Implementing Safety Management Systems for Aviation into an Aviation Technology Curriculum

by

Timothy D. Ropp
Purdue University, Department of Aviation Technology
tropp@purdue.edu

Abstract: While the concept of safety in risk-sensitive industries such as aviation is familiar, organizations still struggle to define and practice effective safety principles on a daily basis, given the dynamic and inherent nature of aviation hazards. This has given rise to the concept of a systems approach to safety and referred to by global standards and regulatory bodies as safety management systems (SMS). Similar in structure to the concept of quality management systems, although with some significant differences, SMS is becoming a regulatory requirement for air operators around the world in all facets of aviation. The migration from the traditional approach of managing safety through a department or official representative is no longer sufficient for maintaining adequate levels of risk control. Managing safety as a "system" has placed new demands and competency requirements on engineering and technology graduates entering aviation. Terms such as "hazard identification," "risk mitigation," and "proactive performance-based safety" must become working competencies; these should be as familiar to graduates as the knowledge and skills of their own technical degree field, if they are to succeed and contribute to the industry. A logical place to educate and equip future industry leaders to manage safety as a system in the aviation environment is in the classroom at the university level before they enter industry. Development and practical application of principles of SMS within an aviation technology laboratory curriculum at Purdue University is currently underway and has shown promising success in learner fluency and proficiency incorporating risk assessment and system management techniques. Implementation techniques and tools for applying basic risk management in a simulated aviation maintenance laboratory using transport category aircraft and the early results are described here.

I. Introduction

Aviation is an industry where system complexity and use of technologies that are inherently hazardous by nature produce unique and unrelenting challenges to operational safety and risk awareness. New and ever-changing threats to safety in ground operations and flight, ranging from internal training issues on complex next generation aircraft to terrorism, have forced the industry to change its thinking on the management of safety. Traditional reactive approaches to hazards and risk in aviation and the view of internal business units (such as engineering, training, maintenance, and flight operations) as stand alone entities have been forced to change as well. These changes have impacted the educational requirements of those entering the aviation industry. Graduates from aviation engineering and technology programs must now be as fluent with hazard and risk management principles as they are with the skills of their own technical degree field, if they are to succeed and contribute to the industry.

II. Teaching Aviation as a Complex System

Students, like workers in industry, tend to develop a narrow view of their roles in organizational safety over time and the impact of individual decision making upon the larger organization. In the technology laboratory setting, it has been observed that once acclimated to a routine, students tend to focus almost exclusively on specialized knowledge, skills, and abilities pertaining to their degree specialty, with less focus and awareness of their impact on the larger laboratory operation and overall safety. A critical learning outcome for the introduction of system safety principles into the student's view of aviation described here was a working knowledge of risk identification and problem solving within the context of aviation maintenance operations. This was thought to be especially critical in preparing students whose aviation career fields routinely operate with hazardous technologies and accepted levels of risk. Aviation operations, maintenance included, do not occur in a vacuum or in isolation. A key goal of using a systems approach to safety was to show how aviation represents a series of interconnected process sub-groups, each impacting the other. This systems view, along with the accepted fact that risk will always be greater than zero, was a foundational course principle, as it is the reason for the associated name of safety management systems (SMS) used by industry as well. Researchers and regulatory agencies have discovered that a systems view toward safety is necessary for the effective management of risk in complex operations using hazardous technologies [1, 2, 3].

To help students understand interconnectivity and complexity of aviation when it comes to safety management, a composite, working definition of an aviation system was formulated from those framed by researchers of high reliability organizations [4] and organizational error and accidents [1]. The resulting composite definition of an aviation system for the purpose introducing the concept of SMS into the aviation technology course described here stated that:

> An aviation system consists of interconnected and interdependent subsystems comprising the larger organization, where actions in one part of the system directly and immediately affect other parts, sometimes in unexpected ways.

This definition was used as a theoretical baseline to introduce the concept of SMS into the semester material of one aviation technology course. It was also used to underpin all practical projects and deliverables practiced in that course's aviation laboratory curriculum for implementing an SMS. It was also used to illustrate how a typical company can consist of a multitude of internal business units, all supporting the overall aircraft maintenance and reliability process. Using this definition of a system, it was stressed that methods and approaches for achieving the ultimate goal of aircraft airworthiness and reliability can, in fact, vary greatly across internal business units. Paradoxically, separate business units within aviation organizations can have completely opposing approaches toward that same goal, actually resulting in approaches that conflict. The final result is often miscommunication and unmanaged risk, eventually impacting the aircraft safety and reliability being mutually sought.

As part of the introduction of SMS principles, the unpredictable nature of risk was explored in class through case studies of aviation accidents, where seemingly simple changes made to a complex system produced broad and unanticipated results. Aviation maintenance in particular is vulnerable to risk. Small changes made with the intent of improvement, such as changes made to streamline a work instruction card but without proper risk and process evaluation, can have unanticipated effects on maintenance operations. It can ultimately affect the safety outcome of the maintenance process itself, impacting downrange aircraft safety and reliability in some cases. One example provided to students during introduction of the concept of SMS was a common problem associated with engineering modifications of an aircraft component or systems. Changes to maintenance procedures with the intent to comply with a manufacturer’s recommendation but made without assessing the actual aircraft fleet type operated by the airline or without proper risk and feasibility assessment have often resulted in unsafe actions carried out by front line personnel to accommodate the change as written or the inability to perform the new procedure altogether. Given the speed at which business plans change and the global and dynamic nature of aircraft maintenance, it was stressed to students that safety responsibility could no longer be allocated to a safety department or delegated to a safety coordinator as previously practiced by industry. Next generation aircraft use suppliers and maintainers around the globe more than ever. The associated increase and unique challenges of multinational workforces and development of entirely new air transportation systems in emerging markets (like China) dictate that safety be actively linked throughout an organization’s entire system to account for dynamic and unpredictable situations driven by this new generation of air transportation.

III. Importance of a Safety Culture in SMS

To sustain aviation’s current remarkable safety record worldwide, safety must encompass every part of the business enterprise. Principles of hazard identification, risk assessment, and corrective and preventive actions are now viewed as much of a necessity of the entry-level graduate’s capabilities as are the skills for changing an engine or servicing a hydraulic flight control system. Inattention to detail in either area by even front line workers can have catastrophic results. Graduates in aviation technology and engineering fields must be prepared to speak and practice principles of this new safety paradigm if they are to meet the challenges of unprecedented growth and overlap of international air transportation systems anticipated within the next decade. The sustainability of the aviation industry relies upon tomorrow’s aviation leaders meeting these challenges.

Referred to as a “systematic, businesslike approach to managing safety,” [2, 5] the concept of SMS has been adapted into guidance material for air operators in both flight and maintenance operations worldwide. Countries who wish to participate and compete internationally in aviation must incorporate SMS principles, which are now stringent safety requirements among the world's major air transportation systems [2, 6, 7, 8, 9]. The takeaway from this is that aviation graduates will face complex issues of safety management, regardless of their specific aviation career field, and must be prepared. Research has shown and standards and regulatory agencies implore in their advisory documents that safety management must be practiced by all members of the organization to achieve positive safety objectives and reliable safety outcomes [1, 2, 5]. A work culture where principles of safety and risk management are practiced routinely as "the accepted way we do things here" by all involved is repeatedly stressed in the industry guidance material. This concept was implemented into the coursework described here.

Significant challenges exist for such a comprehensive approach to safety management when one considers the competitive, dynamic nature of aviation maintenance where daily work pressures compete for an individual's attention at both management and front line levels. In addition to language and social and cultural challenges arising from overseas outsourcing and supply chains, an organization must also consider routine daily challenges of maintenance added into the mix. These routine hazards include operating systems such as landing gear, engines, flight controls, aircraft taxiing, security threats, training currency, and coordination with manufacturer and engineering technical specifications—all bound by tight process tolerances, regulations, and delivery deadlines. To manage safety issues within this environment requires a systems approach and a supporting work culture, where all personnel and processes are linked and coordinated to identify and control risk. Pragmatically, this means utilizing existing components within the operation (existing computer and information/reporting systems, training, and protocols) as supporting tools for risk management. These same dynamics were applied to the educational laboratory setting and used to create an environment closely resembling the industry.

However, the best tools and system structure could be defeated if people do not, or cannot, use them. An SMS must be capable of allowing people to proactively identify risk threats and mitigate them before they progress into errors or accidents. Tools within the system must also be available, effective, and measurable. The aviation community has long viewed safety as a foregone conclusion, and there is rarely disagreement that safety is an ethical responsibility and a necessity. The impact of aviation safety on global commerce, continued growth, and sustainability of the industry is explicitly recognized [10], and it was paramount that this same global view of safety be grafted into the learning material and applications at the curriculum level.

As plans were drafted to incorporate the concept of SMS and its necessary cultural concepts, it became evident that to achieve this level of rigor and understanding required more than what lecture material could provide. For students to internalize and transfer this knowledge and theory into practice, a deliberate hands-on approach to experience the dynamic and often abstract nature of safety was necessary. The best approach determined was to implement an SMS, based upon actual industry standards, into the laboratory operations of a senior level maintenance capstone course. Students would be actively engaged in helping assess, design, and implement the major components of a complex safety system according to industry regulatory requirements, just as they would encounter in industry.

IV. Integrating SMS Principles into the Curriculum

To effectively implement and evaluate the use of industry-based SMS principles within an aviation technology laboratory curriculum, it was necessary to utilize a course that closely approximated an industry operation. As a senior level capstone course, AT 402, Aircraft Airworthiness Assurance, was an ideal candidate course. The course offered an intensive and challenging learning environment designed to challenge students' ability to incorporate management and technical skill sets within a realistic aircraft maintenance environment. The course utilizes Purdue University's two large transport aircrafts (Boeing 737 and Boeing 727) to simulate a large scale aircraft maintenance operation. Both aircrafts had fully functional engines and systems. While non-flying, these aircrafts offered an excellent simulation as live laboratory platforms for practicing industry standard maintenance procedures, as shown in Figure 1. In this class, senior students in the Aeronautical Technology Maintenance program learn to function as operations managers and team leaders, while simultaneously integrating the knowledge, skills, and abilities of technical aircraft maintenance practices acquired throughout the undergraduate Aviation Technology program. Students in AT 402 are tasked with researching, planning, and implementing a large aircraft production maintenance operation using the same tools, required safety equipment, and practices as those in the industry.

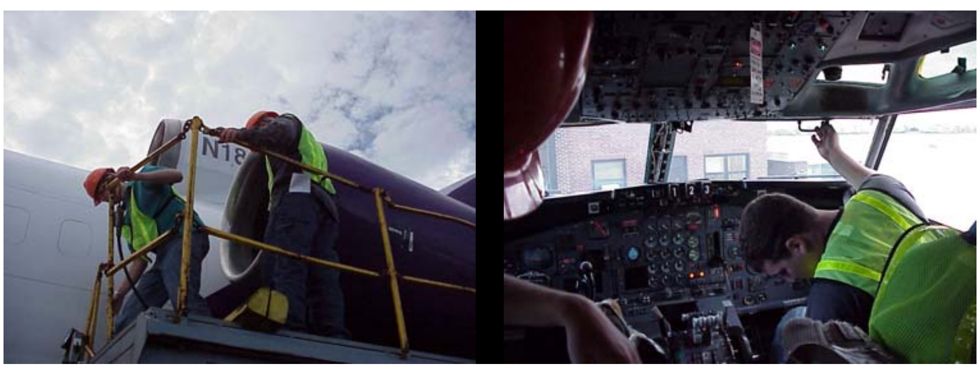

Figure 1: AT 402 Live Laboratory

While accomplishing required maintenance tasks on the aircraft, they must learn to manage the complex and unpredictable communication, planning, resource, and real safety issues that go along with such an operation.

The first half of the course involves intense didactic review of regulatory, leadership, and performance management principles for developing and leading technical teams, as well as technical systems review and requirements of large aircraft maintenance. Approximately five weeks into the semester, the AT 402 senior level class merges with a junior level class, AT 372 (Aircraft Maintenance Practices), for the remaining semester's laboratory portions of both courses. The senior AT 402 students assume the role of maintenance managers and team leaders who must coordinate maintenance projects they have developed and beta tested to be performed by the junior AT 372 students. The junior students take on the role of technical work crews, accomplishing segments of large aircraft maintenance packages developed by the senior AT 402 students with guidance and oversight by the instructors. AT 402 students are gradually developed from a student group into a management team.

In addition to technical maintenance projects directly on the aircraft, the senior AT 402 management team are taught basic problem solving, process mapping, and process hazard assessment tools. They are responsible for development of many major business components common to the industry, including technical writing and creation of job task cards from original equipment manufacturer (OEM) documentation, safety checklists, and job aids. To accomplish this, they research and incorporate basic safety processes and use of process mapping and hazard assessment for job planning, process streamlining, and orientation training delivery to the junior level student technical crews. In essence, the senior students are immersed into an environment requiring problem solving and critical thinking, which forces them to think and deliver results that stretch them well beyond just technical maintenance goals. This dynamic course structure made AT 402 an ideal course to practice the SMS concept. With this arrangement, no one person could rely upon personal technical skills alone to succeed in deliverables. Students were forced to work together, seek knowledge outside their degree area, and innovatively apply existing knowledge to solve problems—skills highly valued in industry and vital to safety management.

V. Building a Safety Culture into an Aviation Technology Maintenance Laboratory

While practice of safety principles in the laboratories was already a mandated requirement within the Aviation Technology department at Purdue, the unique nature of realism and the use of fully functional large aircraft systems posed a unique opportunity to apply more robust industry standard SMS practices of hazard and risk management in a setting that closely resembled large aircraft maintenance operations.

Beginning in fall 2006, the basic premises and working definitions of SMS, risk management, and the concept of a safety culture were introduced into the classroom lecture portion of the three-credit hour senior level course, AT 402, Aircraft Airworthiness Assurance. The class consisted of two hours of lecture and three hours of hands-on laboratory experience each week. Initially, students were introduced to the concept of SMS through introduction to basic theory and definitions of SMS. This was accomplished through classroom lecture delivery, along with research assignments on aviation accident case studies and safety requirements of regulatory agencies around the world. The goal was to form a knowledge base and application strategy for expanding the SMS concept into the practical, hands-on laboratory portion of the course in succeeding semesters. A practical, hands-on approach was the ultimate goal believed to be of greatest impact to learning SMS, where students could put theory into practice. The idea was to incorporate SMS concepts with core technical and leadership competencies required by the existing course material.

By the spring semester of 2007, the fit and implementation strategy for SMS had been developed, largely by using student projects tailored to SMS application. As the concept of risk was taught in lectures, students began evaluating and incorporating principles of risk management within the structure of AT 402 laboratory operations. They were assigned to research regulatory guidance, using global guidance material from a variety of regulatory agencies. A key deliverable of researching various definitions for SMS for application into the class was given. Students discovered that a multitude of similar definitions had been adopted by government regulatory organizations and air transportation systems around the world. Many air transportation systems used similar business-centric language to define and structure their approach to meeting SMS requirements.

As an example, the International Civil Aviation Organization (ICAO), a global aviation standards setting body, used general, non-specific terminology that defined SMS as "an organized approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures" [10]. Similarly, the U.S. Federal Aviation Administration's advisory circular, *AC 120–92*, defined SMS in part as a "quality management approach to controlling risk. It also provides the organizational framework to support a sound safety culture" [2]. Transport Canada defined SMS as a "documented process for managing risks that integrates operations and technical systems with the management of financial and human resources to ensure aviation safety or the safety of the public" [9]. The Australian government in *CASA AC 139-16* [6] defined SMS as an "integrated and documented set of policies, procedures, and practices, for effectively managing the safe operation of your business." Students soon discovered that the concept of SMS lent itself to interpretation of the local government and even the local operator, when it came to specifics. This realization led to students' self-discovery of the explicit pursuit of "outcomes based safety" by industry.

Because many SMS principles were found to be similar (but not identical) to those of quality management systems discussed in the class, it was necessary to identify and articulate specific components to differentiate SMS from established quality approaches. Students were challenged to integrate SMS principles within the AT 402 laboratory in a manner that other students could readily conceptualize and apply as well. This proved to be another key learning point for the students, who discovered that while SMS appeared relatively simple by definition and basic component description, connecting such simple concepts into a functional system was time consuming and difficult. Students immediately discovered the planning and discipline required in the identification and management of actual hazards and risk existing even within the familiar laboratory environment. They soon discovered that aviation organizations face similar and significant challenges constructing, applying, and maintaining such a risk-based SMS structure, as well as achieving the level of organizational situational awareness necessary to proactively identify emerging safety threats. One student recognized this point during a literature review of a European Aviation Safety Agency document, which stated in its own safety plan that:

> There are core similarities in the principles of SMS across a range of organizations within the aviation industry, but the detail will differ according to the particular context and industry sector [11].

The student stated that, "Everything seems to play a part in safety. You can apply so many concepts to safety and SMS, it's overwhelming." This anecdotal comment was considered an early breakthrough moment because many organizations fail to come to that realization when considering foundational in safety management. This comment was used as the basis for discussion on the complexity of safety in aviation in the AT 402 class as SMS was introduced.

VI. Student Experience Implementing a Safety Management System

After an extensive literature review of regulatory guidance documents from around the world, students identified the construct described by Transport Canada [7] as the clearest and most practical SMS framework for use in the laboratory setting. The Transport Canada SMS components, shown in Table 1, were selected by the spring 2007 class as the designated SMS roadmap that, with minor modification, would be used in the current and future AT 402 laboratory development of an SMS.

Table 1: Key SMS Components

1. Safety Management Plan • Senior management commitment and core values • Safety policy, information, and goals • Non-punitive reporting policies and methods	**4. Education and Training** • Safety/human factors awareness • Technical training/practice • Safety reporting system and expectations • Orientation training for the lab
2. Documentation Management • Accident/incident reporting system • Corrective follow-up communication	**5. Quality Assurance Monitoring of Safety** • Audits ensuring the SMS is working by internal and external evaluators
3. Safety Oversight (Risk Monitoring) • Hazard assessment protocols • Reactive and proactive defenses • Standardized CAPA and investigation tools	**6. Emergency Response Plan** • Contingency planning for emergencies • Hazard identification

Although numbered for identification purposes here, the SMS component development and implementation process was not linear. Certain components were implemented simultaneously, as resources permitted, which was very similar to industry's experience with SMS. The safety management plan was implemented by the course instructor early on as an example of the required commitment to the SMS process by senior management, necessary for any safety initiative to be successful. This plan was documented in hard copy, defining the commitment to SMS development in the AT 402 lab and shown as an example to the class.

The remainder of this discussion focuses primarily on concurrent development of Item 3 [Safety Oversight (Risk Monitoring)] and Item 6 [Emergency Response Plan] as examples of the complex process of an SMS implementation experienced by the students.

The priority and sequence for SMS component development was left to the student team to decide. They were reminded that, just as with continuous improvement in industry, safety is not an arrival point but a continuing process and that time constraints of the semester would not allow full development of every component. This was important because the planning for the SMS roadmap and components developed would directly impact future developers and users of the system. Students were divided into two teams and instructed to select the most important next step component(s) to construct. Using basic attributes of risk management, they were instructed to evaluate each component against the following criteria:

- Authority
- Responsibility
- Procedures
- Controls
- Measures

With the knowledge that implementing a completely functional SMS would require more time than the time constraints of a semester would allow, a brief assessment of the six system components was conducted. The teams compared existing tools, training, and practices already used in the AT 402 laboratory to the industry SMS standards and evaluated their ability to fulfill (or partially fulfill) each component. In this way, a simplified gap assessment was conducted for the AT 402 laboratory.

After a general system gap assessment and discussion among the two groups, Item 3 (Safety Oversight / Risk Monitoring, shown in Table 1) was selected as a priority development item, due to heavy instructor emphasis on daily risk management as a paramount core competency in aviation operations. Pressed for further rationale for their decision, students appropriately noted that while the concept of risk was talked about, no tangible tools for risk management actually existed in the laboratory to facilitate hands-on application of risk assessment and management techniques being taught in lecture. The students were then tasked with identifying a performance outcome for Item 3. They were asked, “What would ‘doing’ risk management look like in the AT 402 laboratory maintenance operation? In other words, what should a front line manager or team leader be doing to show this component is functioning?”

Two specific performance indicators were identified, focusing on the continuous improvement concept of Plan-Do-Check-Act. For effective performance of risk management practices at the front line student level, the following development needs were identified: 1) Because a pre-lab team briefing and post-lab safety debriefing were required at every lab “shift” by a designated accountable student manager (a job role rotated among the students each lab), a specific risk assessment protocol should be added as a required part of the routine pre-lab planning/team briefing requirement; and, 2) Corrective actions must actually be taken for identified problems, not just documented. This equated to Corrective and Preventive Action (CAPA) programs used in industry and introduced early on in AT 402 classroom lectures.

The next logical question regarding risk was, "Risk of what?" What types of hazards existed specific to AT 402 lab operations, and what were the associated risk levels for each? It became apparent that hazards in AT 402 lab operations seemed intuitive and obvious but were managed only on the basis of informal "tribal knowledge" by the instructor or more experienced students. Management of the risks involved was often conducted inconsistently, while hazards themselves had not been formally identified and analyzed. Although personal protective gear (helmets, safety glasses, high visibility vests, hearing protection, etc.) was already mandatory and being used as a course requirement, little knowledge existed as to the nature of the specific hazards these and other safety equipment and protocols were intended to protect them from.

This led to a project assignment that became the cornerstone activity of the SMS implementation process in AT 402, which was the creation of a risk-hazard profile, identifying and analyzing top hazards specific to AT 402 lab maintenance operations.

VII. Creating a Risk-hazard Profile

Students were assigned to brainstorm a list of hazards inherent to the AT 402 lab, based on observation and their personal cumulative aircraft laboratory experiences from the start of their degree program as freshmen to present. Because a variety of other laboratory classes and work areas overlapped and shared common resources, like hangar and ramp work areas, the only limit placed was that identified hazards had to relate specifically to the local laboratory and aircraft ramp areas.

The idea was to create a list of both avoidable and unavoidable hazards inherent within the laboratory maintenance operation, such as towing aircraft, use of chemicals and greases, aircraft engine start and low thrust runs, use of powered hand tools, or unauthorized personnel encroachment, to name just a few. Students were encouraged to consider additional factors, such as weather, temperature, resource limitations, student foot traffic through lab areas, and even their own course work loads, as factors potentially affecting safety of daily lab maintenance activity.

The list of hazards was extensive. Discussion of risk prioritization led the class to debate and address the worst case scenarios first, then identify and address hazards posing progressively less severe risk. Evaluation of the hazards and consensus discussion with the students resulted in a preliminary listing of seven top emergency events posing the highest threats and most likely to occur during operation of the AT 402 lab if no hazard controls were in place or if existing controls happened to fail. These were:

- Aircraft fuel spills inside the hangar
- Aircraft fuel spills outside (ramp operations)
- Bomb/mass casualty threats (including active shooters)
- Suspicious activity/security threats focused on the aircraft
- Threatening weather (ramp operations)
- Fire
- Injured person/ground damage

Students were grouped into task teams and assigned one of the top seven possible hazardous events to perform a process hazard analysis (PHA) or a bow-tie diagram for root cause analysis. PHA incorporates adaptation of three conventional system safety techniques: fault tree analysis, causal factors charting, and event tree analysis. This was the assessment tool taught in AT 402 to explain operational hazard and risk evaluation.

The bow-tie diagram assessment was selected due to its graphical nature, which makes it easy to construct and understand the concept of error/hazard progression and safety defenses. The PHA diagram technique also illustrated the necessity and role of systemic defenses, in addition to the overall concept of safety as a managed system. A PHA diagram constructed by a student team assigned to assess for injured person/ground damage is shown in Figure 2.

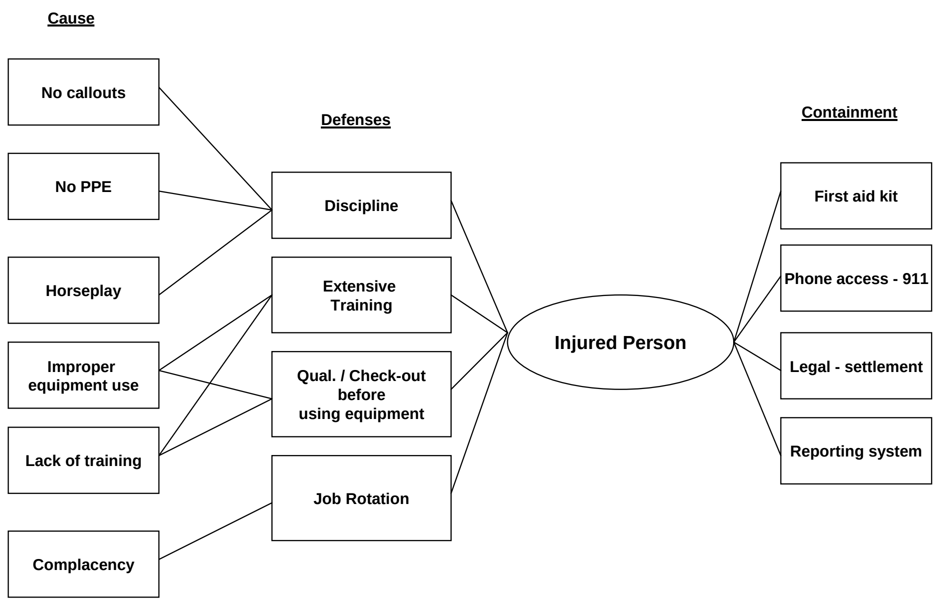

Figure 2: Process Hazard Assessment Bow-tie Diagram

Students analyzed their assigned top emergency event for potential hazards/root causes, preventive defenses, and contingency/containment measures if the event were to occur. They then constructed a risk matrix (Figure 3), assessing the likelihood and severity of each potential hazard/root cause identified on the far left of the PHA diagram.

	Severity	***Negligible***	***Minor***	***Major***	***Hazardous***	***Catastrophic***
Likelihood		1	2	3	4	5
Frequent	5					
Occasional	4		Horseplay	No Call-outs		
Remote	3		Complacency		Improper Equip Use	
Improbable	2		No PPE			
Extremely Improbable	1				Lack of Adequate Training	

Figure 3: Risk Matrix Assessment

Both of these risk tools were covered extensively in the lecture portion of the class. This was the first time most students had used such tools in a real situation, representing a crossover from theory to practice. This allowed students to experience the intricacies and details required within any management system.

This exercise had two cascading results. The top seven events identified and evaluated were compiled into a preliminary Emergency Response Plan (Item 6 of the key SMS components in Table 1) in which each emergency scenario and initial contingency action was documented and formally bound into a binder for use in the laboratory. As well, the list of additional and routinely occurring hazards inherent to AT 402 was formalized into a draft online form as an interactive hazard assessment tool used in required team briefings.

VIII. Discussion

The assessments, checklists, and other safety related tools developed in AT 402 did not represent perfect products. SMS implementation initiated in the AT 402 laboratory was slow but effective and continues to be so. But the tools developed and used represent knowledge transfer from intangible cognitive principles into tangible and useable tools by the student. More significant than the structure was the observation that students with little or no previous industry experience exhibited behavior and produced viable safety system deliverables. These performance skills are highly valued by industry. There were other significant learning outcomes and student self-discoveries, as a result of introducing them to the complex concept of an SMS.

First, students learned early on in the process that achieving safety outcomes that are compliant to regulations and effective throughout an organization is resource and time intensive. It required much more effort and explicit participation by the entire student workforce than they originally envisioned. Students relayed a general sense of the necessity of pre-planning and the broad use of teams required to implement any philosophy and practice system wide. Creation of the Emergency Response Plan (ERP) component of the SMS is one example. Through creation of the ERP as an early step in SMS implementation for the AT 402 laboratory, students with minimal industry experience were able to proactively identify hazards within the laboratory operation and take corrective actions to mitigate the risks through disciplined effort. Evaluating risk in a disciplined manner forced them to ask critical third and fourth questions regarding hazard and error causation (i.e., “how?” and “why?”). These questions are essential for accurate root cause analysis.

Second, SMS was shown to be an effective vehicle for safety management, providing a way to rapidly identify emerging hazards in a proactive manner instead of waiting for an accident to happen. Students were able to experience effort and activity required for being proactive in addition to mere discussion of that principle. However, this level of safety vigilance came at a price to the students’ time and energy. To implement a cross-cutting system of safety, even within a smaller, controlled laboratory operation such as a university course, required persuading change in certain corporate management (instructor) philosophies and training approaches. It also involved critical evaluation and re-adjustment of some existing processes, or development of entirely new and robust communication, reporting, and investigation tools and protocols. Just as in industry, the challenges students faced addressing these issues were, at times, overwhelming, thus requiring time above and beyond that allocated for labs each week. The tools they developed for AT 402 required still more work and refinement. However, students saw for the first time the magnitude of change and ongoing development that must take place to effectively manage safety in complex operations. It was pointed out that this same disciplined approach as a manager has application to all areas of the industry.

Most notably, during the semester debrief of the course, the class arrived at the conclusion that system wide safety required more than posters or written reminders to be safe. Students articulated there was probably no single cure-all or training program that could account for safety within complex operations like aviation maintenance.

Another significant observation as a result of SMS implementation was that AT 402 students, regardless of their lab assignments, began to actively intervene with other student groups, and even faculty, who breeched newly established safety protocols during laboratory operations. On two occasions directly observed by the instructor, AT 402 students proactively intervened and resolved emerging hazardous conditions. In the first, students of the AT 402 team prevented underclassmen from turning on power to the aircraft incorrectly, and then they proceeded to educate those students in the use of the provided checklists and proper techniques. On the second occasion, they observed a faculty member walking toward the aircraft during laboratory operations and were able to convince that person to put on safety glasses and hearing protection; albeit slightly disgruntled at the time, the faculty member complied. These student actions were self-directed (without direction of the lab instructor), whereas similar hazard situations occurring earlier in the semester had gone unaddressed.

IX. Conclusion

Student-led implementation of an SMS went beyond simply adding parts, paperwork, or procedures to the course. As students progressed in their research, development, and application of basic safety and risk principles, the culture of the entire lab operation evolved from one of hesitancy to active participation in assertive safety behavior. Students demonstrated self-initiated behaviors reflecting those of a proactive safety culture by assertively intervening on unsafe acts, active participation, and suggestions for improvement, while adhering to existing safety protocols, along consistent pre- and post-laboratory safety briefings that began to occur even without the instructor present. These are believed to be critical achievements for any safety initiative to survive. Looking to the future, a more defined safety behavioral measurement with a better quantitative assessment of laboratory safety performance is planned.

While SMS implementation within the AT 402 laboratory is far from complete, the examples discussed here represent major steps forward in the spirit of showing students first-hand the concept of continuous improvement and the complex nature of system-wide safety. It also helped in developing student safety and general leadership competencies required in the ever-changing and dynamic field of aviation.

References

[1]Reason, J. (1997). "Managing the Risks of Organizational Accidents," New York: Ashgate, p. 37; 192.
[2]Federal Aviation Administration (2006). "Introduction to Safety Management Systems for Air Operators," *Federal Aviation Administration Advisory Circular 120–92*, June 22, 2006, Appendix 1, p. 4.
[3]International Air Transport Association (2008). "Introduction and Definitions," *Operational Safety Audit Programme Manual*, 3rd edition, IATA: Montreal, Geneva, p. 20.
[4]Weick, K.E. and Sutcliffe, K.M. (2001). *Managing the Unexpected: Assuring High Performance in an Age of Complexity*, San Francisco: Josey-Bass, p 97–98.
[5]International Civil Aviation Organization (2006). *Safety Management Manual, SMM Doc. 9859*, 2006–07, p. 5, 3, and 6.
[6]Civil Aviation Safety Authority-Australia (2005). "Developing a Safety Management System at Your Aerodrome," *Australian Government – Civil Aviation Safety Authority*, Advisory Circular AC 139-16(0), p 2, 4.3–4.4.
[7]Transport Canada (2007). "Implementation Procedures Guide for Air Operators and Approved Maintenance Organizations." *TP 14343E*, April, 2007.
[8]EU-CAA CAP 712 (2002). "Safety Management Systems for Commercial Air Transport Operations," *A Guide to Implementation prepared by the Air Transport Operations—Safety Management Group*, p. 2, Retrieved May 2008, http://www.caa.co.uk.
[9]Transport Canada, (2006). "Canadian Aviation Regulations (CAR) Part 1- 107," General Provisions.
[10]International Civil Aviation Organization (2006). "Global Aviation Safety Roadmap," ICAO/ATAG/WB Development Forum, Montreal, Canada, May 24–26, 2006.
[11]CAA (2006). "European Safety Plan 2006/07 - 2010/11," *Safety Regulation Group*, No. 1, 2006, p. 87.

Biography

TIMOTHY D. ROPP is an Assistant Professor of Aeronautical Technology at Purdue University, where he teaches aircraft airworthiness assurance and safety and human factors coursework. He has internationally recognized expertise in SMS and has been sought by aviation and other risk sensitive industries for his work in SMS applications.