LANG
Engineering, Regulatory
and Program Support

ORIGINAL

DEPT. OF TRANSPORTATION DOCKET SECTION

99 JUN 16 PM 1:5

57547

June 11, 1999

U.S. Department of Transportation Dockets
Docket No. FAA- 1999-5535 - 5
400 Seventh St., SW
Room Plaza 401
Washington, DC 20590

To Whom It May Concern:

This letter provides comments to the Notice of Proposed Rulemaking (NPRM) for Commercial Space Transportation and Reentry Licensing Regulations prepared by the U.S. Federal Aviation Administration/Office of the Associate Administrator for Commercial Space Transportation (FAA/AST).

The task of ensuring public health and safety and safety of property for new launch vehicles is complex and daunting, to say the least. This rulemaking represents a good first step in licensing the initial reusable launch vehicles (RLV) and reentry operations. The structure adapted from AST's approach for expendable launch: vehicles (ELV) on a case-by-case basis provides a complete and well-organized process by which AST and the applicant can identify safety issues and evaluate whether sufficient and necessary measures have been incorporated to assure safety. In general, I commend AST on this NPRM.

My concerns therefore are less on the immediate form of the NPRM, but rather focus on the long-term development of AST's regulatory framework as well as the interpretation and implementation of these regulations. And hopefully somewhere in between, these concerns translate into constructive comments that may improve upon AST's final rulemaking for the interim.

Defining a Regulatory Framework

Industry has traditionally been better than government at determining what future marketplaces should look like. Consequently, AST has relied on industry to propose what directions commercial space will take. But there are some reasonable and appropriate ways in which AST can structure its regulatory framework to ensure public safety as well as foster industry opportunities.

The NPRM focuses on an applicant as the entity with sole and final responsibility assuring that proposed the vehicle and mission do not jeopardize public health and safety and safety of property. In doing so, it assures an effective regulatory system by clearly identifying and limiting authorization between the government and a single licensee. But the less apparent result is that it relies on a limited number of parties to define what will be put forth for licensing. For any launch and reentry vehicle/operation, there are basic areas, such as propulsion systems, avionics, range support, etc., which must be addressed for a successful launch operation. Typically, the license applicant, as the integrator of the vehicle and operations, is the party that defines needs and requests bids to meet these needs. Consequently, these parties drive the development of new systems and operations in commercial space transportation.

In contrast, aviation and other transportation modes involve independent certification and license processes (e.g., for airframe, power-plant, pilot, routes, etc.) where multiple parties may specialize, obtain approvals, and market. By defining areas where independent parties can focus, the aviation industry leverages wider expertise, can draw on larger pools of resources, and spreads costs. An example structure for commercial space transportation may include:

2628 139'" Avenue SE # 14, Bellevue, Washington 98005
Phone: +1-425-644-9294, lang@aa.washington.edu

- Vehicle and System Safety Requirements
- Flight Operations
- Experimental Vehicles and Flight Test Programs
- Operator Safety Requirements
- Passenger Safety (may be included in vehicle and system safety)
- Spaceport Operations and Safety

Congress has been reluctant to authorize AST to follow the FAA's aviation approach for certifying aircraft and operators due to the negative connotations of certification, and AST has been reluctant to make overtures in that direction. But there are economic benefits and efficiencies to this approach if implemented carefully. AST should consider breaking down the proposed licensing structure into individualized approvals and assess their advantages and disadvantages.

Evolving Safety Regulations

1 appreciate AST's case-by-case approach and the desire to assure flexibility for new technologies. I cannot emphasize enough the need to put the regulations into the perspective of an ongoing development process that parallels industry and reusable launch vehicle evolution. Subsequent to the final rule, AST and industry resources cannot, and should not, be "stuck" with this initial regulatory structure. These regulations should be a stepping stone toward a longer-term public safety framework. For example, AST published its first update to the ELV regulations ten year after the original rulemaking. The recent regulations represent considerable thought and legal work to clarify and make complete a licensing process which is fundamentally the same as it was ten years ago. Over the same time period, AST and industry were continually at the cusp of new innovation. But significant energy has been expended trying to force the limited regulatory structure to fit future endeavors and visa versa (i.e., the proverbial square peg and round hole). This is said not to take anything away from AST's valiant efforts to accommodate a developing industry and ensure public safety – particularly given the past political environment and available resources. But much could have been accomplished to explore and incorporate a steep learning curve presented by these opportunities to foster long term industry growth and safety.

As an example, the licensing process for an airborne launched rocket in the early 1990's was at the forefront of challenging the existing regulatory structure. Significant effort focused on how the application fit within legal and financial framework. The unique safety issues led AST to refine its systems engineering evaluation approach. But the aftermath of the National Transportation Safety Board (NTSB) investigation illustrated key areas that AST and the licensee had not emphasized. Commercial space transportation had moved beyond reliance on, or even the capabilities, of a single Federal Range. While significant and necessary effort examined the technical design aspects, it became clear that there were additional dynamics associated with personnel readiness and rest, organizational structure and operational communications. What other lessons can be, or could have been, learned? For example, the early failure of the rocket associated with the control and dynamics of the vehicle showed the limitations of design based on computational fluid dynamics versus wind tunnel testing – an area of increasing interest for safety demonstrations. Renewed interest in two-stage-to-orbit systems by RLV makers recalls past questions about how risk measures are applied to independent stages, overflight restrictions, communications coordination, etc.

In another example, AST's license evaluation for a vehicle with an autonomous flight safety system focused extensively on component tests and validation. This emphasis was a necessary part of safety assurance, there were other issues that received little or belated attention. For example, how did this new safety approach change traditional methods in terms of relaxation to or addition of requirements flight monitoring and displays or flight corridor clearances? How does the automation of system functions change requirements on personnel decision-making responsibilities and readiness requirements? While these issues did not pose an immediate safety concern for that launch system, they do offer potential lessons for future RLV applications.

The purpose of these examples is not to focus on lost opportunities, but rather to illustrate that this is still the early stages of the commercial space transportation industry and regulatory structure, and that we need to view the proposed regulations as an evolving and iterative process. We cannot focus on forcing the regulations to work as they stand, but rather look to how the challenges of upcoming applications can improve the regulatory process.

<u>Defining a Safety Demonstration</u>

The NPRM section entitled, "Public Safety Strategy for Assessing Reusable Launch Vehicle and Reentry Safety," describes the use of a systems engineering approach to link safety component performance and reliability to a numerical casualty expectation. Past evaluations of launch vehicles whose flight safety is embedded into the routine command and control functions have shown that this approach can require significant resources with marginal or questionable benefit. Overemphasis on the accounting of numbers is misleading in that engineering, which is influenced by assumptions, approximations, and empirical interpretation, is not a science. For example, the proverbial six nines versus nine nines reliability debates become moot when probability distributions over time are considered, as seen with the catastrophic Space Shuttle Challenger failure.

At this stage in the evolution of RLVs, there are many complex questions about the relationship between system performance and safety. For example, how does the sinusoidal vibration testing to 6 dB above expected levels for a component designed with a margin of two relates to the failure probability distribution over a lifetime of 20 years? While there is an answer to this question, the regulatory process would not be very efficient or effective if it required an applicant to address this type of question for every system on an RLV. Yet, the design and test requirements in this example may very well be "good engineering practice" that should be imposed on the applicant. Some requirements will simply reflect the public's expectation that specific safety issues be addressed regardless of the quantitative contribution to risk, as shown by AST's adoption of the NTSB's recommendations for safety-related launch personnel rest and rehearsal requirements.

In contrast to the risk-based standard, industry representatives recommended the utilization of FAA airworthiness-type specification standards at FAA's Public Meeting on Reusable Launch Vehicle Safety (February 11, 1999). The objective of AST's standard is to force the applicant to understand the interrelated factors affecting safety. And in this context, it may have seemed that industry desired to have all their "homework" done for them by requesting the government to publish safety specifications which link component performance and reliability requirements to safety. But the underlying message reiterates that the implementation of risk-based performance standards is more complicated to understand and demonstrate, particularly at the detailed component level. Indeed, for more developed industries, regulations based on specification standards compliance tends to be more efficient when dealing with broader and more varied interests.

In the interim, AST should use the casualty expectation as a guiding principle that is imposed at a program level. But it should be recognized that it is the combination of many factors and mechanisms, such as empirical data (e.g., past experience, build-a-little/test-a-little), engineering practices (e.g., safety margins), design and operational measures that assure safety. Thus, AST should also explore the establishment or recognition of accepted practices that can be used in the safety demonstration.

<u>Definition of a Proven Vehicle</u>

In the NPRM section on operational restrictions on reusable launch vehicles and reentry, AST requested feedback on what should constitute a "proven" vehicle, since this demarcation is used to determine the scope of allowable operations. Numerical test requirements to demonstrate reliability levels with specified confidence intervals for a given set of degrees of freedom (i.e., system variables) can be statistically determined. But there must be a balance between safety, public expectation and allowing industry the opportunity to prove itself. AST has already recognized the potential cost impacts associated with test and validation requirements for the flight test phase of the vehicle development. I would just echo this concern. As AST has recognized, the means for developing a confidence level in the RLV capability is through incremental flight tests. AST should continue to foster a "build-a-little/test-a-little" mentality as a matter of safe practice similar to that used by the DC-X program. The flight test program is a balance between expecting and accepting higher, but contained risks.

For routine flight operations, vehicle reliability as well as safety are critical to public confidence in this new industry as well as general safety. However, it is during the flight test program that the applicant is working the unknowns of the system and its operations. AST should weigh in favor the ability for the applicant to contain risks through operational mitigation measures. Such a measure, for example, may be the launch and landing of RLVs in remote locations. Again related to the safety demonstration process, AST should not, a priori through the licensing process, penalize the applicant for the system unknowns that are intended to be worked out during flight tests. AST should work with industry to set public expectation that accepts a common sense measure (as opposed to political and legal concerns) that focuses on the technical aspects of the program during this phase of vehicle development.

Setting Safety Precedents

I encourage AST to take a more proactive role in identifying and establishing public expectation regarding the safe design and operation of a RLV, as it has in the operational restrictions discussion. Flight termination systems were acceptable for ELVs, but acceptance was also influenced by the practical remoteness of the activity from the public's sphere of attention. For example, recent Titan and Delta failures have led to more concern over payload monetary loss than the potential for impact to population centers. On the other hand, the destruction of a vehicle that is regularly observed over populated areas (even if proven safe) does little to boost public confidence and acceptance of the RLV industry. Instead, the public is likely to expect that a vehicle contain the necessary design features, such as engine-out capability or glide descent range, that will allow it be safely diverted to a remote location or nearby landing site. Similar considerations must be made for failures on orbit in order to avoid stranding passengers in space or leaving debris in populated orbits (a present hazard potential with ELV stages and payloads).

"Rules of the road" must eventually be established for operating in space. To date, space has been treated on a "first-come-first-serve basis," but it will be unacceptable at some point for space transport to occur at just any time and place in space. In an extreme example, Arthur C. Clarke predicted that there would eventually be no applications in low earth orbit because of the risks associated with debris and random collisions. While control of the use of regions in space is likely to be controversial, government and industry should further investigate the subject matter. Other examples may include:

- Who has the right-of-way in space?
- What can operators do in space? For example, can they dock with anything they wish? Can they leave debris in the path of others?
- How are emergencies handled? To what extent is there an accepted responsibility of space users to provide assistance to those in need (e.g., United Nations Treaty on the rescue of astronauts)?
- What is the relevance to the United Nation's space object registration reporting requirement for vehicles that routinely enter and depart from space? Should this treaty obligation be modified to be more effective as a space traffic safety mechanism?

New paradigms of accepted practice in flight operations must be established during this early phase of RLV regulation. The concept introduced by the FAA of alternate landing sites is an example of breaking a past space concept that a failure is something for which no one has control. Quite clearly, the public and the government will frown on inadvertent landings in backyards or on highways. We must differentiate and understand the implications of failures leading to uncontrollable incidents versus controlled aborts or diverted flight paths in order to establish appropriate regulatory requirements. The terminology "overflight" has specific connotations and associated risk perceptions from ELV operations. Yet, "flying overhead" is expected and accepted for aircraft approach to airports that are in the middle of, or nearby, population centers.

Planning for Passenger Safety

The NPRM states that passenger safety is to be addressed in future rulemaking actions. This issue will certainly become more important over time – particularly in light of growing public interest in space tourism last year. The presentation by Dr. Melchor Antuñano of the FAA at the 1999 Commercial Space Transportation Forecasting Conference provided significant insight into the complex issues that must be addressed in approving passenger flights. AST should involve industry as it continues its research in this area. Dissemination of guidance material and information publications would encourage industry to build these ideas into their designs early in the development process. A few additional principles and issues are provided below:

- While it may be easier from a designer and regulator's point of view to limit passenger travel to those who are physically able to withstand severe environments, RLVs should eventually to allow anyone to access space. Though this consideration is likely to be addressed by commercial market forces, AST should be assessing the regulatory requirements to facilitate this direction or ensure safety in the event of this situation.
- Past and current astronauts have undergone extensive training and medical evaluation to be able to travel in space. As AST and industry determines whether similar requirements will be imposed on passengers, one must consider the administrative and logistical burdens of implementation. At a minimum, the aviation model illustrates how the general populace can be kept safe by restricting their movement in safety-critical phases of flight, through safety instructions prior to flight and safety devices onboard. Again, resolution of this issue may be driven by market forces.
- Will there be a crew number requirement associated with the number of passengers? Does their presence increase the safety of the passengers, or in some aggregate sense, do they add to the overall risk involved in the flight? The aviation model is aligned with the former, but can the same be said in a space environment?
- Initially, it may not be acceptable strand passengers in space. Until rescue attempts can be made in a timely manner, appropriate design and operational measures may be required to ensure that passengers can return to earth or reach a safe haven in the event of any emergency.
- How will financial responsibility be allocated to the RLV operator? Will the RLV operator be protected from potential unlimited liability under the legislation authorizing licensing of launch and reentry activities?

Recognizing Realistic Costs and Benefits

I appreciated AST's efforts to identify and assess costs and benefits in the Regulatory Evaluation Summary. But the cost-benefit analysis was understated. Comparisons of costs by traditional ELV applicants - particularly those whose license evaluation relies heavily on pre-established AST baseline assessments – vastly underestimates RLV costs. A previous reentry vehicle application evaluation by AST required 0.75-1.25 person years, $300,000/year additional support to develop the regulatory and technical structure for the evaluation. The cost to the applicant was on the order of 1 person-year per year (or about $100,000/year) to prepare application materials, coordinate activities and address technical issues with AST. Keeping in mind that this was a small expendable vehicle, these costs are probably at the lower end of an RLV spectrum. The costs to the applicant for the licensing ELV whose flight safety was embedded in the vehicle's routine command and control elements was also on the order of $100,000-$200,000/year. Both licensing actions required at least 3 years of intense AST and industry resources. The eventual costs to both AST and industry for RLV licensing is more akin to aircraft certification which is on the order of millions to tens of millions of dollars annually. The assessment of performance and reliability for Russian engines proposed for use on current RLVs could easily cost tens of millions of dollars if they must be tested and validated per U.S. Government standards.

The implications of AST's requirements go beyond paperwork and face-to-face meeting costs. For example, requirement to conduct collision avoidance assessments currently involves access and support from the government which is the only source of the on-orbit object database and knowledge of inhabited object locations at ahy given time. The costs charged by the government to companies should be verified, but I have heard estimates on the order of tens of thousands of dollars per launch campaign. This user-fee based cost would be akin to requiring industry to pay for the nation's air traffic control system. This and similar requirements should be reexamined to determine how much can and should be imposed by industry versus government.

I highlight the significant costs involved in this regulatory process, not to impede the rulemaking. These requirements are necessary and the costs are simply the cost of doing business. The benefits are such that we are really talking about the development of billions of dollars industry that will eventually parallel the aviation industry. But recognition of the costs involved is necessary to properly plan and allocate resources both by the government and industry to accommodate this new endeavor. And, perhaps there are strategies that government and industry can develop that facilitate the ability to draw resources and use them more effectively. The prior example of how certification leverages multiple segments of the industry is just one.

Implementing; the Regulatory Process

I would like to add just a few comments on the eventual process for application, evaluation, approval, and compliance monitoring. In particular, the rulemaking should differentiate between areas are part of the decision-making process versus activities that are authorized by the approval. It should clarify the form and components of an application and differentiate between AST insight into the applicant's processes versus data requests for legally binding documents. For example, the system safety program plan, provided by AST for the Public Meeting, indicated that staffing and budgeting data might be submitted by the applicant as part of the application process. Caution must be applied if this was truly AST's intent. There must be a clear delineation between application material and management documents. As AST is readily aware, the legally binding nature of application material could lead to civil penalties if the licensee fails to conduct its activities in the manner represented. Management documents such as staffing, budgets, and timelines constantly change can be used by AST to evaluate the commitment of an applicant to safety and assist in resource planning. However, these documents include activities prior to the license issuance or even final application submittal. As a result, they may vary as part of the vehicle and operations development, would involve burdensome reporting to AST if required, and would cause significant administrative problems if held to the rigor of an audit.

To date, the interaction between AST and applicants has been limited to scheduled visits between office presentations or site visits. Engineering decision-making has significant impact on regulatory compliance and visa versa. AST should seek input or make recommendations regarding closer communications and more interactive decision-making. As an example, the aviation community utilizes company-provided Designated Engineering Representatives to represent FAA interests on site. On the other hand, the use of the same engineers for application evaluation and compliance monitoring have the potential for conflicts of interest and/or complicating AST decision-making in real-time during launch activities and should be avoided.

Final Comments

As we enter this next generation of launch vehicles and regulations, I encourage AST to refine its relationship with the space industry. In space launch programs at the Federal Ranges or between the FAA and aviation community, there is an on-going interaction – both formally and informally – whereby both sides can improve safety and safety oversight. AST should identify a range of regulatory mechanisms with industry, such as system certifications, spaceworthiness standards, advisory circulars, periodic safety meetings and safety committees, which may enhance the safety oversight of the RLV industry. AST's recent use of Advisory Circulars provides an expeditious means for disseminating safety information. Such information also could also receive wider industry recognition and acceptance than past AST safety research reports and data if incorporated into industry working group functions, industry association standards activities, etc. through cooperative research and development efforts.

Again, AST has made significant progress toward the eventual development of a regulatory framework for ensuring public safety for RLVs. I appreciated the opportunity to comment and provide the above suggestions. Good luck in your endeavors.

Sincerely,

Derek Lang
Aerospace Consultant

cc:
Patricia Grace Smith, AST-1
Ronald K. Gress, AST-200