

Analysis of Human Space Flight Safety – Report to Congress

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Presented to COMSTAC
October 30, 2008



Outline

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Contract Summary

- Contract: DTFAWA-07-C-00084
- Objective: To prepare a report analyzing safety issues related to launching humans into space
- FAA Contract Administration:
 - *Kenneth Wong, Management Representative*
 - *Marcus Ward, COTR*
- Aerospace Program Manager:
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Aerospace/GWU/MIT Team

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- GWU School of Engineering:
Prof. Joseph Pelton
- GWU Space Policy Institute:
Prof. Henry Hertzfeld, Prof. John Logsdon
- MIT Department of Aeronautics and Astronautics:
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El Segundo, **Rosslyn, *Houston, ****Vandenberg*

Background

The Commercial Space Launch Amendments Act of 2004, which became Public Law 108-492 on December 23, 2004, required the Secretary of Transportation, in consultation with the NASA Administrator, to enter into an arrangement with a nonprofit entity for a report analyzing safety issues related to launching humans into space. In designing the study, the Secretary should take into account any recommendations from COMSTAC and NASA's Aerospace Safety Advisory Panel (ASAP). The report is to be submitted to the Senate Committee on Commerce, Science, and Transportation and the House of Representatives Committee on Science by December 23, 2008.

Topics Specified in CSLAA (1/2)

1. The standards of safety and concepts of operation that should guide the regulation of human space flight and whether the standard of safety should vary by class or type of vehicle, the purpose of flight, or other considerations
2. The effectiveness of the commercial licensing and permitting regime under chapter 701 of title 49, United States Code, particularly in ensuring the safety of the public and of crew and space flight participants during launch, in-space transit, orbit, and reentry, and whether any changes are needed to that chapter
3. Whether there is a need for commercial ground operations for commercial space flight, including provision of launch support, launch and reentry control, mission control, range operations, and communications and telemetry operations through all phases of flight, and if such operations developed, whether and how they should be regulated

Topics (2/2)

4. Whether expendable and reusable launch and reentry vehicles should be regulated differently from each other, and whether either of those vehicle types should be regulated differently when carrying human beings
5. Whether the Federal Government should separate the promotion of human space flight from the regulation of such activity
6. How third parties could be used to evaluate the qualification and acceptance of new human space flight vehicles prior to their operation
7. How nongovernment experts could participate more fully in setting standards and developing regulations concerning human space flight safety
8. Whether the Federal Government should regulate the extent of foreign ownership or control of human space flight companies operating or incorporated in the United States

Topic #1: What are the standards of safety and concepts of operation that should guide the regulation of human space flight? Should they vary by class or type of vehicle, the purpose of flight, or other considerations?

Conclusions: Standards of safety and concepts of operation should be evolutionary, allowing regulation to mature as the industry gains relevant flight experience. Initial regulation must strike a balance between establishing a regulatory regime that allows and encourages private risk taking and investment, while still protecting the uninvolved public from damage and providing for well-informed consent of participants and involved parties.

Licensing should proceed in a multi-step process, starting with experimental operations handled on a case-by-case basis. In the process, a data standard would be developed for collecting design, test, and flight data related to vehicle safety, as well as mishap/accident-related safety reporting. The initial standard of safety should not vary by type of vehicle, purpose of flight, or other considerations, as there is not sufficient data to substantiate these classifications. Several options for safety analysis and dissemination of safety evaluations were presented in the report.

Topic #1: Summary

- Need to define a balanced and evolutionary regulatory approach that:
 - *Provides acceptable levels of public, space flight participant, and crew safety / survivability*
 - *Does not stifle emerging industry*
- Provided three viable initial regulation options. The goals are:
 - *Collect design, test, and flight data for early operators*
 - *Refine analytical toolset for safety calculations*
 - *Plan for evolutionary changes as the industry matures*
 - *Create informed consumers*

Topic #2: How effective is the commercial licensing and permitting regime under chapter 701 of title 49, United States Code, particularly in ensuring the safety of the public, crew, and space flight participants during launch, in-space transit, orbit, and reentry? Are any changes needed to that chapter?

Conclusions: The current license application, application review, and launch monitoring operations are sufficient at the current time. However, it is recommended that FAA/AST continue examining options for safety approval standards for systems and subsystems, as well as mission assurance processes. FAA/AST should also continue to develop and exercise procedures in collaboration with other affected federal agencies for investigation of possible accidents or mishaps. FAA/AST's licensing and regulating authority is presently limited to launch and reentry operations and does not extend to orbital operations. Regulatory legislation for commercial orbital operations should be considered as needed to address expected future commercial orbital ventures.

Topic #2: Key Issues

- Diversity in Approaches for Developing RLVs for Flights with Spaceflight Participants Aboard
 - *Numerous configurations under development: spaceplanes, suborbital vehicles, orbital vehicles*
 - *Some expendable components*
 - *Lack of subsystem commonality requires specific testing*
 - *Case-by-case licensing*
- Effective U.S. Government Response to Commercial Spaceflight Mishaps
 - *MOAs and MOUs between FAA, USAF, NTSB, etc.*
 - *Need for Accident Response Plan*
- Relevant Recommendations from GAO Study of FAA/AST
 - *Assessment of FAA/AST needs as the industry expands: staffing and resources*
 - *Proactive approach to safety: continually monitor space tourism industry safety indicators*

Topic #3: Is there a need for commercial ground operations for commercial space flight, including provision of launch support, launch and reentry control, mission control, range operations, and communications and telemetry operations through all phases of flight? If such operations are developed, should they be regulated, and if so, how?

Conclusion: Commercial ground operations are needed and will be largely the responsibility of the launch vehicle operators for the foreseeable future due to the diversity of design concepts. FAA/AST already is laying the groundwork for incorporating commercial spaceflight into the National Airspace System while allowing industry efforts in this area to mature at their own pace.

Topic #3: Key Issues

- Ground operations essential component of space launch systems
- Relevant statutory requirements
- FAA/AST CONOPS
- Integration of commercial space transportation into NAS
- Launch range safety regulation
 - *USAF and NASA flight termination practices*
 - *Alternate flight safety systems for commercial RLVs, e.g., abort capability, thrust termination systems, and autoland systems*
- GPS tracking

Topic #4: Should expendable and reusable launch and reentry vehicles be regulated differently from each other? Should either of these types of vehicles be regulated differently when carrying human beings?

Conclusions: Launch of expendable vehicles, when used as a first stage to lift reusable rockets carrying crew and spaceflight participants, as well as launch and reentry of reusable launch vehicles with crew and spaceflight participants aboard, should be regulated differently than launch of expendable vehicles without humans aboard. Range safety controls, regulation, and licensing may have substantial areas of commonality regardless of whether the vehicle is expendable or reusable or has humans aboard. Current range safety processes can continue to apply, with pertinent upgrades as needed. Until more experience is gained with commercial private spaceflight vehicles, however, the regulation of expendable and reusable vehicles for launching humans should remain on a case-by-case basis under existing FAA/AST rule-making, due to the great diversity of vehicle design, system components, and flight characteristics. The development of a metadata system, as recommended under Topic 1, to monitor the development and actual performance of commercial launch systems and to better identify different launch risk factors and criteria, would assist greatly in the regulatory process.

Topic #5: Should the Federal Government separate the promotion of human space flight from the regulation of such activity?

Conclusion: There is no compelling reason to remove promotional responsibilities from FAA/AST at this time. The office is performing these duties adequately and has not yet encountered any conflicts of interest or received complaints on this issue.

- Only about 16% of AST's budget is used to “encourage, facilitate, and promote” industry (conferences, reports, outreach)
- Reinforces rather than conflicts with safety responsibilities
- Analogy: Airline promotion lasted 7 decades before it was ended – due to concerns about public perceptions, not real problems
- Vigilance regarding government/industry relationship is needed whether or not promotional duties are involved

Topic #6: How should third parties be used to evaluate the qualification and acceptance of new human space flight vehicles prior to their operation?

Conclusion: The CSLA defines third parties, for purposes of commercial space launch activities, as the uninvolved public. Independent experts such as consultants and non-government personnel are typically part of the process and are essential to the qualification and acceptance of new human spaceflight vehicles. However, we make no specific recommendations on how they should be used because in the current early stage of development each situation will require different expertise and will be best handled on a case-by-case basis.

Topic #7: How can nongovernment experts participate more fully in setting standards and developing regulations concerning human space flight safety?

Conclusions: In setting standards and regulations, the government frequently uses outside expertise to augment its own personnel. Often outside personnel are experts from the specific industry being regulated, consultants, and academia. There are many ways private sector experts are involved in the standards and regulatory process ranging from providing expertise in a particular technical field to serving as members of review, advisory, and accident investigation panels. Each specific circumstance is unique, and there is no reason at this time to recommend any changes to this system. However, in a related area, the National Transportation Safety Board (NTSB), an independent government agency, does not have space transportation explicitly included in its statutory jurisdiction, although it does have agreements with the FAA and the Air Force under which the NTSB will lead investigations of commercial space launch accidents. Congress may want to consider explicitly designating a lead agency for accident investigations involving space vehicles to avoid potential overlapping jurisdictions.

Topic #8: Should the federal government regulate the extent of foreign ownership or control of human space flight companies operating or incorporated in the United States?

Conclusion: Commercial human spaceflight is an emerging industry that does not yet have a significant impact on the U.S. economy, play a role in national security, or control militarily significant technologies that are unique to the United States. Therefore, it does not have characteristics that traditionally have provided the rationale for regulating foreign ownership. Imposition of foreign investment limits could undermine the industry's ability to succeed and grow.

- Restrictions exist for defense, airlines, shipping, mining, communications, energy
- Existing law and regulations are sufficient safeguards
 - *Exon-Florio provision, as amended*
 - *Export control regime*
 - *Review by Committee on Foreign Investment in the U.S. (rarely results in investment ban; 1 case in 1600 reviews, 1988-2006)*

Stakeholder Inputs

- List of questions provided to stakeholders
 - *Responses very useful to the study*
 - *Questions and summary of responses provided in backup charts*
- Meeting with Personal Spaceflight Federation

NASA Insights

- Interviews with NASA Office of Safety and Mission Assurance (S&MA) and Flight Crew Operations Directorate
- Among many concepts such as a rigorous safety analysis process and human error analyses, NASA's approach to human rating emphasizes establishment of appropriate levels of failure tolerances, which are usually associated with redundancy and reliability requirements. For a system to be human rated, either an appropriate level of redundancy or a high level of reliability must be demonstrated.

The Aerospace/GWU/MIT team is grateful for the valuable inputs provided by industry stakeholders and government personnel, allowing successful completion of this study.



Backup

Questions to Stakeholders: Regulation

- Do you perceive any deficiencies in the commercial licensing and permitting regime established by chapter 701 of title 49 of the United States Code in terms of ensuring safety for:
 - *the public?*
 - *the crew?*
 - *the spaceflight participants?*
- Assuming that commercial space transport for cargo and space flight participant operations will emerge in a fashion similar to commercial air transport:
 - *What should the FAA's regulatory focus be (e.g., integration into the National Airspace System, flight hardware, ground/flight operations, crew training, etc.)?*
 - *Can the necessary regulations be incorporated into existing air transport regulations or does this require a separate regulatory system?*
- Should expendable and reusable vehicles be regulated differently? Should either type of vehicle be regulated differently when carrying humans vs. cargo? Should such regulatory difference be based on exposure of the National Airspace System to the particular type of flight path? Other considerations?
- Should the U.S. government separate the promotion and regulation of human spaceflight rather than assigning both to the same FAA office? If so, where should the responsibility for promotion reside?
- Should the U.S. government regulate the extent of foreign ownership or control of human spaceflight companies operating or incorporated in the United States? What would be the benefits or drawbacks of such regulation for your company and for the industry?

Questions to Stakeholders: Standards & Evaluation (1/3)

- Should safety standards be uniform for all commercial human spaceflight systems? If not, what factors do you think drive the need for different, augmented, or reduced safety standards? Please provide a rationale in each case.
 - *Class/type of vehicle (e.g., horizontal takeoff/landing, vertical takeoff/landing, air launch vehicle, etc.).*
 - *Reusability of vehicle (e.g., partly reusable, fully reusable, total expendable, etc.).*
 - *Purpose of flight.*
 - *Other considerations.*
- Should safety standards be uniform for all spaceports supporting commercial human spaceflight? If not, what factors do you think drive the need for different, augmented, or reduced safety standards? Please provide a rationale in each case.
 - *Ownership/primary responsibility of spaceport (civil/military/commercial).*
 - *Local requirements and laws.*
 - *Scope and limitations of flight vehicle types (e.g., perhaps a spaceport can only accommodate vertical takeoffs or can support multiple launch types but only “runway” landings).*
 - *Scope and limitations of services provided (e.g., perhaps vehicles cannot be serviced at the spaceport, just launched or landed).*
 - *Scope and limitations of types of flights supported (e.g., only supporting tourist flights or science flights).*
 - *Other considerations.*

Questions to Stakeholders: Standards & Evaluation (2/3)

- If differentiated safety standards are developed, what form do you think would be most helpful? Please provide your rationale.
 - *A core set of safety standards applicable across the board for all spaceflight systems and/or spaceports with subsets of additional safety requirements specific to a set of factors.*
 - *A set of safety standards based on the core set of standards but individualized for each specific factor.*
 - *A set of independently derived standards for each specific factor.*
 - *A set of safety standards that are individually defined for each spaceport/spacecraft company/spacecraft determined by the specific needs of that entity developed by FAA or a sanctioned third party.*
 - *Spaceport/spacecraft specific safety standards developed by hardware or facility developers that are bought off individually by FAA or a sanctioned third party.*
- What standardization do you think is necessary between spaceport responsibilities and spaceflight companies for ground operations? Do you think the FAA should be responsible for setting these standards or do you think another agency or group would be more appropriate?
- Do you think existing communication standards (terminology) for aeronautical systems will be sufficient for use in human spaceflight applications or will new or augmented standards be required?
- Should non-government third parties be used to evaluate the qualification and acceptance of new human spaceflight vehicles?

Questions to Stakeholders: Standards & Evaluation (3/3)

- Should non-government experts play a greater role in setting standards and developing regulations? If so, is there a clear path to achieving this in the near future?
- Do you think your company or other companies entering the commercial human spaceflight industry can provide value added in the formulation of standards and regulation for this industry? If so, what can be done to avoid conflict of interest? In what capacity do you think such companies might be best utilized?
 - *Individual advisor or consultant.*
 - *Part of a team to formulate standards/regulations.*
 - *Part of an advisory committee.*
 - *Provider of failure or test data.*
- Regardless of whether aspiring commercial spaceflight companies should be involved in setting standards and regulations, do you think there are useful third parties, other than government, that could be helpful in developing standards and regulations for the human spaceflight industry? Or is this function best performed by the government? Examples of additional third parties include FFRDCs, regulatory agencies, and organizations in support of space, safety, and related industries.
- What would be the most effective venue for commercial human spaceflight companies to challenge or request changes to standards and regulations as methodologies and equipment change and the experience base expands?

Questions to Stakeholders: Ground Operations

- Is there a need and an emerging market for commercial ground operations, such as mission control, range operations, communications, and telemetry? If so, how should it be regulated?
- Of the following potential ground operations that may be necessary for commercial human spaceflight, which ones do you see as the responsibility of the commercial spaceflight company, the responsibility of the spaceport, the responsibility of FAA or other government regulatory body?
 - (a) *Launch control.*
 - (b) *Landing/reentry control.*
 - (c) *Mission control during periods between launch and landing/reentry phases.*
 - (d) *Providing/maintaining communication and/or telemetry to/from spacecraft.*
 - (e) *Providing tracking of spacecraft and other potential interacting bodies during all phases (including range safety).*
 - (f) *Providing potential rescue capability or emergency services including retrieval on both land and sea.*
- For ground operations where multiple spaceflight carriers may be involved, do you favor consolidation of their responsible ground operations with representatives of all carriers (for example, a single mission control room)?

Organizations Contacted

- *AIAA*
- *AirLaunch LLC*
- *Armadillo Aerospace*
- *Bigelow Aerospace*
- *Blue Origin LLC*
- *The Boeing Company, Integrated Defense Systems*
- *COMSTAC RLV Working Group*
- *Garvey Spacecraft Corp.*
- *Interorbital Systems (IOS)*
- *Lockheed Martin/United Launch Alliance*
- *Masten Space Systems*
- *Mojave Air & Space Port*
- *NASTAR Training*
- *National Space Society*
- *Northrop Grumman Corp.*
- *Oklahoma Spaceport*
- *Orbital Outfitters*
- *Orbital Sciences Corp.*
- *Personal Spaceflight Federation*
- *Rocketplane Kistler*
- *Scaled Composites LLC*
- *Space Access LLC*
- *Space Adventures*
- *SpaceDev*
- *SpaceX*
- *Space Florida*
- *Spaceport America*
- *Transformational Space Corp.*
- *United Space Alliance*
- *Virgin Galactic*
- *Virginia Commercial Space Authority*
- *XCOR Aerospace*
- *X-Prize Foundation*

Representative Responses to List of Questions (1/2)

- General
 - *No commercial flights have in fact taken place, and limited data therefore exists. As such, any attempt to assess the effectiveness of the current regulatory regime for human spaceflight operations is premature.*
- Regulatory needs
 - *The code does not address orbital or in-space vehicles.*
 - *[The CLSAA] established a moratorium on new regulations, said moratorium to expire after a specified time period. The occurrence of a specified number of flights, or the attainment of a specified level of experience, would have been a better metric...*
 - *The government should not wait until there is a serious or fatal injury before implementing appropriate safety policies and regulations.*
 - Disagreement on whether ELVs and RLVs should be regulated differently
 - Disagreement on whether regulations can be incorporated into existing aircraft regulations

Representative Responses to List of Questions (2/2)

- Standards & Evaluation
 - *Regulations should not be based on the standards used within individual companies. If those organizations adopt national or international consensus standards, so much the better.*
 - *Safety standards need to be outcome-based rather than prescriptive.*
 - *The standard for the safety of the uninvolved public should not discriminate between different kinds of vehicles. [On the other hand...] trying to write any kind of regulation that's a "one size fit all" is an enterprise doomed from the start.*
 - *All spaceports that are licensed for commercial space activity should be treated in a uniform manner.*
- Ground Operations
 - *Each spaceflight operator should be responsible for its own flight control center.*
 - *For the foreseeable future, [mission control, range operations, communications, and telemetry] are likely to remain very system-specific and therefore the purview of the vehicle operator.*