chapter, on or adjacent to the container, which is secured in such a manner that they are not likely to be separated during crash impact.					UNCHANGED				
		(e) Any novel or unique design or operational characteristics of the aircraft shall be evaluated to determine if any dedicated parameters must be recorded on flight recorders in addition to or in place of existing requirements.					UNCHANGED				
	§23.1529 Instructions for continued airworthiness.				ASTM F3264-17, section 10.6	10.6 Instructions for Continued Airworthiness: 10.6.1 F3120/F3120M – 15 Standard Specification for Ice Protection for General Aviation ¶ 10.6.2 F3117 – 15 Standard Specification for Crew Interface in Aircraft	UNCHANGED	Not captured for experimental aircraft	Not captured for experimental aircraft	Not captured for experimental aircraft	Not captured for experimental aircraft

Subpart	Section	Note	FAA Future Advanced Safety Team (FAST) Gap Analysis to New Technology and FAR 23 ("FAST language recommendation rev0.docx", email from NASA to HSAC, dated 11 Sep 2018)	Associated FAST Footnote	Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA)	Citation of the Means of Compliance in relevant ASTM Standard, Combined with Changes as Noted in {braces} from FAA NOA	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
		The applicant must prepare Instructions for Continued Airworthiness, in accordance with appendix A of this part, that are acceptable to the Administrator. The instructions may be incomplete at type certification if a program exists to ensure their completion prior to delivery of the first airplane or issuance of a standard certificate of airworthiness, whichever occurs later.					UNCHANGED				
FAR 23, Airworthiness Standards: Normal Category Airplanes, Subpart A, General											
	§ 23.2000 Applicability and definitions.	(a) This part prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for airplanes in the normal category.	(a) This part prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for airplanes [, including those with vertical takeoff and landing capability,] (F1) in the normal category.	(F1)–Revised §23.2000 with expanded applicability and definitions to account for unique powered lift characteristics.			REVISED				ORD §§3.3, 4.1.5, DEP Flight Testing; ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; TP-CEPT-004, High Lift Motor Controller Test Plan; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) For the purposes of this part, the following definition applies: Continued safe flight and landing means an airplane is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some airplane damage may occur as a result of a failure condition.	(b) For the purposes of this part, the following definitions apply: ¶ (1) Continued safe flight and landing means an airplane is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some airplane damage may occur as a result of a failure condition. ¶ [(2) Modes of Flight – There are three modes of flight: Vertical, Transition, and Forward flight. Vertical mode is defined as when the vehicle is maneuvering in the vertical plane and lift is predominately from thrust. Forward flight mode is defined as when the vehicle is maneuvering in the horizontal plane and lift is predominately from fixed surfaces. Transition mode is the combination of Vertical and Forward flight modes where both forms of lift are being used. ¶ (3) Phases of Flight – These include ground operations, takeoff, climb, cruise, descent, hover, and landing.] ¶ (4) CONOPS – Concept of Operations.] (F1)	(F1)–Revised §23.2000 with expanded applicability and definitions to account for unique powered lift characteristics.			REVISED				ORD §§3.3, 4.1.5, DEP Flight Testing; ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; TP-CEPT-004, High Lift Motor Controller Test Plan; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
	§23.2005 Certification of normal category airplanes.	(a) Certification in the normal category applies to airplanes with a passenger-seating configuration of 19 or less and a maximum certificated takeoff weight of 19,000 pounds or less.	NO CHANGE				UNCHANGED				
		(b) Airplane certification levels are: (1) Level 1—for airplanes with a maximum seating configuration of 0 to 1 passengers. ¶ (2) Level 2—for airplanes with a maximum seating configuration of 2 to 6 passengers. ¶ (3) Level 3—for airplanes with a maximum seating configuration of 7 to 9 passengers. ¶ (4) Level 4—for airplanes with a maximum seating configuration of 10 to 19 passengers.	NO CHANGE				UNCHANGED				
		(c) Airplane performance levels are: (1) Low speed—for airplanes with a VNO and VMO ≤ 250 Knots Calibrated Airspeed (KCAS) and a MMO ≤ 0.6. ¶ (2) High speed—for airplanes with a VNO or VMO > 250 KCAS or a MMO > 0.6.	NO CHANGE				UNCHANGED				
		(d) Airplanes not certified for aerobatics may be used to perform any maneuver incident to normal flying, including— (1) Stalls (except whip stalls); and (2) Lazy eights, chandelles, and steep turns, in which the angle of bank is not more than 60 degrees.	NO CHANGE				UNCHANGED				
		(e) Airplanes certified for aerobatics may be used to perform maneuvers without limitations, other than those limitations established under subpart G of this part.	NO CHANGE				UNCHANGED				
			[(f) If there is any combination of height above ground and forward speed (including hover) under which a safe landing cannot be made under the applicable power failure condition, certification must be under parts 27 or 29.] (F2)	(F2)–Added §23.2005 (f) to clarify limitations on use of this part.			TAILORED				
	§23.2010 Accepted means of compliance.	(a) An applicant must comply with this part using a means of compliance, which may include consensus standards, accepted by the Administrator.	NO CHANGE				UNCHANGED				
		(b) An applicant requesting acceptance of a means of compliance must provide the means of compliance to the FAA in a form and manner acceptable to the Administrator.	NO CHANGE				UNCHANGED				
FAR 23, Airworthiness Standards: Normal Category Airplanes, Subpart B, Flight											
Performance											
	§23.2100 Weight and center of gravity.	(a) The applicant must determine limits for weights and centers of gravity that provide for the safe operation of the airplane.	NO CHANGE		ASTM F3264-17, section 5.1	5.1 Weight/Mass and Centre of Gravity: 5.1.1 F3082/ F3082M – 17 Standard Specification for Weights and Center of Gravity of Aircraft ¶ 5.1.2 F3114 – 15 Standard Specification for Structures	UNCHANGED				
		(b) The applicant must comply with each requirement of this subpart at critical combinations of weight and center of gravity within the airplane's range of loading conditions using tolerances acceptable to the Administrator.	[(b) The applicant must comply with each requirement of this subpart at critical combinations of weight and center of gravity within the airplane's range of loading conditions.] (F3)	(F3)–Revised §23.2100 (b) for harmonization.			REVISED	PROC-CEPT-003 Phase I Weighing Procedure	PROC-CEPT-003 Phase I Weighing Procedure		
		(c) The condition of the airplane at the time of determining its empty weight and center of gravity must be well defined and easily repeatable.	NO CHANGE				UNCHANGED				
	§23.2105 Performance data.	(a) Unless otherwise prescribed, an airplane must meet the performance requirements of this subpart in — (1) Still air and standard atmospheric conditions at sea level for all airplanes; and (2) Ambient atmospheric conditions within the operating envelope for levels 1 and 2 high-speed and levels 3 and 4 airplanes.	NO CHANGE		ASTM F3264-17, section 5.2	5.2 Performance Data: 5.2.1 F3179/F3179M – 16 Standard Specification for Performance of Aeroplanes	UNCHANGED				

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		(b) Unless otherwise prescribed, the applicant must develop the performance data required by this subpart for the following conditions: (1) Airport altitudes from sea level to 10,000 feet (3,048 meters); and (2) Temperatures above and below standard day temperature that are within the range of operating limitations, if those temperatures could have a negative effect on performance.	NO CHANGE				UNCHANGED				
		(c) The procedures used for determining takeoff and landing distances must be executable consistently by pilots of average skill in atmospheric conditions expected to be encountered in service.	NO CHANGE				UNCHANGED				
		(d) Performance data determined in accordance with paragraph (b) of this section must account for losses due to atmospheric conditions, cooling needs, and other demands on power sources.	NO CHANGE				UNCHANGED				
			[(e) The hovering ceiling must be determined over the ranges of weight, altitude, and temperature, if applicable.] (F4)	(F4)–Revised §23.2105 to account for unique powered lift characteristics.			REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; TP-CEPT-004, High Lift Motor Controller Test Plan; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
	§23.2110 Stall speed.	The applicant must determine the airplane stall speed or the minimum steady flight speed for each flight configuration used in normal operations, including takeoff, climb, cruise, descent, approach, and landing. The stall speed or minimum steady flight speed determination must account for the most adverse conditions for each flight configuration with power set at—	FAST 23.2110 [Minimum safe speed] (F5) The applicant must determine the airplane [minimum safe speed] (F5) for each flight configuration used in normal operations, including [applicable modes and phases of flight] (F5). The [minimum safe speed] (F5) determination must account for the most adverse conditions for each flight configuration.	(F5)–Changed title from "Stall speed" to "Minimum safe speed" to better reflect the characteristics of powered lift configurations. Added reference to modes and phases of flight. Removed §23.2110 (a) and (b) per recommendation to reflect in MOC as needed.	ASTM F3264-17, section 5.3	5.3 Stall Speed: 5.3.1 F3179/F3179M – 16 Standard Specification for Performance of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; TP-CEPT-004, High Lift Motor Controller Test Plan; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(a) Idle or zero thrust for propulsion systems that are used primarily for thrust; and	REMOVED				REMOVED				
		(b) A nominal thrust for propulsion systems that are used for thrust, flight control, and/or high-lift systems.	REMOVED				REMOVED				
	§23.2115 Takeoff performance.	(a) The applicant must determine airplane takeoff performance accounting for— (1) Stall speed safety margins; (2) Minimum control speeds; and (3) Climb gradients.	[The applicant must determine takeoff performance accounting for flight envelope and obstacle safety margins. Airplanes designed for continued flight after a critical loss of thrust must determine takeoff performance and account for performance after the loss of thrust.] (F6)	(F6)–Revised §23.2115 (a) to account for powered lift configurations and their characteristics. Removed §23.2115 (b) and (c) and reflect in MOC if needed. These criteria are too prescriptive for this configuration.	ASTM F3264-17, section 5.4	5.4 Takeoff Performance: 5.4.1 F3179/F3179M – 16 Standard Specification for Performance of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) For single engine airplanes and levels 1, 2, and 3 low-speed multiengine airplanes, takeoff performance includes the determination of ground roll and initial climb distance to 50 feet (15 meters) above the takeoff surface.	REMOVED				REMOVED				
		(c) For levels 1, 2, and 3 high-speed multiengine airplanes, and level 4 multiengine airplanes, takeoff performance includes a determination the following distances after a sudden critical loss of thrust— (1) An aborted takeoff at critical speed; (2) Ground roll and initial climb to 35 feet (11 meters) above the takeoff surface; and (3) Net takeoff flight path.	REMOVED				REMOVED				
	§23.2120 Climb requirements.	The design must comply with the following minimum climb performance out of ground effect: (a) With all engines operating and in the initial climb configuration — (1) For levels 1 and 2 low-speed airplanes, a climb gradient of 8.3 percent for landplanes and 6.7 percent for seaplanes and amphibians; and (2) For levels 1 and 2 high-speed airplanes, all level 3 airplanes, and level 4 single-engines a climb gradient after takeoff of 4 percent.	[The applicant must demonstrate minimum climb performance at each weight, altitude, and ambient temperature within the operating limitations using the procedures published in the flight manual. Airplanes designed for continued flight after a critical loss of thrust must determine climb performance and account for performance after the loss of thrust.] (F7)	(F7)–Revised §23.2120 (a) to account for powered lift configurations and their characteristics. Removed §23.2120 (b) and (c) and reflect in MOC if needed. These criteria are too prescriptive for this configuration.	ASTM F3264-17, section 5.5	5.5 Climb Requirements: 5.5.1 F3179/F3179M – 16 Standard Specification for Performance of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) After a critical loss of thrust on multiengine airplanes— (1) For levels 1 and 2 low-speed airplanes that do not meet single-engine crashworthiness requirements, a climb gradient of 1.5 percent at a pressure altitude of 5,000 feet (1,524 meters) in the cruise configuration(s); (2) For levels 1 and 2 high-speed airplanes, and level 3 low-speed airplanes, a 1 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the takeoff configuration(s); and (3) For level 3 high-speed airplanes and all level 4 airplanes, a 2 percent climb gradient at 400 feet (122 meters) above the takeoff surface with the landing gear retracted and flaps in the approach configuration(s).	REMOVED				REMOVED				
		(c) For a balked landing, a climb gradient of 3 percent without creating undue pilot workload with the landing gear extended and flaps in the landing configuration(s).	REMOVED				REMOVED				

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	§23.2125 Climb information.	(a) The applicant must determine climb performance at each weight, altitude, and ambient temperature within the operating limitations— (1) For all single-engine airplanes; (2) For levels 1 and 2 high-speed multiengine airplanes and level 3 multiengine airplanes, following a critical loss of thrust on takeoff in the initial climb configuration; and (3) For all multiengine airplanes, during the enroute phase of flight with all engines operating and after a critical loss of thrust in the cruise configuration.	[The applicant must determine climb performance at each weight, altitude, and ambient temperature within the operating limitations using the procedures published in the flight manual. Airplanes designed for continued flight after a critical loss of thrust must determine climb performance and account for performance after the loss of thrust.] (F8)	(F8)–Revised §23.2125 (a) to account for powered lift configurations and their characteristics. Removed §23.2125 (b) and (c) and reflect in MOC if needed. These criteria are too prescriptive for this configuration.	ASTM F3264-17, section 5.6	5.6 Climb Information: 5.6.1 F3179/F3179M – 16 Standard Specification for Performance of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) The applicant must determine the glide performance for single-engine airplanes after a complete loss of thrust.	REMOVED				REMOVED				
		(c) …	REMOVED				REMOVED				
	§23.2130 Landing.	The applicant must determine the following, for standard temperatures at critical combinations of weight and altitude within the operational limits:			ASTM F3264-17, section 5.7	5.7 Landing: 5.7.1 F3179/F3179M – 16 Standard Specification for Performance of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(a) The distance, starting from a height of 50 feet (15 meters) above the landing surface, required to land and come to a stop.	[(a) The landing performance, assuming approach paths applicable to the vehicle.] (F9)	(F9)–Revised §23.2130 (a) and (b) to account for powered lift configurations and their characteristics. Removed §23.2130 (b) (1) and (b) (2) and reflect in MOC if needed.			REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) The approach and landing speeds, configurations, and procedures, which allow a pilot of average skill to land within the published landing distance consistently and without causing damage or injury, and which allow for a safe transition to the balked landing conditions of this part accounting for: (1) Stall speed safety margin; and (2) Minimum control speeds.	(b) The approach [, transition if applicable,] (F9) and landing speeds, configurations, and procedures, which allow a pilot of average skill to land within the published landing [performance] (F9) consistently and without causing damage or injury, and which allow for a safe transition to the balked landing conditions of this part accounting for [the minimum safe speed]. (F9)	(F9)–Revised §23.2130 (a) and (b) to account for powered lift configurations and their characteristics. Removed §23.2130 (b) (1) and (b) (2) and reflect in MOC if needed.			REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
Flight Characteristics											
	§23.2135 Controllability.	(a) The airplane must be controllable and maneuverable, without requiring exceptional piloting skill, alertness, or strength, within the operating envelope— (1) At all loading conditions for which certification is requested; (2) During all phases of flight; (3) With likely reversible flight control or propulsion system failure; and (4) During configuration changes.	(a) The airplane must be controllable and maneuverable, without requiring exceptional piloting skill, alertness, or strength, within the operating envelope— ¶ (1) At all loading conditions for which certification is requested; ¶ (2) During all phases [and modes] (F10) of flight [including ground if the aircraft could have a dangerous tendency to oscillate on the ground] (F10); ¶ (3) With likely flight control or propulsion system failure (F11); and ¶ (4) During configuration changes; ¶ [(5) In all degraded electronic flight control system operating modes; (F12) and ¶ (6) Applicant must demonstrate controllability in vertical operation and ability to land safely in wind up to 17 knots from any azimuth angle.] (F13)	(F10)–Revised §23.2135 (a) (2) to add language from §27.241 Ground resonance and a reference to modes of operation to account for powered lift configurations. (F11)–Revised §23.2135 (a) (3) by deleting "reversible" to implement generic flight test requirements for all flight control systems failures. (F12)–Added §23.2135 (a) (5) to account for electronic flight control system characteristics. (F13)–Added §23.2135 (a) (6) to account for unique powered lift characteristics.	ASTM F3264-17, section 5.8, combined with the changes in the following table {…}	5.8 Controllability: 5.8.1 F3173/F3173M – 15 Standard Specification for Handling Characteristics of Aeroplanes, along with {ASTM F3173/F3173M-17, Sections 4.9.1.1 and 4.9.1.2: 4.9.1.1 "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 5 seconds from initiation of roll and" 4.9.1.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+500)/1300 seconds, but not more than 10 seconds, where W is the weight in pounds." ¶ ASTM F3173/F3173M-17, Sections 4.9.3.1 and 4.9.3.2: 4.9.3.1 "For a level 1 or 2 airplane, or level 3 or 4 airplane of 6,000 pounds or less maximum weight, 4 seconds from initiation of roll and" 4.9.3.2: "For a level 3 or 4 airplane of over 6,000 pounds maximum weight, (W+2,800)/2,200 seconds, but not more than 7 seconds, where W is the weight in pounds."}	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) The airplane must be able to complete a landing without causing substantial damage or serious injury using the steepest approved approach gradient procedures and providing a reasonable margin below Vref or above approach angle of attack.	[(b) The applicant must determine if there are any critical control parameters, such as VMC or limited control power margins, and if applicable, account for those parameters where appropriate.] (F14)	(F14)–Deleted §23.2135 (b) and (d) as they are addressed in recommended §23.2135 (a) and could be reflected in MOC. §23.2135 (c) is too prescriptive and is revised based on the original intent of the rule (now the recommended §23.2135 (b)).			REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(c) VMC is the calibrated airspeed at which, following the sudden critical loss of thrust, it is possible to maintain control of the airplane. For multiengine airplanes, the applicant must determine VMC, if applicable, for the most critical configurations used in takeoff and landing operations.	REMOVED				REMOVED				
		(d) If the applicant requests certification of an airplane for aerobatics, the applicant must demonstrate those aerobatic maneuvers for which certification is requested and determine entry speeds.	REMOVED				REMOVED				
	§23.2140 Trim.	(a) The airplane must maintain lateral and directional trim without further force upon, or movement of, the primary flight controls or corresponding trim controls by the pilot, or the flight control system, under the following conditions: (1) For levels 1, 2, and 3 airplanes in cruise. (2) For level 4 airplanes in normal operations.	(a) [If applicable,] (F15) the airplane must maintain lateral, directional [and vertical] (F16) trim without further force upon, or movement of, the primary flight controls or corresponding trim controls by the pilot, or the flight control system, under [normal phases and modes of flight:] (F16) ¶ (1) For levels 1, 2, and 3 airplanes in cruise. ¶ (2) For level 4 airplanes in normal operations.	(F15)–Revised §23.2140 (a) and (b) to include "if applicable" which accounts for powered lift configurations and meets intent of the rule. (F16)–Revised §23.2140 (a) and (c), and added §23.2140 (b) (5) and (b) (6) to account for unique powered lift characteristics.	ASTM F3264-17, section 5.9	5.9 Trim: 5.9.1 F3173/F3173M – 15 Standard Specification for Handling Characteristics of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) The airplane must maintain longitudinal trim without further force upon, or movement of, the primary flight controls or corresponding trim controls by the pilot, or the flight control system, under the following conditions: (1) Climb. (2) Level flight. (3) Descent. (4) Approach.	(b) [If applicable,] (F15) the airplane must maintain longitudinal trim without further force upon, or movement of, the primary flight controls or corresponding trim controls by the pilot, or the flight control system, under the following conditions: ¶ (1) Climb. ¶ (2) Level flight. ¶ (3) Descent. ¶ (4) Approach. ¶ [(5) Hover. ¶ (6) Transition.] (F16)	(F15)–Revised §23.2140 (a) and (b) to include "if applicable" which accounts for powered lift configurations and meets intent of the rule. (F16)–Revised §23.2140 (a) and (c), and added §23.2140 (b) (5) and (b) (6) to account for unique powered lift characteristics.			REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification

Subpart	Section	Note	FAA Future Advanced Safety Team (FAST) Gap Analysis to New Technology and FAR 23 ("FAST language recommendation rev0.docx", email from NASA to HSAC, dated 11 Sep 2018)	Associated FAST Footnote	Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA)	Citation of the Means of Compliance in relevant ASTM Standard, Combined with Changes as Noted in {braces} from FAA NOA	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
		(c) Residual control forces must not fatigue or distract the pilot during normal operations of the airplane and likely abnormal or emergency operations, including a critical loss of thrust on multiengine airplanes.	(c) Residual control forces must not fatigue or distract the pilot during normal operations of the airplane and likely abnormal or emergency operations, including a critical loss of thrust on multiengine airplanes. [The trim control may not introduce any undesirable discontinuities in control force gradients.] (F16)	(F16)–Revised §23.2140 (a) and (c), and added §23.2140 (b) (5) and (b) (6) to account for unique powered lift characteristics.			REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
	§23.2145 Stability.	(a) Airplanes not certified for aerobatics must— (1) Have static longitudinal, lateral, and directional stability in normal operations; (2) Have dynamic short period and Dutch roll stability in normal operations; and (3) Provide stable control force feedback throughout the operating envelope.	(a) Airplanes not certified for aerobatics must— ¶ (1) Have static longitudinal, lateral, and directional stability in normal operations; ¶ [(2) Have dynamic short period and Dutch roll stability appropriate for the airplane] (F17); ¶ [(3) Provide stable control feedback throughout the operating envelope] (F18); ¶ [(4) Exhibit stable characteristics, if applicable, in normal operations, and] (F19)	(F17)–Revised §23.2145 (a) (2) to address dynamic stability in general and allows for the appropriate MOC as needed. (F18)–Revised §23.2145 (a) (3) language from "control force feedback" to "control feedback" to account for anticipated configurations. (F19)–Added §23.2145 (a) (4) to address control system stability at airplane level.	ASTM F3264-17, section 5.10	5.10 Stability: 5.10.1 F3173/F3173M – 15 Standard Specification for Handling Characteristics of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) No airplane may exhibit any divergent longitudinal stability characteristic so unstable as to increase the pilot's workload or otherwise endanger the airplane and its occupants.	(b) No airplane may exhibit any divergent longitudinal stability characteristic [, within its approved flight envelope,] (F20) so unstable as to increase the pilot's workload or otherwise endanger the airplane and its occupants.	(F20)–Revised §23.2145 (b) to account for unique powered lift characteristics.			REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
	§23.2150 Stall characteristics, stall warning, and spins.	(a) The airplane must have controllable stall characteristics in straight flight, turning flight, and accelerated turning flight with a clear and distinctive stall warning that provides sufficient margin to prevent inadvertent stalling.	FAST 23.2150 [Minimum safe speed flight] characteristics, [minimum safe speed] warning, and spins. (F21) (a) The airplane must have controllable [minimum safe speed flight] (F21) characteristics in straight flight, turning flight, and accelerated turning flight with a clear and distinctive [minimum safe speed] (F21) warning that provides sufficient margin to prevent inadvertent stalling [if applicable] (F21).	(F21)–Revised §23.2150 to reflect requirements associated with minimum safe speed, and to clarify applicability.	ASTM F3264-17, section 5.11	5.11 Stall Characteristics, Stall Warning, and Spins: 5.11.1 F3180/F3180M – 16 Standard Specification for Low-Speed Flight Characteristics of Aeroplanes	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
		(b) Single-engine airplanes, not certified for aerobatics, must not have a tendency to inadvertently depart controlled flight.	NO CHANGE				UNCHANGED				
		(c) Levels 1 and 2 multiengine airplanes, not certified for aerobatics, must not have a tendency to inadvertently depart controlled flight from thrust asymmetry after a critical loss of thrust.	NO CHANGE				UNCHANGED				
		(d) Airplanes certified for aerobatics that include spins must have controllable stall characteristics and the ability to recover within one and one-half additional turns after initiation of the first control action from any point in a spin, not exceeding six turns or any greater number of turns for which certification is requested, while remaining within the operating limitations of the airplane.	NO CHANGE				UNCHANGED				
		(e) Spin characteristics in airplanes certified for aerobatics that includes spins must recover without exceeding limitations and may not result in unrecoverable spins— (1) With any typical use of the flight or engine power controls; or (2) Due to pilot disorientation or incapacitation.	NO CHANGE				UNCHANGED				
	§23.2155 Ground and water handling characteristics.	For airplanes intended for operation on land or water, the airplane must have controllable longitudinal and directional handling characteristics during taxi, takeoff, and landing operations.	§23.2155 [Deleted.] (F22)	(F22)–Deleted §23.2155, as its intent is covered in recommended §23.2135 and for harmonization.	ASTM F3264-17, section 5.12	5.12 Ground and Water Handling Characteristics: 5.12.1 F3173/F3173M – 15 Standard Specification for Handling Characteristics of Aeroplanes	REVISED	N/A	N/A	N/A	N/A
	§23.2160 Vibration, buffeting, and high-speed characteristics.	(a) Vibration and buffeting, for operations up to VD/MD, must not interfere with the control of the airplane or cause excessive fatigue to the flightcrew. Stall warning buffet within these limits is allowable.	(a) Vibration and buffeting, for operations up to VD/MD, must not interfere with the control of the airplane or cause excessive fatigue to the flightcrew. Stall warning buffet within these limits is allowable. [Each part of the aircraft must be free from excessive vibration under each appropriate speed and power condition.] (F23)	(F23)–Revised §23.2160 (a) to add language from §27.251 to account for powered lift characteristics	ASTM F3264-17, section 5.13	5.13 Vibration, Buffeting, and High-Speed Characteristics: 5.13.1 F3173/F3173M – 15 Standard Specification for Handling Characteristics of Aeroplanes	REVISED	REQ-CEPT-010 Motor Structure Loads Requirements; PROC-CEPT-031 Ground Vibration Test Procedure		REQ-CEPT-010 Motor Structure Loads Requirements; PROC-CEPT-031 Ground Vibration Test Procedure	REQ-CEPT-010 Motor Structure Loads Requirements; PROC-CEPT-031 Ground Vibration Test Procedure
		(b) For high-speed airplanes and all airplanes with a maximum operating altitude greater than 25,000 feet (7,620 meters) pressure altitude, there must be no perceptible buffeting in cruise configuration at 1g and at any speed up to VMO/MMO, except stall buffeting.	NO CHANGE				UNCHANGED				
		(c) For high-speed airplanes, the applicant must determine the positive maneuvering load factors at which the onset of perceptible buffet occurs in the cruise configuration within the operational envelope. Likely inadvertent excursions beyond this boundary must not result in structural damage.	NO CHANGE				UNCHANGED				
		(d) High-speed airplanes must have recovery characteristics that do not result in structural damage or loss of control, beginning at any likely speed up to VMO/MMO, following— (1) An inadvertent speed increase; and (2) A high-speed trim upset for airplanes where dynamic pressure can impair the longitudinal trim system operation.	NO CHANGE				UNCHANGED				

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	§23.2165 Performance and flight characteristics requirements for flight in icing conditions.	(a) An applicant who requests certification for flight in icing conditions defined in part 1 of appendix C to part 25 of this chapter, or an applicant who requests certification for flight in these icing conditions and any additional atmospheric icing conditions, must show the following in the icing conditions for which certification is requested under normal operation of the ice protection system(s): (1) Compliance with each requirement of this subpart, except those applicable to spins and any that must be demonstrated at speeds in excess of— (i) 250 knots CAS; (ii) VMO/MMO or VNE; or (iii) A speed at which the applicant demonstrates the airframe will be free of ice accretion. (2) The means by which stall warning is provided to the pilot for flight in icing conditions and non-icing conditions is the same.	FAST 23.2165 Performance and flight characteristics requirements for flight in [atmospheric] (F24) icing conditions. (a) An applicant who requests certification for flight in [atmospheric] (F24) icing conditions must show the following in the icing conditions for which certification is requested: (F25) ¶ * (1) Compliance with each requirement of this subpart, except those applicable to spins and any that must be demonstrated at speeds in excess of— ¶ (2) The means by which [minimum safe speed] (F26) warning is provided to the pilot for flight in icing conditions and non-icing conditions is the same.	(F24)–Revised §23.2165 title, (a) and (b) to clarify the type of icing to which the rule applies. (F25)–Revised §23.2165 (a), (b) and (c) to allow for alternative means of complying with requirements for flight in icing. (F26)–Revised §23.2165 (a) (2) to reflect the change from stall speed to minimum safe speed.	ASTM F3264-17, section 5.14	5.14 Performance and Flight Characteristics Requirements for Flight in Icing Conditions: 5.14.1 F3120/F3120M – 15 Standard Specification for Ice Protection for General Aviation Aircraft	REVISED	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE
		(b) If an applicant requests certification for flight in icing conditions, the applicant must provide a means to detect any icing conditions for which certification is not requested and show the airplane's ability to avoid or exit those conditions.	(b) The applicant must provide a means to detect icing conditions for which certification is not requested. (F24) (F25)	(F24)–Revised §23.2165 title, (a) and (b) to clarify the type of icing to which the rule applies. (F25)–Revised §23.2165 (a), (b) and (c) to allow for alternative means of complying with requirements for flight in icing.			REVISED	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE
		(c) The applicant must develop an operating limitation to prohibit intentional flight, including takeoff and landing, into icing conditions for which the airplane is not certified to operate.	[(c) The applicant must: ¶ (1) Develop an operating limitation to prohibit intentional flight, including takeoff and landing, into icing conditions for which the airplane is not certified to operate, and ¶ (2) Show the airplane's ability to avoid or exit those icing conditions for which the airplane is not certified to operate.] (F24)	(F24)–Revised §23.2165 title, (a) and (b) to clarify the type of icing to which the rule applies.			REVISED	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE	GAP, RESTRICTED FROM OPN, per TCDS A62CE
FAR 23, Airworthiness Standards: Normal Category Airplanes, Subpart C, Structures											
	§23.2200 Structural design envelope.	The applicant must determine the structural design envelope, which describes the range and limits of airplane design and operational parameters for which the applicant will show compliance with the requirements of this subpart. The applicant must account for all airplane design and operational parameters that affect structural loads, strength, durability, and aeroelasticity, including:	NO CHANGE		ASTM F3264-17, Section 6.1, combined with the changes in the following table {…}	6.1 Structural Design Envelope: 6.1.1 F3116/F3116M – 15 Standard Specification for Design Loads and Conditions, along with {ASTM F3116/F3116M-15, Section 4.1.4, "Appendix X1 through appendix X4 provide, within the limitations specified within the appendix, a simplified means of compliance with several of the requirements set forth in 4.2 to 4.26 and 7.1 to 7.9 that can be applied as one (but not the only) means to comply. If the simplified methods in appendix X1 through appendix X3 are used, they must be used together in their entirety." ¶ ASTM F3116/F3116M-15, Section 4.10.1.1, "In condition A, assume 100% of the semispan wing airload acts on one side of the airplane and 75% of this load acts on the other side. For airplanes with maximum weight of 1,000 pounds or less, 70% of the load acts on the other side." ¶ ASTM F3116/F3116M-15, Section X1.1.1, "The methods provided in this appendix provide one possible means (but not the only possible means) of compliance and can only be applied to low-speed, level 1 and level 2 airplanes." ¶ ASTM F3116/F3116M-15, Section X1.1.4, Same as published in F3116/F3116M-15 §§X1.1.4 through X1.1.4.5. Add FAA X1.1.4.6: "Wings with winglets, tip tanks, or tip fins."}	UNCHANGED				
		(a) Structural design airspeeds, landing descent speeds, and any other airspeed limitation at which the applicant must show compliance to the requirements of this subpart. The structural design airspeeds must— (1) Be sufficiently greater than the stalling speed of the airplane to safeguard against loss of control in turbulent air; and (2) Provide sufficient margin for the establishment of practical operational limiting airspeeds.	(a) Structural design airspeeds, landing descent speeds, and any other airspeed limitation at which the applicant must show compliance to the requirements of this subpart. The structural design airspeeds must— ¶ (1) Be sufficiently greater than the [minimum safe] (F27) speed of the airplane to safeguard against loss of control in turbulent air; and ¶ (2) Provide sufficient margin for the establishment of practical operational limiting airspeeds.	(F27)–Revised §23.2200 (a) (1) to reflect the change from stall speed to minimum safe speed.			REVISED			REQ-CEPT-006 Structural Loads Requirements for High-Lift Motor	REQ-CEPT-006 Structural Loads Requirements for High-Lift Motor
		(b) Design maneuvering load factors not less than those, which service history shows, may occur within the structural design envelope.	NO CHANGE				UNCHANGED				
		(c) Inertial properties including weight, center of gravity, and mass moments of inertia, accounting for— (1) Each critical weight from the airplane empty weight to the maximum weight; and (2) The weight and distribution of occupants, payload, and fuel.	NO CHANGE				UNCHANGED				
		(d) Characteristics of airplane control systems, including range of motion and tolerances for control surfaces, high lift devices, or other moveable surfaces.	NO CHANGE				UNCHANGED				
		(e) Each critical altitude up to the maximum altitude.	NO CHANGE				UNCHANGED				
			[(f) For aircraft equipped with engine driven lifting devices, lifting device rotational speed and ranges, and the maximum rearward and sideward flight speeds.] (F28)	(F28)–Added §23.2200 (f) to account for parameters relevant to powered lift aircraft with engine driven lifting devices			REVISED			REQ-CEPT-006 Structural Loads Requirements for High-Lift Motor	REQ-CEPT-006 Structural Loads Requirements for High-Lift Motor
	§23.2205 Interaction of systems and structures.	For airplanes equipped with systems that modify structural performance, alleviate the impact of this subpart's requirements, or provide a means of compliance with this subpart, the applicant must account for the influence and failure of these systems when showing compliance with the requirements of this subpart.	NO CHANGE				UNCHANGED				
Structural Loads											
	§23.2210 Structural design loads.	(a) The applicant must: (1) Determine the applicable structural design loads resulting from likely externally or internally applied pressures, forces, or moments that may occur in flight, ground and water operations, ground and water handling, and while the airplane is parked or moored. (2) Determine the loads required by paragraph (a)(1) of this section at all critical combinations of parameters, on and within the boundaries of the structural design envelope.	NO CHANGE				UNCHANGED				
		(b) The magnitude and distribution of the applicable structural design loads required by this section must be based on physical principles.	NO CHANGE				UNCHANGED				
	§23.2215 Flight load conditions.	The applicant must determine the structural design loads resulting from the following flight conditions:	NO CHANGE				UNCHANGED				
		(a) Atmospheric gusts where the magnitude and gradient of these gusts are based on measured gust statistics.	NO CHANGE				UNCHANGED				

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		(b) Symmetric and asymmetric maneuvers.	NO CHANGE				UNCHANGED				
		(c) Asymmetric thrust resulting from the failure of a powerplant unit.	NO CHANGE				UNCHANGED				
	§23.2220 Ground and water load conditions.	The applicant must determine the structural design loads resulting from taxi, takeoff, landing, and handling conditions on the applicable surface in normal and adverse attitudes and configurations.	NO CHANGE		ASTM F3264-17, section 6.5	6.5 Ground and Water Load Conditions: 6.5.1 F3116/ F3116M – 15 Standard Specification for Design Loads and Conditions	UNCHANGED				
	§23.2225 Component loading conditions.	The applicant must determine the structural design loads acting on:	NO CHANGE		ASTM F3264-17, section 6.6, combined with the changes in the following table {…}	6.6 Component Loading Conditions: 6.6.1 F3061/ F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 6.6.1.1 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 6.6.2 F3116/F3116M – 15 Standard Specification for Design Loads and Conditions, along with {ASTM F3116/F3116M-15, Section X2.1.1, FAA: "The methods provided in this appendix provide one possible means (but not the only possible means) of compliance and can only be applied to low-speed, level 1 and level 2 airplanes." ¶ ASTM F3116/ F3116M-15, Section X3.1.1, FAA: "The methods provided in this appendix provide one possible means (but not the only possible means) of compliance and can only be applied to low-speed, level 1 and level 2 airplanes." ¶ ASTM F3116/F3116M-15, Section X4.1.1, FAA: "The methods provided in this appendix provide one possible means (but not the only possible means) of compliance and can only be applied to low-speed, level 1 airplanes."}	UNCHANGED				
		(a) Each engine mount and its supporting structure such that both are designed to withstand loads resulting from— (1) Powerplant operation combined with flight gust and maneuver loads; and (2) For non-reciprocating powerplants, sudden powerplant stoppage.	NO CHANGE				UNCHANGED				
		(b) Each flight control and high-lift surface, their associated system and supporting structure resulting from— (1) The inertia of each surface and mass balance attachment; (2) Flight gusts and maneuvers; (3) Pilot or automated system inputs; (4) System induced conditions, including jamming and friction; and (5) Taxi, takeoff, and landing operations on the applicable surface, including downwind taxi and gusts occurring on the applicable surface.	NO CHANGE				UNCHANGED				
		(c) A pressurized cabin resulting from the pressurization differential— (1) From zero up to the maximum relief pressure combined with gust and maneuver loads; (2) From zero up to the maximum relief pressure combined with ground and water loads if the airplane may land with the cabin pressurized; and (3) At the maximum relief pressure multiplied by 1.33, omitting all other loads.	NO CHANGE				UNCHANGED				
			[(d) Engine driven lifting device assemblies, considering loads resulting from flight and ground conditions, as well limit input torque at any lifting device rotational speed.] (F29)	(F29)–Added §23.2225 (d) to account for parameters relevant to powered lift aircraft with engine driven lifting devices			REVISED			REQ-CEPT-006 Structural Loads Requirements for High-Lift Motor	REQ-CEPT-006 Structural Loads Requirements for High-Lift Motor
	§23.2230 Limit and ultimate loads.	The applicant must determine—	NO CHANGE		ASTM F3264-17, section 6.7	6.7 Limit and Ultimate Loads: 6.7.1 F3114 – 15 Standard Specification for Structures	UNCHANGED				
		(a) The limit loads, which are equal to the structural design loads unless otherwise specified elsewhere in this part; and	NO CHANGE				UNCHANGED				
		(b) The ultimate loads, which are equal to the limit loads multiplied by a 1.5 factor of safety unless otherwise specified elsewhere in this part.	NO CHANGE				UNCHANGED				
Structural Performance											
	§23.2235 Structural strength.	The structure must support:	NO CHANGE		ASTM F3264-17, section 6.8, combined with the changes in the following table {…}	6.8 Structural Strength: 6.8.1 F3114 – 15 Standard Specification for Structures along with {ASTM F3264-17, Section 6.8.1, FAA: "F3114-15 Standard Specification for Structures".}	UNCHANGED				
		(a) Limit loads without— (1) Interference with the safe operation of the airplane; and (2) Detrimental permanent deformation.	NO CHANGE				UNCHANGED				
		(b) Ultimate loads.	NO CHANGE				UNCHANGED				
	§23.2240 Structural durability.	(a) The applicant must develop and implement inspections or other procedures to prevent structural failures due to foreseeable causes of strength degradation, which could result in serious or fatal injuries, or extended periods of operation with reduced safety margins. Each of the inspections or other procedures developed under this section must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by §23.1529.	NO CHANGE		ASTM F3264-17, section 6.9, combined with the changes in the following table {…}	6.9 Structural Durability: 6.9.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 6.9.2 F3115/F3115M – 15 Standard Specification for Structural Durability for Small Aeroplanes, along with {ASTM F3115/F3115M-15, Section 4.4.1, FAA: "For metallic (aluminum), unpressurized, non-aerobatic, low-speed, level 1 airplanes, applicants can demonstrate a 10,000 hour safe-life by limiting the '1g' gross stress, at maximum takeoff weight, to no more than 5.5 ksi. The applicant must show effective stress concentration factors of 4 or less in highly loaded joints and use materials or material systems for which the physical and mechanical properties are well established." ¶ ASTM F3115/F3115M-15, Section 6.1, FAA: "For bonded airframe structure, the residual strength of bonded joints shall be addressed as follows: For any bonded joint, the failure of which would result in catastrophic loss of the airplane, the limit load capacity must be substantiated by one of the following methods."}	UNCHANGED				
		(b) For Level 4 airplanes, the procedures developed for compliance with paragraph (a) of this section must be capable of detecting structural damage before the damage could result in structural failure.	NO CHANGE				UNCHANGED				

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		(c) For pressurized airplanes: (1) The airplane must be capable of continued safe flight and landing following a sudden release of cabin pressure, including sudden releases caused by door and window failures. (2) For airplanes with maximum operating altitude greater than 41,000 feet, the procedures developed for compliance with paragraph (a) of this section must be capable of detecting damage to the pressurized cabin structure before the damage could result in rapid decompression that would result in serious or fatal injuries.	NO CHANGE				UNCHANGED				
		(d) The airplane must be designed to minimize hazards to the airplane due to structural damage caused by high-energy fragments from an uncontained engine or rotating machinery failure.	NO CHANGE				UNCHANGED				
	§23.2245 Aeroelasticity.	(a) The airplane must be free from flutter, control reversal, and divergence— (1) At all speeds within and sufficiently beyond the structural design envelope; (2) For any configuration and condition of operation; (3) Accounting for critical degrees of freedom; and (4) Accounting for any critical failures or malfunctions.	NO CHANGE		ASTM F3264-17, section 6.10	6.10 Aeroelasticity: 6.10.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 6.10.2 F3093/F3093M – 15 Standard Specification for Aeroelasticity Requirements	UNCHANGED				
		(b) The applicant must establish tolerances for all quantities that affect flutter.	NO CHANGE				UNCHANGED				
Design											
	§23.2250 Design and construction principles.	(a) The applicant must design each part, article, and assembly for the expected operating conditions of the airplane.	NO CHANGE		ASTM F3264-17, section 6.11	6.11 Design and Construction Principles: 6.11.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 6.11.1.1 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 6.11.2 F3114 – 15 Standard Specification for Structures	UNCHANGED				
		(b) Design data must adequately define the part, article, or assembly configuration, its design features, and any materials and processes used.	NO CHANGE				UNCHANGED	CDR Day 1, page 166, Safety Factor (SF) Analysis for Engine Nacelle materials and structure			
		(c) The applicant must determine the suitability of each design detail and part having an important bearing on safety in operations.	NO CHANGE				UNCHANGED				
		(d) The control system must be free from jamming, excessive friction, and excessive deflection when the airplane is subjected to expected limit airloads.	NO CHANGE				UNCHANGED				
		(e) Doors, canopies, and exits must be protected against inadvertent opening in flight, unless shown to create no hazard when opened in flight.	NO CHANGE				UNCHANGED				
	§23.2255 Protection of structure.	(a) The applicant must protect each part of the airplane, including small parts such as fasteners, against deterioration or loss of strength due to any cause likely to occur in the expected operational environment.	NO CHANGE		ASTM F3264-17, section 6.12	6.12 Protection of Structure: 6.12.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 6.12.1.1 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 6.12.2 F3114 – 15 Standard Specification for Structures ¶ 6.12.3 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation	UNCHANGED				
		(b) Each part of the airplane must have adequate provisions for ventilation and drainage.	NO CHANGE				UNCHANGED				
		(c) For each part that requires maintenance, preventive maintenance, or servicing, the applicant must incorporate a means into the aircraft design to allow such actions to be accomplished.	NO CHANGE				UNCHANGED				
	§23.2260 Materials and processes.	(a) The applicant must determine the suitability and durability of materials used for parts, articles, and assemblies, accounting for the effects of likely environmental conditions expected in service, the failure of which could prevent continued safe flight and landing.	NO CHANGE		ASTM F3264-17, section 6.13	6.13 Materials and Processes: 6.13.1 F3114 – 15 Standard Specification for Structures	UNCHANGED	CDR Day 1, page 166, Safety Factor (SF) Analysis for Engine Nacelle materials and structure			
		(b) The methods and processes of fabrication and assembly used must produce consistently sound structures. If a fabrication process requires close control to reach this objective, the applicant must perform the process under an approved process specification.	NO CHANGE				UNCHANGED				
		(c) Except as provided in paragraphs (f) and (g) of this section, the applicant must select design values that ensure material strength with probabilities that account for the criticality of the structural element. Design values must account for the probability of structural failure due to material variability.	NO CHANGE				UNCHANGED	CDR Day 1, page 170, Summary Margin of Safety			
		(d) If material strength properties are required, a determination of those properties must be based on sufficient tests of material meeting specifications to establish design values on a statistical basis.	NO CHANGE				UNCHANGED				
		(e) If thermal effects are significant on a critical component or structure under normal operating conditions, the applicant must determine those effects on allowable stresses used for design.	NO CHANGE				UNCHANGED				
		(f) Design values, greater than the minimums specified by this section, may be used, where only guaranteed minimum values are normally allowed, if a specimen of each individual item is tested before use to determine that the actual strength properties of that particular item will equal or exceed those used in the design.	NO CHANGE				UNCHANGED				
		(g) An applicant may use other material design values if approved by the Administrator.	NO CHANGE				UNCHANGED				

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	§23.2265 Special factors of safety.	(a) The applicant must determine a special factor of safety for each critical design value for each part, article, or assembly for which that critical design value is uncertain, and for each part, article, or assembly that is— (1) Likely to deteriorate in service before normal replacement; or (2) Subject to appreciable variability because of uncertainties in manufacturing processes or inspection methods.	NO CHANGE		ASTM F3264-17, section 6.14	6.14 Special Factors of Safety: 6.14.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 6.14.2 F3114 – 15 Standard Specification for Structures	UNCHANGED				
		(b) The applicant must determine a special factor of safety using quality controls and specifications that account for each— (1) Type of application; (2) Inspection method; (3) Structural test requirement; (4) Sampling percentage; and (5) Process and material control.	NO CHANGE				UNCHANGED				
		(c) The applicant must multiply the highest pertinent special factor of safety in the design for each part of the structure by each limit and ultimate load, or ultimate load only, if there is no corresponding limit load, such as occurs with emergency condition loading.	NO CHANGE				UNCHANGED				
Structural Occupant Protection											
	§23.2270 Emergency conditions.	(a) The airplane, even when damaged in an emergency landing, must protect each occupant against injury that would preclude egress when— (1) Properly using safety equipment and features provided for in the design; (2) The occupant experiences ultimate static inertia loads likely to occur in an emergency landing; and (3) Items of mass, including engines or auxiliary power units (APUs), within or aft of the cabin, that could injure an occupant, experience ultimate static inertia loads likely to occur in an emergency landing.	NO CHANGE		ASTM F3264-17, section 6.15	6.15 Emergency Conditions: 6.15.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 6.15.1.1 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 6.15.2 F3083/F3083M – 16 Standard Specification for Emergency Conditions, Occupant Safety and Accommodations	UNCHANGED				
		(b) The emergency landing conditions specified in paragraph (a)(1) and (a)(2) of this section, must— (1) Include dynamic conditions that are likely to occur in an emergency landing; and (2) Not generate loads experienced by the occupants, which exceed established human injury criteria for human tolerance due to restraint or contact with objects in the airplane.	NO CHANGE				UNCHANGED				
		(c) The airplane must provide protection for all occupants, accounting for likely flight, ground, and emergency landing conditions.	NO CHANGE				UNCHANGED				
		(d) Each occupant protection system must perform its intended function and not create a hazard that could cause a secondary injury to an occupant. The occupant protection system must not prevent occupant egress or interfere with the operation of the airplane when not in use.	NO CHANGE				UNCHANGED				
		(e) Each baggage and cargo compartment must— (1) Be designed for its maximum weight of contents and for the critical load distributions at the maximum load factors corresponding to the flight and ground load conditions determined under this part; (2) Have a means to prevent the contents of the compartment from becoming a hazard by impacting occupants or shifting; and (3) Protect any controls, wiring, lines, equipment, or accessories whose damage or failure would affect safe operations.	NO CHANGE				UNCHANGED				
FAR 23, Airworthiness Standards: Normal Category Airplanes, Subpart D, Design & Construction											
	§23.2300 Flight control systems.	(a) The applicant must design airplane flight control systems to: (1) Operate easily, smoothly, and positively enough to allow proper performance of their functions. (2) Protect against likely hazards.	[(a) The flight control systems are designed to: ¶ (1) operate easily, smoothly, and positively enough to allow proper performance of their functions; ¶ (2) protect against likely hazards.	(F30)–Revised §23.2300 (a) and (b) for harmonization.	ASTM F3264-17, section 7.1, combined with the changes in the following table {…}	7.1 Flight Control Systems: 7.1.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 7.1.1.1 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 7.1.2 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation along with {ASTM F3232/F3232M-17, Table 1, Row 4.4.6, FAA Table 1, Row 4.4.6: A white circle ("o") in the following Aircraft Type Code (ATC) character fields: "Airworthiness Level—1" and "Stall Speed—L"; a mark-out ("x") in the following ATC character field: "Number of Engines—M"; and no codes in any other ATC character field. Note: This change applies the standard of ASTM F3232/F3232M-17, Section 4.4.6, to all single-engine airplanes except level 1 airplanes with a stall speed of 45 knots or less.}	REVISED	CDR Day 1, page 172-180, Command System Overview; ISO 11898-2 (high speed CAN) or ISO 11898-3 (low speed or fault tolerant CAN); ; ICD-CEPT-005; PROC-CEPT-029 Cockpit Systems Checkout Procedure			
		(b) The applicant must design trim systems, if installed, to: (1) Protect against inadvertent, incorrect, or abrupt trim operation. (2) Provide a means to indicate— (i) The direction of trim control movement relative to airplane motion; (ii) The trim position with respect to the trim range; (iii) The neutral position for lateral and directional trim; and (iv) The range for takeoff for all applicant requested center of gravity ranges and configurations.	(b) Trim systems, if installed, are designed to: ¶ (1) protect against inadvertent, incorrect, or abrupt trim operation; ¶ (2) provide information that is required for safe operation.] (F30)	(F30)–Revised §23.2300 (a) and (b) for harmonization.			REVISED	PROC-CEPT-029 Cockpit Systems Checkout Procedure			
			[(c) An applicant must design flight control systems to provide indication when control authority is reduced from nominal.] (F31)	(F31)–Added §23.2300 (c) to account for unique characteristics of electronic flight control systems.			REVISED	PROC-CEPT-029 Cockpit Systems Checkout Procedure			
	§23.2305 Landing gear systems.	(a) The landing gear must be designed to— (1) Provide stable support and control to the airplane during surface operation; and (2) Account for likely system failures and likely operation environments (including anticipated limitation exceedances and emergency procedures).	NO CHANGE		ASTM F3264-17, section 7.2	7.2 Landing Gear Systems: 7.2.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft	UNCHANGED				
		(b) All airplanes must have a reliable means of stopping the airplane with sufficient kinetic energy absorption to account for landing. Airplanes that are required to demonstrate aborted takeoff capability must account for this additional kinetic energy.	NO CHANGE				UNCHANGED				

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		(c) For airplanes that have a system that actuates the landing gear, there is— (1) A positive means to keep the landing gear in the landing position; and (2) An alternative means available to bring the landing gear in the landing position when a non-deployed system position would be a hazard.	NO CHANGE				UNCHANGED				
	§23.2310 Buoyancy for seaplanes and amphibians.	Airplanes intended for operations on water, must—				*7.3 Buoyancy for Seaplanes and Amphibians: 7.3.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft*	UNCHANGED	N/A			
		(a) Provide buoyancy of 80 percent in excess of the buoyancy required to support the maximum weight of the airplane in fresh water; and	[(a) Provide buoyancy required to support the maximum weight of the airplane in fresh water with margin appropriate for the expected conditions; and] (F32)	(F32)–Revised §23.2310 (a) to reflect performance based rule language.			REVISED	N/A			
		(b) Have sufficient margin so the airplane will stay afloat at rest in calm water without capsizing in case of a likely float or hull flooding.	NO CHANGE					N/A			
Occupant System Design Protection											
	§23.2315 Means of egress and emergency exits.	(a) With the cabin configured for takeoff or landing, the airplane is designed to: (1) Facilitate rapid and safe evacuation of the airplane in conditions likely to occur following an emergency landing, excluding ditching for level 1, level 2 and single engine level 3 airplanes. (2) Have means of egress (openings, exits or emergency exits), that can be readily located and opened from the inside and outside. The means of opening must be simple and obvious and marked inside and outside the airplane. (3) Have easy access to emergency exits when present.	NO CHANGE		ASTM F3264-17, section 7.4	7.4 Means of Egress and Emergency Exits: 7.4.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 7.4.2 F3083/F3083M – 16 Standard Specification for Emergency Conditions, Occupant Safety and Accommodations	UNCHANGED				
		(b) Airplanes approved for aerobatics must have a means to egress the airplane in flight.	NO CHANGE				UNCHANGED				
	§23.2320 Occupant physical environment.	(a) The applicant must design the airplane to— (1) Allow clear communication between the flightcrew and passengers; (2) Protect the pilot and flight controls from propellers; and (3) Protect the occupants from serious injury due to damage to windshields, windows, and canopies.	(a) The applicant must design the airplane to— ¶ (1) Allow clear communication between the flightcrew and passengers; ¶ [(2) Protect the pilot and flight controls against likely hazards that would preclude continued safe flight and landing; and] (F33) ¶ (3) Protect the occupants from serious injury due to damage to windshields, windows, and canopies.	(F33)–Revised §23.2320 (a) (2) for harmonization.	ASTM F3264-17, section 7.5	7.5 Occupant Physical Environment: 7.5.1 F3061/ F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 7.5.1.1 F3227/F3227M – 17 Standard Specification for Environmental Systems in Small Aircraft ¶ 7.5.2 F3083/F3083M – 16 Standard Specification for Emergency Conditions, Occupant Safety and Accommodations ¶ 7.5.3 F3114 – 15 Standard Specification for Structures ¶ 7.5.4 F3117 – 15 Standard Specification for Crew Interface in Aircraft	REVISED	REQ-CEPT-007 Structural Requirements - Floor			
		(b) For level 4 airplanes, each windshield and its supporting structure directly in front of the pilot must withstand, without penetration, the impact equivalent to a two-pound bird when the velocity of the airplane is equal to the airplane's maximum approach flap speed.	NO CHANGE				UNCHANGED				
		(c) The airplane must provide each occupant with air at a breathable pressure, free of hazardous concentrations of gases, vapors, and smoke during normal operations and likely failures.	NO CHANGE				UNCHANGED				
		(d) If a pressurization system is installed in the airplane, it must be designed to protect against— (1) Decompression to an unsafe level; and (2) Excessive differential pressure.	NO CHANGE				UNCHANGED				
		(e) If an oxygen system is installed in the airplane, it must— (1) Effectively provide oxygen to each user to prevent the effects of hypoxia; and (2) Be free from hazards in itself, in its method of operation, and its effect upon other components.	NO CHANGE				UNCHANGED				
Fire and High Energy Protection											
	§23.2325 Fire protection.	(a) The following materials must be self-extinguishing— (1) Insulation on electrical wire and electrical cable; (2) For levels 1, 2, and 3 airplanes, materials in the baggage and cargo compartments inaccessible in flight; and (3) For level 4 airplanes, materials in the cockpit, cabin, baggage, and cargo compartments.	NO CHANGE		ASTM F3264-17, section 7.6, combined with the changes in the following table {…}	7.6 Fire Protection: 7.6.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 7.6.1.1 F3231/F3231M – 17 Standard Specification for Electrical Systems in Small Aircraft ¶ 7.6.1.2 F3234/F3234M – 17 Standard Specification for Exterior Lighting in Small Aircraft ¶ 7.6.2 F3066/ F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation ¶ 7.6.3 F3083/ F3083M – 16 Standard Specification for Emergency Conditions, Occupant Safety and Accommodations, along with {ASTM F3061/F3061M-17, Section 10.3.2, FAA: "In each area where flammable fluids or vapors might escape by leakage of a fluid system, there must be means to minimize the probability of ignition of the fluids and vapors, and the resultant hazard if ignition does occur. These means must account for the factors prescribed in 10.3.3 through 10.3.7."}	UNCHANGED				
		(b) The following materials must be flame resistant— (1) For levels 1, 2 and 3 airplanes, materials in each compartment accessible in flight; and (2) Any equipment associated with any electrical cable installation and that would overheat in the event of circuit overload or fault.	NO CHANGE				UNCHANGED				
		(c) Thermal/acoustic materials in the fuselage, if installed, must not be a flame propagation hazard.	NO CHANGE				UNCHANGED				
		(d) Sources of heat within each baggage and cargo compartment that are capable of igniting adjacent objects must be shielded and insulated to prevent such ignition.	NO CHANGE				UNCHANGED				
		(e) For level 4 airplanes, each baggage and cargo compartment must— (1) Be located where a fire would be visible to the pilots, or equipped with a fire detection system and warning system; and (2) Be accessible for the manual extinguishing of a fire, have a built-in fire extinguishing system, or be constructed and sealed to contain any fire within the compartment.	NO CHANGE				UNCHANGED				
		(f) There must be a means to extinguish any fire in the cabin such that— (1) The pilot, while seated, can easily access the fire extinguishing means; and (2) For levels 3 and 4 airplanes, passengers have a fire extinguishing means available within the passenger compartment.	NO CHANGE				UNCHANGED				

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		(g) Each area where flammable fluids or vapors might escape by leakage of a fluid system must— (1) Be defined; and (2) Have a means to minimize the probability of fluid and vapor ignition, and the resultant hazard, if ignition occurs.	NO CHANGE				UNCHANGED				
		(h) Combustion heater installations must be protected from uncontained fire.	NO CHANGE				UNCHANGED				
	§23.2330 Fire protection in designated fire zones and adjacent areas.	(a) Flight controls, engine mounts, and other flight structures within or adjacent to designated fire zones must be capable of withstanding the effects of a fire.	NO CHANGE		ASTM F3264-17, section 7.7	7.7 Fire Protection in Designated Fire Zones and Adjacent Areas: 7.7.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 7.7.1.1 F3231/F3231M – 17 Standard Specification for Electrical Systems in Small Aircraft ¶ 7.7.2 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation ¶ 7.7.3 F3114 – 15 Standard Specification for Structures	UNCHANGED				
		(b) Engines in a designated fire zone must remain attached to the airplane in the event of a fire.	NO CHANGE				UNCHANGED				
		(c) In designated fire zones, terminals, equipment, and electrical cables used during emergency procedures must be fire-resistant.	NO CHANGE				UNCHANGED				
	§23.2335 Lightning protection.	The airplane must be protected against catastrophic effects from lightning.	[For operations where the exposure to lightning is likely, the airplane must be protected against catastrophic effects from lightning.] (F34)	(F34)–Revised §23.2335 for harmonization.	ASTM F3264-17, section 7.8	7.8 Lightning Protection: 7.8.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft	REVISED	PROC-CEPT-004 Environmental Test Procedure for X-57 MoTeC D175 Display Screen			
FAR 23, Airworthiness Standards: Normal Category Airplanes, Subpart E, Powerplant											
	§23.2400 Powerplant installation.	(a)…the airplane powerplant installation must include each component necessary for propulsion, which affects propulsion safety, or provides auxiliary power to the airplane.	NO CHANGE		ASTM F3264-17, section 8.1, combined with the changes in the following table {…}	8.1 Powerplant Installation: 8.1.1 F3062/F3062M – 16 Standard Specification for Instal- lation of Powerplant Systems ¶ 8.1.2 F3063/F3063M – 16a Standard Specification for Design and Integration of Fuel/ Energy Storage and Delivery System Installations for Aeroplanes ¶ 8.1.3 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems ¶ 8.1.4 F3065/F3065M – 15 Standard Specification for Installation and Integration of Propeller Systems ¶ 8.1.5 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation along with {An FAA-accepted means of compliance for §23.2400(c), such as the provisions of §23.905(d), amendment 23-59.}	UNCHANGED				
		(b) Each airplane engine and propeller must be type certificated, except for engines and propellers installed on level 1 low-speed airplanes, which may be approved under the airplane type certificate in accordance with a standard accepted by the FAA that contains airworthiness criteria … found appropriate and applicable to the specific design and intended use of the engine or propeller and provides a level of safety acceptable to the FAA.	[(b) Each airplane engine and propeller must have a type certificate or be approved under the airplane type certificate using standards accepted by the Administrator.] (F35)	(F35)–Revised §23.2400 to provide a path to concurrent aircraft and propulsion approval for Level 1-4 aircraft.			REVISED	Not applicable for X-plane			
		(c) The applicant must construct and arrange each powerplant installation to account for—(1) Likely operating conditions, including foreign object threats; ¶ (2) Sufficient clearance of moving parts to other airplane parts and their surroundings; ¶ (3) Likely hazards in operation including hazards to ground personnel; and ¶ (4) Vibration and fatigue.	NO CHANGE			… {ASTM F3065/F3065M-15, Section 4.3, An FAA-accepted means of compliance for §23.2400(c), such as the provisions of §23.905(d), amendment 23-59.}	UNCHANGED				
		(d) Hazardous accumulations of fluids, vapors, or gases must be isolated from the airplane and personnel compartments, and be safely contained or discharged.	NO CHANGE				UNCHANGED				
		(e) Powerplant components must comply with their component limitations and installation instructions or be shown not to create a hazard.	NO CHANGE				UNCHANGED				
	§23.2405 Automatic power or thrust control systems.	(a) An automatic power or thrust control system intended for in-flight use must be designed so no unsafe condition will result during normal operation of the system.	FAST 23.2405 [Power or thrust control systems.] (F36) (a) Any automatic power or thrust control system [, reverser system or powerplant rotation control system] (F36) must be designed so no unsafe condition will result during normal operation of the system.	(F36)–Revised the title of §23.2405 as well as (a), (b) and (c) to account for manual, automatic and reverse power and thrust controls systems in powered lift aircraft.	ASTM F3264-17, section 8.2	8.2 Power or Thrust Control Systems: 8.2.1 F3062/ F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 8.2.2 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems	REVISED	REQ-CEPT-004 Power Subsystem Requirements			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification; DEP Flight Testing
		(b) Any single failure or likely combination of failures of an automatic power or thrust control system must not prevent continued safe flight and landing of the airplane.	"(b) Any single failure or likely combination of failures [or malfunctions] (F36) of an automatic power or thrust control system [, reverser system or powerplant rotation control system] (F36) must not prevent continued safe flight and landing of the airplane."	(F36)–Revised the title of §23.2405 as well as (a), (b) and (c) to account for manual, automatic and reverse power and thrust controls systems in powered lift aircraft.			REVISED	REQ-CEPT-004 Power Subsystem Requirements			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification; DEP Flight Testing
		(c) Inadvertent operation of an automatic power or thrust control system by the flightcrew must be prevented, or if not prevented, must not result in an unsafe condition.	"(c) Inadvertent operation of an automatic power or thrust control system [,reverser system, or powerplant rotation control system] (F36) by the flightcrew must be prevented, or if not prevented, must not result in an unsafe condition."	(F36)–Revised the title of §23.2405 as well as (a), (b) and (c) to account for manual, automatic and reverse power and thrust controls systems in powered lift aircraft.			REVISED	REQ-CEPT-004 Power Subsystem Requirements			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification; DEP Flight Testing

Subpart	Section	Note	FAA Future Advanced Safety Team (FAST) Gap Analysis to New Technology and FAR 23 ("FAST language recommendation rev0.docx", email from NASA to HSAC, dated 11 Sep 2018)	Associated FAST Footnote	Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA)	Citation of the Means of Compliance in relevant ASTM Standard, Combined with Changes as Noted in {braces} from FAA NOA	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
		(d) Unless the failure of an automatic power or thrust control system is extremely remote, the system must—(1) Provide a means for the flightcrew to verify the system is in an operating condition; ¶ (2) Provide a means for the flightcrew to override the automatic function; and ¶ (3) Prevent inadvertent deactivation of the system.	NO CHANGE				UNCHANGED				
	§23.2410 Powerplant installation hazard assessment.	… assess each powerplant separately and in relation to other airplane systems and installations to show that any hazard resulting from the likely failure of any powerplant system, component, or accessory will not—	NO CHANGE		ASTM F3264-17, section 8.3, combined with the changes in the following table {…}	8.3 Powerplant Installation Hazard Assessment: 8.3.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 8.3.2 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 8.3.3 F3063/F3063M – 16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes ¶ 8.3.4 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments ¶ 8.3.5 F3065/F3065M – 15 Standard Specification for Installation and Integration of Propeller Systems ¶ 8.3.6 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation ¶ 8.3.7 F3117 – 15 Standard Specification for Crew Interface in Aircraft, along with {ASTM F3264-17, Section 8.3 through 8.3.2: Same as published in F3264-17. Renumber 8.3.3 to 8.3.6. ¶ Add FAA 8.3.3 through 8.3.5, and FAA 8.3.7: 8.3.3: "F3063/F3063M—16a Standard Specification for Design and Integration of Fuel/ Energy Storage and Delivery System Installations for Aeroplanes". ¶ 8.3.4: "F3064/F3064M—15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems". ¶ 8.3.5: "F3065/F3065M—15 Standard Specification for Installation and Integration of Propeller System".}	UNCHANGED				
		(a) Prevent continued safe flight and landing or, if continued safe flight and landing cannot be ensured, the hazard has been minimized;	NO CHANGE				UNCHANGED				
		(b) Cause serious injury that may be avoided; and	NO CHANGE				UNCHANGED				
		(c) Require immediate action by any crewmember for continued operation of any remaining powerplant system.	NO CHANGE				UNCHANGED				
	§23.2415 Powerplant ice protection.	(a) The airplane design, including the induction and inlet system, must prevent foreseeable accumulation of ice or snow that adversely affects powerplant operation.	NO CHANGE		ASTM F3264-17, section 8.4, combined with the changes in the following table {…}	8.4 Powerplant Installation Ice Protection: 8.4.1 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 8.4.2 F3063/F3063M – 16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations ¶ 8.4.3 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation along with {ASTM F3264-17, 8.4 through 8.4.1: Same as published in F3264-17. Renumber 8.4.2 to 8.4.3. Add FAA 8.4.2: F3063/F3063M—"16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes". ¶ ASTM F3066/F3066M-15, Section 5.1, An FAA-accepted means of compliance for the induction system ice protection aspects of §23.2415, such as the provisions of §23.1093(a), amendment 23-51. ¶ ASTM F3066/F3066M-15, Section 5.2.1.1, FAA 5.2.1.1: "Operate throughout its flight power range, including minimum descent idle speeds, in the icing and snow conditions specified in Specification F3120/F3120M, without the accumulation of ice on engine, inlet system components, or airframe components that would do any of the following:" ¶ ASTM F3066/F3066M-15, Section 5.2.2 [Remove] ¶ ASTM F3066/F3066M-15, Sections 5.2.3, 5.2.3.1, and 5.2.3.2, FAA 5.2.2: "Each turbine engine must idle for 30 min on the ground, with the air bleed available for engine icing protection at its critical condition, without adverse effect, in the ground icing conditions specified in Specification F3120/ F3120M." ¶ FAA 5.2.2.1 Followed by momentary operation at takeoff power or thrust. ¶ FAA 5.2.2.2 During the 30 min of idle operation, the engine may be run up periodically to a moderate power or thrust setting."}	UNCHANGED				
		(b) The powerplant installation design must prevent any accumulation of ice or snow that adversely affects powerplant operation, in those icing conditions for which certification is requested.	NO CHANGE				UNCHANGED	RESTRICTED FROM OPN, per TCDS A62CE	RESTRICTED FROM OPN, per TCDS A62CE	RESTRICTED FROM OPN, per TCDS A62CE	RESTRICTED FROM OPN, per TCDS A62CE
	§23.2420 Reversing systems.	Each reversing system must be designed so that—(a) No unsafe condition will result during normal operation of the system; and (b) The airplane is capable of continued safe flight and landing after any single failure, likely combination of failures, or malfunction of the reversing system.	§23.2420 [Deleted.] (F37)	(F37)–Deleted §23.2420 as its intent is covered in recommended §23.2405.	ASTM F3264-17, section 8.5, combined with the changes in the following table {…}	8.5 Reversing Systems: 8.5.1 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 8.5.2 F3065/F3065M – 15 Standard Specification for Installation and Integration of Propeller Systems along with {ASTM F3264-17, Section 8.5 through 8.5.1: Same as published in F3264-17. Remove 8.5.2 and 8.5.3. Add FAA 8.5.2: F3065/F3065M—"15 Standard Specification for Installation and Integration of Propeller System".}	REVISED	REQ-CEPT-004 Power Subsystem Requirments	REQ-CEPT-004 Power Subsystem Requirments	REQ-CEPT-004 Power Subsystem Requirments	REQ-CEPT-004 Power Subsystem Requirments
	§23.2425 Powerplant operational characteristics.	(a) The installed powerplant must operate without any hazardous characteristics during normal and emergency operation within the range of operating limitations for the airplane and the engine.	NO CHANGE				UNCHANGED				
		(b) The pilot must have the capability to stop the powerplant in flight and restart the powerplant within an established operational envelope.	[(b) The design must allow the shutdown and restart of the powerplant inflight within an established operational envelope.] (F38)	(F38)–Revised §23.2425 (b) to account for characteristics of the automatic distributed electric propulsion system on this aircraft.			REVISED	XREF, DEP Ground Testing		XREF, Traction motor Flight Testing	XREF, DEP Flight Testing

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	§23.2430 Fuel systems.	(a) Each fuel system must—(1) Be designed and arranged to provide independence between multiple fuel storage and supply systems so that failure of any one component in one system will not result in loss of fuel storage or supply of another system; ¶ (2) Be designed and arranged to prevent ignition of the fuel within the system by direct lightning strikes or swept lightning strokes to areas where such occurrences are highly probable, or by corona or streamering at fuel vent outlets; ¶ (3) Provide the fuel necessary to ensure each powerplant and auxiliary power unit functions properly in all likely operating conditions; ¶ (4) Provide the flightcrew with a means to determine the total useable fuel available and provide uninterrupted supply of that fuel when the system is correctly operated, accounting for likely fuel fluctuations; ¶ (5) Provide a means to safely remove or isolate the fuel stored in the system from the airplane; ¶ (6) Be designed to retain fuel under all likely operating conditions and minimize hazards to the occupants during any survivable emergency landing. For level 4 airplanes, failure due to overload of the landing system must be taken into account; and ¶ (7) Prevent hazardous contamination of the fuel supplied to each powerplant and auxiliary power unit.	(a) Each fuel system must— ¶ (1) Be designed and arranged to provide independence between multiple fuel storage and supply systems so that failure of any one component in one system will not result in loss of fuel storage or supply of another system; ¶ (2) Be designed and arranged to prevent ignition of the fuel within the system by direct lightning strikes or swept lightning strokes to areas where such occurrences are highly probable, or by corona or streamering at fuel vent outlets; ¶ (3) Provide the fuel necessary to ensure each powerplant and auxiliary power unit functions properly in all likely operating conditions; ¶ (4) Provide the flightcrew with a means to determine the total useable fuel available and provide uninterrupted supply of that fuel when the system is correctly operated, accounting for likely fuel fluctuations; ¶ (5) Provide a means to safely remove or isolate the fuel stored in the system from the airplane; ¶ (6) Be designed to retain fuel under all likely operating conditions and [to minimize hazards to occupants following an emergency landing or otherwise survivable impact (crash landing).] (F40) For level 4 airplanes, failure due to overload of the landing system must be taken into account; and ¶ (7) Prevent hazardous contamination of the fuel supplied to each powerplant and auxiliary power unit.	(F40)–Revised §23.2430 (a) (6) to include criteria from §27.952 to account for powered lift configurations.	ASTM F3264-17, section 8.7, combined with the changes in the following table {…}	8.7 Fuel and Energy Storage and Distribution Systems: 8.7.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 8.7.2 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 8.7.3 F3063/F3063M – 16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes ¶ 8.7.4 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems ¶ 8.7.5 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation along with {ASTM F3264-17, Section 8.7, 8.7.1 through 8.7.5: Same as published in F3264-17. Add an FAA-accepted means of compliance for the fuel supply aspects of §23.2430, such as the provisions of § 23.991(b), amendment 23-43. ¶ ASTM F3066/ F3066M-15, Section 6.3: An FAA-accepted means of compliance for the fuel/oil tank aspects of §23.2430, such as the provisions of §23.967(d), amendment 23-43.}	REVISED			XREF, N/A or revised for battery bay?	XREF, DEP Flight Testing
		(b) Each fuel storage system must—(1) Withstand the loads under likely operating conditions without failure; ¶ (2) Be isolated from personnel compartments and protected from hazards due to unintended temperature influences; ¶ (3) Be designed to prevent significant loss of stored fuel from any vent system due to fuel transfer between fuel storage or supply systems, or under likely operating conditions; ¶ (4) Provide fuel for at least one-half hour of operation at maximum continuous power or thrust; and ¶ (5) Be capable of jettisoning fuel safely if required for landing.	(b) Each fuel storage system must— ¶ (1) Withstand the loads under likely operating conditions without failure; ¶ (2) Be isolated from personnel compartments and protected from hazards due to unintended temperature influences; ¶ (3) Be designed to prevent significant loss of stored fuel from any vent system due to fuel transfer between fuel storage or supply systems, or under likely operating conditions; and ¶ (4) Be capable of jettisoning fuel safely if required for landing.	(F39)–Deleted §23.2430 (b) (4) for consistency with §25, §27 and §29.			REVISED	N/A or revised for battery bay?			
		(c) Each fuel storage refilling or recharging system must be designed to—(1) Prevent improper refilling or recharging; ¶ (2) Prevent contamination of the fuel stored during likely operating conditions; and ¶ (3) Prevent the occurrence of any hazard to the airplane or to persons during refilling or recharging.	NO CHANGE				REMOVED	N/A or revised for battery bay?			
	§23.2435 Powerplant induction and exhaust systems.	(a) The air induction system for each powerplant or auxiliary power unit and their accessories must—(1) Supply the air required by that powerplant or auxiliary power unit and its accessories under likely operating conditions; ¶ (2) Be designed to prevent likely hazards in the event of fire or backfire; ¶ (3) Minimize the ingestion of foreign matter; and ¶ (4) Provide an alternate intake if blockage of the primary intake is likely.	NO CHANGE		ASTM F3264-17, section 8.8	8.8 Powerplant Induction, Exhaust, and Support Systems: 8.8.1 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 8.8.2 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation	UNCHANGED				
		(b) The exhaust system, including exhaust heat exchangers for each powerplant or auxiliary power unit, must—(1) Provide a means to safely discharge potential harmful material; and ¶ (2) Be designed to prevent likely hazards from heat, corrosion, or blockage.	NO CHANGE				UNCHANGED				
	§23.2440 Powerplant fire protection.	(a) A powerplant, auxiliary power unit, or combustion heater that includes a flammable fluid and an ignition source for that fluid must be installed in a designated fire zone.	NO CHANGE		ASTM F3264-17, section 8.9, combined with the changes in the following table {…}	8.9 Powerplant Installation Fire Protection: 8.9.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 8.9.2 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 8.9.3 F3064/ F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems ¶ 8.9.4 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation along with {ASTM Section 8.9, F3264-17, 8.9 through 8.9.2: Same as published in F3264-17. Renumber 8.9.3 to 8.9.4. Renumber 8.9.4 to 8.9.5 and change to, "F3066/ F3066M-15 Standard Specification for Powerplant Systems Specific Hazard Mitigation." And add FAA 8.9.3:"F3063/F3063M-16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes."}	UNCHANGED				
		(b) Each designated fire zone must provide a means to isolate and mitigate hazards to the airplane in the event of fire or overheat within the zone.	NO CHANGE				UNCHANGED				
		(c) Each component, line, fitting, and control subject to fire conditions must— ¶ (1) Be designed and located to prevent hazards resulting from a fire, including any located adjacent to a designated fire zone that may be affected by fire within that zone; ¶ (2) Be fire resistant if carrying flammable fluids, gas, or air or required to operate in event of a fire; and ¶ (3) Be fireproof or enclosed by a fire proof shield if storing concentrated flammable fluids.	NO CHANGE				UNCHANGED				
		(d) The applicant must provide a means to prevent hazardous quantities of flammable fluids from flowing into, within or through each designated fire zone. This means must—(1) Not restrict flow or limit operation of any remaining powerplant or auxiliary power unit, or equipment necessary for safety; ¶ (2) Prevent inadvertent operation; and ¶ (3) Be located outside the fire zone unless an equal degree of safety is provided with a means inside the fire zone.	NO CHANGE				UNCHANGED				
		(e) A means to ensure the prompt detection of fire must be provided for each designated fire zone—(1) On a multiengine airplane where detection will mitigate likely hazards to the airplane; or ¶ (2) That contains a fire extinguisher.	NO CHANGE				UNCHANGED				

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		(f) A means to extinguish fire within a fire zone, except a combustion heater fire zone, must be provided for— (1) Any fire zone located outside the pilot's view; ¶ (2) Any fire zone embedded within the fuselage, which must also include a redundant means to extinguish fire; and ¶ (3) Any fire zone on a level 4 airplane.	NO CHANGE				UNCHANGED				
FAR 23, Airworthiness Standards: Normal Category Airplanes, F, Equipment											
	§23.2500 Airplane level systems requirements.	This section applies generally to installed equipment and systems unless a section of this part imposes requirements for a specific piece of equipment, system, or systems.	NO CHANGE		ASTM F3264-17, section 9.1	9.1 Systems and Equipment Function and Safety Requirements: 9.1.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.1.1.1 F3230 – 17 Standard Practice for Safety Assessments of Systems and Equipment in Small Aircraft ¶ 9.1.1.2 F3231/F3231M – 17 Standard Specification for Electrical Systems in Small Aircraft ¶ (a) F3235 – 17a Standard Specification for Aircraft Storage Batteries ¶ 9.1.1.3 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 9.1.1.4 F3233/F3233M – 17 Standard Specification for Instrumentation in Small Aircraft ¶ (a) F3229/F3229M – 17 Standard Practice for Static Pressure System Tests in Small Aircraft ¶ 9.1.2 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems ¶ 9.1.3 F3066/F3066M – 15 Standard Specification for Powerplant Systems Specific Hazard Mitigation ¶ 9.1.4 F3117 – 15 Standard Specification for Crew Interface in Aircraft	UNCHANGED	EXTRACT THIS SUBPART FROM "Power and Command IPT"			
		(a) The equipment and systems required for an airplane to operate safely in the kinds of operations for which certification is requested (Day VFR, Night VFR, IFR) must be designed and installed to— (1) Meet the level of safety applicable to the certification and performance level of the airplane; and (2) Perform their intended function throughout the operating and environmental limits for which the airplane is certificated.	NO CHANGE				UNCHANGED				
		(b) The systems and equipment not covered by paragraph (a), considered separately and in relation to other systems, must be designed and installed so their operation does not have an adverse effect on the airplane or its occupants.	NO CHANGE				UNCHANGED				
	§23.2505 Function and installation.	When installed, each item of equipment must function as intended.	NO CHANGE		ASTM F3264-17, section 9.2	9.2 Equipment Function and Installation Requirements: 9.2.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.2.1.1 F3230 – 17 Standard Practice for Safety Assessments of Systems and Equipment in Small Aircraft ¶ 9.2.1.2 F3231/F3231M – 17 Standard Specification for Electrical Systems in Small Aircraft ¶ (a) F3235 – 17a Standard Specification for Aircraft Storage Batteries ¶ 9.2.1.3 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 9.2.1.4 F3233/F3233M – 17 Standard Specification for Instrumentation in Small Aircraft ¶ 9.2.2 F3117 – 15 Standard Specification for Crew Interface in Aircraft	UNCHANGED				
	§23.2510 Equipment, systems, and installations.	For any airplane system or equipment whose failure or abnormal operation has not been specifically addressed by another requirement in this part, the applicant must design and install each system and equipment, such that there is a logical and acceptable inverse relationship between the average probability and the severity of failure conditions to the extent that:	NO CHANGE		ASTM F3264-17, section 9.3	9.3 Equipment, Systems, and Installation: 9.3.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.3.1.1 F3230 – 17 Standard Practice for Safety Assessments of Systems and Equipment in Small Aircraft ¶ 9.3.1.2 F3231/F3231M – 17 Standard Specification for Electrical Systems in Small Aircraft ¶ (a) F3235 – 17a Standard Specification for Aircraft Storage Batteries ¶ 9.3.1.3 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 9.3.1.4 F3233/F3233M – 17 Standard Specification for Instrumentation in Small Aircraft ¶ (a) F3229/F3229M – 17 Standard Practice for Static Pressure System Tests in Small Aircraft ¶ 9.3.1.5 F3227/F3227M – 17 Standard Specification for Environmental Systems in Small Aircraft	UNCHANGED				
		(a) Each catastrophic failure condition is extremely improbable;	NO CHANGE				UNCHANGED				
		(b) Each hazardous failure condition is extremely remote; and	NO CHANGE				UNCHANGED				
		(c) Each major failure condition is remote.	NO CHANGE				UNCHANGED				
	§23.2515 Electrical and electronic system lightning protection.	An airplane approved for IFR operations must meet the following requirements, unless an applicant shows that exposure to lightning is unlikely:	Incorporated introductory sentence into (a) & (b), as appropriate.	(F41)–Revised §23.2515 to account for configurations with electronic flight and propulsion control systems.	ASTM F3264-17, section 9.4	9.4 Electrical and Electronic System Lightning Protection: 9.4.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft	REVISED				
		(a) Each electrical or electronic system that performs a function, the failure of which would prevent the continued safe flight and landing of the airplane, must be designed and installed such that— (1) The function at the airplane level is not adversely affected during and after the time the airplane is exposed to lightning; and (2) The system recovers normal operation of that function in a timely manner after the airplane is exposed to lightning unless the system's recovery conflicts with other operational or functional requirements of the system.	(a) [For level 1 aircraft approved for IFR and all level 2, 3 and 4 aircraft,] (F41) each electrical or electronic system that performs a function, the failure of which would prevent the continued safe flight and landing of the airplane, must be designed and installed such that — ¶ (1) The function at the airplane level is not adversely affected during and after the time the airplane is exposed to lightning; and ¶ (2) The system recovers normal operation of that function in a timely manner after the airplane is exposed to lightning unless the system's recovery conflicts with other operational or functional requirements of the system.	(F41)–Revised §23.2515 to account for configurations with electronic flight and propulsion control systems.			REVISED	Propulsion PMAD protection; Flt Ctrl System;			
		(b) Each electrical and electronic system that performs a function, the failure of which would significantly reduce the capability of the airplane or the ability of the flightcrew to respond to an adverse operating condition, must be designed and installed such that the system recovers normal operation of that function in a timely manner after the airplane is exposed to lightning.	(b) [For an aircraft approved for IFR,] (F41) each electrical and electronic system that performs a function, the failure of which would significantly reduce the capability of the airplane or the ability of the flightcrew to respond to an adverse operating condition, must be designed and installed such that the system recovers normal operation of that function in a timely manner after the airplane is exposed to lightning.	(F41)–Revised §23.2515 to account for configurations with electronic flight and propulsion control systems.			REVISED	Propulsion PMAD protection; Flt Ctrl System;			

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	§23.2520 High-intensity Radiated Fields (HIRF) protection.	(a) Each electrical and electronic systems that perform a function, the failure of which would prevent the continued safe flight and landing of the airplane, must be designed and installed such that— (1) The function at the airplane level is not adversely affected during and after the time the airplane is exposed to the HIRF environment; and (2) The system recovers normal operation of that function in a timely manner after the airplane is exposed to the HIRF environment, unless the system's recovery conflicts with other operational or functional requirements of the system.	NO CHANGE		ASTM F3264-17, section 9.5	9.5 High Intensity Radiated Fields (HIRF) Protection: 9.5.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.5.1.1 F3236 – 17 Standard Specification for High Intensity Radiated Field (HIRF) Protection in Small Aircraft	TAILORED	CDR Day 1, page 145–NASA Electric Aircraft Testbed (NEAT)-EMI Tests ¶ CDR Day 1, page 147–Test & Verification	Parallel Power Cable, SAE AS50881 (reduced inductance & radiated noise); NEAT 125KW motor inverter & DO160 LISN for RF measurement ¶ NTS labs (CEPT-007)		
		(b) For airplanes approved for IFR operations, each electrical and electronic system that performs a function, the failure of which would significantly reduce the capability of the airplane or the ability of the flightcrew to respond to an adverse operating condition, must be designed and installed such that the system recovers normal operation of that function in a timely manner after the airplane is exposed to the HIRF environment.	NO CHANGE				UNCHANGED				
	§23.2525 System power generation, storage, and distribution.	The power generation, storage, and distribution for any system must be designed and installed to—	NO CHANGE		ASTM F3264-17, section 9.6	9.6 System Power Generation, Storage, and Distribution: 9.6.1 F2490 – 05 (2013) Standard Guide for Aircraft Electrical Load and Power Source Capacity Analysis ¶ 9.6.2 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.6.2.1 F3231/F3231M – 17 Standard Specification for Electrical Systems in Small Aircraft ¶ (a) F3235 – 17a Standard Specification for Aircraft Storage Batteries ¶ 9.6.2.2 F3233/F3233M – 17 Standard Specification for Instrumentation in Small Aircraft ¶ 9.6.3 F3117 – 15 Standard Specification for Crew Interface in Aircraft	REVISED	POWER ARCHITECTURE: Batteries: Electric Power Systems ¶ 16125 Gale Ave ¶ City of Industry, CA 91745. INTEGRATED POWER AND CONTROL IPT, Sean Clarke.			
		(a) Supply the power required for operation of connected loads during all intended operating conditions;	NO CHANGE				UNCHANGED				
		(b) Ensure no single failure or malfunction of any one power supply, distribution system, or other utilization system will prevent the system from supplying the essential loads required for continued safe flight and landing; and	NO CHANGE				UNCHANGED				
		(c) Have enough capacity, if the primary source fails, to supply essential loads, including non-continuous essential loads for the time needed to complete the function required for continued safe flight and landing.	NO CHANGE				UNCHANGED				
	§23.2530 External and cockpit lighting.	(a) The applicant must design and install all lights to minimize any adverse effects on the performance of flightcrew duties.	NO CHANGE		ASTM F3264-17, section 9.7	9.7 External and Cockpit Lighting: 9.7.1 F3061/ F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.7.1.1 F3233/F3233M – 17 Standard Specification for Instrumentation in Small Aircraft ¶ 9.7.1.2 F3234/F3234M – 17 Standard Specification for Exterior Lighting in Small Aircraft ¶ 9.7.2 F3117 – 15 Standard Specification for Crew Interface in Aircraft	UNCHANGED				
		(b) Any position and anti-collision lights, if required by part 91 of this chapter, must have the intensities, flash rate, colors, fields of coverage, and other characteristics to provide sufficient time for another aircraft to avoid a collision.	NO CHANGE				UNCHANGED				
		(c) Any position lights, if required by part 91 of this chapter, must include a red light on the left side of the airplane, a green light on the right side of the airplane, spaced laterally as far apart as practicable, and a white light facing aft, located on an aft portion of the airplane or on the wing tips.	NO CHANGE				UNCHANGED				
		(d) Any taxi and landing lights must be designed and installed so they provide sufficient light for night operations.	NO CHANGE				UNCHANGED				
		(e) For seaplanes or amphibian airplanes, riding lights must provide a white light visible in clear atmospheric conditions.	NO CHANGE				UNCHANGED				
	§23.2535 Safety equipment.	Safety and survival equipment, required by the operating rules of this chapter, must be reliable, readily accessible, easily identifiable, and clearly marked to identify its method of operation.	NO CHANGE		ASTM F3264-17, section 9.8	9.8 Safety Equipment: 9.8.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft	UNCHANGED				
	§23.2540 Flight in icing conditions.	An applicant who requests certification for flight in icing conditions defined in part 1 of appendix C to part 25 of this chapter, or an applicant who requests certification for flight in these icing conditions and any additional atmospheric icing conditions, must show the following in the icing conditions for which certification is requested:	An applicant who requests certification for flight in icing conditions must show the following in the icing conditions for which certification is requested: (F42)	(F42)–Revised §23.2540 to allow for future means of complying with flight in icing.	ASTM F3264-17, section 9.9	9.9 Flight in Icing Conditions: 9.9.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.9.1.1 F3233/F3233M – 17 Standard Specification for Instrumentation in Small Aircraft ¶ 9.9.2 F3120/F3120M – 15 Standard Specification for Ice Protection for General Aviation Aircraft	REVISED	RESTRICTED FROM OPN, per TCDS A62CE	RESTRICTED FROM OPN, per TCDS A62CE	RESTRICTED FROM OPN, per TCDS A62CE	RESTRICTED FROM OPN, per TCDS A62CE
		(a) The ice protection system provides for safe operation.	NO CHANGE				UNCHANGED				
		(b) The airplane design must provide protection from stalling when the autopilot is operating.	(b) The airplane design must provide protection from [slowing to less than the minimum safe speed] (F43) when the autopilot is operating.	(F43)–Revised §23.2540 (b) to reflect the change from stall speed to minimum flight speed.			REVISED				
	§23.2545 Pressurized systems elements.	Pressurized systems must withstand appropriate proof and burst pressures.	NO CHANGE		ASTM F3264-17, section 9.10	9.10 Pressurized System Elements: 9.10.1 F3061/ F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 9.10.2 F3229/F3229M – 17 Standard Practice for Static Pressure System Tests in Small Aircraft	UNCHANGED				
	§23.2550 Equipment containing high-energy rotors.	Equipment containing high-energy rotors must be designed or installed to protect the occupants and airplane from uncontained fragments.	§23.2550 Deleted. (F44)	(F44)–Deleted §23.2550 as its intent is covered in §23.2250 (c) and for harmonization.	ASTM F3061/ F3061M-17, section 10.9	…to be entered… 9.11 Equipment Containing High-Energy Rotors: 9.11.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft	REVISED				
FAR 23, Airworthiness Standards: Normal Category Airplanes, G, Flightcrew Interface and Other Information											

Subpart	Section	Note	FAA Future Advanced Safety Team (FAST) Gap Analysis to New Technology and FAR 23 ("FAST language recommendation rev0.docx", email from NASA to HSAC, dated 11 Sep 2018)	Associated FAST Footnote	Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA)	Citation of the Means of Compliance in relevant ASTM Standard, Combined with Changes as Noted in {braces} from FAA NOA	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§23.2600 Flightcrew interface.	(a) The pilot compartment, its equipment, and its arrangement to include pilot view, must allow each pilot to perform his or her duties, including taxi, takeoff, climb, cruise, descent, approach, landing, and perform any maneuvers within the operating envelope of the airplane, without excessive concentration, skill, alertness, or fatigue.	(a) The pilot compartment, its equipment, and its arrangement to include pilot view, must allow each pilot to perform [their duties for all phases and modes of flight] (F46) and perform any maneuvers within the operating envelope of the airplane, without excessive concentration, skill, alertness, or fatigue.	(F46)–Revised §23.2600 (a) to reflect applicable modes and phases of flight.	ASTM F3264-17, section 10.1, combined with the changes in the following table {…}	10.1 Flightcrew Compartment Interface: 10.1.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 10.1.1.1 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 10.1.2 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 10.1.3 F3063/F3063M – 16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes ¶ 10.1.4 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems ¶ 10.1.5 F3117 – 15 Standard Specification for Crew Interface in Aircraft along with {ASTM Section 10.1, F3264-17 10.1.1 through 10.1.5: Same as published in F3264-17. Add an FAA-accepted means of compliance for the windshield luminous transmittance aspects of §23.2600, such as the provisions of § 23.775(e), amendment 23-49. And add an FAA-accepted means of compliance for the pilot compartment view with formation of fog or frost aspects of §23.2600, such as the provisions of § 23.773(b), amendment 23-45.}	REVISED	ORD, Opns Proc's	ORD, Opns Proc's	ORD, Opns Proc's	ORD, Opns Proc's
		(b) The applicant must install flight, navigation, surveillance, and powerplant controls and displays so qualified flightcrew can monitor and perform defined tasks associated with the intended functions of systems and equipment. The system and equipment design must minimize flightcrew errors, which could result in additional hazards.	(b) The applicant must install flight, navigation, surveillance, and powerplant controls and displays [, as applicable,] (F47) so qualified flightcrew can monitor and perform defined tasks associated with the intended functions of systems and equipment. The system and equipment design must minimize flightcrew errors, which could result in additional hazards.	(F47)–Revised §23.2600 (b) to accommodate non-traditional pilot/aircraft interfaces.			REVISED				
		(c) For level 4 airplanes, the flightcrew interface design must allow for continued safe flight and landing after the loss of vision through any one of the windshield panels.	REMOVED	(F45)–Deleted §23.2600 (c) as it is better addressed by MOC.			REMOVED				
	§23.2605 Installation and operation.	(a) Each item of installed equipment related to the flightcrew interface must be labelled, if applicable, as to it identification, function, or operating limitations, or any combination of these factors.	NO CHANGE		ASTM F3264-17, section 10.2	10.2 Installation and Operation Information: 10.2.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 10.2.1.1 F3227/F3227M – 17 Standard Specification for Environmental Systems in Small Aircraft ¶ 10.2.1.2 F3231/F3231M – 17 Standard Specification for Electrical Systems in Small Aircraft ¶ 10.2.1.3 F3232/F3232M – 17 Standard Specification for Flight Controls in Small Aircraft ¶ 10.2.1.4 F3233/F3233M – 17 Standard Specification for Instrumentation in Small Aircraft ¶ 10.2.2 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 10.2.3 F3063/F3063M – 16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes ¶ 10.2.4 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems ¶ 10.2.5 F3117 – 15 Standard Specification for Crew Interface in Aircraft ¶ 10.2.6 F3120/F3120M – 15 Standard Specification for Ice Protection for General Aviation	UNCHANGED				
		(b) There must be a discernible means of providing system operating parameters required to operate the airplane, including warnings, cautions, and normal indications to the responsible crewmember.	NO CHANGE				UNCHANGED				
		(c) Information concerning an unsafe system operating condition must be provided in a timely manner to the crewmember responsible for taking corrective action. The information must be clear enough to avoid likely crewmember errors.	NO CHANGE				UNCHANGED				
	§23.2610 Instrument markings, control markings, and placards.	(a) Each airplane must display in a conspicuous manner any placard and instrument marking necessary for operation.	NO CHANGE		ASTM F3264-17, section 10.3	10.3 Instrument Markings, Control Markings, and Placards: 10.3.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 10.3.2 F3063/F3063M – 16a Standard Specification for Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes ¶ 10.3.3 F3117 – 15 Standard Specification for Crew Interface in Aircraft	UNCHANGED				
		(b) The design must clearly indicate the function of each cockpit control, other than primary flight controls.	NO CHANGE				UNCHANGED				
		(c) The applicant must include instrument marking and placard information in the Airplane Flight Manual.	NO CHANGE				UNCHANGED				
	§23.2615 Flight, navigation, and powerplant instruments.	(a) Installed systems must provide the flightcrew member who sets or monitors parameters for the flight, navigation, and powerplant, the information necessary to do so during each phase of flight. This information must— (1) Be presented in a manner that the crewmember can monitor the parameter and determine trends, as needed, to operate the airplane; and (2) Include limitations, unless the limitation cannot be exceeded in all intended operations.	(a) Installed systems must provide the flightcrew member who sets or monitors parameters for the flight, navigation, and powerplant, the information necessary to do so during each phase [and mode] (F48) of flight. This information must— ¶ (1) Be presented in a manner that the crewmember can monitor the parameter and determine trends, as needed, to operate the airplane; and ¶ (2) Include limitations, unless the limitation cannot be exceeded in all intended operations.	(F48)–Revised §23.2615 (a) to reflect both phases and modes of flight.	ASTM F3264-17, section 10.4, combined with the changes in the following table {…}	10.4 Flight, Navigation, and Powerplant Instruments: 10.4.1 F3061/F3061M – 17 Standard Specification for Systems and Equipment in Small Aircraft ¶ 10.4.2 F3062/F3062M – 16 Standard Specification for Installation of Powerplant Systems ¶ 10.4.3 F3064/F3064M – 15 Standard Specification for Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems along with {ASTM Section 6, F3064/F3064M-15, An FAA-accepted means of compliance for the powerplant instruments aspects of §23.2615, such as the provisions of §23.1305, amendment 23-52.}	REVISED	REQ-CEPT-005 Instrumentation Subsystem Requirements	REQ-CEPT-005 Instrumentation Subsystem Requirements	REQ-CEPT-005 Instrumentation Subsystem Requirements	REQ-CEPT-005 Instrumentation Subsystem Requirements
		(b) Indication systems that integrate the display of flight or powerplant parameters to operate the airplane or are required by the operating rules of this chapter must — (1) Not inhibit the primary display of flight or powerplant parameters needed by any flightcrew member in any normal mode of operation; and (2) In combination with other systems, be designed and installed so information essential for continued safe flight and landing will be available to the flightcrew in a timely manner after any single failure or probable combination of failures.	(b) Indication systems that integrate the display of flight or powerplant parameters to operate the airplane or are required by the operating rules of this chapter must — ¶ (1) Not inhibit the primary display of flight or powerplant parameters needed by any flightcrew member in any normal mode of operation; and ¶ (2) In combination with other systems, be designed and installed so information essential for continued safe flight and landing will be available to the flightcrew in a timely manner after any single failure [or malfunction] or probable combination of failures [and/or malfunctions]. (F49)	(F49)–Revised §23.2615 (b) (2) to clarify applicability.			REVISED	REQ-CEPT-005 Instrumentation Subsystem Requirements	REQ-CEPT-005 Instrumentation Subsystem Requirements	REQ-CEPT-005 Instrumentation Subsystem Requirements	REQ-CEPT-005 Instrumentation Subsystem Requirements

Subpart	Section	Note	FAA Future Advanced Safety Team (FAST) Gap Analysis to New Technology and FAR 23 ("FAST language recommendation rev0.docx", email from NASA to HSAC, dated 11 Sep 2018)	Associated FAST Footnote	Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA)	Citation of the Means of Compliance in relevant ASTM Standard, Combined with Changes as Noted in {braces} from FAA NOA	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§23.2620 Airplane flight manual.	The applicant must provide an Airplane Flight Manual that must be delivered with each airplane.	[The applicant must provide an Airplane Flight Manual that must be delivered with each airplane.		ASTM F3264-17, sections 5.15 and 10.5	5.15 Operating Limitations: 5.15.1 F3174/F3174M – 15 Standard Specification for Establishing Operating Limitations and Information for Aeroplanes ¶ 10.5 Airplane Flight Manual: 10.5.1 F3117 – 15 Standard Specification for Crew Interface in Aircraft ¶ 10.5.2 F3174/F3174M – 15 Standard Specification for Establishing Operating Limitations and Information for Aeroplanes	TAILORED	ORD Opns Proc's	ORD Opns Proc's	ORD Opns Proc's	ORD Opns Proc's
		(a) The Airplane Flight Manual must contain the following information— (1) Airplane operating limitations; (2) Airplane operating procedures; (3) Performance information; (4) Loading information; and (5) Other information that is necessary for safe operation because of design, operating, or handling characteristics.	(a) The Airplane Flight Manual must contain the following information— ¶ (1) Airplane operating limitations; ¶ (2) Airplane operating procedures; ¶ (3) Performance information; ¶ (4) Loading information; and ¶ (5) Other information that is necessary for safe operation because of design, operating, or handling characteristics.				TAILORED	ORD Opns Proc's	ORD Opns Proc's	ORD Opns Proc's	ORD Opns Proc's
		(b) The following sections of the Airplane Flight Manual must be approved by the FAA in a manner specified by the administrator— (1) For low-speed, level 1 and 2 airplanes, those portions of the Airplane Flight Manual containing the information specified in paragraph (a)(1) of this section; and (2) For high-speed level 1 and 2 airplanes and all level 3 and 4 airplanes, those portions of the Airplane Flight Manual containing the information specified in paragraphs (a)(1) thru (a)(4) of this section.	(b) The Airplane Flight Manual must be approved by the FAA in a manner specified by the Administrator.] (F50)	(F50)–Revised §23.2620 to remove (b) (1) and (b) (2) which may be reflected in MOC.			REVISED				
Appendix A to Part 23—Instructions for Continued Airworthiness						10.6 Instructions for Continued Airworthiness: 10.6.1 F3120/F3120M – 15 Standard Specification for Ice Protection for General Aviation ¶ 10.6.2 F3117 – 15 Standard Specification for Crew Interface in Aircraft	UNCHANGED				
	A23.1 General										
		(a) This appendix specifies requirements for the preparation of Instructions for Continued Airworthiness as required by this part.									
		(b) The Instructions for Continued Airworthiness for each airplane must include the Instructions for Continued Airworthiness for each engine and propeller (hereinafter designated "products"), for each appliance required by this chapter, and any required information relating to the interface of those appliances and products with the airplane. If Instructions for Continued Airworthiness are not supplied by the manufacturer of an appliance or product installed in the airplane, the Instructions for Continued Airworthiness for the airplane must include the information essential to the continued airworthiness of the airplane.									
		(c) The applicant must submit to the FAA a program to show how changes to the Instructions for Continued Airworthiness made by the applicant or by the manufacturers of products and appliances installed in the airplane will be distributed.									
	A23.2 Format										
		(a) The Instructions for Continued Airworthiness must be in the form of a manual or manuals as appropriate for the quantity of data to be provided.									
		(b) The format of the manual or manuals must provide for a practical arrangement.									
	A23.3 Content										
		The contents of the manual or manuals must be prepared in the English language. The Instructions for Continued Airworthiness must contain the following manuals or sections and information:									
		(a) Airplane maintenance manual or section. ¶ (1) Introduction information that includes an explanation of the airplane's features and data to the extent necessary for maintenance or preventive maintenance. ¶ (2) A description of the airplane and its systems and installations including its engines, propellers, and appliances. ¶ (3) Basic control and operation information describing how the airplane components and systems are controlled and how they operate, including any special procedures and limitations that apply. ¶ (4) Servicing information that covers details regarding servicing points, capacities of tanks, reservoirs, types of fluids to be used, pressures applicable to the various systems, location of access panels for inspection and servicing, locations of lubrication points, lubricants to be used, equipment required for servicing, tow instructions and limitations, mooring, jacking, and leveling information.									

Subpart	Section	Note	FAA Future Advanced Safety Team (FAST) Gap Analysis to New Technology and FAR 23 ("FAST language recommendation rev0.docx", email from NASA to HSAC, dated 11 Sep 2018)	Associated FAST Footnote	Accepted Means of Compliance; Airworthiness Standards: Normal Category Airplanes (Federal Register, Vol. 83, No. 92/ Friday, May 11, 2018/ Rules and Regulations, Notice No. 23–18–01–NOA)	Citation of the Means of Compliance in relevant ASTM Standard, Combined with Changes as Noted in {braces} from FAA NOA	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
		(b) Maintenance Instructions. ¶ (1) Scheduling information for each part of the airplane and its engines, auxiliary power units, propellers, accessories, instruments, and equipment that provides the recommended periods at which they should be cleaned, inspected, adjusted, tested, and lubricated, and the degree of inspection, the applicable wear tolerances, and work recommended at these periods. However, the applicant may refer to an accessory, instrument, or equipment manufacturer as the source of this information if the applicant shows that the item has an exceptionally high degree of complexity requiring specialized maintenance techniques, test equipment, or expertise. The recommended overhaul periods and necessary cross reference to the Airworthiness Limitations section of the manual must also be included. In addition, the applicant must include an inspection program that includes the frequency and extent of the inspections necessary to provide for the continued airworthiness of the airplane. ¶ (2) Troubleshooting information describing probable malfunctions, how to recognize those malfunctions, and the remedial action for those malfunctions. ¶ (3) Information describing the order and method of removing and replacing products and parts with any necessary precautions to be taken. ¶ (4) Other general procedural instructions including procedures for system testing during ground running, symmetry checks, weighing and determining the center of gravity, lifting and shoring, and storage limitations.									
		(c) Diagrams of structural access plates and information needed to gain access for inspections when access plates are not provided.									
		(d) Details for the application of special inspection techniques including radiographic and ultrasonic testing where such processes are specified by the applicant.									
		(e) Information needed to apply protective treatments to the structure after inspection.									
		(f) All data relative to structural fasteners such as identification, discard recommendations, and torque values.									
		(g) A list of special tools needed.									
		(h) In addition, for level 4 airplanes, the following information must be furnished— ¶ (1) Electrical loads applicable to the various systems; ¶ (2) Methods of balancing control surfaces; ¶ (3) Identification of primary and secondary structures; and ¶ (4) Special repair methods applicable to the airplane.									
	A23.4 Airworthiness limitations section.										
		The Instructions for Continued Airworthiness must contain a section titled Airworthiness Limitations that is segregated and clearly distinguishable from the rest of the document. This section must set forth each mandatory replacement time, structural inspection interval, and related structural inspection procedure required for type certification. If the Instructions for Continued Airworthiness consist of multiple documents, the section required by this paragraph must be included in the principal manual. This section must contain a legible statement in a prominent location that reads "The Airworthiness Limitations section is FAA approved and specifies maintenance required under §§43.16 and 91.403 of Title 14 of the Code of Federal Regulations unless an alternative program has been FAA approved."									

Table A-2, Proposed Compliance Matrix (PCM) for 14 CFR 33 as Test Matrix for X-57

Subpart	Section	Note	*ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)*	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
14 CFR 33, General, Design and Reciprocating Aircraft Engines, Dated 3 October 2018, (https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt14.1.33)									
FAR 33, Airworthiness Standards: Aircraft Engines, Subpart A—General									
	§33.1 Applicability.	… prescribes airworthiness standards for the issue of type certificates and changes to those certificates, for aircraft engines.			UNCHANGED				
	§33.3 General.				UNCHANGED				
	§33.4 Instructions for Continued Airworthiness.	… must prepare Instructions for Continued Airworthiness in accordance with appendix A to this part…	5.1 Instructions for Continued Airworthiness	5.1.1 Instructions for Continued Airworthiness must be prepared. The instructions may be incomplete at the time of certification or approval if: ¶ 5.1.1.1 a program exists to ensure their completion prior to delivery of the first aircraft with the EPU installed, or ¶ 5.1.1.2 upon CAA approval for the aircraft with the EPU installed, whichever occurs later. ¶ 5.1.2 A maintenance manual shall be provided that defines maintenance requirements for the continued airworthiness of the EPU, such as periodic installed maintenance, major inspections, repairs, replacement or overhaul intervals, and any other maintenance limitations including limited life components requiring replacement between overhaul intervals. Maintenance requirements for the continued airworthiness of the EPU also includes special equipment or testing required to ensure the electrical propulsion system is safe to continued operation. ¶ 5.1.3 If applicable, an overhaul manual that provides instructions for disassembling, replacing or overhauling components identified in the manual for such, in order to return the EPU to airworthy condition that is safe for operation until the next major overhaul. ¶ 5.1.4 Updates to the Instructions for Continued Airworthiness must be made available by the EPU manufacturer or other responsible party such that those Instructions remain current.	UNCHANGED				

Subpart	Section	Note	*ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)*	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§33.5 Instruction manual for installing and operating the engine.	… prior to the issuance of the type certificate, and to the owner at the time of delivery of the engine, approved instructions for installing and operating the engine…	5.2 Instruction manual for installing and operating the EPU	5.2.1 Instructions for installing and operating the EPU must be made available to the CAA as part of the certification process and to the customer at the time of delivery of the EPU. The instructions must include directly or by reference to appropriate documentation at least the following: ¶ 5.2.1.1 Installation instructions ¶ Note: Coordination is recommended between the EPU manufacturer and the installer. However, if the installer is not identified at the time of EPU design, the following aspects still need definition in the installation instructions. ¶ 5.2.1.1.1 Note: Coordination is recommended between the EPU manufacturer and the installer. However, if the installer is not identified at the time of EPU design, the following aspects still need definition in the installation instructions. ¶ 5.2.1.1.2 An outline drawing of the EPU including overall dimensions. ¶ 5.2.1.1.3 A definition of the physical and functional interfaces, of all elements of the EPU, with the aircraft and aircraft equipment, including the propeller or fan when applicable. Including the location and description of EPU connections for attachment of accessories, wires, cables, cooling ducts, cowling and any other equipment attached to the EPU. ¶ 5.2.1.1.4 Where an EPU system relies on components that are not part of the EPU type design, the interface conditions and reliability requirements for those components, as used in the safety analysis, must be specified in the EPU installation instructions. If reliability values used in the safety analysis are based on assumptions, these assumed values must be specified in the EPU installation instructions. Requirements for mitigation means, that are not part of the EPU, must be specified in the installation and operation instructions. ¶ 5.2.1.1.5 A list of the instruments necessary for the control and operation of the EPU, including the overall limits of accuracy and transient response requirements, must be stated in a manner that allows the satisfactory nature of instruments as installed to be determined. ¶ Note: "instrument" is used to refer to any device necessary to measure EPU parameters and convey them to the appropriate decision-making center, be that a pilot or software-based control. ¶ 5.2.1.1.6 The limits on environmental conditions, including EMI, HIRF, and lightning, for which the EPU was designed and qualified. ¶ 5.2.1.2 Operation instructions. ¶ 5.2.1.2.1 The operating limitations established within the showing of compliance. ¶ 5.2.1.2.2 The power ratings and procedures for correcting for nonstandard atmosphere. ¶ 5.2.1.2.3 The recommended procedures, under normal and critical ambient conditions for— ¶ 5.2.1.2.3.1 Powering on; ¶ 5.2.1.2.3.2 Operating on the ground; ¶ 5.2.1.2.3.3 Operating during flight. ¶ 5.2.1.2.4 A description of the primary and all alternate modes, and any back-up system, together with any associated limitations, of the EPU control system and its interface with the aircraft systems, including the propeller or fan if these are integral with the EPU.	TAILORED				

Subpart	Section	Note	***ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)***	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§33.7 Engine ratings and operating limitations.	(a) … included in the engine certificate data sheet specified in §21.41 of this chapter, including ratings and limitations based on the operating conditions and information specified… and any other information found necessary for safe operation of the engine.	5.3 EPU operating limitations and ratings	5.3.1 Ratings and operating limitations are established by the Administrator and included in the product certificate data sheet, including ratings and limitations based on the operating conditions and information specified in this section, as applicable, and any other information found necessary for safe operation of the engine. ¶ 5.3.2 EPU operating limitations are established as applicable, including: 5.3.2.1 Maximum Transient rotor shaft overspeed and time, ¶ 5.3.2.2 Maximum Transient EPU overtorque and time, and number of overtorque occurrences ¶ 5.3.2.3 Maximum EPU overtorque and time ¶ 5.3.2.4 Electrical power, voltage, current, frequency and electrical power quality limits ¶ 5.3.2.5 Maximum rated temperature ¶ 5.3.2.6 Maximum and minimum continuous temperature, current, voltage ¶ 5.3.2.7 Vibration limits ¶ 5.3.2.8 Any other information necessary for safe operation of the EPU	TAILORED	CDR Day 1, page 148-152 {Is air cooled, direct drive; Operates in tandem with the MTV-7 propeller; Has an output torque of up to 255 N-m (~188 ft-lbf); Has a full-torque operating speed range of 1700-2700 rpm; Accommodates use of a slip ring and MTV speed controller}	Good: Sufficient torque: 340 N·m demonstrated ¶ Full current extrapolation: 390 N·m (287.6 ft-lbf) ¶ One-inverter capabilities fully demonstrated: 60% torque capable ¶ No heating problems • Bad: Distorted phase current: Non-linear inductance ¶ Inverter specifics		
		(b)(1) Horsepower or torque, r.p.m., manifold pressure, and time at critical pressure altitude and sea level pressure altitude for—(i) Rated maximum continuous power (relating to unsupercharged operation or to operation in each supercharger mode as applicable); and (ii) Rated takeoff power (relating to unsupercharged operation or to operation in each supercharger mode as applicable).		5.3.3 EPU ratings are established as applicable and based on the intended duty cycle and the assignment of ratings as defined below, including: ¶ 5.3.3.1 Power, torque, speed, and time for: 5.3.3.2 Rated maximum continuous power ¶ 5.3.3.3 Rated maximum temporary power and associated time limit	REVISED	(see above)			
		(b)(2) Fuel grade or specification.		NOT APPLICABLE OR X-REF TO ESS	REVISED	N/A			
		(b)(3) Oil grade or specification.		NOT APPLICABLE	REMOVED				
		(b)(4) Temperature of the—(i) Cylinder; (ii) Oil at the oil inlet; and (iii) Turbosupercharger turbine wheel inlet gas.		NOT APPLICABLE	REMOVED	N/A			
		(b)(5) Pressure of—(i) Fuel at the fuel inlet; and (ii) Oil at the main oil gallery.		NOT APPLICABLE OR X-REF TO ESS	REVISED	N/A			
		(b)(6) Accessory drive torque and overhang moment.		NOT APPLICABLE	REMOVED				
		(b)(7) Component life.		NOT APPLICABLE	REMOVED				
		(b)(8) Turbosupercharger turbine wheel r.p.m.		NOT APPLICABLE	REMOVED				
		(c) For turbine engines, ratings and operating limitations are established relating to the following: (1) Horsepower, torque, or thrust, r.p.m., gas temperature, and time for— (i) Rated maximum continuous power or thrust (augmented); (ii) Rated maximum continuous power or thrust (unaugmented); (iii) Rated takeoff power or thrust (augmented); (iv) Rated takeoff power or thrust (unaugmented); (v) Rated 30-minute OEI power; (vi) Rated 21⁄2 -minute OEI power; (vii) Rated continuous OEI power; and (viii) Rated 2-minute OEI Power; (ix) Rated 30-second OEI power; and (x) Auxiliary power unit (APU) mode of operation.		NOT APPLICABLE	REMOVED				
		(c)(2) Fuel designation or specification.		NOT APPLICABLE	REMOVED				
		(c)(3) Oil grade or specification.		NOT APPLICABLE	REMOVED				
		(c)(4) Hydraulic fluid specification.		NOT APPLICABLE	REMOVED				
		(c)(5) Temperature of— (i) Oil at a location specified by the applicant; ¶ (ii) Induction air at the inlet face of a supersonic engine, including steady state operation and transient over-temperature and time allowed; ¶ (iii) Hydraulic fluid of a supersonic engine; ¶ (iv) Fuel at a location specified by the applicant; and ¶ (v) External surfaces of the engine, if specified by the applicant.		NOT APPLICABLE	REMOVED				
		(c)(6) Pressure of— (i) Fuel at the fuel inlet; ¶ (ii) Oil at a location specified by the applicant; ¶ (iii) Induction air at the inlet face of a supersonic engine, including steady state operation and transient overpressure and time allowed; and ¶ (iv) Hydraulic fluid.		NOT APPLICABLE	REMOVED				

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		(c)(7) Accessory drive torque and overhang moment.		NOT APPLICABLE	REMOVED				
		(c)(8) Component life.		NOT APPLICABLE	REMOVED				
		(c)(9) Fuel filtration.		NOT APPLICABLE	REMOVED				
		(c)(10) Oil filtration.		NOT APPLICABLE	REMOVED				
		(c)(11) Bleed air.		NOT APPLICABLE	REMOVED				
		(c)(12) The number of start-stop stress cycles approved for each rotor disc and spacer.		NOT APPLICABLE	REMOVED				
		(c)(13) Inlet air distortion at the engine inlet.		NOT APPLICABLE	REMOVED				
		(c)(14) Transient rotor shaft overspeed r.p.m. and number of overspeed occurrences.		NOT APPLICABLE	REMOVED				
		(c)(15) Transient gas overtemperature and number of overtemperature occurrences.		NOT APPLICABLE	REMOVED				
		(c)(16) Transient engine overtorque and number of overtorque occurrences.		NOT APPLICABLE	REMOVED				
		(c)(17) Maximum engine overtorque for turbopropeller and turboshaft engines incorporating free power turbines.		NOT APPLICABLE	REMOVED				
		(c)(18) For engines to be used in supersonic aircraft engine rotor windmilling rotational r.p.m.		NOT APPLICABLE	REMOVED				
		(d) In determining the engine performance and operating limitations, the overall limits of accuracy of the engine control system and of the necessary instrumentation as defined in §33.5(a)(6) must be taken into account.		5.10.9 EPU control system electrical power ¶ NOTE: The historic basis for this section was to address the use of aircraft supplied electrical power to the engine control system in addition to the use of a dedicated electrical power source very typically an engine driven permanent magnet alternator (PMA). The aircraft supplied electrical power was most often used as a backup to the PMA electrical power.	REVISED				
	§33.8 Selection of engine power and thrust ratings.	(a) Requested engine power and thrust ratings must be selected by the applicant.		5.3.4 Duty Cycle ¶ 5.3.4.1 Declaration of duty - The intended duty cycle of the EPU sets the framework for establishment of the ratings. Ther are a number of typical duty cycles used for electric motors. (Ref IEC 60034-1) As the duty cycle combined with the rating at that duty cycle establishes the capability and the limits for the EPU use, the manufacturer declares the duty cycle or cycles. These can be based on the manufacturer's intended use for the EPU or may be based on the require duty cycle of the installer. As detailed in IEC 60034-1, multiple duties and their associated ratings may be established to address various operational conditions. The duty may be described by one of the following: ¶ 5.3.4.1.1 numerically, where the load does not vary or where it varies in a known manner; or ¶ 5.3.4.1.2 as a time sequence graph of the variable quantities; or ¶ 5.3.4.1.3 by selecting one of the typical duty types in accordance with IEC 60034-1, Paragraph 4 Duty, that is no less onerous than the expected duty.	REVISED	REQ-CEPT-004 Power Subsystem Requirments			

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		(b) Each selected rating must be for the lowest power or thrust that all engines of the same type may be expected to produce under the conditions used to determine that rating.		5.3.5 Assignment of rating - The rating, as defined by "set of rated values and operating conditions", shall be assigned by the manufacturer. In assigning the rating the manufacturer shall select one of the classes of rating defined as defined in the IEC 60034-1 Paragraph 5. Ratings. ¶ 5.3.6 Motor Rate Output - The rated output is the mechanical power available at the shaft and shall be expressed in watts (W). ¶ NOTE - It is the practice in some countries for the mechanical power available at the shafts of motors to be expressed in horsepower (1 h.p. is equivalent to 745,7 W; 1 ch (cheval or metric horsepower) is equivalent to 736 W). ¶ 5.3.7 Machines with more than one rating - For machines with more than one rating, the machine shall comply with this document in all respects at each rating. For multi-speed machines, a rating shall be assigned for each speed. When a rated quantity (output, voltage, speed, etc.) may assume several values or vary continuously within two limits, the rating shall be stated at these values or limits. ¶ 5.3.8 Each selected rating must be for the lowest power that all EPUs of the same type may be expected to produce under the conditions used to determine that rating at all times between overhaul periods or other maintenance.	TAILORED	REQ-CEPT-004 Power Subsystem Requirments			
FAR 33, Airworthiness Standards: Aircraft Engines, Subpart B—Design and Construction									
	§33.11 Applicability.	… prescribes the general design and construction requirements for reciprocating … aircraft engines							
	§33.15 Materials.	… Conform to approved specifications (such as industry or military specifications) that ensure their having the strength and other properties assumed in the design data.	5.4 Materials	5.4.1 The materials and components used in the EPU must be established on the basis of industry or military specification(s) for the intended design conditions of the system. The assumed design values of properties of materials must be suitably related to the minimum properties stated in the material specification. Otherwise, proof of suitability and durability acceptable to the CAA must be established on the basis of tests or other means that ensure their having the strength and other properties assumed in the design data. ¶ 5.4.2 Manufacturing methods and processes must be such as to produce sound structure and mechanisms, and electrical systems that retain the design properties under reasonable service conditions. This includes the effects of corrosion.	TAILORED				
	§33.17 Fire protection.	… design and construction of the engine and the materials used must minimize the probability of the occurrence and spread of fire during normal operation and failure conditions, and must minimize the effect of such a fire…	5.5 Fire protection	5.5.1 The design and construction of the EPU and the materials used must minimize the probability of the occurrence and spread of fire during normal operation and EPU failure conditions, and must minimize the effect of such a fire. EPU high voltage electrical wiring interconnect systems should be protected against arc-faults. Any non-protected electrical wiring interconnects should be analyzed to show that arc faults do not cause a hazardous condition. If flammable materials are used or if arcing is probable in the EPU then this constitutes the need for definition of a fire zone on the aircraft level and should be stated as part of the installation instructions. All fire zone protections must be employed.	TAILORED				
	§33.19 Durability.	(a) Engine design and construction must minimize the development of an unsafe condition of the engine between overhaul periods… (b) Each component of the propeller blade pitch control system which is a part of the engine type design must meet the requirements of §§35.21, 35.23, 35.42 and 35.43…	5.6 Durability	5.6.1 EPU design and construction must minimize the development of an unsafe condition of the EPU between maintenance intervals, removal from service or overhaul periods or mandated life defined in the Instructions for Continued Airworthiness as applicable.	TAILORED				

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	§33.21 Engine cooling.	Engine design and construction must provide the necessary cooling under conditions in which the airplane is expected to operate.	5.7 EPU cooling	5.7.1 EPU cooling must be sufficient under all conditions within the declared operational limitations. ¶ 5.7.2 If aspects of the cooling require the installer to ensure that the temperature limits are met, those limits must be specified in the installation manual. ¶ 5.7.3 Instrumentation or sensors must be provided to enable the flight crew or the automatic control system to monitor the functioning of the EPU cooling system unless appropriate inspections are published in the relevant manuals and evidence shows that: ¶ 5.7.3.1 Failure of the cooling system would not lead to hazardous EPU effects before detection; or ¶ 5.7.3.2 Other existing instrumentation or sensors provides adequate warning of failure or impending failure; or ¶ 5.7.3.3 The probability of failure of the cooling system is extremely remote.	TAILORED	CDR Day 1, page 159-162, Nacelle Cooling Analysis. Stated w/i range, but no test conditions stated.			
	§33.23 Engine mounting attachments and structure.	… maximum allowable limit and ultimate loads for engine mounting attachments and related engine structure must be specified. …	5.8 EPU mounting attachments and structure	5.8.1 The maximum allowable limit and ultimate load for the integral EPU mounting attachment points and related EPU structure must be specified. ¶ 5.8.2 The EPU mounting attachments and related EPU structure must be able to withstand— ¶ 5.8.2.1 The specified limit loads without permanent deformation; and ¶ 5.8.2.2 The specified ultimate loads without failure, but allowing for permanent deformation. ¶ 5.8.3 If flammable fluids are used within the EPU, the mounts and the mounting features must be demonstrated to be fire proof.	TAILORED	REQ-CEPT-006 Structural Loads Requirements for High-Lift Motor			
	§33.25 Accessory attachments.	The engine must operate properly with the accessory drive and mounting attachments loaded. …							
	§33.27 Turbine, compressor, fan, and turbosupercharger rotor overspeed.	(a) For each fan, compressor, turbine, and turbosupercharger rotor, the applicant must establish by test, analysis, or a combination of both, that each rotor will not burst when operated in the engine for 5 minutes at whichever of the conditions defined in paragraph (b) of this section is the most critical with respect to the integrity of such a rotor. …		NOT APPLICABLE	**REMOVED**				

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	§33.28 Engine control systems.	(a) Applicability. These requirements are applicable to any system or device that is part of engine type design, that controls, limits, or monitors engine operation, and is necessary for the continued airworthiness of the engine. … (b) Validation—(1) Functional aspects. … (2) Environmental limits. … (c) Control transitions. … (d) Engine control system failures. … (e) System safety assessment. … (f) Protection systems. … (g) Software. … (h) Aircraft-supplied data. … (i) Aircraft-supplied electrical power. … (j) Air pressure signal. … (k) Automatic availability and control of engine power for 30-second OEI rating. … (l) Engine shut down means. … (m) Programmable logic devices. …	5.10 EPU Controls	5.10.1 The software and complex electronic hardware, including programmable logic devices, shall be designed and developed using a structured and methodical approach that provides a level of assurance for the logic, that is commensurate with the hazard associated with the failure or malfunction of the systems in which the devices are located, and is substantiated by a verification methodology acceptable to the CAA. ¶ 5.10.2 Applicability. These requirements are applicable to any system or device that controls, limits, monitors or protects EPU operation, and is necessary for the continued airworthiness of the EPU. If items that influence the EPU system are outside of the EPU manufacturers control, the assumptions with respect to the reliability and functionality of these parts must be clearly stated in the safety analysis (see section 5.18). ¶ 5.10.3 Validation ¶ 5.10.3.1 Functional aspects. It must be substantiated by tests, analysis, or a combination thereof, that the EPU control system performs the intended functions in a manner which: ¶ 5.10.3.1.1 Enables selected values of relevant control parameters to be maintained and the EPU kept within the approved operating limits over changing atmospheric conditions in the declared flight envelope; ¶ 5.10.3.1.2 Complies with the operability requirements of operation and power response tests, as appropriate, under all likely system inputs and allowable EPU power demands, unless it can be demonstrated that failure of the control function results in a non-dispatchable condition in the intended application; ¶ 5.10.3.1.3 Allows modulation of EPU power with adequate sensitivity over the declared range of EPU operating conditions; and ¶ 5.10.3.1.4 Does not create unacceptable power oscillations. ¶ 5.10.3.2 Environmental limits. Environmental limits that cannot be adequately substantiated in accordance with endurance testing must be demonstrated, via EPU system and component tests (see section 5.13). These tests demonstrate that the EPU control system functionality will not be adversely affected by declared environmental conditions, including electromagnetic interference (EMI), High Intensity Radiated Fields (HIRF), and lightning when applicable for the intended use. The limits to which the system has been qualified must be documented in the EPU installation instructions. ¶ 5.10.4 Control transitions. It must be demonstrated that during both normal operation or as a result of fault or failure, changes in one control mode to another, from one channel to another, or from a primary system to a back-up system, the change occurs so that: ¶ 5.10.4.1 The EPU does not exceed any of its operating limitations; ¶ 5.10.4.2 The EPU does not experience any unacceptable operating characteristics or transient exceedances of any limit potentially leading to unsafe operating conditions. Such non-acceptable operating characteristics include but are not limited to: ¶ 5.10.4.2.1 field excitation at rotor resonance frequency, ¶ 5.10.4.2.2 electromagnetic lock –up (stall), ¶ 5.10.4.2.3 unacceptable power changes or oscillations. ¶ 5.10.4.2.4 other unacceptable characteristics, e.g. electrical arcs, overspeed or overtorque. ¶ 5.10.4.3 There is a means to signal the aircraft to take action or monitor the control transition. The means to alert the aircraft must be described in the EPU installation instructions, and the action or monitoring required must be described in the EPU operating instructions. ¶ 5.10.4.4 The magnitude of any change in power and the associated transition time must be identified and described in the EPU installation instructions and the EPU operating instructions. ¶ 5.10.5 EPU control system failures. The EPU control system must: ¶ 5.10.5.1 Have a	TAILORED	X-57 Cruise Motor Controller Risk Reduction Test Procedure, PROC-CEPT-005			

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	§33.29 Instrument connection.	(a) Unless it is constructed to prevent its connection to an incorrect instrument, each connection provided for powerplant instruments required by aircraft airworthiness regulations or necessary to insure operation of the engine in compliance with any engine limitation must be marked to identify it with its corresponding instrument. … (e) The applicant must make provision for the installation of instrumentation necessary to ensure operation in compliance with engine operating limitations. Where, in presenting the safety analysis, or complying with any other requirement, dependence is placed on instrumentation that is not otherwise mandatory in the assumed aircraft installation, then the applicant must specify this instrumentation in the engine installation instructions and declare it mandatory in the engine approval documentation. (f) As part of the System Safety Assessment of §33.28(e), the applicant must assess the possibility and subsequent effect of incorrect fit of instruments, sensors, or connectors. Where necessary, the applicant must take design precautions to prevent incorrect configuration of the system. …	5.11 Instrument or sensor connection	5.11.1 Provisions must be made for the installation of instrumentation or sensors necessary to ensure EPU operation within all operating limitations. ¶ 5.11.2 The instrument or sensor connections must be designed or labeled to ensure a correct connection. ¶ 5.11.3 Any instrumentation on which the Safety Analysis (see section 5.18) depends must be specified and declared mandatory in the EPU installation instructions and approval documentation. ¶ 5.11.4 The sensors, together with their data transmission hardware and signal conditioning, must be segregated electrically and physically to the extent necessary, to ensure that the probability of a fault propagating from instrumentation and monitoring functions to control functions, or vice versa, is consistent with the failure effect of the fault.	TAILORED	REQ-CEPT-005 Instrumentation Subsystem Requirements			
FAR 33, Airworthiness Standards: Aircraft Engines, Subpart C—Design and Construction; Reciprocating Aircraft Engines									
	§33.31 Applicability.	… prescribes additional design and construction requirements for reciprocating aircraft engines.			REVISED				
	§33.33 Vibration.	The engine must be designed and constructed to function throughout its normal operating range of crankshaft rotational speeds and engine powers without inducing excessive stress in any of the engine parts because of vibration and without imparting excessive vibration forces to the aircraft structure.	5.12 Vibration. The EPU must be designed and constructed to function throughout its normal operating range of rotor speeds and EPU output power without inducing excessive stress in any of the EPU parts because of vibration and without imparting excessive vibration forces to the aircraft structure. In addition to historical sources of vibration such as aero-dynamic excitation, analysis of rotating component resonance induced by field-excitation, should also be assessed,		TAILORED	X-57 Cruise Motor Controller Risk Reduction Vibration & Shock Test Procedure, PROC-CEPT-006			
	§33.34 Turbocharger rotors.	Each turbocharger case must be designed and constructed to be able to contain fragments of a compressor or turbine that fails at the highest speed that is obtainable with normal speed control devices inoperative.		NOT APPLICABLE	**REMOVED**				
	§33.35 Fuel and induction system.	(a) The fuel system of the engine must be designed and constructed to supply an appropriate mixture of fuel to the cylinders throughout the complete operating range of the engine under all flight and atmospheric conditions. …		NOT APPLICABLE OR X-REF TO ESS	REVISED	N/A or revised for battery bay?			
	§33.37 Ignition system.	Each spark ignition engine must have a dual ignition system with at least two spark plugs for each cylinder and two separate electric circuits with separate sources of electrical energy, or have an ignition system of equivalent in-flight reliability.		NOT APPLICABLE	**REMOVED**				

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	§33.39 Lubrication system.	(a) The lubrication system of the engine must be designed and constructed so that it will function properly in all flight attitudes and atmospheric conditions in which the airplane is expected to operate. In wet sump engines, this requirement must be met when only one-half of the maximum lubricant supply is in the engine. ¶ (b) The lubrication system of the engine must be designed and constructed to allow installing a means of cooling the lubricant. ¶ (c) The crankcase must be vented to the atmosphere to preclude leakage of oil from excessive pressure in the crankcase.	5.16 Lubrication System. The lubrication system of the EPU must be designed and constructed so that it will function properly in all flight attitudes and atmospheric conditions in which the aircraft is expected to operate.		TAILORED	GET			
FAR 33, Airworthiness Standards: Aircraft Engines, Subpart D—Block Tests; Reciprocating Aircraft Engines									
	§33.41 Applicability.	… prescribes the block tests and inspections for reciprocating aircraft engines.	5.13 EPU system and component tests		TAILORED				
	§33.42 General.	Before each endurance test required by this subpart, the adjustment setting and functioning characteristic of each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must be established and recorded.	5.13 EPU system and component tests		TAILORED				

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	§33.43 Vibration test.	(a) Each engine must undergo a vibration survey to establish the torsional and bending vibration characteristics of the crankshaft and the propeller shaft or other output shaft, over the range of crankshaft speed and engine power, under steady state and transient conditions, from idling speed to either 110 percent of the desired maximum continuous speed rating or 103 percent of the maximum desired takeoff speed rating, whichever is higher. The survey must be conducted using, for airplane engines, the same configuration of the propeller type which is used for the endurance test, and using, for other engines, the same configuration of the loading device type which is used for the endurance test. ¶ (b) The torsional and bending vibration stresses of the crankshaft and the propeller shaft or other output shaft may not exceed the endurance limit stress of the material from which the shaft is made. If the maximum stress in the shaft cannot be shown to be below the endurance limit by measurement, the vibration frequency and amplitude must be measured. The peak amplitude must be shown to produce a stress below the endurance limit; if not, the engine must be run at the condition producing the peak amplitude until, for steel shafts, 10 million stress reversals have been sustained without fatigue failure and, for other shafts, until it is shown that fatigue will not occur within the endurance limit stress of the material. ¶ (c) Each accessory drive and mounting attachment must be loaded, with the loads imposed by each accessory used only for an aircraft service being the limit load specified by the applicant for the drive or attachment point. ¶ (d) The vibration survey described in paragraph (a) of this section must be repeated with that cylinder not firing which has the most adverse vibration effect, in order to establish the conditions under which the engine can be operated safely in that abnormal state. However, for this vibration survey, the engine speed range need only extend from idle to the maximum desired takeoff speed, and compliance with paragraph (b) of this section need not be shown.	5.20.3 Vibration test	5.20.3.1 Each EPU must be analyzed to establish that the vibration characteristics of those components that may be subject to mechanically or aerodynamically induced vibratory excitations are acceptable throughout the declared flight envelope. At a minimum, the torsional and bending vibration characteristics of the propeller or fan shaft, over the range of propeller or fan shaft speed and propeller or fan power, under steady state and transient conditions, from the minimum shaft speed that the control system can command during operation to a shaft speed that exceeds the maximum desired speed rating by a sufficient margin to determine the maximum vibratory stresses must be established. This margin must be justified using analytical means, prior experience, or empirical data as applicable. The EPU test must be conducted using, for airplane EPUs, the same configuration of the propeller or fan which is used for the endurance and durability test, and using, for other EPUs, the same configuration of the loading device type which is used for the endurance and durability test. ¶ 5.20.3.2 The EPU test shall cover the ranges of power for each rotating component system, corresponding to operations throughout the range of ambient conditions in the declared flight envelope, from the minimum obtainable rotational speed that can be commanded by the control system up to 103 percent of the maximum rotational speed permitted for rating periods of two minutes or longer, and up to 100 percent of all other permitted rotational speeds, including those that are overspeeds. If there is any indication of a stress peak arising at the highest of those required rotational speeds, the EPU test shall be extended sufficiently to reveal the maximum stress values present, except that the extension need not cover more than a further 2 percentage points increase beyond those speeds. ¶ 5.20.3.3 Except as provided by paragraph 5.20.3.4 of this section, the vibration stresses associated with the vibration characteristics determined under this section, when combined with the appropriate steady state stresses, must be less than the endurance limits of the materials concerned, after making due allowances for operating conditions for the permitted variations in properties of the materials. The suitability of these stress margins must be justified for each part evaluated. If the maximum stress in the shaft cannot be shown to be below the endurance limit by measurement, the vibration frequency and amplitude must be measured. The EPU must be run at the condition producing the peak amplitude for a number of stress reversals sufficient to ensure that fatigue failure will not occur in service. Alternatively, the EPU may be run at a condition producing peak amplitude until 10 million stress reversals have been sustained without fatigue failure for steel shafts and, for other shafts, until it is shown that fatigue will not occur within the endurance limit stress of the material. If it is determined that certain operating conditions, or ranges, need to be limited, operating and installation limitations shall be established. Operating and installation limitations shall be established for shafts made from materials that do not have endurance limits. ¶ 5.20.3.3.1 The purpose of this discussion is defined as follows: Endurance limit. The alternating stress that can be repeated for an infinite number of cycles without material fatigue failure. To demonstrate endurance limit for metallic materials, 10^7 cycles have generally been accepted as the test proxy for an "infinite" number of cycles. The endurance limit depends on the steady-state stresses, temperatures, and other factors. ¶ 5.20.3.4 The effects on vibration characteristics of excitation forces caused by fault conditions (such as, but not limited to, out of balance rotating components, local airflow blockage,	REVISED		ANLYS-CEPT-009 Mod II Flutter Analysis		

Subpart	Section	Note	*ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)*	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§33.45 Calibration tests.	(a) Each engine must be subjected to the calibration tests necessary to establish its power characteristics and the conditions for the endurance test specified in §33.49. The results of the power characteristics calibration tests form the basis for establishing the characteristics of the engine over its entire operating range of crankshaft rotational speeds, manifold pressures, fuel/air mixture settings, and altitudes. Power ratings are based upon standard atmospheric conditions with only those accessories installed which are essential for engine functioning. ¶ (b) A power check at sea level conditions must be accomplished on the endurance test engine after the endurance test. Any change in power characteristics which occurs during the endurance test must be determined. Measurements taken during the final portion of the endurance test may be used in showing compliance with the requirements of this paragraph.	5.20.6 Calibration tests	5.20.6.1 Each EPU must be subjected to those calibration tests necessary to establish its power characteristics and the conditions for the endurance and durability test specified in this section. The results of the power characteristics calibration tests form the basis for establishing the characteristics of the EPU over its entire operating range of speeds, torques, and ambient conditions. ¶ 5.20.6.2 A power check must be accomplished on the endurance and durability test EPU after the endurance and durability test described in this section and any change in power characteristics which occurs during the endurance and durability test must be determined. Measurements taken during the final portion of the endurance and durability test may be used in showing compliance with the requirement of this paragraph. ¶ 5.20.6.3 In showing compliance with this paragraph, each condition must stabilize before measurements are taken.	REVISED	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis			
	§33.47 Detonation test.	Each engine must be tested to establish that the engine can function without detonation throughout its range of intended conditions of operation.		NOT APPLICABLE	**REMOVED**				
	§33.49 Endurance test.	(a) General. Each engine must be subjected to an endurance test that includes a total of 150 hours of operation (except as provided in paragraph (e)(1)(iii) of this section) and, depending upon the type and contemplated use of the engine, consists of one of the series of runs specified in paragraphs (b) through (e) of this section, as applicable. The runs must be made in the order found appropriate … for the particular engine being tested. During the endurance test the engine power and the crankshaft rotational speed must be kept within ±3 percent of the rated values. During the runs at rated takeoff power and for at least 35 hours at rated maximum continuous power, one cylinder must be operated at not less than the limiting temperature, the other cylinders must be operated at a temperature not lower than 50°F. below the limiting temperature, and the oil inlet temperature must be maintained within ±10°F. of the limiting temperature. An engine that is equipped with a propeller shaft must be fitted for the endurance test with a propeller that thrust-loads the engine to the maximum thrust which the engine is designed to resist at each applicable operating condition specified in this section. Each accessory drive and mounting attachment must be loaded. During operation at rated takeoff power and rated maximum continuous power, the load imposed by each accessory used only for an aircraft service must be the limit load specified by the applicant for the engine drive or attachment point. ¶ (b) Unsupercharged engines and engines incorporating a gear-driven single-speed supercharger. … ¶ (c) Engines incorporating a gear-driven two-speed supercharger. … ¶ (d) Helicopter engines. … ¶ (e) Turbosupercharged engines. …	5.20.2 Endurance and durability test	5.20.2.1 An endurance and durability test of sufficient duration must show that the development of an unsafe condition is extremely remote between overhaul periods (or during the life of the EPU if no overhaul intervals are prescribed) and loss of power control is below 10^05/flight hour. The test time duration, number of cycles, and test schedule definition should provide sufficient demonstration of durability with regard to the failure modes that could result in major EPU effects or hazardous EPU effects. The test schedule must be justified using validated analytical methods, empirical testing, or experience with EPU or motors with comparable design. During the endurance test the EPU power and the output shaft rotational speed must be demonstrated at or above 100% of the rated values. An EPU that is intended to drive a propeller that is type certificated separately from the EPU must be fitted for the endurance and durability test with a propeller that thrust-loads the EPU to the maximum thrust which the EPU is designed to resist at each applicable operating condition specified in this section. The endurance and durability test must be run on an EPU representative of the type design. Any deviation to the type design must be recorded. It must be justified that any of the recorded deviations to the type design does not affect the results of the test. ¶ 5.20.2.2 The endurance and durability test must consist of at least the following elements: ¶ 5.20.2.2.1 A run consisting of alternate periods of operation at rated takeoff power and the minimum power and periods of operation at maximum continuous power and the minimum power, that can be commanded by the control system during operation. ¶ 5.20.2.2.2 A series of runs consisting of alternate periods of operation at maximum continuous power and successively lower power settings. The range of power settings should be selected to expose any deleterious system responses or vibration. ¶ 5.20.2.2.3 Each period of operation discussed in this section must be conducted at stabilized values for rotational speed, torque, temperature and any other parameter deemed to ensure the safety of the EPU to achieve steady state values. At the ratings and duty cycles established in conjunction with section 5.3 of this standard, the stabilized temperature for the motor and the motor controller must be equal to or greater than the temperature associated with this rating.	REVISED	#1- SPEC-CEPT-001, p.20, §5.4 Endurance Testing, with some conditions: "prop that thrust-loads to the max thrust & drag… however time required for each condition will be reduced by half (but still 150-hour test)"; #2- CDR Day 2, page 194,Airvolt Cruise Motor Endurance Test — concern expressed over time to test to FAR33; CDR Day 2, page 198,Airvolt X-57 Test Plan — Perform Endurance Test; CDR Day 2, page 200, Need COPY of ANLYS-CEPT-005 "Airvolt - FAR Part 33 Aircraft Engine applicability" document released == See ASTM F39.05 §5.20.2 also === #3-Cruise Motor Endurance Test Procedure, PROC-CEPT-010			

Subpart	Section	Note	*ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)*	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§33.51 Operation test.	… operation test must include the testing … to demonstrate backfire characteristics, starting, idling, acceleration, overspeeding, functioning of propeller and ignition, and any other operational characteristic of the engine. If the engine incorporates a multispeed supercharger drive, the design and construction must allow the supercharger to be shifted from operation at the lower speed ratio to the higher and the power appropriate to the manifold pressure and speed settings for rated maximum continuous power at the higher supercharger speed ratio must be obtainable within five seconds.	5.20.7 Operation test	5.20.7.1 The operation test must include testing to demonstrate: ¶ 5.20.7.1.1 Powering on, idling, acceleration, overspeeding, with loading representative of the intended installation; ¶ 5.20.7.1.2 Compliance with the EPU response requirements of paragraph 5.20.8.1; ¶ 5.20.7.1.3 That the EPU has safe operating characteristics throughout its specified operating envelope. The evaluation should include an assessment of thermal and electrical system performance since certain attributes have temperature and altitude dependencies. For the electrical system this would include failure inducing phenomena such as: partial discharge, corona arcing, and dielectric breakdown.	REVISED	Propulsion System Functional Test Procedure, PROC-CEPT-028			
	§33.53 Engine system and component tests.	(a) For those systems and components that cannot be adequately substantiated in accordance with endurance testing of §33.49, the applicant must conduct additional tests to demonstrate that systems or components are able to perform the intended functions in all declared environmental and operating conditions. ¶ (b) Temperature limits must be established for each component that requires temperature controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.	5.20.2 Endurance and durability test		TAILORED				
	§33.55 Teardown inspection.	After completing the endurance test— ¶ (a) Each engine must be completely disassembled; ¶ (b) Each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must retain each setting and functioning characteristic within the limits that were established and recorded at the beginning of the test; and ¶ (c) Each engine component must conform to the type design and be eligible for incorporation into an engine for continued operation, in accordance with information submitted in compliance with §33.4.	5.22 Teardown Inspection	5.22.1 After completing the endurance test, the vibration test, the overtorque test, and the overtemperature test— ¶ 5.22.1.1 Each EPU must be completely disassembled; ¶ 5.22.1.2 Each EPU component having an adjustment setting and a functioning characteristic that can be established independent of installation on or in the EPU must retain each setting and functioning characteristic within the limits that were established and recorded at the beginning of the test; and ¶ 5.22.1.3 Each EPU component must conform to the type design and be eligible for incorporation into a EPU for continued operation, in accordance with information submitted in compliance with the instructions for continued airworthiness. ¶ 5.22.1.4 If the EPU is assembled in a manner that it cannot be disassembled without destructive inspection, such as one that is epoxied together, and it will be non-workable after tear down, alternative inspection can be proposed. There may be non-destructive tests for electrical systems. However, these alternative methods must capture the critical aspects intended for the inspection. Pre-measurements at build must be referenced at teardown. ¶ 5.22.1.5 If a teardown is not performed, then the life limit of the EPU will be established by the length of the endurance test performed.	REVISED	PROC-CEPT-017 JMX57K Motor to Airvolt Installation Procedure			

Subpart	Section	Note	*ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)*	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§33.57 General conduct of block tests.	(a) The applicant may, in conducting the block tests, use separate engines of identical design and construction in the vibration, calibration, detonation, endurance, and operation tests, except that, if a separate engine is used for the endurance test it must be subjected to a calibration check before starting the endurance test. ¶ (b) The applicant may service and make minor repairs to the engine during the block tests in accordance with the service and maintenance instructions submitted in compliance with §33.4. If the frequency of the service is excessive, or the number of stops due to engine malfunction is excessive, or a major repair, or replacement of a part is found necessary during the block tests or as the result of findings from the teardown inspection, the engine or its parts may be subjected to any additional test … necessary. ¶ (c) Each applicant must furnish all testing facilities, including equipment and competent personnel, to conduct the block tests.	5.20.1 General conduct of EPU tests	5.20.1.1 In conducting a EPU test, separate EPUs of identical design and construction may be used in the vibration, calibration, endurance, and operation tests, except that, if a separate EPU is used for the endurance test it must be subjected to a calibration check before powering on the endurance test. ¶ 5.20.1.2 Service and minor repairs to the EPU may be made during the tests in accordance with the service and maintenance instructions submitted in the Instructions for Continued Airworthiness. If the frequency of the service is excessive, or the number of stops due to EPU malfunction is excessive, or a major repair, or replacement of a part is found necessary during the block tests or as the result of findings from the teardown inspection, the EPU or its parts must be subjected to any additional tests the CAA finds necessary. ¶ 5.20.1.3 The following are a set of baseline tests. These may be used to form a test sequence and can be accomplished as a combination of test conditions for a sequential test or they may be used individually. ¶ 5.20.1.4 Upon conclusion of tests conducted to show compliance with this section, each EPU part or individual groups of components must meet the requirements of the teardown inspection (see 5.22). It should be considered what the ramifications are of findings during teardown. If the tests have been run as a combination sequence and there are findings in teardown it may not be clear which particular test was the source of the finding. This will have to be resolved.	REVISED	PROC-CEPT-017 JMX57K Motor to Airvolt Installation Procedure			
Appendix A to Part 33—Instructions for Continued Airworthiness									

Table A-3, Proposed Compliance Matrix (PCM) for 14 CFR 35 as Test Matrix for X-57

Subpart	Section	Note	*ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)*	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
14 CFR 35, Dated 3 October 2018, (https://www.ecfr.gov/cgi-bin/retrieveECFR?&n=pt14.1.35)									
FAR 35, Airworthiness Standards: Propellers, Subpart A—General									
	§35.1 Applicability.	… prescribes airworthiness standards for the issue of type certificates and changes to those certificates, for propellers			UNCHANGED				
	§35.2 Propeller configuration.	… a list of all the components, including references to the relevant drawings and software design data, that define the type design of the propeller to be approved…			UNCHANGED				
	§35.3 Instructions for propeller installation and operation.				UNCHANGED				
	§35.4 Instructions for Continued Airworthiness.				UNCHANGED				
	§35.5 Propeller ratings and operating limitations.				UNCHANGED				
	§35.7 Features and characteristics.	… The propeller may not have features or characteristics, revealed by any test or analysis or known to the applicant, that make it unsafe for the uses for which certification is requested.			UNCHANGED				
FAR 35, Airworthiness Standards: Propellers, Subpart B—Design and Construction									
	§35.15 Safety analysis.	… analyze the propeller system to assess the likely consequences of all failures that can reasonably be expected to occur…			UNCHANGED				
	§35.16 Propeller critical parts.	The integrity of each propeller critical part identified by the safety analysis…			UNCHANGED				
	§35.17 Materials and manufacturing methods.				UNCHANGED				
	§35.19 Durability.	Each part of the propeller must be designed and constructed to minimize the development of any unsafe condition of the propeller between overhaul periods.			UNCHANGED				
	§35.21 Variable and reversible pitch propellers.				UNCHANGED				

Subpart	Section	Note	***ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf)***	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§35.22 Feathering propellers.		5.24 EPU-variable pitch propeller or fan systems tests	5.24.1 These are functional tests of the EPU operation, not an endurance test, to be conducted as applicable for a variable pitch design. If the EPU is designed to operate with a propeller or fan that is not part of the EPU type design, then the following tests must be conducted with a representative propeller or fan installed by either including the tests in the endurance run or otherwise performing them in a manner acceptable to the CAA: ¶ 5.24.1.1 Feathering operation: The propeller should be feathered a sufficient number of times to establish reliable operation of the EPU in the propeller feathering dynamic operation. In absence of other justified number of sufficient test cycles, a minimum of 25 cycles may be used. ¶ 5.24.1.2 Negative torque and thrust system operation: The negative torque and thrust system should be tested from rated maximum continuous power or from the most critical condition a sufficient number of times to establish reliable operation of the EPU in the negative torque and thrust system dynamic operation. In absence of other justified number of sufficient test cycles, a minimum of 25 cycles may be used It should be shown by test that the negative torque effect on the EPU during windmill operation will not adversely affect bearing lubrication system ¶ 5.24.1.3 Reverse thrust operation: The reverse thrust operation should be tested from the least power position to full reverse for a number of cycles sufficient to establish the reliability of the EPU in the dynamic operation of the reverse thrust system. In absence of other justified number of sufficient test cycles, a minimum of 175 cycles may be used. The reverse thrust operation at rated maximum continuous power from full forward to full reverse thrust for a number of cycles sufficient to establish the reliability of the reverse thrust system should also be tested. In absence of other justified number of sufficient test cycles, a minimum of 25 cycles may be used. At the end of each cycle the propeller or fan must be operated in reverse pitch for a time interval sufficient to establish the reliability of the reverse pitch mechanism and must occur at the maximum rotational speed and power specified for reverse pitch operation. In absence of other justified time interval, a minimum of 30 seconds may be used.	REVISED			ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; TP-CEPT-004, High Lift Motor Controller Test Plan; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification	ANLYS-CEPT-018 X-57 Cruise Motor and High Lift Motor Mission Profile Power Requirements Analysis; TP-CEPT-004, High Lift Motor Controller Test Plan; SPEC-CEPT-006 SCEPTOR High-Lift Propeller Specification
	§35.23 Propeller control system.				UNCHANGED				
	§35.24 Strength.	The maximum stresses developed in the propeller may not exceed values acceptable…			UNCHANGED				
FAR 35, Airworthiness Standards: Propellers, Subpart C—Tests and Inspections									
	§35.33 General.	Each applicant must furnish test article(s) and suitable testing facilities, including equipment and competent personnel, and conduct the required tests…	5.24 EPU-variable pitch propeller or fan systems tests		UNCHANGED				
	§35.34 Inspections, adjustments and repairs.				UNCHANGED				
	§35.35 Centrifugal load tests.	…demonstrate that a propeller complies with paragraphs (a), (b) and (c) of this section without evidence of failure, malfunction, or permanent deformation that would result in a major or hazardous propeller effect. When the propeller could be sensitive to environmental degradation in service, this must be considered. (…not applicable to fixed-pitch wood or fixed-pitch metal propellers of conventional design.)			UNCHANGED				

Subpart	Section	Note	***ASTM F39.05, WK47374 Design of Electric Propulsion Units for General Aviation Aircraft, DRAFT STANDARD, "ITEM_2_EPU_WK47374_v2.pdf" Dated 31 July 2018, in revision. (<u>https://compass.astm.org/CUSTOMERS/COLLAB/FILES/10514620180905_WKGROUP.pdf</u>)***	Note in ASTM WK47374 from F39.05	Assessment of Applicability	Validation Method, X-57 Mod I	Validation Method, X-57 Mod II	Validation Method, X-57 Mod III	Validation Method, X-57 Mod IV
	§35.36 Bird impact.	…demonstrate, by tests or analysis based on tests or experience on similar designs, that the propeller can withstand the impact of a 4-pound bird at the critical location(s) and critical flight condition(s) of a typical installation without causing a major or hazardous propeller effect. (…not applicable to fixed-pitch wood or fixed-pitch metal propellers of conventional design.)	5.19 Ingestion ¶ NOTE: Foreign object ingestion is less of a concern for EPUs than for combustion or turbine engines as the incoming air is not needed for a combustion process. Thus, concerns around ingestion for EPUs focus on cooling blockage and structural damage.	5.19.2 A component failure should be based on test or analysis, where the EPU will need to be loaded as it is when installed, using resulting loads from a four pound bird strike to the propeller or the fan. Components include EPU mounts, EPU bearings, EPU shaft wires, avionics and other. The maximum load should be documented in the installation manual.	TAILORED				
	§35.37 Fatigue limits and evaluation.	This section does not apply to fixed-pitch wood propellers of conventional design.	5.25 Tests for fixed pitch propellers or fans when included in the EPU type certificate	5.25.1 The fixed pitch propeller or fan which certification with the EPU is sought should meet all the applicable paragraphs of this standard and should be installed during all applicable EPU tests of this standard.	TAILORED				
		(a) Fatigue limits must be established by tests, or analysis based on tests, for propeller: (1) Hubs. ¶ (2) Blades. ¶ (3) Blade retention components. ¶ (4) Components which are affected by fatigue loads and which are shown under §35.15 to have a fatigue failure mode leading to hazardous propeller effects.			UNCHANGED				
		(b) The fatigue limits must take into account:(1) All known and reasonably foreseeable vibration and cyclic load patterns that are expected in service; and ¶ (2) Expected service deterioration, variations in material properties, manufacturing variations, and environmental effects.		5.25.2 The vibratory stress for the fixed pitch propeller or fan should be shown to be acceptable throughout the declared flight envelope of the intended aircraft installation.	TAILORED				
		(c) A fatigue evaluation of the propeller must be conducted to show that hazardous propeller effects due to fatigue will be avoided throughout the intended operational life of the propeller on either: (1) The intended airplane by complying with §23.2400(c) or §25.907 of this chapter, as applicable; or ¶ (2) A typical airplane.			UNCHANGED				
	§35.38 Lightning strike.	(…not applicable to fixed-pitch wood or fixed-pitch metal propellers of conventional design.) … demonstrate, by tests, analysis based on tests, or experience on similar designs, that the propeller can withstand a lightning strike without causing a major or hazardous propeller effect.			UNCHANGED	CDR Day 1, page 153-155. Lightning Test on promo stand for Motor test w/prop.			
	§35.39 Endurance test.				UNCHANGED				
	§35.40 Functional test.	… variable-pitch propeller system must be subjected to the applicable functional tests of this section. The same propeller system used in the endurance test (§35.39) must be used in the functional tests and must be driven by a representative engine on a test stand or on an airplane. The propeller must complete these tests without evidence of failure or malfunction.			UNCHANGED				
	§35.41 Overspeed and overtorque.				UNCHANGED				
	§35.42 Components of the propeller control system.	… demonstrate by tests, analysis based on tests, or service experience on similar components, that each propeller blade pitch control system component, including governors, pitch change assemblies, pitch locks, mechanical stops, and feathering system components, can withstand cyclic operation that simulates the normal load and pitch change travel to which the component would be subjected during the initially declared overhaul period or during a minimum of 1,000 hours of typical operation in service.	5.24 EPU-variable pitch propeller or fan systems tests	5.24.1.1 Feathering operation: The propeller should be feathered a sufficient number of times to establish reliable operation of the EPU in the propeller feathering dynamic operation. In absence of other justified number of sufficient test cycles, a minimum of 25 cycles may be used.	TAILORED				

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	§35.43 Propeller hydraulic components.	… show by test, validated analysis, or both, that propeller components that contain hydraulic pressure and whose structural failure or leakage from a structural failure could cause a hazardous propeller effect demonstrate structural integrity…			UNCHANGED				
(Appendix A to Part 35—Instructions for Continued Airworthiness)									

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14. ABSTRACT
This report describes a generic method for addressing any new technology to its associated set of regulations and certification criteria. The result is a framework under which a detailed assessment can be conducted. Using just such a framework, the report maps the detailed updated regulations and evolving ASTM standards to the particular technology planning and tests. As a result, a roadmap of NASA technology is documented that shows clear transfer of technology data to industry (standards developers, as well as technology developers) and the FAA regulatory policy and certification staff upon whom certification and policy will be data-driven. A clear description of benefits and gaps are identified, as well.

15. SUBJECT TERMS

X-57; certification; distributed; electric; propulsion; standards

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