Draft Guidelines for Commercial Suborbital Reusable Launch Vehicle Operations with Flight Crew

Federal Aviation Administration
Office of Commercial Space Transportation
800 Independence Avenue, Room 331
Washington, DC 20591

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1. Introduction

On December 23, 2004, President Bush signed into law the Commercial Space Launch Amendments Act of 2004 (CSLAA). The CSLAA promotes the development of the emerging commercial space flight industry and makes the Department of Transportation and the Federal Aviation Administration (DOT/FAA) responsible for regulating commercial human space flight under 49 U.S.C. Subtitle IX, Chapter 701 (Chapter 701).

Prior to the enactment of the CSLAA, the DOT/FAA regarded flight crew as part of the flight safety system, when the flight crew has control over the safety of the vehicle and the capability of averting a potential hazard to the uninvolved public on the ground and in the air. The CSLAA does not change that authority, and these guidelines therefore include guidance on environmental control and life support systems, fire detection and suppression, and human factors, all of which may be necessary to ensure that the flight crew is able to protect the uninvolved public.[1]

In the near term, the CSLAA requires that the DOT/FAA: (1) issue guidelines or advisory circulars to guide the implementation of the CSLAA as soon as practical after the date of its enactment on December 23, 2004; (2) issue proposed regulations that include those relating to crew, space flight participants, and permits for launch or reentry of reusable suborbital rockets not later than December 23, 2005; and (3) issue final regulations not later than June 23, 2006.

2. Purpose

These guidelines fulfill the DOT/FAA's requirement to issue guidance on the implementation of the CSLAA prior to the issuance of regulations related to flight crew. These guidelines address what the DOT/FAA may expect to review and evaluate in an application for a license or permit[2] for a launch that has flight crew on board a suborbital reusable launch vehicle (RLV).

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[1] The CSLAA provides the DOT/FAA authority to issue regulations governing the design or operation of a launch vehicle to protect the health and safety of crew and space flight participants for launches in which a vehicle will be carrying a human being for compensation or hire. 49 U.S.C. § 70105(c). The DOT/FAA may issue such regulations only for practices that resulted in a serious or fatal injury or for practices that contributed to an unplanned event that posed a high risk of causing a serious or fatal injury to crew or space flight participants.

[2] Under the CSLAA, a person may apply for an experimental permit for reusable suborbital rockets only for purposes of research and development and to test new design concepts, equipment, or operating techniques. An RLV operator may also use an experimental permit to show compliance with regulatory requirements or to train crew before obtaining a license. The DOT/FAA must decide whether to issue a permit within 120 days after receipt of an application. In contrast, the agency has 180 days to make a licensing determination.

3. Scope

These guidelines address flight crew on a suborbital RLV. Guidelines concerning space flight participants are issued separately in "Guidelines For Commercial Suborbital Reusable Launch Vehicle Operations With Space Flight Participants," dated February 11, 2005.

4. Applicability

These guidelines apply to any RLV operator licensed or permitted under Chapter 701 who proposes to have flight crew on board a suborbital RLV. These guidelines also apply to flight crew on board a suborbital RLV.

5. Definitions

Crew	Any employee of a licensee or transferee, or of a contractor or subcontractor of a licensee or transferee, who performs activities in the course of that employment directly relating to the launch, reentry, or other operation of or in a launch vehicle or reentry vehicle that carries human beings. 49 U.S.C. § 70102(2).
Flight crew	Any employee of a licensee or transferee, or of a contractor or subcontractor of a licensee or transferee, who is on board a launch or reentry vehicle and performs activities in the course of that employment directly relating to the launch, reentry, or other operation of the launch vehicle or reentry vehicle.[3]
RLV pilot	A designated member of the RLV flight crew who has the ability to exercise flight control authority over a launch or reentry vehicle.
Space flight participant	An individual, who is not crew, carried within a launch vehicle or reentry vehicle. 49 U.S.C. § 70102(17).
Suborbital rocket	A vehicle, rocket-propelled in whole or in part, intended for flight on a suborbital trajectory, and the thrust of which is greater than its lift for the majority of the rocket-powered portion of its ascent. 49 U.S.C. § 70102(19).

[3] Because the CSLAA's definition of "crew" does not distinguish between ground crew and crew on board a vehicle, the DOT/FAA guidelines use the term "flight crew" to identify the crew on board a vehicle. The DOT/FAA does not seek to duplicate the Occupational Safety and Health Administration's (OSHA's) role in regulating worker safety, particularly for ground crew. Most worker safety issues related to preparation of a launch vehicle for flight are under the jurisdiction of OSHA.

Suborbital trajectory	The intentional flight path of a launch vehicle, reentry vehicle, or any portion thereof, whose vacuum instantaneous impact point does not leave the surface of the Earth. 49 U.S.C. § 70102(20).

6. RLV Flight Crew Training and Qualifications

The CSLAA requires that each crew member receive training and satisfy medical or other standards as specified in a license or permit. 49 U.S.C. § 70105(b)(4)(A).

a. The pilot of an RLV that will operate in the National Airspace System (NAS) should possess an FAA pilot certificate, and should hold ratings to operate one or more aircraft with similar characteristics for as many phases of the mission as practicable.

   Rationale: The requirement to hold a pilot certificate and to hold ratings to operate aircraft with similar characteristics ensures that the pilot will have received training and experience in similar aircraft and will have demonstrated the airmanship skills necessary for safe operations in the NAS.

b. The RLV flight crew should possess a valid FAA 2nd-class medical certificate.

   Rationale: The safe operation of an RLV with flight crew can be affected by the health or medical condition of the flight crew. One aspect of a flight crew's ability to perform safety-related functions is the physical and mental state of the individual. The FAA's Office of Aerospace Medicine (AAM), which includes the Civil Aerospace Medical Institute (CAMI), the medical certification, research, and education wing of the AAM, considers the medical qualification standards for 2nd-class airman certification to be adequate standards for RLV flight crew on a suborbital launch due to its inherently short duration. Class 1 medical certificates are required for pilots of scheduled airliners. Class 2 medical certificates are for commercial, non-airline duties. Class 3 medical certificates are for private pilot duties only. 14 CFR part 67, which provides medical qualification standards for 1st-class, 2nd-class, and 3rd-class airman certifications, addresses standards for eye; ear, nose, throat, and equilibrium; mental, neurological, cardiovascular performance and the general medical condition for the purposes of pilot certification.

c. Each member of an RLV flight crew should be trained to operate the vehicle so that it will not harm the public.

   Rationale: Crew who complete a training program in order to know how the vehicle operates will understand how to respond to both planned and anomalous events.

d. The RLV operator should develop a mission- and configuration-specific training program for flight crew and define standards in accordance with paragraph c for successful completion. The RLV operator's training program should include:

(1) Prior to each mission, the RLV flight crew should receive vehicle and mission-specific training to cover all phases of flight by using one or more of the following: i) a method of simulation (operational and/or procedural), ii) an aircraft with similar characteristics for each phase of the mission where the similarity applies, iii) incremental expansion of the mission envelope, or iv) an equivalent method of training as approved by the FAA through the licensing and permitting process.

Rationale: In order to ensure an adequate level of safety for the mission, the flight crew should be trained in the operations that they must perform during the mission, including procedures for operating in the NAS and at a launch site. Crew should be familiar with the flight behavior of the vehicle. Training in the above manner will prepare the flight crew and provide the flight crew the necessary information.

(2) The RLV operator should verify through test, analysis, inspection, or demonstration that any flight crew-training device used to meet the training program requirements realistically represents the vehicle's configuration and mission.

Rationale: The RLV operator should ensure that a crew training device adequately represents the vehicle's configuration and mission so that it provides realistic training to the RLV flight crew.

(3) RLV flight crew training should include nominal and non-nominal flight conditions. The non-nominal situations should include i) abort scenarios, ii) emergency operations, and iii) procedures that direct the vehicle away from the public in the event of a flight crew egress during flight.

Rationale: Training to respond to planned and unplanned events allows an RLV flight crew trainee to be better able to respond to emergencies. They will obtain a competent understanding of vehicle systems, vehicle characteristics, and vehicle capabilities, as well as operational, malfunction, and contingency procedures. Thus, when the flight crew faces any of these situations during flight, they will be better able to respond to them.

(4) If a vehicle relies on multiple control and/or propulsion modes, the training program should include training in each mode, including the transition between modes, so that the crew is able to retain vehicle control.

Rationale: The flight crew needs to train to be capable of maintaining vehicle control as the transition from aerodynamic control surfaces to a reaction control system (RCS) occurs. Furthermore, the flight crew needs to train to be capable of maintaining vehicle control during the transition from one propulsion mode to another mode.

e. The training program should be continually updated to ensure that training accounts for lessons-learned from training and operational missions. This should be accomplished with a documented system to track revisions and updates.

Rationale: The training program should capture, in writing, lessons-learned as experience is gained. Experience will uncover additional events to which the crew should be able to respond. The RLV flight crew should be prepared for events and anomalies discovered during training and mission operations.

f. The RLV operator should document the training completed by each member of the flight crew and maintain the documentation for each active member of the flight crew. The training should be recorded in terms of mission cycles and phases of mission cycles.

Rationale: Gathering and maintaining accurate documentation are vital for tracking and ensuring that flight crew are up-to-date with their training requirements. Recording training in terms of hours is not necessarily germane to RLVs because RLVs are rarely in a condition of steady, level flight.

g. The RLV operator should ensure that all RLV flight crew qualifications are current before undertaking RLV flight crew responsibilities.

Rationale: This ensures that all flight crew are qualified and have received the necessary training at the time of RLV operation.

7. Informing Flight Crew Of The Risk

The CSLAA requires that an RLV operator inform any individual serving as crew in writing, prior to executing any contract or other arrangement to employ that individual (or, in the case of an individual already employed as of the date of enactment of the CSLAA, as early as possible, but in any event prior to any launch in which the individual will participate as crew), that the United States Government has not certified the launch vehicle as safe for carrying flight crew or space flight participants. 49 U.S.C. § 70105(b)(4)(B).

8. Crew Compliance

The CSLAA requires crew to comply with all requirements of the laws of the United States that apply to crew. 49 U.S.C. § 70105(b)(4)(C).

9. Reciprocal Waiver of Claims

The CSLAA requires that flight crew execute a reciprocal waiver of claims with the DOT/FAA. 49 U.S.C. § 70112(b)(2).

10. Environmental Control and Life Support Systems (ECLSS)

a. The RLV operator should provide adequate atmospheric conditions to sustain life and consciousness for all inhabited areas within the vehicle. The RLV flight crew may perform the functions necessary to achieve this. The following may be necessary in order to sustain life and consciousness:

(1) The RLV operator should monitor and control the composition and revitalization of the atmosphere to maintain safe levels for normal respiration for the flight crew.

Rationale: The atmosphere in inhabited areas should have safe levels of oxygen and carbon dioxide to allow normal respiration. Because of normal human metabolic effluent, it is natural for carbon dioxide to accumulate and necessary for it to be removed. The proper functioning of the crew is necessary to ensure protection of the uninvolved public.

(2) The RLV operator should monitor and control the pressure of the atmosphere to maintain safe levels for flight crew respiration.

Rationale: An essential aspect of the body's ability to absorb oxygen from the air is the atmospheric pressure, specifically the partial pressure of oxygen (pO_2). For normal breathing, the pO_2 within the cabin should be kept between 19.5 kPa to 23.1 kPa to avoid the effects of hypoxia. Total pressure and the partial pressure of carbon dioxide should also be monitored and kept at levels sufficient to ensure consciousness and thus proper functioning of the crew.

(3) The RLV operator should control contamination and particulate concentrations for the RLV flight crew to prevent interference with the crew's ability to operate the vehicle.

Rationale: The atmosphere should be free from harmful or hazardous concentrations of gases, vapors, and particulates that can be inhaled. Particulate and contaminant control may also be needed to protect sensitive equipment from damage.

(4) The RLV operator should monitor and control the temperature of the atmosphere to maintain safe levels for the flight crew.

Rationale: Although humans can survive in a relatively wide range of temperatures, it is essential to regulate the temperature within a cabin or suit. Providing proper temperature controls ensures the flight crew maintains a degree of situational awareness sufficient to enable the flight crew to perform its activities. In addition, temperature control is needed to ensure that equipment is being kept within its normal operational environments.

(5) The RLV operator should monitor and control the humidity of the cabin atmosphere to maintain safe levels for the flight crew.

Rationale: If the flight crew depends on visual information through a window, humidity control is necessary to avoid windows fogging and condensation that can hinder the RLV pilot's vision. Humidity control ensures that equipment is kept within its normal operating environment.

(6) The RLV operator should monitor and control the ventilation and circulation of the cabin atmosphere to maintain safe levels for the flight crew.

Rationale: Providing proper ventilation ensures the flight crew maintains a high degree of situational awareness by reducing stagnant air, which may contain a build-up of carbon dioxide. Good circulation also cools equipment.

(7) The RLV operator should provide an adequate redundant or back-up oxygen supply for the flight crew.

Rationale: In the event of a failure of the primary atmospheric control system, the redundant or back-up system will supply oxygen for the flight crew.

b. The RLV operator should make provisions for stowage of all objects in the cabin, to avoid interference with the flight crew's operation of the vehicle during flight.

Rationale: This preserves the ability of the flight crew to perform their activities without being negatively affected by moving objects.

c. The RLV operator should design the flight crew environment to mitigate the effects of vehicle decompression.

Rationale: If decompression should occur, it could have serious physiological effects on the flight crew, including hypoxia, decompression sickness, hypothermia, and vaporization of tissue fluids.

Guidance on environmental control and life support systems may be found in "Designing For Human Presence in Space: An Introduction to Environmental Control and Life Support Systems" (NASA RP-1324) and "Man-Systems Integration Standards" (NASA-STD-3000).

11. Fire Detection and Suppression

Any launch vehicle with flight crew should have the ability to detect and suppress a fire to prevent incapacitation of the flight crew, which may result in risk to the public.

Rationale: Smoke from a fire can rapidly incapacitate an RLV pilot or obscure the pilot's vision so that the vehicle cannot be flown safely. The pilot should be able to respond to a vehicle fire so that the vehicle does not pose additional risk to the public.

12. Human Factors

Human factors should be considered in the design of human-machine interfaces associated with RLV missions and operations so that the flight crew can perform its safety-critical functions.

(1) Human factors engineering should be applied to the design of human-machine interfaces (e.g., displays and controls) and mission design (e.g., allocating functions between human and machine).

Rationale: Human factors engineering is a discipline that applies knowledge of human capabilities and limitations to the design of systems, machines, work environment, and operations. Human–related factors account for the majority of fatal aircraft accidents while aircraft system malfunctions are involved in a relatively small fraction of aircraft incidents and accidents. Some human factors-related lessons learned from aviation may be applicable to suborbital RLVs with a flight crew within the vehicle. Human factors considerations draw on multiple disciplines such as psychology, physiology, engineering, ergonomics, and medicine. The design and layout of displays and controls and the amount of crew workload can have an effect on the ability of the flight crew to perform safety-critical functions. Using mockups, simulators, and training, and conducting human factors analyses such as functional and task analyses are examples of human factors-related applications to assess human-machine interfaces or human-in-the loop functions and performance. "DOD Design Criteria Standard – Human Engineering" (MIL-STD-1472), "Flying Qualities of Piloted Aircraft" (MIL-HDBK-1797), and "Man-Systems Integration Standards" (NASA-STD-3000) may provide guidance on applying human factors engineering.

(2) RLVs should be operated in a manner so that the flight crew can withstand physical stress factors such as acceleration, vibration, and noise.

Rationale: Depending on the magnitude, duration, and direction, excessive acceleration could cause flight crew to lose consciousness. Loss of flight crew consciousness could place the public at risk from the vehicle. Excessive noise could interfere with voice communication. "Man-Systems Integration Standards" (NASA-STD-3000) provides guidance on some of the physical stress factor limits.