



FEDERAL AVIATION
ADMINISTRATION

Report to Congress:

**FAA Evaluation of Commercial Human Space Flight
Safety Frameworks and Key Industry Indicators**

**U.S. Commercial Space Launch Competitiveness Act (CSLCA),
Public Law 114-90, Section 111(5); 51 USC § 50905(c)(5), (6)**

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I. Executive Summary

This report responds to Congress' request to specify key industry metrics that might indicate readiness of the commercial space sector and the Department of Transportation to transition to a safety framework that may include regulations for human space flight. A safety framework can evolve from company-driven to industry-driven, with various levels of potential government involvement, as industry grows and matures. Industry's proactive participation in a safety framework can influence the timing and extent of government regulatory involvement, and successful implementation of an industry-led framework could minimize the need for government involvement.

This report also responds to Congress' request to report on the progress of the commercial space transportation industry in developing voluntary industry consensus standards that promote best practices to improve industry safety.

The report first provides context to Congress' legislative direction by considering the state of the commercial human space flight industry as an evolving industry that is rapidly innovating. In 2004, as part of the Commercial Space Launch Amendments Act, Congress placed a moratorium on the FAA establishing any new regulations related to occupant safety for commercial human space flight. The industry has received two extensions of the moratorium or "learning period" since its inception. During the learning period, significant advancements have occurred in the human space flight industry.

The report also includes a discussion of stakeholders to the safety framework and current legislative and regulatory regimes that are in place for the human space flight industry. Although the FAA is currently prohibited from promulgating any regulations governing the design or operation of a launch vehicle intended to protect the health and safety of crew, government astronauts, and space flight participants until the year 2023, absent death, serious injury, or close call, the FAA is responsible for ensuring the safety of launch and reentry operations as it pertains to public health and safety. The FAA also enforces informed consent and cross-waiver requirements for space flight participants and has the authority to regulate training and medical requirements for crew. These are important aspects of the current regulatory framework for the safety of human space flight operations. The report provides a review of those current authorities.

The report defines specific benefits of a safety framework, and examines the various types of safety frameworks including government led, industry led, and co-led. The report also discusses the types of safety requirements included in any framework, such as performance-based, process-based, and prescriptive.

The legislative direction in the Commercial Space Launch Competitiveness Act required the report to include key industry metrics that might indicate readiness of both the industry and the Department of Transportation to transition to a safety framework that may include regulations related to occupant safety for commercial human space flight. This report provides metrics, in the form of indicators, in the context of the maturity and overall development of the industry. While the indicators are not “pass/fail” necessarily, they do provide a measure of industry’s evolving safety framework and can be used to assess the industry’s approach to safety. This approach provides maximum flexibility for Congress in determining the time and manner of a transition to a safety framework that may include regulations.

Finally, the report provides of assessment on the progress of the commercial space transportation industry in developing voluntary industry consensus standards.

II. Introduction

The FAA has exercised oversight responsibility for commercial space transportation activities since 1995, when the Secretary of Transportation delegated authority over the activities to the FAA Administrator, and the Office of Commercial Space Transportation (AST) was established at the FAA. The FAA, through AST, licenses and permits the launch of launch vehicles, the reentry of reentry vehicles, and the operation of launch and reentry sites consistent with public health and safety, safety of property, and the national security and foreign policy interests of the United States. AST’s mission is unique within the FAA in that it also includes the responsibility to encourage, facilitate, and promote launches and reentries by the private sector. These complementary mission objectives together provide an oversight framework that has proven to be very beneficial both to the industry and to the American people. While the FAA has licensed or permitted over 290 launches, there have never been any fatalities, serious injuries, or significant property damage to members of the public.

The FAA’s responsibilities are not limited to protecting the uninvolved public. In 2004 Congress granted the Secretary of Transportation authority to oversee the safety of the emerging commercial human space flight industry, but limited the FAA’s rulemaking authority. To ensure that the industry has an ample “learning period” to develop, Congress prohibited the FAA, absent death, serious injury, or close call, from promulgating any regulations governing the design or operation of a launch vehicle intended to protect the health and safety of crew and space flight participants until the year 2012. Congress has extended this prohibition twice – the FAA Modernization and Reform Act of 2012¹ extended it to October 1, 2015, and the Commercial Space Launch Competitiveness Act (CSLCA) extended it to October 1, 2023. However, Congress did encourage FAA to continue to work with industry on ways to improve human

¹ Pub. L. No. 112-95, § 827.

space flight safety. In August 2014, the FAA released a set of “Recommended Practices for Human Space Flight Occupant Safety.” This 62-page document covers three major areas: design, manufacturing, and operations. While the recommended practices are voluntary and do not constitute regulations, the document gives industry insight into the various areas of concern that future safety frameworks may address. The FAA is also actively engaged with the commercial space transportation industry in its development of voluntary consensus standards.

Legislative Direction

The CSLCA requires the Secretary of Transportation to submit a report on key industry metrics that might indicate readiness of the commercial space sector and the Department of Transportation to transition to a safety framework that may include regulations. Specifically, section 111(5) of the CSLCA modified 51 USC § 50905(c) by adding, among other things, paragraph (6) which directs the Secretary of Transportation to:

REPORT.—Not later than 270 days after the date of enactment of the SPACE Act of 2015, the Secretary, in consultation and coordination with the commercial space sector, including the Commercial Space Transportation Advisory Committee, or its successor organization, shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report specifying key industry metrics that might indicate readiness of the commercial space sector and the Department of Transportation to transition to a safety framework that may include regulations under paragraph (9) that considers space flight participant, government astronaut, and crew safety.

The CSLCA also required the Secretary of Transportation to submit a series of reports on the progress of the commercial space transportation industry in developing voluntary industry consensus standards that promote best practices to improve industry safety. Specifically, section 111(5) of the CSLCA modified 51 USC § 50905(c) by adding, among other things, paragraph (5) which directs the Secretary of Transportation to:

A) IN GENERAL.—Not later than December 31, 2016, and every 30 months thereafter until December 31, 2021, the Secretary, in consultation and coordination with the commercial space sector, including the Commercial Space Transportation Advisory Committee, or its successor organization, shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report on the progress of the commercial space transportation industry in developing voluntary industry consensus standards that promote best practices to improve industry safety.

(B) CONTENTS.—The report shall include, at a minimum—

- (i) any voluntary industry consensus standards that have been accepted by the industry at large;*
- (ii) the identification of areas that have the potential to become voluntary industry consensus standards that are currently under consideration by the industry at large;*
- (iii) an assessment from the Secretary on the general progress of the industry in adopting voluntary industry consensus standards;*
- (iv) any lessons learned about voluntary industry consensus standards, best practices, and commercial space launch operations;*
- (v) any lessons learned associated with the development, potential application, and acceptance of voluntary industry consensus standards, best practices, and commercial space launch operations; and*
- (vi) recommendations, findings, or observations from the Commercial Space Transportation Advisory Committee, or its successor organization, on the progress of the industry in developing voluntary industry consensus standards that promote best practices to improve industry safety.*

This report fulfills the requirement in 51 USC § 50905(c)(6) and the first report requirement in § 50905(c)(5).

III. State of the Commercial Human Space Flight Industry

Advances in commercial space transportation technology development and investment have been dramatic. According to a recent report by the Tauri Group, 2015 was a record-setting year for space ventures. The investment and debt financing in these enterprises totaled \$2.7 billion, with more venture capital invested in space in 2015 than in the prior 15 years combined.² Nearly two-thirds of the investment in space ventures and startups since 2000 has been in the last five years.

These investments have been augmented by recent actions in government contracting and a strategic vision to advance the development of the industry. The National Aeronautics and Space Administration (NASA) recently announced an expansion of its commercial resupply services program to include three launch providers that are charged to deliver cargo to the International Space Station (ISS). NASA awarded contracts to Orbital ATK Inc., Sierra Nevada

² *Start-Up Space: Rising Investment in Commercial Space Ventures*, Bryce Space and Technology, 2016, available at brycetech.com (follow “Our reports” hyperlink; click on the image of the “Start-Up Space” report).

Corporation, and Space Exploration Technologies Corp. (SpaceX) through this program in January 2016. The FAA licenses all launches and reentries of the commercial resupply program.

NASA is the only current U.S. human orbital space transportation customer, although past customers have included private citizens, in all cases travelling to ISS on foreign launch vehicles. NASA and private citizens are both considered to be potential customers for this service in the future. Based on the vast experience of governmental human orbital flight over the past fifty-five years, de facto standards for human safety exist for this industry segment. NASA has awarded contracts to The Boeing Company and SpaceX to take American astronauts to the ISS beginning as early as 2018 under the Commercial Crew program. The FAA is a critical partner in the program and will license Commercial Crew launches after NASA certifies the Commercial Crew system. The FAA is already working with the companies, NASA, and other stakeholders to ensure smooth processes for conducting these important flights.

As the industry has matured, significant advances in space transportation technology have likewise occurred. This is evident in the recent reusability technology flown by Blue Origin and SpaceX. Blue Origin demonstrated that it can launch and land the same rocket multiple times, and SpaceX demonstrated it can deliver a payload to orbit and land the first stage of its rocket safely, both on land and on a drone ship in the ocean. If the ability to reuse rockets becomes more common across launch service providers, and the companies with this capability can successfully and regularly reuse rockets on missions with customer payloads, the price of reaching orbit will likely drop significantly. These are incredible advancements that demonstrate an ongoing and ever-increasing technological evolution and the competitive nature of the industry. Additionally, the industry supplier network that makes up the materials, subsystems, vehicles and equipment, and infrastructure that supports the human space flight industry is rapidly expanding.

Several companies are working on plans for future operations that will take people to the edge of space, where they can observe the curvature of the Earth, peer into the blackness of space, and experience several minutes of weightlessness. Systems under development include launch vehicles that carry capsules that will land under a parachute, hybrid launch vehicles that take off and land on a runway, and high altitude balloons. The end game for these companies continues to evolve as they push the envelope on what is possible. Some of these companies would like to offer point-to-point travel that enables someone to take off from New York in the morning and land in Tokyo just a few hours later; some want to offer the opportunity to experience space as a thrill of a lifetime that tourists can remember forever; and others want to open up suborbital space to researchers and scientists.

IV. Safety Framework Stakeholders

The commercial human space flight industry has a number of stakeholders. Generally speaking, for the purposes of this report, a stakeholder is considered to be a specific community, organization, or government entity whose interests are closely tied to those of the commercial human space flight industry and the development of a safety framework.

Current and Potential Occupants of Commercial Space Flight Vehicles – The central stakeholders in any safety framework are the occupants of commercial space flight vehicles. They will benefit from the increased safety that a safety framework provides.

Industry – The many companies that comprise the commercial human space flight industry are important beneficiaries of a safety framework, and key to its development. The industry is diverse and includes companies with decades of human space flight experience such as Boeing. It also includes relatively new entrants into the industry such as SpaceX, Blue Origin, and Virgin Galactic.

U.S. Congress – The U.S. Congress has an interest in how well a safety framework for commercial human space flight evolves with the evolution of commercial human space flight industry. Congress may at some point wish to modify the current learning period, define a new legislative framework in which the FAA and the industry interact, or develop legislative proposals of some other variety to provide a new safety framework entirely.

U.S. Executive Branch – The departments and agencies of the U.S. Executive Branch such as NASA, the Department of Transportation, the Department of Commerce, and the Department of Defense, all have some component office or division that plays a role in the greater debate over the utility and development of the industry.

Research Community – The business models of many industry participants include a component of research by academia and others, including government agencies. While academia has certainly been engaged in microgravity research opportunities in the past, it is a newly invigorated part of the research community that will continue to develop as various commercial human space flight companies seek to broaden and diversify their economic base.

Standards Organizations – Nearly every safety framework contemplated in this report will rely in some measure on standards organizations to assist industry stakeholders in developing voluntary consensus standards that will support the continuous improvement of safety and support worldwide interoperability.

Insurance Industry – Should Congress require, or the industry pursue it, the insurance industry may need to respond to commercial human space flight activity with personal insurance to protect against injuries potentially sustained by space flight participants during licensed activity.

The safety framework used in the industry will largely define the various risks involved for space flight participants and thus determine insurance needs and risks absorbed by those insurance policies.

V. Current Legislative and Regulatory Framework for Safety of Human Space Flight

Federal Law

The Commercial Space Launch Act of 1984, as amended and re-codified at 51 USC 50901–50923 (the Act), authorizes the Department of Transportation and thus the 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. The Act 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.

In 2004, the Act was amended to authorize the FAA to issue regulations governing the design or operation of a launch vehicle to protect the safety of its human occupants that (1) are incorporated into the FAA’s launch and reentry licensing process; and (2) govern the design or operation of a launch vehicle carrying a human being for compensation or hire to protect the health and safety of crew and space flight participants. However, the 2004 Act also established an eight-year regulatory “learning period” that restricted this authority.³

During the learning period, the FAA’s regulations may prohibit design features or operating practices that have (1) resulted in a serious or fatal injury to crew or space flight participants during a licensed or permitted commercial human space flight; or (2) contributed to an unplanned event or series of events during a licensed or permitted commercial human space flight that posed a high risk of causing serious or fatal injury to crew or space flight participants. In 2004, the rationale for an eight-year learning period was to give the industry enough time to establish commercial human space flight operations and a body of safety lessons learned. By 2012, commercial vehicles were still in development and had not entered commercial service. As a result, Congress determined more time was necessary for the industry to complete development work and start its commercial operations. In 2012, legislation extended the learning period to September 30, 2015⁴ and the CSLCA⁵ extended it to October 1, 2023.

The 2004 Act also required operators to inform space flight participants of the risks of space flight. The FAA’s regulations require operators to provide information to space flight

³ Commercial Space Launch Act of 2004, Pub. L. 108-492, § 2(c)(14).

⁴ FAA Modernization and Reform Act of 2012, Pub. L. 112–95, § 827.

⁵ Pub. L. 114-90, § 111(5).

participants to enable them to make informed decisions about the risks associated with space flight.⁶ The regulations require launch vehicle operators to inform space flight participants in writing of the risks of space travel generally and the risks of space travel in the operator's vehicle in particular. Space flight participants are also informed that "the United States Government has not certified the launch vehicle as safe for carrying crew or space flight participants."⁷ Space flight participants are also required to sign an informed consent form and receive emergency training prior to flight. This informed consent mechanism is meant to ensure transparency and full disclosure for the participant that there is an inherent risk in space flight.

The FAA's regulations also establish some health and safety requirements for flight crew to further the safety of the uninvolved public. These requirements include medical qualifications and a general training requirement. The FAA regulations also contain basic requirements governing environmental control and life support systems and verification regarding the integrated performance of a vehicle's hardware and software in an operational flight environment.⁸ Verification must include flight testing.

The U.S. legislation and FAA implementing regulations also require a licensee to sign reciprocal waivers of claims with its contractors, its customers, space flight participants, and the U.S. Government. Each party waives and releases claims against the other parties to the waivers and agrees to assume financial responsibility for property damage it sustains, and for bodily injury or property damage sustained by its own employees.

In 1988, Congress created a three-tiered risk-sharing regime for injuries or loss to third parties from commercial space transportation activities. In the first tier, the FAA requires licensed launch and reentry operators to purchase insurance, or otherwise demonstrate financial responsibility, for injuries or loss to third parties arising from launch or reentry activities. The insurance must protect the Government, customers, contractors and subcontractors of both, and space flight participants⁹ to the extent of their potential liability for involvement in launch or reentry services. The amount of insurance required is called the "maximum probable loss" and is capped at \$500 million per launch or an amount available at reasonable costs. This is the first tier.

In the second tier, the Federal Government indemnifies the launch or reentry operator for third-party claims above the insured amount, up to \$3B (\$1.5B adjusted for inflation from January 1989). Those funds are not automatic and are subject to approval of congressional appropriations. The 2015 Act extended this indemnification regime until 2025. In the third tier,

⁶ 14 CFR part 460.

⁷ 51 USC 50905(4)(b).

⁸ 14 CFR §§ 460.11 – 460.17.

⁹ Protection for space flight participants sunsets on September 30, 2025.

liability reverts back to the launch or reentry operator in the rare event that third party claims exceed \$3B plus the insurance obtained by the launch or reentry operator.

The 2015 Act also contains a new provision on jurisdiction. It provides that “any claim by a third party or space flight participant for death, bodily injury, or property damage or loss resulting from an activity carried out under [an FAA] license shall be the exclusive jurisdiction of the Federal courts.” This provision clarifies that tort litigation for injuries or death arising from a commercial space activity licensed by the FAA must be brought in Federal court.

State Law

Six States—Florida, New Mexico, Colorado, Texas, Virginia, and California—have passed legislation shielding commercial space transportation operators from civil liability in their State. For example, the Texas Space Flight Liability Act requires human space flight passengers to sign waivers relinquishing their right to recover from the space operator in the event of an accident. Under the law, a space entity is not liable for a space flight participant’s injury or damages if the space flight participant has read and signed the written consent and waiver. Recovery can be obtained, however, for injuries caused by gross negligence evidencing willful or wanton disregard of the safety of the space flight participant or intentional injury. Some of the State laws require compliance with the Federal informed consent process, but Florida’s law does not. None of the six statutes limit legal liability for gross negligence, willful or wanton disregard of safety, or intentional injurious acts.

International Law

With respect to international legal regimes, parties to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space (Outer Space Treaty) have international responsibility for national activities in outer space whether such activities are carried out by governmental agencies or by non-governmental entities. Under Article VI of the Outer Space Treaty, space activities of non-governmental entities in outer space, including the Moon and other celestial bodies, require authorization and continuing supervision by the appropriate State Party to the Treaty.

Under the Convention on International Liability for Damage Caused by Space Objects (Liability Convention), the United States Government, to the extent it is considered a launching State, is absolutely liable for any damage caused by its space object on the surface of the Earth or to aircraft in flight. The United States Government is also liable for damage to third parties’ persons or property in space if the United States or someone for whom it is responsible was at fault. Such claims must be brought by one State Party against another—a private party cannot file a claim under the Outer Space Treaty or Liability Convention. Moreover, Article VII of the Liability Convention states that the Liability Convention does not apply to damage caused by a space object of a launching State to nationals of the launching State, or foreign nationals during

such time as they are participating in the operation of that space object from the time of its launching or at any stage thereafter until its descent, or during such time as they are in the immediate vicinity of a planned launching or recovery area as the result of an invitation by that launching State.

Neither the International Civil Aviation Organization (ICAO) nor the UN Committee on the Peaceful Uses of Outer Space (COPUOS) currently regulates the safety of human space flight. ICAO, however, has stated that it plans to consider proposals on how it might regulate the safety of suborbital and orbital human space flight. ICAO has set up an informal learning group on commercial space transportation that may also focus on point-to-point suborbital flights that cross international boundaries. In the absence of an international regime, each State has the sovereign right to regulate the safety of its own human space flight operations.

VI. Benefits of a Safety Framework

An evolving safety framework would result in many benefits for stakeholders in the commercial space transportation industry. Some of the general benefits that can be expected include: improved safety, mutually-acceptable levels of safety, and worldwide interoperability.

Improved Safety - The most obvious benefit from the adoption of a safety framework is an improved level of safety for occupants of space vehicles. A safety framework could reduce the probability of fatalities during human space flight by fostering the adoption of a set of consensus standards and best practices, and by encouraging the sharing of key safety information among companies, the FAA, and other stakeholders.

Mutually Acceptable Levels of Safety - Compliance with safety frameworks provides a transparent approach to establishing safety levels. Acceptable safety levels can vary from system to system and evolve with time due to technological advancement and socio-economic changes.

Clearly defined safety performance objectives and constraints are critical to the development of optimal vehicle designs and operations. Thus, the establishment of standardized acceptable levels of safety could facilitate industry growth and efficiency. In the aviation industry, ICAO deemed the establishment of mutually acceptable levels of safety as critical to the objective of continuous improvement of safety using a performance-based approach.

Worldwide Interoperability - Commercial space transportation is inherently international in nature, and the commercial human space flight industry is no exception. A company's ability to operate both in the U.S. and in other nations with essentially the same approach to safety would promote efficiency. A well-defined safety framework will clearly communicate to other nations the U.S. industry's approach to safety.

VII. Elements and Leadership of Safety Frameworks

General

The overarching goal of an occupant safety framework is to advance sound technical and managerial practices that minimize risk to occupants of commercial human space flight vehicles. Occupants should not experience an environment that presents an unacceptable risk of serious injury or fatality, from the time they are exposed to vehicle hazards prior to flight until after landing when they are no longer exposed to vehicle hazards.

Safety frameworks exist today in the human space flight industry, primarily within individual companies. During the early stages of an industry, before industry collaboration on standards is practical, individual companies must develop and implement a safety framework to govern their activities. As industry grows and matures, a safety framework can evolve from company-driven to industry-driven, with various levels of potential government involvement.

Elements of a Safety Framework

A safety framework can include a combination of standards, norms, best practices, regulations, codes of conduct, and guidance. Described below are three elements that are relevant to the commercial human space flight industry and may be included in a safety framework.

1) Voluntary Safety Reporting

a. Internal reporting system.

Widely used in aviation, internal company-sponsored, voluntary safety reporting systems encourage employees to voluntarily report safety information that may help identify and address potential precursors to accidents. Safety reporting systems work best when they are non-punitive in nature because it increases participation and encourages a strong safety culture.

b. Industry-wide reporting system.

Ideally, industry can establish a database to track incidents and share safety data with each other so the industry can collectively benefit from lessons learned. To work, the safety data must be de-identified and anonymous, and the data format and taxonomy must be standardized. Protecting the identity of specific companies is a challenge for a small industry.

Regardless of whether voluntary safety reporting is done company- or industry-wide, it is critical to have data analysis tools to proactively identify emerging safety issues and lessons learned. The nascent nature of the commercial human space flight industry offers the

potential to establish a voluntary safety reporting system while the industry is in its formative stages.

2) Standards

a. General

Lessons learned from fifty-five years of human space flight can provide meaningful insight into future space flight risks and best practices. Standards, particularly voluntary consensus standards, codify and disseminate these lessons learned.

Voluntary consensus standards are standards developed or adopted by a voluntary consensus standards body. A voluntary consensus standards body is a domestic or international organization that plans, develops, establishes, or coordinates voluntary consensus standards using agreed-upon procedures. Such a body is defined by openness, balance of interest, due process, an appeals process, and consensus.¹⁰

Other types of standards include company standards and industry standards, which are developed in the private sector but not using the full consensus process.

b. Safety Elements

A comprehensive set of standards should address the design, manufacture, and operation of a human space flight system, as follows:

Design

- Human Needs and Accommodations – the steps necessary to accommodate specific human needs, such as consumables, human waste disposal, etc.
- Human Protection – the steps necessary to keep an occupant's physical or psychological stress at levels that can be considered safe for space flight participants and sufficient for flight crew and government astronauts to execute the flight.
- Flightworthiness – the minimum system capabilities necessary to maintain occupant safety.
- Human/Vehicle Integration – operational and design constraints necessary to integrate humans with a human space flight system.

¹⁰ Office of Management and Budget revised Circular A-119, Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities, January 27, 2016.

- System Safety – engineering and management principles, criteria, and techniques to achieve acceptable risk, within the constraints of operational effectiveness and suitability, time, and cost, throughout all phases of the system life cycle.

Manufacturing

- Steps necessary to ensure the system manufactured matches its design, including quality assurance, acceptance testing, and configuration management.

Operations

- Management – program controls necessary to ensure proper implementation of safety requirements.
- System Safety – system safety management and engineering principles, criteria, and techniques applicable during the operational phase of a system’s life cycle.
- Planning, Procedures, and Rules – plans and procedures necessary to safely operate a human space flight system.
- Medical Considerations – medical needs and constraints for flight crew and space flight participants.
- Training – training needs of flight crew, government astronauts, space flight participants, ground controllers, and safety-critical ground operations personnel.

c. Types of Safety Requirements

The safety requirements in a standard can be performance-based, process-based, or prescriptive.

Performance-based requirements state a safety objective to be achieved and leave the design or operational solutions up to the designer or operator. Performance-based requirements set forth requirements in terms of required results with criteria for verifying compliance without stating the methods for achieving the required results. This approach provides flexibility for future technological developments.

Process-based requirements address the development of processes to ensure a systemic approach to controlling and minimizing risks or hazards. These risk identification, assessment, and control processes must be undertaken, documented, and continuously updated. Process-based requirements are most commonly used in contexts in which there are multiple risk sources and multiple feasible risk controls.

Although designed to provide flexibility, performance- and process-based requirements need to contain sufficient clarity so that the user understands its responsibilities.

Generally, sufficient clarity can be provided through guidance.

Prescriptive requirements, which provide design or operational solutions, are used as a last resort if other requirements cannot be defined with sufficient clarity to alert regulated entities as to their obligations.

3) Compliance

Also necessary in a safety framework is a demonstration that a requirement has been fulfilled, either through test, demonstration, inspection, or analysis. Confirmation that a requirement has been met can be performed by a company internally, by an external entity such as a trade association or independent third party, or by the government.

Framework Leadership

The development and implementation of a safety framework could be led by industry, jointly by government and industry, or by government. The development and implementation of effective frameworks benefit from participation by all interested parties—industry, government, academia, and nongovernmental groups—however, the roles and responsibilities of the interested parties shift, depending on the leadership.

- 1) An industry-led framework is one in which the industry bears responsibility for safety oversight. Industry members jointly pursue standard-setting activities in the absence of explicit legal requirements. As noted above, ensuring compliance with those standards can be conducted by a company internally or by an external entity such as a trade association or independent third party.
- 2) A co-led framework has a role for both government and industry in regulating an activity. It combines government safety oversight and private industry autonomy in standards setting. The government role can range from oversight and enforcement, to provision of technical competence, to support for a voluntary data reporting system.

An example from aviation is the approach taken by the FAA in its rewrite of regulations for the certification of general aviation aircraft.¹¹ In a final rule issued on December 30, 2016,¹² the FAA replaced prescriptive design requirements with performance-based requirements that would rely on consensus standards developed by industry and accepted by the FAA as the methods of compliance.

¹¹ 14 CFR part 23.

¹² 81 FR 96572

- 3) A government-led framework would rely on regulations, guidance, and processes established by the government to ensure occupant safety. Although the government would lead, the industry and general public would participate in the rulemaking process and have access to key decisions and the information necessary to assess those decisions.

VIII. Industry and Government Readiness Indicators

Premises Underlying the Indicators

A number of core premises underlie the indicators that might indicate readiness to transition to a safety framework that may include regulations. The first is that the human space flight industry must continually improve its safety performance. This is because industry growth depends on attracting new customers beyond early adopters, many of whom will expect higher levels of safety. This is in accordance with 51 USC § 50901(a)(12), which states that “[s]pace transportation is inherently risky, and the future of the commercial human space flight industry will depend on its ability to continually improve its safety performance.”

The second premise is that as industry grows and matures, the depth and breadth of a safety framework should evolve. An industry-wide safety framework can codify and disseminate lessons learned from fifty-five years of human space flight, as well as new lessons learned from the growing industry. Industry conformity with a safety framework will also become necessary to support continuous improvement of the industry’s safety performance.

The third premise is that the public’s expectation of safety will increase as the purpose of flying to space evolves from adventure, to occupation, to transportation. If flying for adventure, people who are willing to take the risk will fly, and those who are not, will not. People who must fly in space as part of their occupation will have a higher expectation of safety. The flying public will have an even higher expectation of safety when space travel becomes a means to get from point A to point B.

A related premise is that once space travel becomes transportation, the Federal Government will likely need to have a regulatory role. Due to the nature of transportation today, the public will likely expect the government to have some oversight role. In addition, due to treaty obligations and other international norms, the international community will likely expect U.S. Government oversight.

The last premise is that until space travel becomes transportation, industry may lead the development and implementation of a safety framework, with limited government involvement. Other industries have developed safety standards and ensured conformity through non-governmental means.

Three Sets of Indicators

The FAA has divided the indicators into three sets. The first set includes indicators of industry's readiness to enter into a safety framework. It focuses on the purpose for which people are flying, the structure of the industry, and its safety. The second set includes indicators of the industry's progress in developing a safety framework. It focuses on voluntary safety reporting, voluntary consensus standards, and compliance. The third set includes indicators of the FAA's readiness to enter into a safety framework. It focuses on FAA's authority and expertise.

All three sets of indicators are related. As the industry changes, so does its need for elements of a safety framework. The first two sets are related to the third in that if the safety framework developed by industry is not sufficient to support the state of the industry, then the FAA could increase its involvement with commensurate resources.

Indicator Set #1: Industry Readiness

Regarding the industry's readiness to enter into a safety framework, the FAA has identified three readiness areas:

- 1) Purpose of people flying in space,
- 2) Size and complexity of the industry, and
- 3) Safety of the industry.

Readiness indicators within each area are discussed below, and summarized in table 1.

1) Purpose of People Flying in Space

The purpose of people flying in space is an indicator of industry readiness. Specific indicators include:

- a. The extent to which people are flying for adventure purposes.
- b. The extent to which people are flying as part of their occupation.
- c. The extent to which people are flying as a mode of transportation.

As noted above, the FAA expects the public's expectation of safety to increase as the purpose of flying to space evolves from adventure, to occupation, to transportation. These indicators reflect the flying public's decrease in risk tolerance.

Currently, hundreds of people have signed up for a suborbital space flight. The primary purpose is adventure and a "once in a lifetime" experience. However, microgravity researchers are also planning to conduct experiments and research and development (R&D) work on commercial suborbital space flights. These experiments and R&D could be conducted either manned or unmanned, depending on the capabilities of the technology and

research areas. Suborbital space flight as a mode of transportation is currently contemplated, but most likely decades away from becoming reality. Commercial launch and reentry of space flight participants to and from orbit is currently being planned.

2) Size and Complexity of the Industry

The size and complexity of the industry is an indicator of industry readiness. Specific indicators include:

- a. The number of suppliers of orbital or suborbital space flight.
- b. The number of suppliers of similar space flight types such as vertical suborbital, horizontal suborbital, and balloon.
- c. The extent to which there is a broad supplier network.
- d. The extent to which operations occur internationally.

As noted above, the FAA expects that as industry matures, the depth and breadth of a safety framework should evolve. The indicators reflect industry maturity, both in the number of suppliers of orbital or suborbital space flight, and in the number of providers of similar types of space flight. In addition, the indicators reflect the fact that the commercial space flight industry is more than just companies that are launching people to and from space, but include a number of sub-tier suppliers of components, subsystems, and services.

Somewhat unique on the list is the extent to which operations occur internationally. This may create a need for interoperability between launch and reentry service providers and governments, which may indicate the need for an industry-driven safety framework.

Currently, there is no active commercial U.S. provider of orbital or suborbital human space flight. However, both orbital and suborbital human space flight services are close to fruition, and the industry supplier network that supports the human space flight industry is growing. U.S. operators are also planning commercial human space flight launches from foreign countries.

3) Safety of the Industry

The safety of the industry is an indicator of industry readiness. Specific indicators include:

- a. The extent to which there is evidence of unsafe operations.
- b. The extent to which the industry is having difficulty attracting new customers.
- c. The extent to which insurance companies are willing to insure human space flight operations.

As noted above, the human space flight industry must continually improve its safety performance. The indicators reflect the safety of the industry either directly, through evidence of unsafe operations, or indirectly, through the ability to attract new customers and obtain insurance.

It is difficult to assess the safety of companies that would like to transport space flight participants to and from space because no FAA-licensed launch or reentry vehicle has carried space flight participants. Although there has been one fatality of flight crew, it would be imprudent to assess the safety of future licensed vehicles on the test program of one vehicle operating under an experimental permit.

Table 1
Industry Readiness Indicators

Readiness Area	Indicators
<ul style="list-style-type: none"> • Purpose of people flying in space. 	<ul style="list-style-type: none"> • The extent to which people are flying for adventure purposes. • The extent to which people are flying as part of their occupation. • The extent to which people are flying as a mode of transportation.
<ul style="list-style-type: none"> • Size and complexity of the industry. 	<ul style="list-style-type: none"> • The number of suppliers of orbital or suborbital space flight. • The number of suppliers of similar space flight types, such as vertical suborbital, horizontal suborbital, and balloon. • The extent to which there is a broad supplier network. • The extent to which operations occur internationally.
<ul style="list-style-type: none"> • Safety of the industry. 	<ul style="list-style-type: none"> • The extent to which there is evidence of unsafe operations. • The extent to which the industry is having difficulty attracting new customers.

	<ul style="list-style-type: none">• The extent to which insurance companies are willing to insure human space flight operations.
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Indicator Set #2: Industry’s Progress in Developing a Safety Framework

Regarding industry’s progress in developing a safety framework, the FAA has identified three readiness areas:

- 1) Voluntary safety reporting,
- 2) Voluntary Consensus Standards, and
- 3) Compliance.

Readiness indicators within each area are discussed below, and summarized in table 2.

1) Voluntary Safety Reporting

The extent of voluntary safety reporting is an indicator of industry’s progress in developing a safety framework. Specific indicators include:

- a. The extent to which individual companies have an internal voluntary reporting system to identify and address potential precursors to accidents.
- b. The extent to which industry members share safety data with each other, with a common data format and taxonomy.

Currently, voluntary safety reporting rests within companies, and the FAA has limited insight into its extent. Although no industry-wide voluntary reporting system exists, the FAA is pursuing a multi-year, multi-phased approach to enabling a voluntary safety data sharing framework for emerging commercial human space flight operations. Specifically, the FAA is conducting research to examine extending to commercial human space flight operations the tools developed for voluntary sharing and mining of aviation data, so that advanced space flight data mining capabilities could inform safety assessments and identify emerging safety issues and lessons learned. The FAA also plans to continue bilateral discussions with operators interested in entering a partnership with the FAA to extend the aviation tools to commercial space applications.

2) Voluntary Consensus Standards

The progress in developing voluntary consensus standards is an indicator of industry’s progress in developing a safety framework. Specific indicators include:

- a. The extent to which industry has formed a consensus on top level performance standards.

- b. The extent to which industry has developed and maintains voluntary consensus standards in high priority areas.
- c. The extent to which industry has developed and maintains a robust set of voluntary consensus standards.

These indicators reflect the progress industry has made in developing voluntary consensus standards. Standards are a critical part of any safety framework. The ultimate goal is to have a robust set of voluntary consensus standards. Interim goals could be to have a consensus on top-level safety performance standards, and a body of standards in high priority areas.

The current state of the industry in developing voluntary consensus standards is discussed in section IX of this report.

3) Compliance

The progress of the industry to ensure compliance with standards is an indicator of industry's progress in developing a safety framework. Specific indicators include:

- a. The extent to which individual companies self-verify compliance with voluntary consensus standards.
- b. The extent to which a third party verifies compliance with voluntary consensus standards.

Standards by themselves cannot influence safety unless there is compliance with the standards. Without some formal process by which a trade association or independent third party verifies compliance with voluntary consensus standards, verification of compliance is wholly dependent on individual companies.

Currently, the industry does not have voluntary consensus standards with which to comply.

Table 2
Industry’s Progress in Developing a Safety Framework Indicators

Readiness Area	Indicators
<ul style="list-style-type: none"> • Voluntary Safety Reporting. 	<ul style="list-style-type: none"> • The extent to which individual companies have an internal voluntary reporting system to identify and address potential precursors to accidents. • The extent to which industry members share safety data with each other, with a common data format and taxonomy.
<ul style="list-style-type: none"> • Voluntary Consensus Standards. 	<ul style="list-style-type: none"> • The extent to which industry has formed a consensus on top level performance standards. • The extent to which industry has developed and maintains voluntary consensus standards in high priority areas. • The extent to which industry has developed and maintains a robust set of voluntary consensus standards.
<ul style="list-style-type: none"> • Compliance. 	<ul style="list-style-type: none"> • The extent to which individual companies self-verify compliance with voluntary consensus standards. • The extent to which a third party verifies compliance with voluntary consensus standards.

Indicator Set #3: Department of Transportation Readiness

Regarding the Department of Transportation's, and in particular the FAA's, readiness to enter into a safety framework, the FAA has identified two readiness areas:

- 1) FAA has authority to transition to a safety framework, and
- 2) FAA has expertise in human space flight safety.

Readiness indicators within each area are discussed below, and summarized in table 3.

1) Authority

The amount of authority required by the FAA to participate in a safety framework depends on how the safety framework leadership is structured. If the safety framework is led entirely by the industry, then the FAA's current authority is adequate. The FAA's ability to participate in the process of standards development or support a voluntary safety reporting system requires no additional legal authorities.

On the other hand, if the safety framework is to be led entirely by the FAA, then the current moratorium would need to end. The FAA's current authority to regulate is limited to design features or operating practices that have resulted in a serious or fatal injury to crew, government astronauts, or space flight participants during a licensed or permitted commercial human space flight, or contributed to a close call. The FAA's current authority does not allow for a government-led approach to occupant safety.

In a safety framework that involves a role for both government and industry, the current moratorium would have to be modified to match the role of the FAA in the safety framework. For example, legislative protections may be required to fully implement the non-punitive environment needed to support voluntary data sharing programs and the sharing of information with the FAA and others in the industry.

2) Expertise

While the FAA has the requisite skillset and capability to provide oversight of human space flight safety, increased staffing resources may be required in the future as the commercial space industry develops, to provide support to the eventual safety framework. Specific indicators of readiness in expertise include:

- a. The extent to which the FAA has helped create elements of a space safety framework.
- b. The extent to which the FAA has engaged with industry regarding standards development.

- c. The extent to which the FAA has published safety practices related to commercial human space flight.
- d. The extent to which the FAA has experience participating in a space safety framework.

Currently, the FAA is engaged with industry to create elements of a human space flight safety framework. In 2014, the FAA released *Recommended Practices for Human Space Flight Occupant Safety*, which provides a framework for industry to create voluntary consensus standards or could serve as a starting point for FAA regulation. The recommendations are broadly written and largely performance-based. The FAA is also actively engaged with industry in its efforts to develop voluntary consensus standards. The status of these efforts is discussed in section IX.

The FAA has required and will continue to require expertise in human space flight safety due to its mission to protect public health and safety and the safety of property. This is because in human space flight systems, flight crew and government astronauts may perform functions during launch or reentry that could impact public safety. Because of that, the FAA issued regulations in 2006 that address the ability of flight crew to protect public health and safety.

The FAA's Civil Aerospace Medical Institute (CAMI) provides expertise and is a valuable resource for the development of medical standards for space flight. Through the FAA's Center of Excellence for Commercial Space Transportation, CAMI helped develop the report *Flight Crew Medical Standards and Spaceflight Participant Medical Acceptance Guidelines for Commercial Space Flight*. The report provides a consolidated set of recommendations for crew medical standards and a consensus set of space flight participant acceptance guidelines that could be used by commercial operators to develop medical programs. This and other CAMI work can become part of a safety framework.

The FAA's Center of Excellence brings over 50 government, industry, and academic organizations as research partners. The Center of Excellence enables the FAA to work with universities and industry to conduct research, and to serve as a resource for the development of a human space flight safety framework.

Table 3
FAA Readiness Indicators

Readiness Area	Indicators
<ul style="list-style-type: none"> • FAA Authority to Transition to a Safety Framework. 	<ul style="list-style-type: none"> • Status of the “learning period”
<ul style="list-style-type: none"> • FAA Expertise in Human Space Flight Safety. 	<ul style="list-style-type: none"> • The extent to which the FAA has helped create elements of a space safety framework. • The extent to which the FAA has engaged with industry regarding standards development. • The extent to which the FAA has published safety practices related to commercial human space flight. • The extent to which the FAA has experience participating in a space safety framework.

IX. Progress of the Industry in Developing Voluntary Industry Consensus Standards

This section reports on the progress of the commercial space transportation industry in developing voluntary industry consensus standards that promote best practices to improve industry safety, as of November 2016. The FAA only addresses progress associated with standards for human space flight. In the past few years, efforts to develop industry-wide standards have been concentrated in three entities – the Commercial Space Transportation Advisory Committee (COMSTAC), the Commercial Spaceflight Federation, and ASTM International. These efforts, along with the answers to questions posed in section 50905(c)(5), are discussed below.

COMSTAC Standards Working Group

In September 2014, COMSTAC formed the Standards Working Group (SWG) to identify and analyze key industry standards for commercial space transportation and to develop and prioritize a list of standards for both expendable launch vehicles and reusable launch vehicles. The SWG has focused on human space flight occupant safety, as well as other areas such as spaceports and airspace integration.

The SWG leads an on-going industry dialogue with the FAA regarding development of commercial space flight industry standards, the establishment of priorities for new standards, and processes for acceptance of industry standards for future safety frameworks.

The SWG has worked to clarify different types of standards, as well as the relationship between recommended practices and standards. The SWG also obtained feedback from U.S. standard development leaders such as the Commercial Spaceflight Federation, the Aerospace Industries Association, the American Institute of Aeronautics and Astronautics (AIAA), the Society of Automotive Engineers (SAE), and the International Standards Organization (ISO). The SWG brought in ASTM to brief industry on its capabilities through COMSTAC and CSF.

The SWG created a task group to develop a Standards and Recommended Practices road map. The road map was to develop and cluster industry voluntary consensus standards and recommended practices into areas for possible future licensing of human space flight and to identify and manage metrics and indicators for industry preparedness for the evolution of a safety framework. The SWG's road mapping effort will likely change to complement a road mapping effort being undertaken by ASTM, as discussed below.

Commercial Spaceflight Federation

The Commercial Spaceflight Federation (CSF) was founded in 2006, and its mission is to promote the development of commercial human space flight, pursue ever-higher levels of safety, and share best practices and expertise throughout the industry. It has over 70 member companies, including providers of orbital and suborbital vehicles, both unmanned and manned, spaceports, and services contractors.

After forming a Technical Standards Committee in November 2012, CSF began work on four standards, two of which were eventually approved:

- 1) Propellant Handling – approved November 2013.
- 2) Hazardous Test Notification – approved September 2015.

In May 2014, CSF began partnerships with AIAA and SAE for the purpose of standards development. The partnership with AIAA produced a standard in November 2016, entitled “Occupant-Impacted Loads for Commercial Suborbital RLVs.”

In April 2016, CSF asked ASTM to establish a new committee to support the commercial space transportation industry's standards development effort.

ASTM International

ASTM was established in 1898, has 147 committees, and over 12,500 standards. ASTM has 32,000 members from 135 countries. It is accredited by the American National Standards Institute. ASTM has a number of committees that develop standards for aviation, including light sport aircraft, general aviation, and unmanned aircraft systems.

ASTM provides the infrastructure and tools for industry to come together to develop voluntary consensus standards. ASTM uses a process that conforms to the principles outlined in OMB Circular A-119, which includes openness, balance of interest, due process, an appeals process, and consensus.

ASTM has been exploring a standards activity for commercial space flight for approximately seven years, engaging with different stakeholders in industry. About three years ago, ASTM started meeting with industry to outline what a standards process and structure would look like. More recently, ASTM began supporting the planning phase of establishing a technical committee, which led to an organizational meeting.

ASTM held an Organizational Meeting for Commercial Spaceflight in Washington, D.C. on October 24, 2016. The objectives of the meeting were to:

- 1) Bring industry experts together from various different aspects of commercial space flight,
- 2) Identify specific standards needs for commercial space flight,
- 3) Develop and approve title, scope, and structure of a potential ASTM standards activity, and
- 4) Determine if ASTM should organize activity based on the needs presented by industry.

Fifty-two attendees participated in the meeting, including representatives from the FAA in a non-voting capacity, and twenty-nine voting interests were represented.

The voting participants agreed to the following title, scope, and structure as an initial proposal to begin standards work with an understanding that an evolution of this may be proposed in the future:

Title: Commercial Spaceflight

Scope: The scope of the Committee shall be the development and maintenance of voluntary consensus standards and recommended practices for the commercial spaceflight industry. Areas to address in standards include, but are not limited to, design, manufacturing and operational use of vehicles used for spaceflight. One purpose of the committee is to create

human spaceflight safety standards. The work of this Committee will be coordinated with other ASTM committees and organizations having mutual interest.

Subcommittee Structure:

- F47.01 Occupant Safety of Suborbital Vehicles
- F47.02 Occupant Safety of Orbital Vehicles
- F47.03 Unoccupied Launch and Reentry Vehicles
- F47.04 Spaceports
- F47.05 Cross-Cutting
- F47.90 Executive
- F47.91 Terminology
- F47.92 Standards Road Mapping
- F47.93 Regulatory Liaison

The subcommittees address subsets of specialized subject matter and organize their expertise into Task Groups to write standards.

The activities that must take place after a technical committee such as Commercial Spaceflight is approved by the industry include:

- 1) Establishing the Committee. The committee must be approved by ASTM's Committee on Technical Committee Operations (COTCO) and its Board of Directors. After approval, ASTM forms the technical committee website and processes membership applications.
- 2) Leadership. All ASTM technical committees are led by industry representatives determined by the technical committee. Leadership positions on the main committee and the subcommittees must be filled with industry volunteers.
- 3) Bylaws. Bylaws must also be developed and approved.
- 4) Liaison. Once the committee is established, a number of organizations are targeted for liaison activities, such as AIAA, ISO, SAE, COMSTAC, and CSF.
- 5) Meetings. A meeting schedule must be set up, for both face-to-face meetings and teleconferences.

In November 2016, COTCO and ASTM's Board of Directors approved the new committee. Once members are added and trained, leadership positions are filled, and other formational activities are complete, the F47 committee can begin the process of road mapping and prioritizing standards development.

Specific Questions from CSLCA section 111(5)

- 1) Voluntary industry consensus standards that have been accepted by the industry at large.

Currently, the FAA is not aware of any industry consensus standards specific to commercial human space flight¹³ that have been accepted by the industry at large. As noted above, the AIAA issued a standard on occupant-imparted loads for commercial suborbital reusable launch vehicles in November 2016. Because it is new, it is unknown at this time the extent to which it will be accepted by the industry.

- 2) Areas that have the potential to become voluntary industry consensus standards that are currently under consideration by the industry at large.

Because the industry has not completed a formal road mapping effort to prioritize and guide work on voluntary consensus standards, no topic areas for standards are under consideration by the industry at large. This will be one of the first efforts of the new ASTM Spaceflight Committee.

The FAA issued its *Recommended Practices for Human Space Flight Occupant Safety* in August 2014 in part to identify subject areas that could benefit from industry consensus standards. It should also be noted that COMSTAC proposed an initial list of potential space flight standards to the FAA in September 2014 as follows:

- a. Breathable Atmosphere
- b. Crew-Imparted Loads
- c. Hazardous Test Notification
- d. Landing Gear
- e. Occupant Restraints and Acceleration Support
- f. Propellant Handling
- g. Risk Communication

Two became CSF standards (propellant loading and hazardous test notification), and one became an AIAA standard, led by CSF (crew-imparted loads).

- 3) FAA's assessment on the general progress of the industry in adopting voluntary industry consensus standards.

¹³ Space transportation vehicles make use of standards developed for common technologies in the aerospace and electronics industries.

Although no voluntary industry consensus standards have been accepted by the industry at large, and a road mapping effort has not been completed to identify areas that have the potential to become voluntary consensus standards, the establishment of a Commercial Spaceflight committee in ASTM is a significant accomplishment.

Although three companies are planning to fly space flight participants in suborbital vehicles in the next several years, a space flight participant has yet to fly. The people that have signed up to fly are doing so for adventure, and will do so domestically. With the creation of the ASTM Commercial Spaceflight committee, the industry can further the development of voluntary consensus standards as space flight participants begin to fly and the size and complexity of the industry grows.

- 4) Lessons learned about, and associated with the development, potential application, and acceptance of, voluntary industry consensus standards, best practices, and commercial space launch operations.

The primary lessons learned to date associated with the development of standards include the need to have an institutional framework to develop standards, and the need to prioritize standards development. The formation of the ASTM committee and its early focus on road mapping addresses these two concerns. Prioritization is particularly important because of the challenge a small industry such as commercial human space flight faces in devoting resources to standards development.

With respect to potential applications, as discussed throughout this report, any safety framework benefits from the existence of voluntary consensus standards and recommended practices. Standards enable industry to share lessons learned, can establish minimum levels of safety, and can eventually be used by the Federal Government to advance various regulatory goals.

With respect to the acceptance of standards and recommended practices, by bringing in ASTM to guide standards development, the industry has recognized that a process that conforms to the principles outlined in OMB Circular A-119, including openness, balance of interest, due process, an appeals process, and consensus, will likely result in standards that have the best chance of being accepted broadly by the industry. Standards not so developed may have less chance of broad acceptance.

- 5) Recommendations, findings, or observations from the Commercial Space Transportation Advisory Committee, or its successor organization, on the progress of the industry in developing voluntary industry consensus standards that promote best practices to improve industry safety.

Table 4 lists all COMSTAC recommendations, findings, and observations since April 2014, when the standards effort in COMSTAC began in earnest, related to the progress of the industry in developing voluntary consensus standards that promote best practices to improve industry safety.

COMSTAC endorses the benefit of standards to continuously improve safety and the benefit of prioritizing standards development. The SWG put considerable effort into road mapping, and that effort will now be shared and coordinated with ASTM. COMSTAC also emphasized the need for an on-going dialogue between industry and the FAA.

COMSTAC also recommends that the FAA monitor and participate in the work of ISO Technical Committee 20, Subcommittee 14 (TC20/SC14), Space Systems and Operations, which develops international standards for manned and unmanned space vehicles. Due to resource constraints, and the uncertain relevance of TC20/SC14 to the commercial space flight industry, the FAA has only participated in the committee on a limited basis.

Lastly, COMSTAC has recommended that the FAA oppose the proliferation of standards following the approach taken by the International Association for the Advancement of Space Safety (IAASS). In March 2010, the IAASS issued a standard entitled “Space Safety Standard, Commercial Human-Rated System,” establishing safety requirements applicable to the IAASS certification of commercial human-rated systems, both orbital and suborbital. IAASS has not yet used this standard to certify any system. The IAASS has also been developing a guideline entitled “Safety Design and Operation of Suborbital Vehicles,” although it has not yet been released.

Below is a table of various recommendations, findings, and observations provided to the FAA through COMSTAC on the topic of industry standards.

Table 4
Recommendations, Findings, and Observations of COMSTAC Regarding Standards

Recommendations, Findings, and Observations
April 2014
<p>Observations:</p> <ul style="list-style-type: none"> • National and international standards initiatives are of material interest to COMSTAC members and industry. Although all such standards are developed as voluntary documents, U.S. federal, state, or local bodies are increasingly referring to them for regulatory or procurement purposes. • To further the FAA AST's mission of safety and industry promotion, it would be beneficial to directly monitor the activities of the Technical Advisory Group (TAG) for the ISO Technical Committee 20 and communicate to the COMSTAC and the broader industry any relevant national and international "consensus" standards that are or might be adopted as early as possible in the development process.
<p>Recommendation:</p> <ul style="list-style-type: none"> • The FAA AST should work with the COMSTAC to influence the formulation of new standards that are beneficial to U.S. industry and to oppose the development of standards that are detrimental.
<p>Recommendation:</p> <ul style="list-style-type: none"> • The COMSTAC recommends that the FAA AST engage with ANSI as a government member and proactively monitor and/or participate on Technical Committee 20 as a Technical Advisory Group (TAG) member.
September 2014
<p>Observation:</p> <ul style="list-style-type: none"> • The International Space Policy Working Group (ISPWG) conducted a conference call with International Association for the Advancement of Space Safety (IAASS) representatives in July 2014 in order to provide input to the IAASS regarding its human spaceflight standards setting initiatives and to gauge the current status of these initiatives.
<p>Finding:</p>

- The teleconference conversation indicated that the IAASS was unresponsive to the concerns expressed by the ISPWG during the conference call and by the Operations Working Group at its May 2014 meeting.

Recommendation:

- While the COMSTAC supports the adoption of a rational and appropriate standard setting process, the COMSTAC recommends that the FAA AST oppose the proliferation of standards following the approach taken by IAASS.

Observations:

- Industry standards for commercial spaceflight are beneficial and needed.
 - Congress and the FAA have stressed the need for the creation of industry standards.
- Standards must be prioritized and an initial list created and submitted to establish the standards development process.

Recommendation:

- FAA AST and industry via COMSTAC engage in on-going dialogue on development of human commercial spaceflight industry standards and establish the process through which a prioritized list of these standards will be established.
 - Proposed Initial Commercial Spaceflight Standards, submitted to the FAA by COMSTAC, 17 September 2014:
 1. Breathable Atmosphere
 2. Crew-Imparted Loads
 3. Hazardous Test Notification
 4. Landing Gear
 5. Occupant Restraints and Acceleration Support
 6. Propellant Handling
 7. Risk Communication

April 2015

Observations:

- COMSTAC observes that Congress has authorized FAA AST to promulgate regulations, consistent with the evolving state of the commercial human spaceflight industry, to promote the safety of crew and spaceflight participants.

<ul style="list-style-type: none"> • COMSTAC observes that industry standards are a key part of producing a culture of continuous safety improvement, but industry is not always willing to develop such standards.
<p>Recommendation:</p> <ul style="list-style-type: none"> • COMSTAC recommends that FAA AST should identify at least three recommendations for potential standards for commercial human spaceflight each year. Standards should be tightly focused – for example, on a specific system or practice which has given FAA AST cause for concern.
<p>Findings:</p> <ul style="list-style-type: none"> • FAA AST Conference Standards Panel was helpful and valuable to industry stakeholders • Industry benefits from rigorous prioritization and subsequent selection and adoption of consensus standards • SWG reports the status of industry’s first 7 prioritized standards as follows: <ul style="list-style-type: none"> ○ Risk Communications: Completed – Ratification May 2015 ○ Propellant Handling: Completed ○ Hazardous Test Notification: Completed ○ Crew Imparted Loads: Draft ○ Occupants Restraints and Acceleration Support: Draft ○ Breathable Atmosphere: Prioritized – Listed ○ Landing Gear: Prioritized – Listed
<p>Recommendation:</p> <ul style="list-style-type: none"> • Industry and SWG recommends to COMSTAC to meet from time to time with FAA/AST to jointly discuss standards prioritization, selection, rationale, drafting, timing and adoption. Consensus standards benefit industry-wide activities including but not limited to, the recommended practice areas for human space flight occupant safety.
<p>October 2015</p>
<p>Finding:</p> <ul style="list-style-type: none"> • The International Standards Organization’s Subcommittee 14 of Technical Committee 20 (Space Systems and Operations) is evaluating the formation of a cross-disciplinary working group to address human spaceflight standards and present U.S. positions to ISO.
<p>Recommendation:</p>

- COMSTAC recommends that the FAA AST support the U.S. TAG chair of TC 20/SC 14 in establishing a cross-disciplinary working group on human spaceflight occupant safety and presenting U.S. positions to ISO.

Finding:

- COMSTAC finds that industry should draft a Standards and Recommended Practices (SARP's) road map to prepare for future regulation.
 - The SARP's road map will address subject areas for possible future regulation, concepts to define "routine" operations and concepts to build a safety framework by managing knowledge and operational experience gained while flying for compensation or hire.
 - The SWG is forming a road map drafting task group, Co-led by Paul Damphousse (Gen-Astro) and James Duffy (R&S Rizing).

Recommendation:

- The COMSTAC recommends that AST participate in a Standards and Recommended Practices (SARP) Subcommittee, which will operate under the auspices of the SWG.
 - The SARP Subcommittee's initial focus area will be to prioritize areas needing work within human spaceflight occupant safety.

April 2016

Findings:

- The COMSTAC will provide FAA AST and IDA-STPI responses and proactive inputs on occupant safety industry standardization areas and also "readiness metrics" to transition to an evolved oversight framework beyond the current moratorium/learning period.
- The COMSTAC agrees with the FAA AST's two potential regulatory road map milestones.
 - Milestone 1- Industry Standards Developed as a precursor to Human Spaceflight Occupant Safety licensing.
 - Milestone 2 - Routine Commercial Space Travel activity as a precursor to potential new safety frameworks, for example, certification of vehicles and operators or others.
- The COMSTAC supports industry's efforts through the Commercial Spaceflight Federation (CSF) leadership role in the formation and structuring of a new Commercial Spaceflight Committee. The new Committee will develop, amongst others, voluntary consensus Standards and Recommended Practices (SARPs) under the auspices of ASTM.

October 2016
<p>Recommendation:</p> <ul style="list-style-type: none"> The COMSTAC recommends that the FAA AST enable effective channels to receive timely industry inputs for required HR 2262 Section 111 Congressional Reports. For instance, industry website dedicated sections, feedback forms, relevant AST and/or its consultants' email addresses.
<p>Recommendation:</p> <ul style="list-style-type: none"> The COMSTAC recommends that the FAA AST join the new industry-led ASTM Commercial Spaceflight Committee.
<p>Observation:</p> <ul style="list-style-type: none"> The COMSTAC applauds FAA AST and the Science and Technology Policy Institute for seeking ample industry response and inputs on occupant safety industry standardization areas and also "readiness metrics" to transition to an evolved oversight framework beyond the current moratorium/learning period.
<p>Recommendation:</p> <ul style="list-style-type: none"> The COMSTAC recommends that the FAA AST enable effective channels to receive timely industry inputs for required HR 2262 Section 111 Congressional Reports. For instance, industry website dedicated sections, feedback forms, relevant AST and/or its consultants' email addresses.
<p>Observation:</p> <ul style="list-style-type: none"> The COMSTAC applauds ASTM, CSF, FAA AST and other industry participants for attending a successful organizational meeting of the new ASTM Commercial Spaceflight Committee.
<p>Finding:</p> <ul style="list-style-type: none"> COMSTAC supports and will assist in the formation of an ASTM Commercial Spaceflight Standards Road mapping Subcommittee in which industry and AST are encouraged to participate. The activities would be to prioritize, develop and promote acceptance of industry consensus standards, recommended practices and other standardization tools benefitting safety. Such activities would be useful to FAA AST, for example, in the planning and implementing future HSF licensing and/or regulation.
<p>Recommendation:</p>

- The COMSTAC recommends that the FAA AST join the new industry-led ASTM Commercial Spaceflight Committee.

Finding:

- It is beneficial for US industry to increase its efforts and participation in ISO's TC 14 to develop new international Space Systems and Operators standards. Such participation is not limited by export controls.

X. Summary

This report responds to Congress' request to specify key industry metrics that might indicate readiness of the commercial space sector and the Department of Transportation to transition to a safety framework that may include regulations. A safety framework can evolve from company-driven to industry-driven, with various levels of potential government involvement, as industry grows and matures. Successful implementation of an industry-led framework could obviate the need for government involvement.

This report also responds to Congress' request to report on the progress of the commercial space transportation industry in developing voluntary industry consensus standards that promote best practices to improve industry safety. Although no voluntary industry consensus standards have been accepted by the industry at large, and a road mapping effort has not yet been completed to identify areas that have the potential to become voluntary consensus standards, the industry has established a Commercial Spaceflight committee in ASTM. With the creation of the ASTM committee, the industry can further the development of voluntary consensus standards as space flight participants begin to fly and the size and complexity of the industry grows.