UNIVERSITY OF SOUTHERN CALIFORNIA

# USC Safety Management System

## FAA Design Challenge IV: Management and Planning


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# 1. Executive Summary

USC-SMS is a system for airport operators to report and manage hazards. It will enhance the operational safety, management, and efficiency of an airport. Information collected and generated by USC-SMS can be shared with other airports to help improve the National Airspace System (NAS). It was designed by a team of three undergraduate computer science students at the University of Southern California as part of Professor David Wilczynski's senior capstone design class. Our system improves airport safety by adhering to the guidelines for safety management systems (sms) to be imposed by the Federal Aviation Administration (FAA). In addition our research, the team met with airport operators and industry experts at the Los Angeles International Airport and Bob Hope Airport in Burbank California.

Our design is based on the four pillars of sms: Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion. USC-SMS consists of a web-based Hazard Reporting System with a portable phone application interface that is used to submit hazard reports, an Accountable Executive Management Interface that managers can use to analyze reported hazards and that assists managers in developing an action plan to mitigate any risks associated with the hazards, and another portable phone application that delivers risk mitigation assignments to maintenance workers. The system is able to provide a general framework for an organization-wide safety management approach to airport operational safety. This approach will actively engage airport management in airfield safety, ensure that formal documentation of hazards and analytical processes is used to analyze, assess, and mitigate risks, proactively look for safety issues through analyses and lessons learned, and distribute pertinent safety information to the appropriate members of the airport community.

## 2. Problem Background

Airport safety is paramount because of the large number of people and expensive equipment that can be affected by an accident at an airport. While major accidents may be relatively rare, situations that appear to be minor still deserve attention, especially if they could lead to larger problems. Any condition or physical entity that has the potential to lead to an incident is a hazard; an incident refers to an actual accident, or dangerous event. Broken runway lighting, harsh weather conditions, vegetation covering signage, foreign object debris (FOD), wildlife, and even a change in management are examples of airport hazards. Since the purpose of the USC-SMS is to improve airport safety, we must be able to find and analyze the various factors that lead up to incidents. This means that we need to minimize the conversion of hazards to incidents as well as reduce the number of hazards.

Currently, safety management practices vary greatly between airports and have weaknesses such as the ones listed in the left-hand column of Table 1. The right-hand column of this table describes the elements of a robust safety management system (sms) that would overcome these weaknesses. Although the International Civil Aviation Organization (ICAO) established an sms requirement for its member airports through the amendment of Annex 14 Volume 1 in November 2005, airports in the United States are not required by FAA regulations to have a sms. Airport safety is regulated by the FAA's Title 14, Code of Federal Regulations (CFR), Part 139 (commonly referred to as "Part 139"). In order for airports to keep their Airport Operating Certificates, they must adopt and comply with an Airport Certification Manual (ACM) that describes operating procedures and responsibility assignments, and pass an annual Part 139 inspection. The Part 139 inspection covers a wide spectrum, including wildlife hazard management, firefighting equipment, paved and unpaved areas, and more. Airports are expected to keep documentation of regular self-inspections and personnel training records which may be requested as part of the Part 139 inspection (Federal Aviation Administration, 2004).

**Table 1: Some Underlying Causes of Man-Made Disasters Identified and Lessons Emerging from Disaster Analysis**

**Source: (Waring, 2005)**

| **Some Underlying Causes within Organizations** | **Lessons to be Learned by Organizations** |
|---|---|
| Poor/weak/fragmented safety management; lack of top-down safety management system (SMS). | Need robust SMS, as designed and as operated. |
| Poor/weak hazard analysis and risk assessment relating to major hazards | Need competent life-cycle hazard analysis and risk assessment regime for major hazards within SMS plus 'safety cases' |
| Weak accountability for safety in managerial reporting lines; lack of Board-level oversight; strong rhetoric about safety commitment among directors and senior managers but weak demonstration in practice. | Board Director should be named as personally responsible for safety. |
| Communication failures. | Better systems for, and fewer assumptions made about, communication. |
| Means to check safety compliance often haphazard and over-reliant on licensing and inspection at expense of in-depth audits and assurance. | Need strong independent validation and verification auditing regime plus independent and internal reviews |
| Erroneous beliefs/opinions about cause-effect relationships in safety; lack of tutored knowledge. | Need for higher quality staff training. |
| Emergency preparedness fragmented and weak. | Need well tested emergency plans. |
| Poor attitudes and motivation towards safety among managers and operatives. | Need strong safety culture to ensure SMS etc do deliver desired results. |

But the FAA plans to create a rule that would complement Part 139 and require Airport Certificate Holders to implement an sms. On October 7, 2010, they released a Notice of Proposed Rulemaking (NPRM) that describes the proposed guidelines for the mandatory sms. These guidelines are based on four pillars: Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion. Safety Policy involves clearly assigning roles in the safety management process, as well as creating and maintaining a safety policy statement and objectives. Safety Risk Management helps achieve the safety objectives through a formalized process of documenting and analyzing hazards and their associated risks, and mitigating the risks when deemed necessary by management. Safety Assurance requires a way of monitoring safety performance, allowing people to anonymously report hazards, and regularly reporting safety data to the accountable executive (whose role is assigned from the Safety Policy). Finally, Safety Promotion involves the encouragement of a positive safety culture through management's example, employee training and proof of the sms's effectiveness (Federal Aviation Administration, 2010).

One of the most important requirements for our design is that it create a predictive, not just reactive system. Using all of the information given about an airport, the system must be proactive in preventing hazards and incidents before they occur. For example, if USC-SMS receives hazard reports for one runway light more often than the other lights, it will "notice" this pattern and notify the appropriate employee of a potential problem with that light. Then, an electrical inspection/repair could be done on that light to prevent it from quickly going out again. Another way in which our system will be predictive is by increasing inspection frequencies when necessary. For instance, if a certain area on the runway receives reports of foreign object debris, USC-SMS will recommend that the area be inspected more frequently than usual. Although this would not prevent the presence of debris in that area, it would prevent incidents caused by unnoticed debris.

## 3. Summary of Literature Review

The International Civil Aviation Organization (ICAO) is a United Nations agency comprised of 190 member states that work together to achieve safe, secure and sustainable development of civil aviation. In November 2001, ICAO amended Annex 11 to the Convention, *Air Traffic Services*,[1] to require that member states establish sms for the provision of air traffic services. As the state regulatory agency in the United States, the FAA has complied and assisted with these efforts. Following its own study in 2000, the FAA determined that the design, development and implementation of an sms were the next steps in its fundamental mission to control and maintain a safe NAS. Literature research into the evolution and development of sms shows the acceptance and adaptation of sms concepts in the aviation safety industry.

In 2007, the FAA released AC (Advisory Circular) 150/5200-37, "Introduction to SMS for Airport Operators." An Advisory Circular is a document containing information that the FAA wants to distribute to the aviation community. AC 150/5200-37 introduced the general concept of a safety management system (sms) for airport operators, while providing general guidelines. For the purpose of our design, this document introduced us to the concept of safety management. The advisory circular outlines the proactive, systematic and integrated method of managing safety for airport operators and the formal Safety Risk Management (SRM) procedures for risk

[1]ICAO Annex 11 to the Convention on International Civil Aviation, Air Traffic Services, Thirteenth Edition – July 2001, Section 2.26.

analysis and assessment. AC 150/5200-37 provides the context for the development of SMS within current FAA guidelines and regulations. However, the Advisory Circular itself is not a regulation and therefore is not a requirement by the FAA; Title 14, Code of Federal Regulations (CFR), Part 139 (14 CFR Part 139), the Federal Airport Certification Requirements, is the governing regulatory document for airport operators in the United States. 14 CFR Part 139 mandates that airport operators (the organizations responsible for the direction and management of one or more airports) obtain an Airport Operating Certificate (AOC) from the FAA. In order to obtain a certificate, an airport must agree to comply with the operation and safety standards specified in 14 CFR Part 139. This involves adopting an Airport Certification Manual (ACM), performing and documenting self-inspections, providing employees with proper safety training, maintaining the premises according to specific requirements, providing and maintaining a safety area, keeping runway signs and markings free of obstructions, having functional runway lighting, snow and ice control, well-equipped rescue and firefighting teams, wildlife management, an airport emergency plan, and other safety features. The current federal airport certification requirements went into effect on June 9, 2004, establishing the minimum standards for maintaining and operating the physical airport environment. 14 CFR Part 139 provided our team with a firm understanding of the requirements of an airport operator.

In keeping with the U.S. obligations under the Convention on International Civil Aviation, it is FAA policy to conform to International Civil Aviation Organization (ICAO) Standards and Recommended Practices to the maximum extent practicable. Since ICAO already has regulation requiring sms, the FAA is following suit. On October 7 2010, the FAA released a notice of proposed rulemaking (NPRM) to revise current Part 139 to require certificated airports to develop, implement and maintain a safety management system (sms). The NPRM describes the four pillars of sms, and for each pillar proposes a list of minimum elements that must be included in compliant sms implementations. It also gives a history of the use of safety management systems, and describes how sms would benefit airports. The release of the NPRM was a significant step in the development and implementation of an sms policy, as it was the culmination of a nearly decade-long study, and the last step before its incorporation into regulatory requirements. The NPRM is open for comments from members of the aviation community and the general public until July 5, 2011. Submitted comments will be reviewed and taken into consideration as a final rule and amendment to 14 CFR 139 is made. This document provided our team with the most current view of sms in the aviation community as well as a look at the proposed federal regulations for sms by the FAA. Establishing sms as a federal regulation for airports in the United States provides a common framework to assess safety risks of changes to the NAS and, in turn, the global airspace system.

The Airports Cooperative Research Program (ACRP), managed by The Transportation Research Board (TRB), conducted two projects to prepare guidance on airport sms, resulting in the publication of two reports that our team used as references. The first report, SMS for Airports Volume 1: Overview describes sms benefits, ICAO requirements, and sms application at U.S. airports. The second, ACRP's SMS for Airports Volume 2: Guidebook, was completed in October 2009 and provides practical guidance on the development and implementation of an airport sms. It was used extensively by our team as a reference for recommended approaches and practices for addressing sms needs.

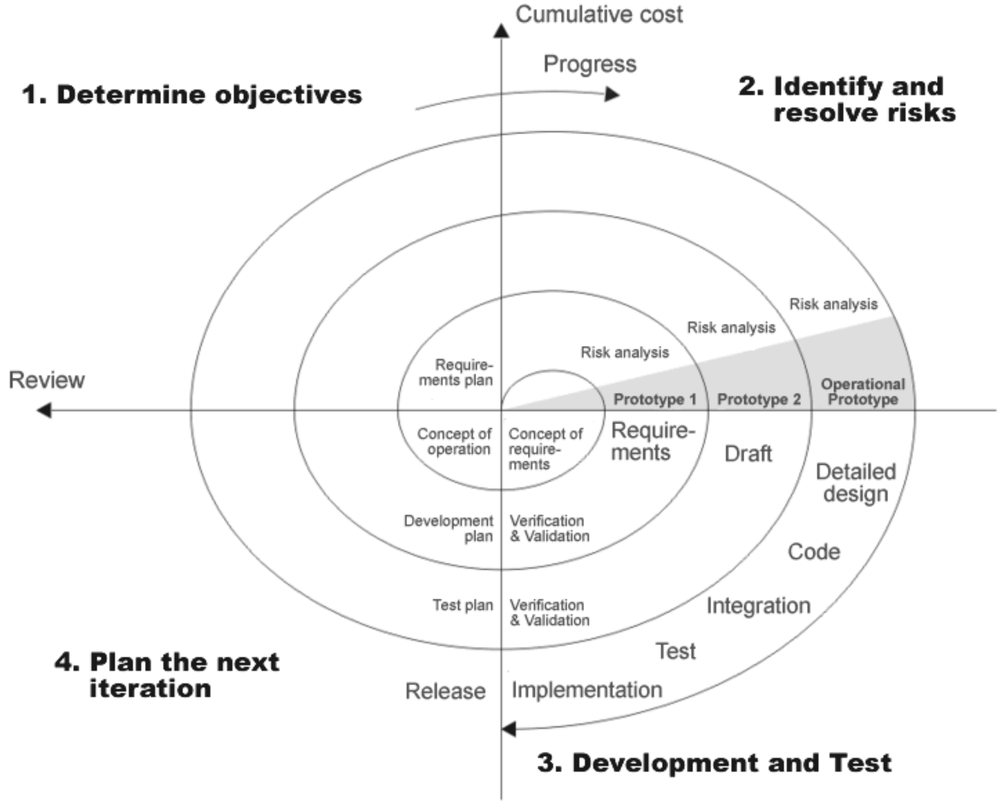
By understanding the current culture of safety in the aviation industry and how the FAA has evolved to its current state, our team was better able to design a system that is usable in today's aviation industry.  This is particularly important at this time, as the FAA is preparing to introduce new federal regulations requiring airport operators to have an sms.

## 4. Team's Problem Solving Approach to the Design Challenge

In approaching the task of designing a Safety Management System our team chose to implement a Spiral Model (Boehm 1986), a variation of the more common iterative development process.  The iterative development process is a cyclical process of developing a product, testing and analyzing it, and refining the product from the results. With each iteration and refinement, the product functionality and user needs are improved and enhanced.

The Spiral Model differs from the traditional iterative process in that it combines development activities with risk management to minimize control risk with each iteration of the product.   With each iteration, the risk analysis weighs different alternatives in light of the requirements and constraints, and the prototyping verifies feasibility or desirability before a particular alternative is chosen. When risks are identified, the developers must decide how to eliminate or maximize the risk.  This approach to developing software is very useful in that it allows the use of the Safety Risk Management process (discussed later in this report), helping to minimize control risks in the development of the software tool, as well as any risks that might arise as a result of its integration into the airport environment.

Figure 1: The Spiral Model has four iterations




## 4.1. First Iteration: Research

The first iteration of the our design process began with the sms requirements as specified in the FAAs NPRM, which specifies the requirements of an sms to be included in the revised version of 14 CFR Part 139. These requirements were chosen, as they currently represent the closest thing to federal requirements for the NAS. In order to put the system requirements into context, our team proceeded to gain a better understanding of the real world environment that our sms is intended to model and operate in. This was done by performing a domain analysis.

Our domain analysis involved a three-pronged approach: a literature review, interacting with domain experts, as well as visiting an operational airport to observe the environment and view how proposed requirements are currently addressed.

Our team visited the Los Angeles International Airport (LAX) control tower and was given the opportunity to interact with domain experts familiar with the airport environment and the management of safety. Mr. Herb King, an Air Traffic Control (ATC) quality control supervisor, familiarized us with the layout of LAX, the runways and the control tower and exposed us to policies, practices and procedures used in the day to day operations of LAX. Of particular interest to members of our group were procedures used by ATC to avoid runway incursions and the emergence of new technology such as ASDE-X to help prevent them. Our visit to the control tower gave us an opportunity to observe air traffic controllers working with computer interfaces as tools to help them in the process of making processes.

We were fortunate to have contact with Mr. Thomas Anthony, the Director of Aviation Safety and Security Program at the USC Viterbi School of Engineering, provide us with an introduction to the concept of safety in the aviation industry. Our team met with Mr. Anthony who gave us a history of safety management and exposed us to important safety terms such as "risks", "hazards", "incidents" and "incursions." Our meeting helped our team to finalize our decision to design a safety management system to enhance the operational safety, management, and efficiency of an airport. Mr. Anthony was very helpful in us gaining a better understanding of documents we reviewed in literature review and helped us put them in context with the development of new federal regulations.

Using our requirements from the NPRM and knowledge gained from our visit to LAX and meeting with industry experts, our team proceeded to construct an initial plan for development, taking into consideration the factors that impacted the development of our proposed system. Factors taken into consideration included budget, constraints and alternatives for staffing, design, and development environment. As undergraduate students, one of the constraints we had to address the difficulty scheduling meetings due to team members' varying class schedules. To address this issue, the team decided to hold meetings during our scheduled class time. Professor Wilczynski was able to facilitate this by making time during our lecture period for us to meet. It was at this stage of our first iteration that our team was able to implement the risk management step involved in the Spiral Model of development. The team was able to weigh different alternatives in light of the requirements and constraints as well as evaluate risks that might be observed from our new deeper understanding of our domain. In weighing our options of how we would be able to meet and discuss our project outside of class, the team looked at meeting using Skype to video conference. Although a viable option, the team decided to take advantage of Google Chat, an instant messaging client application. This alternative had less risk to the development of our design because it is integrated into our university email and computer system and readily available to all team members from most computers. The team scheduled times for members to meet online using Google Chat to discuss our project and make decisions. This resource also allowed for many impromptu meetings by taking advantage of a feature of the instant messaging client that indicated whenever a team member was online and available to collaborate. The product or prototype of the first iteration of our Spiral Model development process was an Operational Concept Document. Our Operational Concept Document (OCD) provided a top-level shared vision and concept of the new system would operate within its environment. The document identified organizational goals, key stakeholders in the airport environment impacted by our proposed USC-SMS, system boundaries and environment it would operate in, project goals and constraints, and stated the proposed system capabilities.  The purpose of this document was twofold.  Firstly to provide any stakeholders, who in the case of the sms might be users, operators, administrators, operations personnel or the general public, to better understand the new system and offer suggestions for any refinements.  Secondly, from the developer's perspective, it enabled us to better understand the system being developed and its constraints, and to make better development decisions.

### 4.2. Second Iteration: Requirements

From the OCD our design team was able to begin the second iteration of our design development process.  This iteration involved a refinement of the proposed system requirements. Our team presented the findings of our first iteration and OCD to an audience of system stakeholders including industry experts, our classmates and our professor.  Feedback from our audience was very helpful.  Presenting the numerous, intricate requirements from the NPRM, we realized how wide sophisticated the scope of our design challenge was. As a result of our interaction with various stakeholders, our set of system requirements was refined and scrutinized to ensure that the requirements were as complete and consistent as possible while still addressing the goals of our USC-SMS.    This process included an assessment of risk and weighing different alternatives to address risks and design options.  With the vast scope of NPRM requirements, the team decided to narrow the scope of our USC-SMS to include the foundation of any sms, the Safety Risk Management process, and only some of the NPRM requirement associated with Safety Policy, Safety Assurance and Safety Promotion.  The result of this iteration was a refined list of requirements describing the services provided by the system in greater detail. Details included in this version of the requirements included more specific descriptions of exactly what the system is supposed to do in order to achieve the capabilities specified in the OCD, identification of constraints on the way the problem would be solved such as mandated technology, and a description of how the software should interface with users or any other software systems for input or output. The conclusion of this iteration produced a set of requirements that were as complete and consistent as possible. This refined list of requirements listed below:

1. The scope of the system must encompass aircraft operation in the movement area, aircraft operation in the non-movement area, and airport operations.
2. USC-SMS must be in compliance with the requirements identified under Title 14 Code of Federal Regulations (CFR) Part 139.
3. Describe management responsibility and accountability for safety issues.
4. Define methods, processes, and organizational structure necessary to meet safety objectives.
5. Establish a system for identifying safety hazards
6. Establish a systematic process to analyze hazards and their associated risks.
7. Provide for assessment to ensure that safety objectives identified by the certificate holder's acceptable level of safety are being met.
8. Establish and maintain records that document the certificate holder's Safety Risk Management processes.
9. Report pertinent safety information and data on a regular basis to the accountable executive.

### 4.3. Third Iteration: Development.

Based on the refined requirements produced in the second iteration, the team was able to undertake the third iteration of our design process. The system as a whole is designed to identify and mitigate risks at airports by proactively identifying potential hazards and performing necessary actions. A key element in the use of USC-SMS is accessibility to the sms to report hazards. It is our goal that all stakeholders in the airport domain have access to our system both to input hazard information as well as to access information generated and communicated. To address this, our team designed a system that is web-based, allowing users to access it from any device that has access to the web. We also wanted to develop an application that was not designed for one specific platform, Windows or Apple. To address these issues our team decided to design a web-based hazard reporting system, and develop an Executive panel application using the Java programming language. We realized that our hazard submission form would be in the forms of an Android application and a web form. With the web form, it was natural that we chose to use a MySQL database being that MySQL is among the world's most popular database management system.

For our Executive applications we chose the Java language to create a portable and reliable desktop application. Since Java applications compile into portable jar files, they can be easily moved between computers running the latest version of Java without needing to do an install.

This iterative development process matches well with the Phased Approach to SMS Implementation outlined in the ICAO Safety Management Manual (Chapter 10). ICAO endorses a phased approach to sms implementation, breaking down the overall complexity of the task as a whole into smaller subcomponents, making the development process both more manageable as well as effective by managing the workload associated with the implementing each phase. This approach allows for simpler fundamental safety management processes to be addressed before moving onto more complex processes. A third reason supporting phased implementation is to avoid what ICAO refers to as "cosmetic compliance" or "ticking the appropriate boxes" implementations. Such systems meet the desired requirements, but are just empty shells and are not effective in any way. A phased implementation might take longer, but the robustness of the resulting sms will be enhanced as each implementation phase is completed.

The results of our fourth iteration are presented in the technical description of our USC-SMS.

# 5. Safety Risk Assessment

The FAA promotes a culture of safety throughout all its operations. An increase in the use of air transportation and the forecasted growth of the industry has further emphasized this objective increasing the effort for new measures to improve the level of aviation safety. In its Introduction to Safety Management Systems (SMS) for airport operators (AC 150/5200), the FAA states: "The use of SMS at airports can contribute to this effort by increasing the likelihood that airport operators will detect and correct safety problems before those problems result in an aircraft accident or incident."[2] The FAA defines sms as "the formal, top-down, business-like approach to managing safety risk that includes systematic procedures, practices and policies for the management of safety." The objective of our team was to develop the USC-SMS, a set of decision making tools and process used to plan, organize, direct and control the business activities of a certified airport operator enhancing safety and compliance to regulations. Using the USC-SMS an airport operator would be able to integrate with the common framework the FAA provides to assess safety risks within the NAS.

The aviation community has changed dramatically with the advancements in engineering, technology, regulation and knowledge. The role and concept of safety in has changed to accommodate the changes in aircraft, equipment and facilities. The result has been an evolution of the safety in aviation from one of reactive policy, to one of a developing a proactive and predictive safety culture that is embodied by our USC-SMS. Traditional reactive safety addressed safety after an incident or accident has already occurred. Safety policy was established in reaction addressing safety issues through extensive inspection and remedial actions. USC-SMS is significantly different, using a systems approach that concentrates more on control of processes.

Advisory Circular 150-37 states that goal of an sms is to provide a structured management system to control risk in operations[3]. As previously mentioned, an sms approaches

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[2] INTRODUCTION TO SAFETY MANAGEMENT SYSTEMS (SMS) FOR AIRPORT OPERATORS, AC 150/5200-37, February 28, 2007.

[3] Introduction to Safety Management Systems for Air Operators, AC 120-92. 6/22/06

safety based on characteristics of an operator's processes that affect safety. To gain a better understanding of the concept of sms, and how our USC-SMS will fits into the changing landscape of safety, our team took a look at the three elements that make up its name: safety, management and system.

Safety is commonly defined as the absence of potential harm. The use of this definition in the context of management of safety implies the complete elimination of potential harm. In the real world is not possible. In designing the USC-SMS, our team adopted the view of safety from the perspective of risk. More specifically, risk is described in terms of severity: how much harm can be caused, and likelihood; how likely harm will be caused. Viewing safety from a risk perspective allows us to evaluate factors in terms of weather they are more or less likely to be involved in an accident or incident as well as being able to evaluate the relative severity of the outcome. A summary of the classifications of severity and likelihood are found in the tables below.

**Table 2: Hazard Severity Classification**

| Effects: | Hazard Severity Classification | | | | |
|---|---|---|---|---|---|
| | No Safety Effect<br>5 | Minor<br>4 | Major<br>3 | Hazardous<br>2 | Catastrophic<br>1 |
| ATC | Slight increase in ATC workload | Slight reduction in ATC capability or significant increase in ATC workload | Reduction in separation or significant reduction in ATC capability | Reduction in separation or a total loss of ATC capability (ATC Zero) | Collision with other aircraft, obstacles, or terrain |
| Flying Public | - No effect on flight crew<br>- No effect on safety<br>- Inconvenience | - Slight increase in flight crew workload<br>- Slight reduction in safety margin or functional capabilities<br>- Physical discomfort of occupants | - Significant increase in flight crew workload<br>- Significant reduction in safety margin or functional capability<br>- Physical distress possibly including injuries | - Large reduction in safety margin or functional capabilities<br>- Serious or fatal injury to small number of occupants or cabin crew<br>- Physical distress/ excessive workload | - Hull loss<br>- Multiple fatalities |

Table 3: Hazard Likelihood Classification

| | Hazard Likelihood Classification | | | | | |
|---|---|---|---|---|---|---|
| | NAS System | | | Flight Procedures | Operational | |
| | Quantitative | Qualitative | | | | |
| | | Individual Item/System | ATC Service/ NAS Level System | | Per Facility | NAS-wide |
| **Frequent A** | Probability of occurrence per operation/operational hour is equal to or greater than $1x10^{-3}$ | Expected to occur frequently for an item | Continuously experienced in the system | Probability of occurrence per operation/ operational hour is equal to or greater than $1x10^{-5}$ | Expected to occur more than once per week | Expected to occur every 1-2 days |
| **Probable B** | Probability of occurrence per operation/operational hour is less than $1x10^{-3}$, but equal to or greater than $1x10^{-5}$ | Expected to occur several times in the life of an item | Expected to occur frequently in the system | | Expected to occur about once every month | Expected to occur several times per month |
| **Remote C** | Probability of occurrence per operation/operational hour is less than $1x10^{-5}$ but equal to | Expected to occur sometime in the lifecycle of an item | Expected to occur several times in system lifecycle | Probability of occurrence per operation/ operational hour is less than $1x10^{-5}$ | Expected to occur about once every 1 -10 years | Expected to occur about once every few months |

| | | | | | | |
|---|---|---|---|---|---|---|
| | or greater than $1x10^{-7}$ | | | but equal to or greater than $1x10^{-7}$ | | |
| **Extremely Remote D** | Probability of occurrence per operation/operational hour is less than $1x10^{-7}$ but equal to or greater than $1x10^{-9}$ | Unlikely but possible to occur in an item's lifecycle | Unlikely but can reasonably be expected to occur in the system lifecycle | Probability of occurrence per operation/ operational hour is less than $1x10^{-7}$ but equal to or greater than $1x10^{-9}$ | Expected to occur about once every 10-100 years | Expected to occur about once every 3 years |
| **Extremely Improbable E** | Probability of occurrence per operation/operational hour is less than $1x10^{-9}$ | So unlikely, it can be assumed that it will not occur in an item's lifecycle | Unlikely to occur, but possible in system lifecycle | Probability of occurrence per operation/ operational hour is less than $1x10^{-9}$ | Expected to occur less than once every 100 years | Expected to occur less than once every 30 years |

The management process of safety management, involves the design and implementation of organizational processes and procedures to control risk. The ICAO Safety Management Manual, identifies safety as," the outcome of the management of organizational processes, which have the objective of keeping the safety risks of the consequences of hazards under organizational control."[4] Once organizational controls are implemented, quality management techniques are used to ensure that they achieve their intended purpose. Our team understood that importance designing our USC-SMS as a set of tools that management would be able to use not

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[4] *ICAO Safety Management Manual (SMM) 2.2.4.*

only to apply controls to risk, but also ensure that those controls are meeting their purpose. The USC-SMS is a set of tools applicable to quality management of safety related processes to achieve safety goals.

A system is described as an, "integrated set of elements that are combined in an operational or support environment to accomplish a defined objective."[5] Elements that make up a system include people, hardware, software, information, procedures, facilities, services and environment. Management of these elements involves planning, organizing, directing and controlling them in support of the organization's goals. In the context of sms, the organizational goals are safety driven. In short, sms is a quality program focused on proactively managing and controlling safety at an airport.

The USC-SMS was designed on four "pillars" or elements that compose sms: Safety Policy, Safety Risk Management, Safety Assurance and Safety Promotion. These elements are generally accepted as safety industry standards and have been adopted as guidance by the FAA and International Civil Aviation Organization (ICAO). The four components work in conjunction; therefore, the development and integration of the elements is critical to the successful application of a sms. Safety Policy, Safety Risk Management, Safety Assurance and Safety Promotion all play integral parts in USC-SMS.

AC 150-37 states, "Essential to a SMS are formal safety risk management procedures that provide risk analysis and assessment[6]." Safety Risk Management (SRM) the central element of

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[5] AC 150-37 Introduction of Safety Management Systems

[6] INTRODUCTION TO SAFETY MANAGEMENT SYSTEMS (SMS) FOR AIRPORT OPERATORS, AC 150/5200-37, February 28, 2007.

USC-SMS. It the set of processes, procedures and practices used to identify hazards, assess and analyze risks and mitigate any risks that are found to be unacceptable. SRM has been implemented by the FAA as a means to address changes with safety impacts to the NAS safety.

It is already part of everyday activity in many organizations. Currently the FAA requires assessments be conducted using the SRM process for any safety significant changes to airspace, air traffic or airport service procedures and standards and in the introduction of new safety equipment, systems (hardware and software), or facilities used in the provision of air traffic services.

As the overseeing agency, the FAA has "ownership" SRM process and its output, known as a "Safety Case". Airport organizations are participants in the SRM process instituted by the FAA. Safety Cases are documented in a Safety Risk Management Document (SRMD) which documents the change that is being made, the findings of the safety risk assessment, and is signed by the appropriate authority effectively implementing the change.

By using USC-SMS, an airport operator takes the role of oversight of the ownership of the SRM process. The transition of ownership to airport operators is significant in the scope of the changing landscape of the FAA regulations and aviation safety because it adds another layer of protection to the NAS. USC-SMS provides a common framework to assess safety risks of changes to the NAS by adopting the cross-functional safety risk management (SRM) process participation in solving the safety challenges of an increasingly complex NAS.

The safety risk assessment impacts USC-SMS on two fronts. Firstly as the main component of the sms system, and secondly as sms gets implemented in airport environments, it is a change to the current standard operating procedures. Therefore, its implementation needs to be evaluated using SRM and by generating a Safety Case for the implementation of an sms.

# 6. Description of Technical Work

## 6.1. Overview

USC-SMS is a set of software tools that provides a structured system that manages all of an airport's safety data and uses it to assess and improve safety levels. It is composed of a hazard reporting system and a safety case management system. The hazard reporting system gathers raw data that users submit to report seemingly dangerous situations. When it is determined that a reported hazard is real and requires action, the information is transferred to the safety case management system where it enters as a new case. Using federal regulations and examples from the past, our system will assist users in the decision-making processes used to plan, organize, direct and control the operational safety of an airport. It does so by providing a guided framework to formally document the risk analysis and assessment, proposed mitigation strategies, and management's acceptance of risk for each case.

USC-SMS has the following capabilities:

1. **Actively Engage Management in Safety:** Members of management identified as "accountable executives" and "responsible parties" will be responsible for risk analysis, compiling risk mitigation strategies, providing safety training for employees, and setting safety goals.
2. **Hazard Reporting System:** Hazards will be reported and entered into USC-SMS through a Hazard Reporting System: a multifaceted, voluntary, non-punitive reporting system that can be used by all stakeholders in an easy, convenient and efficient manner.

3. **Safety Risk Management:** USC-SMS will analyze and assess potential risks associated with identified hazards, prioritize their severity, and prescribe appropriate risk mitigation strategies.
4. **Proactive Hazard Prediction:** Through the analysis of operational safety data from past incidents, the system will be able to proactively identify unknown or undetected hazards. USC-SMS will allow an airport to proactively mitigate hazards and risks and prevent accidents and incidents by informing responsible parties of latent hazards.
5. **Safety Documentation and Data Management:** USC-SMS will formally document identified hazards, risk analyses and assessments, any proposed mitigation strategies, and management's acceptance of risk. All data associated with reported hazards will be archived and retained for auditing purposes and for use as "lessons learned" data.
6. **Safety Level Assessment:** USC-SMS can assess the airport's safety level at any given time and determine whether the airport is meeting the safety goals and objectives set by management.
7. **Incident Notification:** The system will provide a means for timely communication of safety issues between accountable executives, key personnel, and stakeholders, thus allowing for efficient mitigation of hazards and risks.
8. **Safety Promotion:** USC-SMS will provide a means of improving the entire airport's safety by establishing an organizational approach of safety training. Safety policy, goals, objectives, standards, and performance will be communicated clearly and regularly to all employees of the organization. Furthermore, people will be encouraged to submit hazard reports and may submit their contact information with reports so that they can be rewarded with information of how their report helped improve the airport's safety level.

## 6.2. Users

USC-SMS users can be classified into the four groups shown in Figure 2.

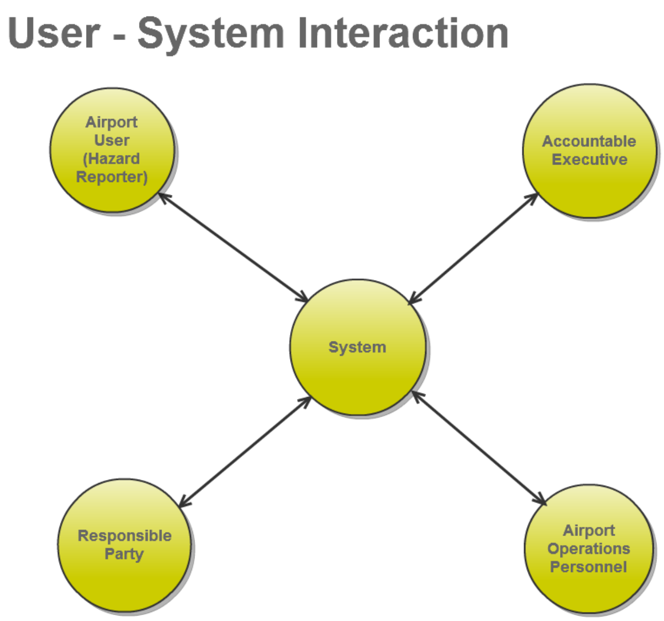



**Figure 2: The four user groups that will interact with the system (USC-SMS)**

Description of each user group and its role in airport safety:

**User-1: General Airport Population -** Anyone in the movement and non-movement areas of aircraft operation or in the airport can identify and report a hazard or potential risk that appears to affect the airport's level of safety. This includes members of the general public, passengers, contractors, employees etc.

**User-2: Airport Operational Personnel (Contractors, Operations Personnel, Pilots)** - All airport employees have safety accountabilities and responsibilities. USC-SMS will provide a means of delivering them job-specific safety information. Employees will be able to use the system to look up policies and procedures pertaining to their individual responsibilities. Additionally, the system will be able to actively distribute safety information to employees. For example, if the airport or the FAA publishes a new policy, USC-SMS would notify the employees of the change. Also, the system, knowing about each employee's operating environment, can provide information to guide employees in addressing hazards found in their area.

**User-3: Responsible Party (Department Heads, Responsible Parties, Supervisors, Key Personnel)** - Every department head or person responsible for a functional unit (line managers) will be involved in the operation of USC-SMS and its safety performance. They are responsible for overseeing hazard risk mitigation and ensuring that their departments abide by regulations and create safety documentation. Also, they create a risk mitigation strategy for each case in the system.

**User-4: Accountable Executives (Designated Accountable Executive, Airport CEO, Chief Safety Officer, High Level Senior Management, Identified Accountable Executives)** - Members of this group are persons within the organization with the authority and responsibility to account for the safety performance of the sms. These authorities and responsibilities include, but are not limited to: full authority for human resources issues. The Accountable Executive retains final accountability for the performance of the USC-SMS.

## 6.3. Use Case

The diagram pictured in Figure 3 is a more detailed version of the user-system interaction diagram in Figure 2. In addition to showing how each user group contributes to the USC-SMS process, it also shows our system's overall process flow in a step-by-step manner.

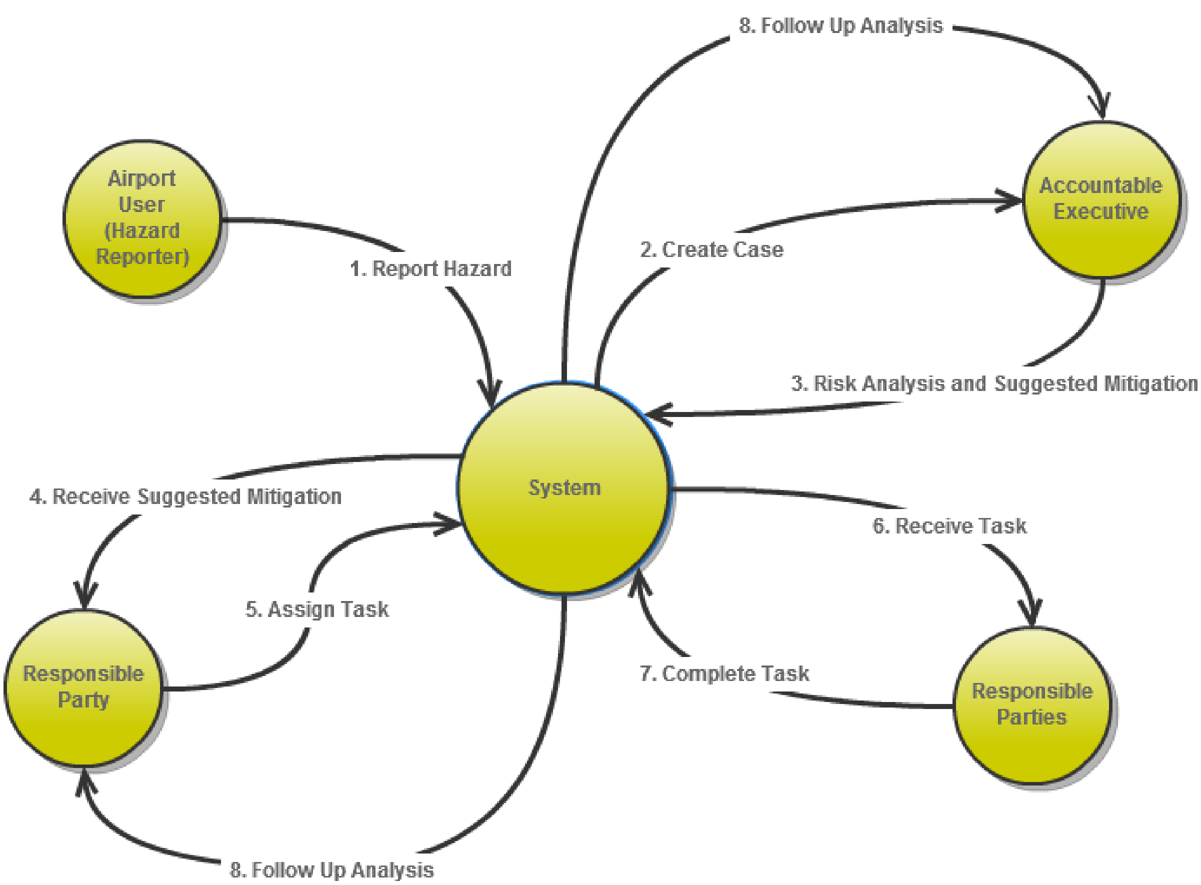
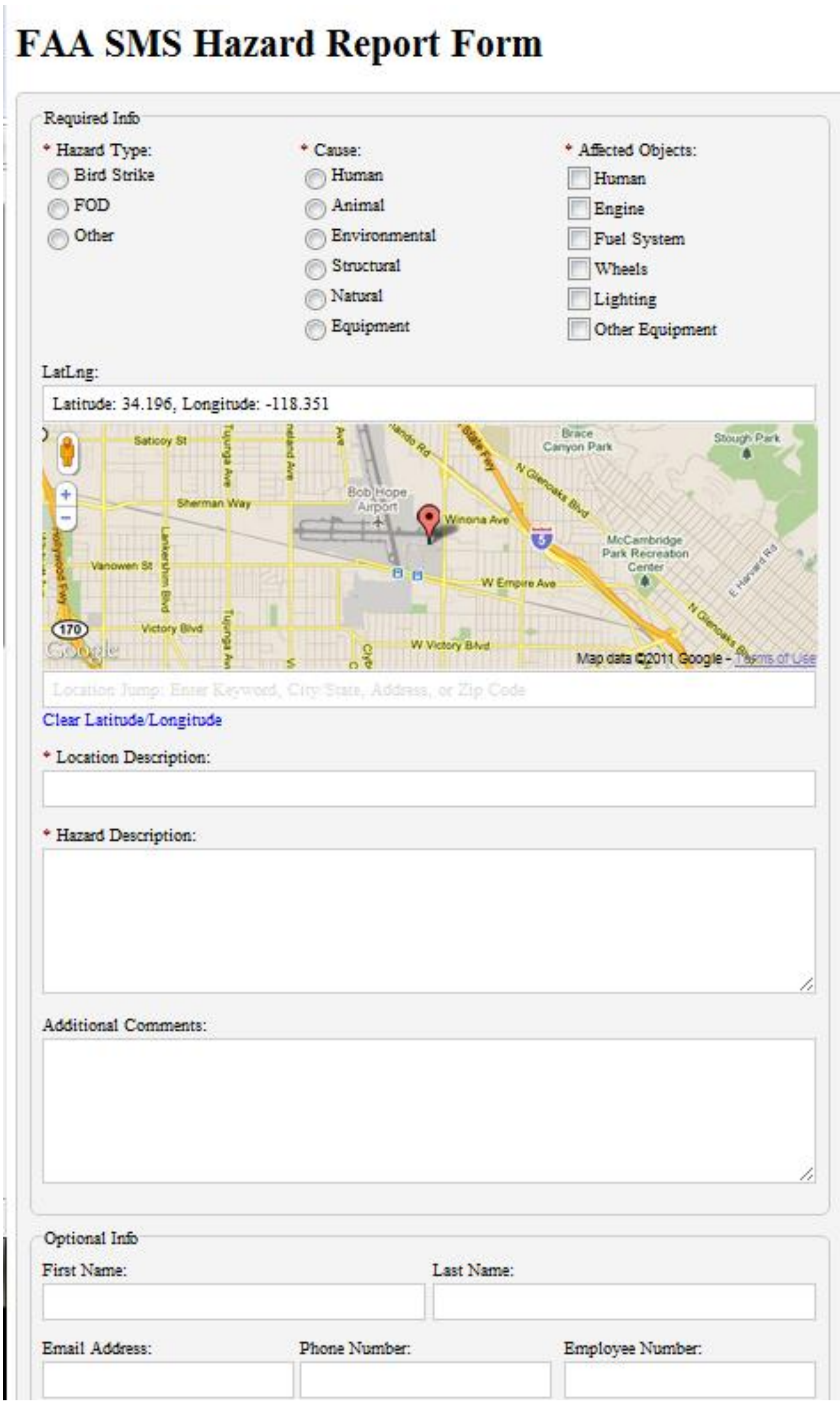



Figure 3: A detailed user-system interaction diagram.

The following use case will go through the USC-SMS process flow using an example in which a passenger named David Wilczynski sees an object fall off a cart while his flight is boarding.

**Step 1: Report Hazard**

Since David noticed foreign object debris (FOD), he should submit a hazard report using either the online web form (Figure 4) or the Android mobile phone application (Figure 5). Both input methods contain the same form fields; David must describe the hazard, the hazard location, identify possible causes, and, if desired, provide his contact information. All data from the hazard reports will be stored in the USC-SMS MySQL database.



# FAA SMS Hazard Report Form

Required Info

* Hazard Type:
  - Bird Strike
  - FOD
  - Other

* Cause:
  - Human
  - Animal
  - Environmental
  - Structural
  - Natural
  - Equipment

* Affected Objects:
  - Human
  - Engine
  - Fuel System
  - Wheels
  - Lighting
  - Other Equipment

LatLng:

Latitude: 34.196, Longitude: -118.351



Location Jump: Enter Keyword, City State, Address, or Zip Code

Clear Latitude/Longitude

* Location Description:

* Hazard Description:

Additional Comments:

Optional Info

First Name: Last Name:

Email Address: Phone Number: Employee Number:

**Figure 4: The web form for hazard reports; can be accessed at www.faa-sms.com**

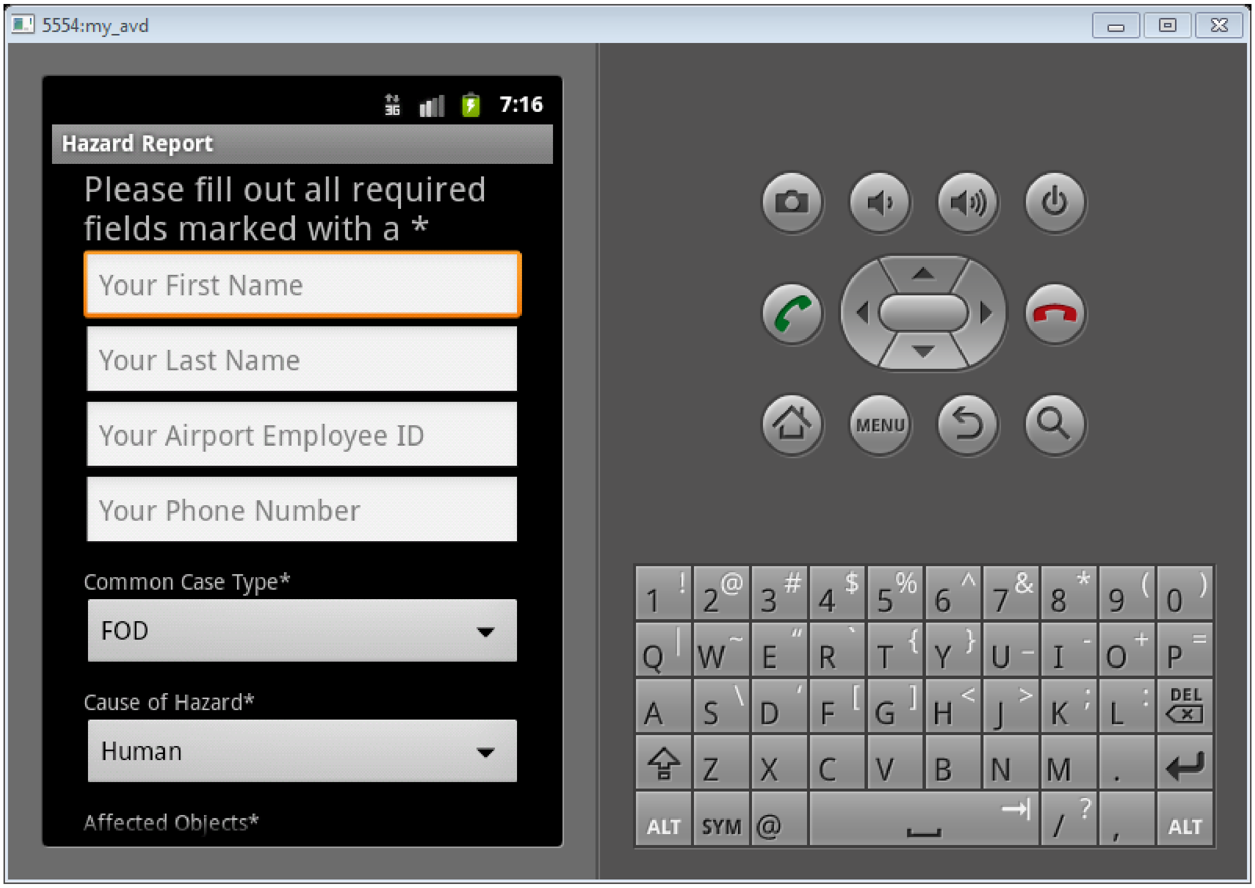



Figure 5: Anyone can download and use this Android application to submit a hazard report.

**Step 2: Create Case**

Once the hazard report is submitted and stored in our online database, our system will see if there is a policy for the reported hazard type (FOD in this example) in the policy database. The policy database contains policies not only from the FAA and ICAO, but also from local authorities and the airport. Since there are policies for dealing with FOD, they will be used to create a list of suggested mitigation strategies that will be attached to the hazard report.

The Accountable Executive, using his Executive Interface on his or her desktop computer, can view a list of all hazard reports and the details of each report (Figure 6).

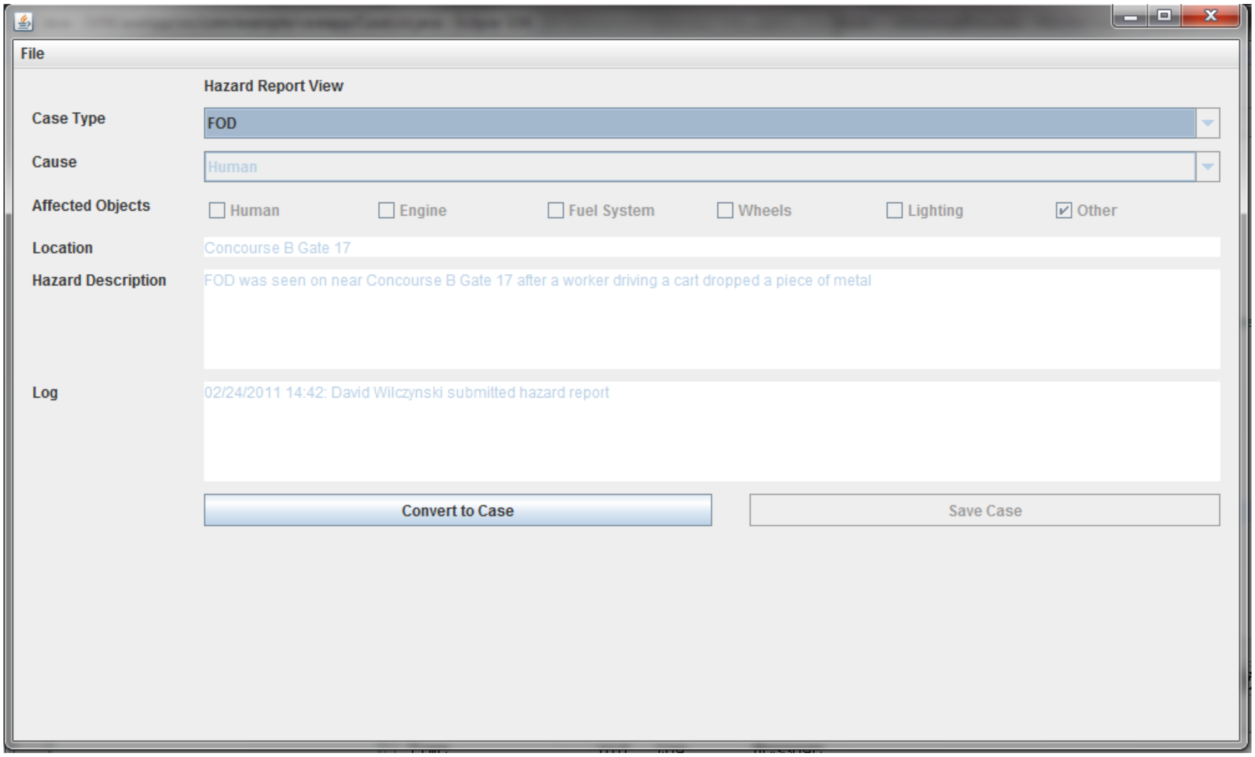



Figure 6: The detailed view of a hazard report on the Executive Interface

After viewing the report details, the Accountable Executive can choose to convert the report to a case. Not every hazard report is converted to a case due to duplicate and false reports.

### Step 3: Risk Analysis and Suggested Mitigation

When converting a hazard report to a case, the Accountable Executive is expected to analyze the report and provide more information. By reading the case description, he or she will be able to assign a severity and likelihood rating based on the risk assessment matrix shown in Figure 7. He or she will also compile a suggested mitigation strategy using items from the list generated by the system.  This strategy will include a number of steps necessary to mitigate the risk associated with the FOD.

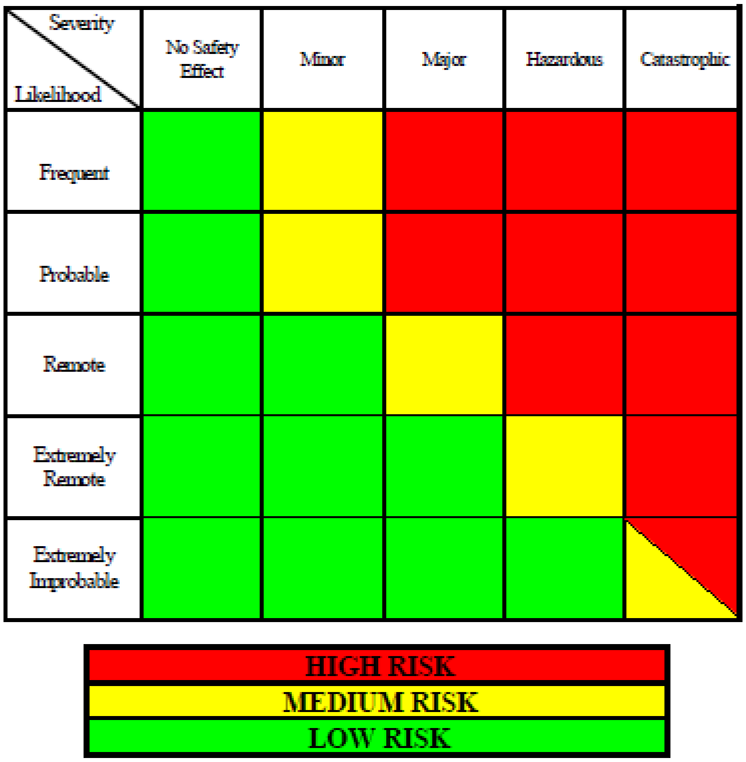



**Figure 7: The risk assessment matrix used to determine the risk level of a hazard (Federal Aviation Administration, 2007)**

At this point, the Accountable Executive may also edit details of the case description for better clarity and more consistent data.

### Step 4: Receive Suggested Mitigation

After the Accountable Executive completes the risk analysis, the data is saved in our database and the case is sent to the Responsible Party.  In this example, this is the manager whose department deals with FOD at the location described in the report.

The Responsible Party uses a desktop application that is similar to the Executive Interface, but is more specific to his or her department. It will display a list of cases with mitigations that need to be reviewed. When the Responsible Party clicks on a case in the list, he or she will be able to view all of the case details and the mitigation strategy selected by the Accountable Executive (see Figure 8).

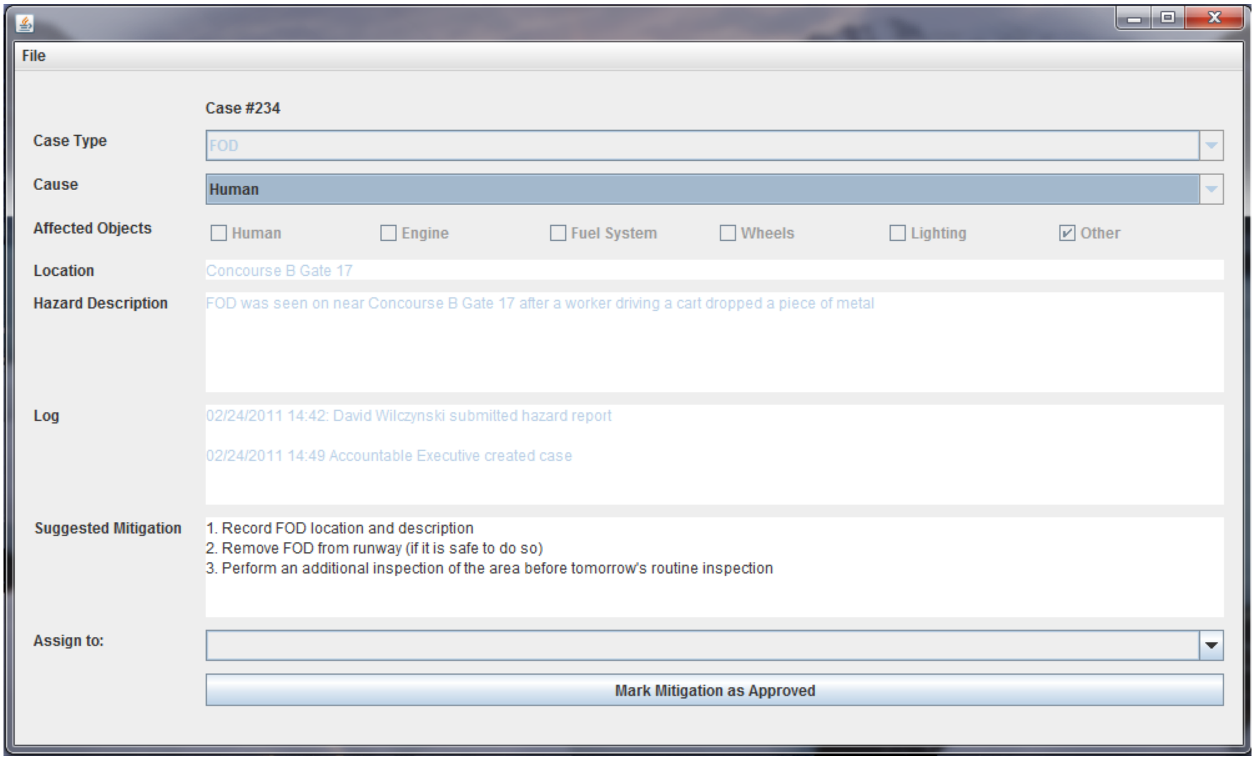



**Figure 8: The Responsible Party's desktop application showing the details of Case #234 and the three-step mitigation strategy chosen by the Accountable Executive**

### Step 5: Assign Task

Since the Responsible Party works more closely with FOD than the Accountable Executive, he or she will have a better idea of if the suggested mitigation is appropriate. After reviewing the mitigation strategy and making changes if necessary, the Responsible Party approves the strategy. He or she also assigns the mitigation tasks to a specific operations person(s) using the desktop application.

**Step 6: Receive Task**

Once the case's mitigation strategy has been approved and assigned, the case information will be sent to the selected employee. Airport operations personnel will have Android phones with the USC-SMS application installed. Using push notification technology, the employee will be alerted through the phone that he or she has a new assignment.

Upon receiving the alert, the employee will open the USC-SMS application and see a list of his/her current assignments, as shown in Figure 9. Tapping/clicking on a case in the list will bring a new screen that shows the case details and the tasks he or she must carry out for risk mitigation (Figure 10).


**Figure 9: The Android application shows a list of cases assigned to the employee.**

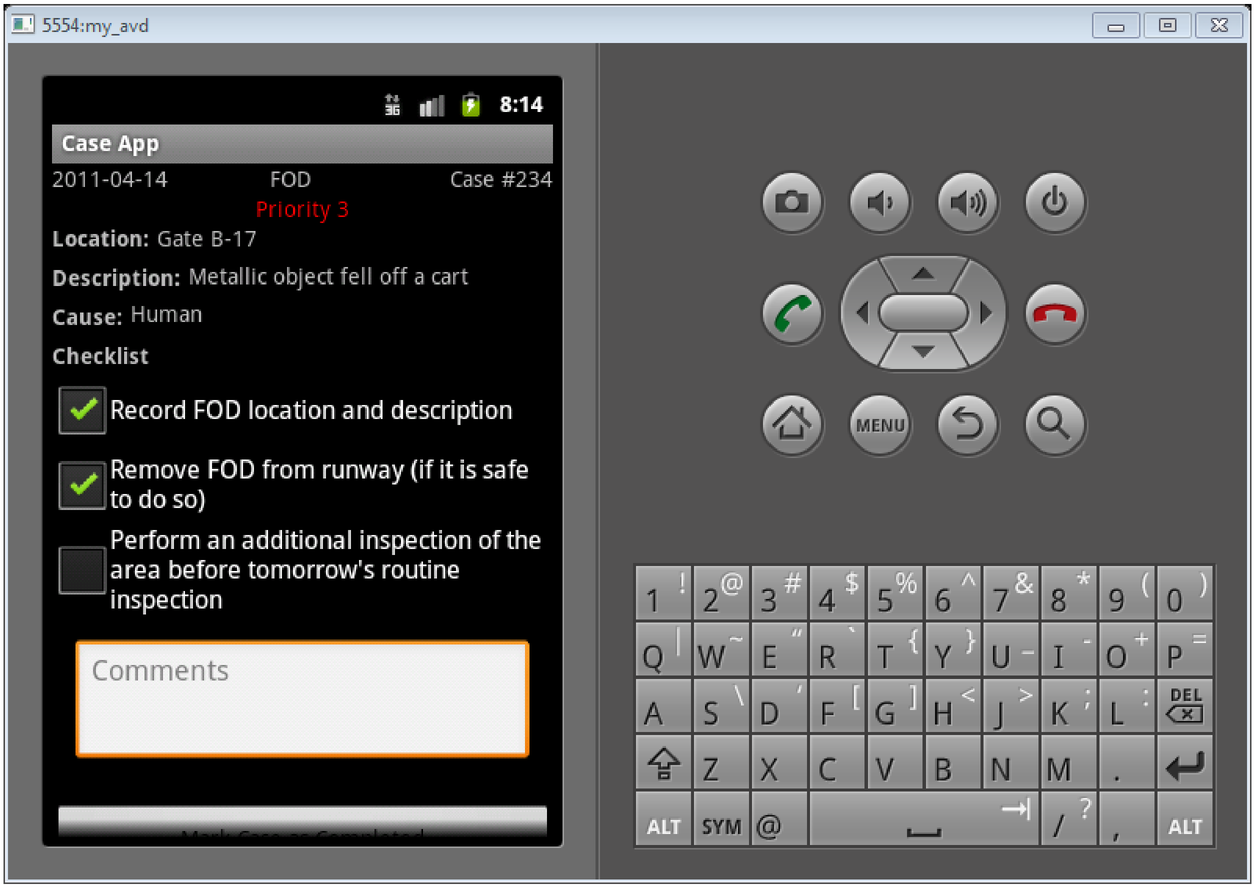



Figure 10: The detailed view of a case in the Android application. It contains a checklist of tasks the employee must complete as part of the mitigation strategy.

**Step 7: Complete Task**

As the employee completes the tasks, he or she is to check them off on the list in the Android application (see Figure 10). Doing so will make mitigation progress information available to the Accountable Executive and Responsible Party through their desktop applications. Once the employee completes everything in the checklist, effectively mitigating the hazard, he or she can tap on the "Mark Case as Complete" button at the bottom of the screen. This will update the Accountable Executive and Responsible Party interfaces to show that the case has been successfully mitigated; the employee may also write comments to document additional information. This will also remove the case from the employee's list on the Android application; it will be moved an archive of cases that the employee can access for future reference.

**Step 8: Follow Up Analysis**

Once the case gets marked as complete, the Responsible Party can perform a follow up with his operations employee if desired. Comments written by the employee in the Android application can help the Responsible Party determine if the mitigation strategy was appropriate. For example, if the employee noted that he needed to perform additional steps to acquire equipment for the FOD removal, the Responsible Party will know to include that in future FOD mitigation strategies.

At completion of a hazard mitigation, the case gets logged into our database under FOD cases. This can then be viewed by both the Accountable Executive and the Responsible Party to track trends in FOD cases.

# 7. Description of Interactions with Airport Operators and Industry Experts

## 7.1. Overview

We were fortunate to have contact with various professionals from the airport industry throughout the development of our project. Mr. Thomas Anthony, the Director of Aviation Safety and Security Program at the USC Viterbi School of Engineering has provided us with guidance since the beginning of our project. In the first iteration of our development process, we also visited the Los Angeles International Airport (LAX) to meet with more industry experts and to gain a basic understanding of the airport environment. Later, we visited the Bob Hope Airport in Burbank, California to learn about airport operations and to get feedback on our design. All of the industry experts we have met with have given us valuable input that has helped us to improve our design such that it could realistically be implemented in the future.

## 7.2. Thomas Anthony

Mr. Thomas Anthony has been our primary contact throughout the development process. As the Director of Aviation Safety and Security Program at the USC Viterbi School of Engineering with previous experience working in the airport operating environment, he is very knowledgeable about the internal operations of airports and, more importantly, about safety management systems and current laws and policies regarding safety.

In our initial meeting with him, he explained the importance of airport safety and exposed us to important safety terms such as “risks,” “hazards,” “incidents,” and “incursions.” On October 5, 2010, after narrowing down the focus of our project, we met with him again to better understand the requirements of our project. He told us that he visualized sms as three gears that spin together: hazard identification, risk assessment, and corrective action. Hazards spin the hazard identification gear, which causes the risk assessment gear to move; motion from the risk assessment gear makes the corrective action gear move, and corrective action links back to the hazard identification gear and keeps it spinning. The hazard identification gear involves many people because anyone can notice a hazard: air traffic controllers, administration, the general public, operations, audits and inspections, etc. The risk assessment is the responsibility of the airport and is currently executed by the Safety Action Group (SAG), which needs representation by all lines of business. The corrective action, which is applied to risks deemed unacceptable from the risk assessment, is implemented by involved management. Finally, after corrective action has been taken, the person who initially reported the hazard receives an update in order to encourage people to report hazards and keep the hazard identification gear, and thus all three gears of sms spinning. Additionally, since sms involves so many different people, he likened good communication through management as the lubricant for the gears. In addition to the three-gear illustration, Mr. Anthony also gave us a preliminary understanding of how risks are assessed using the Risk Assessment Matrix from the FAA Advisory Circular 150/5200-37, which uses the projected severity and likelihood probability to determine if a risk requires corrective action. Mr. Anthony also referred us to some FAA and ICAO documents that would be useful in our research.

Mr. Anthony has given us feedback throughout the design and implementation of our project. As Section 7.7 will describe, we gave presentations of our design to our classmates throughout the semester; Mr. Anthony attended these presentations and let us know if he saw areas for improvement.

## 7.3. LAX Control Tower Visit

Before we decided to focus our project on sms, we only knew that we were going to design something for an airport. In order to gain a better understanding of a real airport environment, we visited Mr. Herb King at the Los Angeles International Airport (LAX) control tower on September 9, 2010. Mr. King first sat down with us to teach us about the configuration of the LAX runways and the various requirements and restrictions such as aircraft size, and the positions of other aircraft that affect when an air traffic controller can allow takeoffs and landings. He also talked about communication and the different groups of people involved in giving permission for a takeoff or landing. Similarly, he spoke about incursions, how and why they might occur, and described new technologies such as ASDE-X that help prevent them. Finally, he gave us a tour of the control tower and allowed us observe air traffic controllers at work and view their computer interface.

### 7.4. Burbank Airport Operations Visit

Mr. Anthony graciously set up a meeting with Burbank Airport's operations personnel. During our meeting with them, we demonstrated our 1.0 version of our Safety Management System. We demonstrated our system by running through a foreign object debris hazard scenario so that all of our system interfaces can be demonstrated. Our demo was well received by the personnel at Burbank. They were most impressed with the idea that our system could potentially log hazard reports automatically where as their current system required manual logging of hazard report data. After our meeting with the operations personnel, we were given a tour around the entire premises of the airport to gain a visual understanding of how the airport operates. We were shown around the airport runways, we were shown the safety stop zone for a runaway plane, and shown around the airport fire department.

### 7.5. Prototype Interaction and Feedback

We have had several opportunities to demonstrate our prototype to both our clients and our fellow classmates. Our demos with our clients, Tom Anthony and the operations personnel of Burbank Airport, were very well received. They were very intrigued that our product could potential automate the long and dull process of hazard logging. Our demonstration to our classmates was done during class as a presentation where again we stepped through our example foreign object debris scenario. The class and our professor were also pleased with our progress.

# 8. Projected Impacts of Team's Design and Findings

Our Safety Management System software could potentially change the way Airport Operations personnel make their daily decisions. Job tasks such as deciding maintenance schedules, drafting hazard reporting standard operating procedures and deciding where budget funds go can be heavily assisted with the proactive information and analysis that our Safety Management System provides.

## 8.1. Financial Analysis

The bulk of financial cost for this system will be in paying the salaries of programmers, graphic designers and that of a project manager. The project manager's job will not only be to keep track of the team's progress, but will also involve meeting with the airport clientele regularly to receive constant feedback during the design and implementation process.

Our prototype took a full semester of our software design class to implement the normative scenario for a foreign object debris hazard case. In total we spent approximately 120 hours spread over four months working on our prototype. Had we not also had a full course load on top of this class, we estimate that we could have accomplished our prototype within one month given 6 productive hours a day and a workweek of 5 days per week.

However, the foreign object debris hazard case is only one scenario that the maintenance department of an airport would handle. Thus, we estimate that in order to fully implement a Safety Management System that includes all of the airport's primary departments such as finance

& administration, operations, security, engineering and maintenance it would take approximately 2 to 3 years to design, implement and test the system.

The table below shows the total cost over three years for four software engineers, one of which is the project manager, and two graphic designers.

**Table 4: Cost of hiring employees for sms**

| Employee Type (# Required) | Median Annual Salary Per Worker | Total Annual Cost | Cost Over Three Years |
|---|---|---|---|
| software engineers (4) | $85,430 | $341,720 | $1,025,160 |
| graphic designers (2) | $47,860 | $95,720 | $287,160 |
| **total:** | | **$437,440** | **$1,312,320** |

Using the agile software development model, we plan to have releases every month or as necessary to be shown to our clients and make sure development is going in accordance with their needs.

# Appendix A – Contact Information

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## Appendix B – University Description

The University of Southern California (USC) is located in Los Angeles, California. Founded in 1880, it is the oldest private research university in the West. It is a world-class institution that attracts people from all over the world. In fact, USC enrolls more international students than any other U.S. university. Approximately 17,500 undergraduates and 19,500 graduate and professional students attend USC; 6,900 of those are regularly enrolled international students.

USC's Andrew and Erna Viterbi School of Engineering has approximately 1800 undergraduate students and offers more than thirty combined degree options. Dr. Andrew Viterbi, the man after whom the school is named, is a USC alumnus and inventor of the Viterbi Algorithm, which is the basis for many applications such as cell phones, DNA analysis, and speech recognition. More than a third of the school's faculty members are fellows in their respective professional societies. Also notable is that it is one of only four engineering schools nationwide, and the only one in California, that houses two active National Science Foundation-funded Engineering Research Centers. The Viterbi School of Engineering is also home to the Information Sciences Institute (ISI), which is the birthplace of key internet technologies, such as the Domain Name System (DNS).

## Appendix C – Non-University Partners

None

## Appendix D – Sign Off Sheet

See attached sheet on the following page

This page is reserved for the sign-off sheet.

## Appendix E – Evaluation of Project Experience

**1. Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

Yes, the FAA Design Competition provided a meaningful learning experience for us since it was unlike any other academic project we have worked on. Months of research and conversations with industry experts allowed us to gain a deeper understanding of the airport industry and of sms in particular.

**2. What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

One primary challenge was that our small team of three meant that a lot more work would be divided amongst the three of us. To overcome this we would meet periodically to discuss what features are most important to implement for our next release and push those features that were not feasible for the current iteration to the next release. Slimming down our design using this process allowed us to make deadlines while fulfilling our task to present a viable prototype.

**3. Describe the process you or your team used for developing your hypothesis.**

We began by learning about airport safety in general by speaking with Professor Wilczynski and Thomas Anthony, doing preliminary readings of FAA documents, and visiting the LAX control tower. Our professor gave us an option of working on a runway incursion or a safety management system project. From what we had heard and read so far, we felt that a safety management system design would be challenging and interesting, so we picked that topic. Then we conducted more in-depth research by reading FAA and ICAO documents and scouring the internet for information about current safety practices and regulations, and existing sms implementations. This gave us a very thorough understanding of the context of our project. We brainstormed and came up with the idea for a predictive sms that involves a desktop application and a mobile application. Starting with this basic idea, we researched more about the specific technologies that would be useful for our design. Along the way, we presented our ideas to our classmates and to Thomas Anthony and operations workers at the Bob Hope Airport in Burbank for direct feedback.

**4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

Yes, participation by industry in our project was appropriate, meaningful, and useful. It was very useful to learn about current industry practices and standards to better understand the requirements of our design. Though our team created the design during our team meetings, the industry experts provided us with solid background information that helped us get started and gave us helpful feedback upon presentation of our design ideas.

**5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?**

We gained a lot of airport and sms-specific knowledge. But we also learned a lot about the software development process and how to work with stakeholders/clients in order to design a system that meets their requirements. These skills will definitely be useful in the workforce, especially for software engineering jobs. We also gained research, writing, and planning skills that would be useful should we decide to pursue further study.

## Appendix F – Citation List

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