AVIATION SAFETY MANAGEMENT SYSTEMS: A COMPARATIVE ANALYSIS BETWEEN SAFETY MANAGEMENT SYSTEMS (SMS) AND MAINTENANCE STEERING GROUP VERSION 3 (MSG-3)

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ABSTRACT

Improving safety was the goal when Maintenance Steering Group (MSG) was first introduced for the Boeing 747 in 1968. The goal was to develop a system of evaluation for scheduled maintenance by using decision logic. This was MSG-1. As theory evolved, MSG-2 brought process orientation and failure modes analysis. Then in 1978, United Airlines, commissioned by the Department of Defense, developed a methodology based on tested and proven airline practices. With that MSG-3 was born. MSG-3 is the current standard for risk management in aviation (McLoughlin, 2006). In 2006, ICAO released a new initiative known as Safety Management Systems (ICAO, SMM, 2006). All domains within aviation will be required to implement a safety management system that complies with ICAO's guidelines set forth by member states within their own regulations. This is the SSP or State Safety Program. The goal is to provide support for continued evolution of a proactive strategy to improve safety performance (ICAO Safety Management, n.d.). Aviation safety is key, but it is certainly not a new goal. The purpose of this paper is to compare the two programs, MSG-3 and SMS. The study reveals similarities and differences of organizational structures and procedures required to carry out the programs. By identifying growth areas for expertise and personnel, this analysis may be of interest to those starting the journey into SMS.

KEYWORDS

Safety Management Systems; MSG-3; evaluation.

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1. INTRODUCTION

The International Civil Aviation Organization has created a world-wide initiative, called SMS (Safety Management Systems), with the goal of enhancing safety through risk reduction for aviation organizational systems. While SMS is a relatively new initiative, it is not the only aviation safety program. MSG (Maintenance Steering Group) addresses engineering and maintenance technology system safety in aviation. Both programs address system safety in aviation operations. Significant parallels exist between these two major aviation safety methodologies.

The paper is organized into several sections. Section 1 is the abstract of the comparative analysis of these two safety systems. Section 2 is the Introduction. Section 3 is the literature review. Sections 4 and 5 provide overviews of origin, evolution, purpose and methodologies for MSG and SMS respectively. Then Section 6 compares MSG and SMS directly by describing the safety systems aligned with the four SMS pillars: Safety Policy; Safety Risk Management; Safety Assurance and Safety Promotion. These pillars are general enough to cover the most relevant material of both programs. Section 7 discusses the issues related to data reporting. Section 8 is the conclusion which highlights the key points revealed within the comparative study.

This comparative study identifies similar strengths that include: the mission of safety in aviation; the methodology of identification of hazards and analysis of risk; constituent participation (team work); and accountability and oversight. Differences are revealed as weaknesses in the area of personnel and their level of expertise. However, MSG has a long history in performing these analyses using well defined data systems and technical knowledge. By analyzing the similarities and differences, best practices can be identified. These practices can be applied to SMS as the program develops.

2. LITERATURE REVIEW

This comparative analysis relates to two major aviation safety systems, MSG-3 (Maintenance Steering Committee, version 3) and ICAO's, SMS (Safety Management Systems). These two safety systems have a significant impact on the entire aviation industry. However, MSG-3 was introduced approximately 40 years prior to SMS. MSG-3 has a more specific focus on technology for aircraft design, but both MSG-3 and SMS are relevant to operations. Valuable resources are available for both systems. Documentation of the purpose, processes and outcomes come from manufacturers, government entities, journal articles and even from personal experience of this paper's author.

Sources for MSG-3 include an original training manual from Douglas Aircraft Company, Boeing publications, Aviation Today, and the Federal Aviation Administration. This MSG-3 training manual (1992) from Douglas Aircraft Company was used to prepare engineering and operational personnel, within transport category manufacturing and airlines, for the rigorous analysis of hazard identification, risk analysis, design and also maintenance and operations requirements. This manual provides detailed information that enable a comparative analysis with the methods required of SMS.

Articles provide clear explanations of the MSG-3 process (Adams, 2009; McLoughlin, 2006). These sources cover the key aspects of the MSG-3 program. The FAA issued mandatory requirements for data gathering and analysis (FAA, 2013). Articles related to Just Culture are valuable for reinforcing the need for reporting as an important but controversial safety issue (A Just Culture, n.d.; Delmas, 2012). Safety reporting is an important issue that should be addressed within the framework of SMS.

Locating sources for SMS was not difficult since SMS is a current and popular topic. Publications are readily available and extensive. The ICAO issued SMS as a Standard and Recommended Practice for all 190 member-states (ICAO Annex 19, 2013; ICAO SMM, 2013). The initiative is so widespread that the member states are still in the process of mandating SMS for the various aviation domains. In the United States, the FAA mandated SMS for the airlines first (FAA, 2015) and then for certificated airports (FAA Federal Register, 2016). It is not known when more FAA SMS directives will be released for other aviation entities.

A steep learning curve currently exists, since many personnel within these organizations are not familiar or comfortable with the rigorous analytical requirements of SMS; hazard identification and risk assessment. In order to facilitate the process of incorporating SMS, the FAA issued Advisory Circular AC 120-92B (2015) as guidance for air operators. The ACRP (Airports Council Research Program) issued several reports that clearly explain SMS procedures for their constituents (ACRP, 2007) (ACRP, 2009) (ACRP Synthesis, 2012). This material provides the necessary guidance for airports. However, guidelines alone are not enough. FAA regional offices offer direct assistance for their jurisdiction (Taira, 2014). Experience will provide a rich environment for fine-tuning SMS policies and methodologies.

MSG-3 has proven to be an effective safety management program over time. It will be years before SMS is fully integrated within the aviation industry. The expected outlook is for improved safety through improved reporting of safety issues (Howell, 2016), implementation of risk analysis, comprehensive data analysis and continuous monitoring of corrective actions.

This comparative analysis of these two major aviation safety programs reveals lessons learned and best practices.

3. SAFETY THROUGH STANDARDIZATION: MSG-3 OVERVIEW

The MSG-3 methodology has been used in aviation for decades. It officially began in 1968 with Boeing and United Airlines who put together the first version of MSG for the Boeing 747. MSG evolved over the years to its present version of MSG-3 (McLoughlin, 2006). The evolution of safety in aircraft design went from reacting to failures (catastrophic accidents) to proactively replacing parts prior to failure or providing a back-up part, system or load path for the potential failure; to prevention of failures through advanced design and inspection. This evolution transpired over 60 years of experience. The changes are tied to advances in design philosophy. Accidents have driven the design standards from safe-life to fail-safe to damage tolerance. Damage tolerance was one of the reasons for MSG-3 development (MSG-3 Training Manual, 1992).

The earliest maintenance programs were developed by experienced maintenance technicians from the operators along with the aircraft manufacturer's engineers. Together they reviewed maintenance issues and determined maintenance procedures and intervals that established the maintenance program. This resulted in a rather conservative program to pre-empt failures due to metal fatigue (MSG-3 Training Manual, 1992).

The purpose of MSG-3 is to design airplanes with the highest possible level of reliability for safety and economic reasons. United was the first airline in 1968 to utilize MSG. Since then, MSG became the standard for the development of airline's maintenance programs. MSG yields hard time inspection and on-condition maintenance requirements that airlines will use (McLoughlin, 2006).

There is empirical evidence that shows that the type of risk analysis done for MSG-3 yields higher safety levels. MSG-3 uses failure data of systems, structures and components to determine the respective faults. That information is used to determine if there is a need for an engineered design change or a change to maintenance or operations procedures.

The baseline MSG program for any aircraft type is available to all operators. Operators can customize the program to fit their unique operating needs. For example, an airline that operates between the Hawaiian Islands, a hot, salty environment that is conducive to corrosion, and typically has a higher number of cycles and compared to flight hours, would have different inspection requirements than an airline that operates over arid land or has long routes.

MSG-3 is task oriented approach to maintenance that analyzes system failure modes from a system perspective. A common term for the analytical methodology is Failure Modes and Effects Analysis, commonly known as FMEA.

This method is used to develop the manufacturer's initial maintenance schedule, as part of the work toward aircraft certification, and is beyond the ken of many in the hands-on maintenance world. "It is often a multi-year process, involving the application of rigorous logic, the analysis of reams of data and the interaction of multiple administrative bodies" (Adams, 2009).

The analytical work of MSG-3 with Industry Steering Committee (ISG) working groups starts before an aircraft enters service when there is no in-service operational data, and it continues through the life of the aircraft type (Adams, 2009). During the design phase of a new aircraft, working groups are formed with engineers for the manufacturers, airlines and regulators for each system on the aircraft. These MSG-3 practitioners make up the ISC working Groups. Working group members do the detailed analysis and generate proposed scheduled maintenance tasks by evaluating data from the manufacturers. The working group members, representatives of the manufacturer and operators, present their results to the ISC, which approves it. The final output is the Maintenance Review Board Report (MRBR) that must be approved by the MRB chairman, a representative from the FAA (for the United States) (Adams, 2009).

Major airlines, such as American and United, have large centers for engineering and maintenance. They employ a staff of engineers dedicated full time to addressing maintenance issues, including inspections, repair and replacement. Reliability engineers evaluate the failures of components. Airline engineers are in close contact with the aircraft and supplier manufacturers' product support and engineering personnel. Data from all technical issues is recorded and shared between manufacturer, operators and the FAA. Major airline operators share authority to determine their maintenance and inspection intervals because huge fleets yield huge amount of information. They are the experts in maintenance operations since it is the airlines, not the manufacturers, who are responsible for all airliner maintenance.

Small airlines typically do not have the resources for staffing support staff like the majors nor can they produce huge amount of data since their fleets are so much smaller. So they rely more heavily on recommendations from the manufacturer.

Each airline must have a maintenance program in order to get an FAA approved operating certificate under FAR Part 121. That maintenance program becomes ATA Chapter 5 of the maintenance manual.

Operators have access to each other’s findings. Aircraft manufacturers host conferences and invite all operators to share technical engineering and maintenance information (Whittaker, n.d.).

The crux of MSG-3 lies with its vast amount of in-service reliability data. Reliability is determined by Mean Time between Failures (MTBF). Air carrier certificate holders and certificated domestic and foreign repair stations are required to submit reports on failures, malfunctions and defects of aircraft, aircraft engines, systems and components (FAA, 2000, p. 56192).

These reports are submitted to the FAA in the form of Service Difficulty Reports (SDR’s) per section FAR part 121.703. The reports provide the FAA, and other aviation constituents, statistical data necessary for planning, directing, controlling and evaluating certain assigned safety-related programs. The data can be used to alert appropriate segments of aviation of safety issues; to support safety inspections and investigations for accidents and incidents and as data for aviation safety/accident prevention programs (FAA, 2000, p. 56192).

The FAA organizes the information by aircraft type and structure, system or component. They send that information to the respective aircraft manufacturer to determine corrective action. This failure data, empirical evidence, also provides reliability data for new aircraft MSG-3 analysis, since most systems and components are not new designs, even for new aircraft models. Most structures, systems and components have been in service on older models and have a documented reliability. These are often used in a new aircraft type if they meet the desired design criteria (Whittaker, n.d.).

4. SAFETY MANAGEMENT SYSTEMS (SMS) OVERVIEW

Standardization is the foundation of safety. ICAO is the pinnacle of aviation safety standards world-wide. All 191 member-states have agreed to abide by ICAO’s Standards and Recommended Policies (SARPs). The United States has been a member since ICAO since 1946. ICAO spearheaded the SMS initiative. Their definition of SMS is that it is an organized approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures. The goals are to address safety risks proactively, manage and support strategic regulatory and infrastructure developments; re-enforce the role played by the State in managing safety at the State level in coordination with service providers; and stress the concept of overall safety performance in all domains (ICAO, Annex 19, 2013).

Safety programs have evolved over time. Changes in rulemaking were considered reactive, in that safety actions were taken only after an accident. Safety organizations realized that moving from reactive to preventive would decrease accidents and save lives. Most recently, safety has evolved to being predictive (Ferguson & Nelson, 2014, p. 83).

From the 1950s into the 1970s, the focus of safety improvement was in designing better airplanes. Today's airplanes are designed with numerous improved safety features through engineering / automation. From the 1970s to the 1990s, safety research focused on human factors. CRM was developed in this era. The most current efforts are to view safety issues from a human error perspective. Rather than blame the end user (the pilot), the organization is evaluated for any and all factors that can ultimately affect the safe outcome of a mission (ICAO SMM, 2013, p. 2-2; Sudarshan, 2011).

Reason's model is well known for its method of "error trapping". Organizational factors are the first of four layers, followed by unsafe supervision, preconditions for unsafe acts and unsafe acts. Any industry can apply this model, and it is common within the aviation industry.

In 2006, ICAO released a new initiative, Safety Management Systems (SMS) with the issuance of the Safety Management Manual, Document 9859 (ICAO SMM, 2013). All domains within aviation will be required to implement a safety management system that complies with ICAO's guidelines set forth in regulations enforced by the Federal Aviation Administration.

Enhancing overall safety in the most efficient manner requires the adoption of a systems approach to safety management. Every segment and level of an organization must become part of a safety culture that promotes and practices risk reduction (ACRP, 2007).

Considering the span of time that MSG-3 has been in existence (40 years) and that SMS began within this decade; a comparison of these two worldwide aviation safety programs will increase our understanding of complex aviation safety systems.

ICAO is spearheading implementation of SMS through their Standards and Recommended Practices (SARPs). SARPs exist to help member states in managing aviation safety risks associated with the expectations for doubling the air traffic within the next 15 years (ICAO Annex 19, 2013). In an increasingly complex global air transportation system, the safety management system provides support for continued evolution of a proactive strategy to improve safety performance. All ICAO member states will have to comply with the SMS guidelines.

The safety management SARP is contained in a new annex, Annex 19 (ICAO Annex 19, 2013) for all domains. Each member state is responsible for issuing and enforcing the program through new regulation. The foundation of the plan lies within the pillars and elements that require specific planning and documentation of safety features.

The specific methodology is the creation of a safety system that is responsible for being proactive by identifying risks, including latent risks, and analyzing the probability and severity of an accident or incident occurrence.

Per the FAA's 2015 issue of SMS regulation for air carriers, credit can be given for an air carriers existing safety system structures. Large air carriers already have an established team of management personnel that have authority and responsibility for safety systems and communicate with an accountable executive. Medium size air carriers have decision making and information sharing with support from a Director of Safety. Small carriers may handle safety situations by convening an ad hoc committee (FAA Federal Register, 2015, page 1310).

SMS is not yet a regulation for organizations other than air carriers and certificated airports. But once required, there are few, if any, personnel who are trained or experienced to conduct the risk assessment analyses. Also complicating the issues is that many smaller companies do not have the personnel to cover the additional workload required of SMS. The methodology is provided in the form of guidelines (ACRP, 2009). Experience will be built upon the largest aviation organizations, such as major airlines and hub airports. The FAA has offered support through their regional offices for SMS program development (Taira, 2014).

While airlines have been reporting failures through the SDR system that benefit MSG-3, they now have to shift to the SMS program requirements of reporting hazards and assessing risk for airline operations. However, given the depth of experience with reporting, data collection and analysis, they have an advantage over other aviation organizations, such as airports.

Most airport organizations possess an insufficient background data collection of hazards and other information system elements. Data collection and management is the backbone of any SMS (ACRP, 2009). SMS relies on the hands-on maintenance and operations world to conduct assessments with rigorous logic but without the benefit of reams of hazard or failure data.

With SMS, data collection is voluntary (but encouraged) and can be confidential. That is actually a cornerstone of SMS (ACRP, 2007). Safety issues can be reported to the aviation organization (airlines or airports), the FAA or even to the NTSB.

The FAA' web-based application tool (WBAT) was originally developed as an ASAP and incident-reporting tool. It has since evolved to support risk management and assurance functions (Broderick, 2015). There are emerging SMS programs by for-profit software vendors, such as SMSPro and Pro DIGIQ. Plus, this is a service that is offered by a company, at a cost. The industry (airlines nor airports) has not agreed to collect aggregate industry safety issue data for SMS.

5. MSG-3 AND SMS COMPARISON BY PILLARS

Significant similarities and differences exist between two major aviation safety programs; MSG-3 and SMS. SMS could benefit from implementing some of the best practices established by MSG-3. The SMS program is arranged with four pillars. Safety Policy and Objectives, Safety Risk Management, Safety Assurance and Safety Promotion. To illustrate key points both programs are compared within each pillar.

<u>Pillar 1 - Safety Policy</u>

MSG-3 is handled within groups, hence as the name suggests. The working groups include the project manager, design engineers, system safety, reliability, certification, technical publications, marketing and product support, along with key maintenance and engineers from the airline operators. MSG-3 practitioners are the Industry Steering Committee (ISC) working groups. The ISC group members are specialists in various aircraft systems and they interact with the manufacturer's design group. The working group members do the detailed analysis and generate the product, maintenance tasks and schedules. They present their work to the ISC for approval (MSG-3 training manual, 1992).

SMS safety policy details management's responsibility and accountability for safety. It also outlines the methods and tools for achieving desired safety outcomes (FAA, 2013, p. 113-1). An accountable executive must be identified who has ultimate responsibility and accountability. Key safety personnel must be appointed, including a safety manager as a focal point for SMS.

<u>Pillar 2 - Safety Risk Management</u>

Both MSG-3 and SMS have common risk evaluation processes. MSG-3 bases its analysis on the failure modes and effects analysis (FMEA). The elements of SRM analysis are hazard identification and risk assessment. Both failures and hazards require a survey of systems. Any system component that could result in serious malfunction must be mitigated.

The causal sequence illustrated in Reason's model for management of safety events addresses "latent" failures, a common thread for both MSG-3 and SMS. Both programs must consider what failures can possibly happen within each "layer" of activity that might ultimately cause a safety issue" (Ferguson & Nelson, 2014, p. 146). The severity of failure has corresponding risk probability. For example, catastrophic failure is categorized as a condition that would prevent the continued safe flight of the airplane. Probability of such failure must be shown to be extremely improbable, such as 1 x 10^{-9} or less (MSG-3 Training Manual, 1992). That means that they must not be a great chance of failure or risk than that, and if there is that infinitesimal chance of occurrence, a change is required to reduce the risk. Probability for the analysis of risk is not as detailed for SMS.

Data collection is a significant difference. MSG-3 obtains in reliability data from many sources including manufacturing testing and airline operations. The SDR (Service Difficulty Report) system provides all failure data. This data is required by the FAA (FAA, 2000). All operators contribute, which provides an aggregate and complete database. Data collection for SMS is an issue. Hazard reporting is encouraged but not required. The collection systems range from drop box submissions from line workers to comprehensive database programs. Currently, the SMS data base of hazards and risk assessments are not shared among like organizations, such as airliners, airports, flight schools, etc. There can even be fear of retaliation and for exposure of liability (Howell, 2016).

Another significant difference is *who* is responsible for conducting the analyses. For MSG-3, the working groups are made up with engineering / maintenance personnel, technical subject matter experts within engineering and operations. For SMS, the personnel must be assigned by each organization. It is possible that there are engineers in safety systems, engineering or reliability departments who could be assigned to do the safety risk assessment for SMS. Large airlines are staffed with employees with that sort of technical expertise. However, this can be a serious challenge for organizations, like airports, who are new to risk analysis. The size of the organization could also limit the number of available and qualified personnel. Training or subcontracting for the task will be needed.

Pillar 3 – Safety Assurance

Safety performance monitoring system for MSG-3 is well established. The Service Difficulty Reports submitted by operation provide reliability data. That data is managed by NASA and disseminated to the manufacturers. Trends identified through data analysis raise red flags that alert the manufacturers and airlines to determine if and what corrective action is needed.

Safety performance monitoring for SMS is identified as safety studies, audits and investigations. Organizations must be proactively engaged by identifying changes within the organization that may affect established processes and services and to minimize risk.

Continuous improvement is common to both MSG-3 and SMS. The review process is required to assure that any corrective action does mitigate or eliminate the issue.

Pillar 4 – Safety Promotion

Safety promotion has little commonality between MSG-3 and SMS.

MSG-3 utilizes subject matter experts and industry working groups. These experts have the ability to conduct the analysis and determine design and maintenance requirements to meet the established safety performance indicators. Reliability data reporting is required.

SMS is still in the development phase. Working groups, reporting and accessible data are not yet defined. Training and education must be provided throughout the aviation organization. The increase awareness of safety is the goal for all employees within an aviation organization. Safety communication processes must be established. Designated employees will have more specific responsibilities in carrying out safety actions (Ferguson & Nelson, 2014, p. 87).

6. DISCUSSION

Safety reporting is controversial for SMS. The data collection process has not been as well defined as that of the MSG-3 program. In order to obtain as much safety data as possible through reporting, the liability issues for individuals and organizations must be addressed.

The Aviation Safety Reporting System (ASRS) is well established in the airline segment, but not without similar concerns. The ASRS program belongs to the FAA and is administered by NASA. Pilots, mechanics, air traffic controllers and others report errors and deficiencies without fear of reprisal. The ASRS dissociates the reporter from the report and promises excusal from penalty if the reported incident results in administrative action. ASRS is the strongest protected reporting system in the US aviation system (A Just Culture, n.d.).

In an aviation safety letter for Transport Canada, Arnaud Delmas also discussed "Just Culture". "To achieve progress in the field of safety, it is much more effective to analyze the errors made by those who were lucky enough to escape and who are willing to talk about it, rather than to try to get the wrecks and the witnesses to give up their secrets when those involved in the tragedy are dead (Delmas, 2012). He goes on to say that flight safety is based on transparency and on the sharing of information. Indeed, to be effective, all feedback systems rely on each person's willingness to provide essential safety information, which often means being prepared to report one's own mistakes and errors. It is essential to establish a "Just Culture" in order to create a climate of trust that encourages and facilitates communication and the sharing of information (Delmas, 2012).

The FAA even encourages the use of ASRS data in Safety Risk Management (SRM). According to the FAA, "risk analyses in operational contexts are often based on expertise and expert judgment, but they should also use data from the carrier's own experience or those of others in the industry where available. Review of accident statistics, failure data, error data (e.g., runway incursion reports or information from the NASA (National Aeronautics and Space Administration) ASRS (Aviation Safety Reporting System) or equipment reliability data may help in determining likelihood" (FAA AC 120-92B, 2015, p. 23).

Customized SMS software systems are emerging. FAA has provided software via WBAT. Hazards can be documented; risk analysis can be conducted. SMSP software is available for a fee. It is a comprehensive, user friendly program that easily produces reports. One issue identified by Christopher Howell, CEO of SMSPro, is that company managers prefer that the content is held confidentially. With any luck, a parent organization will utilize the software program throughout its subsidiaries. Aggregate data collection is not possible at this time. Feedback from managers is that they fear exposing their own liability. And, nationwide reporting is not required. So, how is one single organization to calculate real risk when the sample size is limited to one?

7. CONCLUSION

Safety management systems are not new. Safety has always been a high-level priority in the aviation industry. The MSG-3 program set the precedent for SMS in terms of standardizing safety reporting and risk analysis of aviation technology. Efforts to improve safety through detailed analysis using real world data have been proven to be successful. That information enables predicting failures prior to aircraft being seriously damaged or people being hurt.

ICAO's initiative for safety management provides a formal process for documentation and analysis of aviation operations. The methodology for mitigating risk is similar to MSG-3. Most important is that sharing safety information among similar organizations (large airlines, hub airports) provides a broader and deeper understanding of the likelihood and severity of safety related issues (ACRP Synthesis 37, 2012). The more information that is collected, the better.

In order to conduct the SMS safety analysis for aviation operations, more expertise is required within all aviation domains. Dedicated SMS experts could form a network of industry working groups to evaluate safety issues, identify serious trends and recommend corrective actions. Barriers to safety information sharing must be addressed. As the "Just Culture" explains, transparency is necessary. Communication is key. Organizations must have access to SMS consultants and also train existing employees. Either way, human and financial resources must be allocated to improving safety.

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