[4910-13]

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Waiver of Autonomous Reentry Restriction for a Reentry Vehicle

AGENCY: Office of Commercial Space Transportation; Federal Aviation Administration (FAA), DOT.

ACTION: Notice of waiver.

SUMMARY:

This notice concerns three petitions for waiver related to the launch and reentry of an Orion Multi-Purpose Crew Vehicle. In the first of these petitions, United Launch Alliance (ULA) requested a waiver of the FAA's requirement that the expected number of casualties for a launch not exceed 0.00003 casualties ($E_c \leq 30 \times 10^{-6}$) from debris. For the second and third petitions, Lockheed Martin (Lockheed) requested waivers of the FAA's regulatory requirements that (1) the expected number of casualties for the entire mission, including launch and reentry, not exceed 30×10^{-6} casualties from debris; and (2) an operator only initiate reentry of a reentry vehicle by command. The FAA elects to consider all three petitions together because all three involve the same essential facts and risk analyses. The FAA grants all three petitions.

FOR FURTHER INFORMATION CONTACT:

For technical questions concerning this waiver, contact Charles P. Brinkman, Aerospace Engineer, AST-200, Office of Commercial Space Transportation (AST), Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591; telephone (202) 267-7715; email: phil.brinkman@faa.gov. For legal questions concerning

this waiver, contact Laura Montgomery, Manager, Space Law Branch (AGC-250), Regulations Division, Office of the Chief Counsel, Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591; telephone (202) 267-3150; e-mail: laura.montgomery@faa.gov.

SUPPLEMENTARY INFORMATION:

Background

Lockheed and ULA are private commercial space flight companies. Lockheed entered into a contract with the National Aeronautics and Space Administration (NASA) to provide the first orbital flight test for NASA's Orion Multi-Purpose Crew Vehicle Program. Lockheed has contracted with ULA to provide launch services for the mission.

The FAA is responsible for licensing, in relevant part, the launch of a launch vehicle and the reentry of a reentry vehicle, under authority granted to the Secretary of Transportation by 51 USC Subtitle V, chapter 509 (Chapter 509), and delegated to the FAA's Administrator and Associate Administrator for Commercial Space Transportation.

The mission at issue in this notice is Orion Exploration Flight Test 1, launching from Cape Canaveral Air Force Station in Florida. The mission tests the Orion Multi-Purpose Crew Vehicle in an un-crewed, limited-capability configuration, and serves as a stepping stone towards a crew-capable vehicle that would enable human exploration missions beyond Earth orbit. The mission is comprised of a launch, which is conducted by ULA, and a reentry, which is conducted by Lockheed. The launch vehicle is ULA's Delta IV Heavy launch vehicle, which consists of a Common Booster Core (CBC) as the first stage with two additional strap-on CBCs and a Delta IV Cryogenic Second Stage (DCSS). The first burn of the DCSS places the Orion and the DCSS in orbit, and a

second DCSS burn places the Orion into a highly elliptical, negative-perigee trajectory, to simulate the thermal conditions and high reentry speeds the module would experience returning from missions beyond Earth orbit. After separating from the DCSS, the Orion module reenters over the eastern Pacific Ocean, splashing down 231 nautical miles west of Baja California, Mexico.

Section 417.107(b)(1) of Title 14 of the Code of Federal Regulations (14 CFR) prohibits the launch of a launch vehicle if the expected casualty (E_c) for the flight exceeds 30×10^{-6} for, in relevant part, impacting inert and explosive debris (debris). On February 27, 2014, ULA petitioned for a waiver because the launch has a debris risk of 163×10^{-6}.

Section 435.35 establishes acceptable risk for reentry vehicles, and requires operators to comply with §§ 431.35(a) and 431.35(b)(1)(i) [1], which in turn prohibit an E_c for debris in excess of 30×10^{-6}, for both launch and reentry combined. On February 27, 2014, Lockheed also petitioned for a waiver because the mission has a combined risk of 164×10^{-6}.

Section 431.43(e) requires any reusable launch vehicle (RLV) that enters Earth orbit to be operated such that the vehicle operator can monitor and verify the status of safety critical systems before enabling reentry. This section also prohibits operators from designing a system to reenter autonomously. On February 27, 2014, Lockheed requested a waiver from this prohibition.

Waiver Criteria

Chapter 509 allows the FAA to waive a license requirement if the waiver (1) will not jeopardize public health and safety, and safety of property; (2) is in the public

[1] Although the module is a reentry vehicle and not a reusable launch vehicle, 14 CFR 435.33 incorporates and applies § 431.43 to all reentry vehicles.

interest; and (3) will not jeopardize national security and foreign policy interests of the United States. 51 U.S.C. 50905(b)(3); 14 CFR 404.5(b).

A. Sixty Day Requirement

Section 404.3(b)(5) requires that a petition for waiver be submitted at least sixty days before the proposed effective date of the waiver, which in this case would be March 8, 2014, the date by which the FAA must make its licensing determination. This section also provides that a petition may be submitted late for good cause.

Here, ULA and Lockheed submitted their waiver petitions on February 27, 2014, less than sixty days before the statutory deadline for the FAA's license determination. However, both launch operators have shared drafts of their petitions with the FAA, thus providing the FAA with sufficiently early access to the information to review the information in a timely fashion. Accordingly, the FAA is able to find good cause.

B. Public Health and Safety, and Safety of Property

For the purposes of clarity, the FAA's analysis of public health and safety, and the safety of property, is broken down into subsections reflecting the various issues raised by the risk waivers and autonomous reentry waivers, respectively.

1. Launch and Mission Risk

Although the FAA's regulations prohibit debris risk in excess of 30×10^{-6}, a waiver is warranted in this case because the United States Government's experience conducting other space missions with risk in excess of 100×10^{-6} demonstrates that the risks of this mission are consistent with the public health and safety, and the safety of property. ULA and Lockheed provided risk analyses for both launch and reentry,

respectively, but it was the FAA who calculated the total mission risk for debris as 165 x 10^{-6}. That number may be broken down as follows:

- 20 x 10^{-6} from launch, with approximately 10 x 10^{-6} attributable to local area risk and approximately 10 x 10^{-6} attributable to overflight (downrange) risk;
- 143 x 10^{-6} from random and off-target reentry of the DCSS during the second DCSS burn;
- <1 x 10^{-6} for reentry of the Orion module

The United States Government has repeatedly accepted risk for government launches in excess of the FAA's 30 x 10^{-6} and in excess of 100 x 10^{-6}, without negative consequences for safety. For example, the current E_c requirement for government launches from U.S. National Test Ranges is 1 x 10^{-4} (equal to 100 x 10^{-6}), encompassing all risk from debris, toxics, and overpressure. See Air Force Instruction 91-217, Space Safety and Mishap Prevention Program (2010). Moreover, the Space Shuttle used a debris risk criterion of 200 x 10^{-6} for launch risk to the public. See NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond, Vol. 1 Final Edition, at 2-39 (May 15, 2007). And, in 2005, the U.S. Air Force approved a government launch of a Titan where the risk ranged from 145 to 317 x 10^{-6}. Dept. of the Air Force Memorandum, Overflight Risk Exceedance Waiver for Titan IV B-30 Mission (Apr. 4, 2005).

Additionally, in 2012, the FAA granted a waiver to SpaceX under similar circumstances. Waiver of Acceptable Risk Restriction for Launch and Reentry, Notice of Waiver, 77 FR 24556 (Apr. 24, 2012). SpaceX's 2012 mission was also NASA-

sponsored; involved a test of the company's reentry vehicle, the Dragon module; and posed an estimated total mission risk from debris of between 98 and 121 x 10^{-6}. Id.

ULA's launch risk of 163 x 10^{-6} is less than the risk approved for these government systems. Accordingly, granting a waiver of §§ 417.107(b)(1) and 431.35(b)(1)(i) in this case does not jeopardize the public health and safety, or the safety of property.

2. Safety of Autonomous Reentry Waiver

Because Orion's reentry system allows Lockheed to identify anomalies or other non-compliant conditions, a waiver allowing autonomous reentry in this instance would not jeopardize the public health and safety, or the safety of property. In 1999, in the preamble to the reentry-rule NPRM, the FAA expressed concern that autonomous reentry was not adequately safe. Commercial Space Transportation Reusable Launch Vehicle and Reentry Licensing Regulations, Notice of Proposed Rulemaking, 64 FR 19626, 19645 (Apr. 21, 1999). The FAA was specifically concerned about the possibility that anomalies or other non-compliant conditions occurring in then-existing technology would not be identified prior to an autonomous reentry initiation. Id. By requiring the capability for human intervention, however, the FAA did not intend to permanently foreclose the use of autonomous systems or autonomous decision-making. In fact, the agency expressly acknowledged that safer autonomous systems were feasible, and that greater levels of confidence in a particular system could cause the agency to change its position. Commercial Space Transportation Reusable Launch Vehicle and Reentry Licensing Regulations, Final Rule, 65 FR 56618, 56641 (Sept. 19, 2000). Despite its concerns, the FAA retained the authority to waive the autonomous reentry restriction. Id.

Lockheed's proposed approach to reentry addresses the concerns underlying the FAA's regulatory requirements. Under Lockheed's proposed plan, Lockheed would use two means of detecting anomalies and non-compliant conditions. Lockheed's Flight Control Team can monitor and control the module, and the Orion module monitors itself real-time.

ULA's proven DCSS system propels the module to a targeted reentry location over 200 miles into the Pacific Ocean. In a nominal reentry, the Orion module waits for the DCSS to signal that the module is at its pre-determined time for separation, the DCSS thrusters are inhibited, and the vehicle is operating within pre-determined state vector rate requirements. The Orion then autonomously commands its separation from the DCSS and activates the module's propulsion system. Each string of Orion thrusters is capable of providing closed-loop attitude control in the pitch, yaw, and roll axes, as well as translational delta-velocity. Given the trajectory and landing location chosen for the mission, however, combined with the limited thrust performance capability of the module's individual thrusters and limited total onboard propellant, the module does not have the propulsive capability to move its impact point over land following DCSS separation.

While the module is in flight, Lockheed's Flight Control Team is capable of receiving and monitoring real-time vehicle telemetry transmissions. By doing so, the team will be able to detect anomalies and non-compliant conditions. In the event the Flight Control Team detects an off-nominal condition, the team can send several pre-approved contingency commands to the module to mitigate loss of vehicle and protect public safety. In the event a communications failure causes the Flight Control Team to

lose direct insight into the raw health-and-status telemetry data, the module has the ability to autonomously guide itself to its pre-determined landing site. This autonomous capability allows the module to safely reenter, descend, land, and safe itself post-splashdown—even after a communications failure with the ground.

In addition to the systems already described, the Orion module itself has the ability to identify anomalies or other non-compliant conditions. Orion has the ability to monitor its safety-critical systems in real-time. It has a space-grade vehicle management computer with redundant flight control modules. It has the ability to check the validity of its data by reviewing--using built-in channel selection criteria--data received from redundant sensors. The redundant sensors include redundant GPS receiver antennas and redundant, space-grade inertial measurement units.

Also playing an instrumental role in the FAA's ability to grant a waiver is the fact that Orion is equipped with a number of mitigating features. First, Orion has a "cold-restart" capability and self-checking pair processors to maintain proper vehicle commanding after any unexpected power cycle, radiation upset, or other off-nominal event that would require an automatic restart of the module's computing system. Also, Orion's computing system has fail-silent functionality to prevent off-nominal corrupted or inadvertent vehicle commanding. Finally, Orion has two independent and redundant propulsion strings, which ensure that even if one fails the propulsion system will still perform the planned reentry.

C. Public Interest

The FAA looks to its enabling statute to determine how Congress has defined the public interest. The FAA, through AST, implements the agency's statutory mandate to

encourage the development of commercial space capabilities and the continuous improvement of the safety of launch vehicles designed to carry passengers.
51 U.S.C. 50901(b).

ULA and Lockheed's petitions to waive the FAA's risk and reentry restrictions are consistent with the public interest because the test flight is necessary to the development of NASA's human-missions capability beyond Earth orbit.

D. National Security and Foreign Policy Interests

The FAA has not identified any national security or foreign policy implications associated with granting this waiver.

Summary and Conclusion

The FAA determines that the waivers associated with this mission will not jeopardize public health and safety or safety of property. In addition, the waivers are in the public interest because they accomplish the goals of Chapter 509 and do not unduly increase risk to the public. Finally, they will not jeopardize national security and foreign policy interests of the United States. The FAA therefore waives the requirements of 14 CFR 417.107(b)(1) and 431.35(b)(1)(i) for launch and mission risk, respectively, and of 14 C.F.R. § 431.43(e) for a commanded reentry.

Issued in Washington, DC on February 28, 2014.

Kenneth Wong,
Licensing and Evaluation Division Manager.

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