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SMS and CRM: Parallels and Opposites in their Evolution

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Introduction

Crew Resource Management (CRM) is the effective use of all resources to minimize errors, increase flight safety, and improve performance (Helmreich, Merritt, & Wilhelm, 1999). CRM has matured and developed into a formidable and globally accepted flight safety device since its introduction in the 1970s. CRM has experienced significant growth and evolved to rightfully claim its position as a premier aviation safety tool. During its progression period, CRM was considered a trend and even labeled a psychological brainwash for pilots (Helmreich et al., 1999).

Safety Management Systems (SMS) is the latest mechanism being used to improve an industry with an already exceptional aviation safety record. With the official introduction of SMS, the aviation industry is trying**,** once again**,** to adapt to something new. This study explores the evolution of SMS and CRM and how they relate to one another. The paper will compare and contrast SMS and CRM to determine if they have a historical and practical relationship. The paper will highlight the differences and similarities of each and examine whether or not SMS and CRM share historical and practical resemblances. By analyzing the past and current practices of both, the authors of this research will demonstrate how SMS and CRM synchronize, cross paths, and share a future. Together, these programs have the potential to enhance aviation safety.

Literature Review

SMS and CRM

SMS and CRM "identify and evaluate operational-type hazards, […] consider human system integration factors such as human error, human task overload, cognitive misconception, [and] the effect on humans or hardware failure" (Lu, Bos, & Caldwell, 2007, p. 33). The CRM concept is based on providing quality products through teamwork and plays a major role in

safety management. Various industries, such as the automobile and aviation industries, relied on human factors to reinvent and better redefine the concept of quality products through effective teamwork during the mid-1970s to mid-1990s (Rodrigues & Cusick, 2012).

Both SMS and CRM involve the safe operation of systems and effective teamwork to produce quality products. CRM became accepted in the aviation industry in the late 1970s, while the larger all-encompassing system safety concept was adopted in the aviation industry with the help of the International Civil Aviation Organization (ICAO). In the early 2000s, ICAO required member states implement SMS for air traffic services (Bayuk, 2008). The addition of SMS to the aviation industry reached a turning point when aviation safety shifted from a human-error to larger system concept (Rodrigues & Cusick, 2012). This overarching system concept includes technical, human, and organizational factors (ICAO, 2009) that influence aviation operations.

Defining SMS

The FAA has been incorporating system safety into aviation policy for a while. The FAA requires the Office of System Safety to "incorporate a risk management process for all high-consequences decisions and provide a handbook/manual of System Risk Management and to recommend tools of System Safety to all U.S.-based airlines" (FAA, 1996, p.1, as cited in Lu et al., 2007). Various system safety measures are used regularly in the aviation industry and enforced by regulatory agencies.

SMS is one example of a system safety method. ICAO (2009) defines SMS as an organized approach to managing safety, to include the necessary organizational structures, accountabilities, policies, and procedures. The four pillars of SMS are: 1) Safety Policy, 2) Risk Management, 3) Safety Assurance, and 4) Safety Promotion. The Federal Aviation

Administration (FAA) has embraced SMS in its Advisory Circular (AC) 120-92A and describes each of the components. The four components are explicated as follows:

- Safety policy – establishes senior management's commitment to continually improve safety; defines the methods, processes, and organizational structure needed to meet the safety goals.
- Safety Risk Management (SRM) – determines the need for, and adequacy of, new or revised risk controls based on the assessment of acceptable risk.
- Safety assurance (SA) – evaluates the continued effectiveness of implemented risk control strategies; supports the identification of new hazards.
- Safety promotion – includes training, communication, and other actions to create a positive safety culture within all levels of the workforce. (FAA, 2010; Stolzer, Halford, & Goglia, 2008)

CRM: A Brief History

CRM was a product of human factors research in the 1970s. In 1979, NASA conducted a workshop titled Resource Management on the Flightdeck. Analysis of accident causes revealed 66% of air carriers, 79% of commuters, and 88% of general aviation accidents were the result of flight crew failures in interpersonal communication, decision making, and leadership, not weak technical flying skills (Cooper, White, & Lauber, 1980; Helmreich et al., 1999). Consequently, air carriers accepted the task of incorporating team performance education into their flight training programs. Cockpit Resource Management, the term previously used, focused on the psychological and behavioral aspects of team performance, specifically, the over-authoritarian leadership styles of captains, and the lack of assertiveness in many first officers. Some human

factors items CRM incorporates are communication, decision-making, and teamwork (Lima, 2000).

Human factors concepts evolved through the development of CRM. First-generation CRM failed to take into account how different cultures behave in a hierarchal environment, such as a cockpit. These training programs encountered much resistance from pilots, who saw them as an attempt to manipulate their personalities (Helmreich et al., 1999). First generation CRM courses were characterized by seminar-styled lectures on managerial and psychological aspects of pilot interactions.

The second generation of CRM emphasized team work (Lima, 2000). By introducing topics such as team building, briefing strategies, situation awareness, and stress management, the name Cockpit Resource Management changed to Crew Resource Management. In addition to the importance of team dynamics, the training environment began to resemble situations specifically within aviation operations. During the early 1990s, the third generation of CRM, training extended to other groups, such as flight attendants, dispatchers, and maintenance personnel (Block, Sabin, & Patankar, 2007). Additional topics included organizational culture and pilot-behavioral competencies for improved safety performance.

In the 1990s, the FAA introduced a major change in flight crew training and qualifications called Advanced Qualification Program (AQP) (Helmreich et al., 1999). This game-changing event marked the beginning of the fourth generation of CRM.

> AQP is a voluntary program that allows air carriers to develop innovative training [to fit] the needs of the specific organization. In exchange for this greater flexibility in training, carriers are required to provide both CRM and LOFT [Line-Oriented Flight Training] for all flight crews and to integrate CRM concepts into technical training. […] To complete

> the shift to AQP, carriers are required to complete detailed analyses of training requirements for each aircraft and to develop programs that address the human factors (CRM) issues in each aspect of training. In addition, special training for those charged with certification of crews and formal evaluation of crews in full mission simulation is required (Line Operational Evaluation or LOE). (Helmreich et al., 1999, p. 21)

Specific behaviors and CRM training concepts were processed into checklists. The fourth generation saw an increase in written operating procedures.

The fifth generation of CRM introduced the concept of Threat and Error Management (TEM). It is accepted that errors cannot be eliminated, but perhaps avoided, managed, and its effects mitigated. Helmreich et al. (1999) argued that CRM provides valuable countermeasures to avoid, trap, and mitigate errors. The fifth generation also attempted to use this human factors based CRM to "engage all employees in building a robust safety culture and emphasizes cases where errors were detected and managed effectively" (Block et al., 2007). Currently, at its fifth-generation, CRM is finally embraced by the aviation industry. "The industry now is pursuing a CRM training concept that could be accepted universally and accommodate local cultural aspects" (Lima, 2000, para. 24). Decades later, CRM is still a work in progress. CRM is more widely accepted and practiced in the aviation industry today, decades after it was officially introduced.

Human and organizational factors are cornerstones of CRM, which relies on training to identify and understand potential system failures before they become unsafe. CRM is a practical tool used to "develop skills to help better manage threats and errors that pilots face during every flight" (Maurino & Murray, 2010, p. 10-16). The CRM shift from 'training for the abnormal' to 'training for the normal' allows operators to avoid potential disasters through their experience

and familiarity with a predictive failure through practice (Maurino & Murray, 2010, p. 10-3). Training for the predictive failure allows CRM to be proactive in the system safety concept, ultimately, in SMS. The difference with CRM is its tactical application versus SMS's strategic, all-encompassing application. Whereas SMS is a planned and calculated approach that is cultivated in upper-management and spreads all the way to the user level, CRM is intended primarily for the user.

Although CRM was officially introduced by airlines in the early 1980s, it was not immediately welcomed by the aviation industry. Initial courses were psychological in nature with a special emphasis on concepts such as leadership; thus, many of these courses encountered opposition from pilots who denounced them as a way to manipulate their personalities (Helmreich et al., 1999). However, with the evolution of safety thinking, CRM has transitioned to a globally accepted practice. Regardless of the difficulties in proving its relationship with safety, air carriers today would have difficulties terminating such a program (Pariès & Amalberti, as cited by Maurino & Murray, 2010).

Summary

Managing and controlling errors, hazards, and risks are all part of the overarching safety system defined as SMS. CRM is a key component of this system. Both SMS and CRM seek to identify root causes of undesired events. SMS and CRM aim at being predictive and proactive in improving operational safety. To anticipate human mistakes, both attempt to discover potential system failures before they occur. The anticipation of the potential human mistake is incorporated into SMS and CRM through risk management controls. SMS and CRM recognize and assess hazards in order to develop corrective mitigations against assessed threats.

Research Approach

The purpose of the study is to gain a better understanding of how SMS and CRM interact. The study was guided by the following research questions:

- What similarities and differences exist in the evolution of SMS and CRM?
- What is the future direction of both SMS and CRM?

To answer these questions, an extensive literature review was conducted. The units of analysis included any article, document, form, rule, or study revealing the development of SMS and CRM. Relevant information from these sources were separated and entered individually into a computer-aided qualitative data analysis software called QSR NVivo. The use of such qualitative analysis software allowed the authors the opportunity to explore emerging themes and search for relationships between both concepts (i.e., SMS and CRM).

Parallels and Opposites in their Evolution

Both SMS and CRM share common roots in Human Factors. It was the study of human factors that led to the term *organizational accident* (Reason, 1990). In addition, CRM has progressed from one generation to the next in marked fashion. CRM originated in the U.S. whereas SMS came from a global organization (i.e., ICAO). While SMS is a "systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures" (Galotti, 2006, para. 9), CRM is a critical tool of a safety system. SMS is the ultimate overarching product of the evolution of safety thinking.

Although both have been around for some time, SMS is not as widely accepted by the aviation industry as CRM. SMS is currently transitioning to some parts of the aviation industry. ICAO has made a recommendation that all countries enforce SMS upon their aviation service providers (Hollinger, 2013). ICAO even provided multiple editions of the Safety Management

Manual (SMM) for countries to use as guidance in building their own SMS. The manual is thorough in providing safety organizational management concepts and implementation techniques.

The application of safety has inherently been mentioned in various ways over the last century. Terms such as 1) system safety, 2) safety management, 3) risk management, and 4) hazard identification all have the ultimate goal of improving safety. The goal of improving safety has been around for decades. The idea of groups of people working safely and effectively together has also been around for decades, as well. Unlike CRM, there were no specific aviation incidents or accidents that triggered the movement towards SMS. In any case, SMS improves on an already fine industry safety record. Both SMS and CRM took a while to evolve into something measurable.

SMS and CRM Cross Paths

The focus of the first CRM generation was on pilot personalities and individual hazardous attitudes that caused accidents; it did not have similarities with the early development of SMS (Helmreich et al., 1999). The second generation emphasizes group dynamics in the cockpit (Lima, 2000). CRM and SMS meet during the former's third generation.

According to Maurino and Murray (2010), CRM started to incorporate a bigger *system* to include flight attendants, dispatchers, maintenance, and air traffic control. The fact that CRM training began transcending the cockpit door indicates a shift towards *system safety*. The third generation of CRM was "a change in its underlying safety paradigm: safety was now considered to be a proactive rather than reactive endeavor, and the consequence of a healthy system and its effective performance" (p. 10-4). This period occurred in the 1990s and was greatly influenced by James Reason's (1990, 1997) research on the concept of an aviation *organizational accident*.

The idea that safety, in a flight operational context, is the result of the overall health of a system was highlighted during the fourth generation of CRM. This generation shares common aspects with SMS in that CRM training follows a proficiency-based method, instead of a prescriptive approach where the governing authority (i.e., FAA) prescribes the rules and techniques for crew training. This training concept is called advanced qualification program (AQP). It is a departure from the reactive approach to safety. Instead, it is a more proactive approach in which the crew's training is tailored to the organization's specific needs, similar to SMS training (Stolzer et al., 2008).

The AQP is type-specific (Maurino & Murray, 2010). This signifies that for an AQP training to take place, the air carrier must first "conduct an aircraft-type specific task analysis that includes the identification of CRM behaviors pertinent to the execution of piloting tasks, within the context in which the task will be developed (p. 10-11). These steps share many similarities with SMS. Before implementing an SMS, a gap analysis must be done.

> The first step on identifying sources of safety vulnerability, specified, as hazards in the interfaces between people and other components of the system, is the system description. Once the system is described in terms of components and interactions, the second step is to address these safety vulnerabilities […] through an analysis of the resources already present in the system. (ICAO Doc. 9859, 2009, p. 131)

In summary, a mature SMS and a successful CRM AQP program require a complete process description. Others who felt CRM may impact a whole system, similar to SMS, expand upon the advantages of CRM.

> In this aspect, Paries and Amalberti advocated the term cross-corporate or Company Resource Management to reflect that the benefits of CRM extend beyond safety to

> include cost efficiency, service quality, and job satisfaction. The term Organizational Resource Management (ORM) reflects the same line of thinking (Heinzer, 1993), fully developed by Smith (1992), who viewed CRM as an organizational development. (Maurino & Murray, 2010, p. 10-4)

The Significance of Error Management in SMS and CRM

Similarities between SMS and CRM become prominent in the fifth generation of CRM with the introduction of *threat and error management (TEM).* In the late 1990s, it became evident there was no way of eliminating human error. Flight crews were often using tactics to minimize and mitigate errors found during abnormal and normal (day-to-day) activities. These strategies during operational CRM were termed *Error Management* (Helmreich et al., 1999). TEM made its way into CRM by the end of the 1990s.

> Threat and error management (TEM) is a systems approach to aviation safety originally developed by human factors researchers at the University of Texas. Embraced by airlines worldwide and recognized as an international best practice by, among others, the International Civil Aviation Organization, the Joint Aviation Authorities, the International Air Transport Association, the National Air Transport Association, and the U.S. Federal Aviation Administration, TEM offers an intuitive and flexible approach to practical risk management. TEM not only offers a framework for understanding and directing human performance in complex operating environments, it also provides aviation professionals — regardless of their organizational function or status — a risk management lexicon that supports a positive safety culture. (Flight Safety Foundation, 2014, para. 1)

TEM can be used to classify a wide variety of factors that lead to incidents or aviation safety events in normal and abnormal situations (Stolzer et al., 2008). During TEM, pilots attempt to manage safety by: (1) avoiding errors, (2) trapping errors, and (3) mitigating errors. This three-level safety defense tool is analogous to SMS since both attempt to uncover hazards and manage risk.

Stolzer et al. (2008) continue explaining how TEM can interact with an organization's SMS. When it comes to the classification of hazards, it is very important users employ a taxonomy that allows safety events or incidents to be reported with ease. Stolzer et al. (2008) make a strong case for TEM because the information gathered lends itself easily for classification, review, and the study of factors contributing to unsafe events. Therefore, TEM plays a major role in SMS. TEM allows pilots to communicate in common SMS usable language. Like SMS, TEM also advocates ownership and accountability.

There are many parallels between SMS and TEM. Both focus on latent threats. With CRM, latent threats are those not blatantly observable at the crew level. Instead, they are concealed within the nature of the particular operation or the aviation system, as is the case with SMS. Examples of latent threats include poor maintenance procedures, unfortunate air traffic control practices, badly written operations manuals, and an inaccurate amount of Operations Specifications (Ops Specs).

Refer to Table 1 for a quick summary of the previous sections. The majority of these concepts cover broad themes explored throughout this research, such as origins, definitions, applications, and barriers for effective implementation.

Table 1
Similarities and Differences of both Safety Management System (SMS) and Crew Resource Management (CRM)

Similarities	Differences
SMS and CRM have their roots in Human Factors research; the understanding of human error and the concept of the *organizational accident* paved the way for both programs.	Unlike CRM, SMS borrows concepts from Total Quality Management (Rodrigues & Cusick, 2012).
CRM and SMS advocate standardized and unambiguous procedures for normal or abnormal situations.	For CRM practitioners, procedures are directly written only for crewmembers involved in flight operations (FAA, 2004). In an SMS, duties and responsibilities are detailed for each staff member for routine and emergency operations (ICAO, 2009).
SMS and CRM prepare for, manage, and address potential factors that impact critical safety issues; both programs detect threats and/or hazards and mitigate them before an accident occurs.	A major part of an organization is concerned with threats and hazards within an SMS program, whereas CRM addresses potential safety factors that impact flight operations.
Senior management commitment and organizational culture will affect individual and collective safety awareness and practice for both programs (Broyhill & Freiwald, 2012).	In CRM, the leadership style of the captain will affect the collective safety practices within the cockpit (Helmreich et al., 1999).
SMS and CRM are capable of utilizing routine safety education and/or recurrent training based on regulatory requirements and identified safety gaps in the operational setting (FAA, 2004; ICAO, 2009).	System safety was used in various industries (i.e., marine, railroad) before SMS was recognized in the aviation industry, while CRM originated within the aviation industry and is currently being used in other industries (e.g., medicine, firefighting, off-shore oil industry) (Broome, 2011).
CRM and SMS use voluntary safety programs/tools such as Aviation Safety Reporting System (ASRS), Flight Operational Quality Assurance (FOQA), and Aviation Safety Action Program (ASAP) to document, monitor, and study risk (Stolzer et al., 2008).	Information from ASRS, FOQA, and ASAP can also be used in flight operations, thereby improving CRM practices.
Both are used in aviation operations and experienced resistance during initial implementation.	Because of the time factor advantage, CRM has gained wider acceptance (Gibson, 2007). However, SMS is currently struggling with the implementation phase (Shacklette, 2013).
SMS and CRM include hazard identification and risk management.	SMS manages threats and errors for an organization, whereas CRM manages threats and errors during flight.
CRM and SMS have difficulties demonstrating their effectiveness through empirical research.	There is a current lack of publication, research, and forums in the CRM field (Howell, 2007); the opposite is true for SMS.
Similar to CRM when it started, SMS implementation requires additional expertise, resources, and software which are not readily available to all organizations (Shacklette, 2013).	SMS implementation also requires changes to many FAA operations, whereas CRM did not (Shacklette, 2013). Another challenge with SMS implementation is that it is concurrent with other major projects (i.e., NextGen, Unmanned Aircraft Systems, etc.) that regulatory agencies have oversight of.

What does the future hold for both SMS and CRM?

Throughout the development of CRM, there has been an increase in a positive safety culture. Values such as empowerment, information sharing, collaboration, and data usage have made CRM successful. SMS programs will likely follow suit in order to obtain safety levels never achieved in commercial aviation (Rodrigues & Cusick, 2012). Technology and software combined with data mining techniques should push SMS from a proactive safety device to a predictive aviation safety solution (Stolzer et al., 2008).

For effective safety tools to maintain their status, they must stay up to date with the changing aviation environment. CRM is still progressing and continually experiencing change. Kern (2001) argues CRM is currently going through the sixth generation where the current focus is on how CRM incorporates automation, technology complacency, and its interaction with fatigue. Others have suggested CRM is still evolving without a clear indicator of a generational mark (Beneigh, 2007; Gibson, 2007). Regardless, the possible addition of a sixth generation demonstrates that CRM, a Human Factors based training mechanism that is currently evolving, is part of an overarching safety system, that may possibly be known as SMS.

Hazard and risk identification are core principles of SMS. They have become more defined and independent; risk analysis has become the foundation of fact-based decision-making (Stolzer et al., 2008). SMS will inherently become more dependent as hazard and risk become more controlled items. As risk assessment techniques continue to evolve and become easier to measure, SMS will become easier to incorporate into operations. Other industries have vigorously applied the spirit of SMS into their organization (Stolzer et al., 2008). It will only be a matter of time before SMS moves in full force across the aviation industry as CRM currently

does. A realistic and effective way of implementing and standardizing SMS among aviation service providers has actually been taking place.

Voluntary programs, such as the FAA Safety Reporting System and Database (SRSD), NASA Aviation Safety Reporting System (ASRS), Flight Operational Quality Assurance (FOQA), Air Carrier Operations System Model (ACOSM), and Aviation Safety Action Program (ASAP) are risk management tools intended for top-level decision making based on bottom-up use and middle management supervision, thereby allowing the safety system as a whole to be incorporated from the top down. For example, operators complete these voluntary reports so that middle-management can provide updates to upper management. Upper management then uses this information to make future safety decisions based off hazard identification and risk management measures found in these reports. These voluntary programs are effective because all levels, from the top down, are involved before measures are managed and controlled to reduce errors, hazards, and risks.

Analytical arrangements, such as the Fault Tree Analysis (FTA), Failure Mode and Effective Criticality Analysis (FMECA), and Management Oversight and Risk Tree (MORT) identify potential occurrences of undesired events, mishaps, and accidents to some extent. Similar to the voluntary programs previously mentioned, the FTA, FMECA, and MORT are tools that all levels, from top down, have access to. They "identify accident postulates that lead to implementation of strategic safety prevention programs from the bottom-up" (Lu et al., 2007, p. 34). Again, individuals at the highest level have information from middle-management and users to make informed safety decisions, a key aspect of SMS.

The actual SMS designation itself has yet to reach top-management levels across the aviation industry as a whole; therefore, an SMS-specific safety culture has yet to reach fruition.

SMS requires serious support from top management within industry before it can have a significant impact on safety (Stolzer, Halford, & Goglia, 2011). Once the idea of safety culture in SMS develops and permeates through all levels of leadership in industry, SMS will spread as CRM has. Stolzer et al. (2011) claim safety promotion is truly the only way to make safety culture effective in an organization. The transition of safety promotion from upper-management is a critical milestone SMS must reach before continuing on with its current fast-paced momentum. When leadership promotes and reinforces an idea in an organization, the rest of the team will likely follow suit. Like CRM, SMS will need to be spearheaded by senior management and nurtured within an evolving safety culture that can adequately accommodate it (Broyhill & Freiwald, 2012; Stolzer et al., 2008). It is difficult to prove to senior management that a zero-accident rate is attributed to a more defined safety culture, such as the case with SMS. Safety professionals cannot show senior leadership how many accidents have been prevented by a stronger safety culture, but when an accident does occur, it usually uncovers a flaw in the organization's safety culture (Stolzer et al., 2011).

Although SMS currently appears to be experiencing a major hold-up due to weak acceptance from upper management across the board, SMS is actually moving along through industry at a much faster rate than many realize, even faster than CRM did during its initial stages. It will require time for the official name to gain recognition before it matures into a championed safety instrument. The idea of SMS has adjusted to industry needs to fulfill safety voids in detecting latent failures. The actual terminology SMS itself will become common practice 10, 20, or 30 years from now. General SMS objectives, to include service providers recognizing SMS and utilizing basic SMS guidelines (Block et al., 2007), have been taking place just not acknowledged industry-wide.

Continuous education and guidance to upper leadership will lead to a more SMS specific invested culture as it did for CRM. Building an SMS specific safety culture is a major obstacle for SMS, as it was for CRM. Additional barriers will need to be overcome in order for SMS to mature as a recognized worldwide safety tool. These obstacles include lack of scientific validation, absence of clear guidance from regulatory oversight agencies, and shortage of data tracking, sharing, and monitoring for improved overall system safety. However, once industry truly recognizes a minimal level of SMS safety culture has already been engrained in the aviation industry, it will be easier to recognize and embrace a safety system inherently living in aviation. A more organized and standardized safety system, in the form of SMS, will spawn quickly to the aviation industry and be as useful and embedded into aviation as CRM currently is.

The Evolution of Safety and Human Factors Thinking

In approximately twenty years, CRM went from a training tool that did not incorporate how different cultures behave in a hierarchal cockpit environment to an advanced and common worldwide training tool that manages and normalizes threat and errors by providing valuable countermeasures (Helmreich et al., 1999).

ICAO announced SMS implementation in 2003; SMS manual was introduced by ICAO three years later in 2006 (Lu, Young, Schreckengast, & Chen, 2011). In this short amount of time, airports worldwide already devoted heavy resources to comply with ICAO SMS requirements. Similar to CRM, SMS is experiencing obstacles inherent in a new culture. However, SMS is moving along slightly quicker than CRM.

The timeline in the following two pages illustrates the evolution of safety and human factors thinking from the early 20th century into the 21st century and is divided into two overarching categories: the Introduction of Safety and Human Factors from the 1900s into the

1990s and Safety and Human Factors in Aviation from the 1990s into the future. Table 2 is divided into three eras, 1) Safety in Concept, 2) Safety through Administrations, and 3) Safety through Human Factors. These three time periods cover the beginning form and thought of safety and human factors. In Table 3, there are two critical time periods for safety and human factors in aviation, 1) Organizational Human Factors & Safety in Aviation and 2) Systematic & Shared Safety in Aviation. Both tables demonstrate safety and human factor concepts simultaneously evolving and merging in the 1990s.

Table 2
1900s-1990s: Introduction of Safety & Human Factors

1900s-1945 Safety in Concept	1945-1970s Safety through Administrations	1970s-1990s Safety through Human Factors
WWI (1914-1918) Prompted the development of aeromedical research and aviation psychology (Ferguson & Nelson, 2013).	Post WWII (1945+) Human factors research shifted from designing for the machine to designing for human capabilities (user-centered design concept) (Ferguson & Nelson, 2013).	1979 National Aeronautics and Space Administration workshop titled: *Resource Management on the Flightdeck* leads to Crew Resource Management (CRM) (Cooper, White, & Lauber, 1980).
1926 Air Commerce Act (NewMyer, 2000).	1947 Establishment of the International Civil Aviation Organization (Adamski & Doyle, 2005)	1980s CRM's first generation training was primarily lecture-type format designed for indoctrination on management styles and interpersonal skills (Helmreich, Merritt, & Wilhelm, 1999).
1938 Civil Aeronautics Act (NewMyer, 2000).	1958 Federal Aviation Act (NewMyer, 2000).	
1940s Introduction of system safety due to aviation and aerospace industry (Lu, Bos, & Caldwell, 2007).	1967 Formation of the National Transportation Safety Board (NewMyer, 2000).	1980s CRM's second generation changed CRM from *Cockpit* to *Crew Resource Management* (Helmreich et al.,1999).

Table 3
1990s-Future: Safety & Human Factors in Aviation

1990s-2006 Organizational Human Factors & Safety in Aviation	2006-Future Systematic & Shared Safety in Aviation
1990s Aviation safety philosophy shifted its focus to the organizational era, viewing safety from a systems perspective including technical, human, and organizational factors (Rodrigues & Cusick, 2012).	2006 ICAO produces first manual, SMM (ICAO, 2009).
1990s During its third generation, Crew Resource Management (CRM) hit mainstream; it now includes maintenance, dispatch, and air traffic controllers (Maurino & Murray, 2010).	2006 Federal Aviation Administration (FAA) published Advisory Circular 120-92 Introduction to SMS for Air Operators (Lu, Bos, & Caldwell, 2007).
1990s CRM's fourth generation saw the introduction of Advanced Qualification Program (Helmreich, Merritt, & Wilhelm, 1999).	2007 FAA initiated voluntary SMS pilot projects and voluntary implementation of SMS in the U.S. (Rodrigues & Cusick, 2012).
1995 Aviation Safety Summit (Stolzer, Halford, & Goglia, 2008).	2009 FAA publishes Risk Management Handbook where Single-Pilot Resource Management (single-pilot CRM) is discussed (FAA, 2009).
Late 1990s CRM's fifth generation uses Threat and Error Management (Helmreich et al., 1999).	2010 FAA Notice of Proposed Rule Making extends SMS from airlines to certificated airports (Lu, Schreckengast, & Jia, 2011).
Early 2000s ICAO requires member states establish a Safety Management System (SMS) for the provision of air traffic services (Bayuk, 2008).	Present CRM focuses on automation, technology, and fatigue.
2006 ICAO publishes Safety Management Manual (SMM); Safety Management System (SMS) starts; 4 pillars of SMS defined as (a) safety policy, (b) risk management, (c) safety assurance, and (d) safety promotion (ICAO, 2009).	2020s Both CRM and SMS will place greater emphasis on quantitative methods for prediction and safety; these efforts include data mining and probabilistic methods. 2020s SMS will reach other aviation domains such as 14 Code of Federal Regulation Parts 91, 141, 142, and 135.

Conclusion

Similar to what CRM supporters experienced decades ago, SMS advocates are attempting to build a name and reputation for SMS across the aviation industry, to include academia. In 2007, Embry-Riddle Aeronautical University (ERAU) Bombardier, and Frasca co-hosted a symposium titled "ERAU: CRM Vectors 2007." Such an event looked at the current state of CRM and forecasted its direction into the new decade. The symposium accurately predicted that CRM concepts would extend to the single-pilot domain and that educational guidelines would be developed for General Aviation (GA) pilots searching to benefit from CRM concepts when flying alone. Two years later, the FAA published a Risk Management Handbook (2009), covering topics such as automation, risk management, and Single-Pilot Resource Management.

It is effective to implement safety tools in the academic environment. The Aviation Accreditation Board International (AABI) currently requires all collegiate aviation programs seeking accreditation to develop and use some form of safety management or aviation SMS (AABI, 2013). In addition, SMS is required for airports and FAA Part 121 operations while CRM is required for FAA Part 121 and 135 operations. Flight schools have been teaching CRM principles in the classroom for many years. SMS principles will likely reach FAA Part 141, 142, 135, and 91 operations.

CRM and SMS will continue to evolve in their respective applications. They will benefit from data sharing to further reduce the likelihood of an aviation accident. Certain approaches work well with both programs. A prime example is the continual inclusion of Human Factors, which will be a constant element in CRM and SMS, like it has been since their development. Improving safety through CRM and SMS training will continually be a work in progress. Similar to CRM during its early years, SMS has a long way to go. CRM will continue to push its

cockpit and operational crew boundaries in favor of a systems approach to safety. CRM will remain a pivotal tool in the SMS toolbox, and SMS will progress in the aviation industry.

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