



[4910–13]

**DEPARTMENT OF TRANSPORTATION**

**Federal Aviation Administration**

**Office of Commercial Space Transportation**

**Waiver of 14 CFR 437.29 and 437.55(a) for Scaled Composites, LLC**

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

**ACTION:** Notice of waiver.

**SUMMARY:** This notice concerns a waiver to Scaled Composites, LLC (Scaled) from the requirements of 14 CFR sections 437.29 and 437.55(a) to provide the FAA a hazard analysis that identifies, mitigates, and verifies and validates mitigation measures for hazards created by software and human error. The FAA finds that a waiver is in the public interest and will not jeopardize public health and safety, safety of property, and national security and foreign policy interests of the United States.

**FOR FURTHER INFORMATION CONTACT:** For technical questions concerning this waiver, contact Michael Kelly, Chief Engineer, Commercial Space Transportation, AST-004, 800 Independence Avenue, S.W., Washington, DC 20591; telephone: (202) 267-7588; e-mail: [Michael.S.Kelly@faa.gov](mailto:Michael.S.Kelly@faa.gov). For legal questions concerning this waiver, contact Sabrina Jawed, Attorney-advisor, Space Law Branch, AGC-250, Office of the Chief Counsel, Regulations Division, Federal Aviation Administration, 800 Independence Avenue, S.W., Washington, DC 20591; telephone: (202) 267-8839; email: [Sabrina.Jawed@faa.gov](mailto:Sabrina.Jawed@faa.gov).

**SUPPLEMENTARY INFORMATION:**

**Background:** On May 23, 2012, the FAA's Office of Commercial Space Transportation (AST) issued Scaled Experimental Permit No. 12-007. On March 6, 2013, Scaled submitted an application to renew its experimental permit, which was to expire on May 22, 2013. In its application for renewal, Scaled included modifications to its permit to reflect changes made to SpaceShipTwo (SS2). In March of 2013, Scaled provided updates to the original hazard analysis for FAA assessment. Upon reviewing Scaled's application to renew its permit, the FAA determined that Scaled did not fully meet the requirements of 14 CFR sections 437.29 and 437.55(a).

Scaled did not meet these requirements because it did not identify human or software error as causing hazards. It did not identify these errors as causing hazards on the grounds that the mitigations it had in place would prevent the hazards from occurring. Scaled emphasizes aircraft and spacecraft design redundancy, flight and maintenance procedures, and ground and flight crew training to mitigate against hazards caused by human and software errors.

Scaled employs a number of different approaches to safety derived from its aviation heritage. These include a training program, an incremental approach to flight testing, use of chase planes, use of a two-pilot model, the remoteness of its operating area and use of a winged vehicle.

**The FAA's Authority and Waiver Criteria:** The FAA issues experimental permits under authority granted to the Secretary of Transportation under 51 U.S.C. section 50906 and delegated to the FAA Administrator. The FAA may waive an experimental permit requirement if the waiver (1) will not jeopardize public health and safety or 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. 51 U.S.C. § 50905(b)(3); 14 CFR 404.5(b).

**A. Scaled did not meet the requirements of sections 437.29 and 437.55(a)**

Section 437.29 requires an applicant for a permit to perform a hazard analysis that complies with section 437.55(a), and to provide the FAA all results of each step of the hazard analysis required by section 437.55(a). Section 437.55(a) requires an applicant to perform a hazard analysis that identifies, mitigates, and validates and verifies mitigation measures for each hazard. Scaled did not identify and describe all hazards resulting from human and software error as part of its hazard analysis, and therefore did not fully satisfy sections 437.29 and 437.55(a).

**B. Operation of the SpaceShipTwo Vehicle**

The FAA waives the hazard analysis requirements of sections 437.29 and 437.55(a) for Scaled for software and human error because the SS2 operation will not jeopardize public health and safety or safety of property, national security or foreign policy interests of the United States, and is in the public interest.

**i. Public Health and Safety or Safety of Property**

A hazard analysis serves to reduce risk to the public by limiting the possibility of a vehicle mishap. Although Scaled did not complete its hazard analysis as required by the regulations, the combination of its training program, incremental approach to flight testing, use of chase planes, and two-pilot model, as well as the limited duration of the permit and thus the waiver, the remoteness of its operating area and its use of a winged vehicle combine to allow the FAA to find that Scaled's activities will not jeopardize public health and safety or safety of property.

## **1) Training Program**

Although Scaled's hazard analysis under section 437.55(a) did not associate the hazards it mitigated specifically with whether they were caused by human error, Scaled's training program provides part of the basis for the FAA to find that Scaled's permitted activities will not jeopardize public health and safety or safety of property. Scaled's approach to flight safety and training derives from aviation flight testing. Scaled generally requires that its pilots have at least 1,500 hours of flight time, as well as specific experience in jet and glider aircraft. Scaled uses three different devices to train SS2 pilots and crew. The devices are (1) an SS2 simulator, (2) a WhiteKnightTwo aircraft, and (3) an aerobatic aircraft, or other g tolerance training device.

Scaled's SS2 simulator mimics the SS2 itself. The simulator duplicates the SS2 cabin layout, including the avionics, switches, controls, and windows. The simulator also provides wrap-around video simulation and sound effects. This gives the pilot depth perception and the ability to make accurate landing approaches and other maneuvers. The simulator also mimics SS2 flight dynamics. The simulator has the ability to dynamically simulate both control forces and effectiveness in all flight regimes. The control forces are dynamically linked to aerodynamics of all phases of flight. The simulator also simulates wind profiles, thrust asymmetries, and an array of failure conditions.

Using flight simulators allows for in-depth training, including the practice of critical emergency procedures, in a safer environment. Scaled's use of a flight simulator that mimics the SS2 allows Scaled's pilots to become familiar with how the SS2 operates and responds during launch, flight, and reentry, and helps improve the SS2 pilot's

response time. Simulators allow pilots to gain experience flying the spacecraft.

Simulators also allow pilots and crew to practice flying in emergency or other flight conditions that would be dangerous to recreate in the airspace.

Scaled also uses its flight simulator to develop mission specific trajectories, identify the envelopes of potential failure trajectories, and validate flight rules and abort procedures. The simulator models nominal and off-nominal flight environment and incorporates reasonably foreseeable failure scenarios. Scaled updates the simulations based on data obtained from actual flights to improve the simulator's fidelity and accuracy. Scaled runs its simulator 1.4 times faster than actual flight in order to ensure that pilots and ground crew are trained to respond quickly to various flight conditions and anomalies. By practicing various nominal and non-nominal scenarios in the SS2 simulator, pilots are able to rehearse how to operate the SS2. This training also enhances the speed and reaction time of the crew, and allows the crew to practice working together to run various procedures, such as going through the checklist. Continuous updates ensure that the simulator provides the most accurate modeling of the way the vehicle will perform at various altitudes and attitudes, so that the crew can best experience how the SS2 will react during flight.

SS2's flight crew also uses WhiteKnightTwo for training because it replicates SS2's flight profile. When the WhiteKnightTwo's spoil-flaps are deployed, it has a similar flight path and descent profile to the SS2. SS2 pilots fly at least three WhiteKnightTwo flights simulating SS2 approaches prior to an SS2 flight. Flight crew are able to fly in the WhiteKnightTwo in order to practice what it will be like when they are flying the SS2.

Use of the WhiteKnightTwo builds upon the simulator training. While the simulator mimics flight conditions in most cases, it is not a multi-axis simulator, which means it will not pitch in a vertical motion and not always mimic real flight conditions. The WhiteKnightTwo is able to replicate the full flight and the actual feel of flight in the SS2. Additional training in the WhiteKnightTwo, which has a cockpit that mimics the SS2, allows pilots and crew to experience more accurate flight conditions than the simulator in some instances.

Lastly, as part of ongoing g tolerance training, the SS2 crew completes an aerobatic training course that covers g tolerance, motion sickness, and unusual attitudes. This training is performed in a small aerobatic aircraft. SS2 crew may also train in a g tolerance training device, such as a centrifuge.

To the extent that physical human vulnerability plays a role in safety, Scaled's coverage of g tolerance, motion sickness and unusual attitudes helps safety on two fronts. First, it trains a pilot to recognize the onset of, experience, and recover from the anticipated stresses of launch. Also, it allows an operator to determine that a pilot remains functional while withstanding the anticipated stresses of the launch.

## **2) Incremental Approach to Flight Testing**

Another important factor in the FAA's ability to grant this waiver is Scaled's incremental approach to flight testing. Scaled's test program is divided into three phases: 1) subsonic glide flights, 2) powered flight to maximum altitude, and 3) repeatability demonstrations.

Scaled employs an incremental approach to flight testing, and flight tests in three different phases. Before moving to a new phase, Scaled ensures that it has mitigated or

eliminated the hazards it observed during the previous phase. By changing only a limited number of variables at a time, Scaled is able to identify which variables result in hazards, isolate those variables, and take steps to mitigate or eliminate the hazards. Scaled then runs additional tests until it is satisfied that it has eliminated or mitigated the hazard.

During phase one, WhiteKnightTwo releases SS2 to allow Scaled to observe its actions during glide flight. During phase two, WhiteKnightTwo releases SS2, and SS2 performs rocket-powered flight. Phase two ends with a successful demonstration of the maximum altitude performance of the vehicle. Phase three demonstrates that SS2 can repeatedly perform proficiently during rocket-powered flight. For each new flight, Scaled varies only one parameter at a time, especially in the case of critical components where a failure could quickly take the aircraft from a safe flight condition to a potentially hazardous one. For example, Scaled tests the feathering operation of the vehicle during each phase. To do this, Scaled feathers and defeathers the vehicle in flight at varying Mach numbers and altitudes. Test pilots will evaluate the handling of the vehicle in both the feathered and unfeathered configuration at each Mach number and altitude.

Incremental testing ensures that Scaled is able to study the reactions of the vehicle during different stages of flight. By moving from a less complex flight (glide) to a more complex flight (rocket-powered), Scaled is able to isolate and identify variables that cause hazards, address those hazards, and re-test to ensure that the mitigations were effective.

### **3) Use of Chase Planes and Two-Pilot Model**

Scaled uses two chase planes and two pilots for SS2's flight. Scaled's use of two chase planes and two pilots allows Scaled to identify problems when the system itself

fails to disclose them, and provides redundancy. The chase planes are able to monitor the WhiteKnightTwo and the SS2, so that if there is a computer failure and the pilot would not otherwise know of an external failure, such as the failure of the landing gear to lower, the chase planes are able to provide that information. Upon reentry of SS2, Scaled uses WhiteKnightTwo as an additional chase plane.

The pilots of chase planes look for any external abnormalities in SS2. If an abnormality is identified, the chase plane is able to communicate the issue to both the ground crew and the pilots onboard SS2. If the communications and telemetry systems stop functioning in the carrier aircraft, the chase planes can communicate with the carrier aircraft by radio. The radio operates on a separate frequency than the telemetry system on the SS2 and WhiteKnightTwo. Also, if the SS2 multifunctional displays and the independent attitude/air data computer and display become inoperable during gliding flight, the chase planes can lead the vehicle to landing if necessary.

The chase planes provide additional situational awareness for pilots and crew on the carrier aircraft and SS2, and ground crew. The use of two chase planes is a safety measure that eliminates or mitigates potential hazards. The chase planes are able to identify anomalies and communicate them directly to the SS2 or carrier airplane pilots. They serve as an extra set of eyes to ensure that any unplanned events that do occur are identified and addressed as quickly as possible.

Scaled uses two rather than one pilot because if one pilot becomes incapacitated, the other pilot can fly the spacecraft. In both emergencies and nominal flight operations, both pilots are able to work together to enhance situational awareness. For example, each pilot is able to verify with the other that the checklist is correct and the spacecraft is

functioning normally. Pilot error on the part of one pilot can be corrected by the other, and in situations where a decision must be made, two fully-qualified pilots can consult quickly. The use of two pilots may eliminate or mitigate potential hazards.

#### **4) Duration**

Because an experimental permit is by design a brief authorization of one year, minimal levels of residual error and thus risk may accumulate, but not at levels that would jeopardize public health and safety. Without a full system safety analysis of software and human error, error may accumulate over time. For example, latent software and hardware incompatibilities may develop with changes and updates. Although such error could build over time, it would not within the time period of a permit. Additionally, the one-year duration of the permit means that this waiver will also be of brief duration, and there is a reduced likelihood of employee turnover and any attendant loss of corporate memory at Scaled in that time.

#### **5) Remoteness of Operating Area and Controllability of Vehicle**

Finally, Scaled's operating area is remote enough that, were it to experience a catastrophic failure, it would not jeopardize public health and safety. Additionally, the SS2 is a winged vehicle, and therefore maneuverable.

Scaled is conducting launches of SS2 in a very remote location. The southern end of the operating area where Scaled plans to conduct its test flights has a population density of about 17 people per square mile. The area Scaled plans to use for the rocket-powered ascent phase of flight includes approximately 450 people in a 140 square mile area, or just over three people per square mile. The operating area for SS2 is also very

large at approximately 5,000 square miles, in order to ensure that SS2 operations are contained within a sparsely populated area.

Additionally, SS2 is a winged vehicle. Scaled's pilots are able to control and maneuver SS2 to ensure it stays away from populated areas, including the exclusion zones inside the operating area. The pilots can ensure that the SS2 operates only in the areas with the sparsest population.

Scaled did not fully comply with the hazard analysis required by section 437.55(a), but the FAA finds that Scaled's operations will not jeopardize public health and safety or safety of property because of the combination of its flight test program, training, incremental flight testing, chase planes, two pilots, and the remoteness of its operating area.

**ii. National Security and Foreign Policy Implications**

This waiver does not have an impact on any national security or foreign policy interests of the United States. Scaled's launch operations will take place within the United States and within a specifically defined area that is used for military operations.

**iii. Public Interest**

The FAA finds that granting this waiver is in the public interest. The Commercial Space Launch Act provides that the United States should encourage private sector launches, reentries, and associated services. Additionally, Congress established Chapter 509 to promote economic growth and entrepreneurial activity through use of the space environment for peaceful purposes.

This waiver is consistent with the public interest goals of Chapter 509. The SS2 test flights will stimulate economic growth, spur technological developments and create

aerospace business opportunities such as carrying scientific payloads and space tourists on trips to the edge of space and back. The FAA finds that granting this waiver is in the public interest because the SS2 flights further the purposes Congress articulated for Chapter 509.

Issued in Washington, DC on July 9, 2013.

George C. Nield  
Associate Administrator for Commercial Space Transportation

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