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Standard Guide for Crewed Suborbital Space Vehicle Design[1]

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1. Scope

1.1 This guide addresses the design of suborbital space vehicles that carry flight crew, spaceflight participants, mission specialists or other humans on suborbital trajectories.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Purpose

2.1 The purpose of this guide is to serve as a consensus among the commercial spaceflight technical community as to key practices associated with the design of human-occupied suborbital space vehicles. The guide was created based on industry best practices, historical lessons learned, and existing safety requirements, and is intended to apply to both new and existing suborbital space vehicles. Use of this guide does not purport to address all safety concerns associated with human space flight aboard suborbital space vehicles, but instead provides a set of industry consensus best design practices to mitigate known safety risks associated with human flight aboard suborbital space vehicles. Companies developing suborbital space vehicles are expected to tailor the recommendations herein to fit the specific requirements of their systems and mission profiles.

3. Referenced Documents

3.1 *ASTM Standards:*[2]

F3377 Terminology Relating to Commercial Spaceflight

F3668/F3668M Guide for Occupant Survivability in Orbital Vehicles

3.2 *Federal Aviation Association Standards:*

FAA Recommended Practices for Human Space Flight Occupant Safety Version 1.0, Dated August 27, 2014.[3]

4. Terminology

4.1 *Definitions:*

4.1.1 *abort, v*—terminate the launch countdown, especially in the automated portion late in the countdown.

4.1.2 *egress, n*—scenario where the flight crew/spaceflight participants depart the space vehicle on the ground through the outer hatch and onto the launch tower/pad.

4.1.3 *escape, n*—separation of the crewed space vehicle from its launch vehicle/booster in an off-normal scenario to avoid a hazardous condition.

4.1.4 *failure tolerance, n*—the ability to sustain a certain number of failures and still retain capability; a component, subsystem, or system that cannot sustain at least one failure is not considered to be failure tolerant.

4.1.5 *safety critical function or item, n*—one whose functions are essential to safe performance or operation; a safety-critical system subsystem, condition, event, operation, process, or item is one whose proper recognition, control, performance, or tolerance is essential to system operation such that it does not jeopardize crew, occupant, or public safety.

4.1.6 *vehicle, n*—that portion of a space flight system that is intended to fly to, operate in, or return from space; this includes any launch vehicle, carrier aircraft, equipment, and supplies, but excludes payloads.

5. Significance and Use

5.1 This guide is intended to be used by design teams developing suborbital space vehicles. It contains a consensus of the design topics known through experience of the technical community to be the minimum to which attention must be paid during the design process to ensure a high probability of safe flight and return to Earth of humans.

[1] This guide is under the jurisdiction of ASTM Committee F47 on Commercial Spaceflight and is the direct responsibility of Subcommittee F47.01 on Occupant Safety.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from https://www.faa.gov/about/office_org/headquarters_offices/ast/media/recommended_practices_for_hsf_occupant_safety-version_1-tc14-0037.pdf.

6. Basis of Classification

6.1 The recommendations below reflect the practices identified in the "FAA Recommended Practices for Human Space Flight Occupant Safety," Version 1.0, Dated August 27, 2014. Where appropriate, additional recommendations have been added to cover topics not covered by the FAA document, but which are included in the scope of this document.

7. Recommendations:

7.1 *Human Needs and Accommodations:*

7.1.1 *Atmospheric Conditions:*

7.1.1.1 The vehicle should provide atmospheric conditions to all occupants adequate to protect them from serious injury and allow safety-critical operations to be performed.

7.1.1.2 The system should provide the capability to monitor and react to Environmental conditions.

7.1.2 *Body Waste, Vomitus, Biological Waste and Wet Trash Management*—The system should provide a means to contain body waste, vomitus, biological waste, and wet trash to protect occupants from illness and prevent interference with operations.

7.1.3 *Emergency Survival Equipment and Supplies*—The system should include emergency survival equipment and supplies that provide a reasonable chance of survival and rescue of all occupants for postlanding emergencies. Unless unnecessary for the design reference mission, the emergency survival equipment and supplies should include items from each of the following categories:

7.1.3.1 First aid;

7.1.3.2 Communications (Refer to 7.3.10, Emergency Occupant Location Post-Landing and 7.3.11, Emergency Communication with Rescue Personnel.);

7.1.3.3 Flotation (if operating over water beyond glide distance from land);

7.1.3.4 Signaling; and

7.1.3.5 Environmental Protection.

7.2 *Human Protection:*

7.2.1 *Acceleration Protection*—The system should be designed to limit occupant exposure to transient and sustained linear and angular acceleration such that occupants are protected from loss of consciousness or serious injuries and safety-critical operations can be performed successfully.

7.2.2 *Vibration Protection*—The system should be designed to limit occupant exposure to vibration such that occupants are protected from serious injuries and safety-critical operations can be performed successfully.

7.2.3 *Radiation Protection*—The system should be designed to limit occupant exposure to radiation by following the ALARA (As Low As Reasonably Achievable) radiation principle. At minimum, the system should protect occupants from serious injuries and allow for safety critical operations to be performed successfully. System design should consider the solar cycle, solar particle events, and all sources of ionizing radiation both internal and external to the vehicle.

7.2.4 *Noise Exposure Protection*—The system should be designed to limit occupant exposure to continuous, intermittent, and impulse noise such that occupants are protected from permanent hearing loss or serious injuries and safety-critical operations can be performed successfully. System design should consider both audible and infrasonic and the combined noise level of multiple acoustic sources.

7.2.5 *Mechanical Hazards Protection*—The system should be designed to protect occupants from serious injuries and to ensure no interference with the successful performance of safety-critical operations due to:

7.2.5.1 Moving parts;

7.2.5.2 Entrapment;

7.2.5.3 Stored potential energy;

7.2.5.4 Burrs;

7.2.5.5 Pinch points;

7.2.5.6 Sharp edges;

7.2.5.7 Sharp items; and

7.2.5.8 Temperature.

7.2.6 *Orthostatic Protection*—The system should provide orthostatic intolerance countermeasures to the extent necessary to protect occupants from serious injury and perform safety-critical operations.

7.2.7 *Fire Event Detection and Fire Suppression*—A fire can quickly put the occupants into extremis. The absence of ventilation, the permeation of combustion products in a zero-g environment, and the limited source of emergency breathing air to supplement the environment until the toxic gasses can be purged combine to make a zero-g fire uniquely dangerous. To provide the maximum chance of occupant survival following a fire, spacecraft should, at a minimum, provide the following fire mitigations:

7.2.7.1 Fire detection system that senses combustion products from the primary environmental control system flow path;

7.2.7.2 Means to suppress credible fire types given the known fuel and combustion sources;

7.2.7.3 Automatic or manual ventilation system cutoff to prevent fire propagation; and

7.2.7.4 Personal Breathing Apparatus (PBA) to offset effect of the combustion products.

7.2.8 *Emergency Response to Contaminated Atmosphere*—In order to respond to a contaminated atmosphere, the system should provide equipment and provisions to limit occupant exposure to the contaminated atmosphere such that occupants are protected from serious injuries and safetycritical operations can be performed successfully. Specific mitigations should be dependent on the conditions present such as:

7.2.8.1 Provide breathable air and eye protection for each occupant.

7.2.9 *Emergency Response to Loss of Cabin Pressure*—In the event cabin pressure integrity is lost, the system should be designed to prevent incapacitation of flight crew and serious injury to the occupants. See 7.7 of Guide F3668/F3668M, Standard Guide for Occupant Safety of Orbital Vehicles for specific recommendations.

7.2.10 *Emergency Response—Escape and Egress.* The system should provide the capability for the occupants to self-egress from the vehicle on the ground. The system should provide continuous ascent escape capability from pre-lift-off through the end of powered flight.