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## DEPARTMENT OF TRANSPORTATION

### Federal Aviation Administration

#### 14 CFR Part 431

#### Waiver of Acceptable Mission Risk Restriction for Reentry and a Reentry Vehicle

**AGENCY:** Federal Aviation Administration (FAA), DOT.

**ACTION:** Notice of waiver.

**SUMMARY:** This notice of waiver concerns two petitions for waiver submitted to the FAA by Space Exploration Technologies Corp. (SpaceX): A petition to waive the requirement that a waiver petition be submitted at least sixty days before the proposed effective date; and a petition to waive the restriction that the combined risk to the public from the launch and reentry of a reentry vehicle not exceed an expected average number of 0.00003 casualties ( $E_c \leq 30 \times 10^{-6}$ ) from debris. The first petition is unnecessary because, as explained below, SpaceX demonstrated good cause for its late filing. The FAA grants the second petition and waives the restriction that the combined risk to the public from the launch and reentry of a reentry vehicle not exceed an expected average number of 0.00003 casualties ( $E_c \leq 30 \times 10^{-6}$ ) from debris.

**FOR FURTHER INFORMATION CONTACT:** For technical questions concerning this waiver, contact Philip Brinkman, Licensing Program Lead, Commercial Space Transportation—Licensing and Safety Division, 800 Independence Avenue, SW., Washington, DC 20591; telephone: (202) 267-7715; e-mail: [phil.brinkman@faa.gov](mailto:phil.brinkman@faa.gov). For legal questions concerning this waiver, contact Laura Montgomery, Senior Attorney for Commercial Space Transportation, AGC-200, Office of the Chief Counsel, Regulations Division,

Federal Aviation Administration, 800 Independence Avenue, SW., Washington, DC 20591; telephone: (202) 267-3150.

#### SUPPLEMENTARY INFORMATION:

##### Background

On October 11, 2010, SpaceX submitted a waiver petition to the Federal Aviation Administration's (FAA's) Office of Commercial Space Transportation (AST) requesting two waivers with respect to a reentry license for Dragon, a reentry vehicle, to be carried aboard Falcon 9 flight 002. First, SpaceX requested a waiver of 14 CFR 404.3(b)(5), which requires that a waiver petition be submitted at least sixty days before the proposed effective date of the waiver. Second, SpaceX requested a waiver of 14 CFR 431.35(b)(1)(i),<sup>1</sup> which prohibits a mission involving a reentry vehicle when the total expected average number of casualties ( $E_c$ ) for that mission exceeds  $30 \times 10^{-6}$ .

The FAA licenses the launch of a launch vehicle, reentry of a reentry vehicle, and the operation of a launch or reentry site under authority granted to the Secretary of Transportation in the Commercial Space Launch Act of 1984, as amended, codified in 49 U.S.C. Subtitle IX, chapter 701 (Chapter 701), and delegated to the FAA Administrator. The Associate Administrator for Commercial Space Transportation exercises licensing authority under Chapter 701.

SpaceX is a private commercial space flight company. It has entered into a Space Act Agreement with the National Aeronautics and Space Administration (NASA) as part of NASA's Commercial Orbital Transportation Services (COTS) program. The COTS program is designed to stimulate efforts by the private sector to demonstrate safe, reliable, and cost-effective space transportation to the International Space Station.

The petition addresses an upcoming demonstration flight that SpaceX plans to undertake as part of the COTS program. At the time of the filing of the petition, the launch was scheduled for November 8, 2010. SpaceX's Falcon 9 launch vehicle will launch a reentry vehicle, named Dragon, into orbit. Once

<sup>1</sup> Even though Dragon is a reentry vehicle and not a reusable launch vehicle, 14 CFR 435.35 incorporates and applies section 431.35 to all reentry vehicles.

Dragon is in orbit, it will be subjected to a ground-implemented health check. The health check is designed to check time-dependent variables to ensure the health and functionality of the propellant, power, and avionics subsystems. If Dragon passes the health check, a ground operator will issue a remote command to reenter, which will initiate Dragon's reentry and ultimately result in Dragon splashing down in the ocean off the coast of Southern California. If Dragon fails the health check, the ground operator will issue a remote command that will disable Dragon's reentry, leaving Dragon in orbit.

While planning for this mission, SpaceX calculated that  $21 \times 10^{-6}$  is the expected average number of casualties ( $E_c$ ) to which the public will be exposed by vehicle or vehicle debris impact hazards associated with the launch of Falcon 9 and reentry of Dragon. Because this  $E_c$  was less than the  $30 \times 10^{-6}$  limit imposed by 14 CFR 431.35(b)(1)(i), SpaceX believed that it complied with the regulations.

The FAA informed SpaceX that the FAA assessed the risk for the launch of Falcon 9 and reentry of Dragon as  $47 \times 10^{-6}$ . The  $E_c$  for the launch of Falcon 9 is  $19 \times 10^{-6}$ , and by adding an  $E_c$  of  $7 \times 10^{-6}$  to account for the nominal reentry of Dragon and an  $E_c$  of  $21 \times 10^{-6}$  to account for the possibility that Dragon will initiate a failed attempt at reentry, the FAA obtained a total  $E_c$  value of  $47 \times 10^{-6}$  for the launch of Falcon 9 and reentry of Dragon. Because the FAA's calculations resulted in a total  $E_c$  value that exceeded the  $30 \times 10^{-6}$  limit imposed by section 431.35(b)(1)(i), the FAA informed SpaceX that it would need to obtain a waiver.

In response, SpaceX filed two petitions for a waiver. First, SpaceX requested a waiver of the requirement that a petition be submitted at least sixty days before the proposed effective date of the waiver. Second, SpaceX requested a waiver of the restriction that the total  $E_c$  for a launch and reentry not exceed  $30 \times 10^{-6}$ . In its waiver request, SpaceX emphasized that it had attempted to ensure public safety by adopting the following risk mitigation measures for Dragon:

1. Dragon's thermal protection system has been modified so that if it enters facing down it will burn and demise.

2. Dragon can keep orbiting in order to increase the probability of initiating a safe reentry.

3. Dragon will automatically vent its propellants if it is not able to reenter as planned. Venting occurs autonomously, but SpaceX has the ability to issue a back-up command from the ground.

4. In the case of a failed or degraded deorbit burn, Dragon automatically drains propellants and subsequently deploys its parachutes.

5. A ground command received through one of three receivers and through multiple RF links, via TDRSS and multiple ground stations, can command the venting of any remaining fuel and the draining of battery power to reduce the possibility of explosion or toxic fumes when Dragon lands.

6. Dragon has the ability to autonomously guide itself to a pre-determined site located more than 780 km from the coastline.

7. Dragon has the ability to monitor its safety-critical systems in real-time.

8. Dragon has over 100% margin on both power and propellant budgets.

9. Dragon has a space-grade Inertial Measurement Unit and space-grade flight computer, both of which have extensive flight heritage including use on the International Space Station.

10. Dragon has redundant drogue parachutes and dual redundant main parachutes.

11. The vehicle's thrusters are plumbed such that Dragon can deorbit and reenter with the loss of any two entire propulsion modules.

12. The vehicle has backup capabilities within all of its major subsystems.

#### Waiver Criteria

Chapter 701 allows the FAA to waive a license requirement if the waiver (1) will not jeopardize public health and safety, safety of property, (2) will not jeopardize national security and foreign policy interests of the United States, and (3) will be in the public interest. 49 U.S.C. 70105(b)(3) (2010); 14 CFR 404.5(b) (2010).

#### Section 404.3 Waiver Petition

Section 404.3(b)(5) requires that a petition for a waiver be submitted at least sixty days before the proposed effective date of the waiver. However, this section also provides that a petition may be submitted late if the petitioner shows good cause. *Id.* (b)(5).

Here, SpaceX submitted its waiver petition on October 11, 2010, which was less than sixty days from its planned November 8, 2010, launch date. However, in its petition, SpaceX explained that it initially calculated the

risk for the launch of Falcon 9 and the reentry of Dragon in a different manner than the FAA, and was not aware that a waiver would be required until so informed by the FAA. Once the FAA informed SpaceX that it needed to obtain a waiver, SpaceX proceeded to apply for the waiver "in a timely fashion." As such, the FAA has found that SpaceX had good cause for submitting its waiver petition less than sixty days from the planned November 8, 2010, launch date. Therefore, SpaceX's late submission does not violate section 404.3(b)(5), and a waiver of that section is unnecessary.

#### Section 431.35(b)(1)(i) Waiver Petition

Section 431.35(b)(1)(i) prohibits a launch and reentry mission if the total  $E_c$  for that mission exceeds  $30 \times 10^{-6}$ . For reasons described below, the FAA waives this restriction to allow SpaceX to conduct a mission whose total  $E_c$  is  $47 \times 10^{-6}$ , where launch and reentry are each less than  $30 \times 10^{-6}$ . In deciding whether or not to issue a waiver, the FAA had to analyze whether the waiver: (1) Would jeopardize public health and safety or safety of property; (2) would jeopardize national security and foreign policy interests of the United States; and (3) was in the public interest. *See* 49 U.S.C. 70105(b)(3); 14 CFR 404.5(b).

##### A. Public Health and Safety and Safety of Property

In order to determine whether granting a waiver would jeopardize public health and safety or safety of property, the FAA considered: (1) Whether section 431.35 requires that the  $E_c$  calculations account for the possibility of a random uncontrolled reentry that occurs as a result of a reentry vehicle ceasing to function upon arrival in orbit; (2) whether granting a waiver would be consistent with the safety rationale underlying section 431.35; and (3) whether there were any other factors that would impact the waiver decision in this case.

##### i. Random Uncontrolled Reentry

At the outset, the FAA first addressed whether to account for random uncontrolled reentry not associated with a licensed reentry. Section 431.35 could apply to two types of random uncontrolled reentry: (1) A random uncontrolled reentry occurring as a result of a failed reentry attempt; and (2) a random uncontrolled reentry occurring as a result of a reentry vehicle ceasing to function upon arrival in orbit.

The preamble to the final rule provides ambiguous guidance on this matter. *Commercial Space Transportation Reusable Launch*

*Vehicle and Reentry Licensing Regulations, Final Rule*, 65 FR 56618 (Sep. 19, 2000). When discussing the possibility of requiring contingency abort locations for reentries, the preamble states that an applicant would have to show that an uncontrolled random reentry would not exceed acceptable risk criteria for the mission. *Id.* at 56641. Another part of the preamble states that risk to public safety from a reentry that is "essentially random or otherwise non-nominal" would be assessed as part of the licensing process and an applicant would have to demonstrate that such a reentry would not exceed acceptable risk criteria for the mission. *Id.* at 56623 n.2. As a result of this waiver petition, the FAA has had to address to which of the two possible random reentry scenarios this assessment must apply.

One possible interpretation of the preamble is that section 431.35 requires that the  $E_c$  calculations account for the possibility of a random uncontrolled reentry that occurs as a result of a reentry vehicle ceasing to function upon arrival in orbit. However, this interpretation would be problematic because Chapter 701 limits the FAA's licensing of reentry to scenarios involving purposeful reentry. *See* 49 U.S.C. 70102(12) (defining "reentry" as a purposeful act); *see also* 65 FR at 56624 (clarifying that, under Chapter 701, section 431.35 is intended to regulate scenarios in which "survivability by design is combined with the purposeful act of reentry"). Because a random uncontrolled reentry arising out of a reentry vehicle ceasing to function upon arrival in orbit is not purposeful and is thus not licensed, an interpretation that section 431.35 applies to this type of reentry would conflict with Chapter 701.

The better approach is to limit the risk associated with a random uncontrolled reentry to that caused by a failed reentry attempt. Because an attempt at a reentry is a purposeful act and thus requires a license, the FAA should account for the risk associated with a random uncontrolled reentry that occurs as a result of a failed attempt. *See* 49 U.S.C. at 70102(12); 65 FR at 56624.

Under the above rationale, the total  $E_c$  for the reentry of Dragon is the  $E_c$  for nominal reentry ( $7 \times 10^{-6}$ ) plus the  $E_c$  for the possibility of a failed attempt at reentry ( $21 \times 10^{-6}$ ), which results in a total reentry  $E_c$  of  $28 \times 10^{-6}$ . When the  $E_c$  for the launch of Falcon 9 ( $19 \times 10^{-6}$ ) is added to the reentry  $E_c$  of Dragon, the combined  $E_c$  for the Falcon 9 launch and Dragon reentry comes out to  $47 \times 10^{-6}$ .

ii. Consistency With Rationale for Section 431.35

The next matter that the FAA addressed was whether granting a waiver in this case would be consistent with the safety rationale underlying section 431.35. In the preamble to the notice of proposed rulemaking (NPRM), the FAA explained that, when it was drafting section 431.35, it decided to use a single aggregate risk threshold for a mission involving the launch and reentry of a reentry vehicle. *Commercial Space Transportation Reusable Launch Vehicle and Reentry Licensing Regulations*, NPRM, 64 FR 19626, 19635 (Apr. 21, 1999). However, the FAA also acknowledged that there could be circumstances where it would be appropriate to separate launch from reentry risk, such as where different operators were involved and could be apportioned allowable risk thresholds, or where intervening events or time made reentry risks sufficiently independent of launch risks as to warrant separate consideration. *Id.*

Here, the health check of Dragon, a different vehicle than the Falcon 9 launch vehicle, that will take place once Dragon is in orbit is an intervening event that makes the launch risk associated with the launch of Falcon 9 independent of the reentry risk associated with the reentry of Dragon. The health check will permit SpaceX to reevaluate Dragon's condition after the launch has taken place, and to make a fresh determination about whether Dragon should be permitted to reenter. If, after conducting a post-launch health check of Dragon, SpaceX finds safety concerns associated with reentry, SpaceX will be able to issue a command to disable Dragon's reentry. As such, because the reentry of Dragon is based on the results of an in-orbit health check that will be conducted independently of the launch, the risks associated with the launch of Falcon 9 and reentry of Dragon are sufficiently independent to warrant separate consideration in this case.

Evaluating these risks separately, the  $E_c$  for the launch of Falcon 9 is  $19 \times 10^{-6}$ , which is within the  $30 \times 10^{-6}$  limit imposed by section 431.35(b)(1)(i). Likewise, the  $E_c$  for the reentry of Dragon is  $28 \times 10^{-6}$ , which is also within the  $30 \times 10^{-6}$  limit that the FAA applies to launch hazards. Accordingly, the FAA has determined that granting a waiver in this case would be consistent with the safety rationale underlying section 431.35.

iii. Other Factors Impacting the Waiver Decision

Dragon's mitigation measures were another factor that influenced the FAA's analysis with regard to whether a waiver would jeopardize public health and safety and safety of property. As stated above, the Dragon capsule employs numerous risk mitigation measures to reduce the risk to the public from the launch of Falcon 9 and reentry of Dragon.

The FAA has taken particular notice of the way in which Dragon's electrical power system (batteries), flight computer, and propulsion system will reduce risk to the public. For instance, Dragon has more than four times the propellant needed for a safe reentry in the target area. The additional propellant increases the probability that Dragon will land in its nominal target area instead of a population center. Dragon also has three parachutes, which decrease risk to the public because only one of these parachutes is necessary for a low impact landing. The additional parachutes reduce the chance that Dragon will crash into the ground while attempting to land.

SpaceX has also designed the Dragon reentry vehicle to vent propellants in the case of an aborted or off-nominal reentry. This mitigation measure greatly reduces the risk to the public because it allows Dragon to safely dispose of hazardous propellant materials if something should go wrong with the mission.

As a result of Dragon's mitigation measures, as well as the other considerations discussed above, the FAA has determined that granting a waiver in this case would not jeopardize public health and safety or safety of property.

*B. National Security and Foreign Policy Implications*

The FAA has identified no national security or foreign policy implications associated with granting this waiver.

*C. Public Interest*

Two of the public policy goals of Chapter 701 are: (1) To promote economic growth and entrepreneurial activity through use of the space environment; and (2) to encourage the United States private sector to provide launch and reentry vehicles and associated services. 49 U.S.C. 70101(b)(1) and (2). Here, granting this waiver is consistent with the public interest goals articulated by Chapter 701.

A goal of the COTS program's mission is to ultimately develop the capability to

resupply the International Space Station. SpaceX's demonstration launch of Falcon 9 and reentry of Dragon is a step toward achieving that goal. This demonstration launch is important in light of the fact that the U.S. Government is ending the Space Shuttle Program and NASA plans to rely upon its COTS Program to develop a robust domestic commercial space transportation capability. This capability will provide the United States with the ability to resupply the International Space Station. As such, granting SpaceX's waiver request will be consistent with Chapter 701's policy goals by: (1) Promoting SpaceX's entrepreneurial activity in the space environment; and (2) encouraging a private U.S. company to develop and launch a launch vehicle (Falcon 9) and a reentry vehicle (Dragon).

**Summary and Conclusion**

A waiver will not jeopardize public health and safety or safety of property because: (1) The risk associated with the launch of Falcon 9 and the risk associated with the reentry of Dragon are each under an  $E_c$  of  $30 \times 10^{-6}$ ; and (2) the Dragon capsule employs numerous risk mitigation measures including an in-orbit health check. The waiver also will not jeopardize national security and foreign policy interests of the United States. A waiver is in the public interest because it furthers the statutory goals of Chapter 701. For the foregoing reasons, the FAA has waived the restriction that the combined risk to the public from the launch of Falcon 9 and reentry of Dragon cannot exceed an expected average number of 0.00003 casualties ( $30 \times 10^{-6}$ ) from debris.

Issued in Washington, DC, on November 30, 2010.

**Kenneth Wong,**

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**DEPARTMENT OF TRANSPORTATION**

**Federal Aviation Administration**

**14 CFR Part 431**

**Office of Commercial Space Transportation; Waiver of Autonomous Reentry Restriction for a Reentry Vehicle**

**AGENCY:** Federal Aviation Administration (FAA), DOT.

**ACTION:** Notice of waiver.