

Future Safety:

Apply Lessons Learned in Human Factors to Commercial Space Operations

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Abstract

In 2015, the National Transportation Safety Board identified several substantial safety issues during the investigation of the in-flight break up of the suborbital rocket SpaceShipTwo. One of these deficiencies identified the lack of regulatory guidance concerning human factors for use in commercial space operations. With the current learning period extended until 2023, the Federal Aviation Administration is unable to correct this problem through regulatory means. Fortunately, the human factors principles and error mitigation strategies developed for the commercial aviation industry are transferable, and commercial space operators have a responsibility to develop applicable safety platform using this previously mined data.

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Introduction

Aircraft accident investigation is a well developed, yet dynamic, part of the aviation industry. It exists in a constant balance between reactive and proactive actions; reactive, in the conclusions and recommendations that are derived from an investigation, and proactive in the development and implementation of the various mitigation strategies aimed at preventing a reoccurrence.

The future of aviation is attaining new heights, as the commercial space industry continuously achieves unprecedented successes. Even with exceptional technological advancements, and an evolution in operational environment, spacecraft operators must remember that at least one element has remained constant; the human.

Human error mitigation strategies, that have been previously developed for other industries, including aviation, have been established through decades of data gathering and analysis. Failure to implement these strategies will result in the genesis of latent and active errors that when combined with other operational oversights, will develop an error chain (Reason, 1990; Wiegmann & Shappell, 2003).

Commercial space operators must incorporate the lessons learned through past experiences in related fields to improve future operational safety.

Human Factors and Commercial Space Operations

The commercial space industry is one that demands exceptional precision, with little remorse for errors, and yet it must include the human element that remains fallible in nature. Failing to incorporate error mitigation strategies has severe and often fatal repercussions as

evidenced during the in-flight break up of the reusable suborbital rocket, SpaceShipTwo, on October 31, 2014. As a result of the investigation, the National Transportation Safety Board (NTSB) identified seven safety issues that contributed to the accident, one of which was a “lack of human factors guidance for commercial space operators” (National Transportation Safety Board, 2015, p. vii).

The term, human factors, is often used to describe an exceptionally broad topic that incorporates a vast subject array including ergonomics, human cognition, sensation and perception, aeronautical decision making, crew resource management, human physiology, effective communication, and threat and error management, for example. All of these elements have been incorporated into commercial aviation operations, through the Code of Federal Regulations (C.F.R.) part 121 and 135, as preventative methods to reduce human errors and improve performance (Pilots and flight engineers, 2019; Crew member training requirements; 2019)

Unfortunately, the C.F.R. guidance on pilot licensing for commercial space operations does not mandate a commercial or airline transport license, which could result in a pilot commanding a spacecraft with substandard human factors training, if any at all (Crew qualifications and training, 2019). The application of different human factors concepts has greatly improved aviation safety, while improving synergy and teamwork amongst crew members. These concepts will provide a similar benefit to commercial space operations if they are incorporated into regulatory provisions.

Oversight and Accident Prevention

The Code of Federal Regulations 14 C.F.R. §460, provides federally regulated guidance on training elements that must be incorporated to satisfy the licensing requirements for human

space flight (Aeronautics and space, 2019). 14 C.F.R. §460.15 identifies the necessity of human factors training to incorporate elements that could “affect a crew’s ability to perform safety-critical roles” (Human factors, 2019, para. 1). This four-item list primarily discusses ergonomics, in an effort to improve the flight crew’s operational efficiency, and decrease dissonance when liveware interfaces with the hardware and software of a spacecraft (International Civil Aviation Organization, 1993).

Although important, ergonomics is only one small aspect of human factors. The lack of federally regulated guidance on the additional aforementioned components is a severe detriment to the future of spaceflight safety. Unfortunately, U.S. law has limitations on the authority of the Federal Aviation Administration (FAA) when it comes to regulating the commercial space industry. U.S. Congress established a dedicated learning period that was extended from October 1, 2015 to September 30, 2023, resulting in the moratorium on the development and implementation of new safety regulations for commercial space operations (Ward, 2016; Reimold & Sloan, 2017)

It would be irresponsible to rely solely on perfect compliance with the federal regulations to mitigate the industry from risk, and as such, commercial space operators must identify the gaps in the regulations and mitigate the associated risks. Risk identification and mitigation is a combined effort between several participants including, but not limited to, the federal regulator and the operator. The creation and implementation of federally regulated requirements provides the necessary foundation upon which operators can build their own defences; however, when this foundation has not yet been developed, it behooves the operator to build it themselves.

Operator Involvement in Accident Avoidance

In the late 1970's it was identified in the first generation of Crew Resource Management (CRM) that the aviation industry had an unrealistic expectation of human performance, and incorrectly assumed that humans could be trained to execute their duties with zero human error (Helmreich, Merritt, & Wilhelm, 1999; Maurino & Murray, 2010). Fortunately, this erroneous thought process was, for the most part, corrected in the subsequent generations of CRM, and appropriate provisions have been in place for the past several decades.

Unfortunately, the assumption that training could result in perfect human performance was one of the primary failures in the hazard analysis that was conducted by Scaled Composites LLC prior to the launch of SpaceShipTwo (National Transportation Safety Board, 2015). The Transportation Safety Board of Canada, has identified that the majority of accidents, regardless of size, can be attributed to the failure of an organization to identify and mitigate hazards and manage risk (Fox, 2016).

The aviation industry has spent the better part of fifty years analyzing the limitations of both cognitive and physiological human performance, and from this, was able to develop and implement mitigation strategies. These conclusions were developed from previous accident investigations, incidents, voluntary reporting, and other forms of data gathering. Even though operations in space likely contain unique elements, the foundation of human performance and error prevention that have been established in the aviation industry is transferrable.

Data Application

The purpose of aircraft accident investigation is to develop an understanding of the actions and decisions that led to the unfavorable outcome, and to apply that information to the development of mitigation strategies (Wiegmann & Shappell, 2003; Wood & Sweginnis, 2006). Approximately 80% of all aircraft accidents have some element of human related error, and it is

imperative to apply the lessons learned to future actions in an effort to prevent a reoccurrence (Campbell & Bagshaw, 2002). The aviation industry is well versed with data mining, and has identified relationships, links, and trends that have already benefitted aviation safety; but this too, has its shortcomings.

First, there is not a singular database that contains all of the related information, and as such not every relationship or trend can be identified. Second, the databases that do exist are built on a combination of quantitative and qualitative data, the latter being subject to bottom-up and top-down information processing errors (Gibb, Gray, & Scharff, 2010). Information recalled through human memory is never perfect, and as such cannot be considered a fact; but is still valuable for the sake of data mining and accident prevention. Third, databases are incomplete as not every incident or accident is reported.

Furthermore, there are situations where an intervening action caused the cessation of the accident sequence, leaving the crew unaware of the potential disaster that would have occurred. These scenarios are almost impossible to track, simply because it is exceptionally difficult to document an event that did not happen. Clearly, data collection and mining are not perfect, but even so, provide valuable predictors of future behavior.

How the Past Predicts the Future

Using the central limit theorem, behavioral and social scientists specializing in inferential statistics often witness a normal distribution pattern in the majority of populations in nature (Aron, Coups, & Aron, 2011). This results in 68% of the population falling within one standard deviation of the average, and 96% within two standard deviations. The distance from the average for any value, is derived from a variety of factors, including environmental and educational, as well as the physiological and cognitive abilities of the participant. Values that are found on the

extreme of the population curve are referred to as outliers, but are rare in populations that follow a normal distribution (Aron et al., 2011).

Understanding that human performance is likely to follow the normal curve, given that the fluctuation of influential variables remains relatively consistent, future human performance can be predicted with relative accuracy based on previously acquired behavioral data (Aron et al., 2011). With relative simplicity, the commercial space industry could implement mitigation strategies to improve human performance during operations in space.

Conclusion

Even though commercial spaceflight is a unique and attractive mode of transportation, there are exceptional risks involved. Human spacecraft operators are fallible, and their performance is comparable to highly-trained aircraft pilots, and as such, the lessons that have been previously learned in aviation-centered human factors, should be evaluated and adapted for flight in space. Furthermore, federal regulations must eventually evolve to develop a satisfactory level of safety that protects the operating crew and passengers from avoidable risks.

In addition, research must be conducted to develop specialized oversight for the commercial space industry, as well as, additional education for investigators of spacecraft accidents. Regulations and policies must be created to facilitate data gathering, and mining, specific to operations in space, as well as, a process for implementing risk mitigation strategies.

The development of safe and efficient commercial space operations is entirely dependant on the ability of industry leaders to remember the past and apply this wealth of knowledge to the creation of future safety measures.

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