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The Lockheed Martin Skunk Works (LMSW) welcomes the opportunity to comment on the FAA's Notice of Proposed Rule Making for Commercial Space Transportation Reusable Launch Vehicle and Reentry Licensing Regulations. LMSW is currently developing the X-33 Advanced Technology Demonstrator under cooperative agreement with the National Aeronautics and Space Administration. The technologies demonstrated by the X-33 are intended for a commercial reusable launch vehicle to be operated by *VentureStar*™ LLC. LMSW recognizes the importance of FAA's licensing activity in assuring public safety. Uncertainty with regard to licensing requirements presents a risk to potential suppliers of commercial launch services with reusable launch vehicles. The completion of the rule making process and issuance of well defined rules will reduce this risk, and promote the development of a commercial reusable launch vehicle industry.

The following are LMSW comments, supporting information and recommendations for clarification and/or improvement to the proposed rules.

In Part 40 1.5 the proposed rule defines launch as follows:

> Launch means to place or try to place a launch vehicle or reentry vehicle and any payload from Earth in a suborbital trajectory, in Earth orbit in outer space, or otherwise in outer space, and includes activities involved in the preparation of a launch vehicle for flight, when those activities take place at a launch site in the United States. The term launch includes the flight of a launch vehicle and pre-flight ground operations beginning with the arrival of a launch vehicle or payload at a U.S. launch site. Flight ends after the licensee's last exercise of control over its launch vehicle.

The proposed rule is substantially the same as that for expendable launch vehicles. However, unlike an expendable vehicle, the reusable launch vehicle will return to earth and undergo processing for the next launch. These ground processing activities will impact the safety of the next launch. Post-flight activities may also present hazards to the general public similar to pre-flight if hazardous propellants or materials are present on the vehicle. LMSW believes that post-

flight processing of a reusable vehicle inherent in the performance of a flight falls within the intent of launch indemnification provisions of current law. LMSW recommends the following definition of launch:

> Launch means to place or try to place a launch vehicle or reentry vehicle and any payload from Earth in a suborbital trajectory, in Earth orbit in outer space, or otherwise in outer space, and includes activities involved in the preparation of a launch vehicle for flight or turnaround between flights, when those activities take place at a launch site in the United States. The term launch includes the flight of a launch vehicle and pre-flight and post-flight ground operations beginning with the arrival of a launch vehicle or payload at a U.S. launch site. Flight ends when the vehicle comes to a stop at the reentry site.

In Part 43 1.35 the proposed rule states:

> (b) Acceptable risk for a proposed mission is measured in terms of the expected average number of casualties (E_c) to the collective members of the public exposed to vehicle or vehicle debris impact hazards. To obtain safety approval, an applicant shall demonstrate –
>
> (1) For public risk, the risk level associated with a proposed mission does not exceed an expected average number of 0.00003 casualties per mission (or E_c criterion of 30×10^{-6}) to members of the public from the applicant's proposed activity; and
>
> (2) For persons within a 100-mile distance from the border of the designated reentry site and contingency abort locations, if any, the risk level associated with a proposed mission does not exceed an expected average number of .000001 casualties per mission (or E_c criterion of 1×10^{-6}).

The specification of a separate lower E_c for a 100 mile radius of the reentry site may have the unintended consequence of increasing the launch risk and consequently the overall mission risk for RLV operations. Many potential launch sites with ascent ground tracks over water have inhabited areas on the descent and approach ground tracks for the same orbital inclinations. This includes current ELV launch sites in Florida and California. Although the risk of casualties for a reentry related accident is much less than for a launch related accident (primarily because of the reduced explosive potential of a vehicle that has expended its ascent propellants) the specification of a reentry related E_c 30 times less than the total mission E_c may make this the limiting factor in spaceport site selection. For an individual placed at risk the portion of the mission in which the accident occurred is likely to be of little interest. Attempts to define risk levels for subsets of the general population, such as a separate E_C for the population in the immediate vicinity of an RLV operating site may be perceived as assigning a higher value to the lives of some populations relative to others. The FAA should avoid setting separate standards for populations exposed to risk during launch and reentry phases of the mission and utilize the mission risk of $Ec=30X10^{-6}$ as the governing criteria for mission safety. LMSW recommends the rule should be:

(b) Acceptable risk for a proposed mission is measured in terms of the expected average number of casualties (E_c) to the collective members of the public exposed to vehicle or vehicle debris impact hazards. To obtain safety approval, an applicant shall demonstrate –

(1) For public risk, the risk level associated with a proposed mission does not exceed an expected average number of 0.00003 casualties per mission (or E_c criterion of30×10^{-6}) to members of the public from the applicant's proposed activity.

In Part 43 1.43 the proposed rule requires that:

(c) For an RLV mission-

(1) A collision avoidance analysis shall be performed in order to maintain at least a 200-kilometer separation from any inhabitable orbiting object during launch and reentry.

The analysis shall address:

(i) For launch, closures in a planned launch window for ascent to outer space or, for an orbital RLV, to initial orbit through at least one complete orbit;
(ii) For reentry, the reentry trajectory;
(iii) Expansions of the closure period by subtracting 15 seconds from the closure start-time and adding 15 seconds to the closure end-time for each sequential 90 minutes elapsed time period, or portion there of, beginning at the time the state vectors of the orbiting objects were determined;

VentureStar™ LLC intends to address space station servicing as part of the commercial launch services market. In order to service this market it will be necessary to approach and dock with the station, an inhabited vehicle. As a practical matter the launch vehicle is unlikely to approach the station on the first orbit after launch. However, LMSW would like to avoid precluding a first orbit approach to an inhabited orbiting object if that is in fact the ultimate destination of the launch. In addition, an inhabited launch vehicle docked at the space station may, in the event of a life-threatening emergency at the station, be forced to initiate a departure and reentry as rapidly as possible. Therefore LMSW proposes the rule should read:

(c) For an RLV mission-

(1) A collision avoidance analysis shall be performed in order to maintain at least a 200-kilometer separation from any inhabitable orbiting object during launch and reentry, unless the inhabited orbiting object is the intended destination for the launch.

The analysis shall address:

(i) For launch, closures in a planned launch window for ascent to outer space or, for an orbital RLV, to initial orbit through at least one complete orbit;
(ii) For reentry, the reentry trajectory;

(iii) Expansions of the closure period by subtracting 15 seconds from the closure start-time and adding 15 seconds to the closure end-time for each sequential 90 minutes elapsed time period, or portion there of, beginning at the time the state vectors of the orbiting objects were determined

In Part 43 1.43 the proposed rule requires that:

(2) The projected instantaneous impact point (BP) of the vehicle shall not have substantial dwell time over densely populated areas during any segment of mission flight;

The terms “substantial dwell time” and “densely populated” are subjective and will produce considerable uncertainty for launch service providers and space port operators in planning for future RLV operations. As the EC analysis already factors in the population density and dwell time Lockheed Martin recommends deleting this portion of the proposed rule.

In Part 43 1.43 the proposed rule also requires that:

(d) In addition to requirements of paragraph (c) of this section, any unproven RLV may only be operated--
(1) Such that the projected instantaneous impact point (BP) of the vehicle does not have substantial dwell time over populated areas; or
(2) Such that the expected average number of casualties to members of the public does not exceed 30×10^{-6} ($E_c < 30 \times 10^{-6}$) given a probability of vehicle failure equal to 1 ($p_f = 1$) at any time the IIP is over a populated area;

In all likelihood no developer of an RLV will be able to comply with the provisions of (d). Inevitably the ground track of the instantaneous impact point passes over some inhabited areas during launch and reentry. For any reasonable debris model estimated EC will exceed $30X10^{-6}$ if the failure occurred at that spot. Each RLV developer will be forced to seek a waiver, and the FAA will be forced to review each developer’s first flight certification plan in sufficient detail to substantiate the developer’s claimed Pf resulting in substantial expense to the FAA and significant uncertainty to the RLV developer.

New aircraft typically go through a flight test program during which the functioning and performance of the aircraft and systems are checked out in a flight environment before they are permitted to fly over densely populated areas. But even experimental rocket aircraft like the X- 15 have overflown low population density areas adjacent to major test ranges. Although several new launch vehicles have experienced failures on their first flight the cause of those failures does not appear to be strongly related to the fact that they are propelled by rocket engines. A review of stage failure rates by ACTA to establish average failure rates for stages without solid rocket

boosters undertaken in support of the X-33 has established that a failure rate of 1 in 250 is reasonable. Only one of the four stages considered (the current space shuttle) had an engine out capability. The other three (Atlas, Delta and Titan) did not. Consider the flight history of American liquid stages with engine out capability.it will be possible to find some point on the instantaneous impact ground track where the

	Engines	Flights	In Flight Shutdowns	Vehicles Lost
Space Shuttle(minus the SRBs)	3	93	1	0
Saturn V S-IC	5	13	0	0
Saturn V S-II	5	13	3(1)	0
Saturn I&IB S-I&S-IB	8	19	1(2)	0
Saturn I S-IV	6	6	0	0

1) 2 separate incidents - one experienced a single other shutdown, the other shutdown two of five engines
2) A planned engine out flight test

After 144 flights of five different stage designs no American liquid fueled stage with engine out capability has ever been lost in flight because of engine failure. Five engines have been shutdown in flight, four due to engine failure. Recent launch vehicle failures on first flight have been caused by bad aero databases Pegasus XL, Delta III), software validation (Ariane V), and subsystems qualified to the wrong environments (Lockheed Launch Vehicle). These issues are not very different from those faced in the first flight of an aircraft and should be addressed in the manufacturers first flight certification plan. LMSW believes that for substantially aircraft like reusable launch vehicles a first flight probability of failure of 1 in 250 can be substantiated and recommends the following rule:

> (d) In addition to requirements of paragraph (c) of this section, any unproven RLV may only be operated--
> (1) Such that the projected instantaneous impact point (IIP) of the vehicle does not have substantial dwell time over populated areas; or
> (2) Such that the expected average number of casualties to members of the public does not exceed 30×10^{-6} ($E_c < 30 \times 10^{-6}$) given a probability of vehicle failure equal to 1 ($p_f = .004$) at any time the IIP is over a populated area;

In Part 43 1.43 the proposed rule requires that:

> (e) Any RLV that enters Earth orbit may only be operated such that the vehicle operator is able to —

(1) Monitor the status of safety-critical systems immediately before enabling reentry flight and verify that the vehicle can reenter safely to Earth; and

(2) Issue a command enabling reentry of the vehicle. Reentry cannot be initiated autonomously under nominal circumstances without prior enable.

The proposed rule appears contrary to current expendable launch vehicle practice in which many critical activities such as ignition of an upper stage may be controlled autonomously by the vehicle. Autonomous control has allowed launch vehicles with complete telemetry failures to safely and successfully complete a mission and deploy a payload. Similar procedures are followed for aircraft operating within the current air traffic control system. A pilot experiencing complete loss of communication in flight is expected to continue to the planned destination in accordance with his flight plan. A reusable launch vehicle in low earth orbit will eventually decay and reenter. In the event of loss of communication with the vehicle the safest option would be to return to the planned destination at the expected time. LMSW recommends the rule be revised to read:

(e) Any RLV that enters Earth orbit may only be operated such that the vehicle operator is able to —

(1) Monitor the status of safety-critical systems during flight; and

(2) Issue a command disabling reentry of the vehicle.

In Part 43 1.79 the proposed rule requires that:

(b) Not later than 15 days before each licensed RLV mission, a licensee must notify the FAA, in writing, of the time and date of the intended launch and reentry or other landing on Earth of the RLV.

A key competitive feature of future reusable launch vehicles is the ability to schedule a launch on short notice. While current expendable vehicles take weeks or months to prepare for launch Lockheed Martin envisions designing a reusable launch vehicle for a two day turnaround time between missions. This will require modular payload provisions allowing one payload to substitute for another on short notice. Provided all safety and mission approvals are in order and control of appropriate air space around the launch and recovery sites is provided the launch service provider should be allowed to take advantage of the versatility inherent in a reusable vehicle. Lockheed Martin recommends the rule be revised to read:

(b) Not later than 24 hours before each licensed RLV mission, a licensee must notify the FAA, in writing, of the time and date of the intended launch and reentry or other landing on Earth of the RLV.

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