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FAA'S IMPLEMENTATION OF THE COMMERCIAL SPACE LAUNCH AMENDMENTS ACT OF 2004 – THE EXPERIMENTAL PERMIT

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ABSTRACT

A number of entrepreneurs are committed to the goal of developing and operating reusable launch vehicles for private human space travel. In order to promote this emerging industry, and to create a clear legal, regulatory, and safety regime, the United States (U.S.) Congress passed the Commercial Space Launch Amendments Act of 2004 (CSLAA). Signed on December 23, 2004 by U.S. President George W. Bush, the CSLAA makes the Federal Aviation Administration (FAA) responsible for regulating human spaceflight. The CSLAA, among other things, establishes an experimental permit regime for developmental reusable suborbital rockets. This paper describes the FAA's approach in developing guidelines for obtaining and maintaining an experimental permit, and describes the core safety elements of those guidelines.

1. INTRODUCTION

The Commercial Space Launch Act of 1984, as codified and amended at 49 U.S.C. Subtitle IX, ch. 701 (Chapter 701)[5], authorizes the United States (U.S.) Federal Aviation Administration (FAA), through delegations, to oversee, license and regulate commercial launch and reentry activities and the operation of launch and reentry sites as carried out by U.S. citizens or within the United States. Chapter 701 directs the FAA to exercise this responsibility consistent with public health and safety, safety of property, and the national security and foreign policy interests of the United States. The FAA is also responsible for encouraging, facilitating and promoting commercial space launches by the private sector.

On December 23, 2004, President George W. Bush signed into law the Commercial Space Launch Amendments Act of 2004 (CSLAA) [1]. The CSLAA promotes the development of the emerging commercial space flight industry and makes the FAA responsible for regulating private human space flight under Chapter 701. Among other things, the CSLAA establishes an experimental permit regime for developmental reusable suborbital rockets.

Until it issues regulations prescribing requirements for launch operators to obtain and maintain an experimental permit, the FAA will issue experimental permits on a case-by-case basis. For use during this interim period, the FAA issued Guidelines for Experimental Permits for Reusable Suborbital Rockets (Guidelines) in May, 2005 [3]. Although not binding, the guidelines address what the FAA may expect to review and evaluate in an application for an experimental permit. The guidelines also identify the safety measures that the FAA would expect a permittee to comply with while conducting permitted activities.

This paper describes the provisions of the guidelines and how the FAA approached their development.

2. THE EXPERIMENTAL PERMIT UNDER THE CSLAA

2.1 Eligibility

Prior to enactment of the CSLAA, a launch license was the only mechanism available to the FAA to authorize the launch of a launch vehicle. The CSLAA's creation of an experimental permit regime provides the FAA with an alternative mechanism for a specific class of launch - the launch of a developmental reusable suborbital rocket on a suborbital trajectory.[1]

To be eligible for an experimental permit, an applicant must propose to fly a reusable suborbital rocket for the following purposes:

- Research and development to test new design concepts, new equipment, or new operating techniques,
- Showing compliance with requirements as part of the process for obtaining a license under Chapter 701, or
- Crew training before obtaining a license for a launch or reentry using the design of the rocket for which the permit would be issued.

[1] The CSLAA defines a *suborbital rocket* as 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 ascent. A *suborbital trajectory* is defined in the CSLAA as 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 [1].

2.2 The Experimental Permit Compared to a License

Under the CSLAA, an experimental permit differs from a license in several ways.

- The FAA must determine whether to issue an experimental permit within 120 days of receiving an application. For a license, the FAA must make a similar determination within 180 days of receiving an application.

- No person may operate a reusable suborbital rocket under a permit for carrying any property or human being for compensation or hire. No such restriction applies for a license.

- Damages arising out of a permitted launch or reentry are not eligible for "indemnification," the provisional payment of claims under Chapter 701. To the extent provided in an appropriation law or other legislative authority, damages caused by licensed activities are eligible for the provisional payment of claims.

- A permit must authorize an unlimited number of launch and reentries for a particular reusable suborbital rocket design. Although licenses can be structured to authorize an unlimited number of launches, no statutory mandate to do so exists.

2.3 Congressional Intent

In developing the guidelines, the FAA looked to the intent of the U.S. Congress. Although not binding, the Congressional intent behind the statutory language was helpful to the FAA in understanding why Congress saw the need to create an experimental permit regime.

Congress's purpose in creating the experimental permit regime was to reduce the regulatory burden on developers of reusable suborbital rockets. As the legislative history states, Congress intended that, "[a]t a minimum, permits should be granted more quickly and with fewer requirements than licenses." [4]

Significantly, the House Science Committee suggested that the FAA "carefully review the methodology and assumptions currently applied when calculating expected casualty rates, to assess the appropriateness of such calculations with respect to the issuance of permits, and to explore possible alternate methods of calculating expected casualty rates." [4]

The House Science Committee also stated that the regulatory approach to issuing experimental permits was to be modeled on the FAA approach to issuing experimental airworthiness certificates (EAC) for experimental aircraft. Under an EAC, the public is protected by confining aircraft flights to areas over open water or to sparsely populated areas.

3. FAA'S APPROACH TO THE EXPERIMENTAL PERMIT COMPARED WITH A LICENSE

3.1 Licensing Approach to Safety

To develop the guidelines, the FAA examined, for purposes of streamlining, the regulatory strategy currently used to license the launch of reusable launch vehicles (RLVs). This strategy combines three safety approaches:

- A licensee must demonstrate that the risk from a launch falls below specified quantitative collective and individual risk criteria,

- A licensee must have a comprehensive system safety program consisting of both system safety management and system safety engineering, to identify hazards and reduce risks to the public, and

- A licensee must comply with several operating requirements, developed by the FAA from lessons learned in the launch vehicle industry.

Just as system redundancy may compensate for failure or flawed design or performance, this three-pronged approach protects the public through three different yet interrelated means.

In developing the guidelines, the FAA modified this strategy to account for the unique needs of experimental flight testing of reusable suborbital rockets, while preserving the benefits of redundant safety approaches. Each prong is discussed separately below.

3.2 Quantitative Risk Analysis

The guidelines do not include a launch operator's calculation of collective or individual risk to obtain or maintain an experimental permit. Under the guidelines, an applicant would instead propose one or more operating areas that meet qualitative criteria. This is perhaps the greatest difference between a license and an experimental permit under the guidelines.

Under the license regime, an applicant must demonstrate to the FAA that its launch will meet certain individual and collective risk criteria. Individual risk is the risk to an individual member of the public. Under a license, the risk level to an individual must not exceed 1×10^{-6} per mission. Collective risk is the risk to a population. Under a license, the risk level to the collective members of the public exposed to vehicle debris impact hazards must not exceed an expected average number of 30 ×

10^{-6} casualties per mission (commonly referred to as expected casualty).

The strength of any quantitative risk analysis lies not only in the resulting values, but also in the decisions reached through the analysis to limit risk to the public. In that regard, a quantitative risk criterion may serve as an indicator of when sufficient risk reduction measures and operating requirements have been applied.

Most RLVs are intended to launch from inland launch sites near significant populations, such as airports. Even though the RLVs currently proposed are typically much smaller than their expendable counterparts,[2] RLVs operating from these sites under the same risk criterion would be required to have a lower probability of failure. Preliminary calculations using the characteristics of several proposed and operational suborbital rockets have shown that a probability of failure of 5% or less would have to be achieved to meet the expected casualty criterion of 30×10^{-6}. A developmental RLV will have little operational experience and data available to support or refute that low a value for probability of failure.

The FAA considered several courses of action in developing the guidelines. One solution would have been to require the operators of reusable suborbital rockets to produce the data needed to demonstrate the necessary probability of failure. This is the current approach for vehicles applying for a launch license. The problem with this solution is that the data necessary to obtain this reliability data does not yet exist for developmental suborbital rockets. In fact, this reliability data will be obtained by the very research and development testing that Congress intends permits to enable.

Alternatively, the FAA could have raised the risk criterion for developmental suborbital rockets to reflect the lack of data that creates a need for an increased conservatism in the inputs. Choosing an appropriate risk criterion was a challenge.

The FAA researched the risks from other activities and identified the risks to people living near a major U.S. airport as the involuntary risk most similar to the risks to people living near a spaceport. Empirical data does exist about that risk, expressed as an annual risk to individuals living near a major U.S. airport. Converting annual individual risk data into a per-mission collective risk criterion for permitted activities is sensitive to the assumptions applied in the conversion. This is particularly the case with the assumed annual flight rate of reusable suborbital rockets, and the assumed populations exposed to risk. Because of this sensitivity, the FAA could reasonably propose risk values spanning an order of magnitude from the same underlying data.

Such uncertainty in the proper value has the potential for producing a value that would be too easy to meet by a launch operator, thus failing to require the safety decisions that make quantitative risk analyses so valuable, and perhaps leading to a false sense of safety. On the other hand, if the value was too difficult to meet, it could create a regulatory environment that would be too burdensome to be conducive to research and development activities. Accordingly, the FAA chose not to pursue a new criterion for allowable quantitative risk in the absence of conclusive data to support a particular value.

Although not included in the guidelines, the FAA will continue to conduct these quantitative risk analyses for the industry as a whole to provide further insight into safety issues, identify trends, and collect data that may assist in defining future criteria. The FAA will also recommend that launch operators perform these analyses for their own use. The FAA will provide guidance and tools to assist them in doing so.

3.3 System Safety

Under the guidelines, an applicant would conduct a hazard analysis of its proposed launches in order to obtain a permit. This is different than the system safety management and system safety engineering requirements of a license.

A hazard analysis is a system safety engineering tool that identifies and characterizes hazards and qualitatively assesses risks. A permit applicant would use this analysis to identify risk elimination and mitigation measures to reduce risk to an acceptable level. No other system safety engineering provisions are included in the guidelines.

The FAA realizes that by not including other system safety engineering tools in the guidelines, some hazards may not be uncovered. A more rigorous approach would entail both "bottoms-up" subsystem analyses such as a Failure Modes, Effects, and Criticality Analysis, and "top-down" system analyses such as a Fault Tree Analysis. However, containment within an FAA-approved operating area, discussed below, will ameliorate many of these unknown risks.

With respect to system safety management, the FAA did not define in the guidelines, as it does for existing licensing requirements, explicit system safety organization requirements or requirements for specific safety personnel. The FAA recognizes that pioneers

[2] Vehicle size is relevant to risk because a smaller vehicle, in general, will have less of a potential for harm to people and property on the ground than a larger vehicle.

within the commercial RLV industry need freedom to organize their companies in various innovative ways to conduct launches. The FAA chose not to place emphasis on the management structure but on the commitment to safety throughout the organization.

The FAA believes that the most effective safety organizations are created not only by identifying individuals responsible for safety, but also through developing a strong and effective safety culture. In a strong safety culture, responsibility for safety is spread throughout the organization, upper-level management is committed to public safety, employees have a voice in safety decisions, and safe behavior is rewarded. It will be important for a permittee to establish an organization that has a strong safety culture to achieve safe operations. An operator with a strong safety culture will incorporate prudent approaches to ensuring safe flight based on lessons learned from previous launch industry mishaps and lessons learned from experimental aircraft testing and inspection.

3.4 Operating Requirements

The guidelines do not include as comprehensive a list of prescriptive operating requirements as required under a launch license. This is because the FAA expects a great variation of vehicle operators and rocket concepts. Prescriptive operating requirements can, of course, provide specific solutions to specific safety issues, if known. Due to the variation in vehicle operators and rocket concepts, the FAA believes that most operating requirements under a permit are best derived from the hazard analysis process.

Perhaps another reason to deemphasize prescriptive operating requirements is that they can be perceived as placing the locus of safety responsibility on the FAA as opposed to the permittee. Research reported in [2] shows that whether a regulator or its regulated entity is perceived as taking the primary responsibility to ensure safety varies with different regulatory strategies. The perception of prescriptive requirements is that they remove responsibility for safety from the regulated entity and place it with the regulator. Note that perception aside, a permittee has the primary responsibility for safety and the FAA oversees whether this responsibility is being carried out.

Under the permit regime, most safety solutions are derived by the launch operators themselves. The guidelines do, however, contain a minimum number of operating requirements that the FAA believes are too important to omit. These involve collision avoidance analyses, tracking, communications, flight rules, and mishap reporting, responding, and investigating. Personnel rest rules are also included.

4. CORE SAFETY MEASURES IN FAA'S EXPERIMENTAL PERMIT GUIDELINES

The guidelines include a variety of safety measures that protect the public. The following are the core safety measures outlined in the experimental permit guidelines.

4.1 Hazard Analysis

Under the guidelines, an applicant performs a hazard analysis and provide the results to the FAA. Typical elements of a hazard analysis include:

- Identifying and describing hazards,[3]

- Assessing risk using qualitative severity and likelihood levels,

- Identifying and describing risk elimination and mitigation measures to reduce the risk to acceptable levels, and

- Demonstrating that the risk elimination and mitigation measures are correct, complete, and achieve an acceptable reduction in risk.

The U.S. Department of Defense, the National Aeronautics and Space Administration, and the aerospace industry have successfully used hazard analyses for decades to identify, characterize, and analyze hazards and reduce risks to acceptable levels.

The guidelines include the following criteria to determine the acceptability of the risks:

- The occurrence of any hazardous condition that may cause death or serious injury to the public should be extremely unlikely, and

- The likelihood of an occurrence of any hazardous condition that may cause major property damage to the public, major safety-critical system damage or reduced capability, decreased safety margins, or increased workload should be remote.

In developing qualitative criteria to assess risk, the FAA incorporated industry practice and existing government standards.

4.2 Operating Area Containment

Central to the experimental permit approach is containment of the reusable suborbital rocket within a defined operating area. The use of an operating area is

[3] Hazards can result from component, subsystem, or system failures or faults; software errors; environmental conditions; human errors; design inadequacies; and procedural deficiencies.

similar to that used by the FAA in granting EACs to experimental aircraft. By following the guidelines, a permittee would operate its reusable suborbital rocket such that its instantaneous impact point (IIP)[4] remains within an operating area and outside any FAA defined exclusion area.

4.2.1 The Operating Area

An operating area is a three-dimensional region where permitted flights may take place. The FAA would approve an operating area based on the following criteria:

- No densely populated area should be present within or adjacent to an operating area,
- An operating area should be large enough to contain each planned trajectory, accounting for expected dispersions,
- An operating area should contain enough unpopulated or sparsely populated area to perform key flight-safety events, discussed below, and
- The operating area should not contain significant automobile traffic, railway traffic, waterborne vessel traffic, or large concentrations of members of the public.

The FAA would use the above criteria to prohibit the operation of a reusable suborbital rocket over areas where the consequences of an uncontrolled impact of the vehicle or its debris would be catastrophic. Given the number of people in a densely populated area and their proximity to each other, the likelihood of multiple casualties from an uncontrolled impact of a vehicle or its debris would be much higher in densely populated areas than in sparsely populated areas.

Agreements with FAA Air Traffic Control would also influence the size and location of an operating area. Although conditions on the ground may be favorable for flight test, airspace concerns may limit the feasibility of an otherwise acceptable operating area.

An operating area might also include "exclusion areas," defined by the FAA, which would consist of areas where a reusable suborbital rocket's IIP could not traverse. An exclusion area is an area on the ground that deserves special protection for safety or policy purposes.

A launch operator can propose multiple operating areas based on the needs of its flight test program.

[4] An impact point, following thrust termination of a launch vehicle, calculated in the absence of atmospheric drag effects.

4.2.2 Containment

During the application process, an applicant would identify and describe the methods and systems used to contain its reusable suborbital rocket's IIP within the operating area and outside any exclusion area. Acceptable methods and systems would include but would not be limited to:

- Proof of physical limitations on a vehicle's ability to leave the operating area, and
- Abort procedures and safety measures derived from a system safety process.

Proof of physical limitations on a vehicle's ability to leave the operating area could be obtained through an analysis that showed that the maximum achievable range of the reusable suborbital rocket from the launch point was within the boundaries of the operating area, assuming the rocket flew a trajectory optimized for range and that all safety systems failed. Such a proof would simplify an operator's permit requirements considerably.

An applicant could use its hazard analysis to determine safety measures that keep a reusable suborbital rocket's IIP within its operating area. Alternatively, an applicant could perform a separate and more comprehensive system safety analyses solely for containment. The FAA believes that most launch operators will need to use a variety of system safety tools to prove containment, utilizing a number of safety-critical systems.

Specific safety measures obtained from a system safety process could include a dedicated flight safety system. A dedicated flight safety system could protect the public and property from harm if a vehicle did not stay on its intended course by stopping the vehicle's flight. A dedicated flight safety system is the typical approach used in ELVs. A flight safety system consists of all components that provide the ability to end a launch vehicle's flight in a controlled manner. For example, a reusable suborbital rocket may use a thrust termination system in combination with other measures, such as propellant dumping, for containment.

Safety measures could also include systems and procedures that, while not dedicated exclusively to flight safety, help to protect the public. For example, an operator may choose to use a real-time IIP ground or cockpit display. An operator would use abort criteria and information from this display to assist in containment of the IIP.

Under the guidelines, an applicant would show that the system or method selected will contain the vehicle's IIP.

That demonstration could include flight demonstration test data; component, system, or subsystem test data; inspection results; or analysis.

4.3 Key Flight-Safety Event Limitations

Operating within an acceptable operating area and implementing safety measures obtained from a hazard analysis are only part of what would be necessary to maintain public safety. Because of the uncertainty in operation of developmental reusable suborbital rockets, the guidelines include additional operating limitations for "key flight-safety events."

A key flight-safety event is a permitted flight activity that has an increased likelihood of causing a failure compared with other portions of flight. Events such as rocket engine ignition, staging, and envelope expansion have historically had the highest probability of catastrophic failure for rocket-propelled vehicles. Under the guidelines, a launch operator would conduct key flight-safety events over unpopulated or sparsely populated areas.

In its application, an operator would identify and describe how it would keep these key flight-safety events over unpopulated or sparsely populated areas, and demonstrate to the FAA that it had verified the operation of any system necessary to do so.

Lastly, a launch operator operating under the guidelines would conduct each reusable suborbital rocket flight so that the reentry impact point would not loiter over a populated area. A reentry impact point is the location of a reusable suborbital rocket's IIP during the period of unpowered exoatmospheric suborbital flight. The lengthy dwell time over one point can create high risk to any population below.

4.4 Anomaly Reporting

Analyses of mishaps often show that clues existed prior to the mishap in the form of anomalies during the project life cycle. Examination and understanding of launch vehicle system and subsystem anomalies throughout the life cycle can warn of an impending mishap and can provide important information about what conditions need to be controlled to mitigate public risk. Because of this, the FAA has placed special emphasis on anomaly reporting in the experimental permit regime.[5]

Under the guidelines, a launch operator would record anomalies and, after analyzing the root cause of each anomaly, implement corrective actions for those anomalies. This would promote informed safety decisions by a launch operator.

An operator would also report to the FAA any anomaly to any system or process associated with containing the vehicle's IIP within an operating area, with restricting the location of a key flight-safety event, and with the safety measures obtained from a hazard analysis. The permittee would report to the FAA any anomaly of those systems or processes during ground test, inspection, or flight test.

5. SUMMARY

With the Guidelines for Experimental Permits for Reusable Suborbital Rockets, the FAA has attempted to craft a regulatory regime that is conducive to developmental rocket test flights, but that still protects public safety. Although streamlined compared to a license, the experimental permit regime places great emphasis on operating area containment, a hazard analysis to adequately identify hazards and reduce risks, tracking of anomalies, and limitations on the most hazardous activities. The FAA will carefully monitor the safety of launches that take place under an experimental permit to ensure that the approach outlined in the guidelines adequately protects the public.

6. REFERENCES

1. Commercial Space Launch Amendments Act of 2004, Pub. L. No. 108-492, 108th Cong., 2d Sess.

2. Durbin, N., et al. "Regulatory Strategies for Assuring Safety: Results of an International Study of the Oversight of Nuclear Power," Proceedings of the 23rd International System Safety Conference, 2005.

3. Federal Aviation Administration, *Guidelines for Experimental Permits for Reusable Suborbital Rockets,* Version 1.0, May 2005.

4. H.R. Rep. No. 108-429 (2004).

5. The Commercial Space Launch Act of 1984, as codified and amended at 49 U.S.C. Subtitle IX--Commercial Space Transportation, ch. 701, Commercial Space Launch Activities, 49 U.S.C. 70101-70121.

[5] An anomaly is an apparent problem or failure that affects a system, a subsystem, a process, support equipment, or facilities, and that occurs during verification or operation.