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Tara Halt
haltt@my.erau.edu

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Exploring the Possibility of Using Independent Oversight to Determine Standards for Space Vehicles Who Will Operate in the NAS

Tara Halt

Embry-Riddle Aeronautical University, USA, haltt@my.erau.edu

As the number of activities in space and near-space increase, both government and industry will need to consider the best practice to maintain safe operations for their activities. The National Airspace in the United States is already extremely complicated with over 5,000 flights taking off and landing daily. Standards and eventually some type of certification will need to be developed for the launch vehicles in the commercial space industry. The implementation of standards and certification will help to ensure that the spacecraft will not be a danger to the other vehicles operating in the NAS. These standards would most likely be derived from a safety organization. By exploring the standards and rules that have been developed by organizations in other industries, the commercial space industry can efficiently and effectively create standards that will not compromise safety or hinder the growth of the industry.

I. BACKGROUND

Spaceflight has changed greatly since its inception in the 1950s. Space was once the sole domain of the United States and the Soviet Union, who were engaged in an intense international competition for “space supremacy” and national pride. Today, spaceflight has evolved to encompass both other entities and a myriad of other objectives. Instead of just two countries using orbital and suborbital space (hereinafter “orbital resources”), the entities vying for orbital resources include more than a dozen countries and hundreds of private corporations. This just includes parties with a direct access to space; there are thousands of other companies and organizations that interact indirectly with space in a multitude of support roles. Additionally, these other entities have extremely diverse objectives including recreational manned flights; manned planet and moon colonization; space station re-supply (both manned and unmanned); planet, moon, and asteroid mining; and satellite launching and repair, just to name a few examples. As this evolution continues, it is expected that the number of entities involved and the diversity of goals will only increase. Additionally, coordination between international governmental and private enterprises is rudimentary at best.

This evolution has set the stage for a fairly chaotic and arguably unsafe environment for commercial space operations. This is evidenced by recent commercial and governmental space launch failures, which included loss of life. What is needed is a framework for international governmental agencies and corporations to continue to develop and implement their objectives, while providing the public with assurances of safety. Preferably, this system would include a system of incentives for safe development of space resources. For example, one of the incentives could be priority over other entities when operating in the National Airspace.

Space is filled with cutting edge, high-risk technologies and scenarios. Due to its cutting edge nature, spaceflight activities come with risks that may include the possibility of a catastrophic failure.

However, spaceflight is only the most recent form of transportation that has been developed. Other sectors of transportation including railroad, automobile, aeronautical and maritime preceded the space industry. There have been accidents in every type of transportation and, as a result, each of the various industries have always attempted to remedy their mistakes by creating new organizations or committees to regulate safety. Accordingly, the space sector can learn a great deal from both its own mistakes and the mistakes of other transportation sectors. The aeronautical and maritime industries are particularly useful guides because in both cases, people lives are often placed in great danger if there is a catastrophic failure en route to a destination.

Due to the continually evolving nature of the worldwide commercial spaceflight industry, and the diversity of the entities involved, space traffic management is expected to present extreme challenges. However, as with the development of the commercial aviation industry, safety should be paramount in any spaceflight traffic management scheme. It is proposed herein to study and take advantage of the strides in safety that other industries have achieved. The space industry will use this knowledge to develop a framework of safety regulations and processes that incentivize the developing commercial space transportation industry to implement safety best practices, in order to receive priority in the space traffic management schemes that are ultimately developed. Accordingly, companies or countries that implement best practices in safety will benefit from receiving prioritized status in a spaceflight traffic management scheme.

This paper will provide an overview of the successful implementation of safety regimens of other transportation sectors, and how they can be utilized as an international framework for incentivizing safety in the commercial spaceflight industry by providing higher priority in a space transportation management scheme.

II. GOVERNMENTAL, PRIVATE INDUSTRY OR THIRD-PARTY FRAMEWORK

Governmental bodies (both national and international) are often accurately accused of being bureaucratic and slow to react. For example, in the United States, new regulations often take four to six years or longer until they officially become a part of the federal registry. A slow, nonresponsive and reactionary framework will not benefit the commercial space transportation industry.

Leaving oversight to private industry, however, presents its own challenges. Many companies put forth the argument that they are clearly incentivized to ensure that their systems will be safe because they would not want to kill their own customers. While this is a valid point when viewed on a macro-scale, a look at history proves otherwise. During the development of components, systems or processes, companies are making what are perceived as small, non-consequential decisions; they tend to make compromise safety if the cost savings are significant. This is a pattern in many industries that are related or unrelated to transportation. For example, for offshore drilling platforms, large and small companies in the oil and gas industry been known to make shortcuts in certain safety areas in order to increase their profit margins. Accordingly, relying upon industry to “do the right thing” will likely not result in a migration toward safer practices.

An independent safety organization could be an ideal compromise between the bureaucratic and complicated government and the ambitious and sometimes short-sighted nature of the commercial space industry. Collaboration between the government, companies, and an independent safety organization would decrease the chance that a potential risk would go unnoticed.

III. BEST PRACTICES OF OTHER INDUSTRIES A. ACCIDENT THEORIES

Safety experts have two schools of thought in regards to safety: 1) Normal Accident Theory and 2) High Reliability Theory. These theories can be essential when trying to decide what the scope and focus of an independent or dependent regulatory agency should be. Normal Accident Theory is a concept that originates in Charles Perrow’s book, “Normal Accidents: Living with High-Risk Technologies”. Normal Accident Theory

emphasizes that technological and organizational complexities contribute to failures (Greenfield). Accidents are often inevitable in highly complex systems. This is why normal accidents can also be referred to as “inevitable accidents (Perrow).” Normal Accident Theory focuses on systems approaches and system thinking. Incidents or “close calls” can often give a company or organization insight into how all the systems are inter-related (Greenfield). In order to prevent normal accidents, companies need to understand all the details and complexities of their program and systems (Perrow). They must also analyse close calls and mishaps to determine root causes. The company should then use all this knowledge to improve future programs and operations.

High Reliability Theory was developed by a group of researchers at the University of California, Berkeley. This team was tasked with examining aircraft carriers, the FAA’s air traffic control system and nuclear power operations (Greenfield). High Reliability Theory believes that if a high-risk technology is properly designed and managed, then the system should be robust enough to account for human errors and avoid situations that would lead to catastrophic failures (Columbia). This theory looks at a program or a system from the bottom up. The premise is that if each individual component is sufficiently reviewed and determined to be highly reliable, then the overall system will be highly reliable and safe. These two theories were used to help support the conclusions that the Columbia Accident Investigation made after the tragic Space Shuttle accident in 2003 (Columbia).

If an organization were to focus on normal accident theory, then that organization would require a highly technical team that would be able to understand all the complexities of a spacecraft and its system. While the organization would believe that accidents are inevitable, the culture would be focused on learning from close calls and mishaps to minimize the probability that an event would occur or the damage that it could create. Normal accident theory is often described as a “top down approach (Perrow).” On the other hand, the independent organization could also decide to accept the high reliability theory which would involve a lot of testing and research in order to determine if a system is safe and reliable. Since high reliability theory focuses on each component, it is often referred to as a “bottom up approach (Columbia).” An organization that implements both approaches, both top-down and bottom-up reviews of their systems and processes, would receive extra points toward a point-based prioritized status in a space traffic management scheme. The number of points that a company has would determine their level of prioritization in this model. A higher level would give a company a higher priority status in a space traffic management scheme.

B. NAVAL REACTOR SAFETY PROGRAMS

The Navy Submarine Force was mentioned in the Columbia Accident Investigation Report as a good example of an adaptive and effective safety program. The Naval Reactor Program has been particularly successful with 5,500 reactor years of experience without an accident (Columbia). SUBSAFE, the navy's non-nuclear safety program, is also an excellent model which can help guide other industries and organization through the development of their own safety programs. NASA, following a recommendation from the Columbia Accident Investigation Board, has established a dialogue with the Navy to learn more about their programs and what elements make its safety program so successful (Columbia). A successful program is based on key principles such as:

- Communication and Action
- Recurring Training and Learning from mistakes
- Encouraging Minority Opinions
- Retaining Knowledge
- Worst-Case Event Failures (Columbia)

For proper communication and action, an organization should maintain a program with clear checks and balances. All of the involved parties within the organization should know their responsibilities, and how they fit within the overall organization.

The second element that is highly valued in the Navy Submarine Force is training and learning from mistakes. All personnel involved in the Navy Reactor program have received stringent training and have been thoroughly educated on accidents in other sectors outside the marine world such as NASA's Challenger accident. A view of these outside incidents would provide a good basis for understanding the nature and cause of accidents, and how to avoid them. In essence, the companies would be learning from the mistakes of others.

Commercial space companies should also try to encourage minority opinions like the Navy to make sure that safety issues are not ignored simply because it is an unpopular opinion. Some employees may feel that they should keep their concerns to themselves. It is important to express these concerns because it may save people's lives in the future. There should be a way that people can express their doubts and concerns without the fear that it will impact their employment status. Minority opinions are important because it helps to ensure that all potential problems have been identified.

The ability to retain knowledge would help a company focus on its guiding principles and keep track of its overall goals when facing obstacles and making important decisions. Employees should have at least a basic understanding of all systems on a satellite or spacecraft even if it is not their area of expertise.

While it can be unpleasant or demotivating to think about, all companies should prepare for the worst-case scenario and be fully aware of all the consequences that could stem from a catastrophic failure. These principles should be the focus of any independent oversight organization that is charged with keeping spaceflight safe.

IV. UNITED NATIONS SPECIALIZED AGENCIES

The United Nations has a plurality of related organizations that can act as a guide for the implementation of any future space organization.

The International Civil Aviation Organization (ICAO) is a specialized UN Agency that develops international Standards and Recommended Practices (SARPs) that countries can reference when creating their own laws in the aviation industry. Their overall vision is to "achieve the sustainable growth of the global civil aviation system (About ICAO)." Almost all countries are member states of ICAO. With over 100,000 flights operating daily in the air transport network, it is essential that there is overall acceptance of the SARPs that are created by ICAO (About ICAO).

The International Maritime Organization is very similar model to ICAO, but for the maritime industry. The IMO is the "global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented (About IMO)." The International Maritime Organization work is focused on the environment, collaboration between countries, legal issues, security, and safety.

There has been some discussion among experts about creating an organization similar to ICAO and IMO for the space industry, but so far there has been no significant progress in that area (Taking a page). The United Nations Office of Outer Space Affairs (UNOOSA) is the best example of international leadership that the space industry currently has. UNOOSA works to "promote international cooperation in the peaceful use and exploration of space, and in the utilization of space science and technology for sustainable economic and social development (About UNOOSA)." UNOOSA has helped to develop five treaties and five sets of principles that are supposed to guide the activities of outer space. It remains unclear if UNOOSA would be capable of any disciplinary action if those treaties were to be broken. One of the primary issues with the treaties that UNOOSA created is that some of them have not been ratified by the primary space faring nations, for example, Russia, China, and the United States (About UNOOSA).

UNOOSA and ICAO have tried to start preparing for the future by creating a portal on both websites where interested parties can upload documents and start a dialogue (About ICAO). Points of contact are also included on the portal as an attempt to facilitate collaboration from all interested parties. Some of the more prominent organizations that have been included are NASA, Canadian Space Agency, DLR, FAA, and the International Association for the Advancement of Space Safety (IAASS). The main challenge for UNOOSA and ICAO in regards to space is the all the uncertainty. It is difficult to determine at this time the type of guidance that the space sector will need from an international organization. While it is important to have dialogue at an international level, the United States should establish its own oversight models first since many countries look to the United States as the prime example when developing their own organizations and regulations.

V. CLASSIFICATION SOCIETIES

Besides IMO, the marine sector also relies on the expertise found in its classification societies. In fact, the International Association of Classification Societies (ICAS) provides the technical support for the International Maritime Organization (About IMO). The fact that the IMO uses ICAS as its technical support shows how well respected classification societies are in the marine sector. ICAS consist of 12 maritime classification societies. These societies are “impartial organizations consisting of technical experts that have established a system of public safety based on private law contracts. They are often described as the unofficial ‘policemen’ in the marine world (Classification).”

Merchants and ship owners developed classification Societies in the 1800s (Lloyd’s). The captains and owners would share the risks and rewards of a voyage by a process that is referred to today as underwriting (Classification). The involved parties needed a way to assess the quality of the ship before they would feel confident moving forward with the underwriting process. This is where the concept of classification societies began and has been a vital part of the maritime industry ever since.

A classification society sets standards for the design, construction, and maintenance of maritime vessels. According to the ICAS website, the rules and standards set by the 12 members of ICAS encompass “More than 90% of the world’s cargo carrying tonnage (Lloyd’s).” Certification is often done by these societies for a fee. For ship owners, it is worth the time and money to get certified because often insurers will not insure the ships without certification from those societies. In the marine sector, classification societies have reached a high level of credibility and prominence. An important aspect of classification societies is that they are independent, self-

regulating, and externally audited (Classification). These societies have no commercial interests in the areas of ship design, manufacturing etc.... Therefore, It would be very unlikely that a classification society would place more value on profit rather than safe practices.

Commercial Space could most likely adopt a similar system with the same success. In commercial space, a classification society could do similar activities and services that it does for the marine sector such as developing standards and certifying vehicles. With an established certification and standards process, companies would know what is required even before they begin the design phase. This would reduce the need to issue waivers that could potentially compromise the overall safety of the system. With an independent body giving its stamp of approval, a commercial company could apply for a license from the FAA with more confidence. A certification from an independent body could be thought in the same light as a more in depth safety approval, a process that is currently done by the FAA for safety elements such as training or an identified safety component.

VI. AEROSPACE CORPORATION

While an international organization may be necessary in the future, the US would also benefit from having an independent safety organization domestically. Launches are always risky but that risk of failure can be decreased when an independent organization is involved. One the best and most relevant examples of an independent safety organization is the relationship between The Aerospace Corporation and the Air Force. The Aerospace Corporation is a non-profit organization and a Federally Funded Research and Development Center (FFRDC). The Department of Defense identified the main areas that The Aerospace Corporation focuses on since it is a FFRDC. These elements are launch certification, system-of-systems engineering, systems development and acquisition, process implementation, and technology application (Columbia). The Aerospace Corporation independent launch verification process has proven to be quite effective. The Air Force “only has a 2.9 percent probability of failure rate in comparison to the commercial sector which is 14.6 percent (Columbia).” Before a launch, The Aerospace Corporation sends a letter to the Air Force that states that the vehicle has been independently verified as ready for launch. The staff of the Aerospace Corporation has a very thorough review process that goes through every aspect of launch from payload integration to the adequacy of flight and ground hardware (Columbia). As a result, the Air Force can launch their payloads with increased confidence. More than two thirds of the people that are employed at The Aerospace Corporation have highly technical backgrounds (Sgobba). These

people are the experts in their respective fields, which make them great assets when they are hired as consultants to other commercial space companies. The Aerospace Corporation employees are able to understand the complexities a space vehicle's components and consequences of system failures. The Aerospace Corporation embodies that idea that a safety certification should be even more knowledge and experienced than the design team of a launch vehicle (Sgobba).

VII.RELEVANCE TO SPACE TRAFFIC MANAGEMENT

Analysing the safety requirements of other organizations is an important step when trying to determine how space traffic will be integrated into the National Airspace system. When spacecraft are operating, it is acknowledged that they will be flying over other countries; possibly even in that country's airspace. This paper focuses on the National Airspace System in the United States for the purposes of simplicity. A spacecraft should not endanger other aircraft especially since aircraft are more vulnerable to debris than buildings on the ground. A breakup of a spacecraft can cover a very large area. In October 2014, Virgin Galactic and Scaled Composites' SpaceShipTwo broke up during its 4th powered test flight. The debris from the incident was mainly spread over a 5-mile area but there were some pieces found as far as 35 miles (SpaceShipTwo). No company can say with absolute certainty where debris would land in the event of a catastrophic failure. Inflight breakdown is an important consideration for suborbital flights since many designs that are in development consists of a vehicle that will be flown like an airplane or a glider during take-off or landing. Suborbital vehicles will spend a lot more time in the National Airspace System than a traditional orbital launch vehicle that only operates for brief periods of time. Airlines will not be very cooperative if they have to always reroute their flights to accommodate space traffic. During the Space Shuttle days, airlines usually were very cooperative when NASA wanted to launch but this pattern of accommodation is not expected to continue for commercial space companies. With both air and space companies looking to make a profit, no one wants to have to delay their flight or launch because of another company.

Airline regulations are often referred to as "blood laws." The basis of many regulations comes from a fatal accident. The fatal inflight collision between TWA Flight 2 and United Airlines Flight 718 near the Grand Canyon motivated the government to upgrade the air traffic control system and create the

Federal Aviation Agency (Administration) to oversee aviation safety in the United States (FAA History). After the fatal fire aboard Air Canada 797 killed 23 people, the Federal Aviation Administration made new regulations in response (FAA History). Since the fire started in lavatory, the first regulation required that all airplane lavatories are equipped with smoke detectors. The FAA also implemented regulations that required that seats be fitted with a flame resistant layer and adequate floor lighting should be provided for passengers (FAA History). It seems a bit morbid to continue this practice where regulations are only developed after human lives are lost. Currently the FAA Office of Commercial Space Transportation (AST) has moratorium on creating regulations for crew and spaceflight participants. The moratorium is expected to be extended by the Senate until at least 2020. The House of Representatives has discussed extending it even further until 2025 (Messier).

If the government is unable to create regulations, for occupants, standards for space vehicles should be developed by an independent body. The FAA AST office focuses on licensing activities but they do not license vehicles. In fact, the NTSB investigation of the SpaceShipTwo crash revealed that most companies do not even approach the government until after their vehicle is already developed (SpaceShipTwo). This being the case, there should be an independent body such as a classification society that can certify that the vehicle will not cause a disruption to the complicated national airspace system. Currently, commercial aircraft require an extensive certification and inspection. While the commercial space industry may not be ready for a similar stringent process, there needs to be more guidance to manufacturers than what is currently offered. Standards could help companies design their vehicles so that they can receive license from the FAA more quickly and avoid the potential high costs of having to redesign a vehicle close to a planned launch date. Customers who want to launch payloads will want the vehicles they are riding on to be dependent and have a reasonable chance of mission success. Thus far, no paying customers have been flown on a commercial launch vehicle. It seems unreasonable to allow these unproven vehicles to operate in the National Airspace without some type of standards from a trusted safety organization.

Standards and other recommended practices could be used as the basis for a prioritization model. In the model, companies that comply with the standards would be given priority over those who do not. For example, if two companies are vying for the same launch date, priority would be given to the company that follows the standards set by the independent safety organization. The safer the vehicle is, the higher the priority they will receive. There could be various levels

within this scheme. A company's prioritization level would be determined by the number of points a company has. For example, a company would receive more points if they analysed their systems with the both top down and bottom approaches that were mentioned earlier in this paper. There are some issues that would need to be resolved in order for this model to be both effective and efficient. The main issue is how to compare suborbital and orbital vehicles since there are many differences between spacecraft that operate in space or near space.

VIII. CONCLUSION

An independent oversight organization that was a combination of the classification society model and The Aerospace Corporation model could help the commercial space industry grow and maintain a high level of safe operations. Oversight of the commercial space industry should not be prescriptive. It is much more beneficial to all involved parties to focus on safety cases rather than explicit design requirements. It is important to note that even with these independent agencies having some oversight it would still be necessary to have spaceport and launches licensed by the FAA. For example, at a launch The Aerospace Corporation could verify that a vehicle is ready for launch, while an FAA Inspector could ensure that the safety of the uninvolved public. This would create an effective system of checks and balances that minimize the chance that a safety issue was overlooked.

The prioritization model presented in this paper would be an excellent incentive for the industry. Those who do not meet the standards would be less likely to receive their desired launch date if there are conflicts with other companies. It will be challenging to integrate spacecraft with the National Airspace System but the

technology innovations that will be developed as a result could make the National Airspace System even more efficient than it is currently.

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