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The Elements of a Commercial Human Spaceflight Safety Reporting System

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Abstract

In its report on the SpaceShipTwo accident the National Transportation Safety Board (NTSB) included in its recommendations that the Federal Aviation Administration (FAA) "in collaboration with the commercial spaceflight industry, continue work to implement a database of lessons learned from commercial space mishap investigations and encourage commercial space industry members to voluntarily submit lessons learned." In its official response to the NTSB the FAA supported this recommendation and indicated it has initiated an iterative process to put into place a framework for a cooperative safety data sharing process including the sharing of lessons learned, and trends analysis. Such a framework is an important element of an overall commercial human spaceflight safety system.

As the industry matures and approaches a time of regular operational flights carrying paying commercial passengers, the time is right to consider the development of an industry-wide safety reporting system focused on operational hazards, incidents, and close calls. Mature safety reporting systems of this nature exist, both in the aerospace sector and in other industries. For example:

- The Aviation Safety Reporting System (ASRS) in the United States
- The Federal Railroad Authority Confidential Close Call Reporting System
- The NASA Safety Reporting System (NSRS)
- Aviation safety reporting systems operated by several civil aviation authorities around the globe

These successful systems offer a number of lessons learned and operational best practices that might be applied to a prospective commercial human spaceflight safety reporting system. Through a review of these programs, focusing on systems in the U.S., this paper will describe elements of a safety reporting system that might be developed in support of the commercial human spaceflight industry. Factors to be addressed include:

- Origins and motivations for the system
- Organizational and operational approaches
- Treatment of confidentiality, both for reporters' personally identifiable information, and for proprietary or commercially sensitive information
- Relationship to lessons learned and safety data exchange programs
- Authority to act upon information received

One element that these systems often have in common is that they were established following a tragic incident involving the loss of multiple lives. The FAA's efforts to analyze and implement a commercial spaceflight safety lessons learned database offers a window to develop a safety reporting system, in consultation with industry, prior to similar tragic incidents involving commercial spaceflight participants

Keywords: human spaceflight safety, safety reporting

Acronyms/Abbreviations

ASAP Aviation Safety Action Program

AST FAA's Office of Commercial Space Transportation

ASRS Aviation Safety Reporting System

CAA Civil Aviation Authority

C^3RS Confidential Close Call Reporting System

FAA Federal Aviation Administration

FRA Federal Railway Administration

FOQA Flight Operations Quality Assurance

MOU Memorandum of Understanding

NSRS NASA Safety Reporting System

NTSB National Transportation Safety Board

PII Personally Identifiable Information

1. Introduction

On July 28, 2015 the U.S. National Transportation Safety Board (NTSB) issued its report on the October 2014 fatal in-flight break-up of the Virgin Galactic SpaceShipTwo vehicle during a test flight (operated by Scaled Composites). This report represented the findings from the first accident investigation that the NTSB has led related to commercial human spaceflight [1]. The NTSB report emphasized human factors as key contributors in the events leading to the accident, and included several recommendations to improve safety of future commercial human spaceflight activities. Amongst those recommendations was a recommendation to the Federal Aviation Administration (FAA) to:

> "8. In collaboration with the commercial space flight industry, continue work to implement a database of lessons learned from commercial space mishap investigations and to encourage commercial space industry members to voluntarily submit lessons learned. [2]"

This recommendation was in partial response to a NTSB finding that the FAA's Office of Commercial Space Transportation (AST) had begun, in 2010, efforts to develop a Commercial Space Transportation Lessons Learned System, but that that system had yet to be fully developed or implemented [2].

In October of 2015 FAA AST issued a formal response to the NTSB's recommendations. In this response the FAA supported Recommendation 8 (above), recognizing the "profound impact that voluntary safety data sharing has had in aviation, the FAA believes that facilitating an appropriate framework for voluntary safety data sharing can also bring significant continuous safety improvements to the emerging commercial human space flight operations [3.]" Prior to the NTSB Report AST had already conducted an internal feasibility study assessing the opportunities for voluntary safety data exchange between the spaceflight industry and FAA. This study suggested it would take a number of years to implement such a system, which would have to overcome a number of challenges including: "De-identification & protection of proprietary data, creating a non-punitive environment, [and] availability of data-mining and analysis tools [4]." AST recommends a stepwise approaching to implementing such a system, following research of safety data exchange tools and programs in place in the FAA aviation portfolio, focusing on the Flight Operations Quality Assurance (FOQA) program and the Aviation Safety Action Program (ASAP) [4]. Both ASAP and FOQA represent voluntary safety incident, hazard and/or mishap reporting systems.

2. Safety and Incident Reporting Systems

The NTSB writes that "the aviation industry has databases documenting accident and incident findings and effective corrective actions, which have been highly beneficial in preventing accidents and reducing fatal accident rates. [2]" ASAP and FOQA are two examples of these types of systems, which also exist in the medical, maritime, railroad, nuclear, and other 'high hazard' industries.

Safety incident reporting or lessons learned collection systems exist for several purposes, including: to implement corrective action for specific incidents or hazards, to prevent accidents, to collect and analyze system level data in order to "increase safety, efficiency, and profitability" of operations, and to monitor the efficacy of regulations and company procedures [5]. Information feeding into these purposes is collected from a variety of sources, and there is recognition that safety incident reporting systems are "a proven and effective way to fill in the gaps, left by the accident investigations, mandatory event reporting, and other information gathering systems [6]." Successful safety reporting systems both support regulatory and policy efforts to improvement systemwide safety and support industry development efforts; as well as company and industry specific safety management efforts.

These successful systems offer a number of lessons learned and operational best practices that might be applied to a prospective commercial human spaceflight safety reporting system. Through a review of these programs, focusing on systems in the U.S., this paper will describe elements that should be considered in discussions of a safety reporting system that might be developed in support of the commercial human spaceflight industry.

3. Regulatory Authority – Voluntary vs. Mandatory

Safety occurrence reporting systems can be either voluntary – such as ASAP – or mandatory (required by statute or license obligations) – such as the FAA Air Traffic Organization's (ATO) Mandatory Occurrence Reporting criteria or the UK Civil Aviation Authority's Mandatory Occurrence Reporting Scheme. FAA AST is currently subject to a restriction in its ability to put into place regulations concerning the "health and safety of crew and spaceflight participants [1]." This 'learning period' was recently extended until 2023. While this provision does not prevent the FAA from working with the human spaceflight industry on voluntary practices to improve spaceflight safety, it does mean that it is unlikely that the FAA will be able – or willing – to impose a mandatory safety incident or hazard reporting scheme. For this reason, this paper will focus its discussion on the evaluation of lessons learned from existing voluntary reporting systems, in the aviation, maritime, space, and railroad industries.

4. A Review of Selected Existing Voluntary Safety Reporting Systems.

Linda Connell, a director of the Aviation Safety Reporting System (a joint NASA – FAA activity) writes that "in large, complex, and dynamic environments like aviation, nuclear power, medicine, and other industries, where sometimes minor errors or flaws in systems can lead to severe incidents or accidents, the challenge of maintaining safety is significant. [7]" Accordingly many of these 'high hazard' industries have adopted voluntary safety incident or close call reporting systems as an element of a multi-tier safety risk management approach. Examples include:

- The Aviation Safety Reporting System (ASRS) in the United States
- The Aviation Safety Action Program (ASAP) in the United States
- The Federal Railroad Authority Confidential Close Call Reporting System in the United States
- The NASA Safety Reporting Systems (NSRS)
- The Patient Safety Reporting System in the United States
- The Confidential Reporting Programme for Aviation and Maritime in the United Kingdom
- Aviation safety reporting systems operated by several civil aviation authorities around the globe
- The joint IAEA/NEA Incident Reporting System for the global nuclear power plant operator community.

In general, these systems share a common goal to "provide lessons learned about safety that can assist in improving safety performance [8]." At a high-level they operate in similar fashions: reports are submitted by an individual system's users; usually are then stripped of personally identifiable information (PII) – de-identified in other words; investigated by technical experts; analyzed for trends and system-level impacts; and then reported on in the aggregate. Many systems also include mechanisms to respond to or mitigate the specific issues reported in individual reports. This paper conducted a comparative analysis – focusing on structure and operations, handling of PII, and research and outcome approaches – of a selected number of existing reporting systems. The FAA's FOQA system was not included in this analysis, as it is an automated data collection system not a human-in-the-loop reporting system.

4.1 The Aviation Safety Action Program (ASAP)

Operated by the FAA's Flight Standards Service, the objective of ASAP is to "encourage air carrier and repair station employees to voluntarily report safety information that may be critical to identifying potential precursors to accidents [9]." ASAP operates as a partnership between the FAA and FAA-certified carriers and repair stations that have signed a MOU to participate in the program. Only those employees of participating company may report through ASAP, and industry has a role in the investigation of ASAP reports. Incidents must (in general) be reported to ASAP within 24 hours of occurrence, and investigations are generally focused on company level events. ASAP reports are de-identified to remove reporters' names, but other potentially identifiable information (such as time/date/location and employer) remains in the report during the investigation [6,9,10,11].

ASAP reports are closely tied to outcome actions at the specific participating company from which the report occurred, providing for close articulation between investigations and corrective action. The FAA can use ASAP information, in some circumstances, to initiate enforcement action on carriers; and in all cases ASAP information is analyzed for trends and issues that may impact safety of the aviation system as a whole. [6,9,10,11]. However, because the system is focused on actions at the company-level, information and impacts might not be shared across companies, unless that data is also shared with a national-level reporting system [6].

4.2 The Aviation Safety Reporting System (ASRS)

Operated by NASA, under an interagency agreement with the FAA, the ASRS "receives, processes and analyzes voluntarily submitted incident reports from pilots, air traffic controllers, dispatchers, cabin crew, maintenance technicians, and others" that operate in the National Airspace System. ASRS has a particular focus on "the quality of human performance in the National Airspace System. [12]" ASRS was established in response to a 1974 fatal commercial airline accident in which a TWA flight misunderstood air traffic control instructions and flew into terrain while approaching Dulles Airport. A United Airlines flight had narrowly avoided the same fate (and terrain) six weeks earlier; but information was not shared between the airline companies [6,7].

ASRS operates at the national (or system) level – reports are processed and investigated by a contractor of a neutral third party – NASA – that is neither a regulator nor a promotor of the industry implicated in the system. Reports are investigated and analyzed by aviation sector experts that are employed by the ASRS contractor. Reporting and investigation is not tied to the specific companies from which reports originate and the system is open to all aviation users and actors in the U.S., and not based upon a limited-participation model. This approach focuses ASRS on the analysis of system level safety impacts and trends, and may lessen the closeness of its outcomes to industry corrective action [6, 11, 12].

Worldwide a number of aviation safety reporting systems have been modeled after ASRS [6]. The International Confidential Aviation Safety Systems (ICASS) Group is a coordination body of aviation industry confidential reporting systems. It currently includes systems from 13 countries, including Brazil, Canada, South Africa, South Korea and several others, which operate similarly to ASRS.

4.3 The UK Confidential Reporting Programme for Aviation and Maritime

The UK Confidential Reporting Programme for Aviation and Maritime (CHIRP) aims to support "the enhancement of aviation safety in the UK and maritime safety worldwide, by providing a totally independent confidential (not anonymous) reporting system for all individuals employed in or associated with these industries." Like ASRS, CHIRP is a system-level activity and an open participation system. In the aviation segment, it is designed as a complement to the mandatory reporting scheme required by the UK Civil Aviation Authority. CHIRP also operates as an independent third party – in this case as charitable organization. Unlike ASRS – and more like ASAP – CHIRP uses experts employed by industry to investigate reports, however they are acting in an independent not industry capacity.

4.4 The Confidential Close Call Reporting System (C^3RS)

Operated by NASA, under an interagency agreement with the Federal Railroad Authority (FRA), the C^3RS "is designed to improve railroad safety by collecting and analyzing reports which describe unsafe conditions and events in the railroad industry. Employees will be able to report safety issues or "close calls" voluntarily and confidentially [14]." Like ASAP, C^3RS is a closed participation system, with participation limited to only the employees of those rail carriers that have signed MOUs with the FRA to participate. Like ASRS, C^3RS uses an independent third party to de-identify, process and analyze reports, however like ASAP the program is focused on company level reporting and impact. Accordingly, C^3RS does include mechanisms for involving specific companies in the investigation of reports received, through the use of peer-review teams.

4.5 The NASA Safety Reporting System (NSRS)

Somewhat more limited in scope that the other system described in this section, NSRS was "designed to give NASA employees at any level and contractors an alternate avenue or channel through which to communicate safety concerns and issues to upper management [15]." The system is open for anyone present on a NASA facility, or working on a NASA-funded activity, to report "any hazard presented by a NASA operation that can affect the public, the NASA workforce or NASA assets [15]." NSRS was established in 1987 following the Challenger Space Shuttle accident. NSRS is operated by NASA via an independent contractor who receives, characterizes and de-identifies the reports prior to passing to the NASA's Office of Safety and Mission Assurance for investigation. NSRS is focused on impact to NASA's operational safety and the Office of Safety and Mission Assurance is able to use information submitted to the NSRS to implement corrective or mitigative action to NASA programs and facilities.

4.6 A Comparison of Systems

Table 1, on the following page, compares attributes of these systems. It focuses on three elements:

- *Operations:* How the system is organized and operated, who its users (those who submit reports) and its customers (those who use the resulting safety information) are
- Reporter Identity Considerations: how PII is handled and what immunity provisions exist
- Investigations and Outcomes Considerations: how reports are investigated, what outcomes result and what is industry role in the operations of the system.

This paper's analysis focused on operations and structural elements in the design and purpose of the reviewed reporting systems; the software and analysis tools and methods used in each system, while an important element, were not within the scope of this analysis.

Table 1. A Comparison of Selected Confidential Reporting Systems

Table 1A: Operations and Structure Considerations

	ASAP	ASRS	CHIRP	C³RS	NSRS
Country	US	US	UK	US	US
Type of System	Closed, voluntary	Open, voluntary	Open, voluntary	Closed, voluntary	Open, voluntary
Industry	Aviation	Aviation	Aviation Maritime	Railroad	Civil Space
Scope	Aviation-related safety concerns and events that may have otherwise gone unreported	Unsafe occurrences and hazardous situations with a particular focus on human performance factors [12]	A complement to the UK Civil Aviation Authority Mandatory reporting system, for flight safety in the UK, emphasis on human factors [13]	Reports of unsafe of conditions or events	"Any hazard presented by a NASA operation that can affect the public, the NASA workforce or NASA assets" [15] System is a secondary resource to program or facility led channels
Users *those who submit reports*	Limited: Flight and maintenance crew of participating "air operators" (including commercial, charter, and FAA-certified repair stations) via MOU with FAA	Open: All users of the national airspace and anyone involved in commercial or general aviation	Open: All users of the national airspace and anyone involved in commercial or general aviation	Limited: Only those who work at rail carriers with a C³RS MOU with the FRA can report to the system	Open (within scope): All NASA employees & contractors; anyone on a NASA facility
Customers *those who utilize outcomes*	Participating Air carriers, FAA-certified repair stations, FAA	All aviation system users, government regulatory agencies (FAA, NTSB)	All aviation system users, UK government regulatory agencies	Participating organizations and FRA	NASA management
Operator	FAA jointly with air operators via individual MOUs	NASA on behalf of FAA – via independent contractor	Operated by an independent charitable trust	NASA on behalf of FRA – via independent contractor	NASA – via independent contractor

Table 1B: Reporter Identity Considerations

	ASAP	ASRS	CHIRP	C^{3}RS	NSRS
PII Protection Provisions	Reports are de-identified (name only) Information in individual ASAP reports is protected from public disclosure by both FAA regulation and federal law	All reports strictly de-identified, with all information pertaining to reporters' identities, removed prior to investigation and analysis	Totally confidential system, reporters' identify information not passed to investigators or regulatory agencies	All reports strictly de-identified, with all information pertaining to reporters' identities, removed prior to investigation and analysis	All reports strictly de-identified, with all information pertaining to reporters' identities, removed prior to investigation and analysis
Immunity Provision	Immunity is secondary aspect of program: if ASAP report is accepted, there "can be no civil penalties or certificate suspension imposed by the FAA," and carriers and the employers generally agree to not pursue disciplinary action [11]	Primary aspect of program: FAA is forbidden by statute (FAR Sec. 91.25) from using ASRS reports to impose suspensions or civil penalties against reporters, except for in very limited circumstances		Through MOUs with FRA "reporters are provided waivers from carrier discipline and FRA enforcement for qualifying events" [16]	

Table 1C: Report Investigations and Outcomes Considerations

	ASAP	ASRS	CHIRP	C^{3}RS	NSRS
Report Investigators	Event Review Committee: composed of FAA, airlines, and MOU-specified third parties (e.g. unions); or referred to FAA experts	Reports analyzed, indexed, and researched by industry experts working for the ASRS contractor	Reports analyzed, indexed, and researched by industry experts acting as "individual expert advisers and not as representatives of their sponsoring organisations" [13]	Reports analyzed, indexed, and researched by industry experts working for the C^{3}RS contractor Carrier-specific Peer Review Teams (PRTs) may also review reports, depending on MOU	Reports are investigated by NASA staff designated by the Office of Safety and Mission Assurance
Industry Stakeholder Engagement	Industry has direct role in investigation of submitted reports – tied specifically to their company	Industry Advisory Committee to provide strategic guidance, with no role in individual report processing, but currently not active	Industry Advisory Boards which both provide strategic guidance to the program, and involved in the review and analysis of reports	Industry engaged as direct stakeholders through MOUs and participation in Peer Review Teams	No formal industry engagement in operations, systems focused on NASA workforce

	ASAP	ASRS	CHIRP	C³RS	NSRS
Research Links	"Analyses of ASAP data are conducted to identify trends and develop corrective action(s) and/or recommendation(s)" [10]	Regular trend and analysis publications, also links to ASAP and other FAA databases	Regular trend and analysis publication	The C³RS "Distributes de-identified reports on safety trends and corrective actions to participating organizations and FRA" [17]	Limited, internal to NSRS
Authority for Outcomes	Carriers/stations have authority to implement corrective action but not disciplinary action to individual employee FAA can use ASAP information, in some circumstances, to initiate enforcement action on carriers/employees, these actions remain on individual files for up to 2 years	ASRS used to inform system level safety hazard identification; analysis results used by FAA and other stakeholders to improve policies and operations Scaled level of "alerts" published by ASRS based on time/severity of issues		Carriers can implement corrective action, through results of PRT reviews. FRA can use C3RS information to implement system-wide improvements	NASA has the authority to implement remedial actions with NASA facilities and programs in response to NSRS reports

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5. Conclusion: Elements to be Considered in Establishing a Commercial Human Space Flight Safety Reporting System

The comparison of systems represented in Table 1 shows that no system is alike, rather that each system has unique elements as well as elements that are shared with other systems. As the NTSB recommendation to develop and implemented a commercial space flight lessons learned system is considered; the choices made in construction of safety reporting systems in other industries offer suggestions of elements to consider:

- Open vs. Limited Participation System: Should a human spaceflight safety reporting system or lessons learned database be a limited participation system (like ASAP or C³RS) or an open participation system (such as ASRS or CHIRP)? Limited participation systems like ASAP offer closer articulation with industry actors and may thus offer easier links to corrective action and integration into corporate safety management systems and risk management frameworks. However, they also involve significant direct role for industry (employers) in the investigation of reports, which might impact the level of trust reporters have in the system, adversely affecting their willingness to report [6.9].
- Protection of PII: A common element of most reporting systems is the de-identification of personal information from submitted reports, though the level of removal and processes for during varies. This is often viewed as a critical to ensuring reporter's trust in the system. Notably, most systems operate on the basis of confidentiality, not anonymity. This allows reporters to be contacted for clarity, while providing provisions to protect them from discipline, retribution, or enforcement.
- Immunity Provisions: A number of reviewed systems include specific protections to provide immunity for reporters from disciplinary actions in response to submitted reports. These immunity provisions may be statutory (ASRS, ASAP) and in limited participation programs may be supported by provisions in the MOUs between the agency and companies that act to limit company disciplinary action on reporters.
- Operations Model: Several systems have chosen to involve a neutral third party to operate the system. This is seen as removing potential for conflict of interest and for increasing the trust that reporters

place in the system [6]. It mitigates tensions agencies might feel between an enforcement or regulatory role and an industry promotion role. However, it places a tier of actor between the reporting of issues and the ability to issue corrective actions.

- Distinction in Purpose: Closely related to the concept of open vs. closed system, is the concept the while systems of this type may appear to be focused on the same challenges, there are in fact key distinctions. Some systems – such as ASAP, C[3]RS – focus on more immediate corrective actions, with contribution to cross-cutting trends as a more secondary feature. While others – such as ASRS – focus on trends and cross-cutting factors – with immediate corrective action secondary. This choice of purpose has implications for the design of the system

Writing in an early analysis of the railroad-industry C[3]RS Jordan Multer and colleagues suggest that in 'high hazard' industries "bridging the gaps between event reporting, problem identification, and implementation of solutions presents significant challenges to the effectiveness of reporting systems [18]" No single system can serve all objectives. In reality most industries have multi-tiered safety reporting structures. The C[3]RS is implemented in conjunction with company-level reporting systems at the participating carriers. The ASRS and ASAP exchange information and data, and the FAA analyzes outputs in conjunction with data obtained from FOQA (and other systems). CHIRP operates as complement to mandatory reporting systems in the United Kingdom. This may be most significant lesson to be drawn from this paper's analysis of reporting system practices in other 'high hazard' industries – that while systems like ASAP offer analogs, the most beneficial architecture as the human spaceflight industry matures will be one in which multiple voluntary systems exist in concert.

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