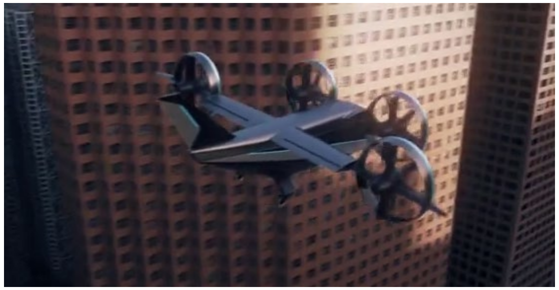


Image: Bell


Image: Lilium

ASTM F44 as a Means of Compliance for Part 23


Image: Airbus

Image: Volocopter

CONTENTS

Introduction to ASTM

What is ASTM?

A Proven and Practical System

- Established in 1898
- 150 Committees & 12,500+ Standards
- 32,000 members
  - 8,000+ International Members from 135 countries
  - 5,100 ASTM standards used in 75 countries
- Accreditation:
  - American National Standards Institute (ANSI)
  - Standard Council of Canada (SCC)
- Process complies with WTO principles: Annex 4 of WTO/TBT Agreement

BENEFITS

- Development and delivery of information made uncomplicated
- A common sense approach: industry driven
- Market relevant globally
- No project costs

Types of Standards

Company Standard

– Consensus among the employees of an organization.

Consortium Standard

– Consensus among a small group of organizations; like-minded companies undertaking an activity to collectively conserve resources.

Industry Standard

– Consensus among the many companies within an association or society.

Government Standard

– Multiple degrees of consensus. Some written by individuals within agencies, sometimes developed with private sector then adopted by reference as mandatory.

Voluntary Consensus Standard ***(ASTM sits here)***

– Consensus is developed by representatives of all sectors that have an interest in the use of the standard (producers, users, and those having a general interest, consumers). Consensus standards, with their broad input, are considered by many as the most technically sound and credible documents. They are often used as the basis for commercial and regulatory action.

ASTM Aviation Standards Committees

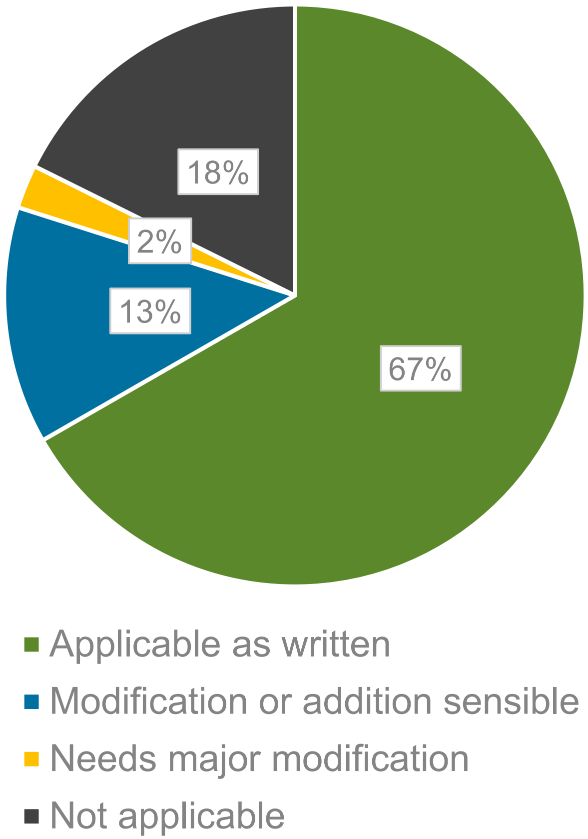
THE FOLLOWING ASTM COMMITTEES ARE FOCUSED ON AVIATION STANDARDS

- F37 – LIGHT SPORT AIRCRAFT
- F38 – UNMANNED AIRCRAFT SYSTEMS
- F39 – AIRCRAFT SYSTEMS
- F44 – GENERAL AVIATION AIRCRAFT
- F46 – AEROSPACE PERSONNEL

Standards support innovation

- One of the key motivations for the CS/Part 23 rewrite that was completed in 2017 was to “future proof” the regulations to allow new technologies to be certificated.
- Industry standards, particularly ASTM standards, were selected as an Accepted Means of Compliance to these new Rules.
  - ASTM F44 Committee on General Aviation Aircraft was created to produce the Means of Compliance library for the new CS-23 Amdt 5 / Part 23 Amdt 64
  - The Rule is intended to be at a performance-based “safety intent” level while the Standards provide an acceptable “what” and/or “how” to satisfy that safety intent.
- EVTOL aircraft were not contemplated with the new CS/Part 23, nor with the original library of standards, but they are still acceptable starting points.
  - ASTM’s committees have roadmaps to rapidly accommodate new technology standards, such a eVTOL

2019 Applicability of ASTM F44 Standards by Sub-Paragraph to EVTOL



Part 23 Accepted Means of Compliance

- Accepted ASTM standards for 14 CFR Part 23 Amendment 64
  - Latest version published in Federal Register Vol. 85, No. 184 on September 22, 2020 (https://www.federalregister.gov/documents/2020/09/22/2020-17911/accepted-means-of-compliance-airworthiness-standards-normal-category-airplanes)
- 65 regulations are covered by ASTM standards
  - Standards are accepted "as is" for 42 regulations
  - Standards are accepted with changes or supplements required for 23 regulations

An integrated requirements landscape

- Operations and certification are closely related for eVTOL/UAM aircraft
- There is a trade space between what the aircraft is certified to do and the role of the human(s) in/on the loop
- Standards have a role in each of these areas.

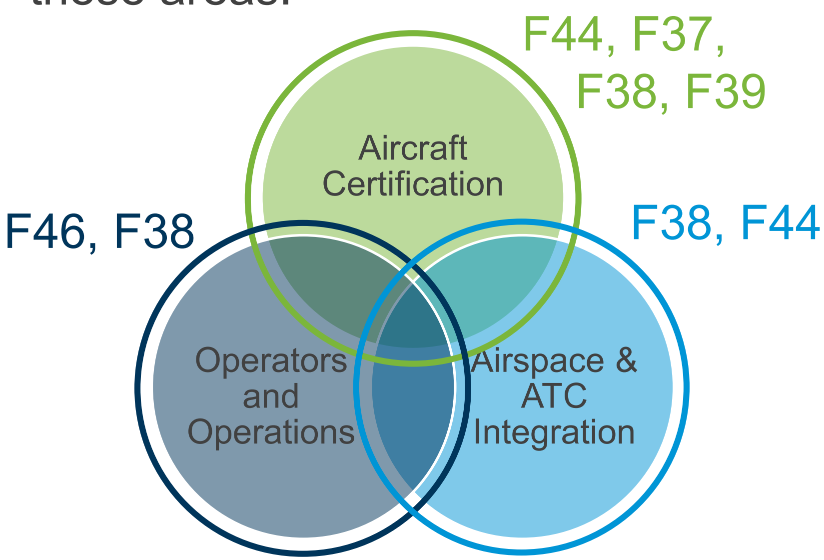


Image: NASA

- ASTM provides valuable support:
  - F44 standards are already accepted as a Means of Compliance to CS/Part 23
  - The highly involved general aviation community brings the appropriate “risk spectrum” perspective to small aircraft to be used in commercial operations
  - High level of regulator involvement assists in harmonization and acceptance
  - Flexibility and nimbleness of the consensus process mean timely solutions can be developed that capture the collective industry knowledge and best practices

Efforts underway to address EVTOL needs

AC377

- Focused on Autonomy in all aspects of aviation, from sUAS through GA & UAM
- 1st technical report out in 2019
  - Terminology, alternative requirements framework to provide more nuance than the automotive-style "Levels of Autonomy"
- Now working on guidelines for key technical pillars of autonomous systems

AC433

- New effort focused on **identifying and filling gaps in the existing Standards library for EVTOL/UAM aircraft**
  - 1st meeting May 2019. Complimentary to other Standards Development activities
- Identifying and scoping gaps then working with technical committees to fill them

F38 & F39

- F38 working on UAS technologies that can be applied to UAM: bounding complex systems, detect & avoid (DAA), etc.
- F38 working on vertiports design.
- F39 working on electric propulsion system components: energy storage systems, electric propulsion units, etc.

F44

- Alternative approaches to system safety
- Distributed, hybrid, and all-electric propulsion system integration
- Indirect flight controls (e.g., fly-by-wire)
- Flight/Performance standards for VTOL for vertical and horizontal flight considerations

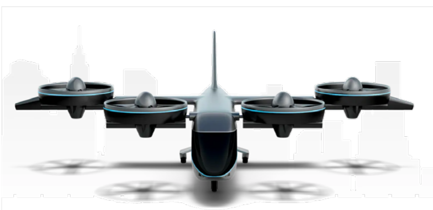
AC 433 Gap Analysis for Incorporation of eVTOL into Standards

Overview of Identified higher priority gaps in standards

- Electric Propulsion System (EPS) Design & Installation
- Electric Propulsion Unit Design (EPU)
- Electric Propulsion Energy Storage Systems
- Emergency Conditions ★
- Bird strike
- Handling Characteristics
- Performance
- Energy Shedding (Crashworthiness)
- Integral Thrusters
- Aircraft Powerplant Control and Indication
- Aircraft Propeller System Installation
- Powerplant Hazard Mitigation
- Safety Assessment of Systems and Equipment
- Distributed Electric Propulsion
- Inadvertent Icing
- Simplified Vehicle Operations (SVO)

eVTOL Certification

What are Certification Paths for eVTOL's?



14 CFR § 21.17(a)
Existing Class of Aircraft
Parts 23, 27 (33, 35)

14 CFR § 21.16
Special Conditions Derived from Other Parts or New Requirements

14 CFR § 21.17(b)
Special Class of Aircraft
Derived from
Parts 23, 27, 33, 35 and new requirements

Certification Basis
Primarily
Part 23 (Amdt. 23-64)

Occupant Protection

Existing Regulatory Requirements for Occupant Protection:

FAA

Part 23

- §23.2270 – Emergency Conditions
- §23.2315 - Means of egress and emergency exits
- §23.2320 - Occupant physical environment

Part 27

- §27.561 - General (loads)
- §27.562 - Emergency landing dynamic conditions
- §27.725 - Limit drop test. (landing gear)
- §27.727 - Reserve energy absorption drop test (landing gear)
- §27.952 - Fuel system crash resistance *

EASA

SC-VTOL

- SC-VTOL.2270 – Emergency conditions
- SC/VTOL.2325 – Fire protection
- SC/VTOL.2315 - Means of egress and emergency exits
- SC/VTOL.2320 - Occupant physical environment

* Need to consider battery failure modes

§23.2270 Emergency conditions

(a) **The airplane, even when damaged in an emergency landing, must protect each occupant against injury that would preclude egress when—**

(1) Properly using safety equipment and features provided for in the design;

(2) The occupant experiences ultimate static inertia loads likely to occur in an emergency landing; and

(3) Items of mass, including engines or auxiliary power units (APUs), within or aft of the cabin, that could injure an occupant, experience ultimate static inertia loads likely to occur in an emergency landing.

(b) **The emergency landing conditions specified in paragraph (a)(1) and (a)(2) of this section, must—**

(1) Include dynamic conditions that are likely to occur in an emergency landing; and

(2) Not generate loads experienced by the occupants, which exceed established human injury criteria for human tolerance due to restraint or contact with objects in the airplane.

(c) **The airplane must provide protection for all occupants, accounting for likely flight, ground, and emergency landing conditions.**

(d) **Each occupant protection system must perform its intended function and not create a hazard that could cause a secondary injury to an occupant. The occupant protection system must not prevent occupant egress or interfere with the operation of the airplane when not in use.**

(e) **Each baggage and cargo compartment must—**

(1) Be designed for its maximum weight of contents and for the critical load distributions at the maximum load factors corresponding to the flight and ground load conditions determined under this part;

(2) Have a means to prevent the contents of the compartment from becoming a hazard by impacting occupants or shifting; and

(3) Protect any controls, wiring, lines, equipment, or accessories whose damage or failure would affect safe operations.

- What are the appropriate loading conditions for eVTOL?
- Are requirements of §23.561/.562 (amendment 62) or §27.561/.562 appropriate?

ASTM F3083 – Standard Specification for Emergency Conditions, Occupant Safety and Accommodations

The current ASTM F3083 Occupant Safety Standards are focused for fixed-wing airplanes using FAA 14CFR Part 23 requirements and guidance (based on Amendment 62).

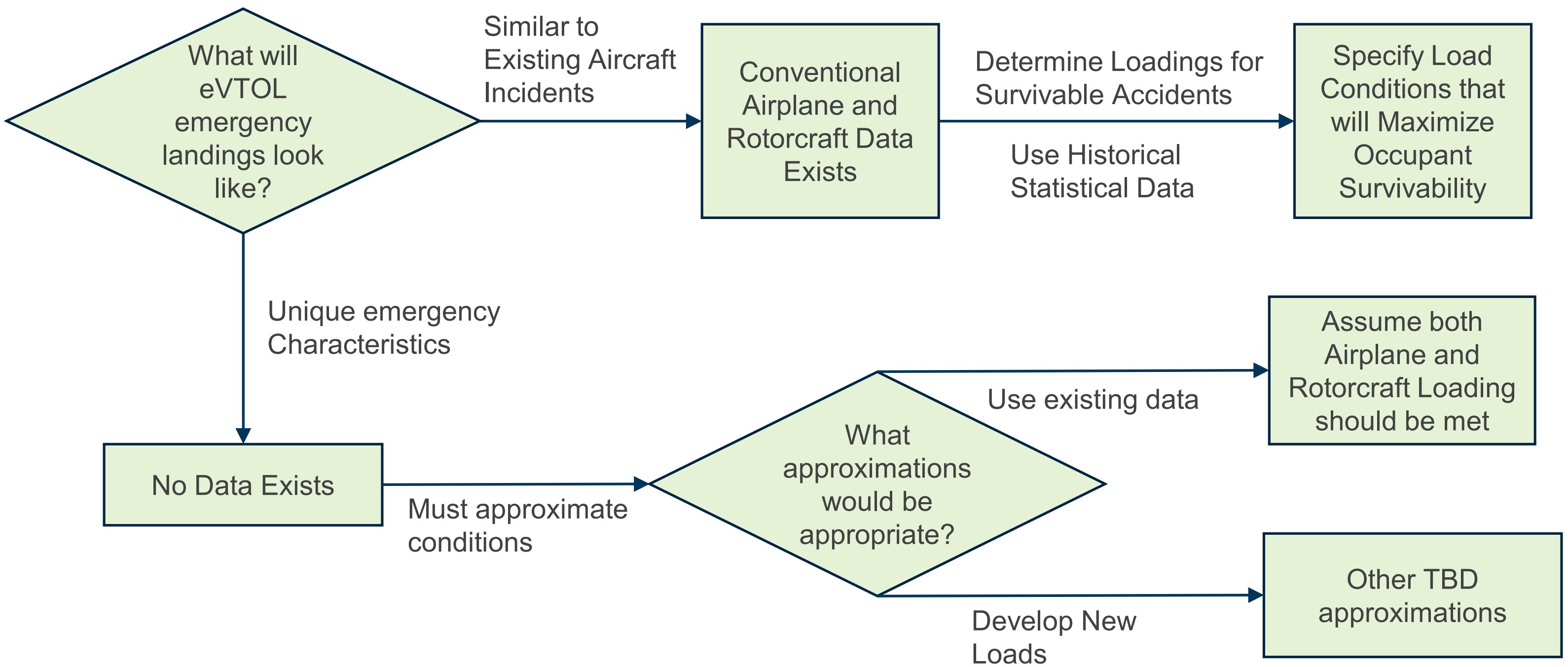
The incorporation of eVTOL aircraft requires consideration of eVTOL aircraft flight characteristics including:

- Higher vertical loads during “emergency” events (thrust failures during T/O, climb, descent and landings) for all phases of VTOL flight operations
- Mass items located above and behind occupants that could cause injury if not contained (powerplants, propellers, fans, etc.)
- Higher demands on landing gear for energy absorption during vertical descents compared to Conventional Take-Off and Landing (CTOL) aircraft
- Potential energy storage hazards (batteries along with petroleum based fuels for hybrid vehicles)

WK68781 has been established to evaluate the applicability of the current F3083 standard for aircraft with VTOL capabilities

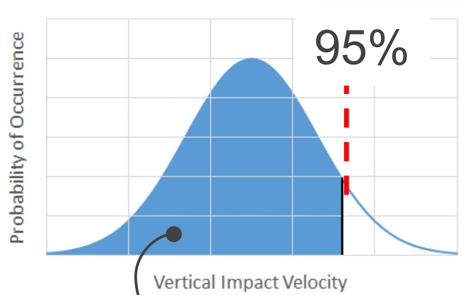
Considerations for Developing a New Standard

Considerations for Emergency Landing Loads

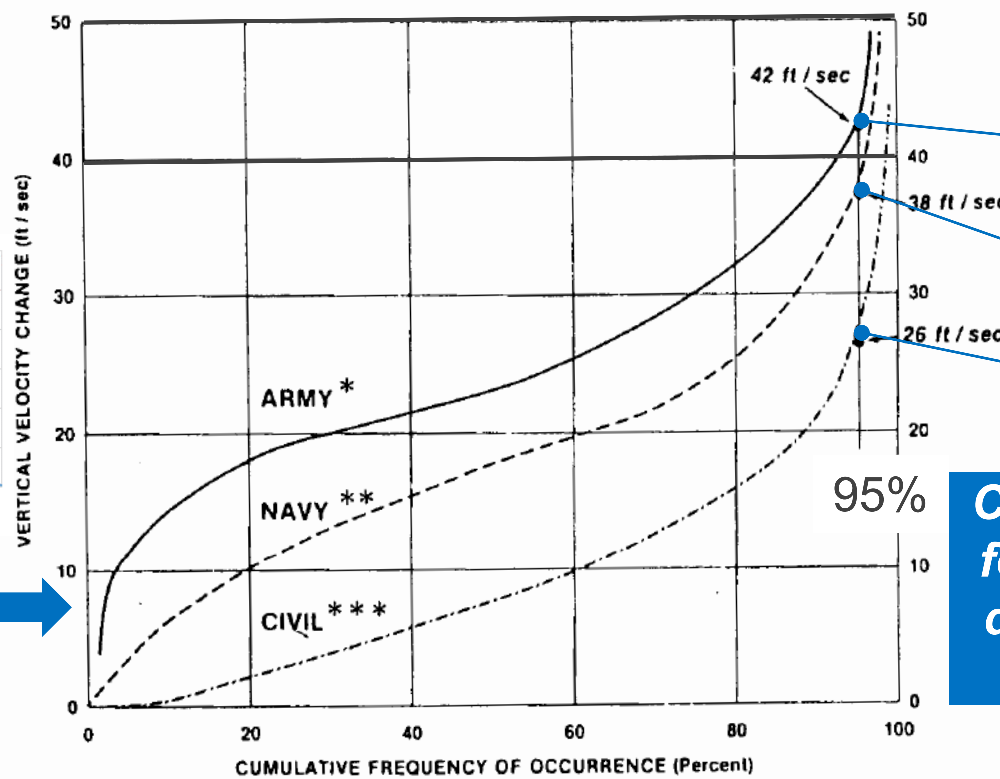


Comparison of survivable impact velocity changes for Army, Navy, and Civil rotorcraft.

Crash statistics



$$D(v) = \int_0^{V_I} P(v)dv$$



Rotorcraft

Army 42 ft/s

Navy 38 ft/s

Civil 26 ft/s

Crash velocities for aircraft type differ based on type and use

* USARTL TR-79-22, AIRCRAFT CRASH CRASH SURVIVAL DESIGN GUIDE

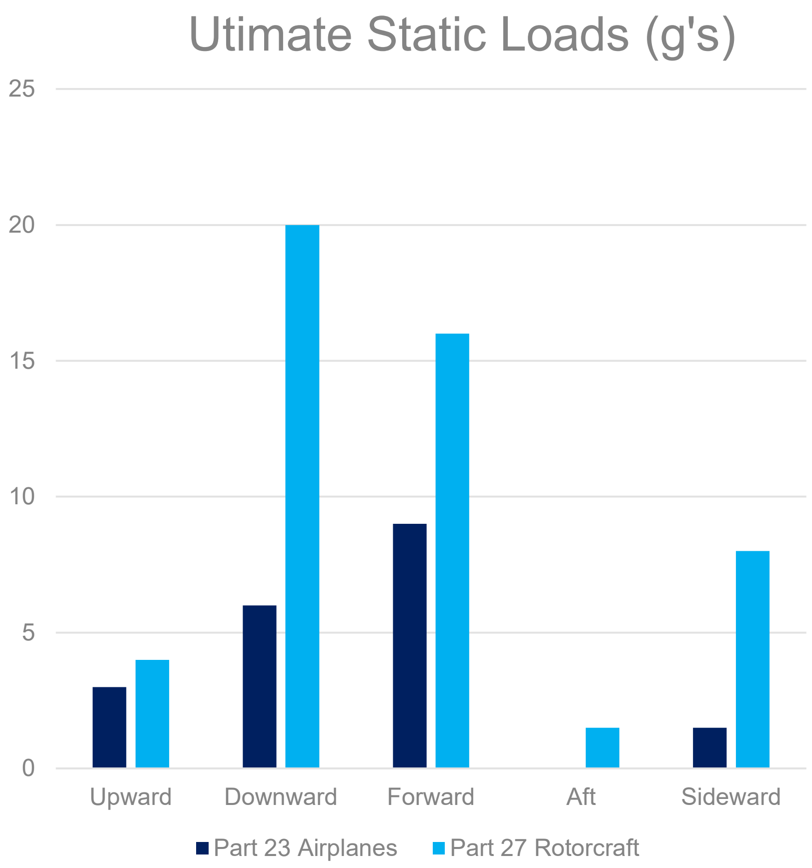
** NADC-TR-84406, THE NAVAL AIRCRAFT CRASH ENVIRONMENT

*** DOT/FAA/CT-85/11 ANALYSIS OF ROTORCRAFT CRASH DYNAMICS FOR DEVELPMT OF IMPROVED CRASHWORTHINESS DESIGN CRITERIA

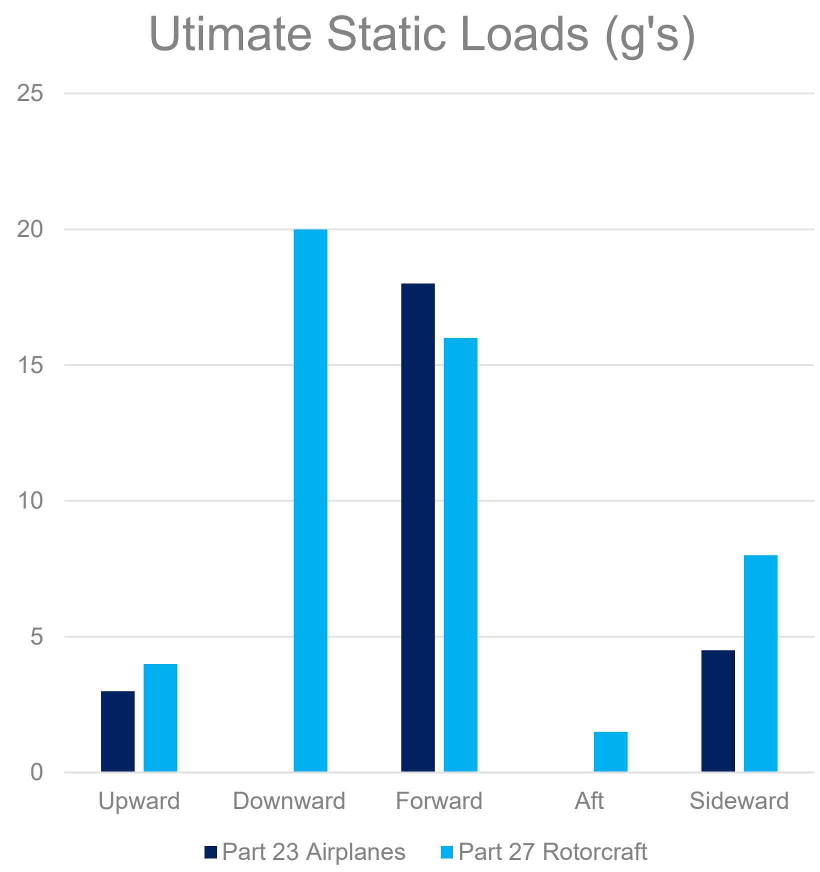
Ref. **DOD JSSG-2010-7 Joint Service Specification Guide Crew Systems Crash Protection Handbook**

Static Emergency Landing Loads §23/27.561

Emergency Loading for Occupants

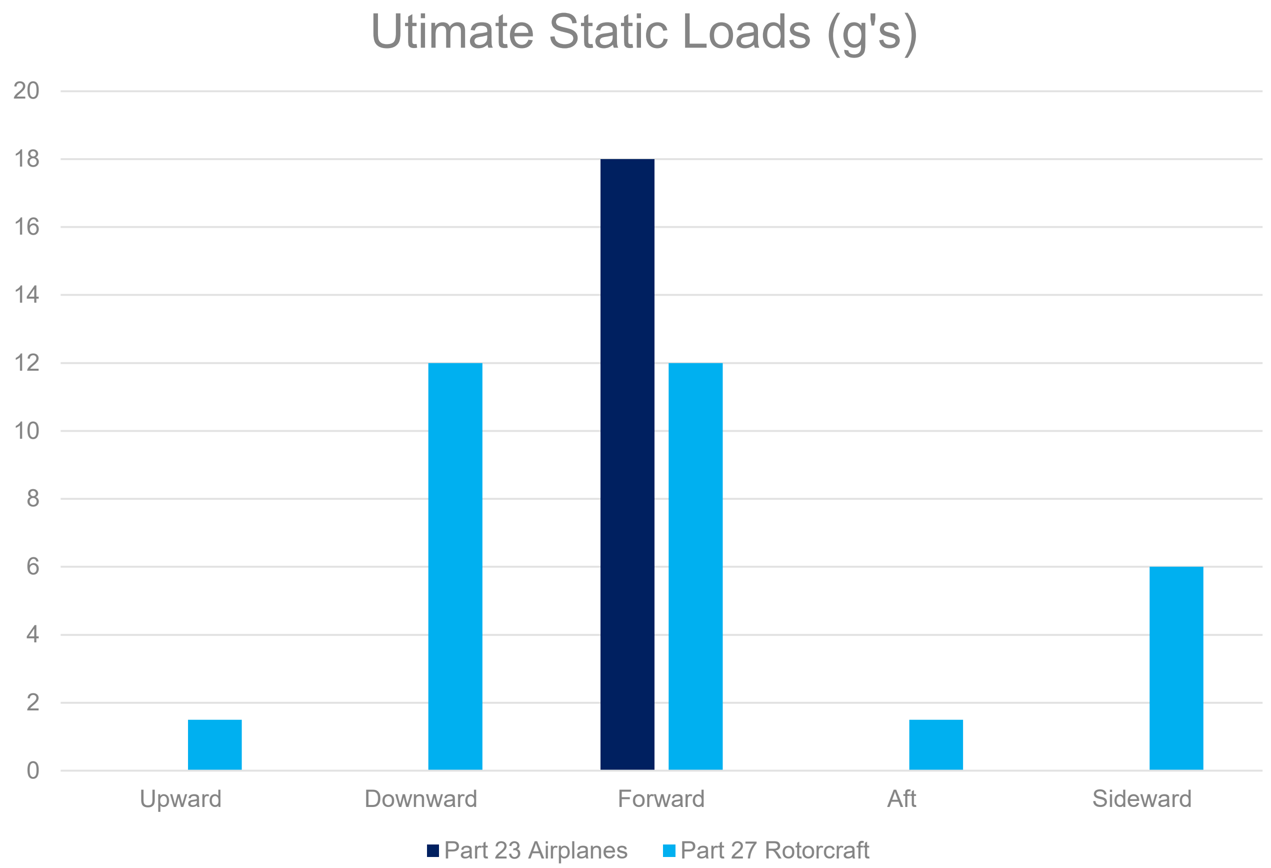


Emergency Loading for Items of Mass In Cabin



Static Emergency Landing Loads

Emergency Loading for Items Above or Aft of Passenger Compartment (Part 23 reflects requirements for engines mounted in fuselage behind cabin).



Emergency Landing Dynamic Conditions

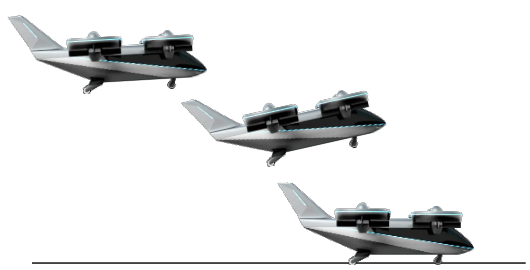
§ 27.562(b) Amdt. 27-54
$\dot{X} = 42\ ft/s\ @\ 18.4g$
$\dot{Z} = 30.0\ ft/s\ @\ 30.0g$

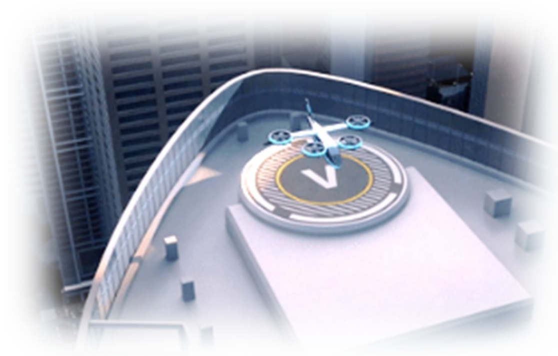
§ 23.562(b) Amdt. 23-62
$\dot{X} = 42\ ft/s\ @\ 26g^{*}$
$\dot{Z} = 31\ ft/s\ @\ 19g^{**}$

* 26g for first row
21g for other rows
** 19g for first row
15g for other rows

Statistical data used to establish emergency landing conditions for rotorcraft § 27.562(b) and general aviation airplanes § 23.562(b) reveal they crash at about the same impact velocities but different decelerations

Urban eVTOL operations will likely be similar to rotorcraft hence require similar crashworthiness





Call for Participation

Working Groups focused on Occupant Protection

- F3083/F3083M-19 Standard Specification for Emergency Conditions, Occupant Safety and Accommodations
  - WK68781 - Emergency Landing Conditions for eVTOL aircraft assessment

- F3114-19 Standard Specification for Structures
  - WK68805 - Bird Strike for eVTOL aircraft assessment

- F3239-19 Standard Specification Aircraft Electric Propulsion Systems
  - WK65629 Energy Shedding (Crashworthiness)

QUESTIONS?