The Emerging Role of Safety Management Systems in Aerospace

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Abstract - **This paper outlines the reasons as to why the Aerospace organizations should begin to adopt Safety Management Systems in preventing accidents and incidents from occurring through examining case studies within the industry. It also identifies the required composition of an SMS program, as taught at the USC Aviation Safety & Security Program and adopted by the International Civil Aviation Organization and the Federal Aviation Administration. The legislative background, recommendations, and standard procedures are outlined in the ICAO documentation and FAA CFRs are presented as the regulatory framework for why aerospace should implement SMS as these statutes will likely be the guiding documents for future regulations in private aerospace.[1][2]**

Index Terms – **Safety management Systems, International Civil Aviation Organization, Government Regulations**

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I. SAFETY MANAGEMENT SYSTEMS

Technology throughout all industries is changing at an unprecedented pace. Safety and security risks continue to proliferate as systems become more complex – depending upon industry, government, and consumers all adapt to their respective roles. Whether risk is being introduced into a system through newly automated tasks, newly created manned operations, or newly created roles for individuals – the human interaction with any system plays an important role in the assessment of risk and mitigation of that risk. While a variety of models exist for either identifying hazards or mitigating against them, the model instituted by aviation internationally is the right one for aerospace. Only by implementing a complete safety management plan which incorporates the latest understanding of risk assessment and risk mitigation tools can stakeholders attain a reliable, standardized, regulatory compliant program. It is vital that the aerospace industry recognize the developing trends in safety and move forward in implementing similar systems in order to maintain secure and less accident prone operations.

Safety begins from the top down. The ideal organizations have executives leading the way by developing a safety culture that permeates their whole organization. Their safety advisor has the attention of all upper level management. The managers, closer to the front-line operations and engineers promote reporting and data collection through non-punitive reporting protocols and by encouraging individual responsibility as a method of safety assurance. The front line operators, understanding that they will not be punished for reporting errors or making honest mistakes, but report their incidents and feel a personal role in creating a safe operating environment. This is the ideal company –policy, procedure, implementation, and execution. Every person, working on different levels of organization but towards the same goal, operates with safety in mind.

While Safety Management Systems (SMS) are becoming well known for the effectiveness in promoting safety in highly complex systems and organizations, there is some resistance to full integration in many companies. Most often, there are a few misconceptions associated with the cost of implementing a full SMS program and what it means for company structure. It is often not explained that the SMS is a supplemental process - able to complement most any safety process already in place. Very soon the United States government and a variety of international organizations may mandate Safety Management Systems throughout all transportation sectors – not simply aviation. Aerospace will likely not be excluded. Currently, regulations existing in the Code of Federal Regulation (CFRs) and those being proposed by the Federal Aviation Administration (FAA) include language that does not recommend, but necessitate, full development of SMS for any commercial airport or

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commercial air service provider operating within the United States.

These SMS regulation parallel the syntax of other SMS guidelines operating internationally and include all future Unmanned Aircraft Systems (UAS) that may someday operate in the NextGen National Airspace. Already, the FAA has been tasked with commercial space flight licensing and creating the framework for further regulation in manned aerospace. To think that Safety Management Systems won't be implemented for all transit operations is foolish, and therefore it is vital to understand how a successful SMS operates, the legislative and historical background of SMS, and how SMS is being implemented in a variety of technologically diverse and complex systems.

Safety Management Systems is a term used to identify a standardized, data driven system of hazard identifiers, risk assessment, and risk mitigation that enables highly complex systems to run. The international safety regime modeled and replicated by ICAO and the FAA, as well that taught at the USC Aviation Safety & Security Program, identifies the SMS, "as the formal, top-down business-like approach to managing safety risk. It includes systematic procedures, practices, and policies for the management of safety..."[1] This model of safety promotion is one which demands involvement by the top executives and must continue through its managers and into the line operators. A culture of safety is vital to diminishing risk – starting with policies specifically developed to promote that culture. Further, a successful SMS includes "processes that identify potential organizational breakdowns and necessary process improvements allowing management to address a safety issue before a noncompliant or unsafe condition results."[2] It is often said that regulations are written in blood – that for government or industry to change, to focus on improving the safety and security of an environment - there must be an accident that costs lives, costs time, or costs jobs. The SMS does not; it improves operations before accidents happen – identifying problem areas through data driven trend analysis of incidents and counter-productive events before they become costly, sometimes fatal, accidents.

Safety Management Systems is different from previous methods of risk prevention in a number of ways. The old method of risk mitigation and assessment consists of a reactive mindset. This "old mindset," persists in the belief that "Complex systems are inherently safe, we just need to get rid of a few bad apples and everything will be okay."[3] In other words, the human element is unreliable, prone to making errors and cannot be satisfactorily mitigated out– there will always be accidents, though they should be made to be survivable on an organizational level. This understanding is representative of not safety, but of compliance. The underlying that by complying with laws and regulation at hand and by getting rid of those who commit human errors – mistakes – the organization is legal and safe. Unfortunately, this does nothing but continue to ignore systematic problems indicative of a reactive, "written in blood," safety process.

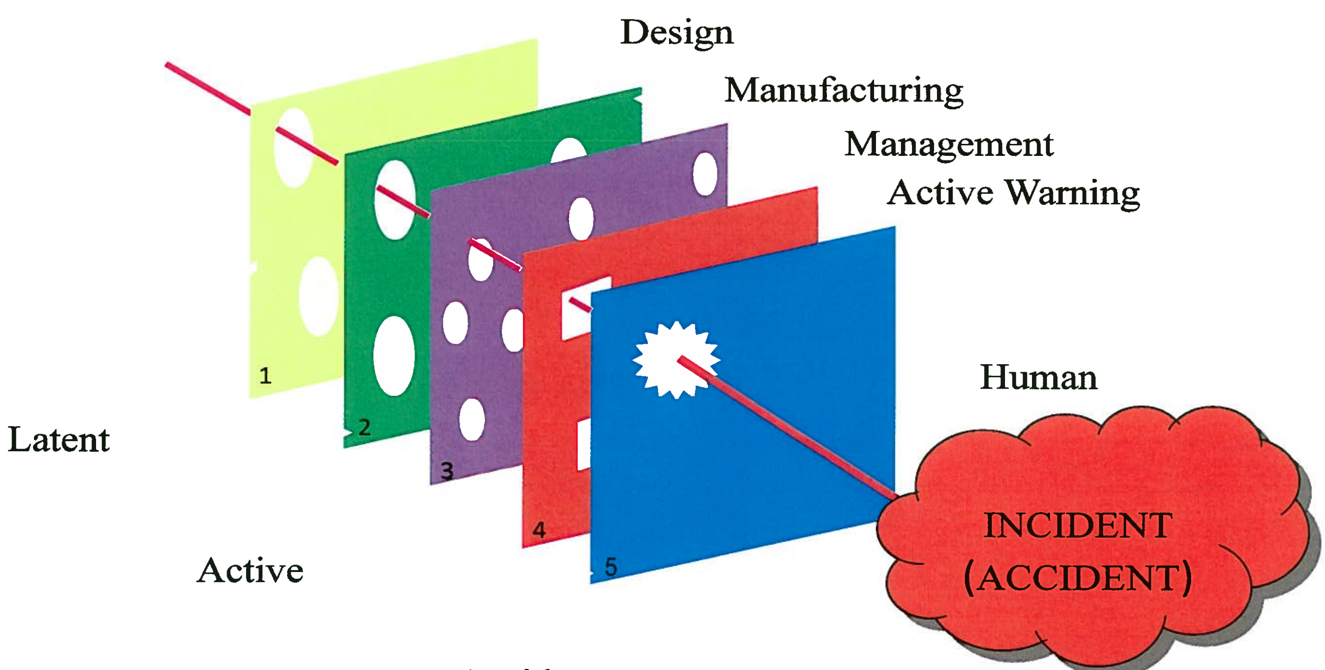

Figure: 1.1 Accident Causation Chain of Events

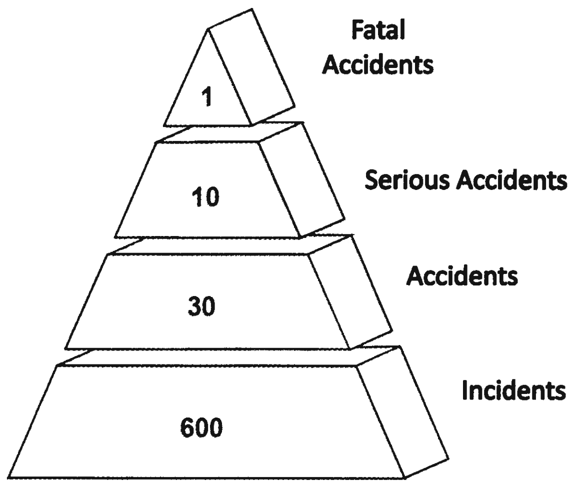

Figure 2.1: Byrd's Accident Ratio Pyramid

Accidents are not randomly occurring events left to the whim of fate; resting upon the shoulders of individuals. Engineers, operators, or managers do not work to create risk or cause damage – therefore the "human error" causation of accidents is not a valid conclusion to an investigation, and should be not used to "explain away" accidents. Accidents must be understood to be the systematic, final repercussion in a flawed system. Individuals do not intend to cause accidents, not do a poor job; yet somehow accidents occur from human interaction in the system. Human error, therefore, "is the effect or symptom, of deeper trouble… [It is] not random. It is systematically connected to features of people's tools. Tasks and operating environment… [It is] not the conclusion of an investigation. It is the starting point."[4] Most systems currently have some mitigation that helps to prevent errors – redundant systems, checklists, multiple "sets of eyes" that must okay an operation are all examples of these mitigations; however no system is completely safe and incidents do occur signaling flaws. When these flaws are repeated, regardless of the many layers of mitigations already in place, incidents will happen for a variety of reasons – complacency, mechanical failings, maintenance errors, or a variety of other organizational behaviors that tend to exacerbate systematic inefficiencies. These hazards begin to align, and eventually an accident occurs – a depiction of this can be seen in Figure 1.1. Systems are flawed (prone to risk), and those flaws are inevitably expressed in incidents that do not cause damage, death, or injury. Those incidents, however, lead to accidents unless the tensions and stressors that create the flaws within the system are successfully assessed and mitigated. By acknowledging that systematic flaws, not flaws within individuals, lead to incidents which are then expressed in accidents, the first step towards SMS is taken.

Frank E. Bird, Jr., writing in 1969 as the Director of Engineering Services for the Insurance Company of North America, offered the first insight into the organizational behavior model employed by SMS today while he attempted to determine the definitive ratio of accidents to incidents for manufacturing. By examining 1,753,498 accidents reported by 297 cooperating companies from 21 different industrial groups, he created the chart found as Figure 1.1. Byrd found that for every 600 incidents that occur within a system, there will be 30 accidents, 10 serious accidents, and 1 fatal accident.[5] These findings, now widely accepted as cannon by safety engineers, show that incidents and accidents are systematic and not individual in nature; that "bad apples" are not to blame for problems, but that problems should be traceable – through data collection and analysis. This is where only a Safety Management System provides the assessment and mitigation tools and techniques necessary for aerospace, aviation, and rail. Highly risk prone systems such as those fundamental to aviation, rail, aerospace, etc. must implement safety mitigation techniques at the forefront of safety science and thought.

Safety Management Systems is not a term that is undefined or can be used to identify any number of safety improving, or accident preventing, methods of risk mitigation. There are a few very important characteristics that define an SMS; being included in the official definitions supported by the United Sates Government. Within the SMS there are basic components which help to codify the four basic elements of the SMS: The Safety Policies and Objections, the Safety Risk Management, the Safety Assurance, and Safety Promotion. These two elements of Safety Management Systems can be found in all documentation referring to implementation of an SMS program. In the Aviation industry, an SMS reference can be found in regulations from the International Civil Aviation Organization (ICAO) acting as the international civil aviation authority, Canadian Aviation Authority (CAA), Australian Civil Aviation Authority (ACAA), or the Federal Aviation Administration (FAA) acting as domestic aviation authorities – all signatories to the ICAO accords.

The Safety Policies and Objectives can be broken down into five obligations and definitions vital to the success of the SMS. These obligations are: 1) Management commitment and responsibility; 2) Safety accountabilities; 3) Appointment of key safety personnel; 4) Coordination of Emergency Response Planning; 5) SMS Documentation. The Safety Risk Management sections contain only two obligations: 1) Hazard Identification; 2) Safety Risk Assessment and Mitigation. Ultimately, this succeeds in assigning roles and responsibilities for safety and emergency planning, outlines how data will be collected, explains the methods risks will be assessed, and designs mitigations for those risks. The Safety Assurance sections often refer to how the changes to safety are monitored and by what measurement the changes are evaluated. The final component, Safety Promotion, outlines training and education as well as other methods of communicating the importance of safety. These "four pillars" of SMS combine to create a management process that empowers individuals from the top down, and explains exactly how safety can be promoted within a technical organization. Coupled with an organization that actively promotes a "just culture" on all levels – engaging front-line operators and engineers in non-punitive self-reporting for data acquisition – the four pillars of SMS will create a safer, more secure, organization.

II. THE PROBLEM

Many in the aerospace industry are still stuck in the mind frame of blame – user error, poor systems engineering, and disregard for standard operating procedures on the part of the design teams or operators leading to the failings of systems and missions. However, as Nancy Leveson of the Software Engineering Research Laboratory at MIT points out in her team's comprehensive examination of both aircraft and aerospace accidents, "…some striking similarities in systemic factors were identified… flaws in the safety culture, ineffective organizational structures and communication, and ineffective or inadequate technical activities…" were fundamental causes of the accidents.[6] Leveson's team examined 10 different accidents from both the aerospace and aeronautic industries to evaluate the use and effectiveness of the accident reports for preventing future incidents accidents. This investigative analysis of causation chain accident reports included: Ariane 5, Challenger, Mars Climate Orbiter, Mars Polar Lander, Titan IV/Milstar, Warsaw, Nagoya, and Cali events. Among all accidents were found the following assessment identified above. The findings of the report support the belief that developing a just and pervasive safety culture of non-punitive measure designed to pro-actively assess risk to prevent accidents is needed as the accident reports and findings were unsatisfactorily written and investigated through "information filtering," "subjectivity or bias," and "attempt to assign blame."[7] While the report goes on to recommend that an entirely new form of accident investigation be developed - different from the accident causation chain in that it uses control theory of system engineering in order to attain a more scientific approach to fault analysis and causation – this is maybe unnecessary and would only add to the "overbearing, strangulating" safety engineering taking place in many organizations.[8] A full Safety Management Systems, developed and implemented modeled along the lines of the Aviation Industry would go a long way in helping to prevent the incidents and accidents costing tremendous drain on reputation and financial wellbeing of NASA specifically, and aerospace more generally, while lessening the burdensome "strangulation" of in-house safety departments. Aerospace is a field now in which costs are very high on a per mission basis, exposure to the public is very high, and questions as to mission significance by the public is are constantly being raised. Each and every accident brings significant costs, and therefore aerospace must explore every opportunity to promote safety in order to maintain support.

Organizational behavior is a component of all business public or private, operations or development, engineering or policy. All industries have certain cultural elements that define the pervasive characteristics impacting decisions of engineers, operators, and management. While they are not all negative – and a variety of organizations within industries that are inundated with negative cultural elements may have very positive environments – they do lead to incidents, accidents, and fatalities. Accident reports often overlook these elements and provide an incomplete understanding as to how important organizational behavior can be in the operations of complex systems; instead of choosing to focus on "simplistic" answers, and "human error." While finishing investigations with human error as the causal factor has recently become taboo, alleviating the systematic factors within complex organizations remains more difficult, and thus SMS is necessary. Simply put, the need for SMS integration goes beyond industry, organization, or system.

Creating a culture that embraces safety and efficacy should be a priority for all managers and executives; however, the entrenched standards of operation often prevent momentum building in favor of real, systematic change. Such is the case in the Deepwater Horizon accident investigation entitled Deepwater: the Gulf Oil Disaster and the Future of Offshore Drilling – Report to the President. In this report to the President of the United States, the Chief Council reported, "all of the technical failures at Macondo can be traced back to management errors by the companies involved in the incident… BP personnel were not properly trained and supported." Further, they reported, "BP did not adequately identify or address risks… and that it is common in the offshore oil industry to focus on increasing efficiency to save rig time and associated costs. But management processes must ensure that measures taken to save time and reduce costs do not exacerbate overall risks."[9] Failures in communication and management were found to be directly related to inadequate safety culture focused on profits above safety. Another of the greatest disasters of our time can be linked directly to mismanagement and an inadequate safety culture. The Chernobyl accident investigation had immediately determined that "the root cause of the Chernobyl accident, it is concluded, is to be found in the so-called human element… the lessons drawn from the Chernobyl accident are valuable for all reactor types."[10] That is to say, that human error – an individual's mistake – had led to the tragic nuclear disaster at Chernobyl. The investigation would be finished; no systematic errors rooted out nor lessons learned. However, in 1992, the IAEA revisited the issue of Chernobyl and determined, "The (Chernobyl) accident can be said to have flowed from deficient safety culture, not only at the Chernobyl plant, but throughout the Soviet design, operating and regulatory organizations for nuclear power that existed at the time… Safety culture… requires total dedication, which at nuclear power plants is primarily generated by the attitudes of managers of organizations involved in their development and operation."[11] Revisiting the issue led to the IAEA changing the findings of the investigation; it was decided that safety culture, organizational mismanagement, and failings in upper level safety training led to the Chernobyl accident. This finding helped to prevent future accidents. It showed that the Chernobyl accident was not the random confluence of events caused by individuals but systematic failings by multiple levels of management.

There is the problem. Organizations exist today that believe their safety management and structure are working and will continue to work. Unfortunately, as Dr. James Reason pointed out, "If you are convinced that your organization has a good safety culture, you are almost certainly mistaken – A safety culture is something that is strived for but rarely attained – the process is more important than the product." As to aerospace, is there an example where safety management failed and resulted in an accident? There perhaps is no better example so widely known as the Challenger accident, investigated by the Rogers Commission in which they found factors, "not unique to NASA, but… common in many industries and organizations."[12] Among the systematic factors contributing to this national tragedy are: "Overconfidence and complacency… because… Shuttle flights had become routine…. Acceptance of escalating risks"… and contradictory perceptions of risk held by engineers and upper management; "Over relying on redundancy;" "Ignoring warning signs" presented via "engineers writing memos" and "management briefs;" "Low priority Assigned to Safety" beginning with the undervalued and ultimately "silent" Apollo safety program to which resources were cut, reductions made to quality control, safety, and reliability assurance; and "Flawed resolution of conflicting goals."[13] All of these contributing factors led to a tragic accident based in systems engineering rather than individual failure. Like any other industry prone to high levels of risk, aerospace must integrate advanced SMS techniques. Assessing that risk present is the first step in preventing future accidents, and ensuring that the race further into space continues and picks up speed.

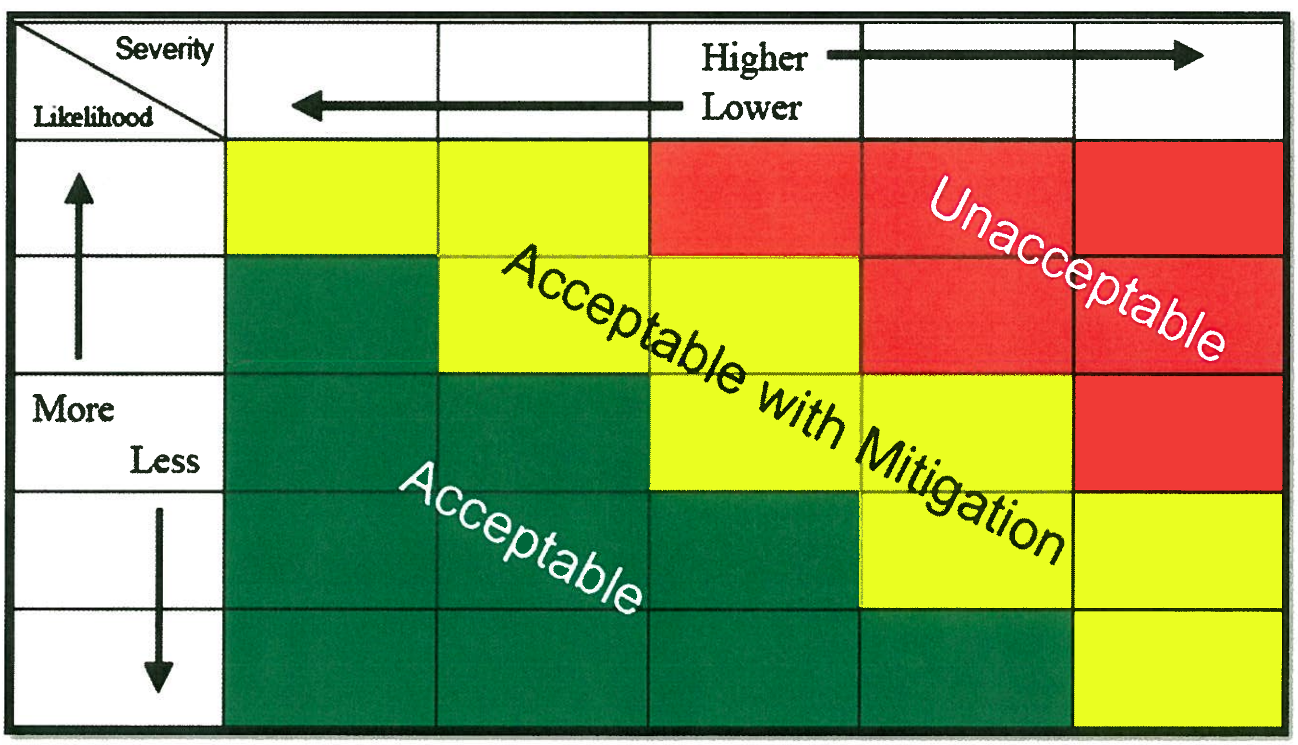

Figure 3.1: FAA Risk Assessment Matrix

III. RISK ASSESSMENT:SEVERITY AND LIKLIHOOD

Proper risk assessment is the key to a successful SMS program. Without appropriate and replicable methods for assessing risk there is no foundation for a program to understand the role of identified hazards within a system. Risk assessment is now understood within a variety of industries to consist of two necessary elements for determining impact on any transportation system – aeronautical or otherwise. These two elements determine the level of risk to an organization presented by a given event (accident/incident) and thus to what degree it must be mitigated. These two parts are severity and likelihood. By understanding these very important characteristics of any hazard, the necessary mitigation can be established and the necessary precautions are explored. Often times this matrix brings together both quantitative and qualitative analyses to produce a grid on which events are graphically represented. Events are then plotted into such categories as desirable, tolerable, or intolerable. Risk must start with an identified hazard and its accurate consequences.

Severity is a fundamental term taken to mean the level of impact an event will have on an organization in the "worst credible state.[14]" Understanding that severity relates to the impact on the organization - the degree of negative effect – is vital to determining what risks are necessary to mitigate immediately, mitigate through constant vigilance, or tolerate in the long-term as endemic to a system. Incorrect assessment of the severity of an event, however, can occur as this is a qualitative analysis, highly dependent on the opinion and foresight of individuals within an organization; this the greatest criticism of this method in the science commuting – that it leaves too much decision processing to qualitative measures.[15] While severity is vital in categorizing the types of events tolerable and intolerable within a system, the second aspect – likelihood – is just as important in developing the matrix for mitigation. The FAA requires that all SMS programs include severity as a determinant for event mitigation. The equation for determining a risk when a hazard within a system (an assumption) is identified is:

$$Hazard \times Severity \times Liklihood = Risk \qquad (1)$$

The second variable for the analysis of hazards in a system looks toward the probability that an event will happen and is highly dependent upon the effective use of acquired data through organizational reports. Likelihood of an event to occur examines the rate of occurrence characterizing a specific undesirable event within a system. Probabilities are examined for how often the event occurs based upon acquired data from within an organization via personal reports, employee debriefings, computer error reporting, accident and incident investigations, and security reports. From external sources, a Transportation System wide system of data reporting can be the greatest source of data in preventing incidents and accidents; the Aviation Safety Reporting System run by NASA is the best example of this type of public data source as its sources are highly reliable and secured through non-punitive reporting methods. By encouraging any aviation industry front-line operative to report incidents with the promise of immunity from prosecution, the data contained within the ASRS is constantly used to examine incident occurrences and therefore show likelihood of specific event occurrences in a system wide population. The rail system in the United States has also adopted the use of non-punitive reporting though it is less used, and far less useful for developing a system event probabilities – this is often attributed to the very low rate of incident reporting due to an inadequate safety culture culminating in a much higher rate of accidents.[16]

By bringing together these two elements of risk analysis, we begin to see how assessments can be used to evaluate the types of risks that do not require mitigation and those that do, as well as the hazards that may be endemic to a system, but should be watched and looked for in a system. By examining both the likelihood that a risk will occur and the severity characteristics of those risks, an appropriate decision can be made as to how to allocate resources to better ensure the safety and security of a transportation system such as aerospace, aviation, rail, or marine. Figure 3.1 shows the Federal Aviation Administration's Risk Assessment Matrix used as an example as to how risk assessment is to be used for risk mitigation. As likelihood increases, the threshold for acceptable severity diminishes, while conversely as likelihood diminishes severity may increase for tolerable risks. In this example given by the FAA, green is the coding for acceptable – meaning to be taken into consideration but not actively mitigated against; yellow must be mitigated through data acquisition, training, monitoring, and other techniques though operations may continue; and red is completely unacceptable and must mitigated against immediately through procedural change or operating change.

Taking into consideration likelihood and severity are not simply recommendations in the aviation world, but are outlined as necessities throughout organizational guiding literature and regulations. It is paramount to promoting safety in all transportation fields – aerospace, aviation, marine, rail, and all autonomous variation therein.

IV. LEGISLATIVE GUIDANCE

Aerospace will not be an industry dominated by government mission or relegated to fringe elements of the private sector much longer. Already, privately funded space tourism has developed great interest. Companies like SpaceX, Virgin Galactic, EADS, Space Adventures Limited, and Bigelow Aerospace are pushing for sub-orbital, orbital, and circumlunar space tourism within the next two decades driven by private business models rather than government contract. The question of spaceflight for profit rather than science is not an *if*, but a *when*, and therefore legislation and the books of regulation empowered by legislative acts are soon to follow. By examining current trends in regulation in similar industries, aerospace can better prepare itself for the future of safety regulation in both private and public sectors. Further, by identifying those organizations most likely to influence aerospace safety programs in the future, companies can better prepare for the regulation to come. The domestic organization thus far to be empowered by Congress in governing commercial space flight is the Federal Aviation Administration, FAA, while the international regime will more than likely be a United Nations sub-committee much like ICAO.

Safety Management Systems regulation has taken sometime to evolve into its current form. Until recently, SMS has been just a recommended practice throughout aviation, however this is changing and it is clear the International Civil Aviation Organization, as well as the Federal Aviation Administration, will be expecting all parties to their jurisdiction to adopt SMS practices if not a full SMS program. By examining the regulations presented by both organizations, as well as recognizing the safety trends in similar industries, aerospace will garner a better understanding of how future regulation may require SMS programs for the industry. The question then becomes, as international organizations begin to explore privately managed manned spaceflight, what organizations will take the lead in developing regulations. Already the FAA has issued regulations regarding screening procedures and training for emergency situations, and the infrastructure exists for the licensing of public safety and safety of property for suborbital rocket missions under the Code of Federal Regulations Title 14, Chapter III, given power by the Commercial Space Launch Amendments Act of 2004. Simply put, as aerospace diversifies in number and in mission, the regulatory regime governing it will also grow to include SMS. Within the United States aerospace companies will adhere to FAA regulations, while internationally they will be guided by an organization similar to ICAO.

The International Civil Aviation Organization

SECTION	Chart 1.1: ICAO, Annex 6, Section 3
3.3.1	**States shall establish a State safety programme in order to achieve an acceptable level of safety in civil aviation.**
3.3.3	**States shall require, as part of their State safety programme, that an operator implement a safety management system acceptable to the State of the Operator, that as a minimum:** **a)identifies safety hazards;** **b) ensures the implementation of remedial action necessary to maintain agreed safety perfomance;** **c) provides for continuous monitoring and regular assessment of the safety performance; and** **d) aims at continuous improvements of the overall performance of the safety management system.**
3.3.4	**A safety management system shall clearly define lines of safety accountability throughout the operator's organization, including direct accountability for safety on the part of senior management.**
3.3.6	**An operator of an aeroplane of a maximum certificated take-off mass in excess of 27 000 kg shall establish and maintain a flight data analysis programme as part of its safety management system.**
3.3.7	**A flight data analysis programme shall be non-punitive and contain adequate safeguard to protect the source(s) of data.**

(ICAO) acts as an organization to establish international aviation standards in which the various aviation authorities (FAA, CAA, etc.) of the United Nation member states (190 in total) agree to abide by the ICAO standards. Further, it is tasked with providing, "Assistance to Contracting States in the development and implementation of projects across the full spectrum of air transport aimed at improving the security, efficiency, regularity and operational safety of national and international civil aviation with a view to achieving standardization, as specified in ICAO's Standards and Recommended Practices (SARPs)." [17] In doing so, ICAO sees fit to outline at various stages the most important aspects of aviation safety to promote an international environment of security and diminished risk operations. As such, ICAO creates Standards and Recommended Practices that act "...as the minimum Standards applicable to the operation of aeroplanes by operators authorized to conduct international commercial air transport operations... to include scheduled international air services and non-scheduled international air transport operations for remuneration or hire."[18] To enforce these standards, ICAO, as part of the United Nations, utilizes audits of national safety programs to ensure signatory compliance. Further, signatories may disallow other national carriers from entering into sovereign airspace if they believe the airline to be unsafe based upon violations of the ICAO Standards and Recommended Practices. Ultimately, the national safety program regulation enforces the safety and security of air carriers while the ICAO Standards and Practices act as the guiding documents for minimum standards.

ICAO Annex 6 outlines the necessary role of SMS in flight operations. Annex 6, Section 3.3 defines the SMS inclusions as first the necessity of having an SMS and third in defining what must be included in the SMS as per Chart 2.1 As such, ICAO creates Standards and Recommended Practices that act "...as the minimum Standards applicable to the operation of aeroplanes by operators authorized to conduct international commercial air transport operations... to include scheduled international air services and non-scheduled international air transport operations for remuneration or hire."[19] To enforce these standards, ICAO, as part of the United Nations, utilizes audits of national safety programs to ensure signatory compliance. Further, signatories may disallow other national carriers from entering into sovereign airspace if they believe the airline to be unsafe based upon violations of the ICAO Standards and Recommended Practices. Ultimately, the national safety program regulation enforces the safety and security of air carriers while the ICAO Standards and Practices act as the guiding documents for minimum standards.

ICAO Annex 6 outlines the necessary role of SMS in flight operations. Annex 6, Section 3.3 defines the SMS inclusions as first the necessity of having an SMS and third in defining what must be included in the SMS as per Chart 1. ICAO clearly requires that an SMS program exist for all carriers operating in signatory countries, defines the minimum make-up of the SMS and includes recommendations as to how to ensure that the SMS is successful. In 3.3.4, ICAO ensures that there will be "clearly defined lines of safety accountability," recognizing the vital role that communication and role definition plays in SMS. In Section 3.3.6, ICAO includes the need for flight data analysis and accumulation of that data, but does not go into process. By also including the the data source acquisition method – 3.3.7 – ICAO attempts to outline the most advanced method for data collection as exemplified by the Aviation Safety Reporting System Database run by NASA; non –punitive, protected reporting by anyone in an organization. Further along in ICAO International Standards and Recommended Practices documents, Annex 8, Airworthiness of Aircraft follows the same SMS outline-paralleling the same thoughts for how to promote safety not in operations, but in development of aircraft. The wording is nearly identical in Annex 8, Section 5 as seen in Chart 1.2Using the same wording for operations and design/manufacture offers an interesting trend or thought behind developing the Safety management System. There must be an underlying belief that these core elements of the SMS – pro-active risk assessment, risk mitigation, data acquisition, and constant revisiting of safety goals and realizations – are vital to safety from the very beginning of development to the very end of operations. Annex 14 regarding Aerodromes further uses this model for SMS requirement in Annex 14, Section 1.5 reinforces this belief in SMS design. As ICAO outlines these safety program inclusions, so do does the United States parallel these requirements; defining a safety program with the exact same wording.

The management and data acquisition/data analysis portions are also paralleled in Annex 8 but for the purposes of this paper are not necessary to include verbatim. The domestic governing body in the United States is of course the Federal Aviation Administration. The FAA – as the regulatory agency tasked with ensuring that United States promotes safety and continues to remain internationally compliant with ICAO – has modeled the domestic safety programme requirements upon the ICAO model. The FAA, already responsible for regulating space flight launch licensing, is thus identified as the most likely entity within the government to set those requirements - as their operations are both similar in nature and specialized in airspace control.[20] With the FAA already regulating space takeoffs within the United States, it is not unthinkable that the future of private space flight will further be regulated by the SMS model adopted by the FAA.

SECTION	Chart 2.1: ICAO Annex 8, Section 5
5.1	**States shall establish a State safety programme in order to achieve an acceptable level of safety in civil aviation**
5.3	**from 14 November 2013, a State of Design or Manufacture shall require, as part of its State safety programme, that an organization responsible for the type design or manufacture of aircraft implement a safety management system acceptable to the State that as a minimum** **a) identifies safety hazards** **b) ensures the implementation of remedial action necessary to maintain agreed safety performance;** **c) provides for continuous monitoring and regular assessment of the safety performance; and** **d) aims at continuous improvements of the overall performance of the safety management system.**

Mandating Safety Management Systems in the United States is fairly new. While many industries have voluntarily adopted this high standard of safety program, the United States government has not been as quickly to act as international governing boards. This is quickly changing as there exist two main rules open for comment by the public as Notice of Proposed Rule Makings (NPRMS) – the final stop before final rule issuance and inclusion into the Code of Federal Regulations. Further, Advisory Circulars regarding SMS for aviation have been issued by the FAA since 2006 denoting what an SMS program is and how to implement it in a satisfactory way. The two NPRMs most important to SMS in the national airspace are 14 CFR Parts 5 and 119[21], and 14 CFR Part 139.[22] Both proposed rules require "each certificate holder…to develop and implement a safety management systems (SMS) to improve the safety of their aviation related activities… an organization-wide safety policy; formal methods for identifying hazards, controlling, and continually assessing risk; and promotion of a safety culture." Both NPRMs also include reference to previous FAA Advisory Circulars and reference the "four pillars" of an SMS program – "the safety policy…development of processes and procedures to provide an understanding of the carrier's operational systems to allow individuals to identify hazards associated with those systems… safety assurance [ensuring] the performance and effectiveness of safety risk controls established under risk management… and the fourth component… safety promotion… training and communication of safety information to employees to enhance the organization's safety performance."[23] The final stakeholder comments for these proposed regulations are due July 5, 2012 at which point the FAA will modify the proposed rules based on industry comments and then issue the final rule making decision which will then be put in the Code of Federal Register as Federal regulation. On March 31, 2010, in support of SMS implementation based upon pilot program analysis, the FAA issued a Final Report from the SMS Aviation Rulemaking Committee with the conclusion that there was "evidence of cost savings and cost avoidance within organizations that have implemented major tenets of SMS."[24]

The final piece of regulation that helps to identify why the aerospace should expect to adapt their safety processes to a FAA model, is the example of Unmanned Aerial Systems operating in the national airspace. With foresight, the FAA has already begun to include all Unmanned Aerial Systems (UAS) with other aviation systems for SMS regulations. Unmanned Aerial Systems, in a similar developmental phase as commercial spaceflight within the national airspace – in that operations are heavily regulated by the Federal Government, but with future launches and flights expected to multiply dramatically in a less regulated manner - is already being included in FAA publications. In the latest Advisory Circulars concerning Safety Management Systems, published in August 2010, the FAA asserts that:

Within the context of this document, the term aviation service provider refers to any organization providing aviation services. The term includes certificated and non-certificated aviation organizations, air carriers, airlines, maintenance repair organizations, air taxi operators, single pilot operators, corporate flight departments, repair stations, pilot schools, approved training organizations that are exposed to safety risks *during the provision of their services. This includes all entities involved in Unmanned Aircraft System activities. The term aviation service provider is interchangeable with the term service provider and organization within this document.*[25]

The FAA is preemptively including unmanned operations into the federal register. An industry heavily regulated by the United States government that cannot operate without special licensing is included in the SMS framework issued by the FAA Advisory Circular. This indicates that the FAA will impose the SMS regulation on all of the industries it regulates – to include the aerospace industry as soon as commercial space flight and private aerospace missions become more common and feasible. Aerospace and Unmanned flight are both on the forefront of technology, introducing new complexities into the national airspace, and advancing the science of transportation. Both industries will be required to implement SMS by the FAA, and both will be successful or fail based upon their safety record. The similarities are enough to explain why aerospace must examine the safety management systems necessary to be compliant with regulations and safe in operations.

V. CONCLUSION

The aerospace industry is moving forward into an exciting frontier that promises to offer old and new challenges alike. Their ability to assess and mitigate hazards will ensure the success or failure of their missions. By adopting the Safety Management Systems model exemplified in the aviation industry, as required by the International Civil Aviation Organization of the United Nations, and as modeled by the Federal Aviation Administration of the United States, the aerospace industry will proactively increase design and operation safety as well as be compliant with regulations most likely to be proposed and implemented. As the Federal Aviation Administration has already been empowered by Congress to regulate commercial space flight requirements, it will continue to design and implement regulations for the industry and will model its safety standards after those already utilized in manned and unmanned aviation.

This paper outlined the problems that aerospace faces in terms of organizational behavior and safety culture using case study identifications from a wide variety of highly complex and important industries. It also identified the required composition of an SMS program, as taught at the USC Aviation Safety & Security Program and adopted by the International Civil Aviation Organization and the Federal Aviation Administration. The Legislative background, recommendations, and standard procedures as outlined in the ICAO documentation and FAA CFRs were presented as the regulatory framework for why aerospace should implement SMS as these statutes will be the guiding documents for future regulations in private aerospace.

VI. REFERENCES

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