Crew Resource Management in International Helicopter EMS Systems: A Look at the Differences in Air Medicine Outside the United States

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Helicopter EMS (HEMS) is a critical tool in the safety net for medical emergencies around the world. It incorporates a team working in precise unison to both safely operate the aircraft and provide high quality and state of the art care to critically ill and injured patients. Crew Resource Management (CRM), the planning and implementation of allocating flight resources, has been recognized by the HEMS industry to be a critical factor in the safety of HEMS operations. There is no question that there is a risk associated with every flight and as studies have shown, the danger of an accident has not decreased but increased dramatically over the past ten years. The HEMS community is working diligently to surmount obstacles in the path of change to making HEMS operations safer while continuing the research and advancement of medical care.

Change is on the horizon for HEMS and there is no better time than now to find and fix the flaws in our system. The leaders in the HEMS community are researching and investigating how and where these changes must be made, but their reviews and evaluations are being done exclusively here in the United States. In attempts to approach this issue at a different angle, a project was initiated at the University of Pittsburgh through the Center for Emergency Medicine of Western Pennsylvania (CEM) and the University of Pittsburgh Honors College (UHC). This project attempts to examine the variance in CRM methods employed by HEMS programs outside the United States, the efficacy of implementing those methods, and some of the best practices applied by these programs. By looking at the techniques, methods, and cultures of these services selected, we may expand our understanding of CRM and our own safety culture in Helicopter EMS to advance the industry to a new standard.

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PREFACE

While the makings of this paper and the words in it are not magnanimous and earth shattering, the ideas herein and that may spawn from this paper do have a meaning and importance far beyond the author. The purpose of examining this subject matter is in the prevention of accidents, improvement of a vital public service, and saving the lives of every day heroes that risk their lives on some level for their fellow man.

The most important people to thank first are my excellent parents who always led me to question, and for my father telling me about every helicopter accident he ever investigated. I thank Doc Stewart for "investing in people and not ideas" and believing time and again that I could pull off what I claimed. I thank all members of the University Honors College for their efforts in making this project possible and for allowing me the honor of being a candidate for the B-Phil program.

Many thanks also go to S. Robert Seitz who has taken out countless hours to aid in the direction and development of this project. Thanks also to Frank Guyette, who took interest in this project from the beginning despite having absolutely no free time somehow did find it to guide me in this study.

Finally, I thank each person of all the programs that I was privileged to visit over the course of 4 months. I did not have a single misadventure anywhere and at each location I was welcomed as family. In many cases I have made life long connections and am so fortunate to have met individuals that created and currently shape the HEMS community.

Special thanks go to Alastair Wilson for coming all the way from London to participate in the defense of this thesis and to Bruce Baker who aided in funding this project.

1.0 INTRODUCTION

1.1 OVERVIEW & DISCUSSION OF PROBLEM

Helicopter Emergency Medical Services (HEMS) are a key part in the safety net for the public around the world. Almost every country in the world has some form of HEMS operation used to transport the critically ill and injured. Many lives have been saved thanks to the people that make up the HEMS community and their dedication to the sanctity of human life. However, these services to the public are not without risk. Since the inception of HEMS, accident rates have been markedly higher than other air-taxi helicopter operations (FAA Part 135).[1]Worse still, the rate at which accidents have happened has increased dramatically over the past ten years and even more so in the past three years. In the last 15 months (Starting October 2007), there have been a total of 18 helicopter accidents. Of these accidents, 11 had fatal injuries totaling 36 lives lost, representing the worst period ever for HEMS operation. [2]

HEMS provide an extraordinary value to the communities in which they serve. A helicopter is often the best way to transport patients from the scene of a serious trauma, the scene

[1]Low R, Dunne M, Blumen J, Tagney G. (1991). Factors associated with safety of EMS helicopters. *Am J of Emergency Medicine.* 8 (2):103-106.
[2]Duqette A. (2009). FAA HEMS Fact Sheet.www.faa.gov

of a critical medical problem, and to ferry patients from rural hospitals to definitive care. Rural EMS services and hospitals are often overwhelmed and unable to cope with these critical patients. It has been shown that patients with traumatic injuries, patients suffering from acute myocardial infarction (AMI), and from acute Cerebral Vascular Accidents (CVAs) have better outcomes when transported by air.[3,4]

1.1.1 Safety Concerns and Problems Associated with HEMS Accidents

Safety for HEMS operations has been a primary concern for many years. Several organizations exist that have a focus in HEMS industry safety. Despite safety being a chief priority of nearly every HEMS program, aircraft are crashing at an alarming rate and current efforts to prevent similar types of accident have met with limited success. One study found that after a 15-year decline in accident rates, EMS accidents increased from 1.7 per 100,000 flight hours in the mid 1990s to 4.8 in 2004-2005.[5] This increase in accidents is likely due to the HEMS community's inability to maintain a standard as it has grown enormously in size. At the present moment there are approximately 840 helicopters solely devoted to medical operations in The United States, where as in the mid 1990s the number was closer to 375-400. The National

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[3] Mitchell AD, Tallon JM, Sealy B. (2007).Air versus ground transport of major trauma patients to a tertiary trauma centre: a province-wide comparison using TRISS analysis. *Can J Surg*, 50(2):129-33

[4] Chappell VL, Mileski WJ, Wolf SE, Gore DC.(2002). Impact of discontinuing a hospital-based air ambulance service on trauma patient outcomes. *J Trauma*, 52(3):486-91.

[5] Baker SP, Grabowski JG, Dodd RS, Shanahan DF, Lamb MW, Li GH.(2006). EMS helicopter crashes: what influences fatal outcome? *Ann Emerg Med*, 47(4):351-6.

Transportation Safety Board (NTSB) has made several recommendations for the HEMS industry which could potentially improve safety but does not have the ability to make recommendations required. Concern networks exist which put out notifications to subscribers regarding accidents and incidents from individual services so that programs may learn from each other, but little change has actually taken place. [6]

The root causes of accidents remain proportionally the same despite nearly doubling in rate since the beginning of civilian medical evacuation by helicopter. The majority (70%) of accidents are due to human factors in pilot error. Accidents are often the result of Controlled Flight into Terrain (CFIT), continued flight into Inadvertent Instrument Meteorological Conditions (IIMC), lack of situational awareness in nighttime operations, improper management of in-flight emergencies, and failure to ensure aircraft readiness prior to takeoff. [7] Few accidents are found to have been caused by mechanical failure. [8]

What are the factors associated with these accidents and why have previous attempts to stay HEMS accidents failed? HEMS is an incredibly demanding class of flying for pilots and is equally demanding for medical personnel. Everything from crew sleep schedules, weather, time of day, cost of operation, available funding, and the emotions associated with responding to a medical emergency are factors. Pilots and medical crewmembers alike may feel pressured to accept a mission based on the severity of the patient's illness or injury. They may also be

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[6] National Transportation Safety Board Public Hearing on Helicopter EMS Safety. February 2009.
[7] Duqette A. (2009). FAA HEMS Fact Sheet.www.faa.gov
[8] Crew Resource Management Training. (2004). *Federal Aviation Administration*. Advisory Circular: AC 120-51E.

influenced by indirect pressure associated with the service's poor financial status or low call volumes; a commonality linked with globally low profit margins in the HEMS industry.

A study assessing what influences fatal outcomes in HEMS found that the risk of death in a HEMS accident increases 3 times in night time operations and 8 times if the accident occurred in adverse weather. An unexpected finding in more recent accidents found that there has been an increase in crew death associated with a lack of shoulder harness seatbelts in non-pilot positions. [9]

Cost is a key issue in the implementation of better, safer, practices. To operate in the HEMS environment a pilot must have extensive experience, recurrent training, and ideally would be provided with the most up to date technology; all of which cost a great deal. With poor reimbursements from insurance companies, costs often have to be controlled by making hard choices. More services in the United States are moving from dual engine helicopters into single engine aircraft because they are much more economical to maintain and require less fuel to operate. Some HEMS programs a forego improvements in equipment because of limited funds must be spent on government required training and fixed operational costs. Items such as Night Vision Goggles (NVGs), simulator training, check rides for pilots, additional instrumentation such as Terrain Awareness Warning Systems (TAWS), and Traffic Collision Avoidance Systems (TCAS) are known to improve flight safety and mitigate risk in flight. These items may improve safety but take time to implement, cost money, and shortens aircraft range and max take-off weight by trading the added weight of new technology.

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[9] Baker SP, Grabowski JG, Dodd RS, Shanahan DF, Lamb MW, Li GH.(2006). EMS helicopter crashes: what influences fatal outcome? *Ann Emerg Med*, 47(4):351-6.

Crew Resource Management (CRM) is a proven method to reduce human errors n aviation. The advantage of CRM in HEMS applications is that it is a low cost (often free) solution to many issues and can aid in the reduction of flight risk.[10] Indeed, the lack of standardized implementation of CRM in Helicopter EMS has played a role in many accidents, which could have easily been avoided with its implementation and regular practice.

One avenue that the industry has not actively pursued with respect to CRM is how HEMS operations are carried out outside of the United States. There are several organizations inside the United States that dialogue when a safety issue arises and regularly meet to discuss research and current events. However, there is a lack of international communication between our sister services abroad. The following section will detail how investigating other methods outside the current paradigm in the United States may be beneficial in applying new and better CRM techniques and best practices for HEMS operators internationally.

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[10] McGreevy JM, Otten TD.(2007). Briefing and debriefing in the operating room using fighter pilot crew resource management. *J Am Coll Surg*, 205(1):169-76.

1.2 OBJECTIVES AND HYPOTHESIS

1.2.1 Objectives

The objective of this research is to investigate how Crew Resource Management (CRM) is carried out in Helicopter EMS (HEMS) programs outside of the United States. The specific aims of this project are four fold.

Specific Aim #1: To describe how HEMS systems operate outside the known paradigm of the United States operationally.

Specific Aim #2: To ascertain in what ways that Crew Resource Management (CRM) differs among the programs observed.

Specific Aim #3: To characterize variances in safety culture between the services visited with special focus on their implementation of CRM.

Specific Aim #4: To establish a better connection between these services abroad and to set up a mechanism for communication between international HEMS services for further research and improvement of HEMS globally.

This project is intended to be a pilot study, establishing a base line to which researchers may build on for more focused analysis of HEMS safety.

1.2.2 Hypothesis

It is hypothesized that all HEMS services employ CRM to some degree. However, it is suspected that there is a great variance in the way that CRM is carried out. In order to gain a better understanding of HEMS operations internationally, site visits were made to several providers on three continents. In addition, a better understanding of these systems may increase the flow of dialogue between programs internationally and inside the United States and better methods for CRM may be accepted as standard across the industry.

2.0 LITERATURE REVIEW

By and large, HEMS programs around the world hold themselves to a very high medical standard providing excellent medical care to high acuity patients backed by peer-reviewed research. There have been many studies done on the efficacy of Rapid Sequence Intubation (RSI), implementation of new field instruments such as point of care lab testing and portable ultrasound, and new protocols for Traumatic Brain Injury (TBI). Relatively few studies have been done regarding safety in HEMS despite it being recognized as a significant issue. Even less definitive research has been published regarding CRM specific to HEMS and air medicine. There are however, multiple published sources in press regarding the history, advancements, and future predictions regarding CRM in other areas.

To better understand Crew Resource Management (CRM) in HEMS, a comprehensive literature review was carried out looking at CRM not only in aviation or aviation specific to HEMS, but CRM as it has been applied to the operating theater, the trauma bay, and day-to-day interactions between medical professionals in hospital. In hopes of a plenary understanding of what CRM is and its significance to HEMS, the history of CRM in aviation will be recounted, items relating to CRM in medicine will be expressed, and specific topics correlated to HEMS will be reviewed.

2.1 CREW RESOURCE MANAGEMENT BACKGROUND

2.1.1 CRM Concepts

Before moving into how CRM plays a critical role in HEMS, one must first understand the foundations of CRM and the concepts that may be applied to any team that means to mitigate risk of error in high acuity procedures and situations.

Human Factors: The multidisciplinary field of human factors research is devoted to optimizing human performance and reducing human error. It is the applied science that studies people working together with machines. Individuals who study human factors recognize and bring to light inadequate system design, product design, or operator training that can contribute to an individual human error or series of errors by multiple individuals that leads to a catastrophic failure. [11]

Crew Resource Management (CRM): CRM is the application of team management concepts in a high-risk environment. Team management typically recognizes the use of techniques, procedures, and tools for a group to achieve a common goal. The key difference is that CRM applies concepts from team management to tasks in which errors have significant ramifications. More over, it is the efficient and effective use of all available resources: human, hardware, and information. This paper defines the scope of CRM to include *all* human elements involved in coordination, decision-making, and purpose of the flight. It includes all pieces of

[11] Crew Resource Management Training. (2004). *Federal Aviation Administration*. Advisory Circular: AC 120-51E.

equipment (helmets, fire suits), materials (written checklists), concepts (dual decision making, cross checking), behaviors, attitudes, and skills that may be employed in safe practices.

Crew Monitoring (CM): Crew monitoring is a method of error prevention that is an integral part of CRM. It is visual verification that a task is properly executed by another member of the flight crew. An example of CM may be a medical crewmember sitting in the cockpit verifying that the pilot is about to toggle the correct switch. Monitoring is an essential skill in HEMS as the medical crew (non-aviation) can aid the pilot considerably in avoiding a CFIT accident by scanning the flight path periodically. *Cross-Checking*, which is similar to the concept of crew monitoring, may be more verbal and formalized where as CM may be performed without the monitored member of the team being aware of the event.

Decision-making and Conflict Resolution: When working as a team no decision is to be made alone. Dual decision-making is always an available resource which allows the pilot and any other member of the flight team to confer on a decision before action is taken. If there is a disagreement in the correct course of action, proper attitudes and behaviors will ensure that the conflict is resolved while maintaining the integrity of the flight.

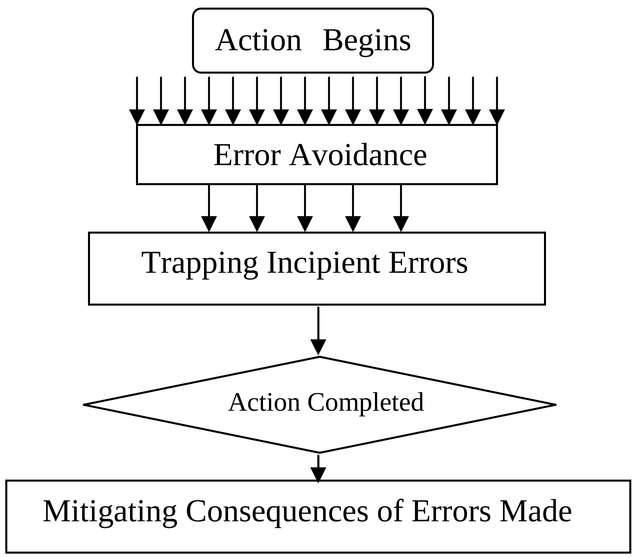
Upper Management Commitment: CRM should be applied through an organization in a top down method. If upper management supports and reinforces CRM concepts they are much more likely to disseminate to employees in operations.

How does CRM improve safety?

Initially, CRM was designed and focused on pilot error only and called for behavioral training to accept information presented by other members of the flight deck. CRM now has progressed into increasing efficiency and managing error. Teams that practice good CRM should operate more effectively and efficiently in non-jeopardy conditions and should cope with non-routine situations (both emergent and non-emergent) better.

In terms of error management, CRM can be viewed as a triad. It protects the integrity of the flight in error avoidance, traps incipient errors, and mitigates the consequences of errors that have been made. Effective CRM marks not only the prevention of errors, but also the execution of good decision-making that could be thus described as a well-managed error.

Figure 1: Error Management Triad



2.1.2 Components of a CRM Program

Successful implementation of CRM requires the utilization of several concepts that are published with regularity in text.

Standard Operating Procedures (SOPs): SOPs are the strategic architecture around which operations are to be carried out including CRM. Desired components of CRM would be clearly defined in the SOPs which crewmembers would be trained to follow. The SOPs of a HEMS organization would incorporate policies such as sterile cockpit policy, usage of pilot-crew challenge and response, and the integration of equipment such as TAWS. SOPs should reflect the shared mental model upon which good crew performance depends.[12]

Initial and recurrent training: Studies show that initial CRM training is extremely effective however the desirable behaviors taught by CRM extinguish or disappear without regular recurrent training.

Briefings: Daily, pre- and post-flight (debrief) briefings are a critical component to CRM as they involve all members of the team in information verification and reinforce a safety culture.

Communication: Closed loop communication so that miscommunications are a rare event. (Closed loop communication involves the confirmation that information was understood correctly by repeating the statement just heard.)

Maintaining Situational Awareness: The constant review of the flight and system status by the operator, which is vigilantly crosschecked by the other members of the flight team.

Workload Management: Recognition by the Pilot in Command (PIC) that the demands of flight are reaching or have reached a critical point and subsequently the proper delegation of tasks to available crewmembers.

Reinforcement: Immediate closed loop feedback as to a task which has been completed.

2.1.3 NTSB Case Review

Single engine takeoff of the EC-135 illustrates an industry wide problem addressed by CRM. The EC-135 is a dual engine Full Authority Digital Engine Control (FADEC) equipped aircraft that is ubiquitous in the HEMS industry. The EC-135 requires only the toggling of two

[12] Crew Resource Management Training. (2004). *Federal Aviation Administration*. Advisory Circular: AC 120-51E.

switches to start and to engage the engines into flight mode instead of manual modulation of the engine throttles during start-up. On multiple occasions industry wide (estimated 50+ separate events) pilots have taken off with one of two engines at idle. This is due to an error of omission during start up procedures, omitting the toggle of the second engine to fly after start. This critical failure has resulted in several near accidents, and indeed the confirmed cause in two HEMS accidents.

Recently, a HEMS aircraft operating in a United States HEMS system took off responding to an accident with serious mechanism and patient criticality. In this particular program a challenge and response procedure is not required. The pilot failed to use the start-up checklist either in part or in its entirety and took off with one engine at idle. The aircraft lost ability to fly when coming out of Ground Effect (GE) off the elevated helipad and crashed. The pilot, flight nurse, and flight paramedic had minor injuries and a six million dollar aircraft was destroyed.[13] This accident likely would not have happened if good CRM had been used. Unfortunately, this case exemplifies the effectiveness of the CRM triad quite well. The error would initially have been avoided if the pilot had followed a written checklist. If he then failed to execute the checklist properly the cross check (crew challenge) may have caught the mistake of one engine at idle, trapping the incipient error. Finally, if the first two checks failed, strong SOPs calling for a Category A take-off would have lessened the risk of a catastrophic accident and may have reduced the event to an incident. [14] (A Category A take-off involves a specific way to take off which allows the pilot to come back to the same Landing Zone if a power failure occurs.)

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[13]NTSB Aviation Accident Reports: www.ntsb.gov

[14] FAA CFR Title 14 Chapter 1 Part 29.59 Take of Path: Category A. 2005.

2.1.4 History of Crew Resource Management in Aviation

First Generation: *Cockpit* Resource Management

CRM originated out of National Aeronautics and Space Administration (NASA) workshop entitled *Resource Management on the Flight Deck in 1979*, which presented research in determining the human factors associated with commercial airliner accidents. CRM was officially moved to the commercial airline industry in 1981, first adopted by United Airlines on the recommendation of the National Transportation Safety Board (NTSB). The NTSB had made such recommendations due to several documented accidents in which the pilot did not accept information or suggestions made by his fellow crewmembers or the crewmembers did not voice concerns or imminent dangers due to the pilot's assumed seniority. It was determined that the seniority of the pilot either blinded the pilot to co-pilot observations or the co-pilot did not have the confidence to be aggressive or felt that the pilot experienced enough regarding a situation of safety threat.[15]

Hence, the early definition of CRM in its first iteration was efficient usage of all *human* resources in flight decision-making. The focus was on behavioral training for the pilot so that they would accept and welcome information and contributions from the co-pilot and flight engineer. CRM did not yet incorporate training that was specific to flight operations, involvement of other members of the flight, or incorporate elements of the flight that were outside of the human element.

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[15] Helmreich R, Merritt A, Wilhelm J. (1999). Evolution of Crew Resource Management Training in Commercial Aviation. *International Journal of Aviation Psychology*, (1):19-32.

Second Generation: *Crew* Resource Management

A growing number of commercial airlines had incorporated CRM training by the next benchmark NASA workshop in 1987. Concepts specific to aviation began to be applied in by this time. Training became more team oriented in nature rather than focusing on one single person, the pilot. In this variant of CRM training new concepts were introduced such as team building, strategies for pre-flight briefings, situational awareness, and stress management. Notably, the concept of breaking the chain of errors that can result in a cataclysmic event and decision making strategies associated with error management came to the forefront. Second generation training was still limited however to lecture based training sessions, which depended on exercises unrelated to aviation to explicate concepts. One limitation that became widely recognized was that there were some pilots that would never accept CRM training. In the second generation, the fundamentals of CRM were still closely linked to psychology. The predominant attitude of pilots being infallible made it difficult for some to accept sharing decision-making. [16]

Third Generation CRM

The third generation as defined by Helmrich et al in *The Evolution of Crew Resource Management* begins in the early 1990s. The first change of many was that CRM began to diverge down multiple pathways in general aviation. Different methods and definitions began to emerge and were being taught by a wide spectrum of entities in the aviation industry. Many programs

[16] Byrnes R, Black R.(1993). Developing and Implementing CRM Programs. *Cockpit Resource Management.* 421-446. Academic Press.

began to include all members of the flight such as the flight attendants, mechanics, and air traffic controllers. CRM transitioned into applying error management concepts into specific skills that could be practiced in the aircraft on the flight line, called Line-Oriented Flight Training (LOFT).

Fourth Generation CRM

The Fourth Generation of CRM is marked by the authoritative role taken by the Federal Aviation Administration (FAA) in the direction of CRM advancement. In 1990, the FAA initiated the Advanced Qualification Program (AQP), which called for voluntary involvement in the customization of CRM to meet the needs of a specific organization. [17] At this point, most Part 121 airlines and Part 135 air taxi services that transport people for hire or as a business had incorporated CRM to some extent. Those who participated in AQP were required to provide CRM and LOFT training for all flight crew. They were also required to design a detailed CRM training program specific to each aircraft model used within the organization. Formal evaluations were required as well as high fidelity flight simulators.

2.1.5 CRM in Medicine

40,000 to 98,000 patients die each year due to avoidable medical errors.[18] These errors of omission and commission are often due to a single event by one individual who failed to access

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[17] Birnbach R, Longridge T. (1993).The Regulatory Perspective. *Cockpit Resource Management.* 263-282. Academic Press

[18] Sundar E, Sundar S, Pawlowski J, Blum R, Feinstein D, Pratt S.(2007). Crew resource management and team training. *Anesthesiol Clin.* 25(2):283-300.

the available human knowledge, skills, and equipment. In recent years, CRM has carried over from the aviation industry for this very reason.[19] Many medical institutions have applied concepts unaltered from aviation CRM such as pre and post operation briefing, performance monitoring, and team orientation. Of these components, performance monitoring and team orientation are most similar to aviation CRM. A structured system of decision-making must be established where there is one team leader (pilot in command, surgeon) that delegates tasks and accepts input and suggestions in an organized and controlled fashion with closed loop communication and designated responses. Each individual in the team then has an equal opportunity to cross check the procedures and decisions that other members of made. In a cross check scenario, one nurse would have another double check the correct dosage and amount to be administered for a medication before it is given. And if the nurse omitted the check, which would be verbalized out loud, any one person in the room would have authority to stop the task and check it. Again, identical to aviation, a briefing may be done which involves all members of the operation or task and ensures adequate knowledge, preparation, and availability of resources.

Similarly to aviation, compliance is a huge issue in medical CRM. One study reports that after introductory training, CRM practice retention averaged approximately 60%. Surgical teams tend to have higher compliance scores but only for certain tasks. Operating Room (OR) teams seem to be very good at basic tasks measured such as correct patient verification (97%), correct surgical procedure verification (97%), but scored very low in other critical tasks such as verification of surgical site (17%). The OR is arguably the most natural fit in the medical field

[19] McConaughey E.(2008). Crew resource management in healthcare: the evolution of teamwork training and MedTeams. *J Perinat Neonatal Nurs*, 22(2):96-104.

for CRM application yet has some of the poorest corresponding reports for consistent compliance. [20]

CRM training for Health Care Workers (HCWs) varies significantly. Methods include lecture presentation, targeted behavior training, and scenario or protocol specific application of CRM techniques such as practicing with an actual checklist to be implemented in a department. One method that is currently under evaluation for its effectiveness is the usage of high fidelity simulated patients, or Simulation Based Training (SBT). Recognizing the cost associated with advanced simulators, one study focused solely on a single technique from fighter pilot CRM procedures: the briefing and debriefing process. It recognized becoming more performance review oriented, focusing on guidance from solid Standard Operating Procedures (SOPs), and employing techniques such as time synchronization as ways to set tones for professionalism. (Time sync is a group procedure of synchronizing all team member watches just prior to the brief.)[21] Other programs such as LifeWings in Memphis Tennessee have taken to using former aviation pilots to lead training to reduce medical errors.[22] Specific scenarios can be carried out with taught responses and desired interactions. These skill sets can then be honed to desired level of performance in real situations. One major limitation of the studies reviewed was that there is no uniformity in CRM education for medical team members and the recognized issue with a lack

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[20] France DJ, Leming-Lee S, Jackson T, Feistritzer NR, Higgins MS.(2008). An observational analysis of surgical team compliance with perioperative safety practices after crew resource management training. *Am J Surg*,195(4):546-53.

[21] McGreevy JM, Otten TD.(2007). Briefing and debriefing in the operating room using fighter pilot crew resource management. *J Am Coll Surg*, 205(1):169-76.

[22] Baker D, Gustofson S, Beaubain M. Medical team training programs in health care. *Advances in patient safety*. 4:253-267.

of firm definition in CRM. All papers reviewed clearly established that CRM has not escaped doubts regarding its effectiveness.

2.1.6 CRM in HEMS

CRM found its way into air medical aviation as it is the perfect meld between the two industries that are predominantly exploring its benefits. Nearly every HEMS program in existence employs CRM on some level, but the ways in which CRM is most effective are currently not well understood and has not been definitively evaluated with respect to Helicopter EMS specifically. Surprisingly, there is a lack of peer-reviewed studies regarding CRM specific to HEMS.

One reason for the lack of literature available regarding the efficacy of CRM in HEMS is the lack of a suitable outcome by which to quantify whether CRM played a role in the prevention of an error. Unlike the airline industry, most HEMS aircraft are not equipped with flight data recorders. Hence, there is a lack of data regarding decision-making just prior to an air medical accident. Likewise, most CRM publications recognize that accidents and accident rates are very poor markers because they happen too infrequently per total sorties flown and total flight hours flown. One particularly unique publication evaluated the effectiveness of a challenge and response checklist in ensuring pre-departure procedures were carried out. While limited to one HEMS program, the study found that proper execution of the challenge and response checklist had a low rate of detecting an omission in the pre-departure procedures (21.2%).[23]

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[23] Frakes MA, Van Voorhis S.(2007).Effectiveness of a challenge-and-respond checklist in ensuring safety behavior compliance by medical team members at a rotor-wing air medical program. *Air Med J*, 26(5):248-51.

A separate study done by the same principle investigator most closely correlates to the aims of this research project. In this particular study, the authors aimed to decipher adherence to safety guidelines and fundamental safety practices in HEMS systems. The study population was 120 individuals from 10 Commission on Accreditation of Medical Transport Systems (CAMTS) certified HEMS programs. The study found a wide range of compliance in the 19 guidelines with no consistent explanation as to observed variability. Individual reporting via survey from pilots, nurses, and paramedics showed high compliance with basic safety items such as seatbelts (99.2%) but low compliance with challenge-and-response checklists (43%). Interestingly, one finding for helmet compliance showed an 86% return in programs that helmets were provided at no cost to the crew.[24] This finding is an extremely good example of the lack of true standardization in HEMS as helmets are *required* to be worn by all crewmembers in CAMTS accredited rotor-wing programs. This is a particularly distressing example as it demonstrates that the loose standards for HEMS safety that are in place are not regularly enforced.

[24] Frakes M, Kelly J.(2007). A Survey of Adherence to Community-Generated Safety Guidelines in Rotor-wing Air Medical Programs. *Air Med J*, 26(2):100-3.

3.0 METHODS

3.1 SELECTION PROCESS

Institutional Review Board approval was obtained through the University of Pittsburgh at the start of this project. Six services were then selected based on unique practices, special area of operation, and monetary feasibility. Background information was collected so that a general foundation of knowledge about each program was established prior to contacting that program. By the time the candidates for participation were contacted, the Principal Investigator (PI) had reviewed what research they had conducted and any progressive techniques they may have reported. For example, one service had recently published a study on the efficacy of ultrasound in Helicopter EMS. Likewise, another service has been recognized for their work in prehospital thoracotomy. While these achievements where not directly related to the focus of this project, they were indicative of a program actively engaged in advancement in the HEMS industry. The medical directors of each program were then contacted asking their willingness to participate in the study. The amount of time spent at each base site varied on the program's schedule and time made available to the PI. A total of 3.5 months was spent traveling from base site to base site collecting data, interviewing participants, observing, and evaluating these programs.

3.2 DATA COLLECTION: INTERVIEWS AND OBERSVATIONS

3.2.1 Interview Process

A simple questionnaire was to be filled out by each crewmember anonymously in the initial set up to collect the desired data. In the initial design, a 180 question survey was to be completed with different areas excluded depending on the duties of the person filling out that particular survey. For example, the base site mechanic would fill out questions that were under the subheading of maintenance but not questions under the subheading of medical capabilities. The survey did ask what the person's position was in the company and for pilots, their amount of flight time, but did not ask for any other identifiers. The survey was modified to an interview process using the same questions. Interviews were conducted informally during a time when the crew was not on a mission. All individuals who participated were extremely willing to answer the questions put forth to them and no individuals requested exclusion after the interview was initiated. The subsections of the survey included questions specific to aviation operations, medical equipment carried, medical techniques performed, questions relating to maintenance, questions relating to safety of equipment (high visibility flight suits, location of personal flotation devices), questions specific to training, and finally communications. See Appendix A for a complete version of the interview questions.

3.2.2 Observation

In addition to the data collected from the interview process, several traits were anonymously recorded to trend over all groups in the study. The items or characteristics that were observed included whether crew members wore helmets, proper seat belts use, the pilot was knowledge of the call nature, if weather minimums were met, and if a sterile cockpit policy was observed. Aside from the above items that were recorded numerically, the PI noted crew attitudes and interactions with respect to safety culture, and company policies and procedures that exemplify best practices in the HEMS community according to guidelines found in the Federal Aviation Administration (FAA) supplement on CRM Training and the peer-reviewed literature for CRM in aviation as well as in medicine and articles specific to HEMS.

3.2.3 Organization of Data

Data collected from the interviews and the observation of the flight crews allowed for two types of results to be made: Items that could be quantified which pertained directly to CRM as well as all items that were recorded as observations which were presented using descriptive statistics. Comparison of programs and base sites were organized in groups.

4.0 RESULTS

Table 1 displays some basic demographic information regarding the HEMS programs visited and their base sites.

Table 1: Demographic Information

Identifier	Number (n=1,2,3…)	Percentage of Total
HEMS Program		
Number of Programs Visited		
European	2	33
Middle East	1	16
North America	3	50
Program Size		
1 Base	2	33
2-5	2	33
6-20	2	33
Program Funding		
Charity	2	33
Government Based	1	16
Non-For Profit	3	50
For Profit	0	0
Program Medical Crew Configuration		
Physician/Paramedic	2	33
Nurse/Paramedic	2	33
Dual Paramedic	1	16
Paramedic/EMT	1	16
Pilot Configuration		
Dual	3	50
Single	3	50
Call Volumes by Service		
Service 1	40,000	
Service 2	800	
Service 3	1400	
Service 4	2400	
Service 5	1400	
Service 6	11,000	
Aircraft Observed In (By Base Site)		
BK-117	8	62
EC-135	1	7
MD-902	2	15
S-76	2	15

4.1 QUANTITATIVE DATA

Stakeholder interviews performed at each HEMS base site resulted in observations of CRM practices. These practices were evaluated using descriptive statistics. It was found that 84% of base sites enforce a helmet policy for all crew members, seat belt compliance was 92% by base site, 54% of base sites used some form of written checklist, 54% used a challenge and response check before takeoff, 38% had a daily briefing, 69% of base sites gave the observer (the PI) a safety briefing, 46% (n=6) of HEMS programs had a system in place to prevent the pilot from being aware of patient information before accepting the mission, and 100% of programs stated that they had a sterile cockpit policy in place with an observed compliance of 31% by base site. All programs reported having some form of Crew Resource Management training.

4.2 QUALITATIVE DATA

In this section qualitative data regarding the interview of HEMS crewmembers, observing patient care, organizational traits, and personal characteristics are described. Their significance to CRM and potential implications will be explored in the discussion. The information is presented here by service.

Service 1

Service 1 is a 20 base site program working in a universal health care system in Europe. The system is a non-profit publicly traded organization. Service 1 uses a single pilot, a doctor, and paramedic that fly during daytime VFR (Visual Flight Rules) operations. Most aircraft do not have an autopilot, but all are equipped with radar altimeter and GPS. Service 1 responds to both medical and trauma scene calls and also performs critical care transports from rural hospitals to more urban centers. This service fulfills unique requirements of the government to have a doctor at the patient's side within 8 minutes in certain parts of the country and 12 minutes in others.

The pilot, paramedic, and physician all have some form of crew resource management training on varying levels. The crewmembers have designated seats for operations. The paramedic is designated to ride up front with the pilot when en route to a call to assist in radio communications and setting up the GPS unit for navigation. One SOP for Service 1 is the ability for the pilot to have the paramedic remain in the cockpit to assist if the mission has carried on into night time operations or if poor weather conditions are observed. The physician has duties regarding operations during the mission. The first of which is to visually monitor both engines during start up for unusual smoke or fire, and then to remove the Auxiliary Power Unit (APU) prior to take off. Another written procedure permits the physician to open the sliding door on final approach to scene runs to monitor tail rotor clearance and voice any other information regarding the parts of the Landing Zone (LZ) that are invisible to the pilot. Communication with personnel in the LZ is typically not established and so the LZ is not typically set up by ground crews.

Service 2

Service 2 is a relatively new single base site program operating in a booming industrial market in desert conditions. Service 2 operates for both trauma and medical calls during daytime VFR conditions only, but is single pilot IFR capable with an autopilot and TCAS. The crew is comprised of a single pilot, a paramedic, and EMT. LZs are typically uncoordinated with sporadic communication with ground crews. On several observed flights, the LZ was compromised by civilian personnel and vehicles entering the LZ without regard to the aircraft.

A sound structure of SOPs is still under development. One safety practice unique to service 2 is the staffing of a second EMT which rotates with the first EMT responding to missions while the other remains at base. The role of the second EMT is to remove the APU post start and monitor the engines during start-up similar to the role of the physician in Service 1. The non-flying EMT may coordinate certain aspects of the operation at base and assist the responding crew in finding a scene. The EMT is often more familiar with the scene areas having for a longer period of time in EMS than the pilots and paramedics.

Service 3:

Service 3 is charity funded single base site program which services an intercity population in a universal health care system. Missions are flown for trauma patients only. Service three employ two pilots with an emergency physician and specially trained paramedic.

Service 3 flies in VFR conditions only, but is equipped with an autopilot and TCAS. The program is based on an elevated hospital helipad in a densely developed area.

Service 3 has several SOPs in place that are pertinent to CRM and best safety practices. Performing Category A takeoff is required from the elevated helipad and also from scenes if possible. Pre-take off challenge and response checks are required as well as in-flight checks and pre-landing checks. Recurrent CRM training takes place on a daily basis. Each day the crew on duty will go through an emergency aviation procedure. An observed characteristic of all flight crews was the constant implementation of dual decision making when entering into a LZ.

Nearly all missions in Service 3 involve very tight LZs which typically have a densely populated perimeter making a high flight load for the Pilot in Command (PIC) who is at the controls. This flight load was reduced by distributing tasks to the Pilot Not Flying (PNF). Closed loop communications were observed from all flight members. During final approach to an LZ, a large amount of communication was observed in a short amount of time. Both pilots and medical crew in the rear of the aircraft contributed information regarding the scene and all information was voiced over the Intercom System (ICS).

All crewmembers participate in coordination for the landing zone. In practicing the procedure of challenge and response, the PNF cross checks the PIC before take-off, before landing, and during normal operations in flight. The pilots interviewed reported cross checking any statements that the PIC makes regarding the flight's integrity. Service 3 performs daily safety briefs prior to mission readiness. The daily brief follows a written protocol and involves all crewmembers with their various responsibilities.

The medical crews at Service 3 apply concepts of CRM to medical procedures on a regular basis in the form of briefings, closed looped communications, and use of checklists. An informal brief was often done when arriving on scene and a written checklist is used for all Rapid Sequence Intubation (RSI) procedures. In preparation for RSI, the paramedic organizes the equipment necessary where each item is placed in a set location so that it can be readily accessed whether its use is anticipated or not.

Service 4:

Service 4 is a government funded two base site program in an urban area and services both urban and rural communities in a socialized health care system. Missions are flown for both trauma and medical patients using an auto-launch protocol as well as interfacility transfers. Service 4 flies both VFR and IFR missions day and night, without the use of NVGs. The crew is comprised of two pilots and two paramedics. The two aircraft in use are not equipped with an autopilot, but do have GPS, weather radar, and a flight voice recorder. Pilots are provided a company based CRM training program while the paramedics are not trained in CRM.

Pilot and crew quarters are in separate locations approximately 1 mile away from each other. Therefore, crewmembers are only all together immediately pre mission, during the mission, and briefly after the mission has been completed making frequent or update briefings difficult. SOPs at Service 4 stated that pilots were to be blinded to the nature of the patient's illness. On every flight, cockpit communications were isolated from the rear of the aircraft since there were two pilots. Pilots did report using written checklists and performed cross-checks during pre-take off and pre-landing conditions. Use of a checklist was confirmed via observation by the PI.

Service 5

Service 5 operates as a non-profit charity organization using three separate base sites in a socialized health care system. The system employs a dual pilot crew with a nurse and a paramedic. The aircraft are not equipped with an autopilot, TAWS, or TCAS but are equipped with NVGs for both pilots and GPS. On occasion, a physician will ride along if the situation warrants for interfacility transfers of critical patients. One item of particular interest is their method of using a command physician to consult with the outlying hospital requesting physician. The purpose of this consult is to determine if the patient's condition warrants air transport.

Being that Service 5 is a charity, there is no pressure to accept flights that may come from having low flight volumes or to satisfy a relationship with a hospital or EMS service that may give future business. Hence, if the patient does not meet certain clinical criteria by the air service's command physician, the transport may be declined or delayed until a later date. This only occurs with critical care transfers from other hospitals, not with trauma or medical patients in which a ground ambulance service has requested transport from a scene. Typical pilot training reported involves a training event approximately once every 2-3 weeks. In addition, pilots are given simulator training at a separate facility once every 3 years. Similar to Service 4, during all phases of flight the front and rear of the aircraft are isolated from each other on the aircraft communication system.

Service 6

Service 6 is a 20 base site non-for profit HEMS program which operates in rural environments flying both medical and trauma patients from scene runs and interfacility transfers. Service 6 operates in both VFR and IFR conditions day and night with a typical crew configuration of a single pilot, a flight nurse, and flight paramedic. All aircraft are equipped with an autopilot, all aircraft have TCAS, and some aircraft have TAWS.

One aspect of CRM unique to Service 6 is that all crewmembers are provided NVGs. Service 6 also has several CRM procedures in place regarding questionable weather conditions. If the weather is questionable, the pilot is required to call the flight follower at the communications center to confer on whether or not the mission can be carried out safely. Service 6 uses challenge and response checklists.

5.0 DISCUSSION

5.1 DISCUSSION OF DATA

The purpose of the qualitative data was to illustrate that there is a lack of definition of CRM, its practices, and its degree of implementation industry wide in Helicopter Emergency Medical Services. The data in conjunction with the literature review further supports that the disorganized fashion in which CRM is implemented is a significant hindrance to the uniform safety of the HEMS industry. Despite the recent history of accidents, most crewmembers downplay the risks associated with HEMS aviation.

Four components of CRM from the literature review can be used as themes to categorize the best practices and to explain why certain practices are not favorable with safety in mind.
The four components are: safety culture, communications, situational awareness, and error management.

5.1.1 Safety Culture

The foundation of any HEMS program is its safety culture. A strong safety culture propagates good behaviors and empowers individuals to make good choices and to be vocal when others are practicing unsafe procedures.

Standard Operating Procedures

The architecture of a strong safety culture is a well-founded base of Standard Operating Procedures (SOPs). Those SOPs are further reinforced if upper management practices and encourages good CRM techniques. Some of the programs visited had extensive SOPs on the shelf that were regularly referenced by employees who were encouraged to do so. Programs which had well developed SOPs had better training programs and had a strong safety culture. One organization had a written SOP stating that all crew members would depart the aircraft with their helmets on and visors down. Every crewmember observed carried out that technique and when the observer did not follow that procedure, he was corrected. At another HEMS program, the physician took off his helmet in the aircraft after the aircraft had landed and departed the aircraft unprotected. There was no written policy regarding departing the aircraft in that particular program.

Training and Recurrent Training

"Amateurs practice until they get it right. Experts practice until they cannot get it wrong.'-Graham Chalk

Good safety practices and a strong safety culture call for initial CRM training and regular recurrent training. It also depends on the character of the individuals that comprise the flight team. Disciplined people make disciplined actions continue to reinforce desired behaviors. [25]One of the study HEMS programs observed practiced a different in-flight emergency procedure with all members of the crew *daily*! At another program, the pilots and the crew rarely interacted with each other and both parties had a relatively poor knowledge of what to expect from each other if

[25] Collins J.(2001).*Good to Great.*

the integrity of the mission was compromised. When interviewing with a pilot regarding challenge and response checklists from one HEMS program which reported having yearly CRM training for pilots, he stated that he had never heard of the technique. This leads one to wonder what exactly this program uses to define CRM.

Dynamic Vigilance: Recognition of New Risks

The foundation of safety culture must be refinished regularly. When a new piece of equipment is incorporated into operations, when a new technique is postulated, and when new findings regarding safety are published, the safety culture must be refreshed. New technologies such as TAWS and TCAS have the potential to prevent Controlled Flight into Terrain (CFIT), the most common cause of HEMS accidents. However, if HEMS pilots and medical crews are not trained and educated on their potential effectiveness, the usefulness of this technology is limited. New, detailed procedures must be written in organizations which incorporate this equipment so that they are not misused or underutilized. In one of the study programs, the aircraft in service was equipped with TCAS. However, during most of the observed missions at this program, the device's aural warning was muted due to pilot preference. If a strong SOP regarding the operation of this device as well as a cross check by the medical crew was in place, it would be more effective.

5.1.2 Communications

Communication is arguably the most vital component to the best practices associated with CRM. Communication in CRM is not simply the exchange of information. It is also the use of proper behaviors associated with conveying and accepting information.

Conflict Resolution

A crew has a strong safety culture when they can voice any concern knowing that it will be discussed properly. Issues between crewmembers do arise on a regular basis. The programs with a strong foundation in CRM use conflicts to strengthen their program rather than distance individuals. Conflicts often arise when there is a lack of understanding or a breakdown of communication. Many programs may not realize what nuances in the organization of a HEMS program can cause a breakdown in conflict resolution until they have studied CRM. Pilot and medical crew offices and quarters should be close to one another so relationships can be built and trust established. In one program studied, the medical crews complained about a particular pilot due to his tendency to take longer to launch the aircraft and his increased frequency of declining missions due to weather. This service had pilot and crew quarters in separate locations. Since the pilot was not present to address this issue with the medical crew, a disconnect exists due to a lack of understanding.

Knowing when to communicate is just as important as knowing when not to. All programs in this study claimed to have sterile cockpit procedures however few crews practiced the policy. Limiting conversations to mission specific information is a crucial part of practicing good CRM. Even more advanced than sterile cockpit procedures is the use of formalized statements and responses which can enhance efficiency and increase compliance with other CRM procedures.

5.1.3 Situational Awareness

Situational awareness is a different kind of vigilance than what is mentioned above. Pilots and medical crews must be vigilant as individuals but also as teams. HEMS crews must recognize when risks exist and must take measures to mitigate those risks.

Crew Monitoring

Crew monitoring requires a constant state of vigilance on the part of the medical crew. All members of the crew must constantly be scanning instruments, looking outside the aircraft for hazards, and monitoring each other for signs of fatigue. This technique can be effective because it empowers the medical crew past what may be covered in SOPs. A flight paramedic from one of the services visited recounted a perfect example of crew monitoring. In this particular program, a challenge and response checklist is performed between the pilot and the medical crewmember. During the procedure, the pilot stated that he had two engines up to fly when in fact he had one engine in the idle position. The paramedic recognized the error and voiced his observation, trapping the error before the incipient incident occurred. In contrast, a flight paramedic at another program was found reading a newspaper during a mission in which poor weather conditions had developed and an IFR flight plan had been filed.

Cross Checking

Similar to the concept of crew monitoring, cross checking is yet another way of verifying that a task has been completed and that a task has been completed properly. Cross checking can incorporate written checklists, verbal interactions, questioning a decision, and visually verifying that any statement about the flight integrity is true. One method currently under development as a recommendation from the NTSB is the usage of a formalized risk evaluation for every flight.

This can help bring to light additional risks that may be present regarding that mission and establish a team plan regarding procedures to mitigate such a risk.

The following is a good example of the benefits of formalized risk evaluation:

> During a shift with one of the study HEMS base sites, the aircraft was dispatched to rescue a stranded person in the water near the coast in the base's area of operations. This type of mission was not typical for this crew and involved the added risk of hovering close to the water while the flight paramedic retrieved the patient on a static line (not a winch). As the crew prepared the aircraft, the observer voiced a concern regarding wearing Personal Flotation Devices (PFDs) due to the nature of the call. The Pilot in Command (PIC) agreed that this was a prudent idea and all crewmembers did put on their PFDs.

The mission was completed safely but if the observer had not voiced this concern, the mission would have been carried out without PFDs. If a formalized risk assessment had been in place, the crew may have recognized the additional hazard associated with this unique mission and taken the proper precautions.

Acting on Emotion

Situational awareness also involves recognition of the role of human emotion. Some of the programs reviewed 'blinded' pilots to the nature of the call to prevent them from making the decision of accepting a mission based on emotion when poor weather conditions may exist. This simple procedure can significantly mitigate the risks associated with emotional decision making. HEMS programs that employ this technique should evaluate that this technique is in indeed carried out as it was observed on several occasions at different programs that this procedure was circumvented. There is little published evidence regarding the theories associated with acting on emotion in HEMS. However, one HEMS program visited in this study did their own research regarding the variances in driving patterns for paramedics in their fast response car depending on the nature of the call. Such a significant difference was found that the program put a policy in place that only the doctor (not driving) would be aware of the patient's condition. Interestingly, the pilots in the HEMS component of this service are aware of the nature of the patient's illness.

5.1.4 Error Management

Due to the lack of established CRM guidelines and definitive scientific evidence supporting the efficacy of challenge and response based checklists, briefings, situational awareness, and crew monitoring many do not believe in the practices of CRM. When one doctor was prompted on the benefits of having a daily brief he replied,

"What's the point? We all know each other and we are here every day."

For someone who has not had comprehensive CRM training this may seem like a valid argument. When CRM was first incorporated into commercial aviation practices, its sole purpose was the prevention of errors. CRM in some practices has come to mean any practice that improves efficiency, mitigates risk, and traps incipient errors. Part of error management and error prevention is the comprehensive and effective education of all crewmembers. If only some of the crewmembers believe in its practices, CRM's effectiveness is severely diminished. HEMS programs with a well established culture of CRM used is concepts not just for flight safety but also for patient safety. Service 3 employed the use of checklists for RSI and performed daily simulated patient scenarios. Service 5 used high fidelity simulators for practicing medical procedures. Service 6 uses a checklist for ventilated patients that have a sudden change in airway status. It is clear that a culture of CRM practices has infiltrated every aspect of these programs and continues the reinforcement of fundamental safety practices.

5.2 RECOMMENDATIONS AND BEST PRACTICES

5.2.1 Recommendations to the HEMS Industry

Redefine CRM

The leaders in the HEMS industry first must identify and accept a new and all encompassing definition of Crew Resource Management that is comprised not of not only the concepts described in the literature review, but also techniques that are specific to the technology present in the aircraft designed for safer operations.

Crew Resource Management for HEMS is: the prevention of error, the means by which to smoothly facilitate exchanges of information when the safety of the aircraft is compromised, efficiency in normal operations, and is the foundation which ensures a baseline standard of safety which is guaranteed if all SOPs regarding CRM are properly executed. With the new incorporation of TAWS and TCAS, CRM in HEMS must now create industry-wide SOPs to ensure that these technologies do not go unnoticed.

5.2.2 Recommendations for HEMS programs

1. Develop a customized and comprehensive CRM-based Safety Culture

Review the recommendations from the Federal Aviation Administration Crew Resource Management Training Advisory Circular AC 120-51E. This circular provides specific guidelines and defines many concepts broached in this paper and can be used as instructions on how to incorporate CRM into a HEMS program.

2. *Incorporate the concepts of CRM into every aspect of your HEMS program*

The more CRM is a part of an organization the more its concepts and practices disseminate into the behaviors of its individuals. The effectiveness of a safety culture starts with the first day of employment.

3. *Develop a strong foundation of SOPs that incorporate all practices of the organization*

The more specific and comprehensive the volume of SOPs is, the more specific behaviors with become.

4. *Train on a daily basis*

Daily training does not require high fidelity simulation and sophisticated equipment. Some practices such as ‘chair flying’ can be equally effective when practiced right.

5. *Pre and Post Flight Briefings*

One of the best ways to develop a safety culture is to hold formalized, written daily pre and post mission briefings.

6. *Incorporate Challenge and Response Checklists into pre-take off and pre-landing procedures*

Challenge-verification-response checklists are extremely effective at catching errors and verifying tasks have been correctly executed.

7. *Abolish response times which place undo pressures on pilots*

One program in this study had a target response time of 2 minutes from time of dispatch to being airborne. This is an impossible target which causes pre-takeoff procedures to be rushed.

8. *Do not isolate the pilot(s) from the medical crew in aircraft communications (ICS)*

Several observed programs had the cockpit and cabin isolated for the entire flight during a mission. This may prevent vital dialogue from taking place. Instead, practice better sterile cockpit procedures.

9. *Incorporate a formalized written risk assessment into every mission*

Per the recent NTSB recommendations, performing risk assessment can guide pilots and medical crews in making the correct decision regarding accepting a mission.

10. *Evaluate and incorporate new technology that reduces the risk of accidents at night*

The use of NVGs, TAWS, and TCAS may significantly decrease the risk of accidents. Make a feasible progression into the use of these technologies.

6.0 CONCLUSIONS, LIMITATIONS, AND FURTHER RESEARCH

6.1.1 Conclusions

This research established four specific aims:

First, to describe how HEMS systems operate outside the known paradigm of the United States.

Second, to ascertain in what ways Crew Resource Management differed among the observed programs.

Third, to characterize variances in safety culture between the services visited

Fourth, to establish a better connection between HEMS programs internationally.

By directly observing the practices of these programs, a working knowledge of how CRM practices are carried out was established. In visiting the described HEMS programs, it is clear that a high degree of variance in the implementation of Crew Resource Management exists. The standard of safety differs throughout the systems studied. These differences in safety culture can partially be attributed to the level of implementation of CRM with respect to each program visited. A lack of strong Crew Resource Management places any Helicopter EMS mission at unnecessary risk. Adoption of the best practices from HEMS operations around the world may mitigate the inherent risks associated with HEMS operations. Better communications between services in the HEMS community is an ongoing goal which is paramount in the continued development of techniques and theories associated safety in Helicopter EMS.

6.1.2 Limitations

There are several limitations associated with this research. The first of which is the small sample population interviewed and observed. This research does not claim to be commensurate of the entire HEMS industry, merely a representation of it. Having reviewed the data collected and having learned from the experience, certain questions in the interview and the way the data was recorded would have been more effective if asked and recorded in a more yes/no format. One unexpected complication in data collection was the difficulty in finding enough time for participants to complete the survey in the unpredictable environment of HEMS. It was quickly realized that an interview process would be more time efficient than having the participants complete the survey. Thus, participants could be engaged while off base site between missions.

One anticipated complication was the language barrier found with participants in Service 1. It was found that pilots could easily answer questions from the survey since they are required to speak English, as it is the international language for flight communications. The majority of physicians at Service 1 base sites were able to fully participate without translation by the pilot as many have learned English as a second language. Paramedics often did not speak fluent English or did not feel confident to respond in English. The interview process was often conducted through the pilot as a translator to make the interview possible. Other limitations independent of this study are also worth mentioning. The lack of a clear, universally recognized definition of what Crew Resource Management creates an issue when determining to what degree or even if a program exists when questioning a program employee.

Finally, the limitation of CRM itself should be mentioned. The broad goal of this research was to study the present status of CRM in HEMS to prevent accidents and to better manage in flight mechanical failures. CRM is not an all-inclusive answer. Even if CRM is employed to the highest level and in the best circumstances, errors will still be made and accidents will still happen. CRM is only one tool in the management of errors in Helicopter EMS operations.

6.1.3 Further Research

This research project was not intended to be definitive. Further manuscripts from data collected on this project will be written in the near future. This study calls for further investigation of unique CRM practices and the compliance to presently existing CRM guidelines. Potential areas for future study are investigation of CRM techniques specific to new safety equipment currently being implemented in HEMS such as Night Vision Goggles, Terrain Awareness and Warning Systems (TAWS) and Traffic Collision Avoidance Systems (TCAS). The use of these devices in helicopters is novel and Standard Operating Procedures (SOPs) regarding their effective incorporation into HEMS missions are not yet established nor reviewed on an industry-wide level. Another potential study could focus on developing CRM training specific to mitigating risk of night flights and poor weather conditions which are a contributing factor in the majority of HEMS accidents.

APPENDIX A: Interview Process Questions

Air Medical Research Survey

1 Demographics

1. You are a: Pilot Doctor Paramedic Nurse Other:____________

2. Time spent in the Helicopter EMS (years):

3. Are you employed full time or part time?

4. How many hours a week do you work?

5. Do you also work for another service?

6. If so to #5, how many hours total do you work at all of your occupations?

Pilots:

1. Total amount of flying hours:
2. Total amount of flying hours in aircraft type:
3. Total amount of IFR flying hours:
4. Amount of IFR flying hours in rotor-wing aircraft:
5. Amount of IFR flying hours in type:
6. Amount of IFR flying hours in the past year to date:

2 Helicopter Base

1. Is there a computer weather station at the base?
2. Is there a local reported weather station or a direct reading weather station?
3. Is the aircraft kept in the hangar or outside during readiness for service?

Question 4 applies to retractable landing pads

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4. A Is a retractable helipad part of the base?
   B If so what is the time to retract/extend the pad?
   C Are auxiliary power sources on the pad for aircraft APU and medical equipment?
   D Is there a refueling station at the extended position of the pad?

5. The number, location, and type of fire extinguishers outdoors?

6. Quantity and location of fire extinguishers on the base helipad?

7. What material is the helipad made of? (gravel, asphalt, wood, etc.)

8. Is the helipad lit?

9. Is there a windsock on the helipad? Is it lit?

10. Is there an IFR approach to the base?

11. Is there a GPS approach to the base?

12. Is the hangar facility heated?

3 The Aircraft

1. Make and Model of the aircraft:
2. Number of total hours on aircraft?
3. Does the aircraft have dual pilot IFR capability or single pilot IFR capability?
4. Does the aircraft have a hazard warning system (TAWS, TWOS, Hellas)?
5. Does the aircraft have an FAA (or equivalent) certified GPS navigation system?
6. Does the aircraft have wire strike cutters?
7. Is the aircraft equipped for the use of night vision goggles for the pilot(s)?
8. Is the aircraft equipped with night vision goggles for the medical crew?
9. Does the aircraft have an Emergency Locator Transmitter (ELT)?
10. Does the aircraft have a water activated pinger (over water operations)?
11. Does the aircraft have an emergency float system (over water operations)?
12. Does the aircraft have a fixed float or an emergency float system?
13. Does the aircraft have a flight data recorder?

4 Pre-Flight (External)

1. At what time during a 24 hour period is the daily pre-flight usually performed?
2. Is a daily check performed that is somewhat more extensive to ensure aircraft readiness and then a short pre-flight to ensure no changes before take-off?

3. Are items on preflight checklist visually inspected, physically inspected, or both?

    4. What steps/checks are done in the external preflight at flight page?

    5. Do all crewmembers assist in the visual inspection of preflight?

4. Is the base mechanic involved with daily check?
5. A Does the pilot coming on shift receive a report on the aircraft status by mechanic when coming on duty?
    B If yes, what is the format of that report? (verbal, written, electronic)
    C What is the information included in that report?

------------Question 7 may not apply to daylight flying base sites-------------

7. A Does the pilot coming on shift receive a brief from the pilot coming off duty?
    B If yes, what is the format of that report? (verbal, written, electronic)
8. Are the pilot and medical crew required to have a daily safety meeting/shift brief before flight can occur?
9. Do you perform your preflight mostly indoors or mostly outdoors?
10. Is a ladder or work stand available to you to use to perform preflight?

5 Pre-Start

1. Is it in your company's preflight checklist to check that cyclic and collective locks are removed?

2. Who makes sure that shore or ground powers cords including a/c power, tannis heater cords, covers, pitot, intake, tail rotors, blade tie downs, and ground handling wheels are removed?

6 Flight Responsibilities for Medical Crew

1. Do you scan for possible hazards while in the rear of the aircraft?
2. Are you authorized to open the door of the aircraft to gain better view of the landing zone?
3. Do you operate the radio to communicate information not regarding the patient (e.g. coordinating the landing with the ground crew)
4. Are you trained to assist the pilot in setting up autopilot system and engaging it if requested?
5. Are you trained to assist the pilot in setting up the aircraft for other IFR procedures if requested?
6. Do you assist the pilot in performing aircraft checks in the cockpit before start?
7. Do you assist the pilot in performing aircraft checks in the cockpit before flight?

7 Medical Responsibilities

For Pilot:

1. To what degree do you assist in the patient care? (assist in lifting, moving the stretcher, none)
2. When do you become aware of the patient's medical status?

3. Do you ever update the receiving facility of the patient's medical status?
4. When the medical crew contacts the receiving facility, are you able to listen on the channel?

For Medical Crew:

1. What medical procedures are you authorized to perform on ground?
   (e.g. intubation, chest tube placement, IV access, ultrasound)
2. What medical procedures are you authorized to perform in flight?
   (e.g. intubation, chest tube placement, IV access, ultrasound)
3. Do you have a required quota for certain procedures (e.g. intubation)?
4. What is the number of intubations you have performed this year?

8 Medical Capabilities

1. How many patients can your aircraft transport?
2. Does the aircraft have an IV warming device?
3. Does the aircraft have a pediatric intubation kit?
4. What is the maximum number of drips that can be managed simultaneously?
5. Is a Doppler device to assess pulses available in the aircraft?
6. Is a FAST ultrasound or other visual ultrasound device present in the aircraft?
7. What is the manufacturer and model of the aircraft cardiac monitor?
8. Are capnography /capnometry devices available in the aircraft?
9. Are arterial pressure and central venous pressure (CVP) measuring devices available?
10. What immobilization equipment (if any) is carried on the aircraft?
11. Is a balloon pump available for applicable flights?
12. Is an ECMO machine available?
13. Is a portable suction device carried on the aircraft?
14. Are pressure infusers carried on the aircraft?
15. Are rapid infusers (e.g. Level One) available on the aircraft?
16. What are the active re-warming methods available?
17. Is there a refrigerated IV saline pack available for hypothermia treatment protocol?
18. Is hypertonic solution available/used?
19. Is a nasogastric tube kit available/used?
20. Is a central line kit available/used?
21. Is a cut down kit available/used for IV access?
22. What blood products are available? (eg FFP, PRCs, whole blood)

9 Flight Page

1. How is the crew initially notified of a flight request?
2. Is the base notified by Personal Line (PL) tones, phone, or other?
3. What information is given in the initial page before acceptance of flight?
4. Is it required that the patient's diagnosis, chief complaint, mechanism of injury and age withheld from the initial page?
5. Is there a required time to respond and be in the air after acceptance of flight?
6. A What is the average time taken to respond and be airborne?
   B Is this tracked?
7. Is a weather check required of the pilot?
8. Does a flight follower also monitor the weather in the area that the aircraft will be operating in to confer with the pilot?
9. Is there a mutual equality among all of the crewmembers to have the power to decline the flight for any reason?
10. Does your system have a structure in place to put you on a standby alert while the communications specialist determine the need of a helicopter or are you notified only when it is a full page?
11. What is your organization's minimums for weather:
    VFR:
    IFR:
    Night:
12. Are you (the pilot) required to call the flight follower when weather is questionable?

10 Acceptance of Flight Request

1. Is there a required minimum time to accept/decline a page?

2. If so what is that time limit?

4. Once the flight is accepted, what tasks must be performed before beginning the preflight?

5. What is the method (radio,phone) used to respond accepting or declining the mission?

6. At what point after acceptance of the flight request do you receive a medical brief for the patient?

11 Flight Operations

1. Is a sterile cockpit policy in place? (No conversation other than regarding the mission)
2. When does sterile cockpit condition begin?
3. Is there a medical crew challenge that fuel quantity is adequate for scheduled flight?
4. Is there a medical crew challenge to the pilot asking if temperatures and pressures are good?
5. Is there a medical crew challenge that caution and warning indicators are clear?
6. Is there a medical crew challenge that all engines are up to fly?
7. Is there a written checklist for cyclic & collective lock removed?
8. Is there a crew challenge for cyclic & collective lock removed?

12 Scene Questions

1. Who trains the ground crews to set up Landing Zones?

2. How often recurrent training done for ground crews?

3. How often are you (medical crew) the first responder to a scene?

4. How often are you the first Advanced Life Support (ALS) provider on scene?

13 Flight Crew Personal Safety Equipment

1. Are all flight personnel required to wear a helmet?
2. If no to question #1, are medical crews required to wear a helmet?
3. Do the flight crew members have fire retardant flight suits and gloves (Nomex® or equivalent)?
4. Are crewmembers required to wear steel toe boots or protective equivalent?
5. Do all members of the flight crew wear a flight suit with reflectors?
6. Do all members of the flight crew wear a high visibility color flight suit?

14 Emergency & Incident Procedures/ Egress/ Survival

1. What is the accident/incident procedure for crewmembers pre and post crash?
2. Are medical crewmembers trained to egress from an underwater accident?
3. Are the medical crewmembers trained to shut down engines in emergency situation?
4. Are medical crewmembers trained to arm and discharge fire bottles in a fire on the aircraft situation?
5. Are the medical crewmembers trained in any other procedure to assist the pilot in an emergency situation?
6. Are all crewmembers provided with an individual survival bag or is there one unit pack for the entire crew?
7. What are the contents of the aircraft survival pack?
8. If an aircraft is forced into landing or has an accident is there a protocol in place for other company aircraft to respond to the accident scene?
9. Is there training specific to reduced rotor clearance egress in a post accident/ incident situation that may have resulted in reduced rotor clearance or unusual attitude of the helicopter?
10. Is there training specific to uneven terrain egress?
11. Are you trained/have you assisted in the functions of the pilot in an emergency operation/procedure? (e.g. shut down the engines in case of fire)
12. Does the aircraft have Personal Floatation Devices (PFDs) for all crew members and patient?

15 The Patient

1. Mark the manner in which patients are typically loaded into the aircraft:

loaded ‘cold’ (engines off, rotors stopped)

loaded ‘hot’ (engines idle, rotors turning)

16 Fuel/Re-fueling/ Fuel Availability

1. Are pilots authorized to refuel the aircraft in your service?
2. Are pilots trained to refuel the aircraft in your service?
3. Are medical crews authorized to refuel the aircraft in your service?
4. Are medical crews trained to refuel the aircraft in your service?
5. Are mechanics trained and authorized to refuel the aircraft in your service?

6. Is there a dedicated refuel person (other than pilot) available at all times when aircraft is in service?
7. Is it your company's policy for pilots to perform fire guard on refuel?
8. Is it your company's policy for medical crews perform fire guard on refuel?
9. If the aircraft's normal fuel source is a truck, how is that truck notified?
10. Does your base have refueling capabilities?
11. If so, what capacity is the fuel tank (U.S. Gallons or Liters)
12. Is the fuel tank underground or above ground?
13. Does your aircraft refuel at a location other than your base?
    (No, Sometimes, Frequently, Always)
14. Do you reposition from the receiving facility while the crew hands off the patient to get fuel?
15. Are there refuel stations on hospital helipad in your service area?
16. Do you perform 'hot' (engines running, rotors turning) refueling?
    A (never, seldom, sometimes, frequently, always)
    B Are hot refuels performed at night?
17. Who has the responsibility to insure the fuel quality (does the pilot or mechanic sump the fuel cells)?
18. Is it company policy to perform daily fuel sumps to check for fuel quality and water contamination?

17 Crew Configuration

1. What is the typical number of pilots for VFR conditions in your system?
2. What is the typical number of pilots for IFR conditions in your system?
3. What is the typical number of pilots for night flying?
4. What is the typical medical crew compliment? (Nurse/Paramedic, Physician/Paramedic, Nurse/Nurse, Single Paramedic)
5. Do the various crewmembers have designated positions in the rear of the aircraft?
6. Does a medical crewmember always accompany the pilot in the front of the aircraft on the way to pick up the patient to aid in spotting hazards and assisting in flight load?

18 Schedule, Staffing, & Shift Policy

For Pilots:

1. What is the typical cycle for your work schedule during a month period?
2. How many pilots does your base staff for one aircraft?
3. How many hours are in one shift at your service?
4. Are you regulated to fly a limited amount of hours without sleep or relief off shift?
5. If so, what is the number of hours you can be on shift before you are unable to fly legally?
6. Do you perform any job on the side in addition to working for this air medical service?
7. Are pilots allowed to sleep on shift at your service?

For Medical Crew:

1. What is the typical cycle for your shift during a month period?
2. How many persons of your position are staffed for one aircraft?
3. How many hours do you work for one shift?
4. Are you regulated to work a maximum amount of hours?
5. If so what is that number?
6. Are medical crews allowed to sleep on shift at your service?

19 Maintenance

1. How many mechanics are employed to manage one aircraft at your service?
2. Does the mechanic have a Quality Assurance (QA) inspector available to check work performed on the aircraft before it is returned to service?
3. Does your service have a 'duty time' policy that regulates the hours worked without relief for mechanics?
4. Do the mechanic and the pilot have a daily brief on the status of the aircraft?
5. What is the method of updating the pilot on maintenance performed and aircraft inspection and retirement status? (verbal, written, computer)
6. Are mechanics at your service required to attend factory school for the aircraft and engine before you can service it?
7. Is major aircraft maintenance performed on site?

8. Is an airframe and power plant (A&P Certified or equivalent) mechanic on site daily at your base site?
9. Are there indoor facilities for maintenance of aircraft at your base site?
10. Does the base keep spare parts on hand or are parts ordered?

11. Are there indoor facilities used for maintenance?

20 Communications

1. Does your aircraft base have a central or local communications center?
2. How many company employees staff the communications center?
3. Does the communications center have flight following software that tracks the aircraft automatically which the personnel in communications can monitor?
4. How many hours are in a shift for the communications specialist?
5. Is there a flight follower in the communications center at all times?
6. What is the means of communication with the aircraft?
7. Does the communications center have a recording device that records all radio traffic with the aircraft so that it can be reviewed later?
8. Does your communications center make you aware of aircraft that are in your flight area within a certain distance?

Use the space below for any additional questions, comments, and ideas:

Thank you very much for taking the time to complete this survey

If you have any questions, comments, or concerns please contact:

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APPENDIX B: LIST OF ABBREVIATIONS AND GLOSSARY

Air Ambulance: Either a fixed-wing or helicopter aircraft dedicated to the transport of medical patients.
Advanced Qualification Program (AQP): A program instituted in 1990 by the FAA which called for voluntary involvement in the program to advance and customize individual CRM programs specific to an organization.
Autopilot: A sophisticated avionics device that controls flight surfaces via programmed inputs made by the pilot.
Base Site: The location of a base for a HEMS program.
BK-117: A dual engine helicopter that is used by many HEMS programs.
Category A Take-off: A form of takeoff for helicopter aircraft in which the pilot directs the aircraft aft off the helipad to decision height. The theory behind this technique is that if the aircraft were to have a mechanical failure the pilot can perform an autorotation back to the helipad or has enough altitude once the transition into horizontal flight has occurred to trade altitude for airspeed and climb out of the power loss if in a dual engine aircraft.
Commission on Accreditation of Medical Transport Systems (CAMTS): Organization which is generally acknowledged as the baseline standard for air medical transport practices.
Code of Federal Regulation (CFR): The codification of the general and permanent rules published in the Federal Register by the departments and agencies of the United States Federal Government.
Checklist: A tool used as an aid in memory. Its purpose is to ensure consistency and completeness of a set of items that need to be carried out in a specific order.
Challenge and Response (Challenge-Verification-Response): The use of a second crew member to challenge a completed step in a protocol which the pilot must do.
Controlled Flight into Terrain(CFIT): A type of accident common to HEMS in which the pilot has inadvertently flown the aircraft into the ground, hillside, or a near ground object causing an accident when no mechanical failure was present.
Cockpit Resource Management: Term coined in the first generation of Crew Resource Management.
Crew Resource Management: The efficient use of any and all available resources made to the pilot to carry out the safe operation of a flight or high risk mission and the prevention of errors.
Decision Height: The height at which the pilot decides to transition the aircraft from vertical into horizontal height.
EC-135: A mid-size, dual engine, FADEC controlled aircraft which is very common to the HEMS industry.
Emergency Locator Transmitter (ELT) A device that may be activated manually or on a hard landing which broadcasts the location of a downed aircraft.
Federal Aviation Administration (FAA): One of the governing bodies of the HEMS industry in the United States.

Full Authority Digital Engine Control(FADEC): An electronic system that starts and monitors turbine engines in both helicopters and fixed-wing aircraft.
First Limit Indicator(FLI): An instrument specific to the EC-135 and EC-145 which presents the most critical gauge on a central panel while displaying all other pertinent information in the margins of the same screen.
Global Positioning System (GPS): Device used to track aircraft as well as aid in navigation.
Ground Effect (GE): A condition of improved performance when a helicopter is hovering near the ground.
Health Care Workers (HCWs): Any person employed with duties involving patient contact
Helicopter Emergency Medical Services (HEMS): Organizations which provide treatment and transport of acutely ill and injured persons.
Instrument Flying Rules (IFR): Regulations and procedures for flying aircraft by referring only to the aircraft instruments for navigation.
Inadvertent Intermittent Meteorological Conditions(IIMC): A condition in flying where the aircraft suddenly or unexpectedly enters poor weather conditions and low or zero visibility requiring the immediate transition from VFR flying into IFR flying.
Landing Zone(LZ): Area in which the aircraft lands.
Loss of Tail Rotor Effect(LTE): A phenomena which causes the un-commanded spin of the aircraft not easily corrected not associated with a mechanical failure.
Manual Engine Start: The modulation of turbine engine throttles while monitoring turbine outlet temperature before the engine is self-sustaining. One common problem with manually starting turbine engines is the inadvertent ‘hot start’ of the engine by demanding too much fuel before the engine speed is within limits from the starter.
MD-902: Dual engine, FADEC equipped mid-size helicopter
Night Vision Goggles(NVGs): Devices used to aid pilots in seeing the flight path and Landing Zones during nighttime operations.
Nomex®: Fire retardant material which is the material of choice for HEMS flight suits.
Non-Jeopardy Condition: Normal flying operations where the mission is not compromised.
Non-Routine Situation: A situation which has compromised the safety of the aircraft
National Transportation Safety Board (NTSB): One of the governing bodies of the HEMS industry
Part 91 (General Aviation)FAR: The written flight rules that govern non-transport category flying
Part 121 FAR: Flight rules that govern airline transport category aircraft
Part 135 (Air Taxi) FAR: Flying rules which govern the transport of persons for hire including the HEMS industry.
Personal Flotation Device (PFD): A life vest used to maintain positive buoyancy.
Pilot in Command (PIC): The pilot who is at the controls making the final decision regarding the flight.
Pilot Not Flying (PNF): The Co-pilot
Radar Altimeter: A device emitting a beam that reflects off the ground below in real time which is returned back to the aircraft indicating the exact altitude above ground level.
Sikorsky S-76: A larger dual engine helicopter common to the HEMS industry.
Sortie: A flight mission

Standard Operating Procedures (SOPs): Written policies that employees of an organization must adhere to.
Terrain Avoidance Warning System (TAWS): An instrument in the cockpit which indicates if the aircraft
TCAS: An instrument in the cockpit that indicates other aircraft in the immediate vicinity and will sound warnings to the pilot both visually and aurally if the aircraft becomes dangerously close to another.
Visual Flight Rules(VFR): A set of regulations which allow the pilot to operate an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going.
Weather Minimums: A set numerical value for the cloud ceiling and horizontal visibility which a pilot must adhere to when accepting a flight.

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